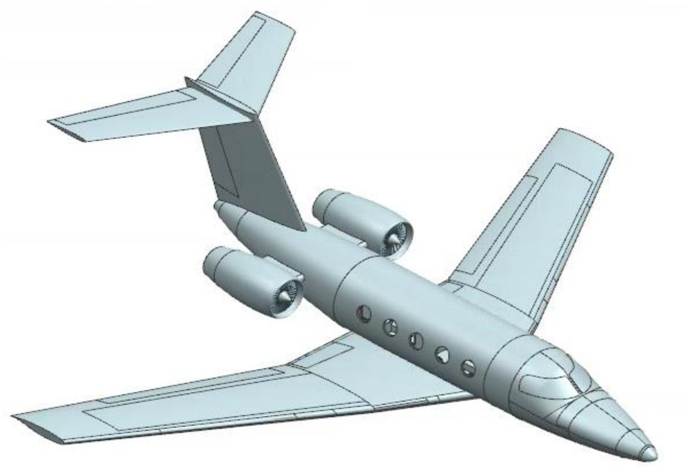
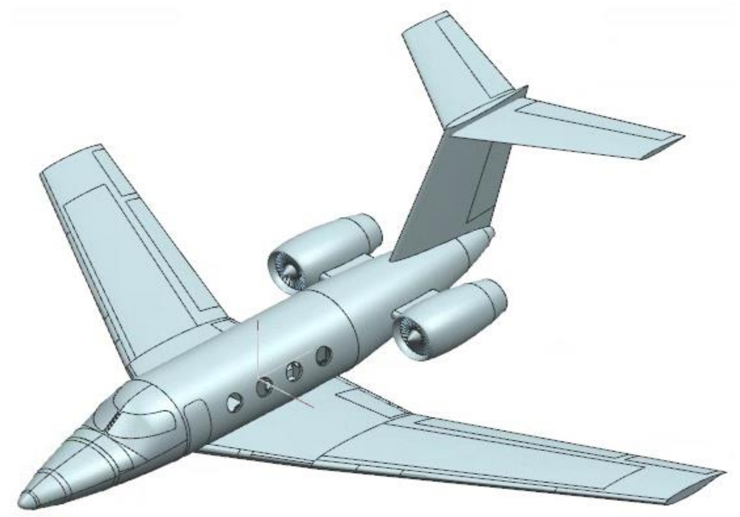


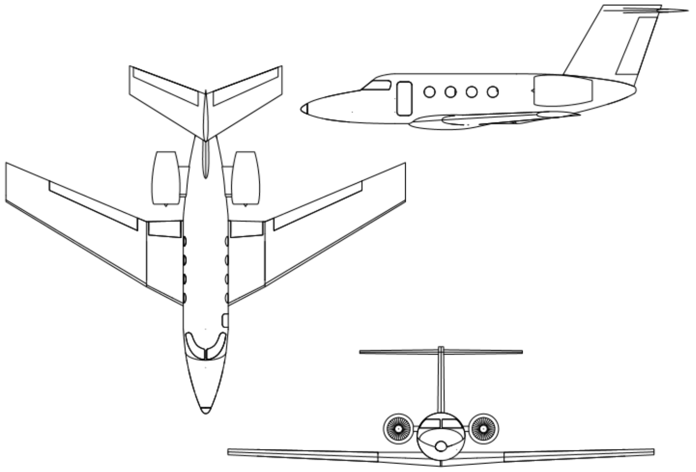
Team Yehudi Light

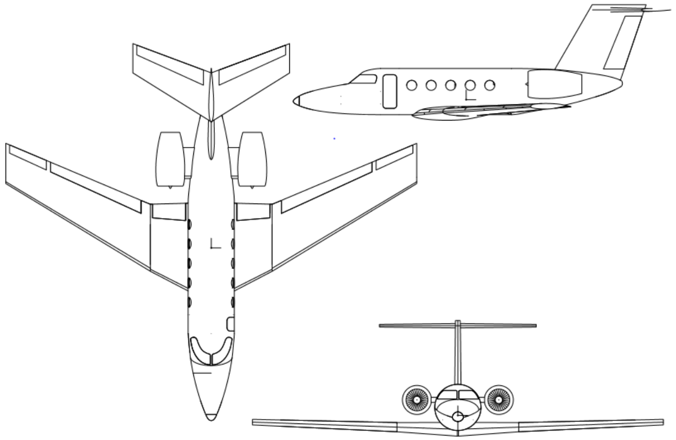


AE 442 Fall 2016

Overview

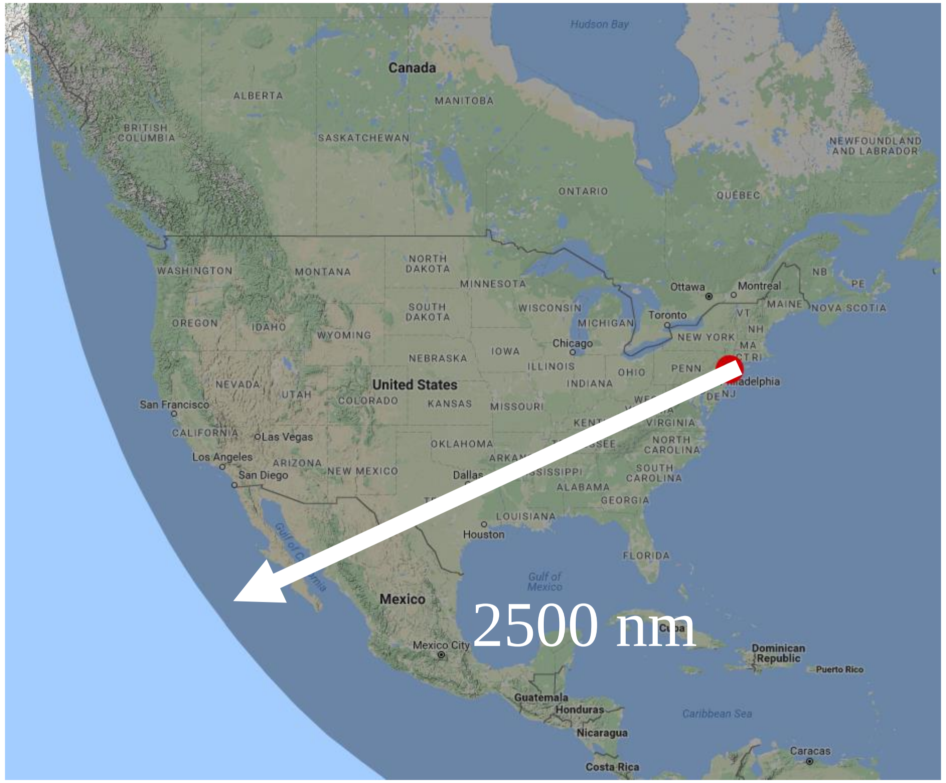
- Chief – 6 passengers
- Commander – 8 passengers
- 2500 nm range
- Mach 0.85 cruise speed
- 70% commonality between aircraft





Design Philosophy

- Provide customers with high value product
- Minimize ownership and maintenance costs
- Make fast, comfortable business travel more accessible at a lower price point



Liam McHugh

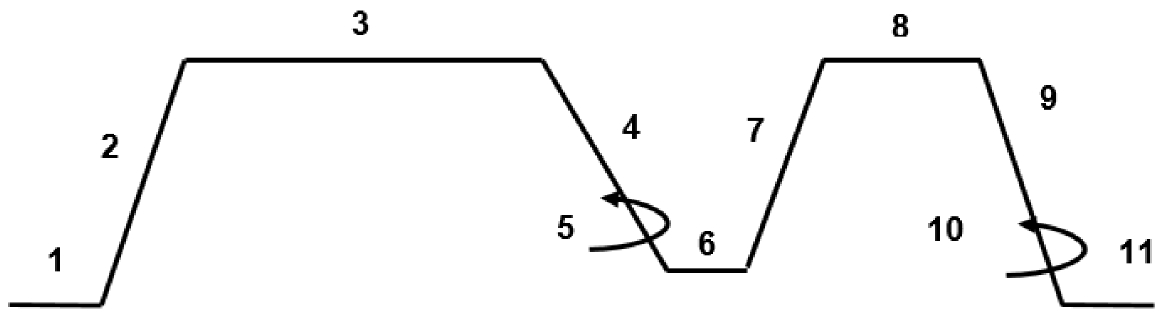
CON-OPS

Goals

- Capitalize on market struggles
- ‘Leapfrog’ Competition
- Meet consumers base expectations
  - Short trip time
  - Comfortable & connected cabin environment
  - Short runway capability
- Great Value: Minimize acquisition & operating costs
  - Optimize commonality

Mission Profile

Mission Leg	Description	Altitude [ft]	Speed	Range	Time [min]
1	Warmup, Taxi & Takeoff	-	-	< 4000 ft	8
2	Climb	-	3,500 fpm	-	-
3	Cruise	35,000	490 knots	2,500 nm	308
4 & 5	Descent & Loiter	5,000	-	-	30
6 & 7	Aborted landing & Climb	-	-	-	-
8	Cruise	35,000	490 knots	100 nm	12
9 & 10	Descent & Loiter	5,000	-	-	30
11	Landing	-	-	< 3600 ft	-



Fielding & Maintenance

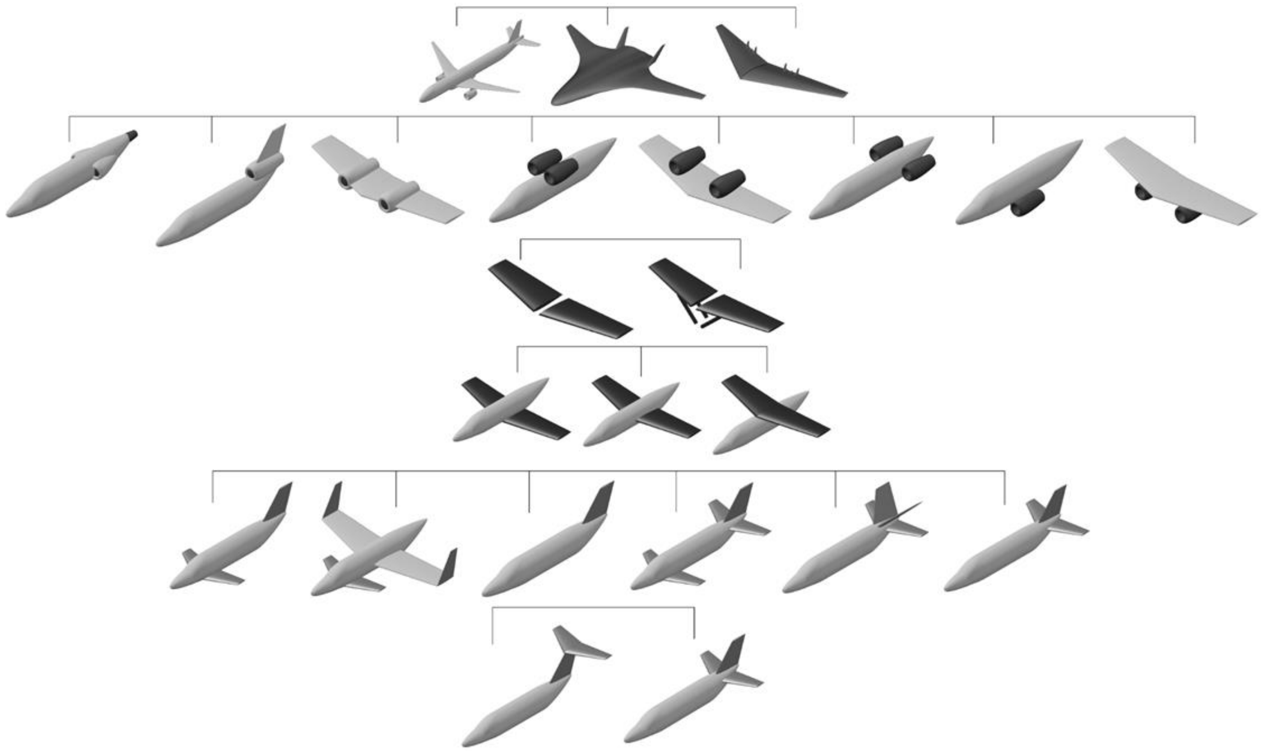
- Manufacturer's responsibilities
- Factors affecting reliability
- Factors affecting accessibility
- FAA regulations

