GAT-AIR AID

Phoenix Tanker

FIREFIGHTING AIRCRAFT CONCEPT

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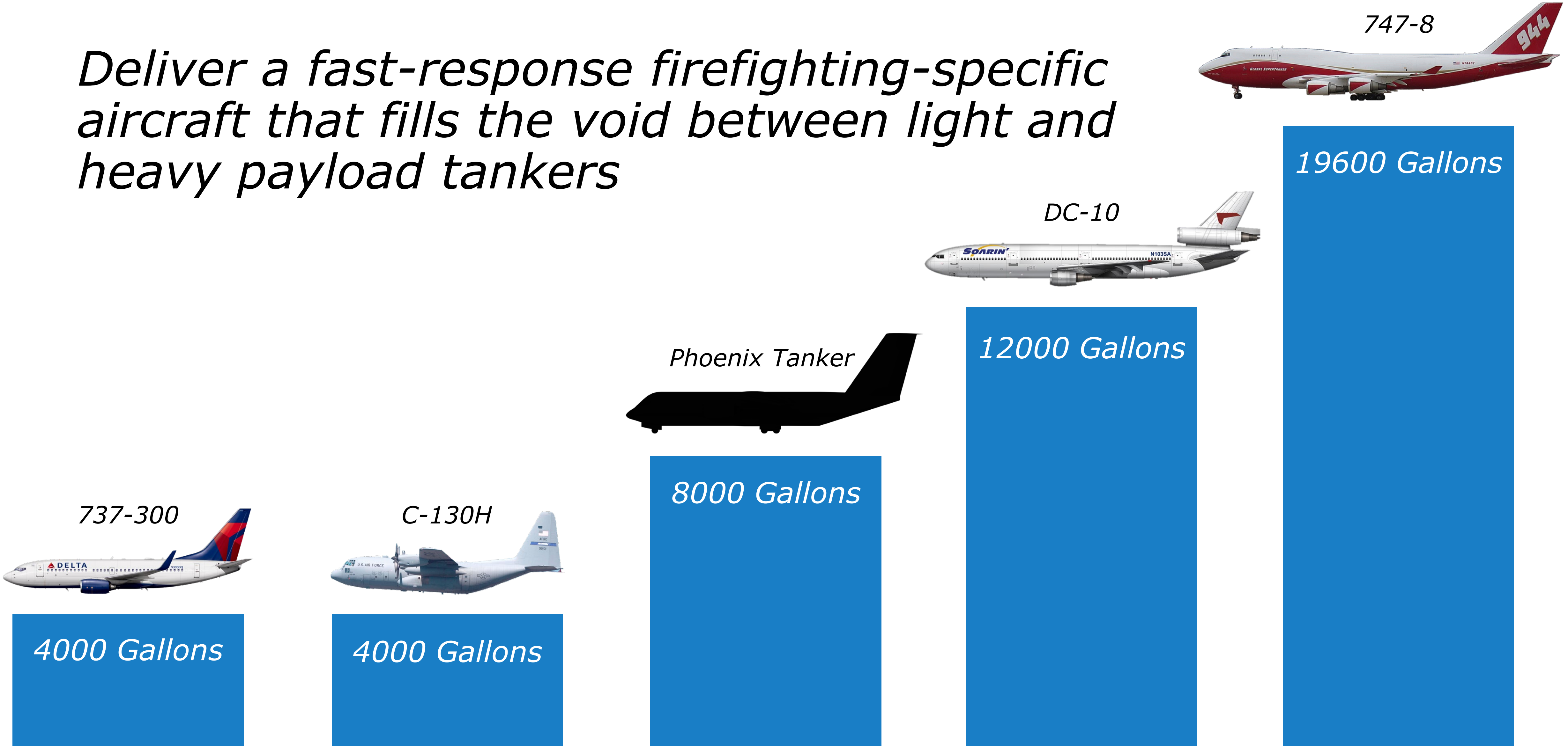
Our Task

Deliver a fast-response firefighting-specific aircraft that fills the void between light and heavy payload tankers



AIAA Aircraft Requirements

Requirement	Required Value	Objective Value
Entry into Service	2030	-
Engines	Existing	Deployed by 2028
Fire Retardant Capacity (gal)	4000	8000
Multi-Drop Capable	2000/Drop	-
Reload Rate (gal/min)	500	-
Retardant Density (lbs./gal)	9	-
Payload Drop Speed (knots)	150	125
Payload Drop Altitude (ft)	300	-
Design Radius w/ Max Payload (NMI)	200	400
Design Ferry Range (No Payload) (NMI)	2000	3000
Dash Speed (knots)	300	400
Balanced Field at 5000ft MSL on +35F Hot Day (ft)	8000	5000

Phoenix Tanker

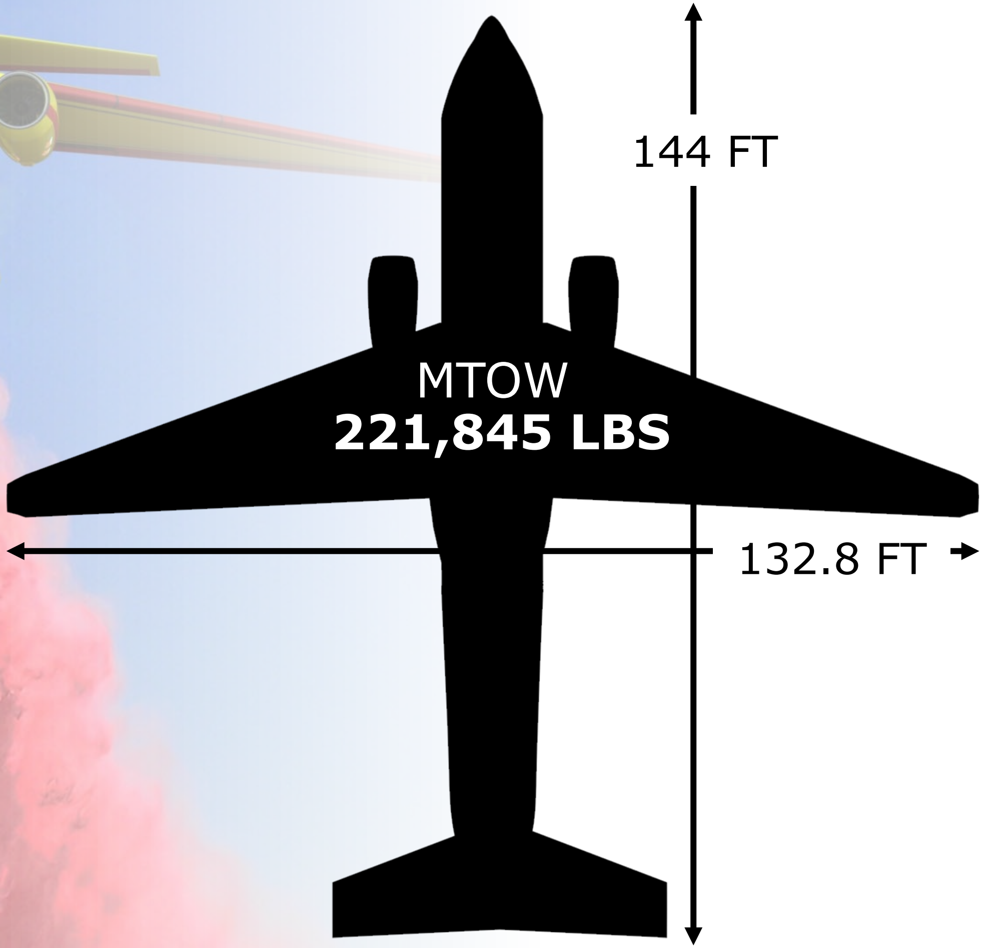
PAYLOAD CAPACITY
8000 GAL

MISSION RANGE
1811 NMI

FERRY RANGE
3320 NMI

DROP SPEED
<150 KTS

DROP HEIGHT
300 FT



CREW
2 PILOTS

ENGINES
2 PW1133G/2-JM (2024)

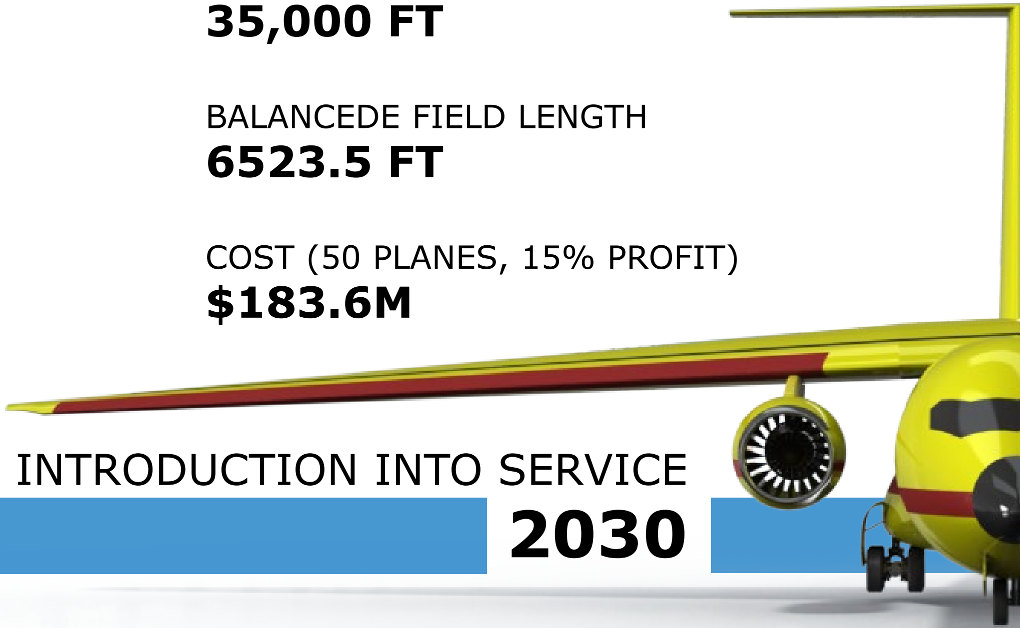
THRUST
36,580 LBF (PER ENGINE)

CRUISE SPEED
430 KTS

CRUISE ALTITUDE
35,000 FT

BALANCEDE FIELD LENGTH
6523.5 FT

COST (50 PLANES, 15% PROFIT)
$183.6M

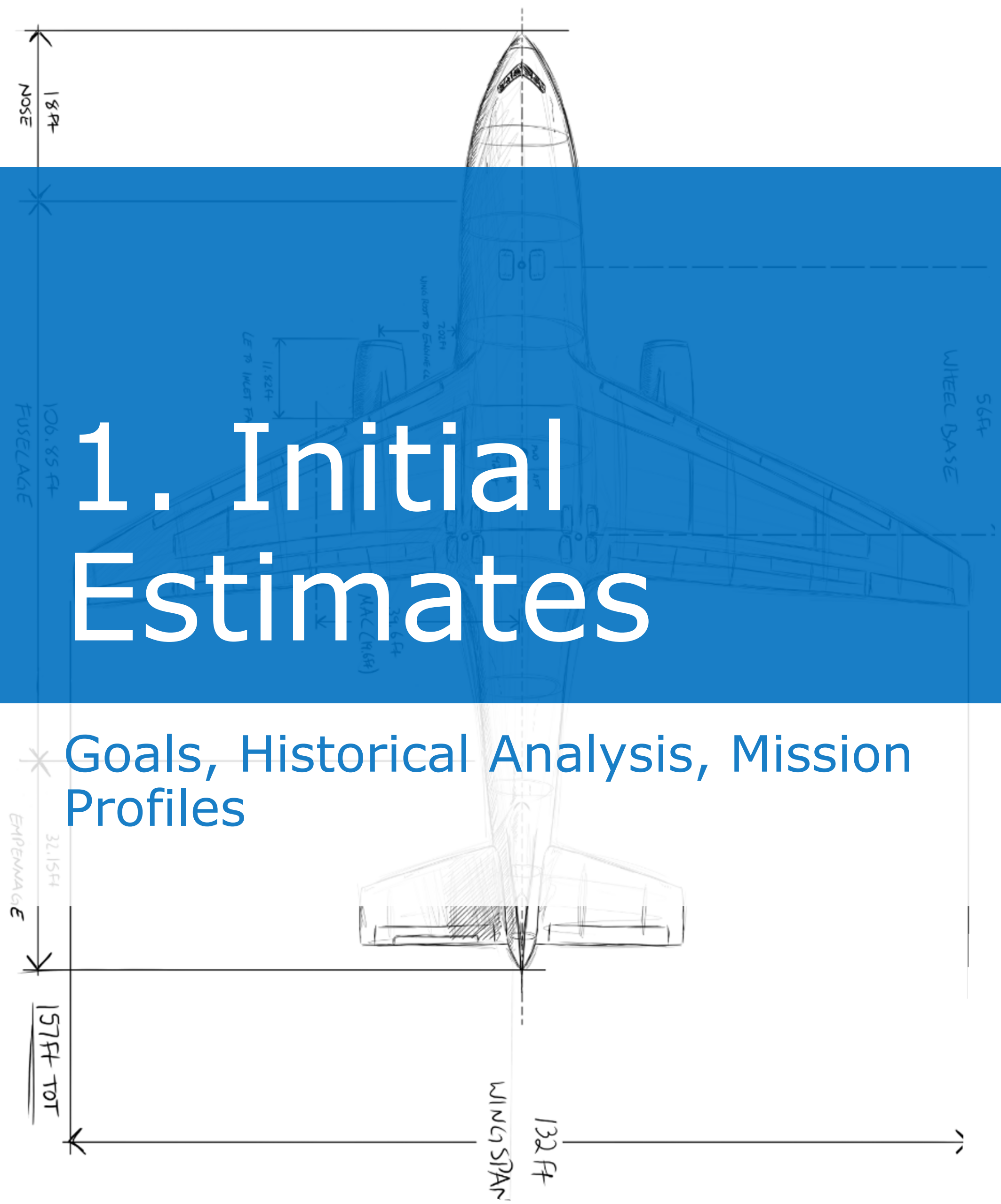


INTRODUCTION INTO SERVICE
2030

The Next Generation Medium Firefighting Tanker

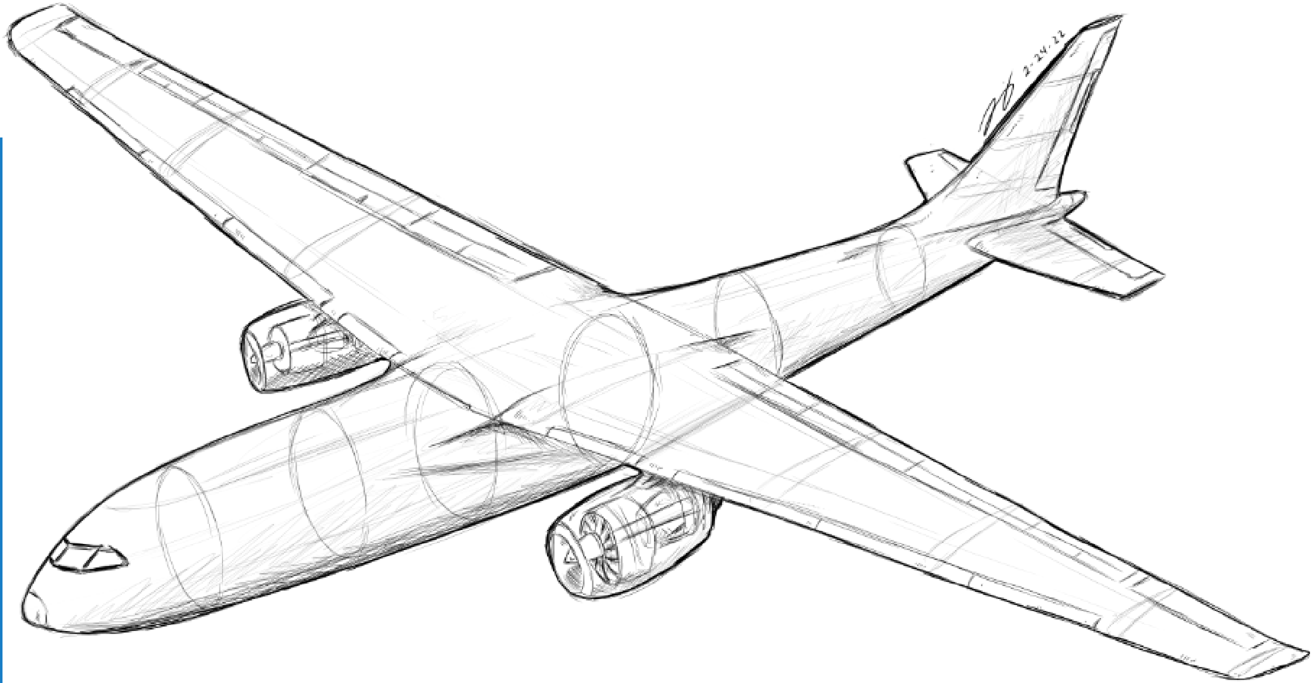
Outline

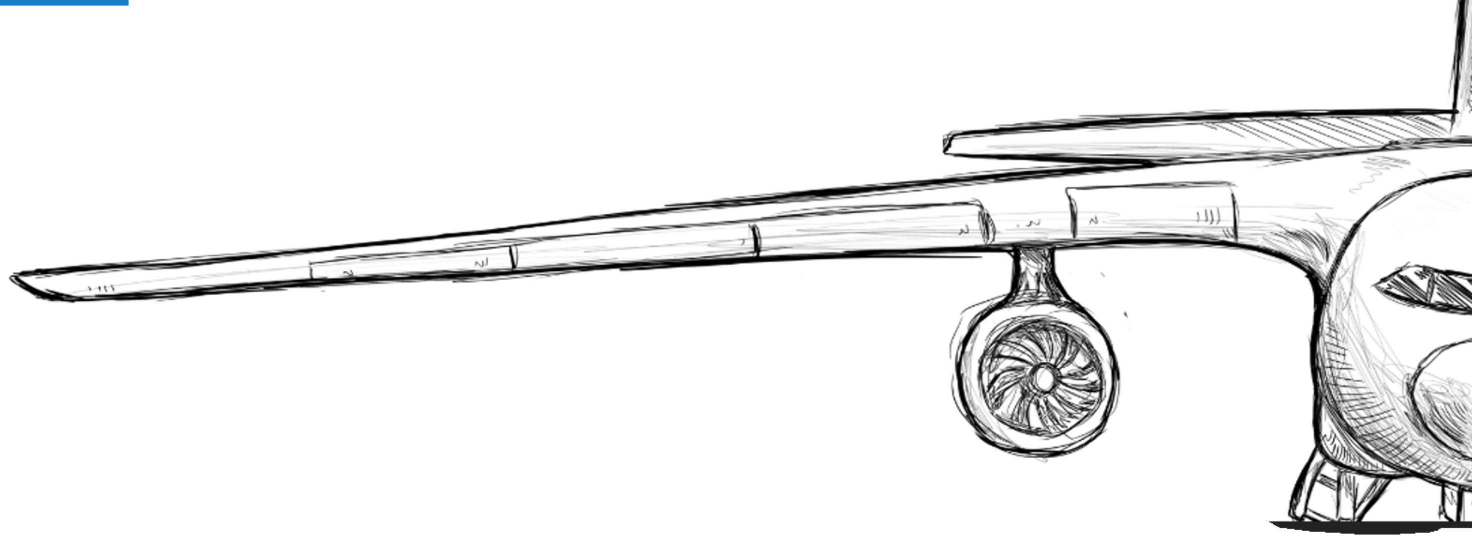
1. Initial Estimates	Initial Estimation Phase
2. Aerodynamic Design	Design Phase
3. Propulsion Design	
4. Landing Gear Design	
5. Structural Design	
6. Fuselage/Payload Design	
7. Tail Design	
8. Weight and Stability	Analysis Phase
9. Performance Analysis	
10. Cost Analysis	



1. Initial Estimates

Goals, Historical Analysis, Mission Profiles





Aircraft Goals

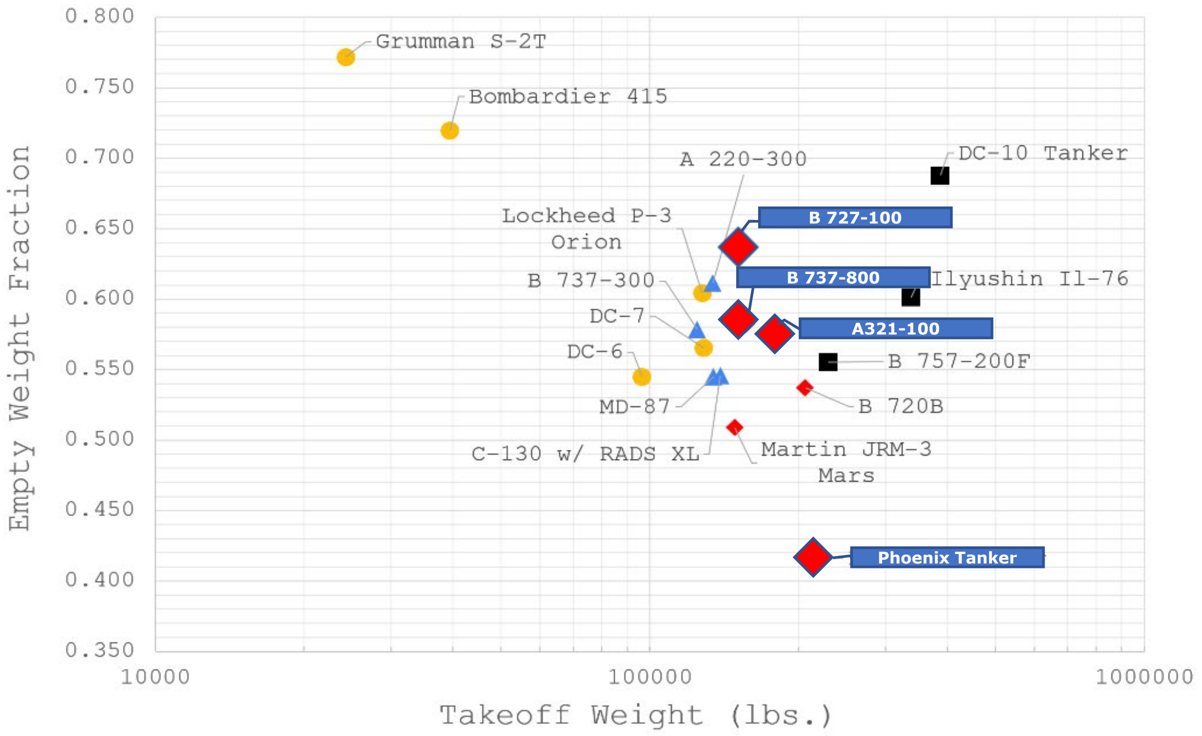
- Intended to meet mission objectives for payload capacity and design radius
- Planned to surpass mission requirements for both Ferry Range and Balance Field Length

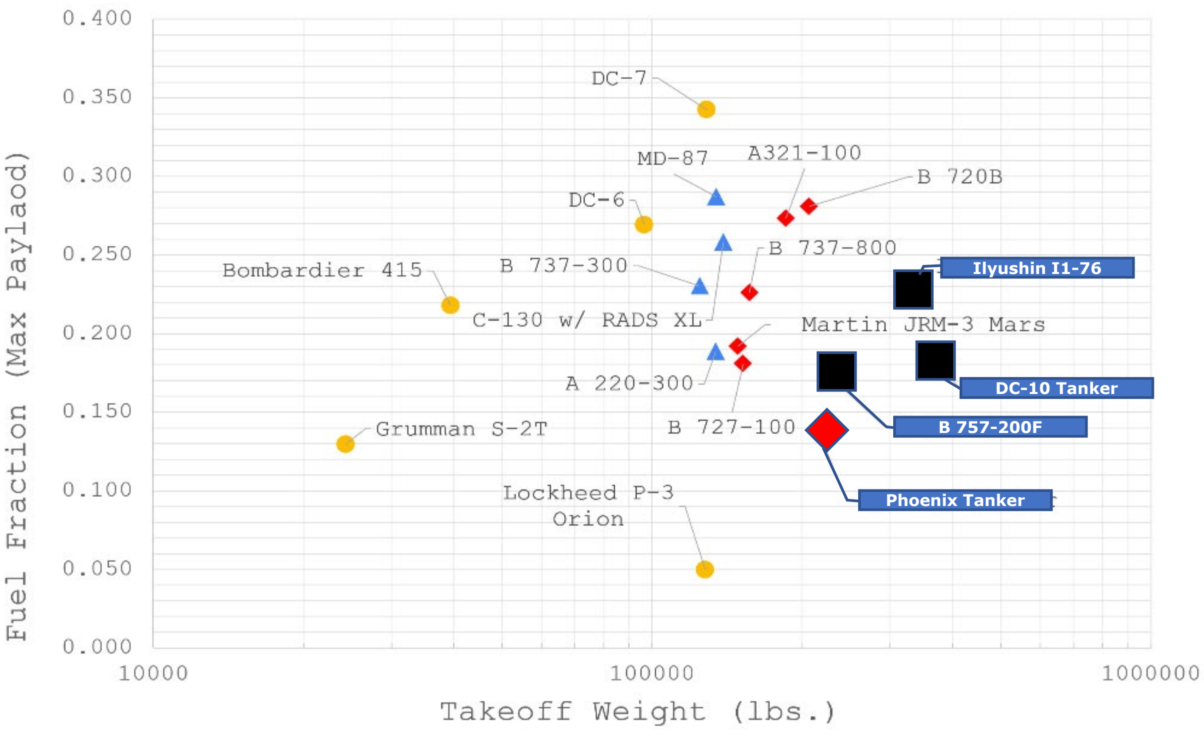
Requirement	Goals
Fire Retardant Capacity (gal)	8000
Retardant Density (lbs./gal)	12
Payload Drop Speed (knots)	150
Payload Drop Altitude (ft)	300
Design Radius w/ Max Payload (NMI)	400
Design Ferry Range (No Payload) (NMI)	2000
Dash Speed (knots)	400
Balanced Field Length at 5000 ft MSL on +35F Hot Day (ft)	8000