Patchara Choakpichitchai

CONFIGURATION

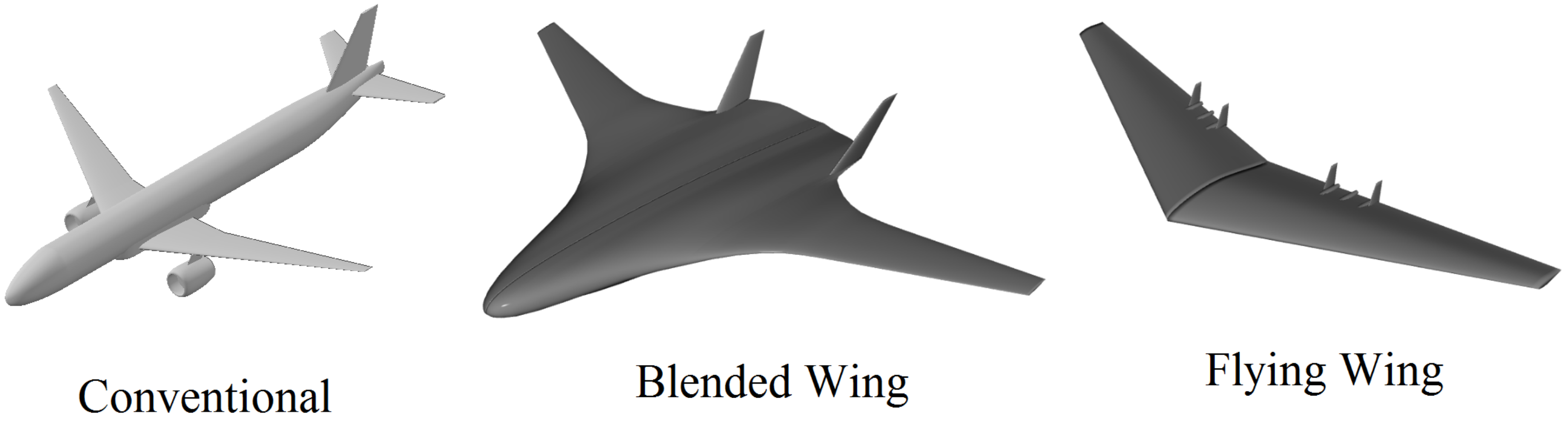
Morphology

Eliminating Individual Configurations

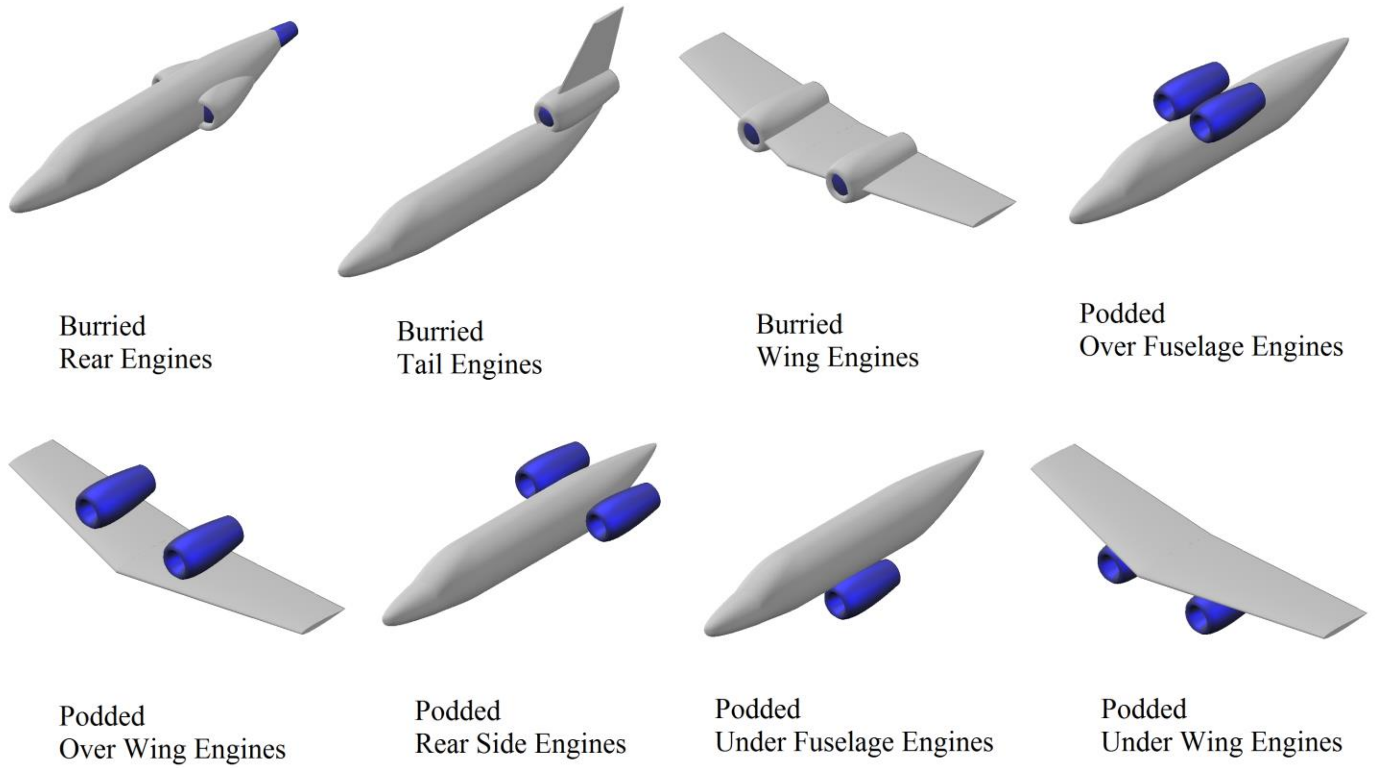


Eliminating Integrated Configurations

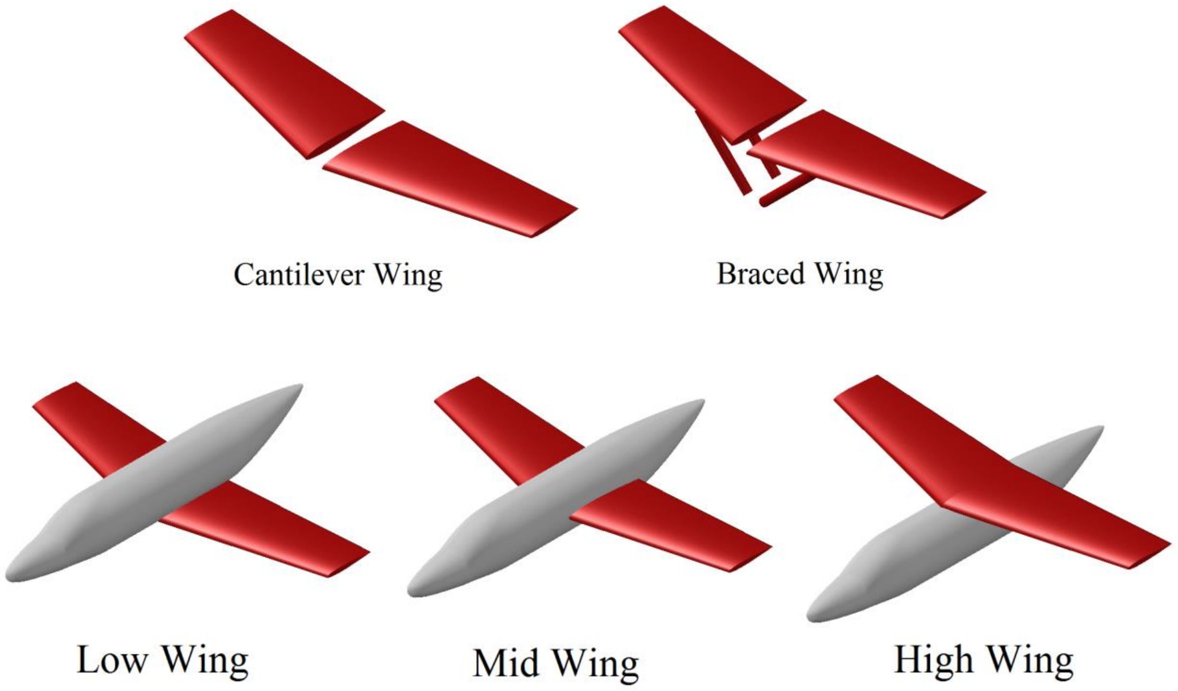
Morphology – Fuselage Configuration



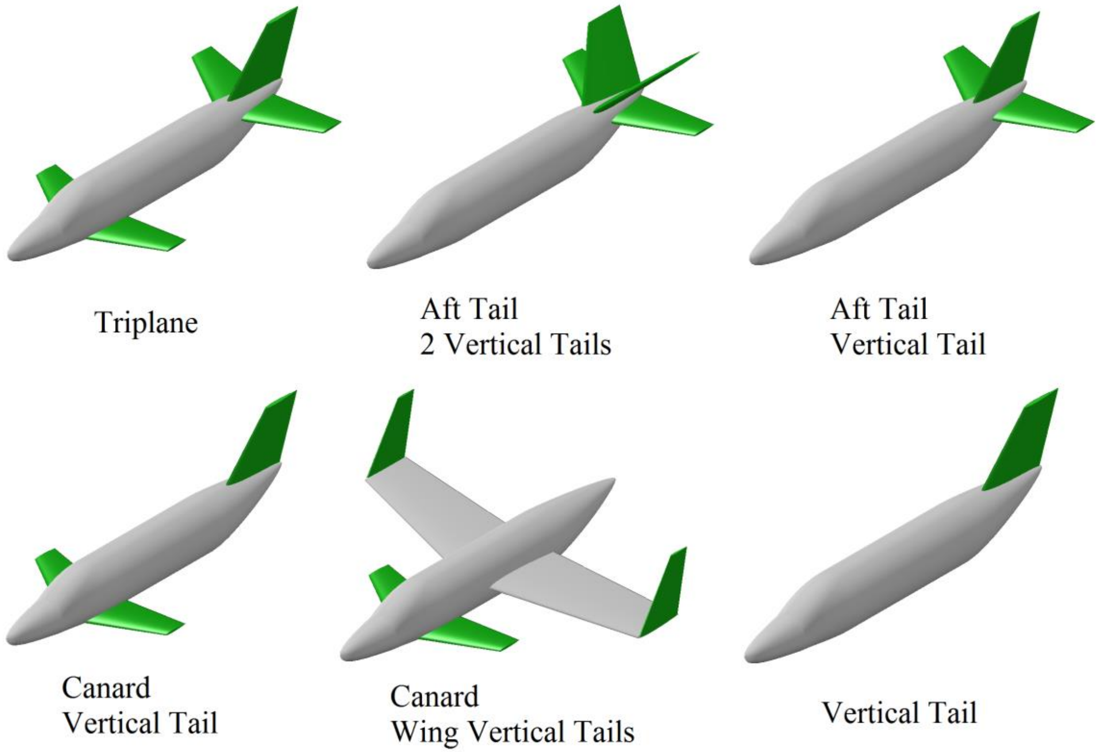
Morphology – Engine Configuration



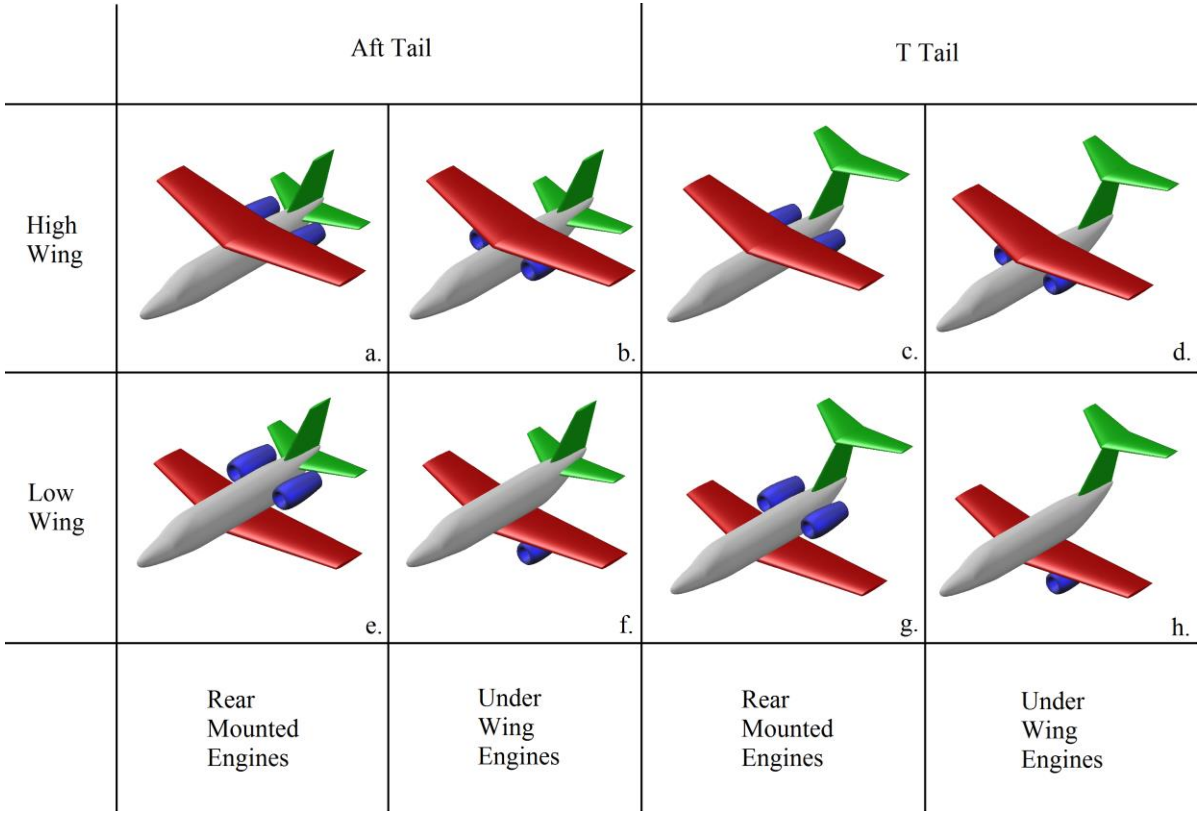
Morphology – Wing Configuration



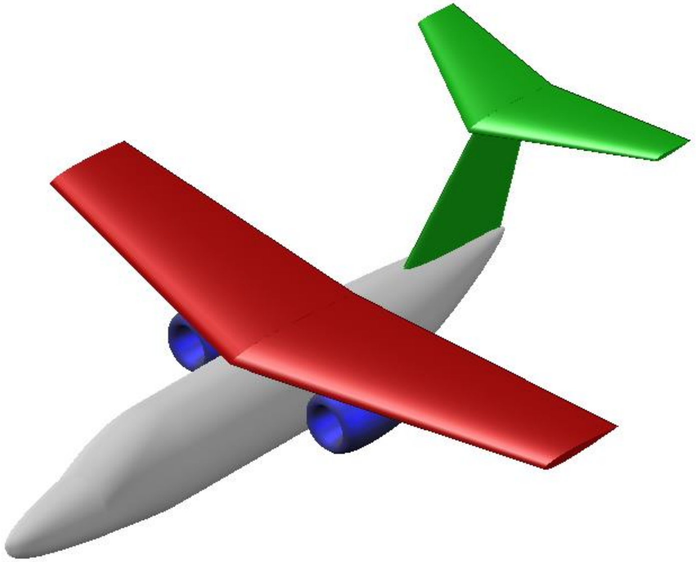
Morphology – Empennage Configuration

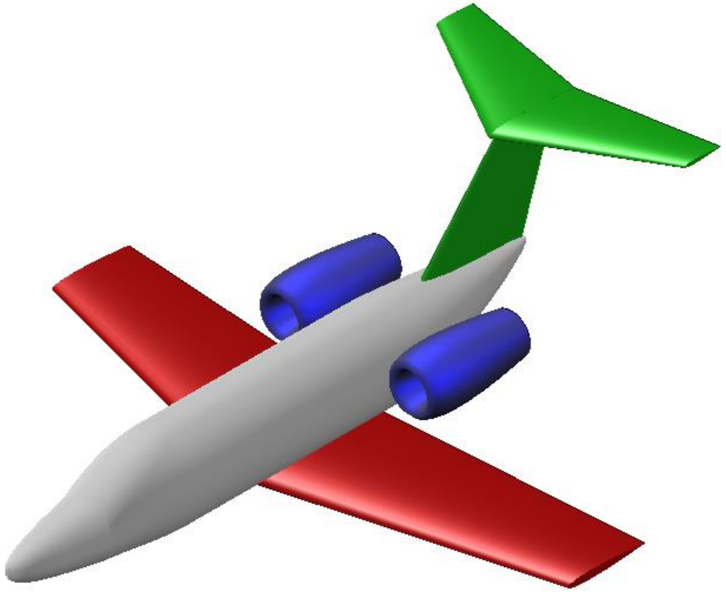


Morphology – Integrated Configurations

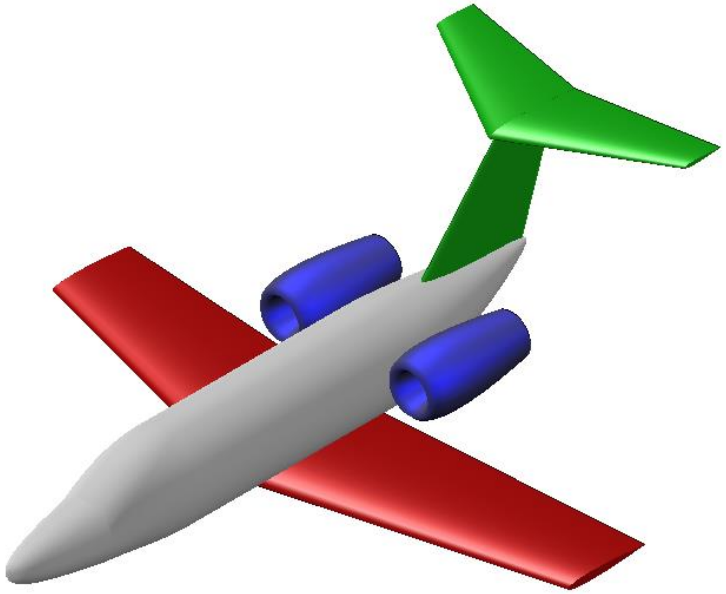


Trade Studies





Final Configuration



Patchara Choakpichitchai

WEIGHTS AND CENTER OF GRAVITY

Methodology - Weights

Fixed Equipment Weights

- Flight Control System
- Hydraulic and Pneumatic System
- Instrumentation, Avionics and Electronics
- Air-conditioning and De-icing System
- Auxiliary Power Unit
- Furnishings

Structural Component Weights

- Wing
- Tail
- Empennage
- Fuselage
- Cockpit
- Landing Gear
- Engine Nacelles

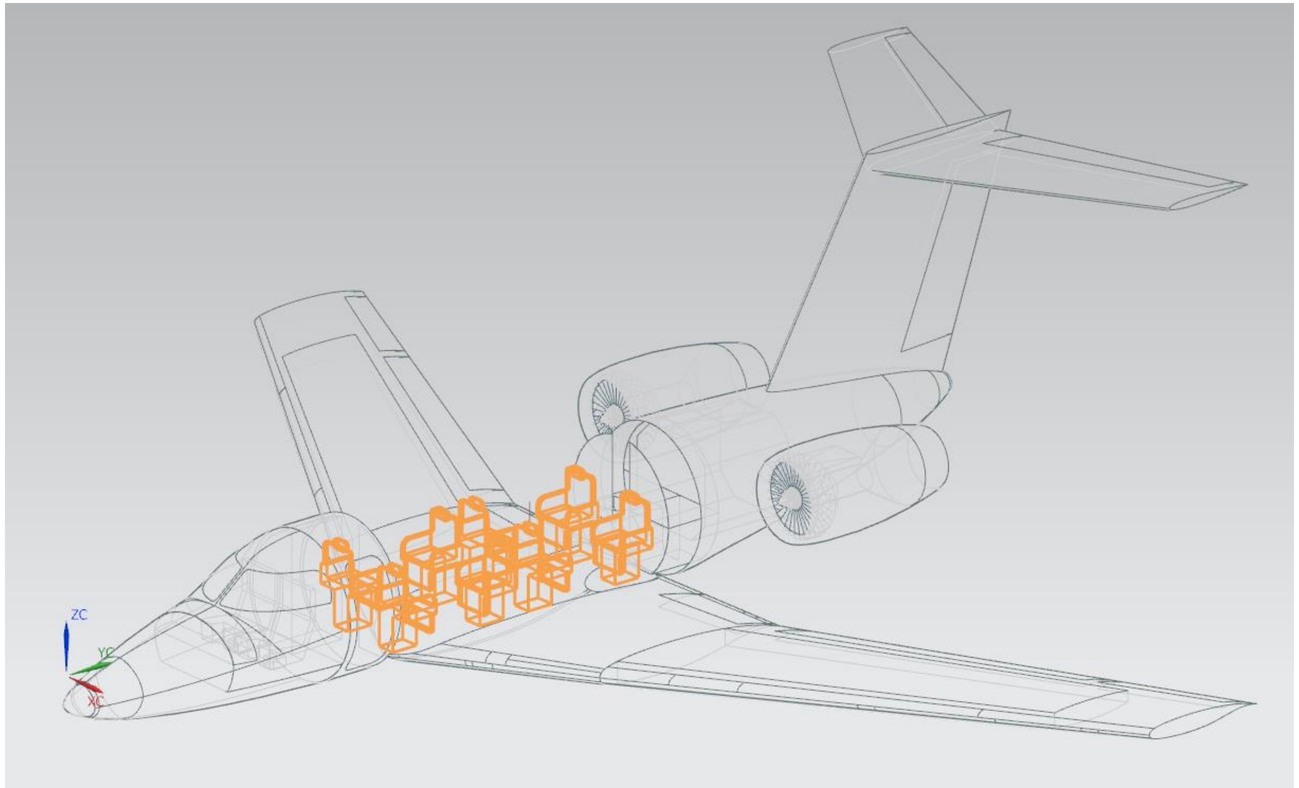
Propulsions Weight

- Fuel Systems
- Engines

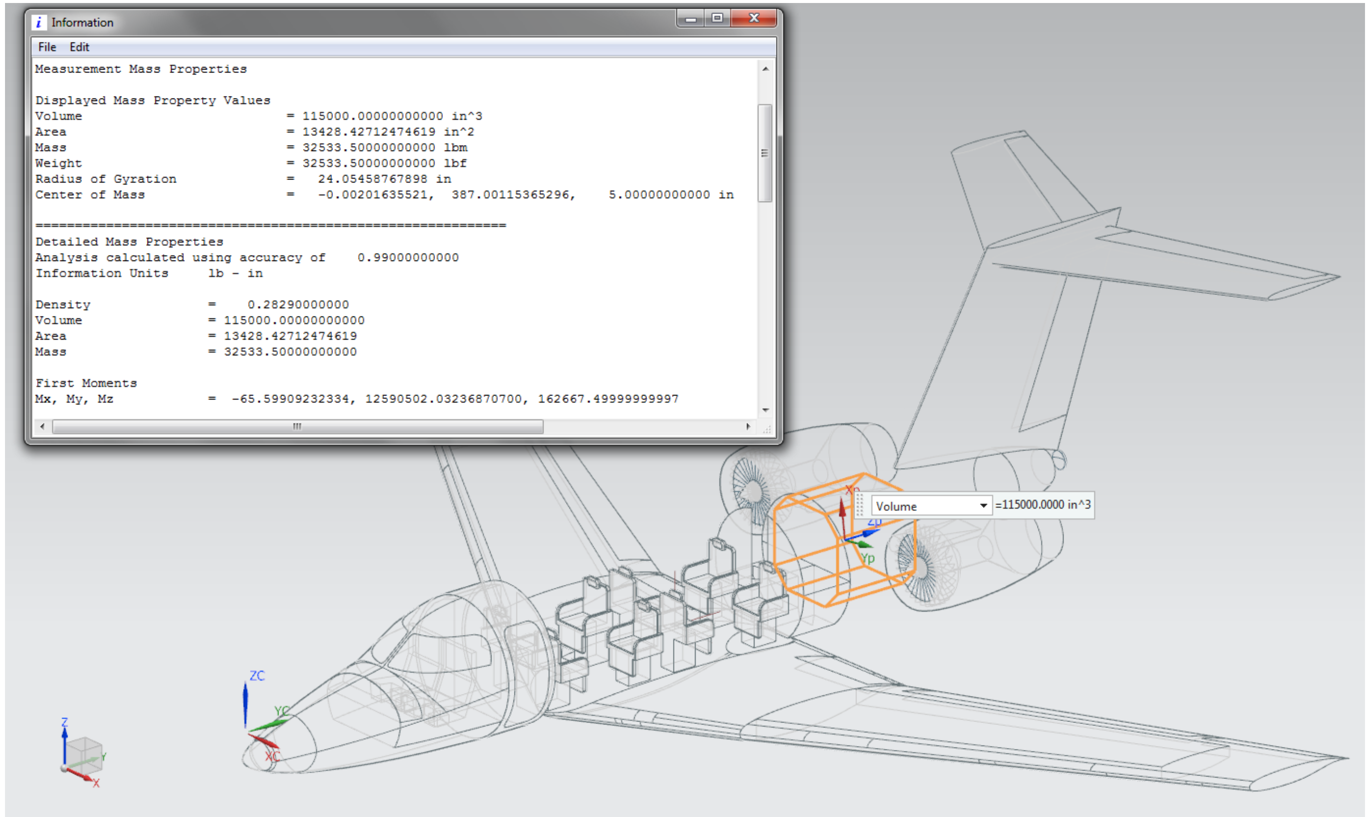
Operational Weights

- Passengers
- Flight Crew
- Fuel
- Baggage

Methodology – Center of Gravity

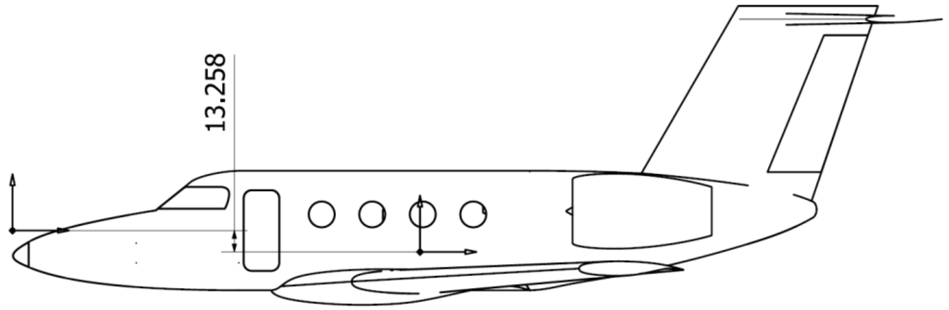


Methodology – Center of Gravity



RESULTS - CHIEF

System	Subsystem	Weight (lb)	Horizontal Distance from tip of radome (in)	Vertical Distance from tip of radome (in)	Horizontal Moment (ft*lb)	Vertical Moment (ft*lb)
Fixed Equipment Weight		3381.2			309596.336	-9290.768
Flight Control System		502.5	Distributed	Distributed	0	0
Hydraulic and/or Pneumatic System		154	Distributed	Distributed	0	0
Electrical System		637.6	Distributed	Distributed	0	0
Instrumentation, Avionics and Electronics		402.4			31185.416	219.872
	Honeywell Primus Radar	36.4	23.69	-14.17	862.316	-515.788
	Proline 21	366	82.85	2.01	30323.1	735.66
Air-conditioning and De-icing System		234.73	Distributed	Distributed	0	0
Auxiliary Power Unit		88	467.09	10.88	41103.92	957.44
Furnishings		1361.97			237307	-10468.08
	Passenger Seats	840	243.515	-10.642	204552.6	-8939.28
	Pilot Seats	280	116.98	-5.46	32754.4	-1528.8
	Lavatory, Galley and Furnishings	241.97	Distributed	Distributed	0	0
Structural Components Weight		4911.156795			1408607.522	-56640.208
Wing		2213.72938	160	-37	630780.0495	-69931.71111
	Shell (Skin)	257.40288	124.94	5.41	73344.37663	-8131.356979
	Structural	1956.3265	124.94	5.41	557435.6729	-61800.35414
Tail		595.749	377	19	283910.1434	63232.79886
	Shell (Skin)	79.307	99.56	87.14	37794.54392	8417.64498
	Structural	516.442	99.56	87.14	246115.5995	54815.15388
Empennage		239.688615			93775.77375	1234.396367
	Shell (Skin)	38.83	391.24	5.15	15191.8492	199.9745
	Structural	200.858615	391.24	5.15	78583.92455	1034.421867
Fuselage		550.6172			127761.1172	-3676.212316
	Floor (Plate - no structure)	128.1522	236	-28.78	30243.9192	-3688.220316
	Walls (Plate - no structure)	8	273.781	1.501	2190.248	12.008
	External Barrel (Skin)	127.77	230	0	29387.1	0
	Structural	286.695	230	0	65939.85	0
Cockpit		336.2426			28496.56035	-3258.190794
	Structural	307.0936	84.75	-9.69	26026.1826	-2975.736984
	Skin	29.149	84.75	-9.69	2470.37775	-282.45381
Landing Gear		951		-102.153	234363.628	-48186.689
	Nose Landing Gear	194	76.462	-51.764	14833.628	-10042.216
	Main Landing Gear	757	290	-50.389	219530	-38144.473
Engine Nacelles		24.13			9520.2502	3945.4
	Skin	24.13	394.54	10	9520.2502	3945.4
Propulsions Weight		1888.18	160	-37	770335.8046	8972.9756
Fuel System		244.18	136.47	6.42	72392.0446	-7467.0244
Engines		1644	424.54	10	697943.76	16440
Operational Weight		7493.29	160	-37	1966304.686	-177354.8082
Passengers	6 pax	1200	243.515	-10.62	292218	-12744
Flight Crew	2 pax	400	116.98	-5.46	46792	-2184
Fuel	Fuel Tanks	5393.29	136.47	6.42	1598948.686	-164926.8082
Baggage	30 cubic feet	500	56.692	5	28346	2500
Total		17673.8268	252.0588439	-13.25761598	4454844.349	-234312.8086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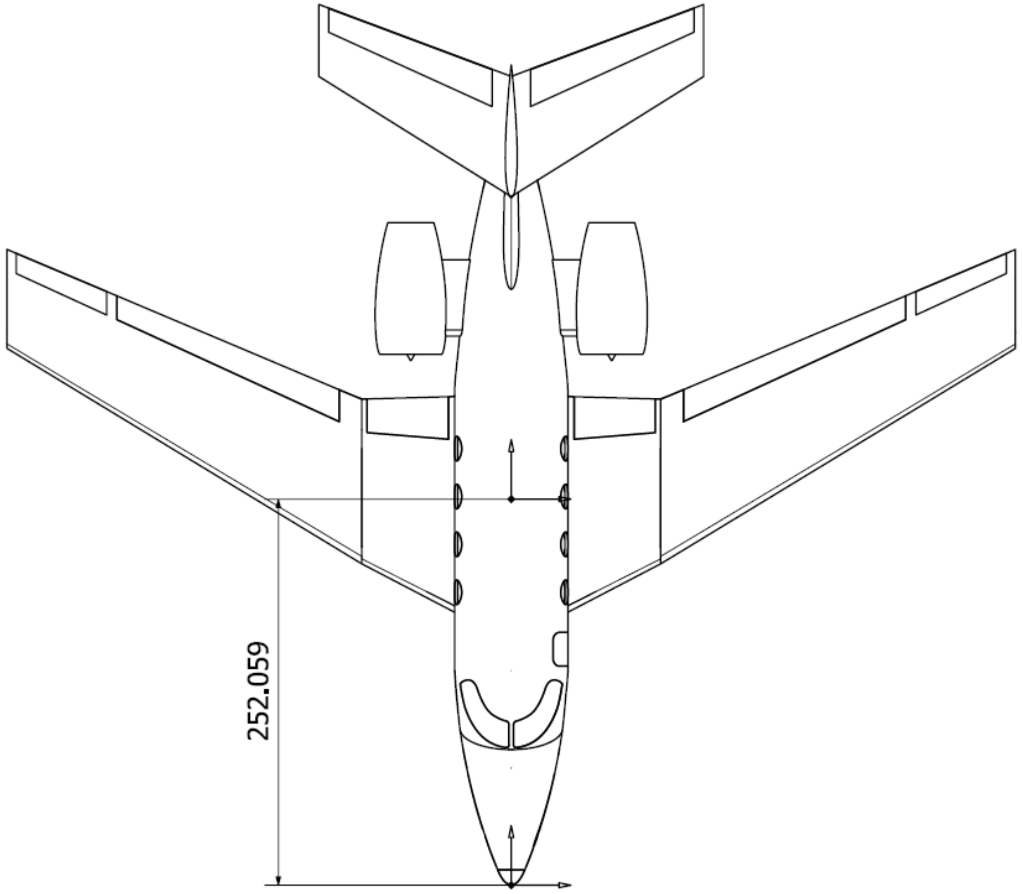
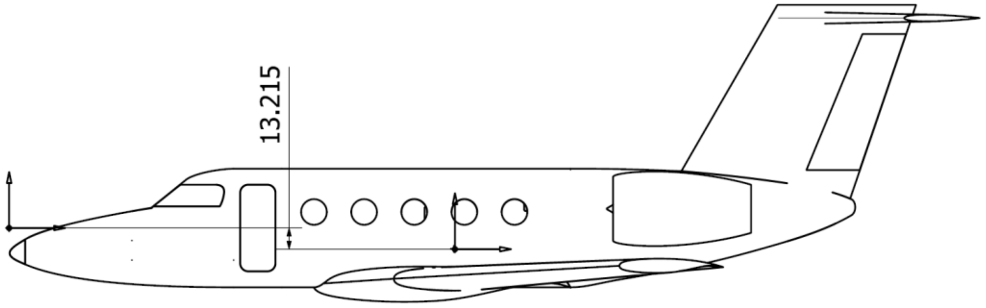

252.059

RESULTS - COMMANDER

System	Subsystem	Weight (lb)	Horizontal Distance from tip of radome (in)	Vertical Distance from tip of radome (in)	Horizontal Moment (ft*lb)	Vertical Moment (ft*lb)
Fixed Equipment Weight		3808.68			389363.736	-12268.288
Flight Control System		502.5	Distributed	Distributed	0	0
Hydraulic and/or Pneumatic System		154	Distributed	Distributed	0	0
Electrical System		699.3	Distributed	Distributed	0	0
Instrumentation, Avionics and Electronics		402.4			31185.416	219.872
	Honeywell Primus Radar	36.4	23.69	-14.17	862.316	-515.788
	Proline 21	366	82.85	2.01	30323.1	735.66
Air-conditioning and De-icing System		282.7	Distributed	Distributed	0	0
Auxiliary Power Unit		88	497.09	10.88	43743.92	957.44
Furnishings		1679.78			314434.4	-13445.6
	Passenger Seats	1120	251.5	-10.64	281680	-11916.8
	Pilot Seats	280	116.98	-5.46	32754.4	-1528.8
	Lavatory, Galley and Furnishings	279.78	Distributed	Distributed	0	0
Structural Components Weight		5000.264095			1546204.354	-56916.50096
Wing		2213.72938	190	-37	697191.9309	-69931.71111
	Shell (Skin)	257.40288	124.94	5.41	81066.46303	-8131.356979
	Structural	1956.3265	124.94	5.41	616125.4679	-61800.35414
Tail		595.749	407	19	301782.6134	63232.79886
	Shell (Skin)	79.307	99.56	87.14	40173.75392	8417.64498
	Structural	516.442	99.56	87.14	261608.8595	54815.15388
Empennage		239.688615			100966.4322	1234.396367
	Shell (Skin)	38.83	421.24	5.15	16356.7492	199.9745
	Structural	200.858615	421.24	5.15	84609.683	1034.421867
Fuselage		639.7245			158019.0385	-4252.50528
	Floor (Plate - no structure)	148.176	251	-28.78	37192.176	-4264.50528
	Walls (Plate - no structure)	8	294.685	1.5	2357.48	12
	External Barrel (Skin)	149.07	245	0	36522.15	0
	Structural	334.4785	245	0	81947.2325	0
Cockpit		336.2426			28496.56035	-3258.190794
	Structural	307.0936	84.75	-9.69	26026.1826	-2975.736984
	Skin	29.149	84.75	-9.69	2470.37775	-282.45381
Landing Gear		951			249503.628	-48186.689
	Nose Landing Gear	194	76.462	-51.764	14833.628	-10042.216
	Main Landing Gear	757	310	-50.389	234670	-38144.473
Engine Nacelles		24.13			10244.1502	4245.4
	Skin	24.13	424.54	10	10244.1502	4245.4
Propulsions Weight		1752.18	190	-37	719923.7646	7612.9756
Fuel System		244.18	136.47	6.42	79717.4446	-7467.0244
Engines		1508	424.54	10	640206.32	15080
Operational Weight		8956.09	190	-37	2768176.702	-196345.2322
Passengers	8 pax	1600	251.5	-10.64	402400	-17024
Flight Crew	2 pax	400	116.98	-5.46	46792	-2184
Fuel	Fuel Tanks	5956.09	136.47	6.42	1944484.702	-182137.2322
Baggage	60 cubic feet	1000	374.5	5	374500	5000
Total		19517.2141	277.8915336	-13.21484943	5423668.557	-257917.0456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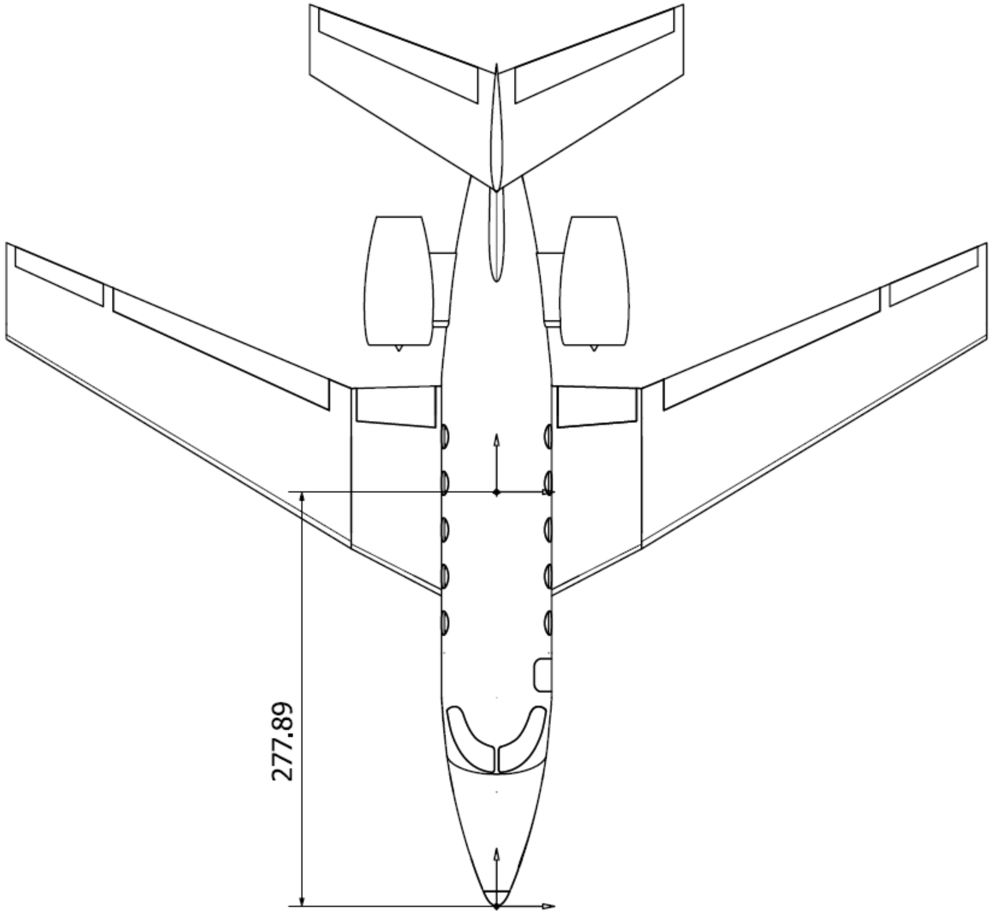