Initial Weight Estimations

Variable	MTOW	Empty	Payload	Fuel	Crew
Weight (lbs.)	215,832	89,768	96,000	29,569	450

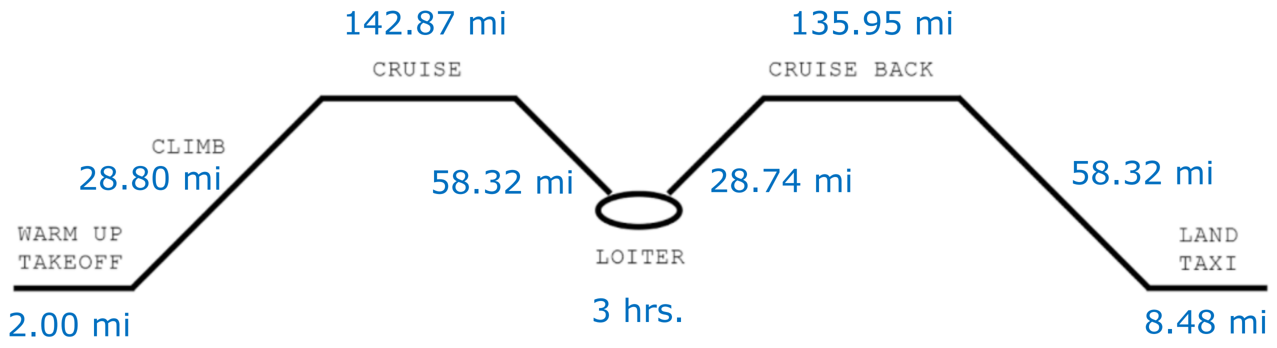
Payload Class			
●	Very Light	◆	Medium
▲	Light	■	Heavy



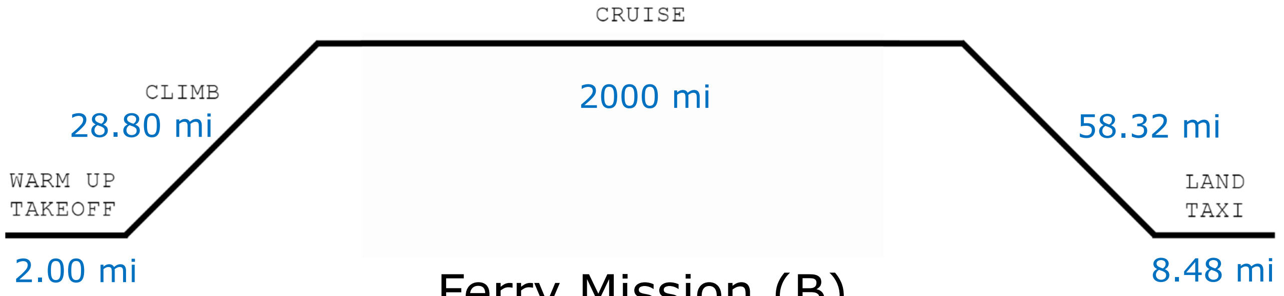


Mission Profiles

Fuel Weight Fractions, $\frac{W_i}{W_{i-1}}$		
Segment	**A**	**B**
Warm-up/Takeoff	0.970	0.970
Climb	0.985	0.985
Cruise	0.987	0.781
Loiter	0.918	-
Cruise Back	0.987	-
Descent	1.000	1.000
Land/Taxi	0.995	0.995



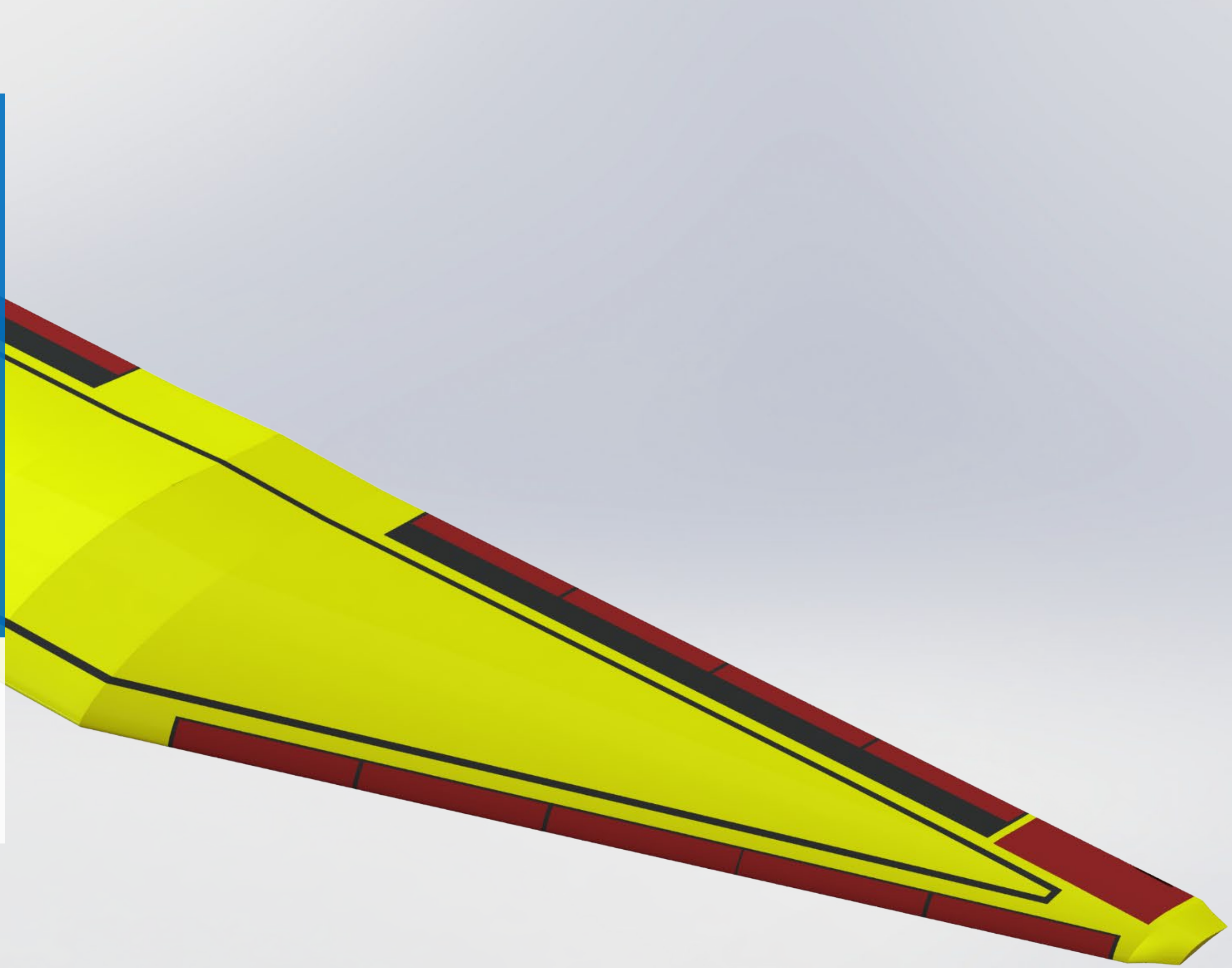
Payload Drop Mission (A)



Ferry Mission (B)

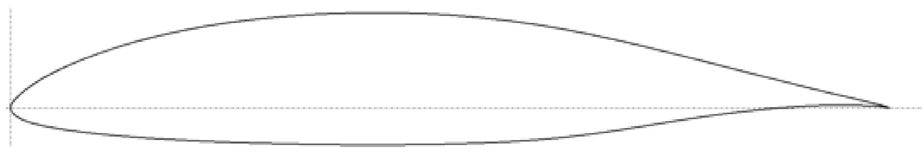
2. Aerodynamic Design

Airfoil Selection, Wing Design, High-Lift Devices

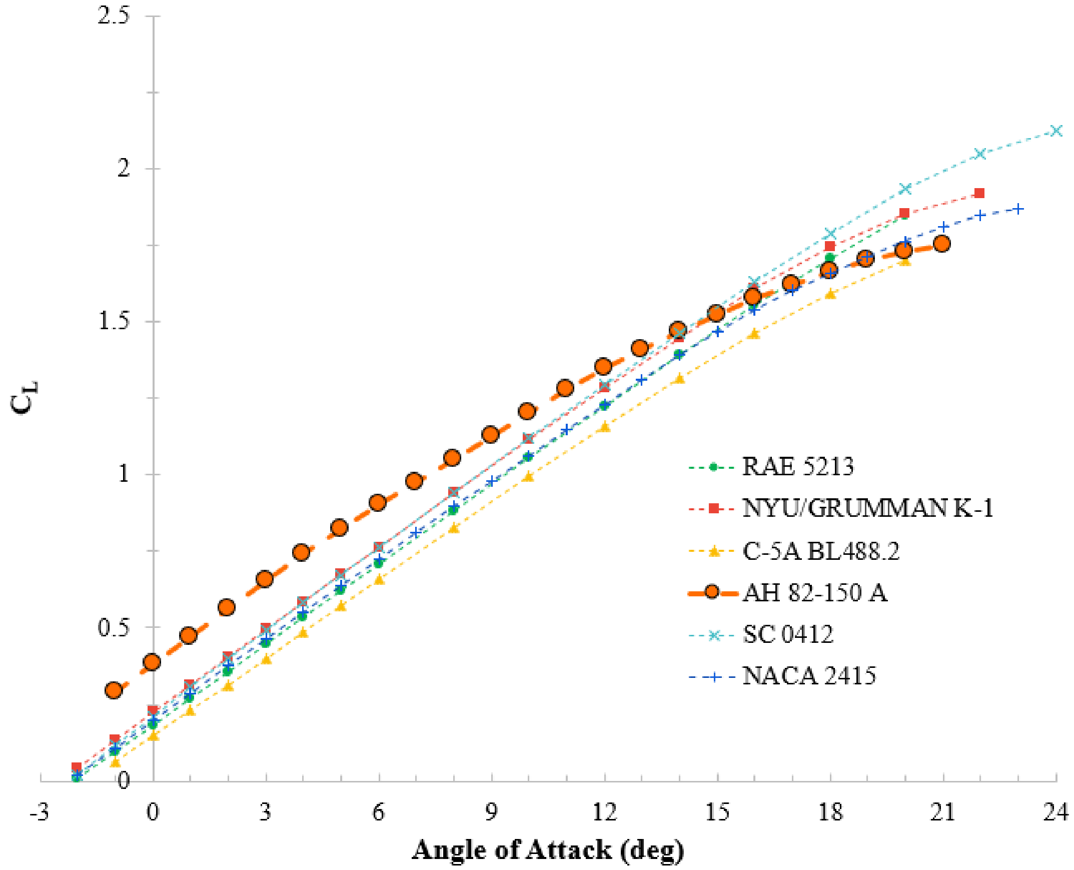


Airfoil Selection

- Compared C_L and C_L/C_D of six different airfoils
  - Airfoils chosen for high lift characteristics
- XFLR5 simulation used
  - Re = 3.00 x 10^7, M = 0.75
- AH 82-150 A performed best
  - Highest C_L from -1 to 14°
  - Highest C_L/C_D from -1 to 2°
  - Large thickness for fuel tanks