277.89

Hyung Woo You

INTERNAL CONFIGURATION

Overview

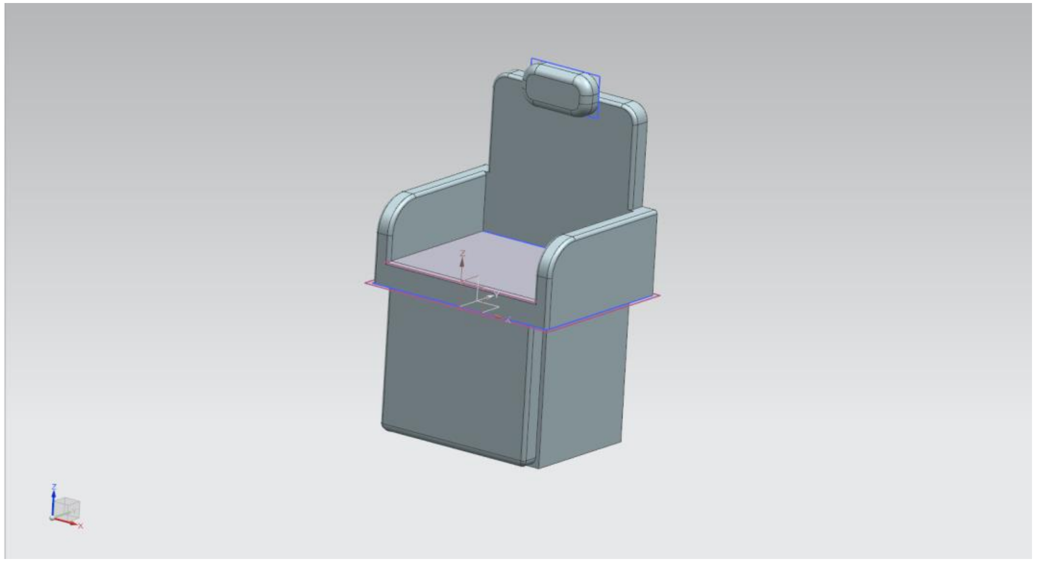
- Seat Selection
- Fuselage Dimensions
- Empennage
- Cockpit
- 6 – Seater Fuselage
- Future Work

Seat Selection

- Spatial constraints – Fuselage, Dimensions
- Consultation with B/E Aerospace
- Customizable for customers
- Dimensions of the seat decided through iteration
- 7.5 in of empty pace behind
- 15 in of empty space at the front

Item	Provided by B/E Aerospace [in]	Chosen Dimensions [in]
Between Armrests	19 – 25.5	19
Armrest Width	2 – 5	2
Overall Height	36 – 40	42
Headrest	2 – 5 above the backrest	2.6 above the backrest
Bottom Cushion	18 - 20 from the floor	18
Legrest Width	19 – 25.5	19

Seat Selection



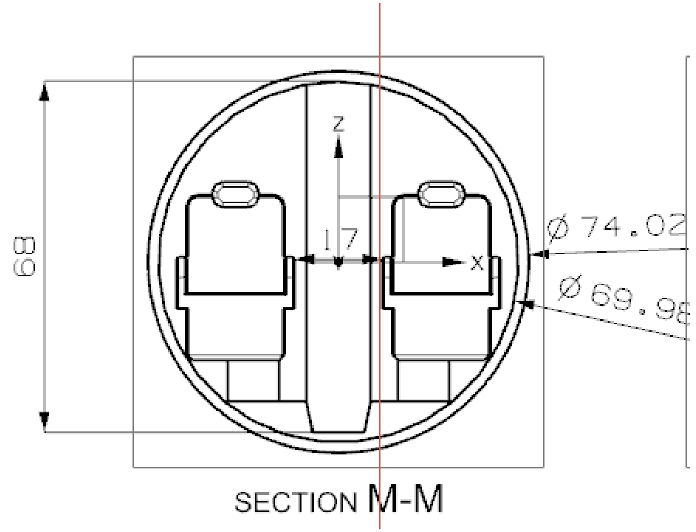
CAD Model of a Seat

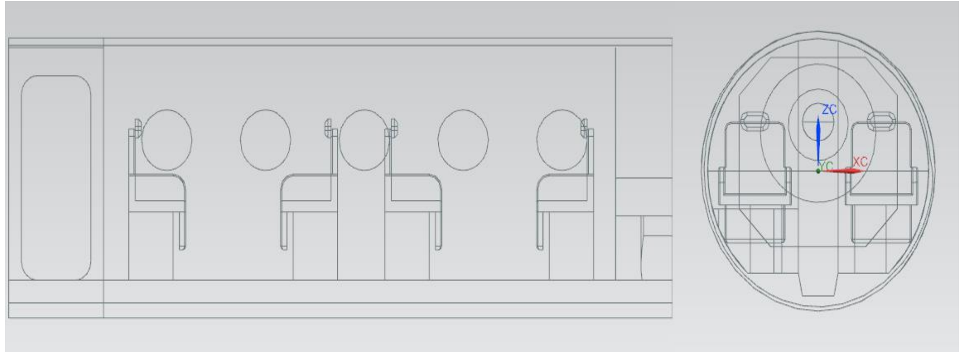
B/E Aerospace UCT 2.0

Fuselage Dimensions

- 3 main factors:
  - The passengers – 17 in of passage space
  - The fuselage shape – circular cross sections
  - The seats, galley, and lavatory

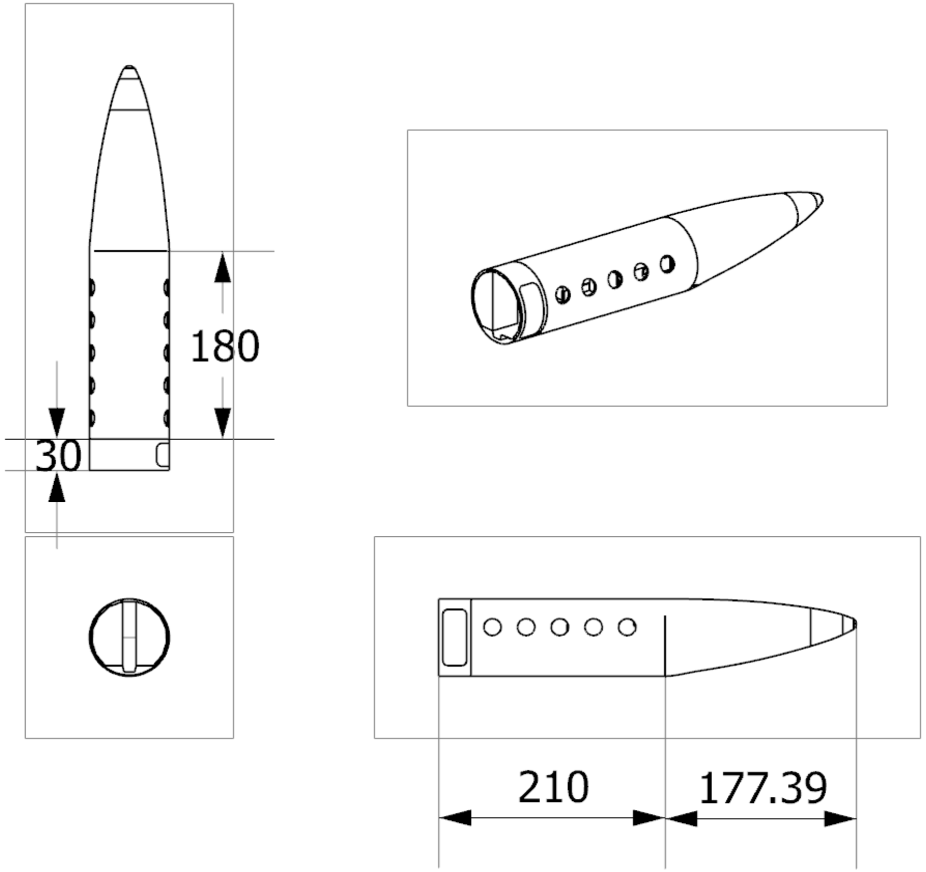
- Outer Diameter: 74 in
- Inner Diameter: 70 in
- Galley & Lavatory: 30 in for both in length
- Overall Fuselage Length: 180 in without galley (210 in w/ galley)





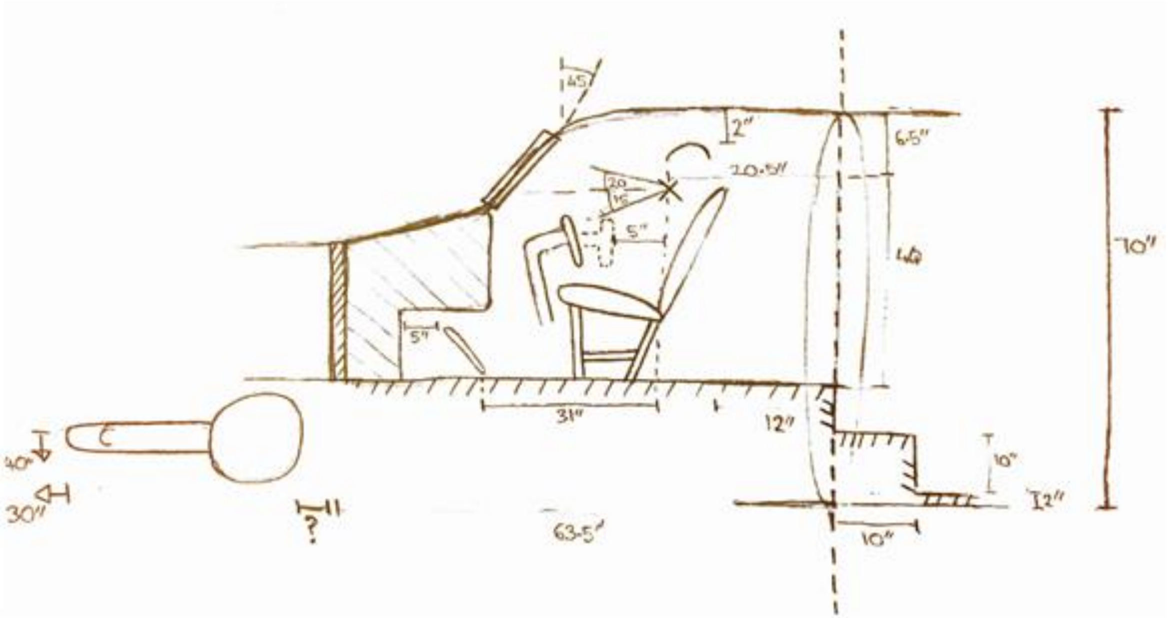
Empennage

- Rear portion of the fuselage
  - Typically used as cargo space
- Circular Cross Sections
  - Structural stability
- Fineness Ratio = 2.4
  - For a business jet, about 2.
  - Ratio = (Length of the empennage) / (Diameter of the fuselage)
- Varying Diameters
  - the angle determined to avoid creating too much drag from flow separation



Cockpit

- Security of Sight
  - FARs
  - Anthropometry Studies of Pilots
  - Industry Conventions
- Nose Landing Gear
- Avionics



Cockpit

Federal Acquisition Regulations (FAR)

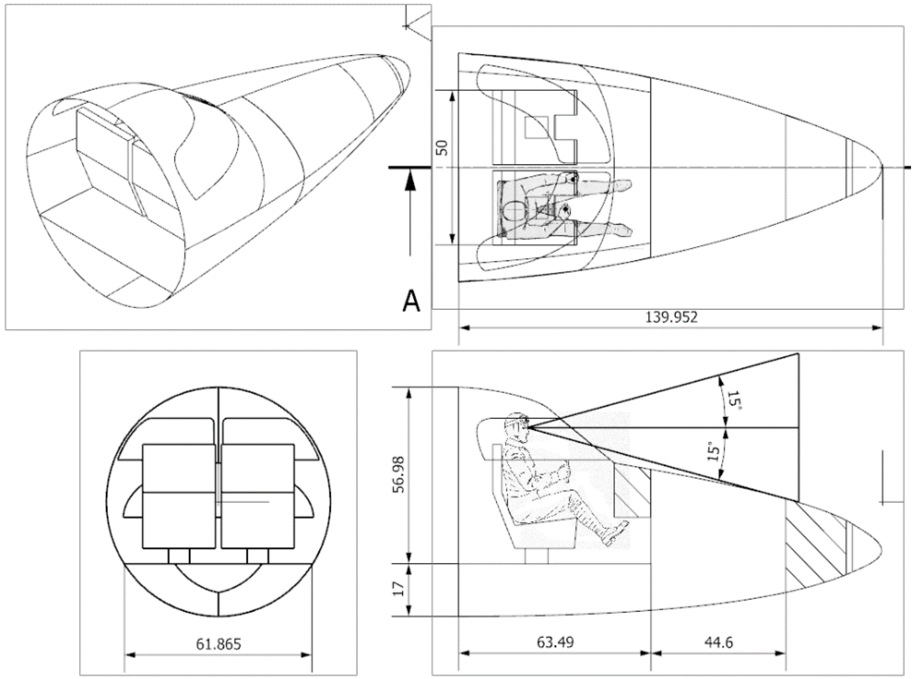
- Must allow the pilot 15° of visibility below their eye level and 20° above it
- The windows must be less than 45° above the horizontal line of the flight controls to avoid issues with reflection.
- Initial design based on circular cross sections

X-direction [in]	Needed space total [in]	Needed interior space [in]	Need floor space [in]	Radius [in]	Centered at [in]
0	74	68		37	37
20.5	73		50.5	36.5	37.5
40.2	67.02	63.02	47.02	33.51	35.51
51.5	55.72	51.72	35.72	27.86	29.86
63.5	52.5	48.5	32.5	26.25	28.25
100				approx 18	approx 23
130	nose				

Initial Dimensions of the Cockpit

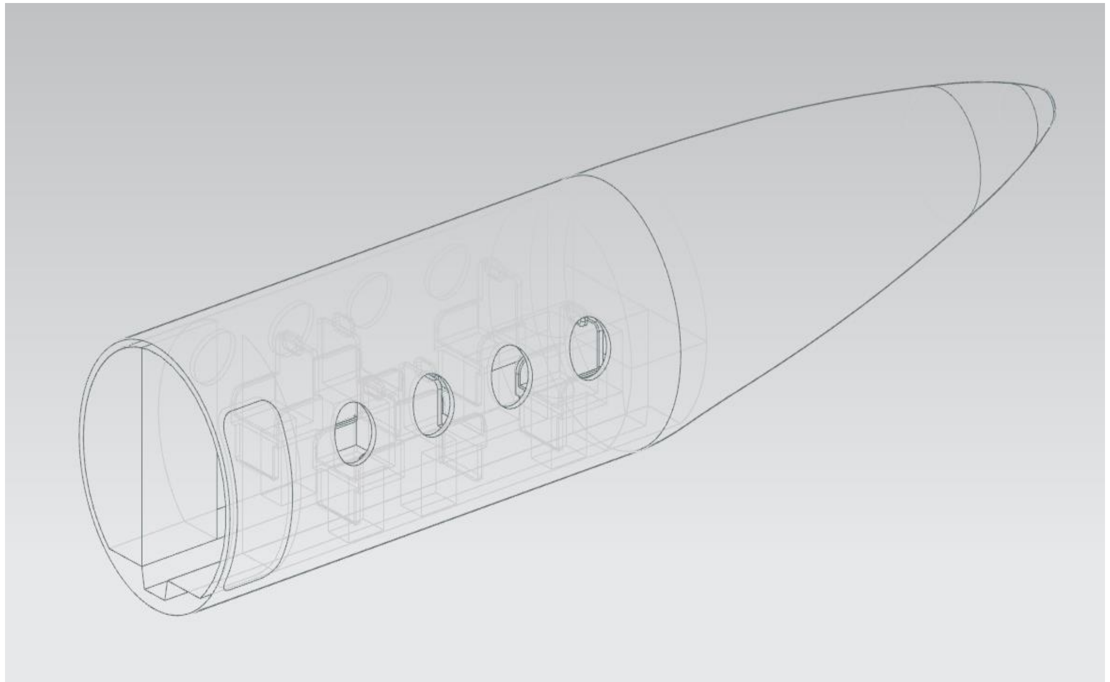
Cockpit

- Based on the initial sketch, minor modifications done to make the cockpit more aerodynamic and procure space for pilots
- Floor height adjusted for the nose landing gear
- After deciding dimensions, pilot seats and avionics are placed in the cockpit



Six Seater Fuselage

- Decrease in the fuselage length from 180 in to 150 in
- Removing two seats provide more space
- Reduces weight of an aircraft
- Lower thrust requirement



Future Work

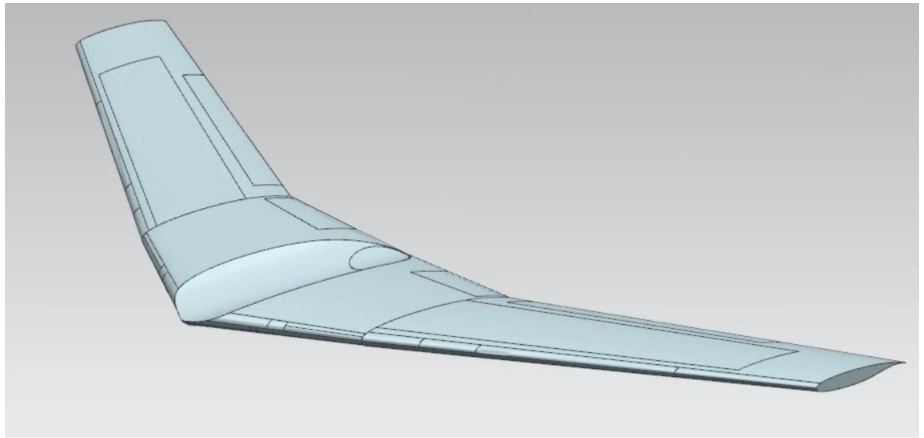
- Resulting features from changing other factors as well as the fuselage length by changing fuselage diameter, length of an empennage, resizing the cockpit, etc.
- Analysis of the effectiveness of each factor in designing an aircraft and further optimize the design for the business jet

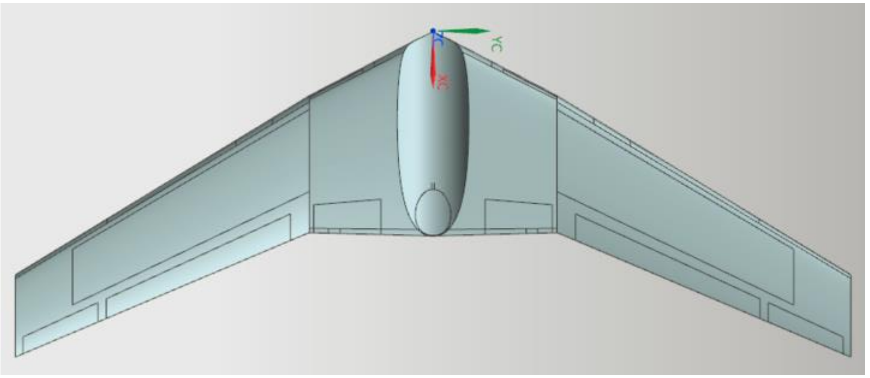
Kevin MacDuff

AERODYNAMICS

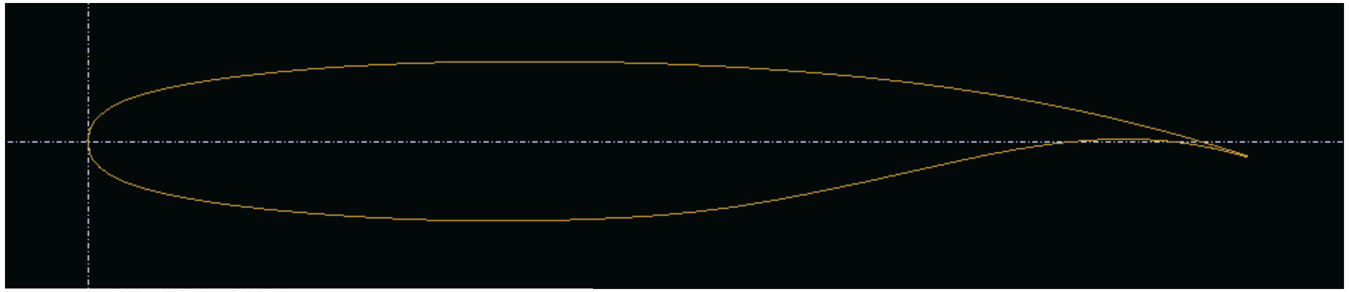
Aerodynamics

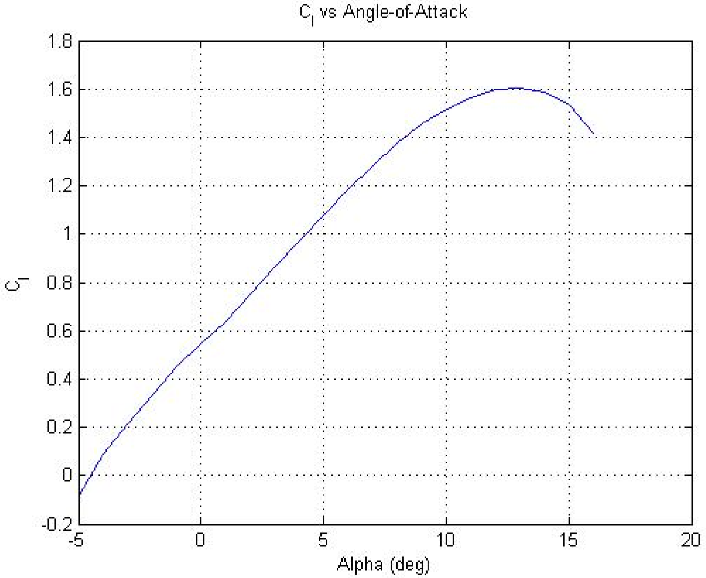
- Airfoil Selection
- Wing Selection and Shape
- Aircraft Drag Buildup
- High Lift System
- Aircraft Lift Curves and Drag Polars
- Future Work

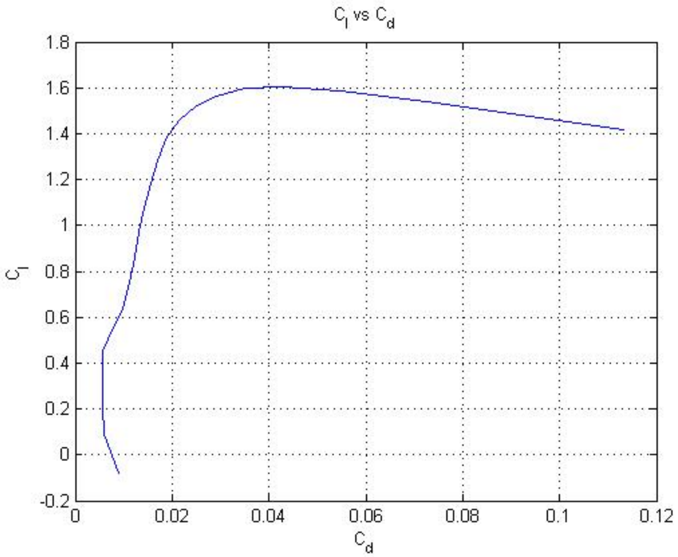




Aerodynamics



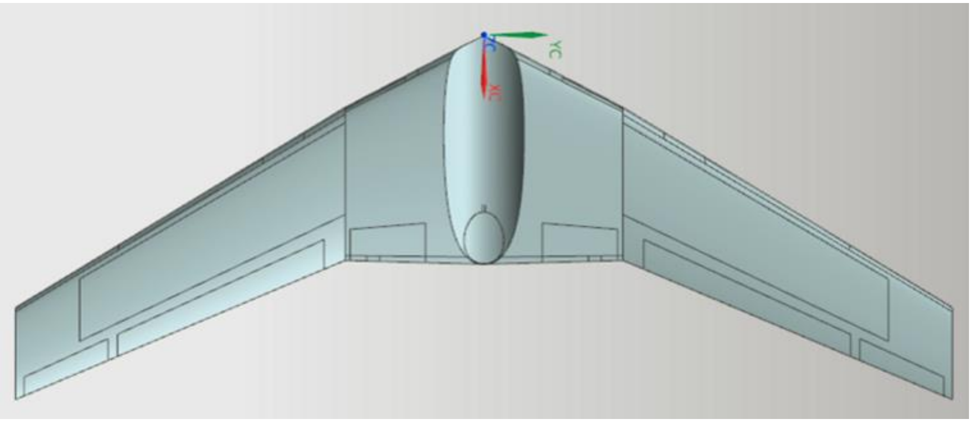




NASA SC(2)-0714

Aerodynamics

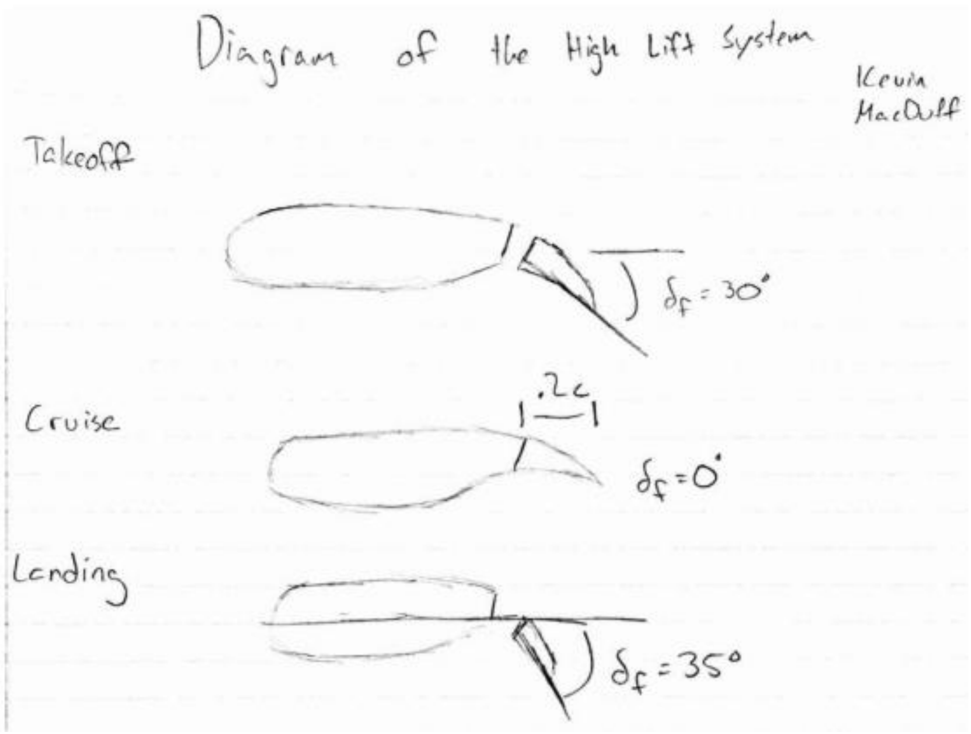
- Wingspan of 55 feet
- Wing Area of 459.39 square feet
- Root Chord of 13.424 feet
- Tip Chord of 5.369 feet
- MAC of 8.907 feet
- AR of 6.585
- Taper Ratio of 2.5
- Root to Tip Sweep of 26.958°



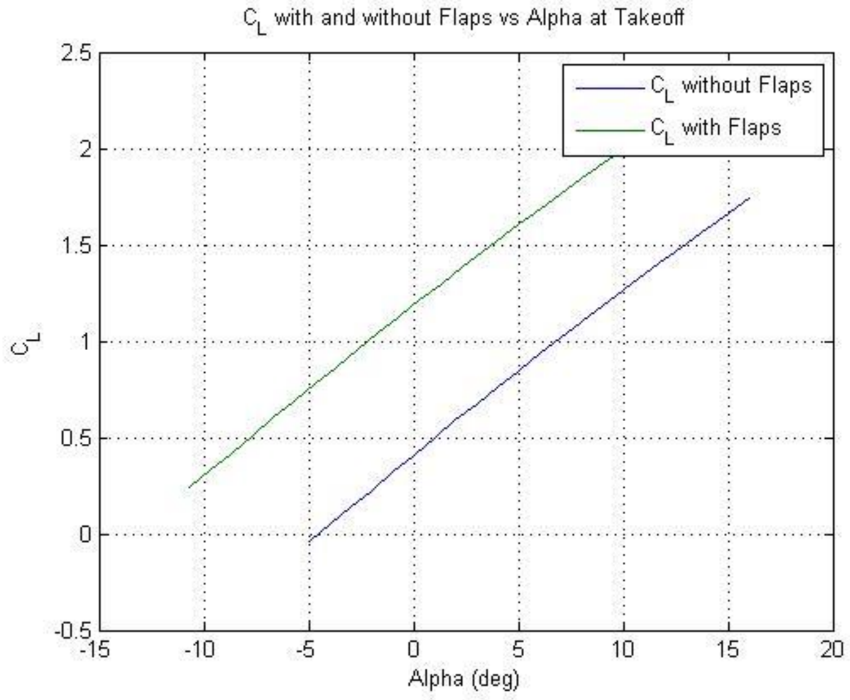
Aerodynamics

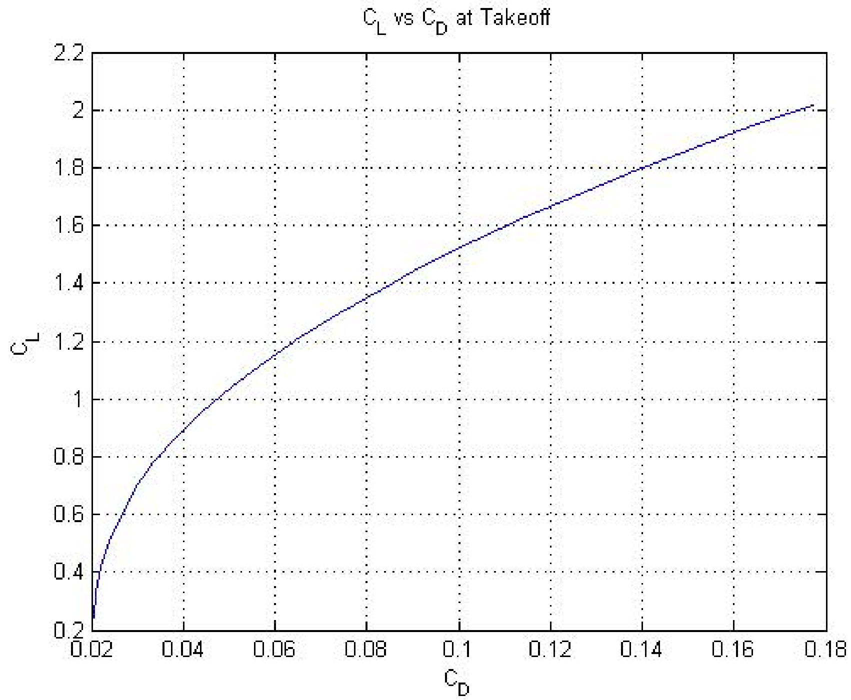
Component	C_D (Takeoff)	C_D (Cruise)	C_D (Landing)
Wing	0.149	0.013	0.149
Horizontal Tail	0.00342	0.00567	0.0033
Vertical Tail	0.005	0.005	0.005
Fuselage	0.0098	0.0093	0.0098
Nacelles (x2)	0.002	0.0019	0.00203
Landing Gear Interference	0.017	N/A	0.017
Flaps	0.015	N/A	0.060

Aerodynamics

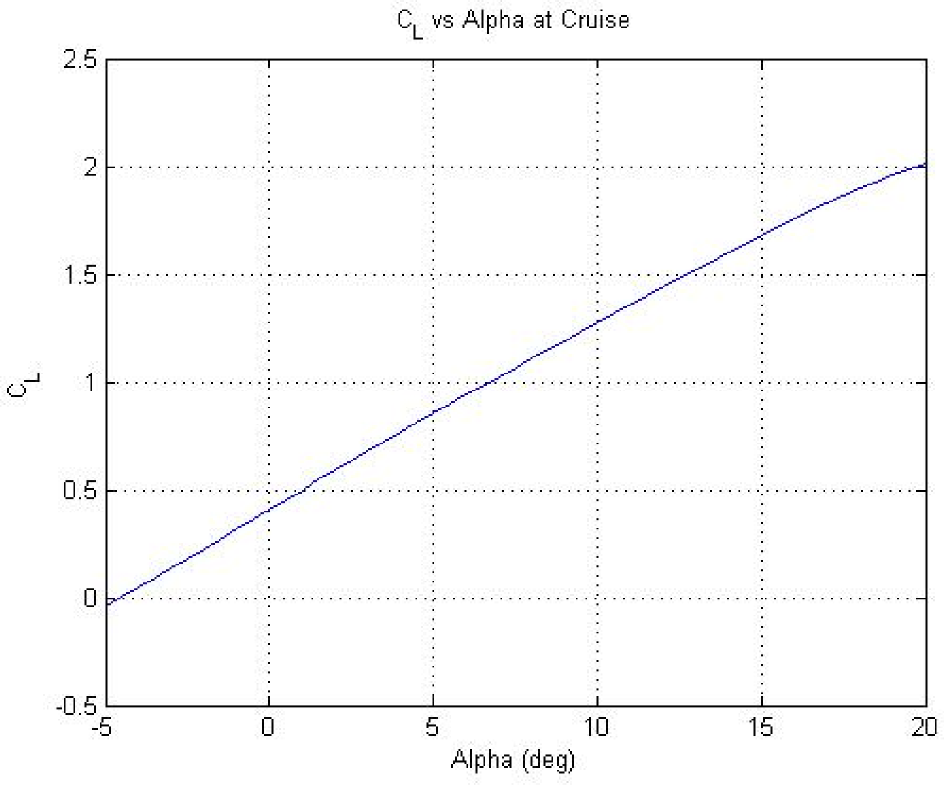


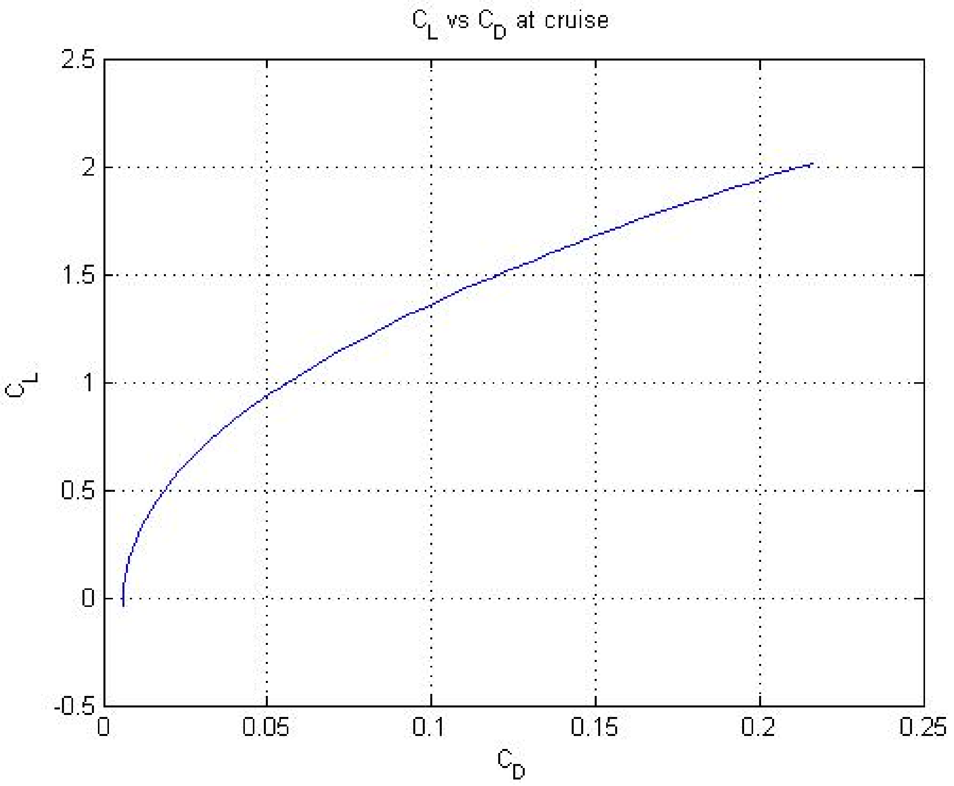
Aerodynamics



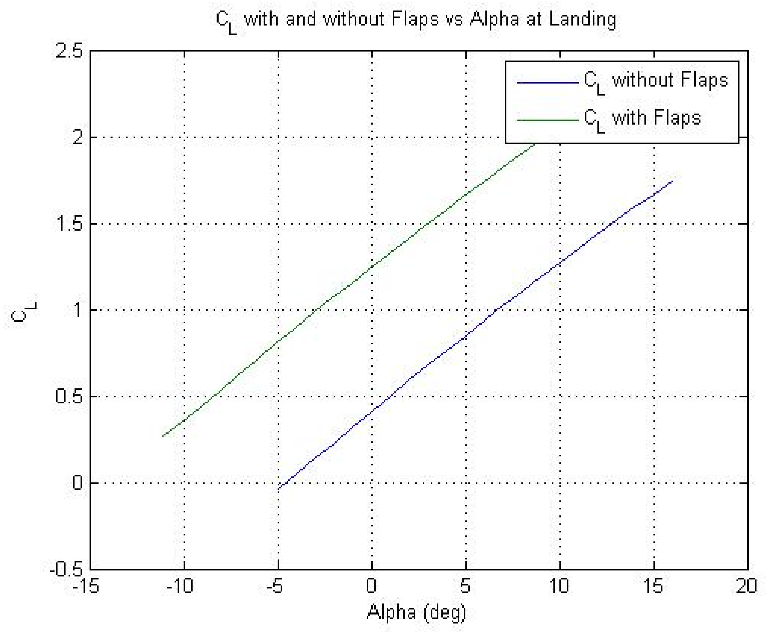


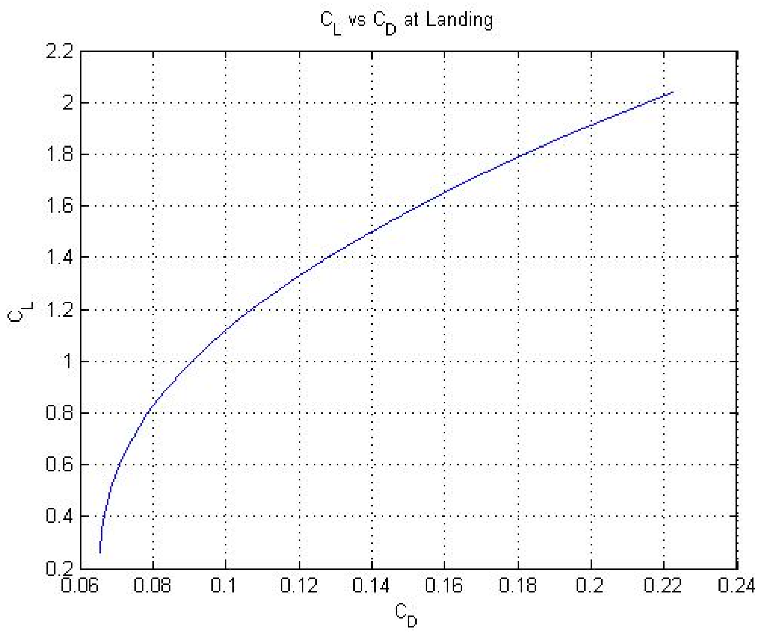
Aerodynamics





Aerodynamics





Aerodynamics

- Future Work
  - Get more accurate measurements of aerodynamic properties to better balance tradeoffs for performance and stability and control
  - Possible Examples: Slight downsizing of the wing to generate less lift, drag, and moment so that the size of the tail could possibly be downsized, airfoil design modification, and winglets

Martynas Vasiliauskas

PERFORMANCE

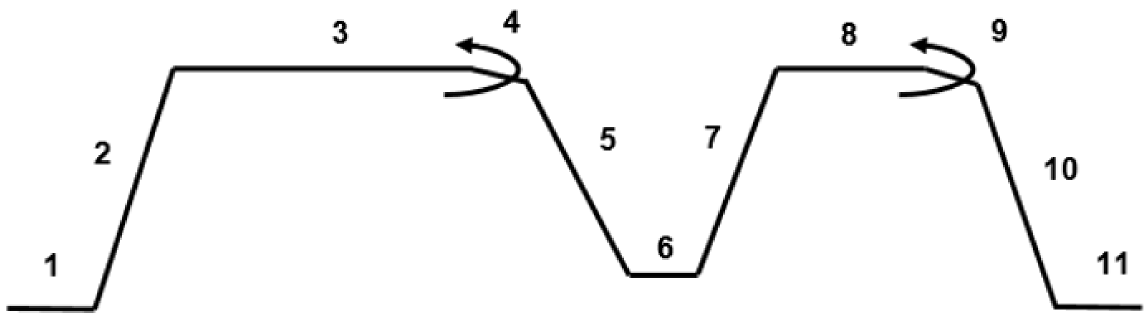
Performance

- Initial Sizing
- Constraint Analysis
- Meeting Requirements
- Drag per Segment
- Fuel Requirements
- Future Work: Achieve higher estimation accuracy as design process continues

Leg	Segment	M	Height (10^3 ft.)	Range (nm)	L/D	Assume	$\frac{W_i}{W_{i-1}}$	$\frac{W_i}{W_0}$
1	Engine Start-Up Taxi, and Takeoff	-	0	-	-	Business Jet has high bypass turbofan engines Payload = 3000 lb	0.980	0.980
2	Climb	-	-	-	-	-	0.980	0.960
3	Main Cruise	0.85	35	2500	13	Mach 0.85 at 35,000 ft is 823.8 ft/s; $(L/D)_{cruise}=0.866*(L/D)_{max}$ c=0.5 (lb/hr)/lb for high bypass turbofan in cruise	0.821	0.788
4	Loiter	0.63	35	-	15	Max L/D during loiter; Loiter for 60 minutes; c=0.4 (lb/hr)/lb for high bypass turbofan in loiter	0.974	0.768
5	Descend	-	-	-	-	Descend remaining altitude	0.99	0.760
6	Aborted Landing	-	5	-	-	-	0.99	0.752
7	Climb	-	-	-	-	-	0.98	0.738
8	Alternate	0.85	35	100	14.72	Same as Leg 3	0.992	0.732
9	Loiter	0.63	35	-	17	Same as Leg 4 except loiter for 30 minutes	0.987	0.722
10	Descend	-	-	-	-	-	0.99	0.715
11	Land	-	-	-	-	-	0.992	0.709

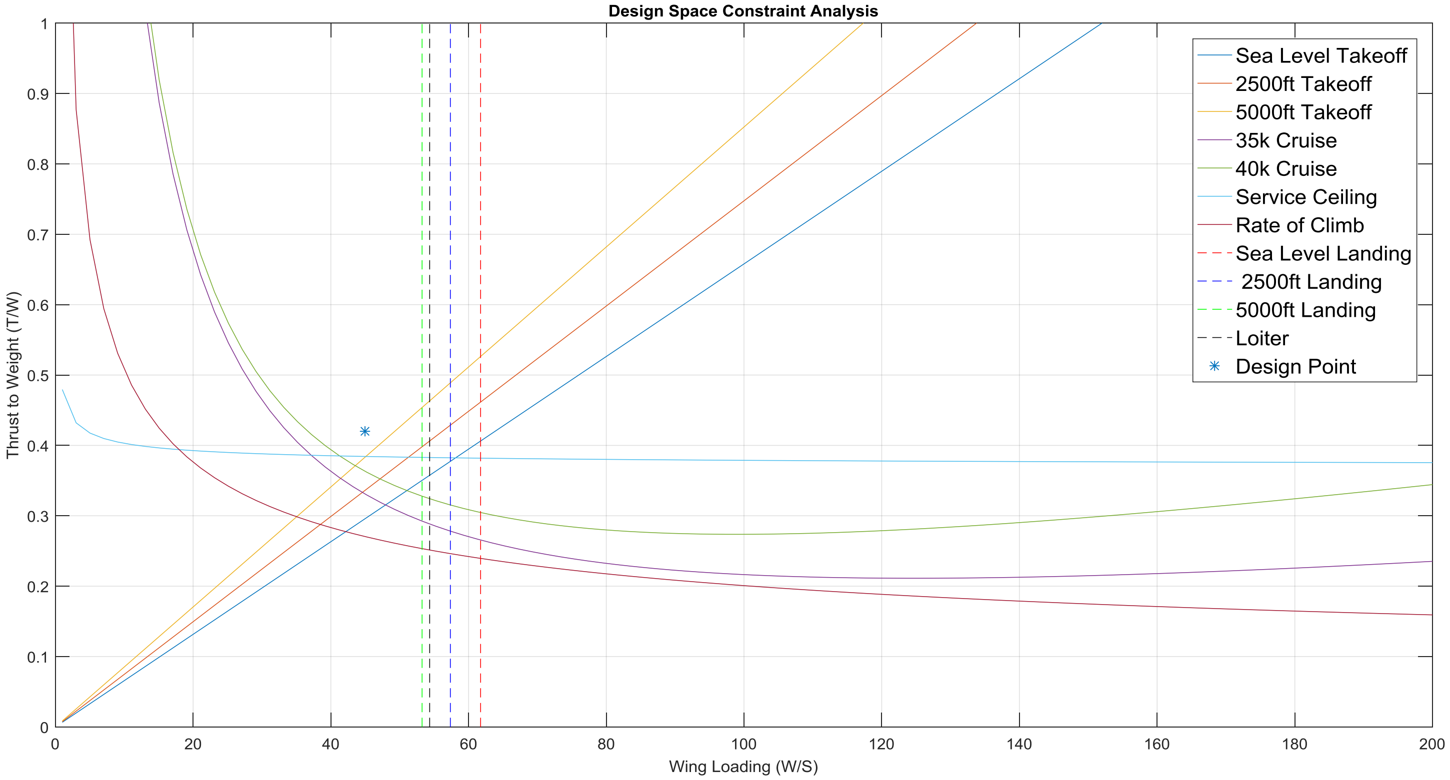
Initial Sizing

- Worst Case Scenario
  - Fully loaded Commander (2 pilots, 8 passengers, and 1000 pounds baggage) with 2500nm Cruise, hour loiter, aborted landing, 100nm alternate, and half hour loiter
- Oversize at the outset to account for inherent underestimations of initial sizing method
  - Conservative parameter value approach
- Commander: 22,100 lb
- Chief: 16,510 lb