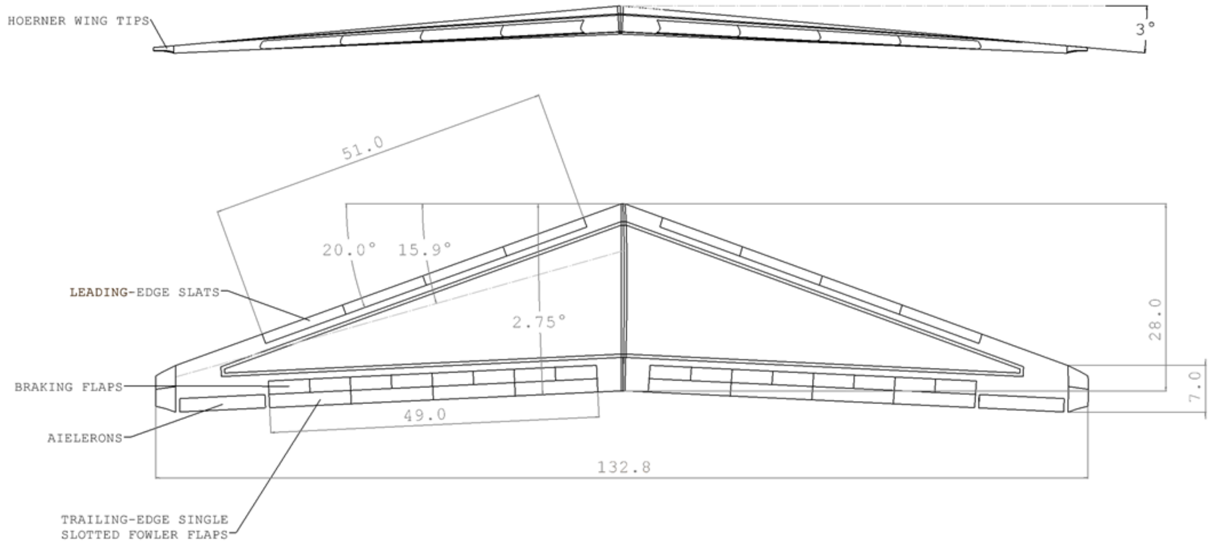
AH 82-150 A



Wing Design

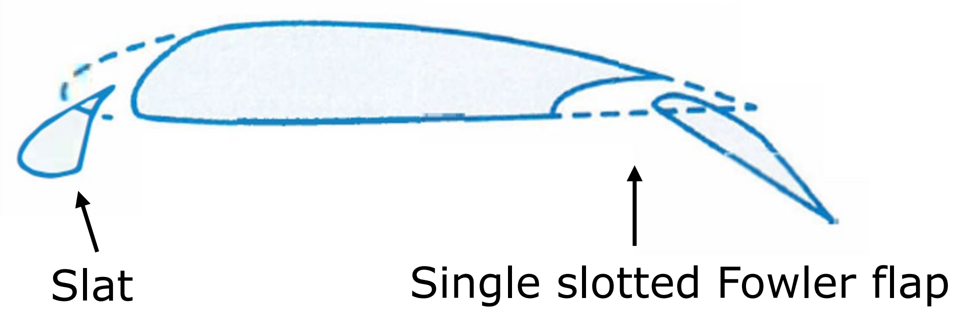
- Aspect Ratio and Ref. Area determined by:
  - Estimated takeoff weight
  - Wing loading estimation
  - Designed Mach number
- Taper ratio and wing angles chosen to:
  - Maximize efficiency at M = 0.75
  - Provide sufficient lift at takeoff and cruise
  - Avoid tip stall (STAR-CCM+ software used)

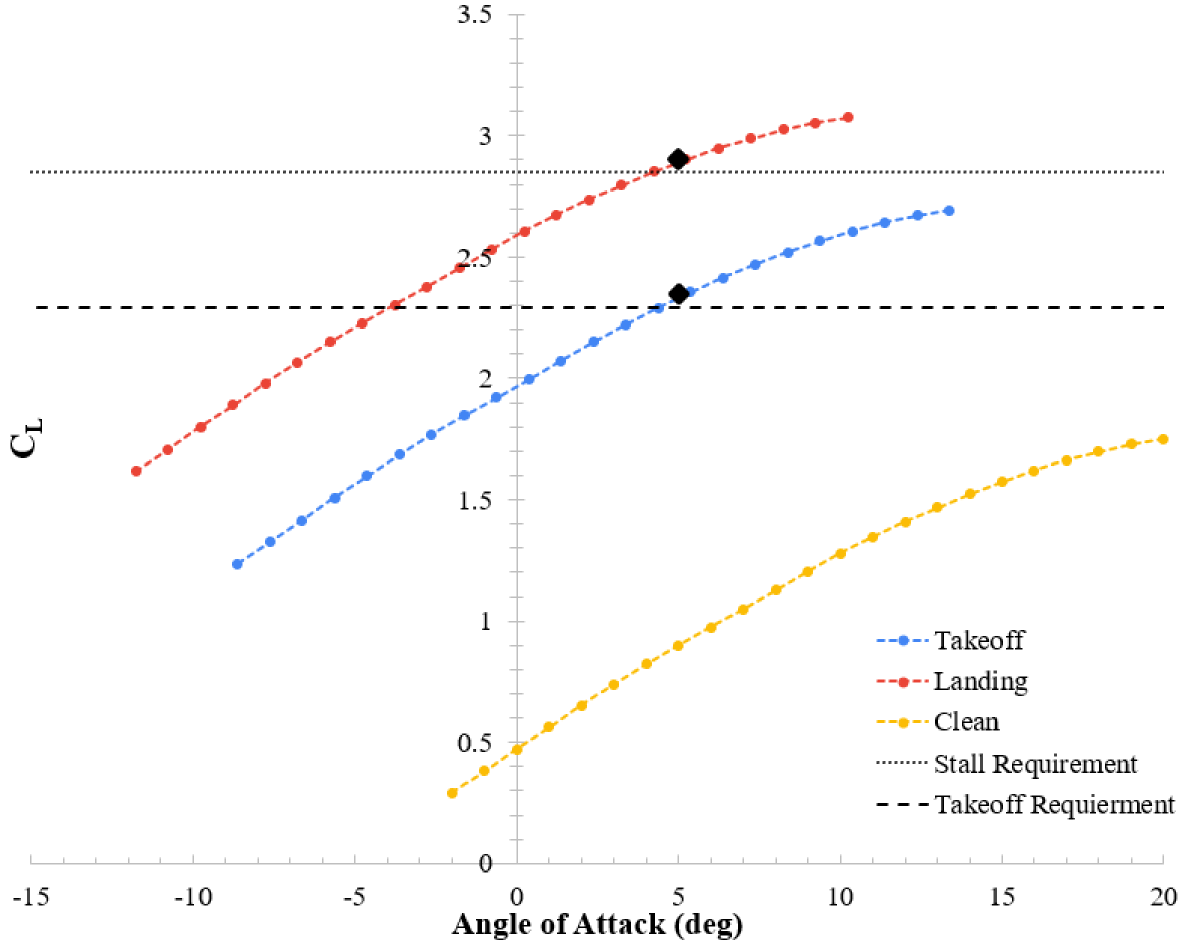
Parameter	Value
Aspect Ratio	7.6
Incidence	1
Twist	-3°



High-Lift Devices

- High lift devices needed to increase C_L at takeoff & landing
  - $C_{L,\ Takeoff} = 2.35$
  - $C_{L,\ Landing} = 2.90$
- Least complex technology that would meet needed C_L chosen
  - Slat for leading edge
  - Single slotted fowler flap for trailing edge



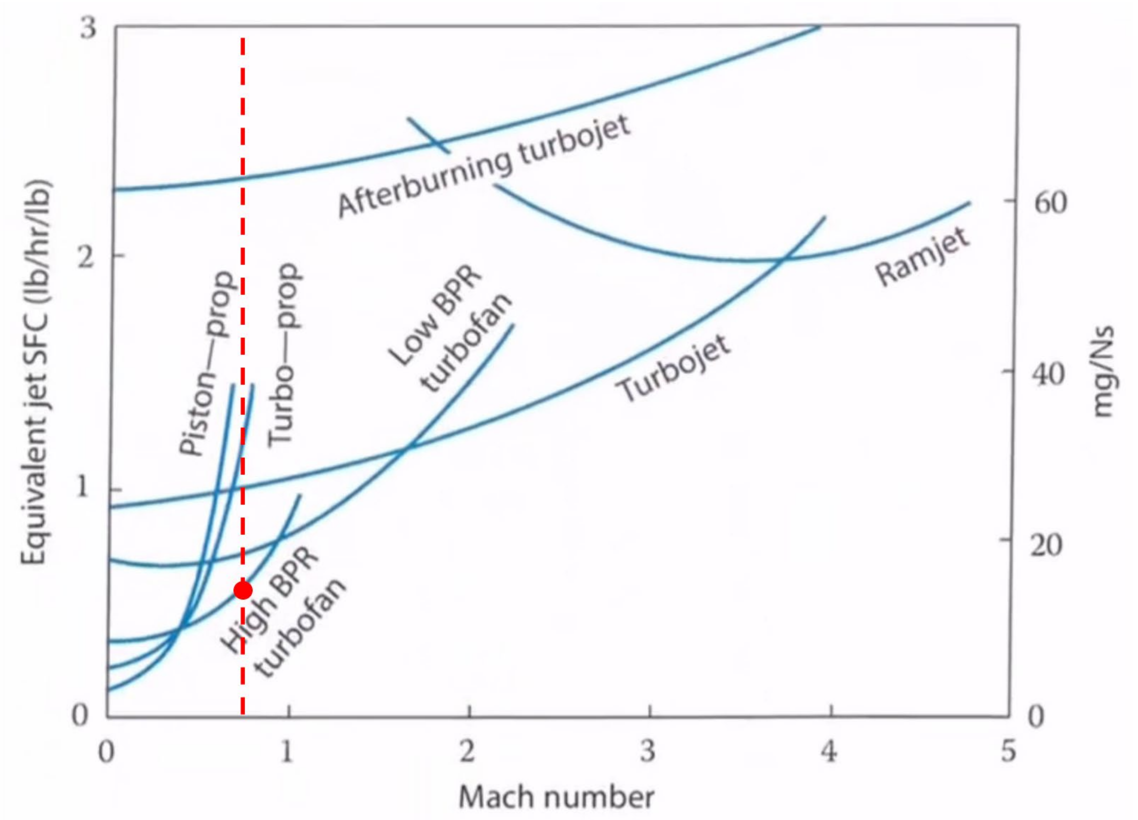


3. Propulsion Design

Engines, SFC, Fuel Capacity

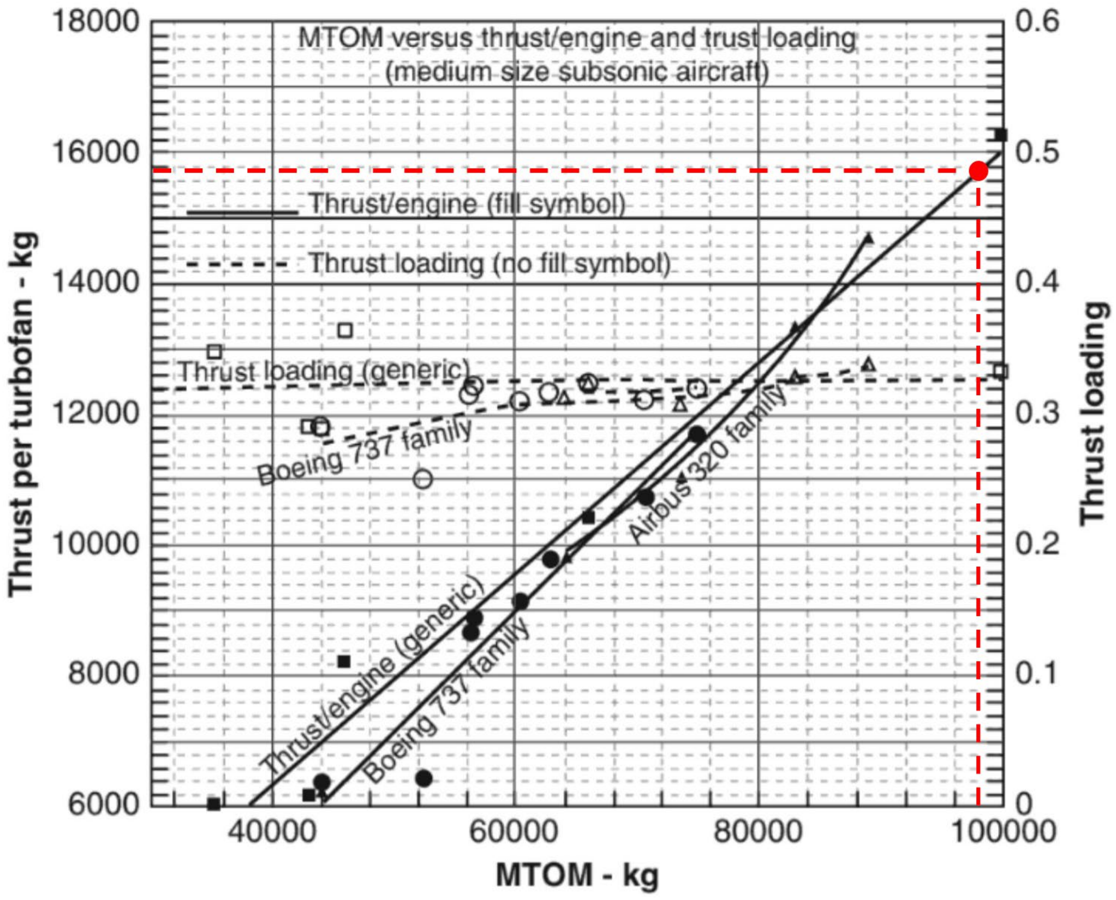
Powerplant – Turbofan

- Designed for Cruise Speeds of M=0.75
- Able to operate at higher speeds for quick response times
- Payload Drop Speeds Achievable with High Lift Devices