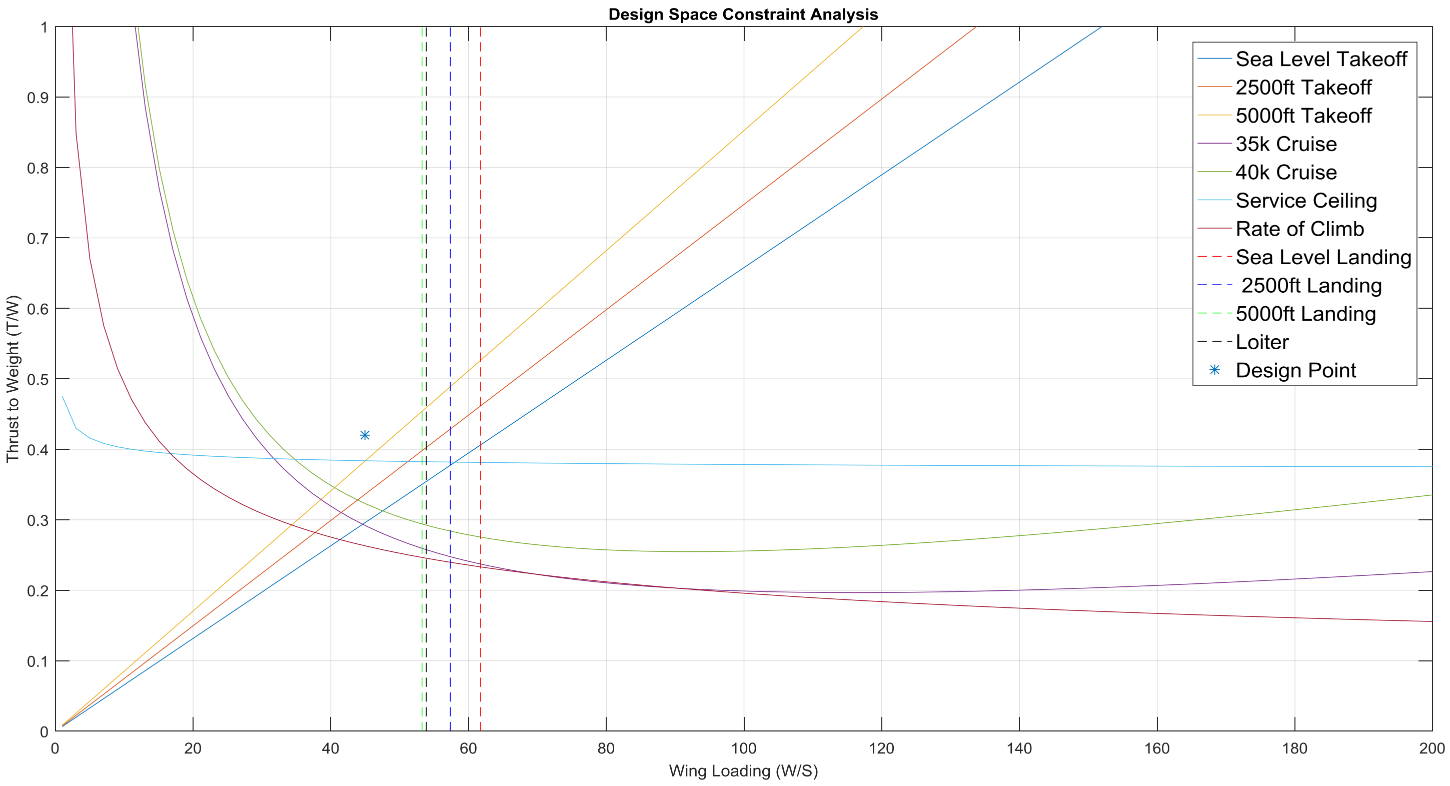
Commander Constraint Analysis

- Continually updated as parameters were changed
- Design Point
  - T/W = 0.42
  - W/S = 55



Chief Constraint Analysis

- Main wing and tail remained the same, fuselage shortened
- Design Point
  - T/W = 0.42
  - W/S = 55



Meeting Requirements

- Takeoff
  - 4000 ft Balanced Field Length at Sea Level at Maximum Gross Weight
- Landing
  - 3600 ft Landing Field Length at Typical Landing Weight
- Climb Rate
  - 3500 fpm
- Service Ceiling
  - 45,000 ft
  - Drag build up too high

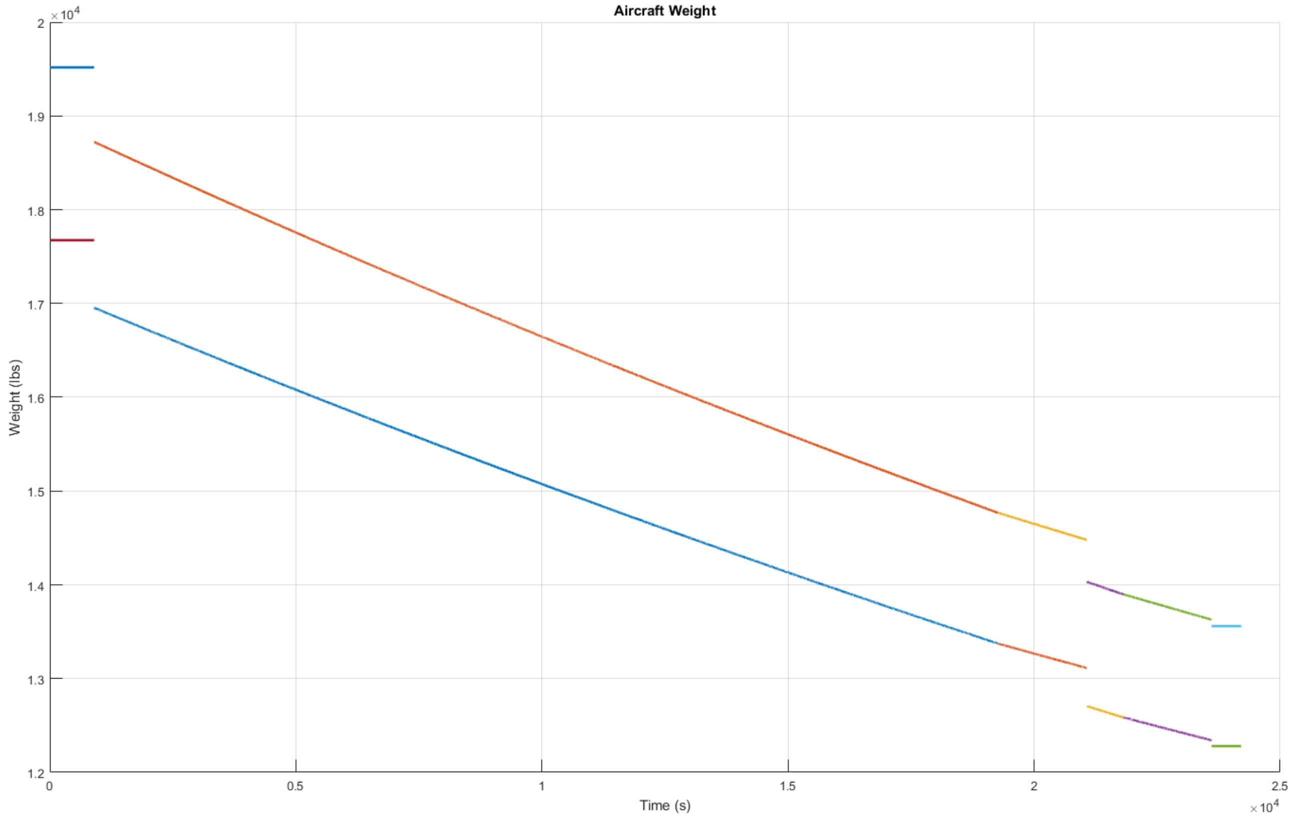
	Balanced Field Length [ft]	Landing Field Length [ft]	Rate of Climb [fpm]
Commander	3,390	3,190	4,240
Chief	3,455	2,880	3,815

Drag Per Segment

- Using drag buildup data from aero, drag per segments was calculated
- Wetted Area from CAD
  - Commander: 707.5 square feet
  - Chief: 683.3 square feet
- Optimization of the size of both jets required in future

	Takeoff (lb_f)	Cruise (lb_f)	Landing (lb_f)
Commander	**5421**	**6511**	**7783**
Chief	**5241**	**6340**	**7522**

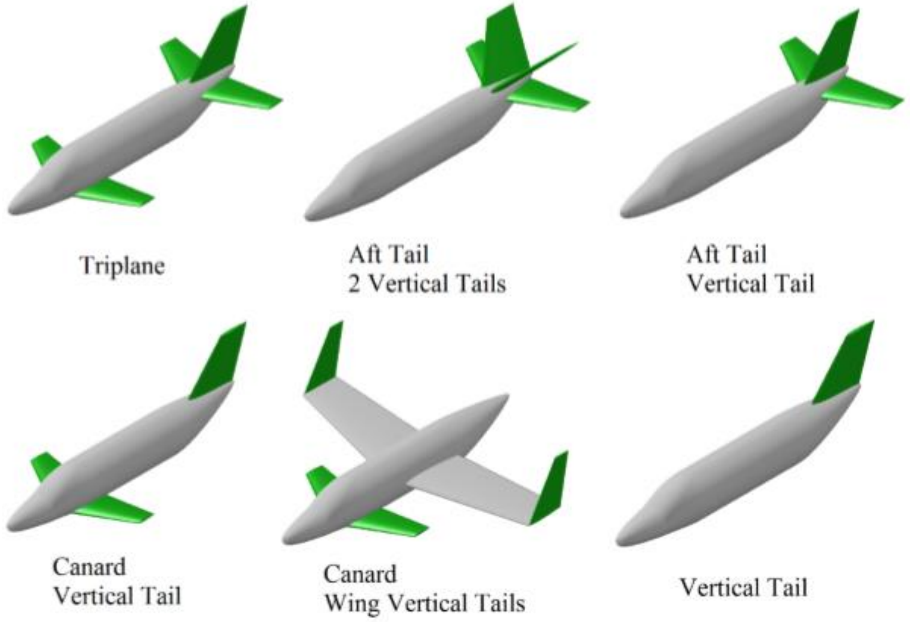
Fuel Burn



- Iteratively solved for fuel burn throughout mission profile
- Commander fuel burn:
  5956 lb
- Chief fuel burn:
  5394 lb

Stability and Control

- Tail Configuration
- Tail Sizing
- Control Surface Sizing
- Trim analysis
- Static Margin

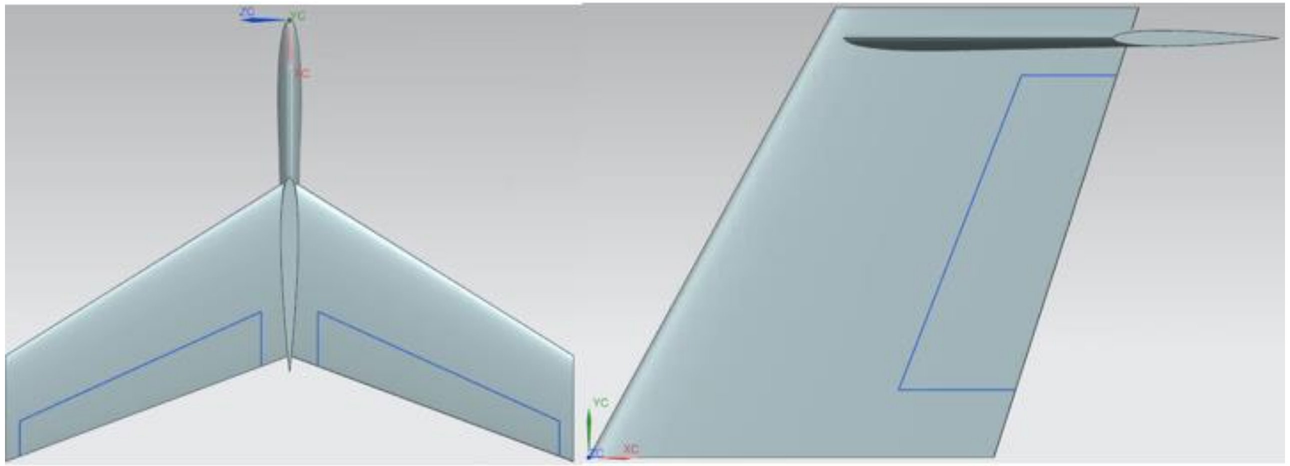


Tail Configuration

- Research of in-service business jets
  - Configuration comparison
    - Decision:

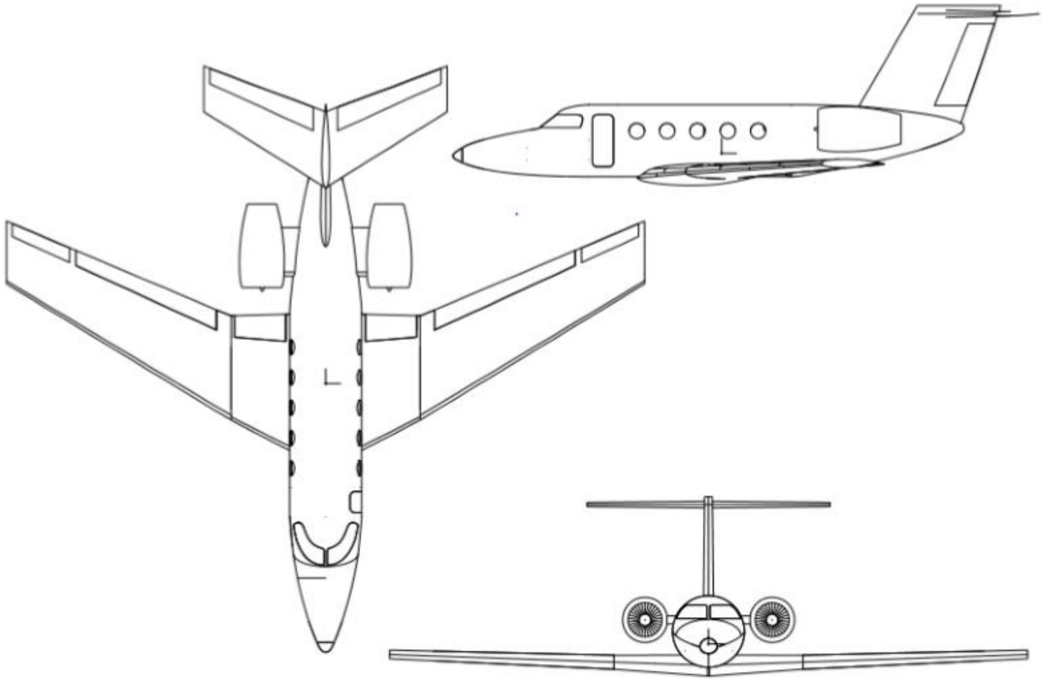
      T-tail

      NACA 0009 airfoil



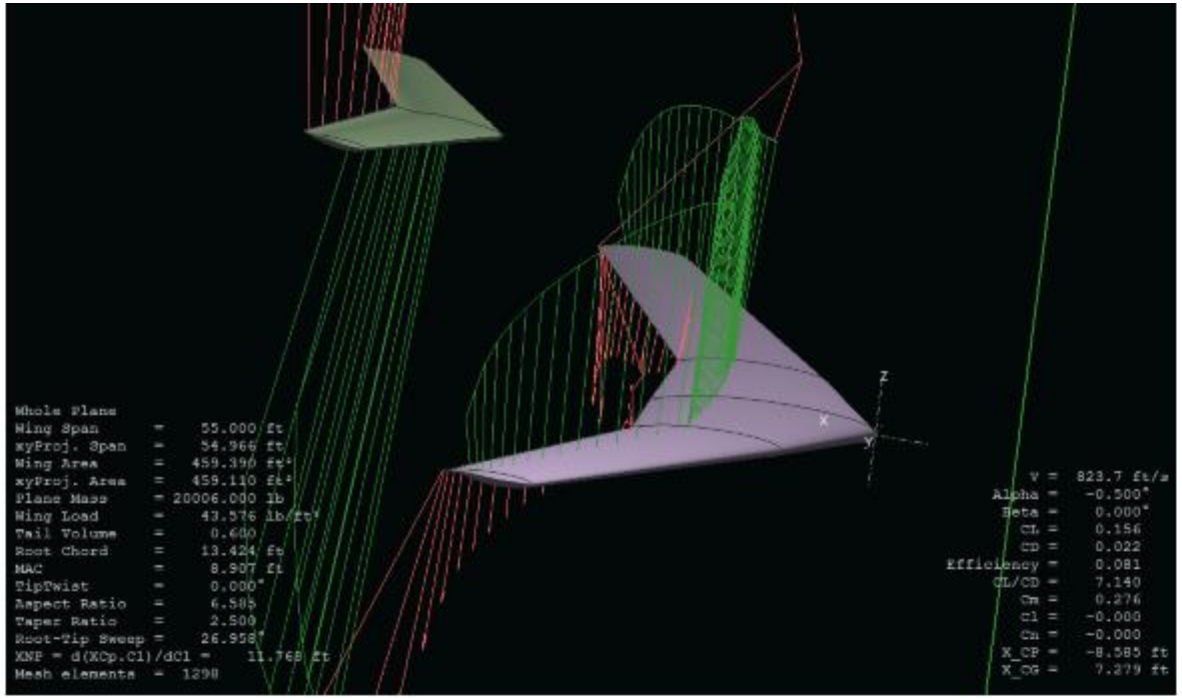
Tail Sizing

- Volume Coefficient Estimation
- Considerations of initial parameter repercussions (i.e. Aspect ratio, taper ratio, sweep angle…)
- Control Surface Sizing
  - Historical guidelines for ailerons, elevator, and rudder
  - Flap size determined by aero to create necessary coefficient of lift for takeoff and landing



Pitching Moment Trim Analysis

- Simplified estimation of C_{Mcg} to see if tail sizing/airfoil combination could work with main wing design
- New tail considerations/airfoil selection
  - Drag contribution due to new natural laminar flow airfoil too high
  - Perhaps go forward with tail and wing resizing for optimization of lift and drag created vs. what is necessary



Basic Static Margin

Static Margin Percentages

	Takeoff	Cruise	Landing
Commander	32%	32%-44%	44%
Chief	28%	28%-40%	40%

- Rough estimation of neutral point
  - Only tail and wing contributions included using XFLR5
- These numbers are most likely off, as whole aircraft contributes to neutral point; c.g. might change
- Future work
  - Static and Dynamic Stability around each axis
    - Control surface resizing

Aarav Balsu

PROPULSION

Overview

- Thrust
  - Extremely important to an aircraft’s capability
  - Determines how far and how fast you can fly
  - Also provides main source of power to various other subsystems on board.

Engine selection

- Customer satisfaction and economy are of the greatest value
- Therefore, propulsion system must satisfy the following requirements:
  – Minimized cost of ownership
    - Easy maintenance
    - Proven record of lengthy lifespans
  – Best product value
  – Sufficient thrust capacity to allow for design morphology
- Ideally, same vendor to streamline acquisition and integration process

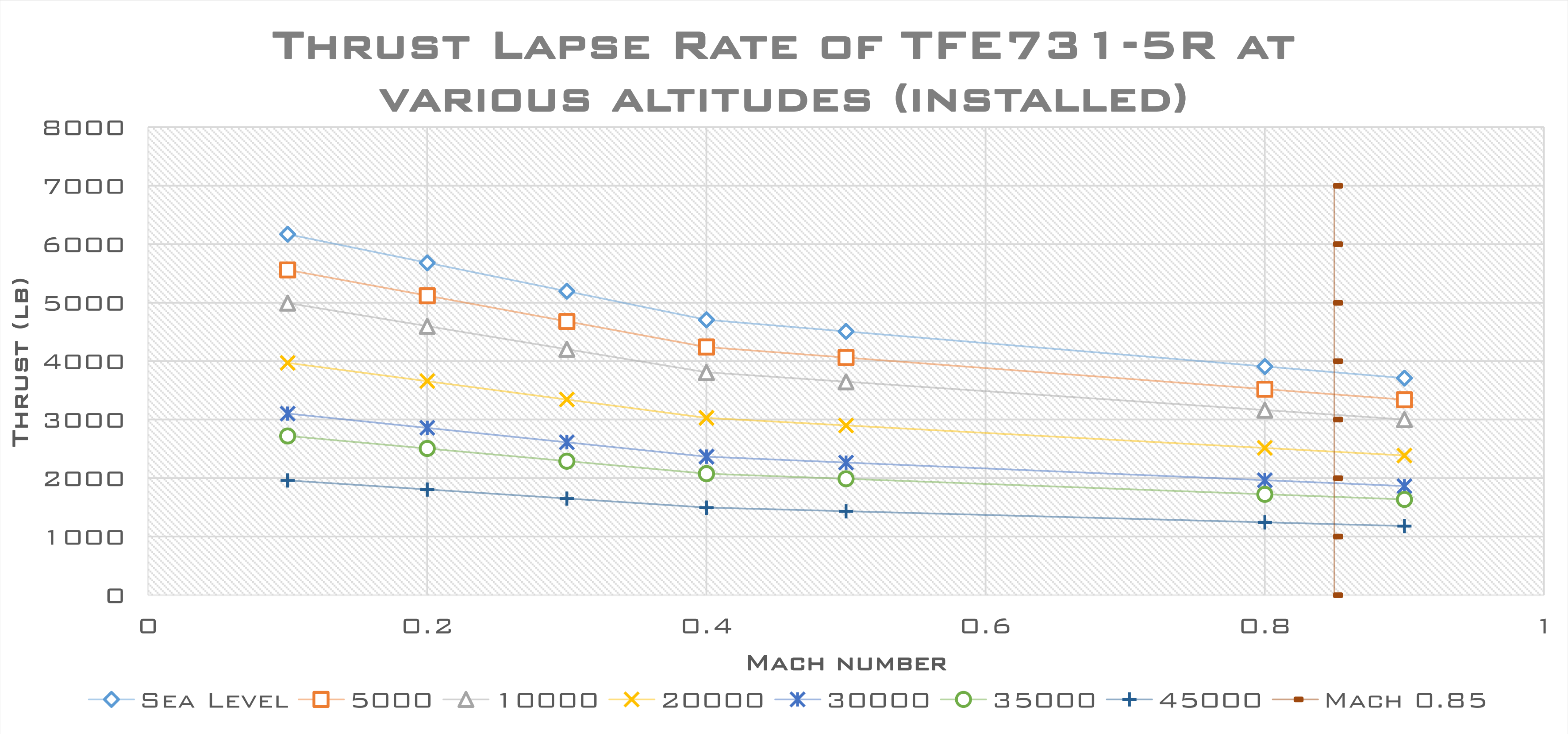
8 SEAT VARIANT

ENGINE SELECTION FOR THE COMMANDER

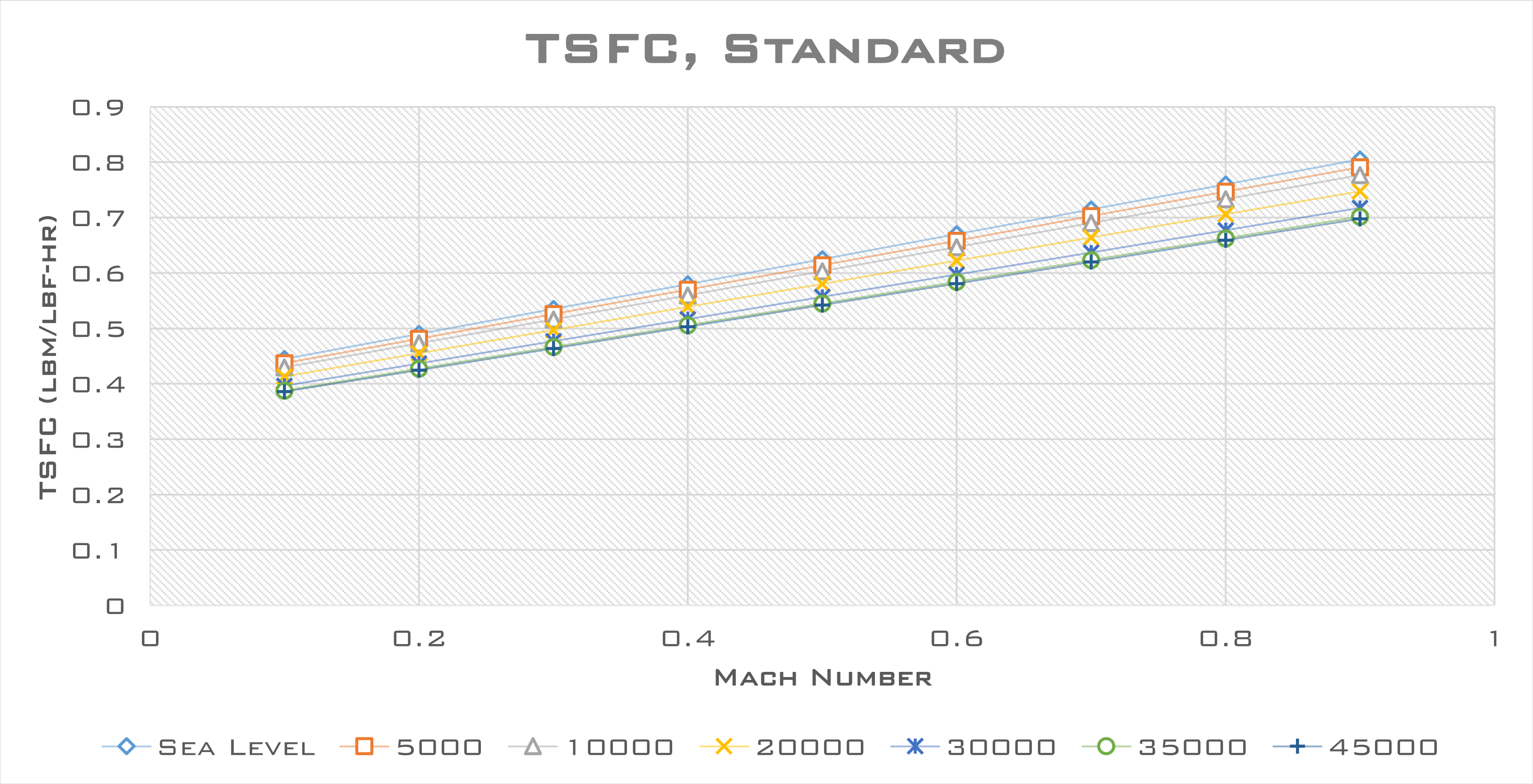
Selected Engine: TFE731-5R

- Selected because:
  - Excellent T/W = 0.410
  - Lighter than comparable engines such as the PW 305A
  - Proven track record on comparable aircraft
    - Dassault Falcon
    - BAE125-800 (Hawker 800)
  - Easy maintenance
  - Very compact, length = 65.6 in, fan diameter = 40.5 in
    - Allows for optimal placement on the aircraft
    - Enables easier process for the configuration team

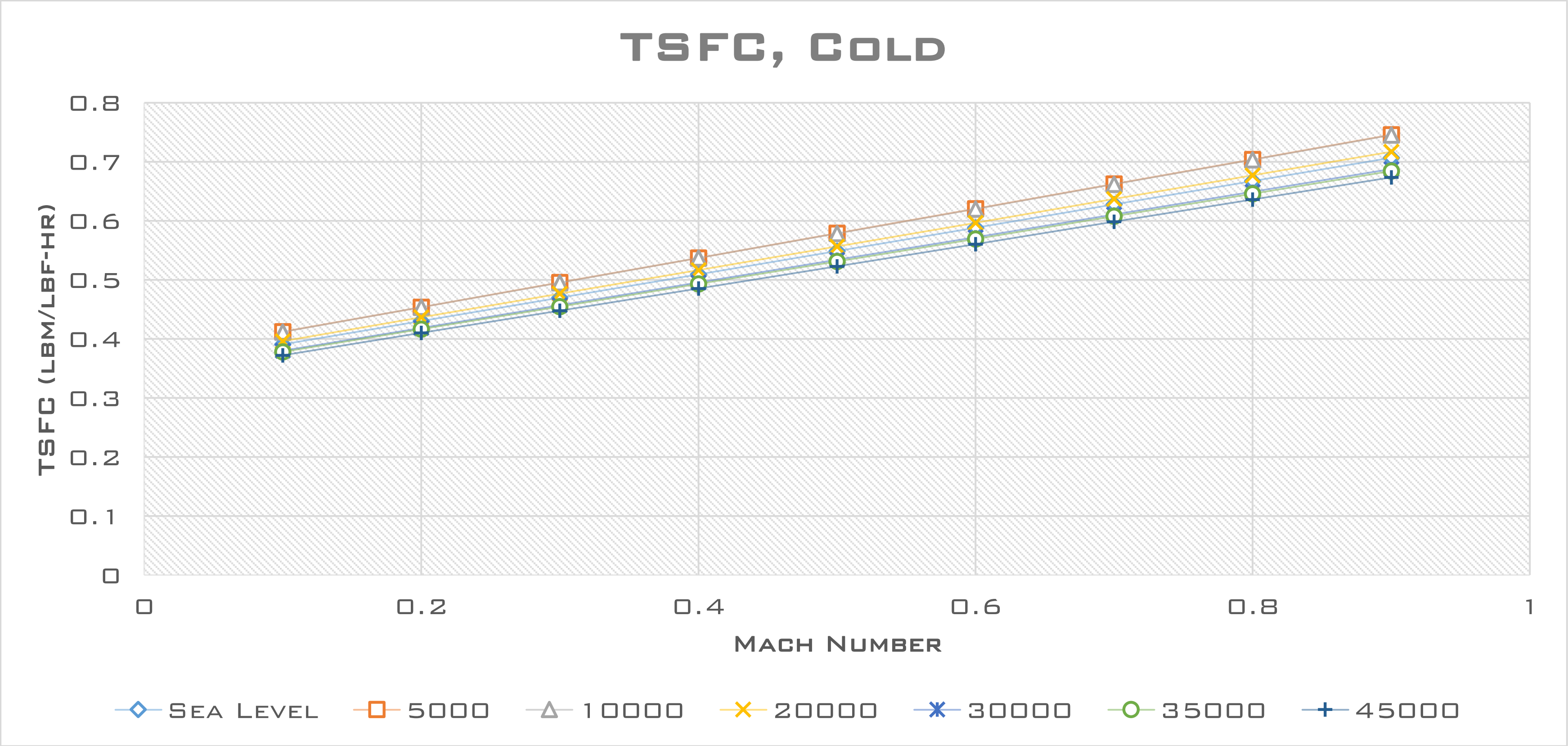
Thrust Lapse Rate for the Commander



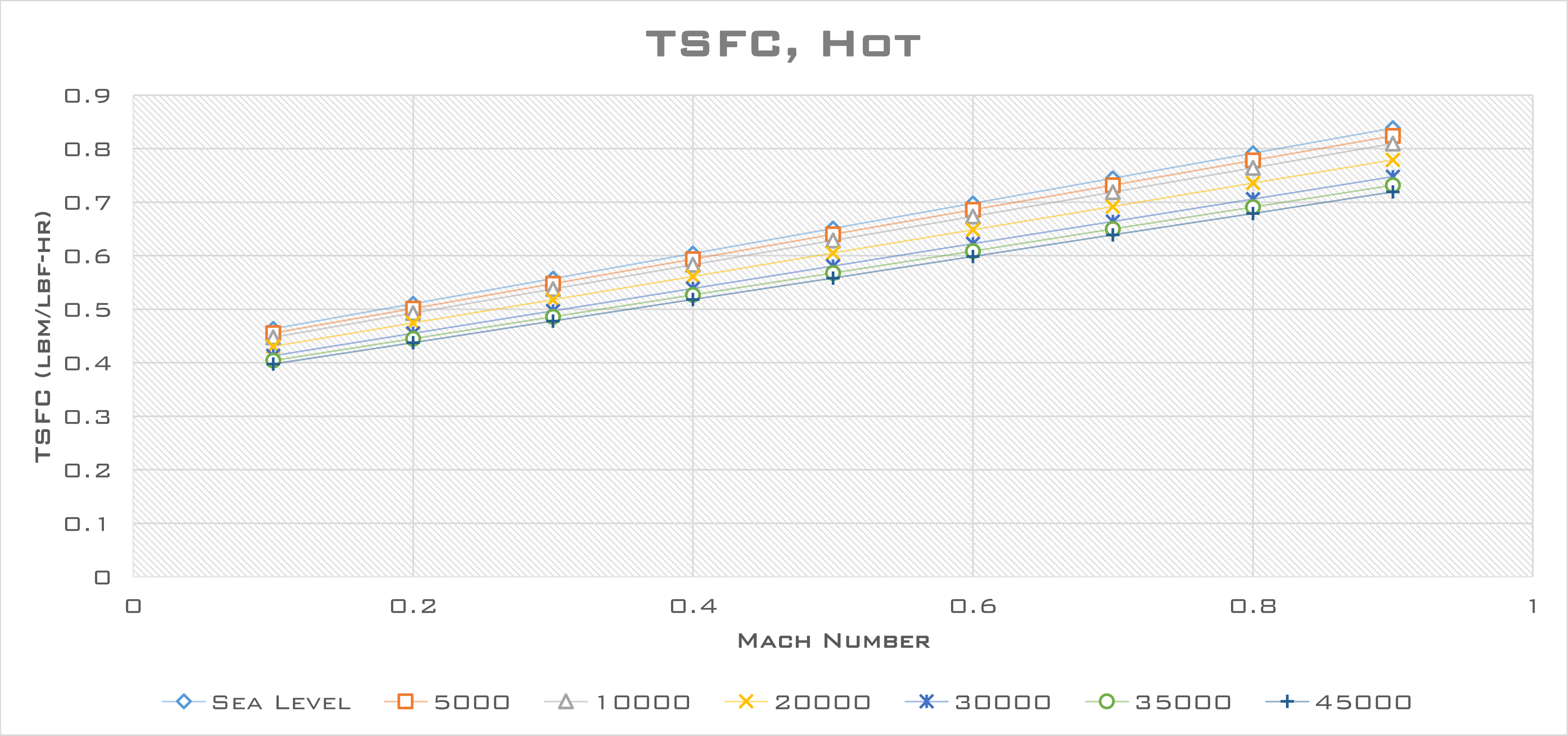
TSFC for the Commander (Standard)



TSFC for the Commander (Cold)



TSFC for the Commander (Hot)

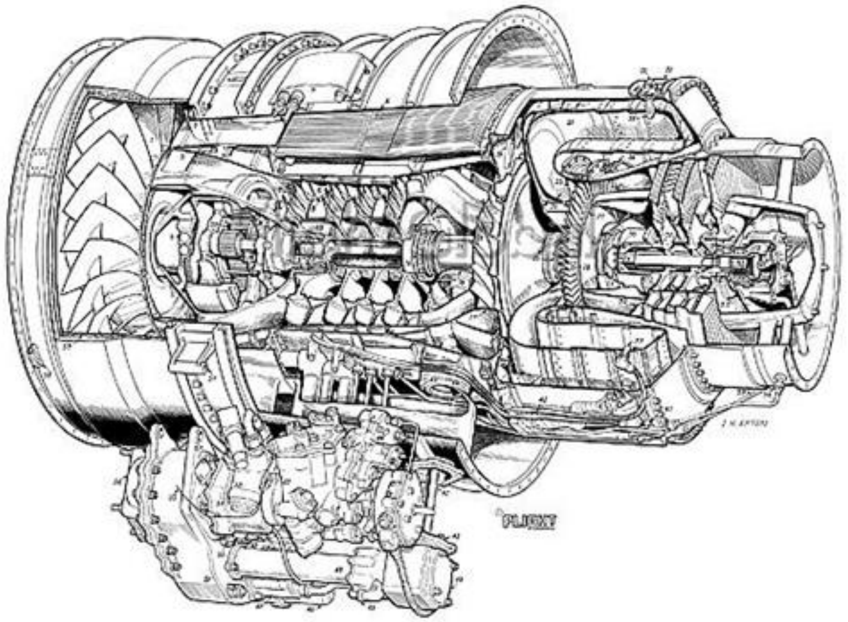


6 SEAT VARIANT

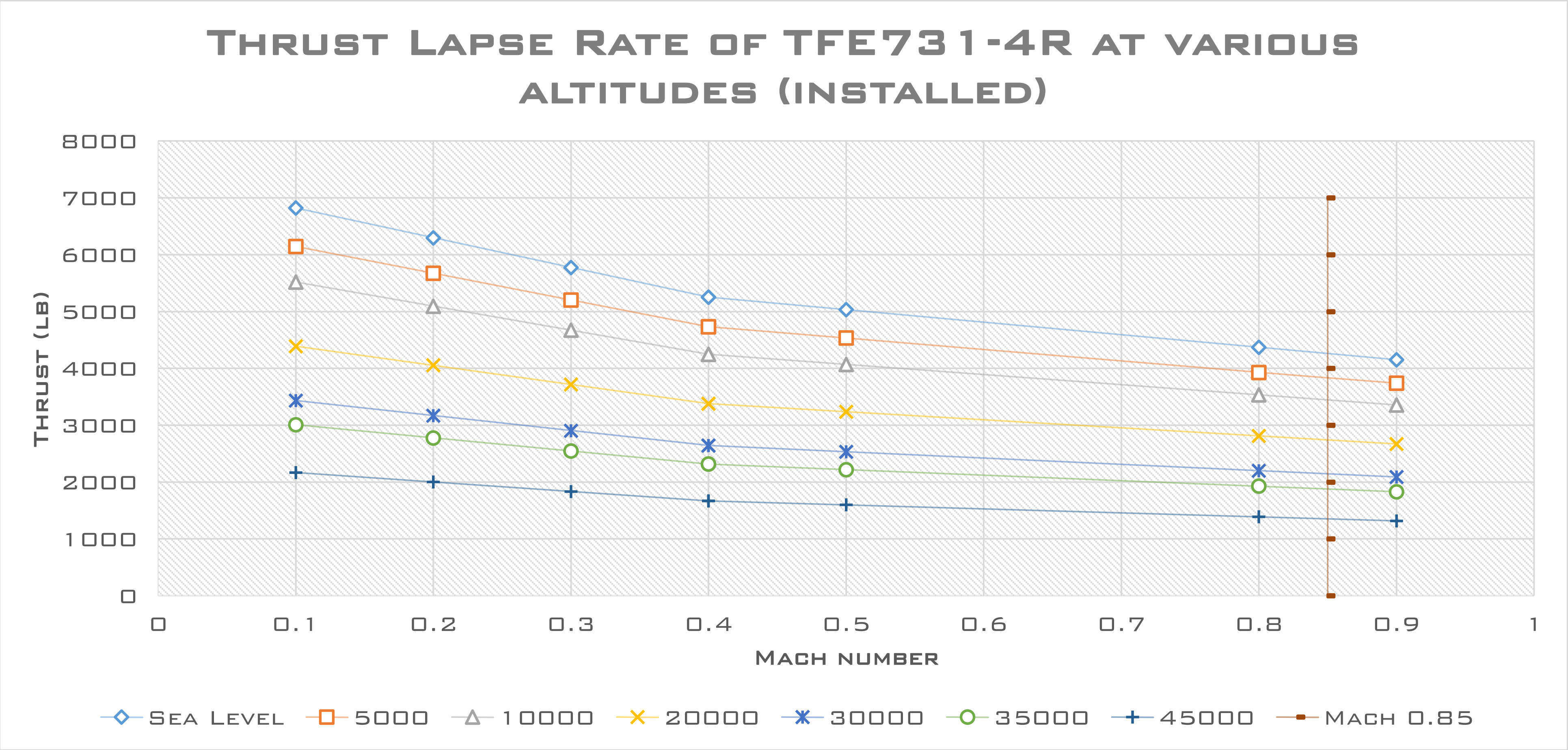
ENGINE SELECTION FOR THE CHIEF

Selected engine: TFE731-4R

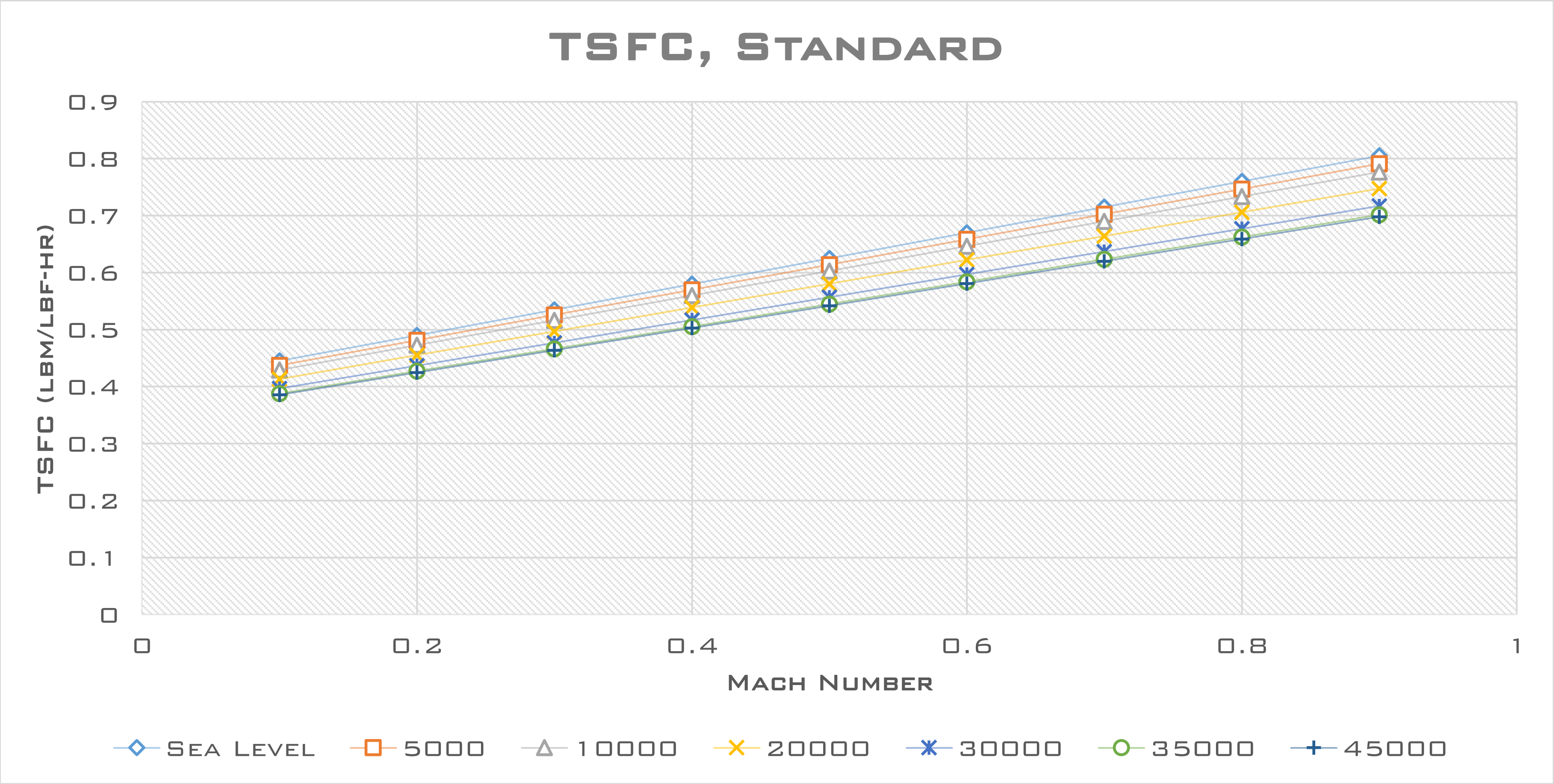
- Great T/W = 0.453
- Produces excess thrust
  - Accounts for undesirable weight increase in design morphology
  - Safe bet
- Easy maintenance
- Used on comparable aircraft like:
  - Cessna 650 Citation VII
- Also extremely compact
  - Length = 60.2 in
  - Fan Diameter = 39.4 in



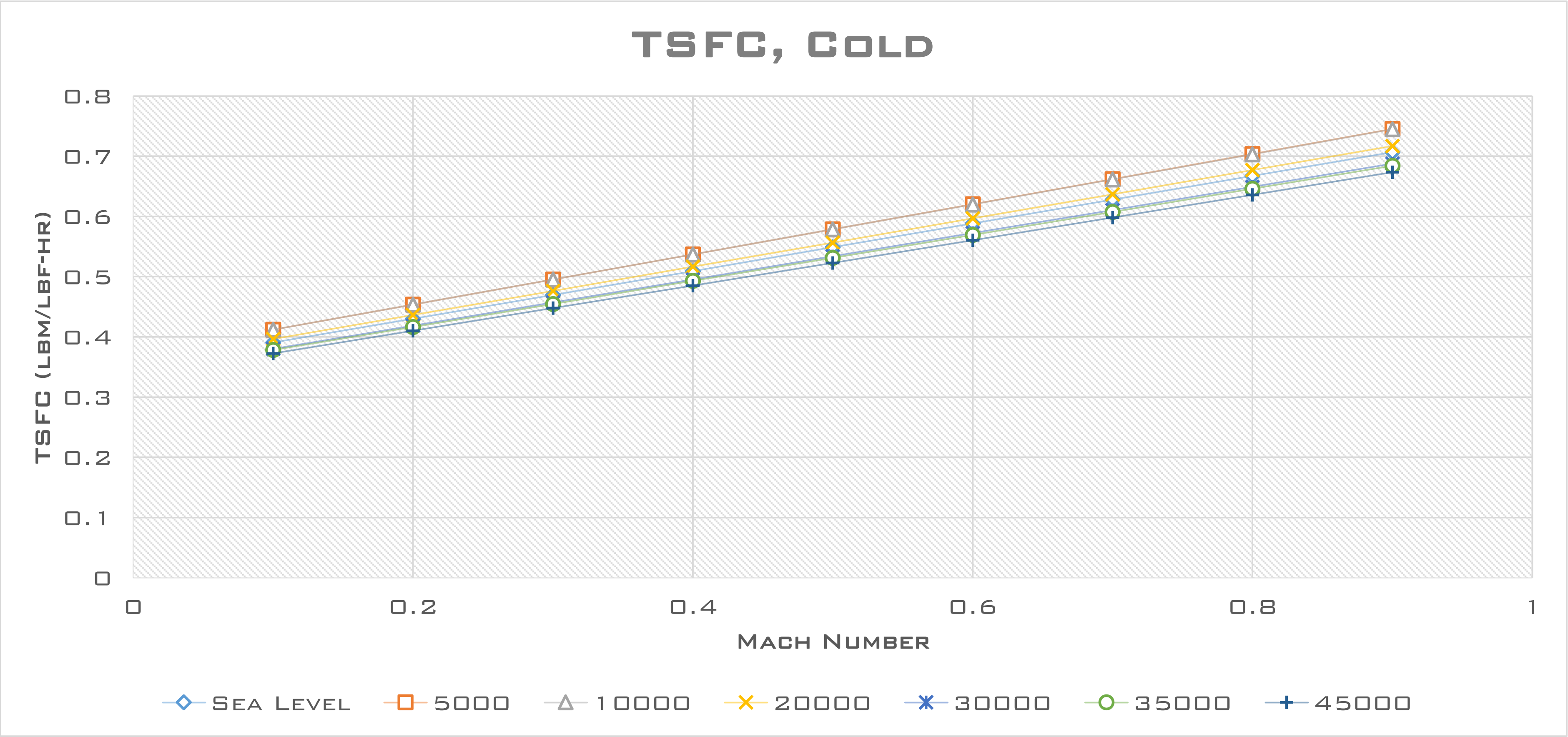
Thrust Lapse Rate for the Chief



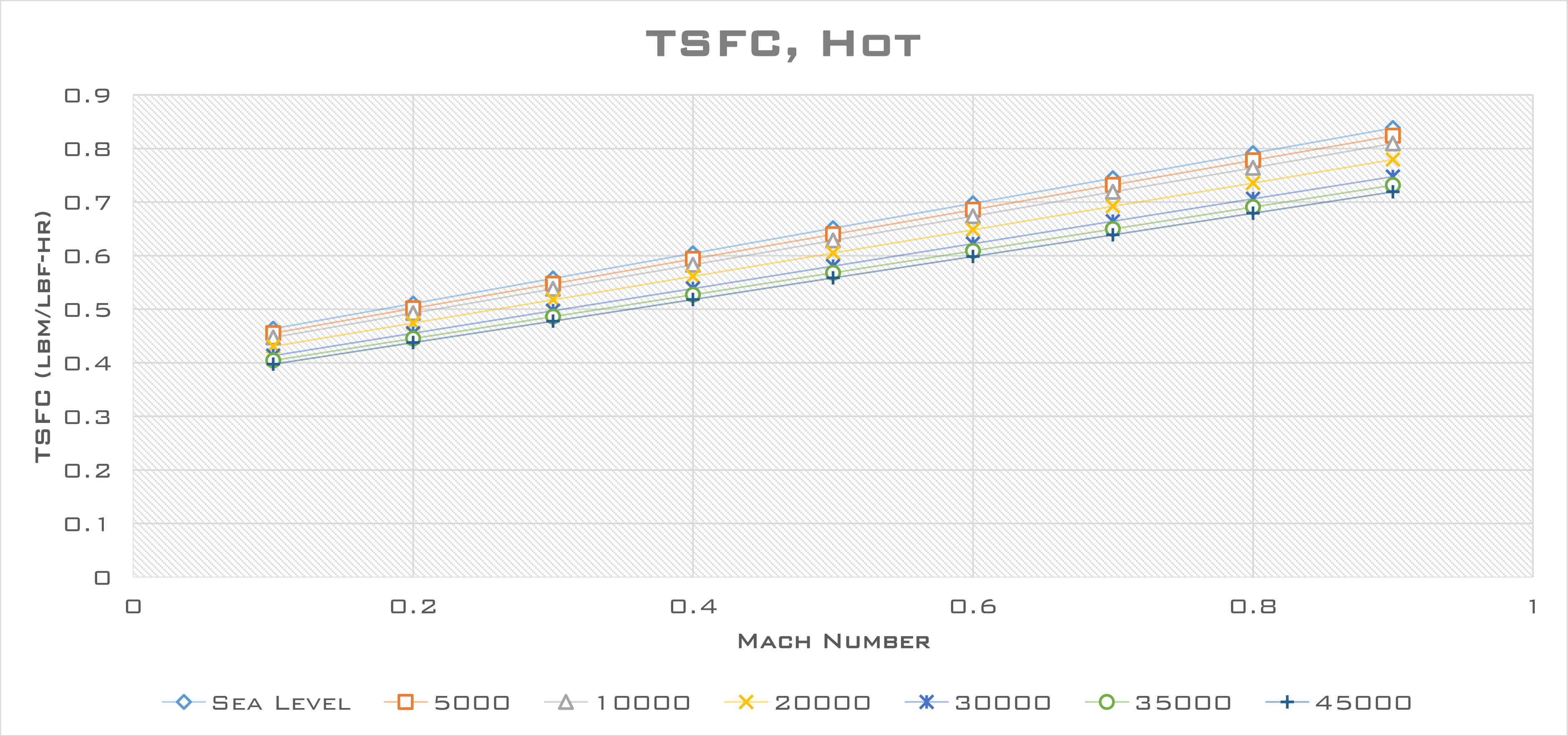
TSFC for the Chief (Standard)