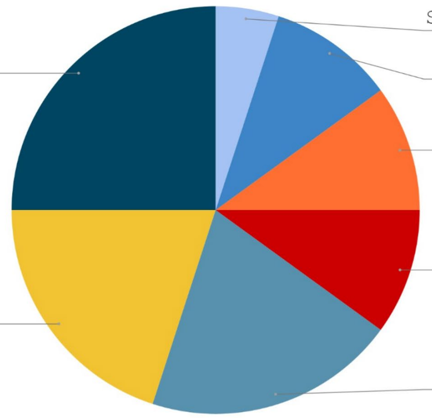


Powerplant – Thrust Required

- Required Thrust with 5% margin: 162.75KN (36,588 lbs.)
- 35 Turbofans investigated
- Down-selection and decision matrix used to choose engines



Powerplant – Decision

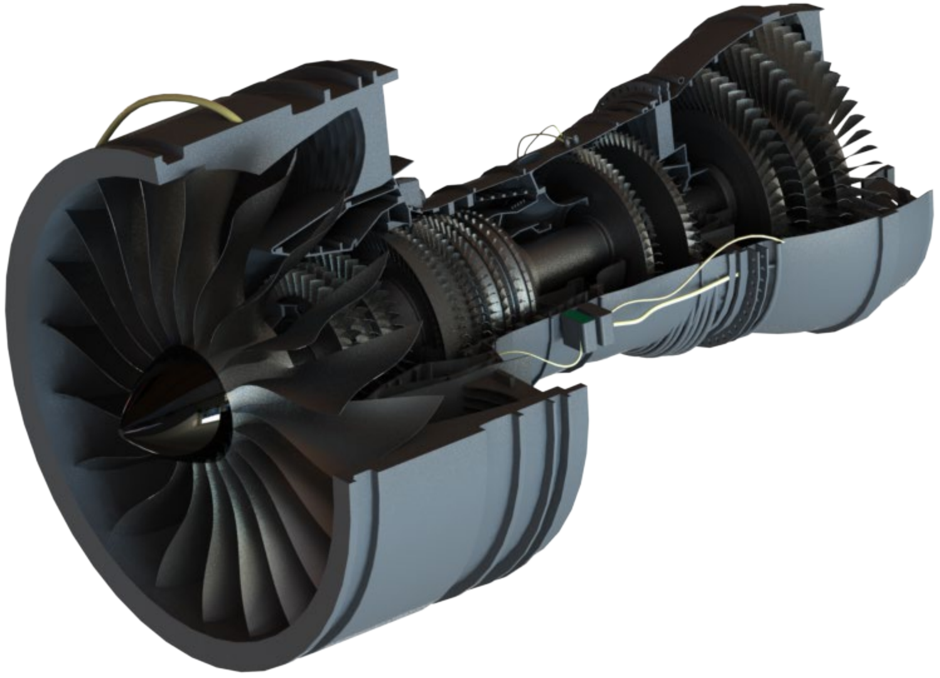


- Down-selected from 35 to 6 engines within 25% of thrust required
- TSFC, Weight, and Cost were prioritized
- Highest value given a 10, linear decrease for the rest

Variables:	BPR	D	W	SF	TSFC_C	Cost	OPR	Total
Weights:	0.1	0.1	0.2	0.05	0.25	0.2	0.1	X/10
CFM LEAP 1A	0.86	0.38	0.28	0.11	1.78	0.33	1.00	4.41
PS-90 A1	0.23	0.76	1.62	0.48	0.72	2.00	0.55	4.35
IAE V2531-5E	0.25	1.00	1.78	0.08	0.94	1.87	0.62	4.67
CFM56-5B3	0.32	0.87	2.00	0.23	1.34	1.83	0.55	5.32
PW1100G	0.95	0.31	1.00	0.23	2.43	1.17	1.00	5.93
PW1133G/2-JM	1.00	0.37	1.24	0.31	2.50	1.17	1.00	6.41

Powerplant – PW1133G/2-JM

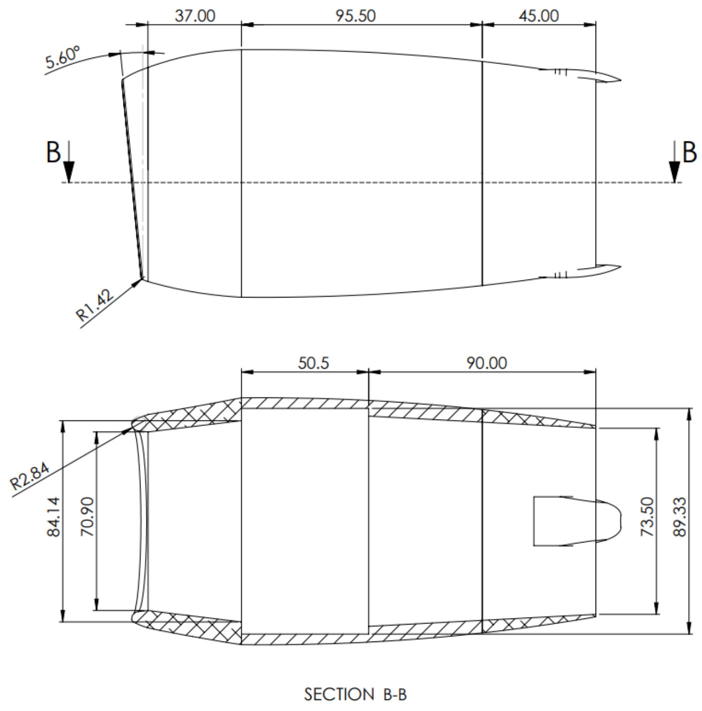
Parameter	Value
Year into Service	2024
Scale Factor	1.0764
Bypass Ratio	12.5:1
OPR	40:1
Length	137.86 in
Fan Diameter	84.14 in
Weight	6829.83 lbs.
Thrust	36587.8 lbs.
TSFC Cruise	0.47
Cost	$12M

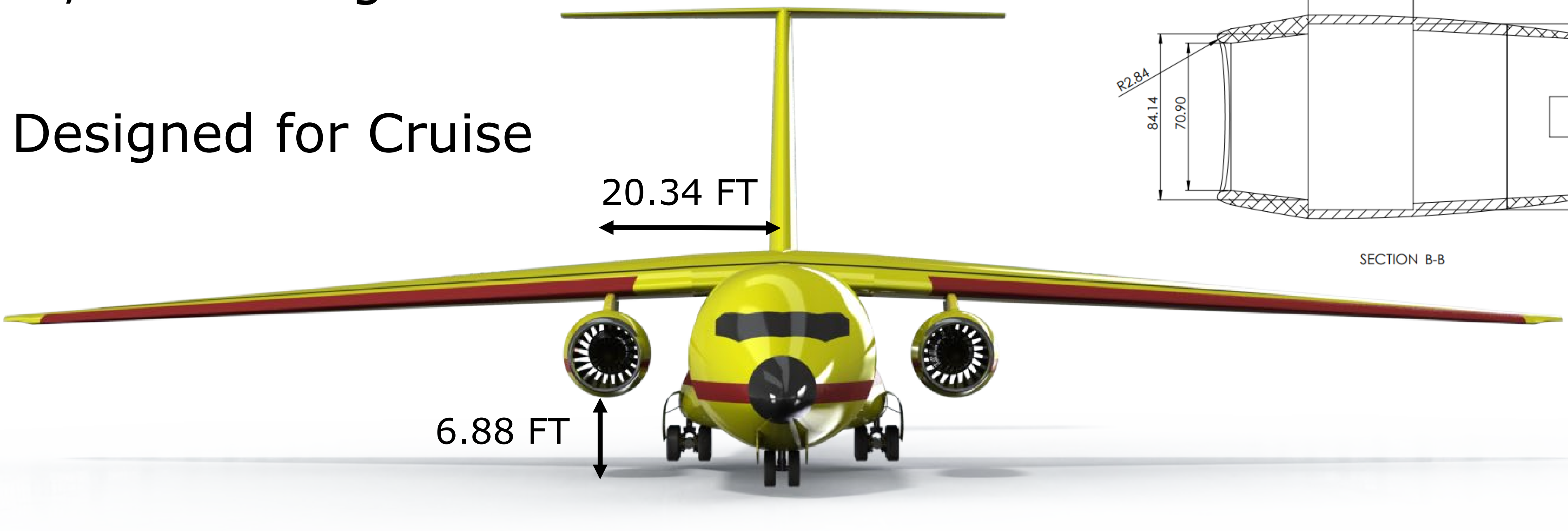


Representative Model – Scaled PW1100G Engine

Powerplant – Integration

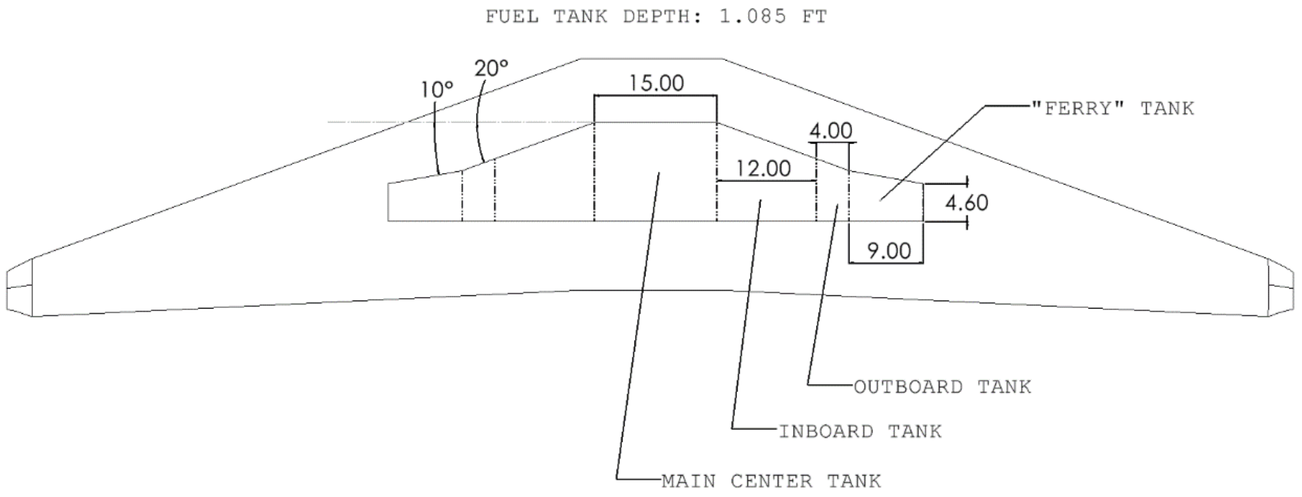
- Twin-Engine Layout
- Podded, Underwing
- Inlet Designed for Cruise





Fuel Tanks

- Jet-A Fuel (6.71 lbs./ft^3)
- Integrated Tank Design
- 3750 Gals (4500 Gal w/ Ferry Tanks)
- Ferry Tanks included to meet demands of mission range. Not filled for Firefighting Missions