TSFC for the Chief (Cold)



TSFC for the Chief (Hot)



Design Tools

- Excel = great way to create a highly automated process!
- Just requires a few user inputs (Uninstalled thrust, bypass ratio) to create a set of Thrust Lapse rates and TSFC
- Required to develop it from scratch:
  - Algorithms had to be input as functions
  - Plots had to be manually calibrated to be visually appealing

Benefits of using Honeywell Engine family

- Proven track record of excellence in business jet capacity
- Well established vendor with capacity to be flexible on delivery
- Single vendor:
  - Easier to coordinate and optimize manufacturing process
  - Streamlined maintenance
  - Minimized compatibility problems
  - Faster staff training: similar engines to work with and integrate into the aircraft
  - Principle of one phone number, one contact, one invoice
  - Essentially, commonality principle is satisfied

Aarav Balsu

AVIONICS

Overview

- Increasingly vital to smooth operation of aircraft
- Pilots expect to do more with less
- Industry is rapidly growing, adding new innovations constantly
- The Commander and Chief avionics requirements are:
  - One vendor solution
    - Ensures smooth integration with all subsystems and components
    - One phone number, one contact, one invoice
  - Capacity for growth in software capabilities
  - Pilot comfort

Rockwell Collins Pro Line 21

- Rockwell Collins Pro Line 21
- Established vendor
- Proven record of excellence in avionics development and deployment
- Capacity to outfit the entire aircrafts' avionics and communication systems with tried and tested products
- Capacity for software upgrades
- Rated highly by pilots for building intuitive, well integrated products
- Will tailor the avionics package to the shape of the cockpit, ensuring optimal placement

Rockwell Collins
Building trust every day

Rockwell Collins Pro Line 21

Rockwell Collins Pro Line 21

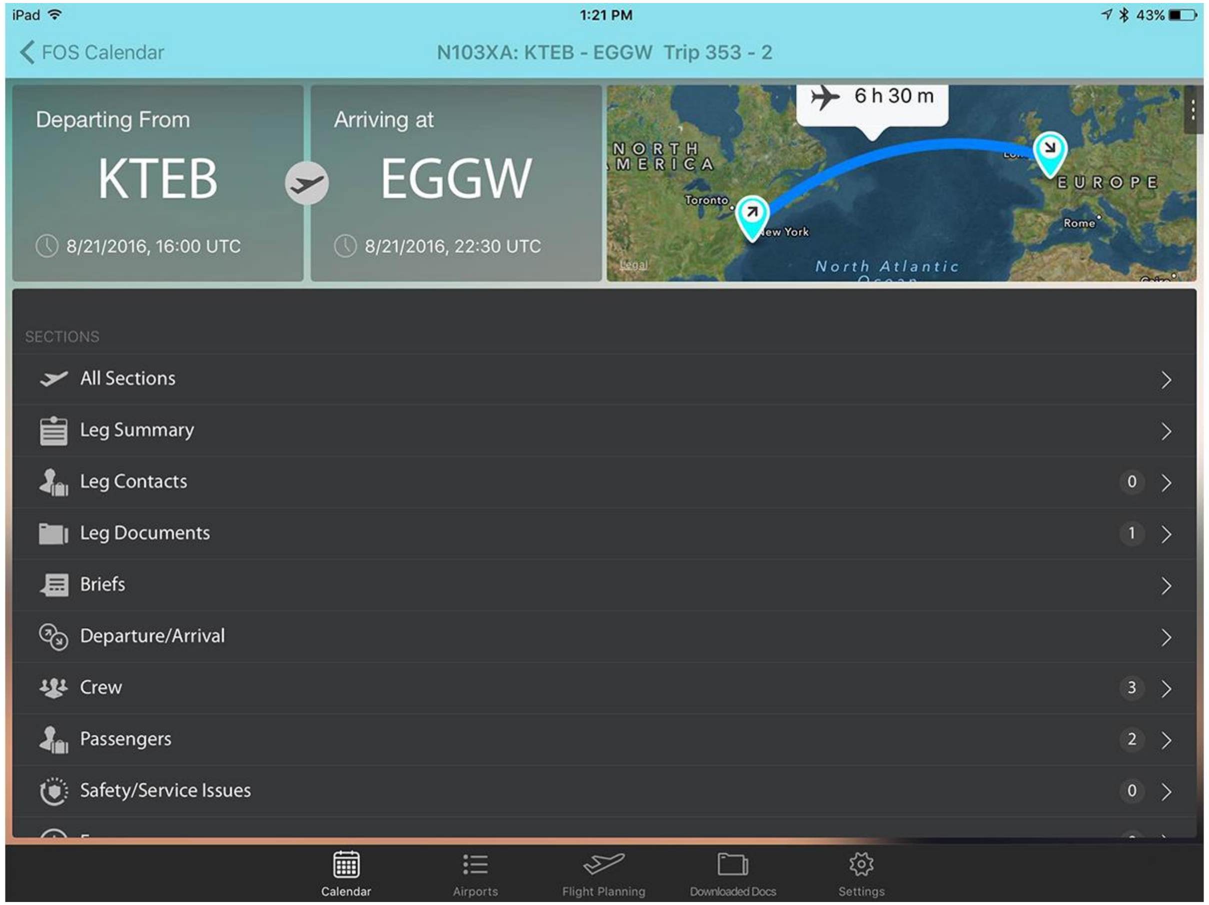
Features

- **Rockwell Collins flight guidance system**
- **Large AMLCDs (Active Matrix Liquid Crystal Displays)**
- **Weather radar**
- **TCAS**
- **TAWS**
- **Electronic checklist**
- **3-D flight plan maps**
- **Electronic charts**
- **Digital data-links**
- **Real time weather graphics (which allow for a high degree of situational awareness)**
- **Mature designs (higher dispatchability)**
- **Upgradeability**
  - **Synthetic Vision System (SVS)**
- **Designed with growth in mind**

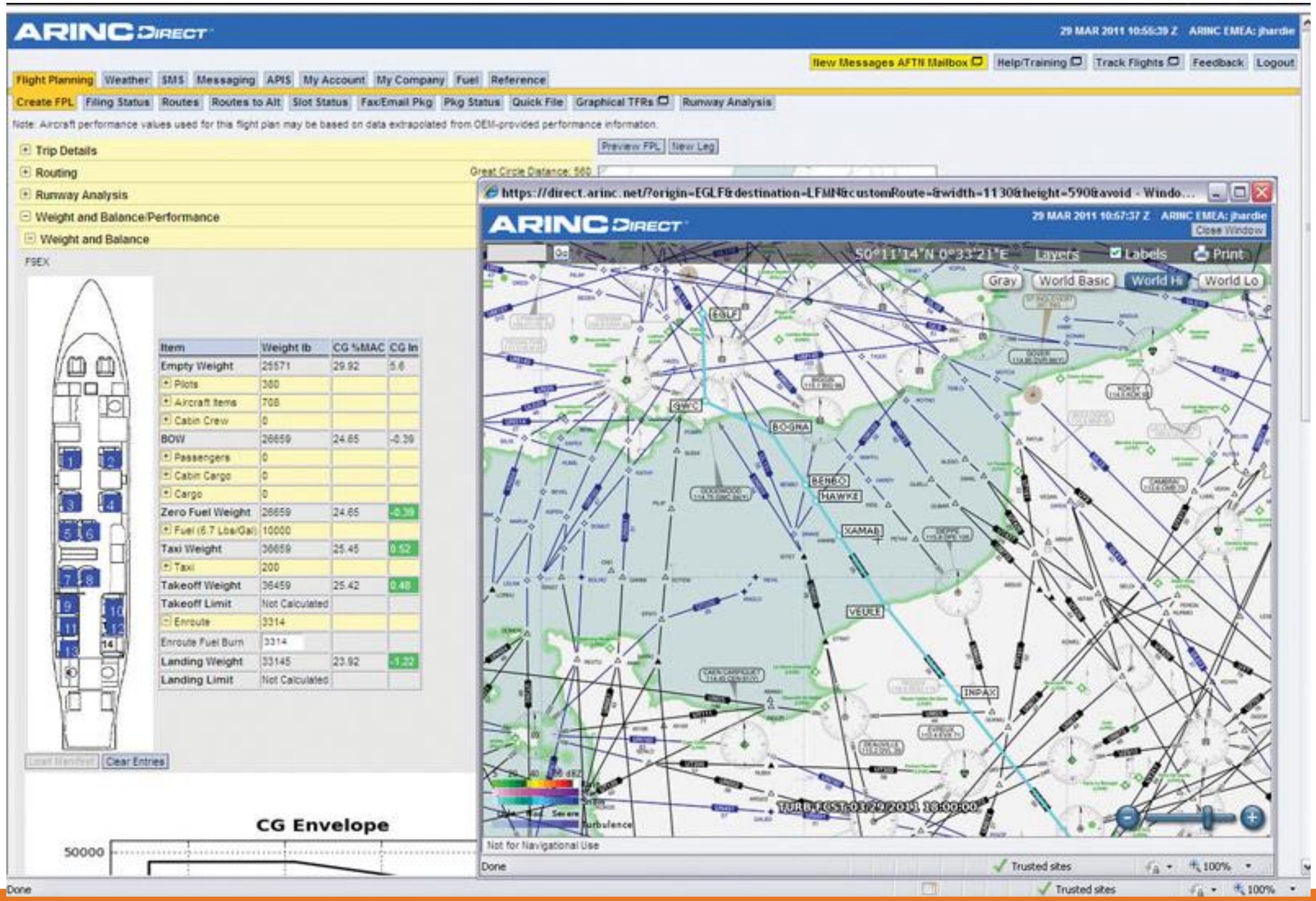
Communication

- Rockwell Collins ARINCDirect Inmarsat Jet Connex Services
- One vendor integration
- Rated highly by customers for reliability
- Installed on many other comparable corporate jets
- Enables the passengers to stay connected
  - Vital capability in today's increasingly data-centric world
  - Will increase product satisfaction dramatically
  - Empowers the passenger by allowing them to enjoy a seamless transition between working and travelling
  - Leisure capacity is also important, and is present!

ARINCDirect example



ARINCDirect example



Communications features

- **Seamless global satellite coverage for continuous, consistent service**
- **Upgradeable bandwidth for new devices and applications**
- **Airborne Data Router (ADR) for next gen connectivity from the flight deck to the cabin**
- **One price for a complete connectivity package**
- **One invoice for all service calls**
- **One phone number for technical, customer, and billing support**
- **Upgradeability**
  - **Stage™ digital entertainment service**
  - **Live TV**

Conclusion

- One vendor solution is ideal to the customer and is centerpoint of avionics development strategy for the Commander and Chief
- Establishing a valued relationship with Rockwell Collins
  - Can lead to future discounts on purchases
  - Ensures optimal integration between products
  - Guarantees streamlined maintenance process

Anthony Klepacki and Alicia Qiu

STRUCTURES

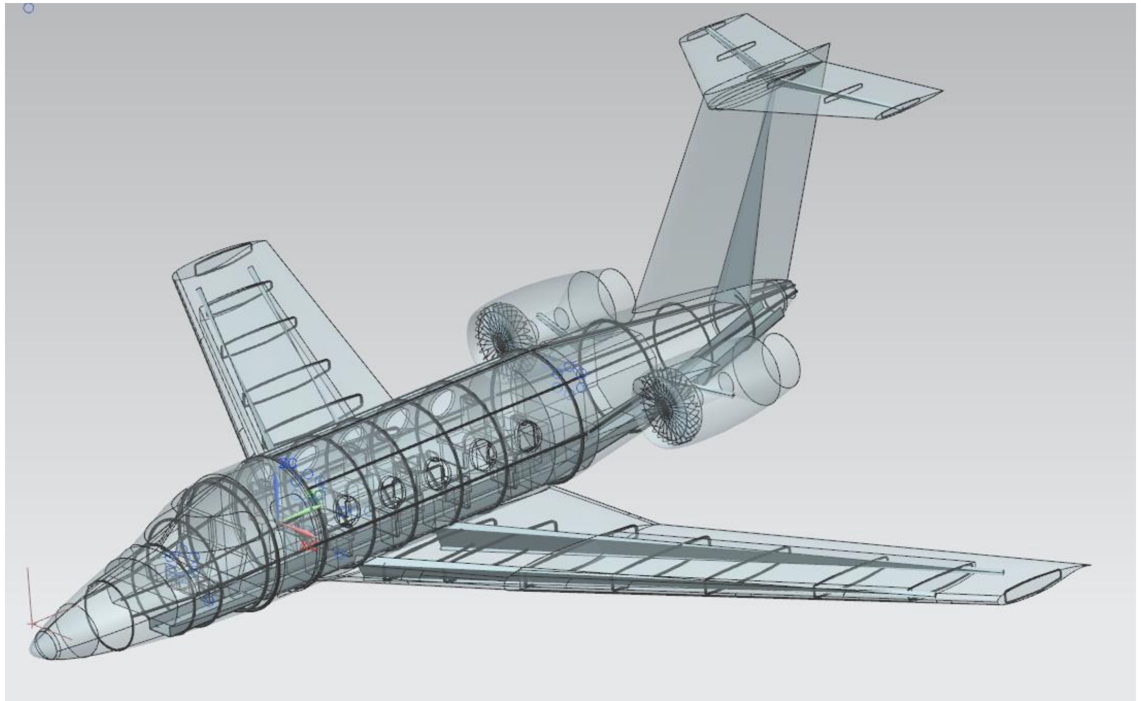
Overview

- Design Considerations, Constraints and Methodology
- Wing Primary and Secondary Structures
- Fuselage Structures
- Structures Commonality
- Weight Overview

DESIGN CONSIDERATIONS, CONSTRAINTS AND METHODOLOGY

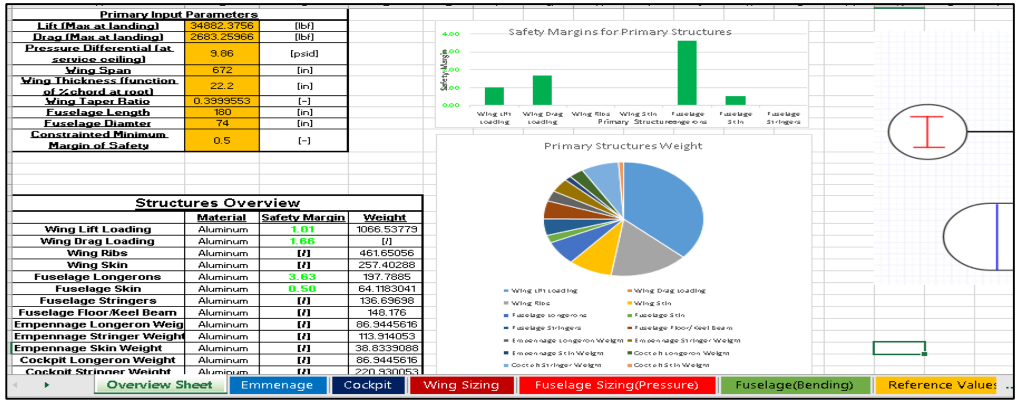
Design Considerations and Constraints

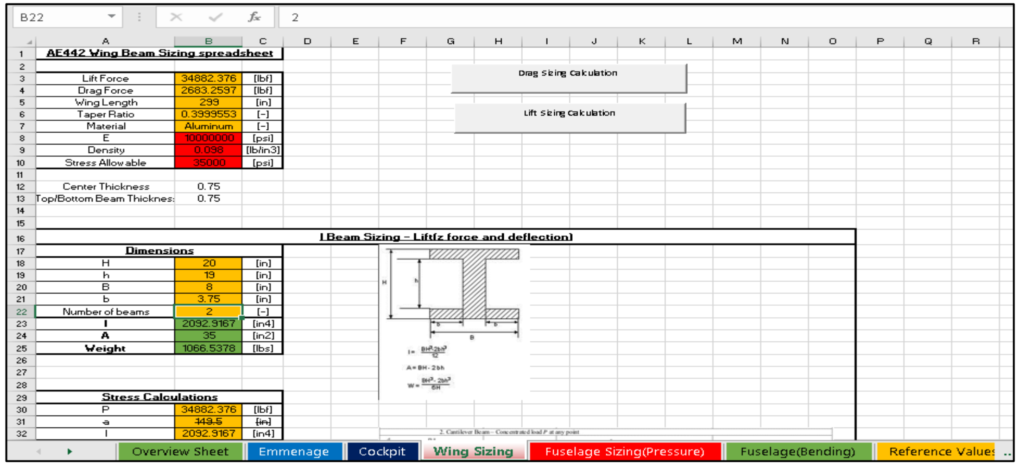
- Weight consciousness
- Commonality between family of aircraft
  - 70% Structures
- Ease of manufacturability
  - First plane to be manufactured in ~3 years
- Robust design



Design Methodology

- Microsoft Excel-based automated and iterative solver
- Useful for quick first order trade studies
- Small amount of inputs to size many key structural elements simultaneously





Material Selection and Trade Study

- Choice between aerospace grade Aluminum, Steel and Titanium
- Aluminum has a far superior specific stiffness and strength when considering cost
- Ease of manufacturing through common methods

Physical Properties	Metric	English	Comments
Density	2.81 g/cc	0.102 lb/in³	AA; Typical
Mechanical Properties			
Hardness, Brinell	150	150	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	191	191	Converted from Brinell Hardness Value
Hardness, Rockwell A	53.5	53.5	Converted from Brinell Hardness Value
Hardness, Rockwell B	87	87	Converted from Brinell Hardness Value
Hardness, Vickers	175	175	Converted from Brinell Hardness Value
Ultimate Tensile Strength	572 MPa	83000 psi	AA; Typical
Tensile Yield Strength	503 MPa	73000 psi	AA; Typical
Elongation at Break	11 %	11 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Elongation at Break	11 %	11 %	AA; Typical; 1/2 in. (12.7 mm) Diameter
Modulus of Elasticity	71.7 GPa	10400 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Poisson's Ratio	0.33	0.33	
Fatigue Strength	159 MPa	23000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen

WING PRIMARY AND SECONDARY STRUCTURES

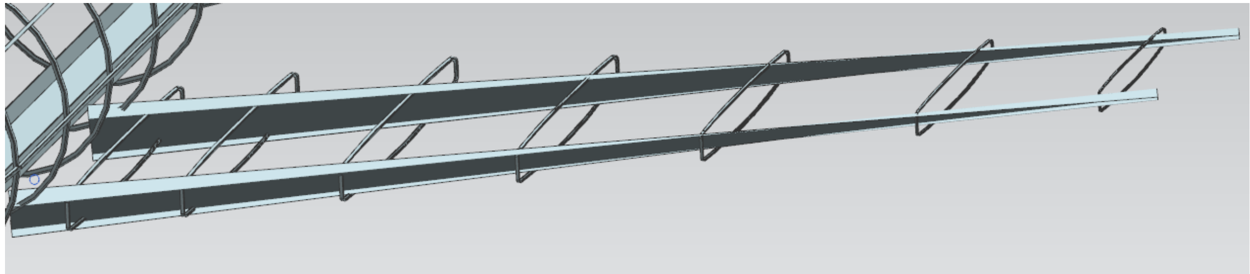
Wing Structures

Primary Structures

- Dual I-beam centric design
- High specific bending stiffness in lift and drag direction
- Allows for easy interfacing between other components
- Ease of manufacturing through extrusion or casting
- Taper design through linearity of bending moments

Secondary Structures

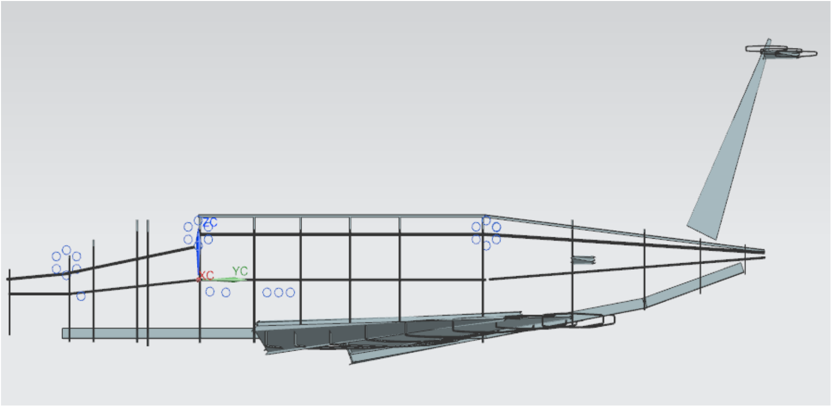
- Airfoil-shaped ribs
- T-Beam cross-section to withstand torsional and compression loading
- Allows for easy fuel tank integration
- Skin sized to withstand service ceiling pressure loads

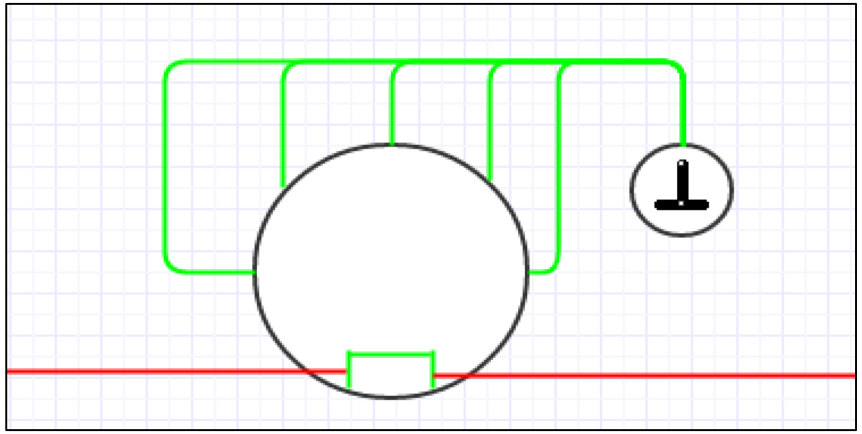


FUSELAGE STRUCTURES

Fuselage Structures

- Five Upper Longerons
  - Constant area T-beam cross section
- Central Floor Beam
  - High bending stiffness and compatibility with configurations group
- Primary Stringers
  - Interface points for critical load bearing structures
  - Constant area T-beam

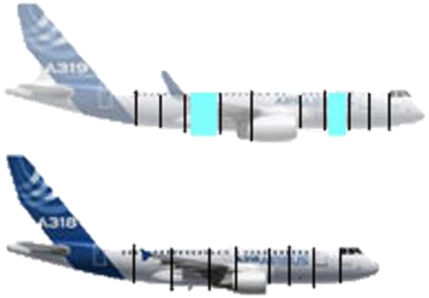


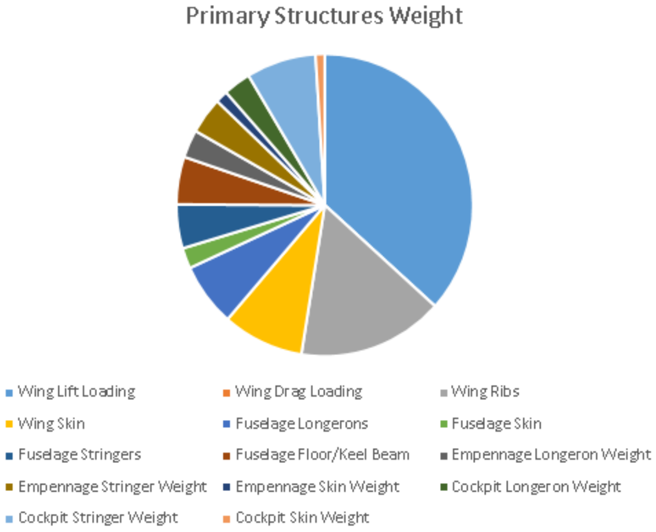


STRUCTURES COMMONALITY

Structures Commonality and Weights

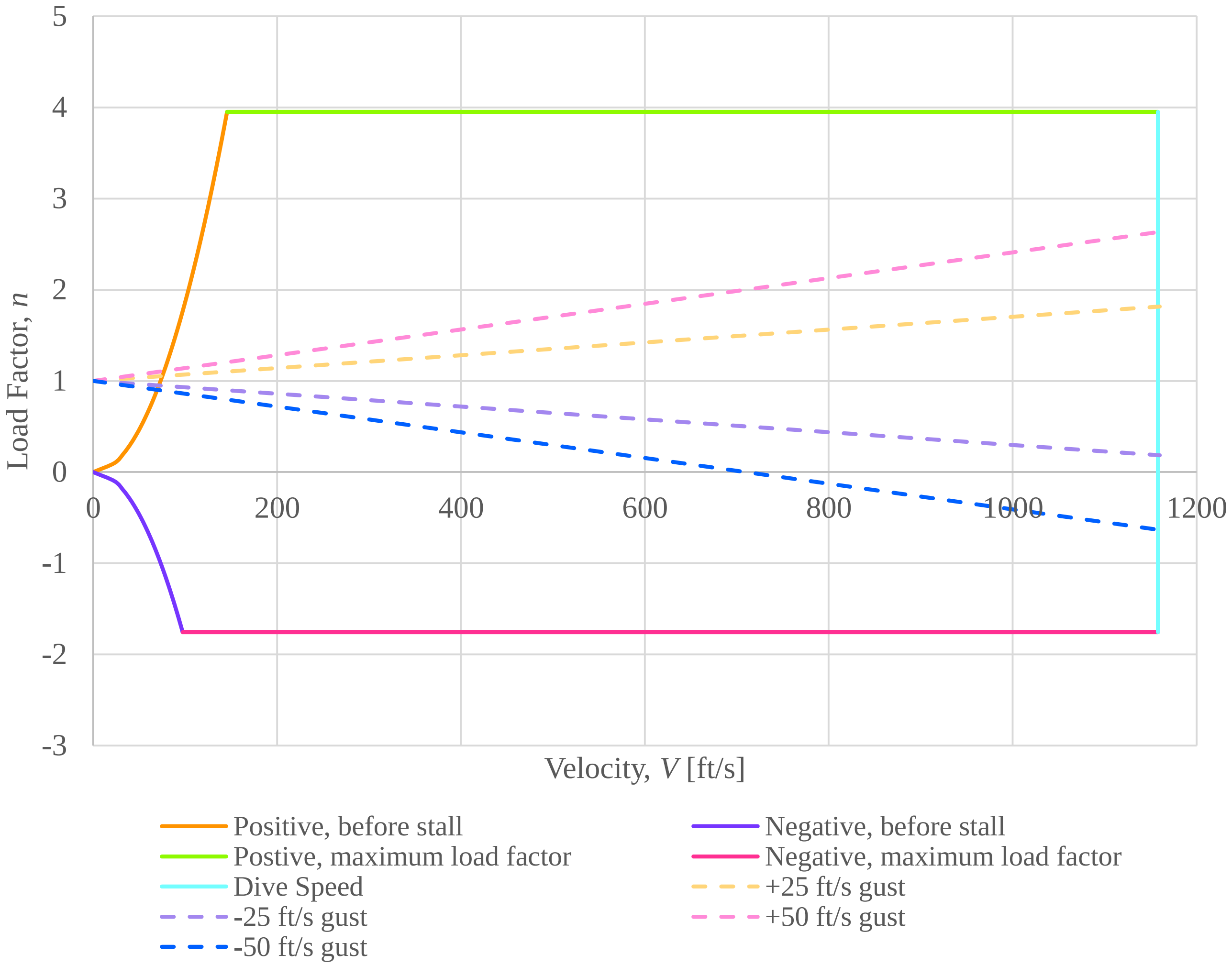
- Requirement for 70% structures commonality between aircraft met through use of a highly common airframe
  - Removal of stringer section corresponding to a row of seats
  - Stringers are typically decoupled from other primary structures
- Total Primary Structures Weight: ~2600lbm
  - Sized and weight for 8-person aircraft
- 6-person variant will be reduced in weight by removal of a stringer section~11% reduction in fuselage structures





V-n Diagram

- Must remain in the flight envelope to maintain structural integrity
- Maximum load factor, $n_{max} = 3.951$
- Minimum load factor, $n_{min} = -1.756$
- Gust Analysis
  - ±25 ft/s and ±50 ft/s
  - Will not achieve structural damage



Landing Gear Design

Trade Studies

- Gear Configuration: Tricycle
- Shock Absorption: Shock strut absorber

Nose Landing Gear Components

- Inner and outer cylinder
- Upper and lower torsion link
- Upper and lower steering plate
- Nose gear axle
- Taxi lights

Main Landing Gear Components

- Inner and outer cylinder
- Upper and lower torsion link
- Upper and lower drag strut
- Main gear axles (2 per strut)

Landing Gear Loads

The Chief

Weight Configuration	Weight [lb]	Nose Landing Gear Load [lb]	Main Landing Gear Load [lb]
Takeoff Gross Weight	16329.53	2958.14	13371.39
Empty Fuel Weight	11329.53	1898.35	9431.18

Load Percentages

- Takeoff Gross Weight
  - NLG: 18.115%, MLG: 81.885%
- Empty Fuel Weight
  - NLG: 16.756%, MLG: 83.244%

The Commander

Weight Configuration	Weight [lb]	Nose Landing Gear Load [lb]	Main Landing Gear Load [lb]
Takeoff Gross Weight	19261.12	2701.39	16559.72
Empty Fuel Weight	13561.12	2077.67	11483.44

Load Percentages

- Takeoff Gross Weight
  - NLG: 14.025%, MLG: 85.975%
- Empty Fuel Weight
  - NLG: 15.321%, MLG: 84.679%

Landing Gear Tire Selection

- Type VII/New Design tires
  - Built to carry extra high pressure
  - Carry the largest load capacity
  - Travel at very high takeoff speeds
  - Narrow width, insignificant size when stored in wheel well

Nose Landing Gear Wheel Sizing

- Selected tire must carry maximum nose gear loads of the Commander and Chief
  - 2958.14 lb distributed through 2 tires, 1,479.07 lb per tire
- Goodrich's Tire Data Catalog
  - Tire Type: New Series
  - Dimensions: 14.5 in diameter, 5.5 in width
  - Maximum Loading: 3550 lb

Main Landing Gear Wheel Sizing

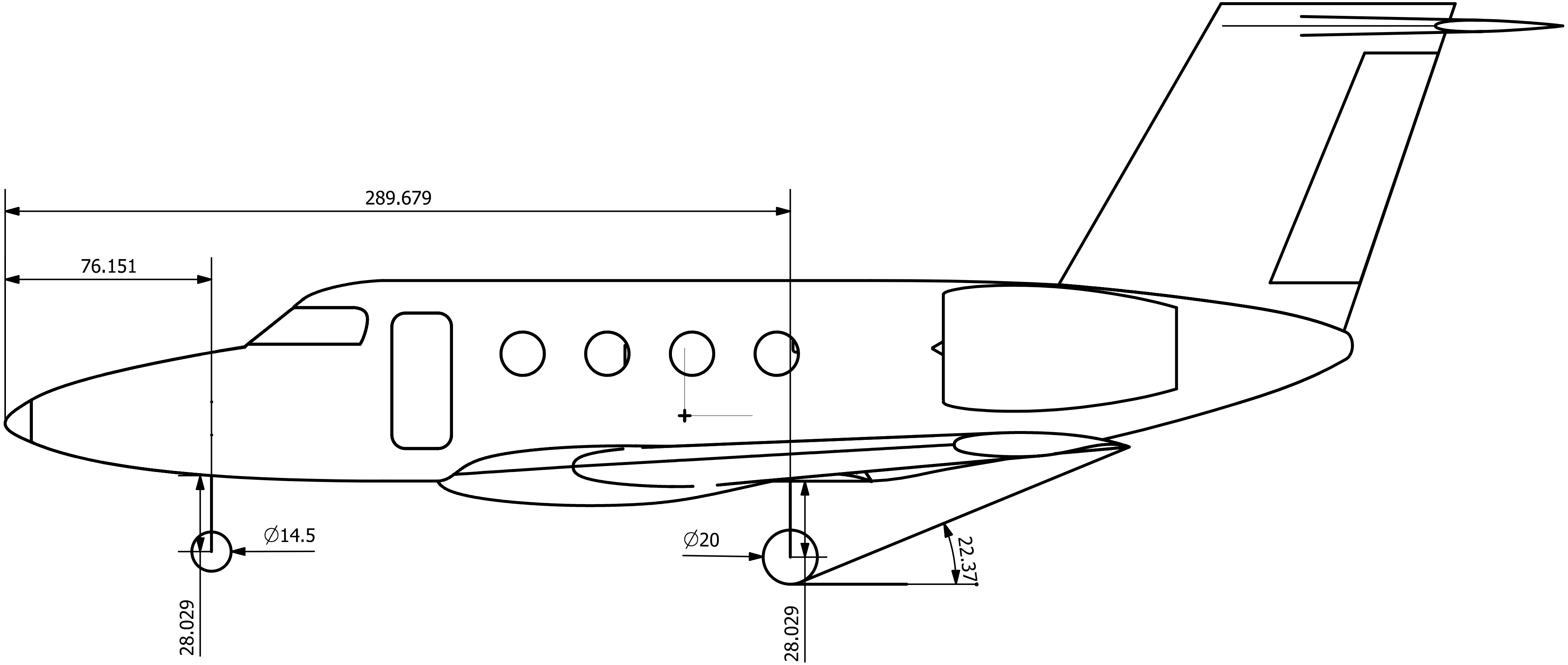
- Selected tire must carry maximum nose gear loads of the Commander and Chief
  - 13371.4 lb distributed through 4 tires, 3,342.85 lb per tire
- Goodrich's Tire Data Catalog
  - Tire Type: Type VII
  - Dimensions: 20 in diameter, 5.5 in width
  - Maximum Loading: 7200 lb

Shock Strut Sizing

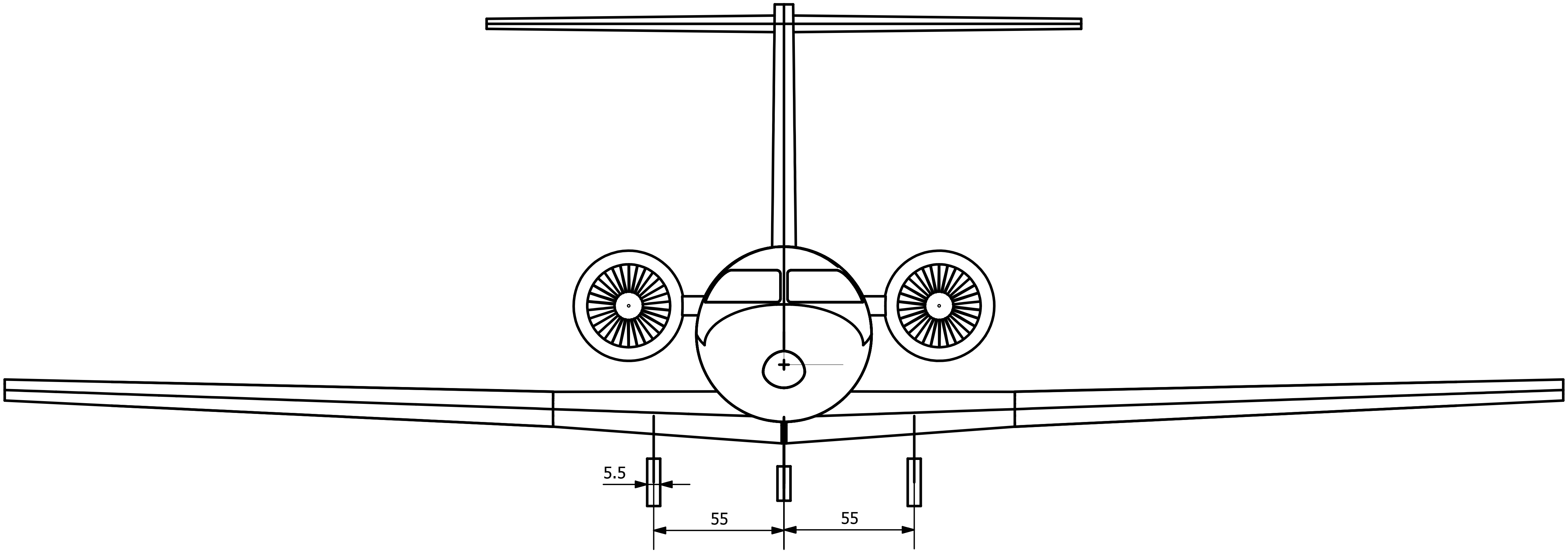
- Same shock strut length for the nose landing gear and main landing gear for both the Commander and Chief
- Gear offset to compensate for the different tire dimensions

Gear Height Calculation	
Item	Height [in]
Fuselage OD	74
Fuselage clearance	7.874
Shock stroke - single	19.63935319
Shock strut assembly	39.27870638
NLG tire radius	7.25
MLG tire radius	10
Desired MLG gear height + wheel	**49.27870638**
Desired NLG gear height + wheel	**46.52870638**
Gear offset	**2.75**
Unseen NLG	8.5
Visible NLG	30.77870638
Visible NLG + wheel	38.02870638
Unseen MLG	11.25
Visible MLG	28.02870638
Visible MLG + wheel	38.02870638
Distance from z-direction - MLG	50.38935319
Distance from z-direction - NLG	51.76435319

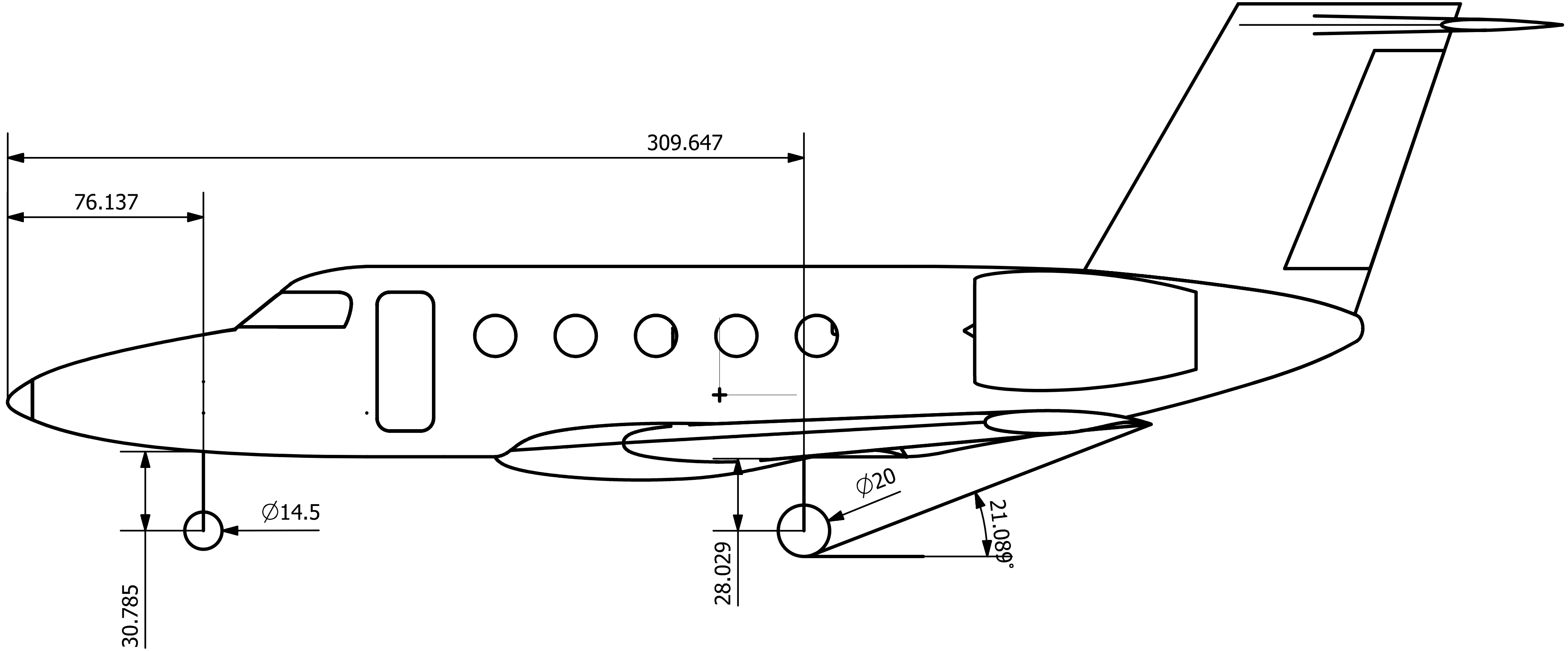
The Chief – Side View



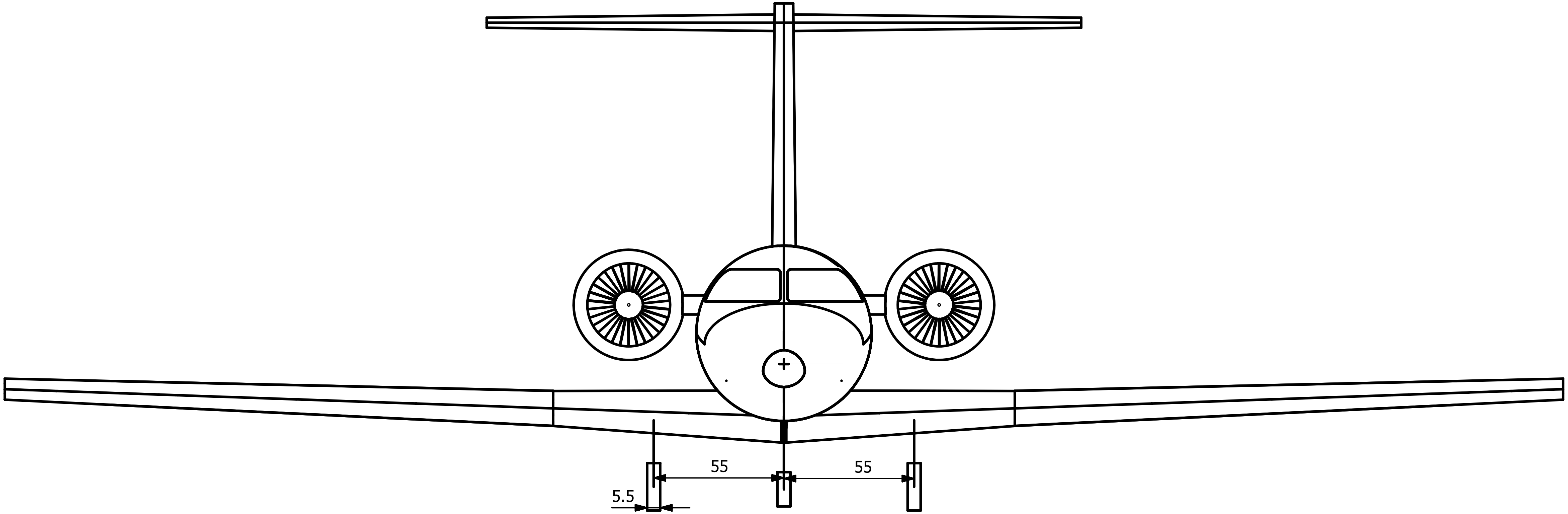
The Chief – Front View



The Commander – Side View



The Commander – Front View



Liam McHugh

COST ANALYSIS

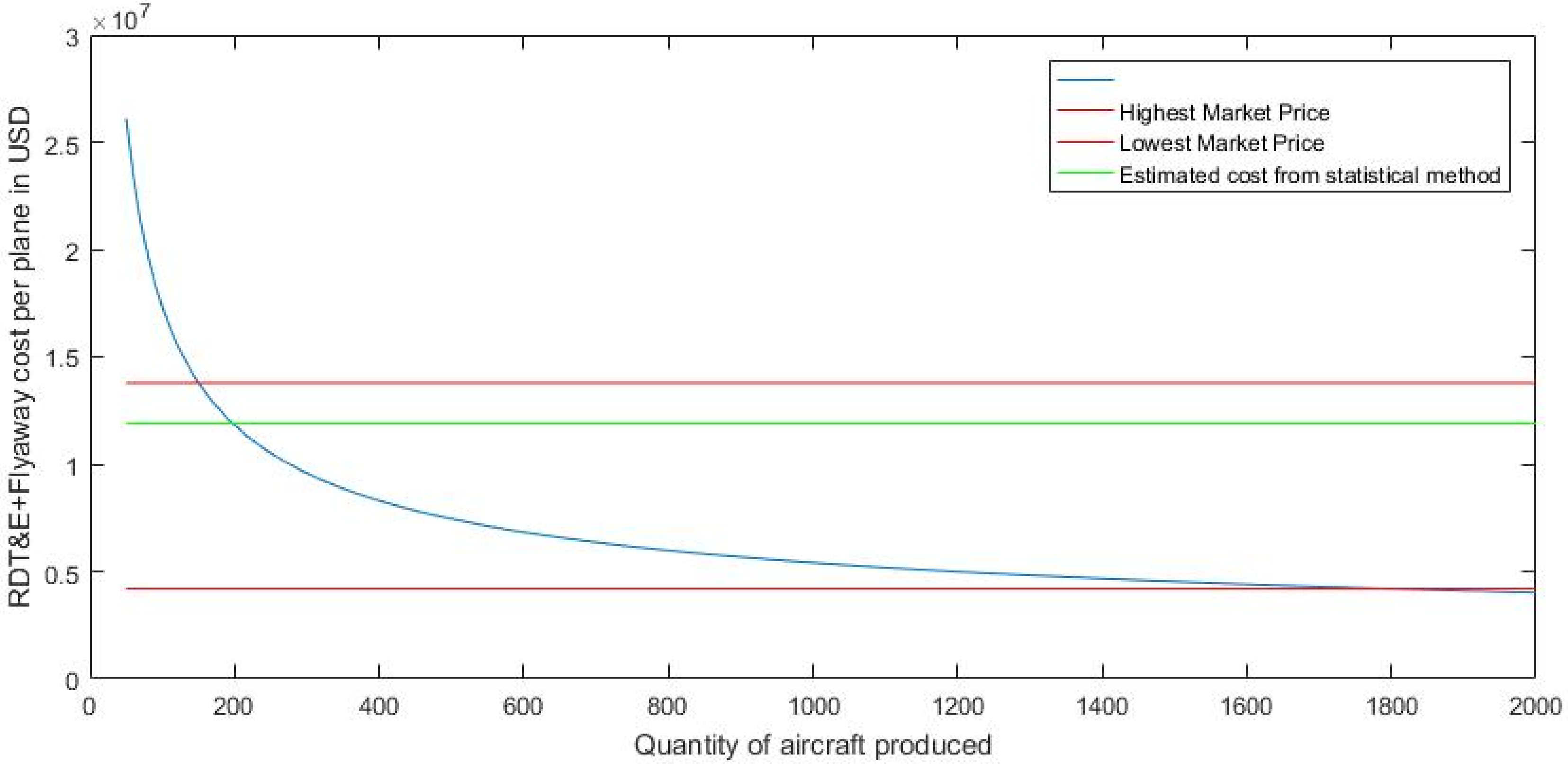
Method 1: Cost-Weight Ratio

Model	W_e (lb)	Cost (USD)	W_e Cost Ratio (USD/lb)
Cessna Citation CJ3+	8,185	8,300,000	1014.05
Syberjet SJ30	8,500	7,900,000	929.42
Cessna Citation CJ4	6,765	9,000,000	1330.38
Embraer Phenom 300	14,000	8,760,000	625.71
Learjet 70	13,890	11,300,000	813.53
Average	[-]	[-]	942.62 USD/lb
The Commander	12,633	11,900,000	[-]
The Chief	12,116	11,400,000	[-]

Method 2: Multi-Variable Analysis

Model	Seats	MTOW [lb]	W_e [lb]	Cost [USD]
Average	**7.25**	**17242**	**9,590**	**8,886,000**
Z-score	0.60984 / -1.0164	0.95358 / 0.17378	0.67064 / 1.4151	[-]
Correlation Coefficient	0.53783	0.94898	0.77662	[-]
Weighted Z-score	0.14494	0.39988	0.23015	[-]
The Commander	8	21,300	12,633	11,667,000
The Chief	6	18,500	12,116	9,312,000

Method 3: RAND CER’s



Market Analysis

- Competition Analysis
  - Life Cycle Production Quantity
- Projected Market Potential in 2020
- High Investment Risk

RDT&E + Flyaway Costs

Cost (USD)		Variable		Total (USD)
Engineering Hours	4,506,000	Engineering wrap rate	130.35	587357100
Tooling Hours	2,884,700	Tooling wrap rate	133.88	386203636
Manufacturing Hours	12,347,000	Manufacturing wrap rate	110.50	1364343500
Quality Control Hours	1,642,100	Quality Control wrap rate	122.19	200648199
Development Support Costs	51,762,000	[-]	[-]	51762000
Flight Test Costs	9,774,700	[-]	[-]	9774700
Manufacturing Materials Costs	272,840,000	[-]	[-]	272840000
Engine Production Costs	3,164	Number of engines	600	1898400
Avionics Costs	2,627,400	[-]	[-]	2627400
Total RDT&E + Flyaway Costs	[-]	[-]	[-]	2,875,531,034
Cost per Aircraft	[-]	[-]	[-]	9,585,103
Purchase Price	[-]	[-]	[-]	11,000,000

Conclusion

- Chief and Commander meet and exceed requirements
- Future development will further improve aircraft