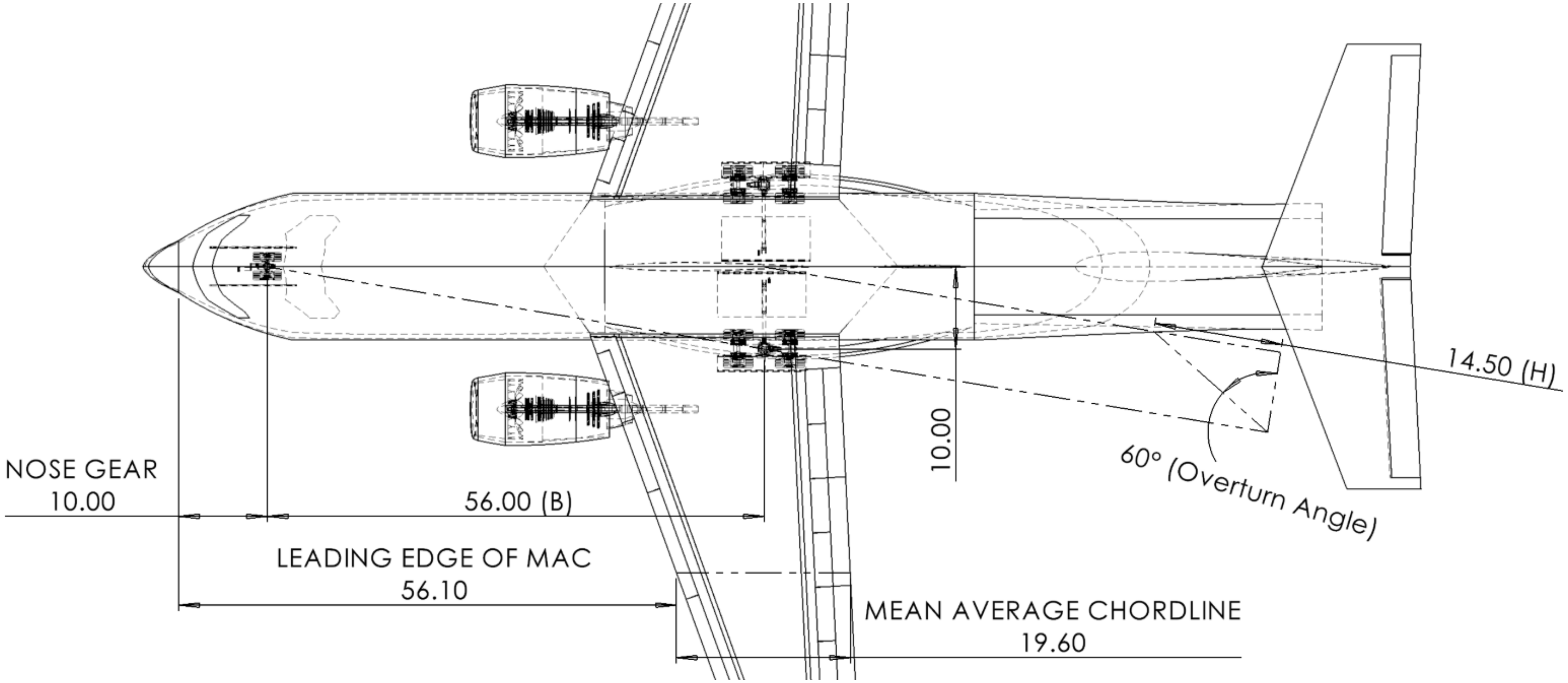


4. Landing Gear Design

Layout, Tire Selection, Shock Absorbers, Mechanisms

Landing Gear – Layout

- Tricycle gear layout selected for pilot visibility, ground stability, and large crab angle during landing



Landing Gear – Tire Selection

- Brakes on all wheels on main
- Wheels size based on landing kinetic energy
- Tire pressure set to 171 psi for increased tire life

Quantity	Requirements	H38x12.0-19 (Nose)	H40x14.5-19 (Main)
Rated Speed (mph)	161	210	225
Rated Load (lbs.)	25,250 (Nose) 32,765 (Main)	25,300	33,200
Rated Inflation (psi)	132	193	200
Tire Diameter (in)	37.43	38 (max)	40 (max)
Tire Width (in)	12.37	12(max)	14.5 (max)
Rolling Radius (in)	16	16	16.65
Rim Diameter (in)	19.5	19	19

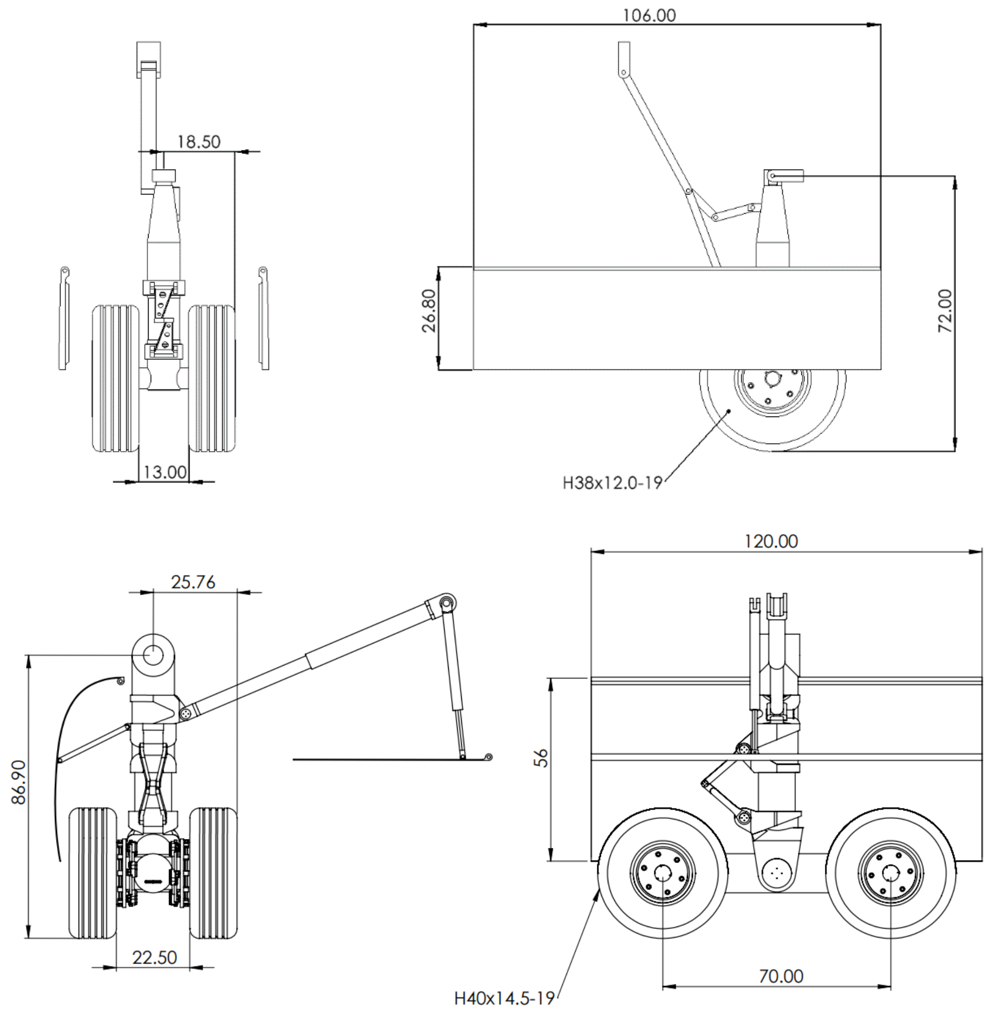
Landing Gear – Shock Absorbers

- Oleo-pneumatic struts selected based on aircraft size and compact size
- Sized based on maximum vertical velocity 10 feet per second as per FAA 14 CFR 25 with reserve
- Designed to allow for clearance requirements

Description	Requirement	Actual
Engine Ground Clearance (ft)	3.89	7.30
Maximum Takeoff Angle (Degrees)	5.5°	10°
Angle Between Rear Wheel and CG at 5.5° Pitch Up Takeoff (Degrees)	15°	18.4°
Ground Clearance of Wingtip (ft)	0.5	10.96

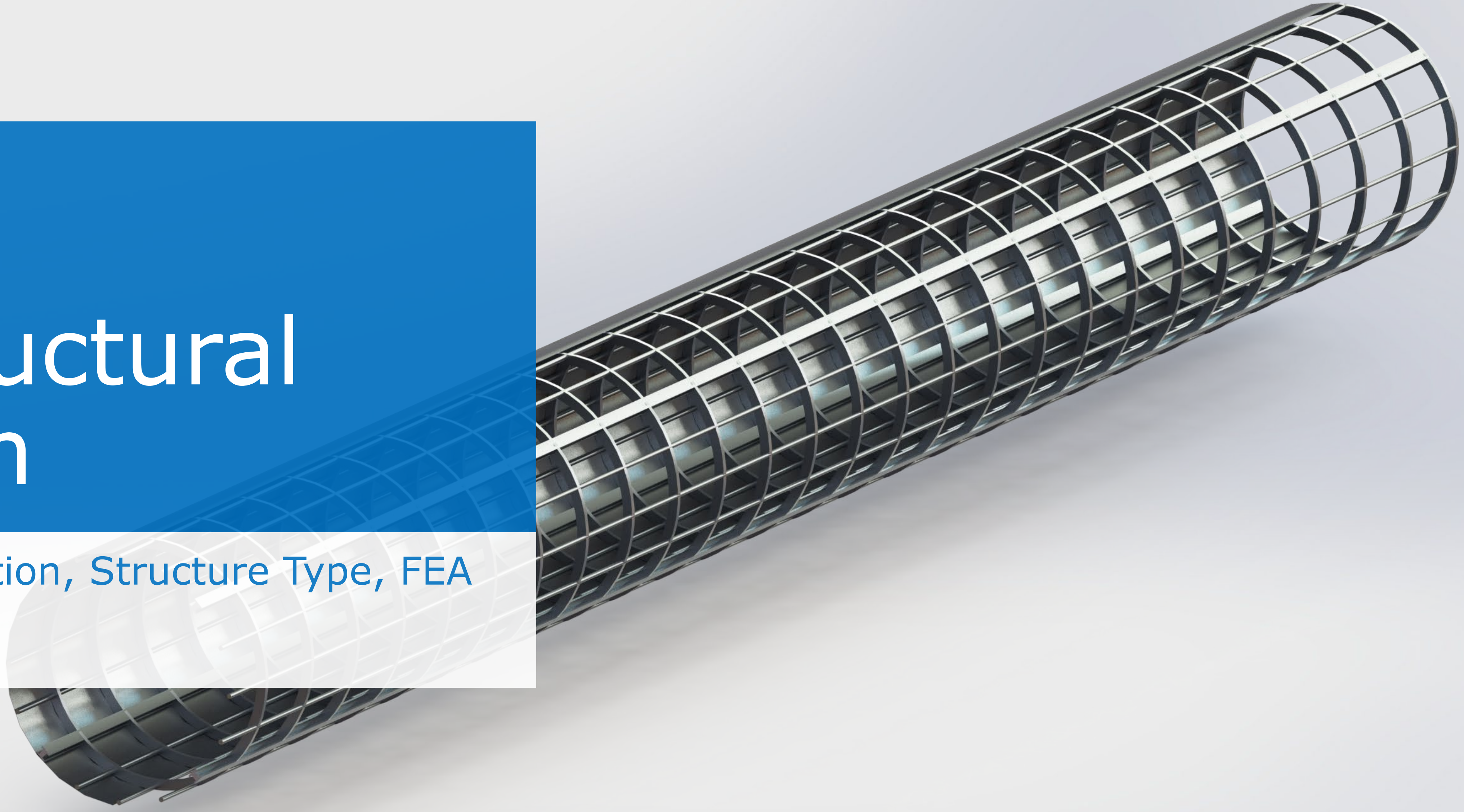
Landing Gear – Retraction Mechanism

- Forward retraction for front gear, inward for main gears
- Hydraulic system for activation
- Landing gear naturally extends to landing position due to drag and weight in event of a hydraulic system failure



5. Structural Design

Material Selection, Structure Type, FEA

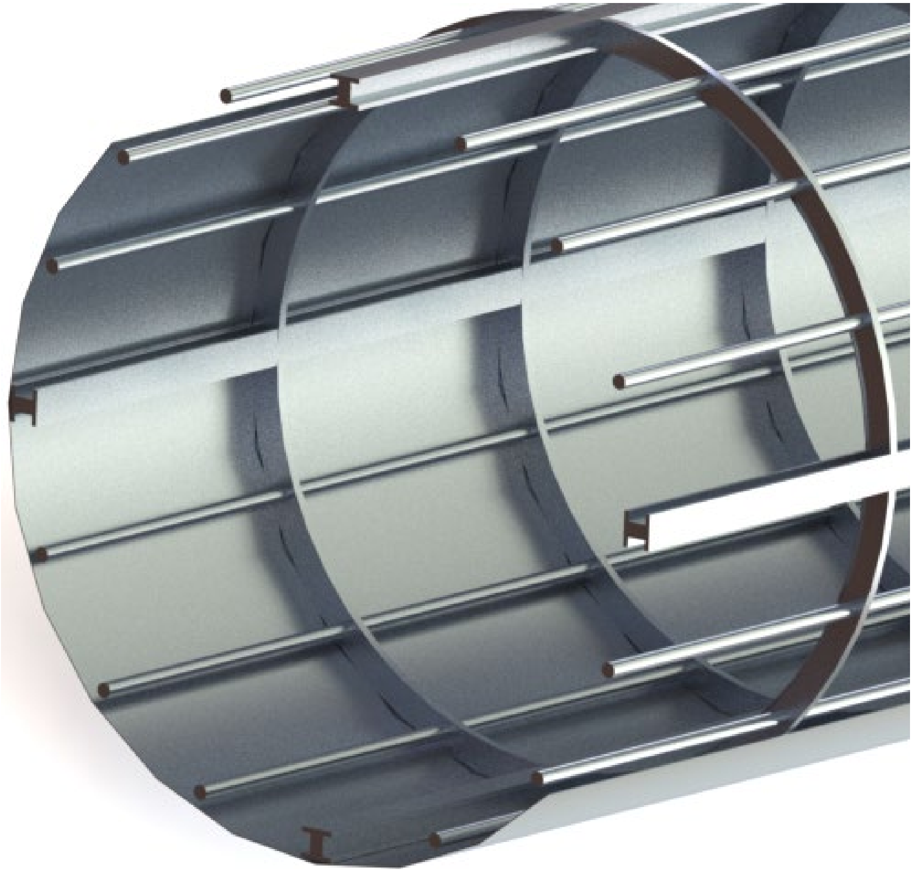


Structure – Fuselage

Semi-monocoque

- Strength-to-weight ratio
- Damage tolerance
- Maintenance costs

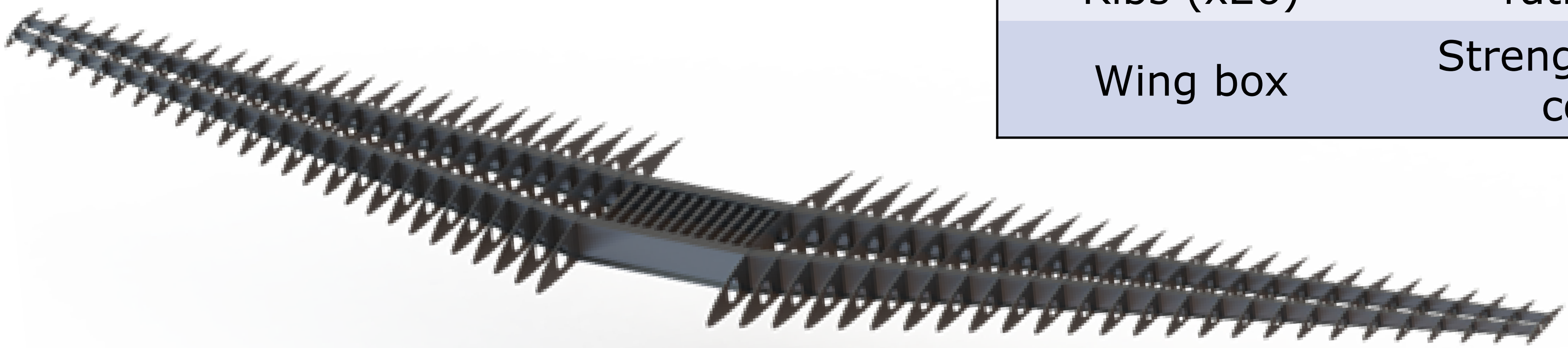
Component	Requirement	Material
Frames (x20)	High load	7010-T3651
Stringers (x16)	Low load	2024-T4
Longerons (x4)	Light weight	2024-T4
Aircraft skin	Corrosion	2024-T4



Structure – Wing

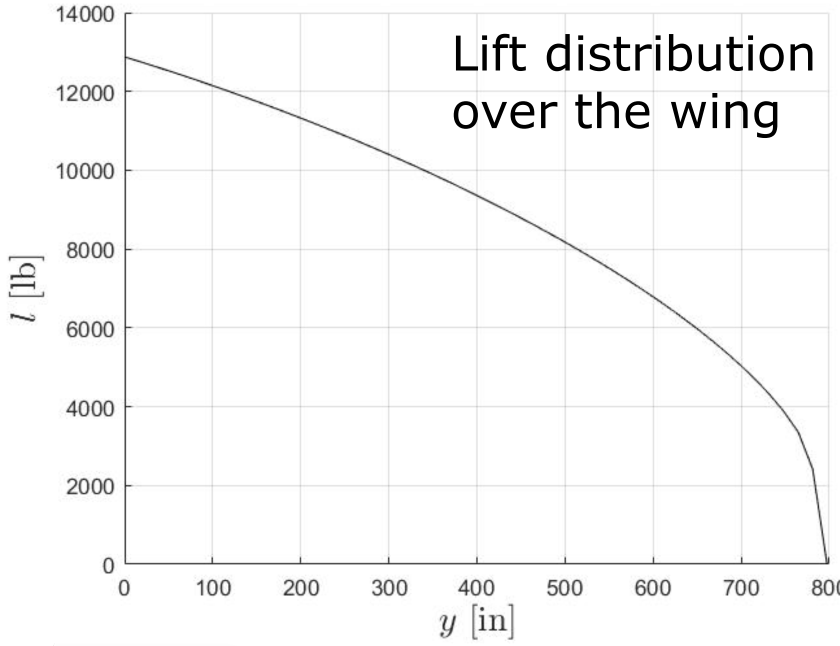
- Spar design led by max bending moment at wing root
- Rib specs estimated from Airbus 320 with similar wingspan & loading

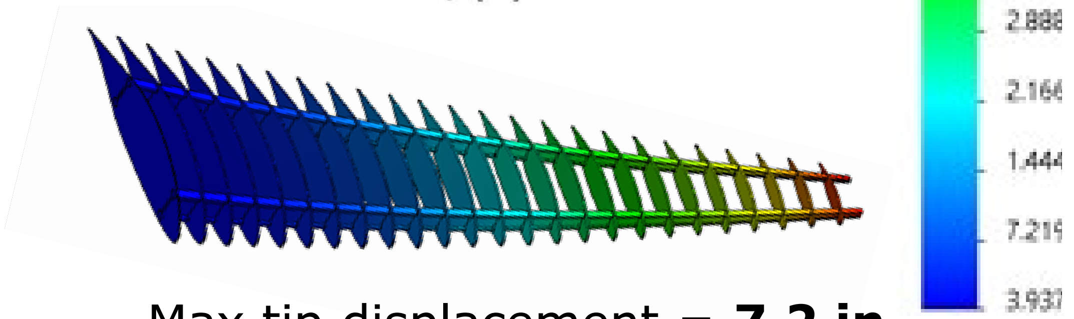
Component	Requirement	Value
Spar height	Wing geometry	50.4 in
Web thickness	Critical buckling	4.6 in
Flange thickness	Weight	2.8 in
Flange length	Weight	12.5 in
Rib thickness	A-320	2 in
Spars (x2) Ribs (x26)	Strength-to-weight ratio, fatigue	7075-T6
Wing box	Strength, stiffness, corrosion	CFRP



Structure – FEA Analyses

- Theory Factor of Safety (FS) = 1.8 at max stress
    - Max bending moment (wing root)
    - Schrenk's estimation for lift distribution
- SolidWorks FEA FS = 1.3 at max stress
    - Schrenk 5-point approximation
    - Lift on 5 ribs, spars fixed at root

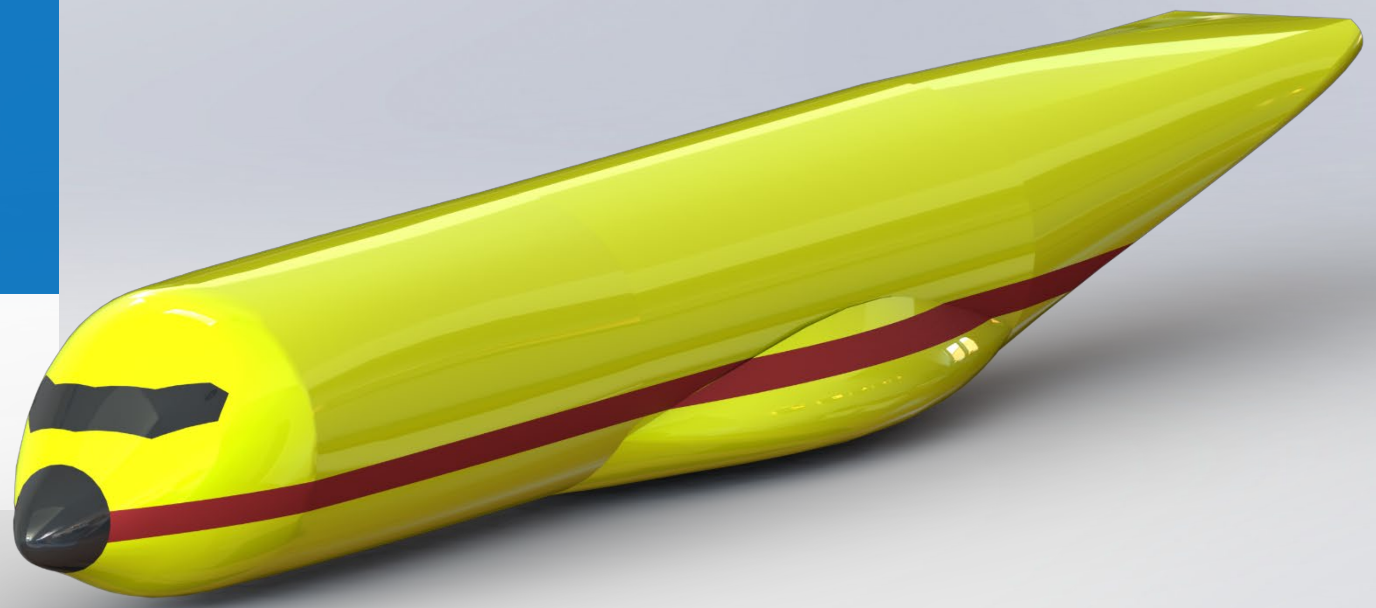




Max tip displacement = **7.2 in**

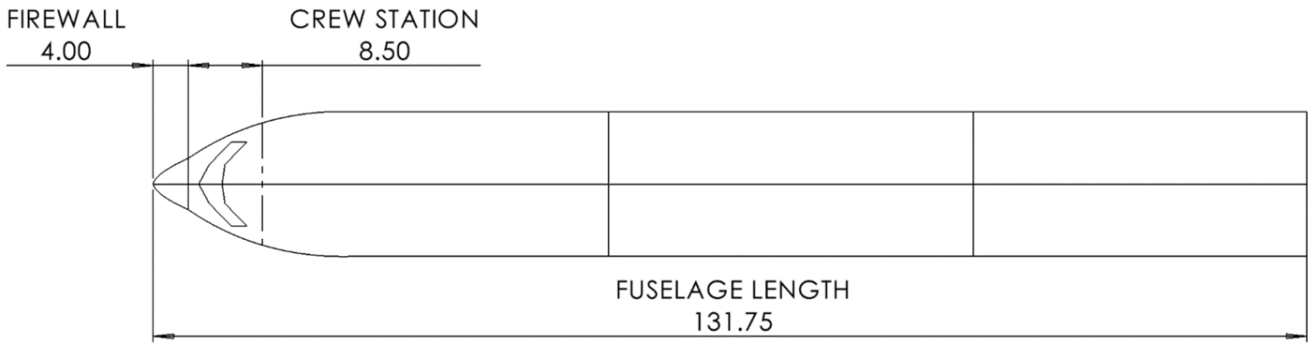
6. Fuselage/ Payload Design

Lofting, System Integration, Crew Station, Payload

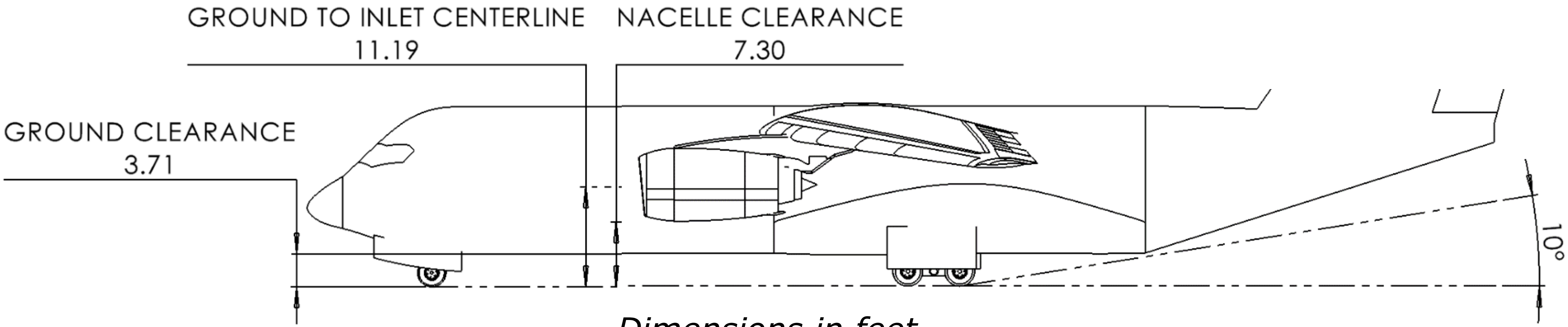


Fuselage Design

- Length referenced from Jet Transport
- Fineness ratio is Length over Diameter, chosen as 8
- Fuselage diameter comes from fineness ratio: 16.5 ft
- Initially designed as straight cylinder



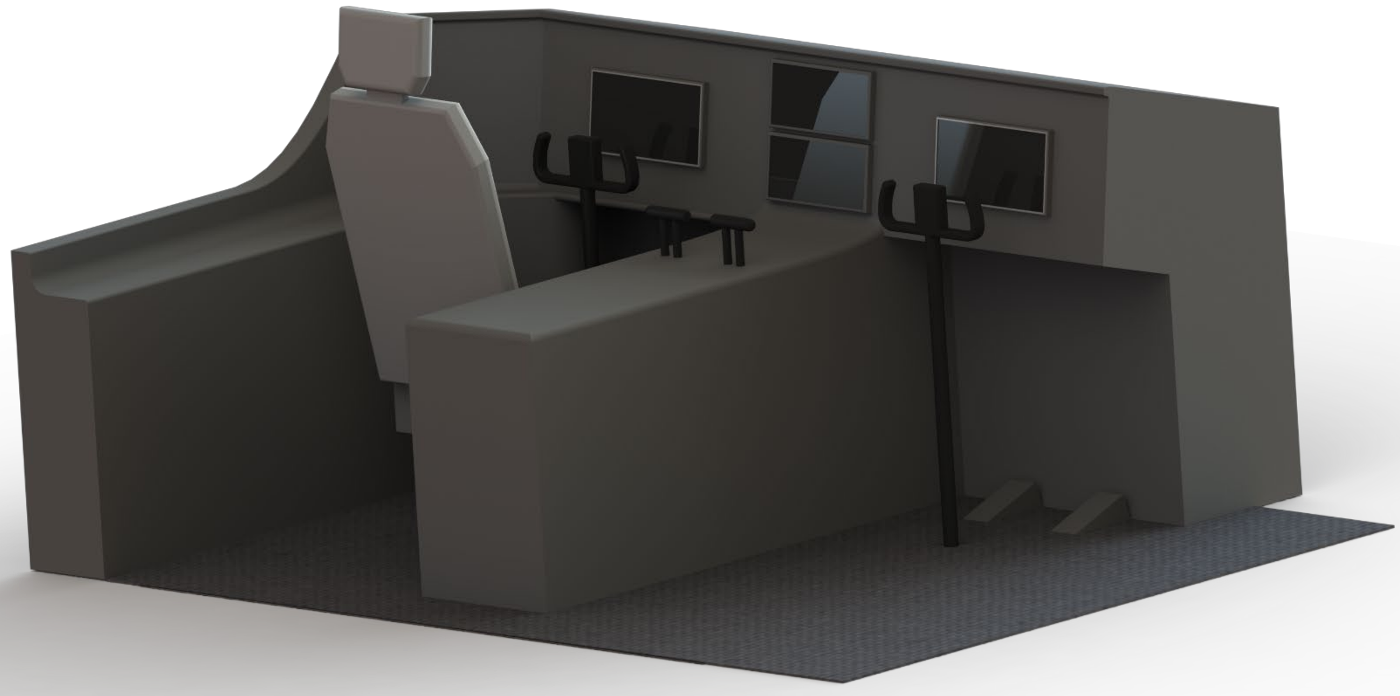
Fuselage Clearances



Dimensions in feet

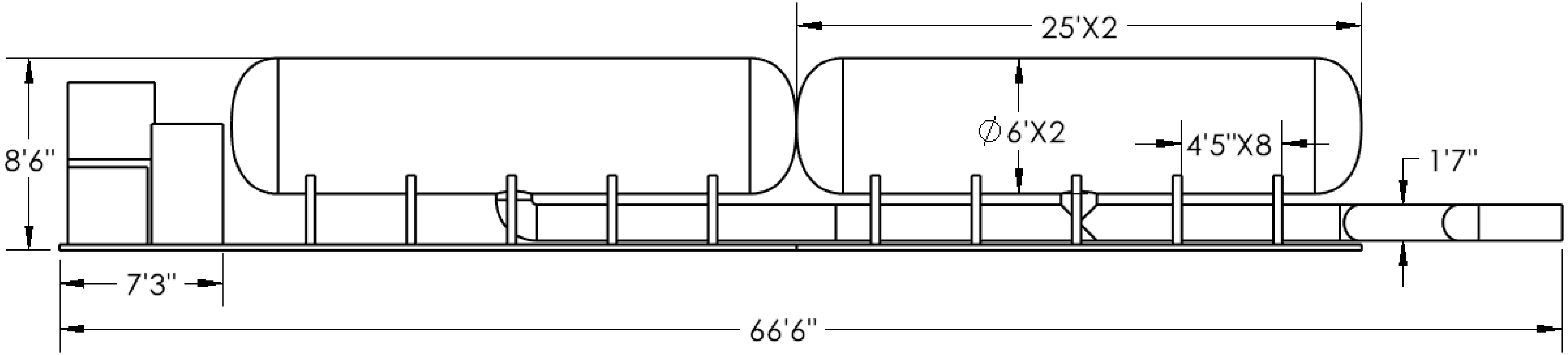
Crew Station/Cockpit

- Systems
  - VFR and IFR flight with autopilot
  - Heating for leading edges of wings, pitot tubes, etc…
- Equipment such as radio and GPS
- Pilot and co-pilot seating.
  - 102 inch cockpit length



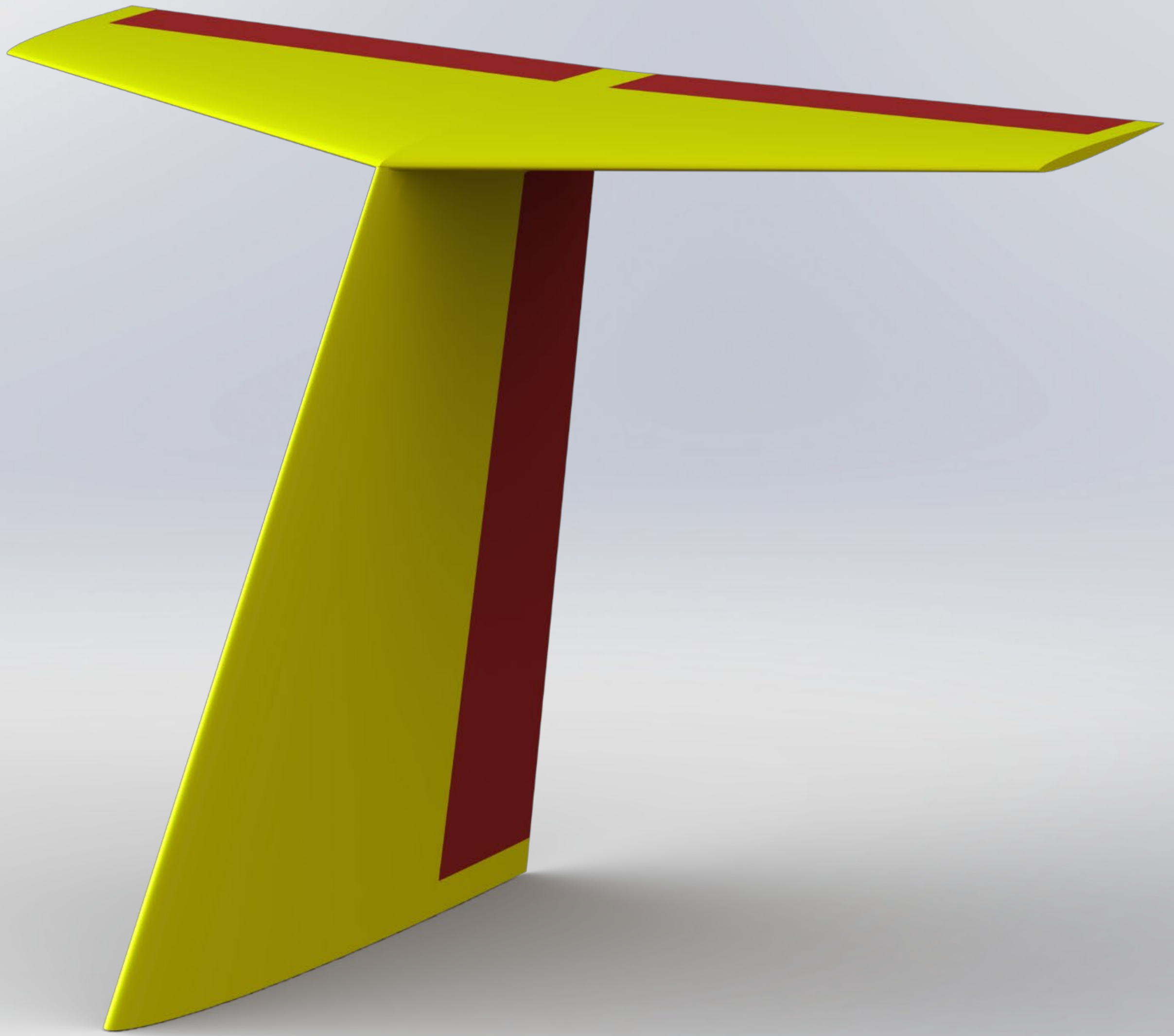
Payload Design

- Tank diameter: 6 feet
  - Tank length: 25 feet
- Two tanks for redundancy
  - Each tank is partitioned into two
  - Tanks can shift payload between themselves
- Payload drop minimizes CG shifting



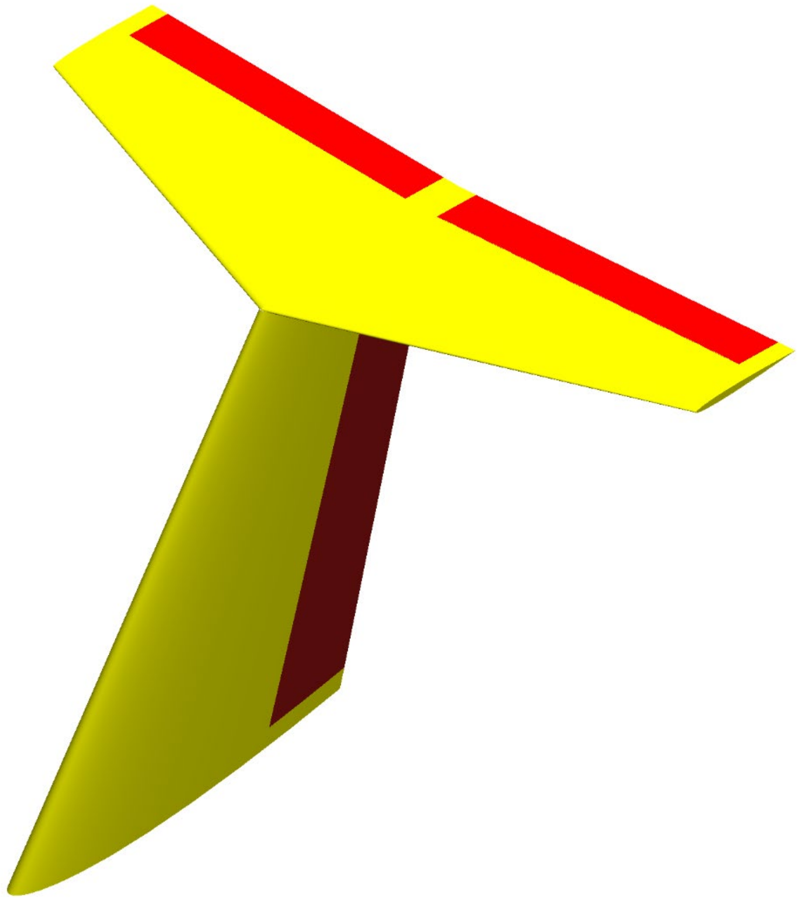
7. Tail Design

Horizontal Stabilizer, Vertical Stabilizer, Control Surfaces



Tail - Configuration

- T-tail configuration was chosen
  - Avoids air disturbances from high mounted wing and engines
  - Endplate effect increases vertical tail effectiveness
  - Ensures no blockage of rudder



Tail - Geometry

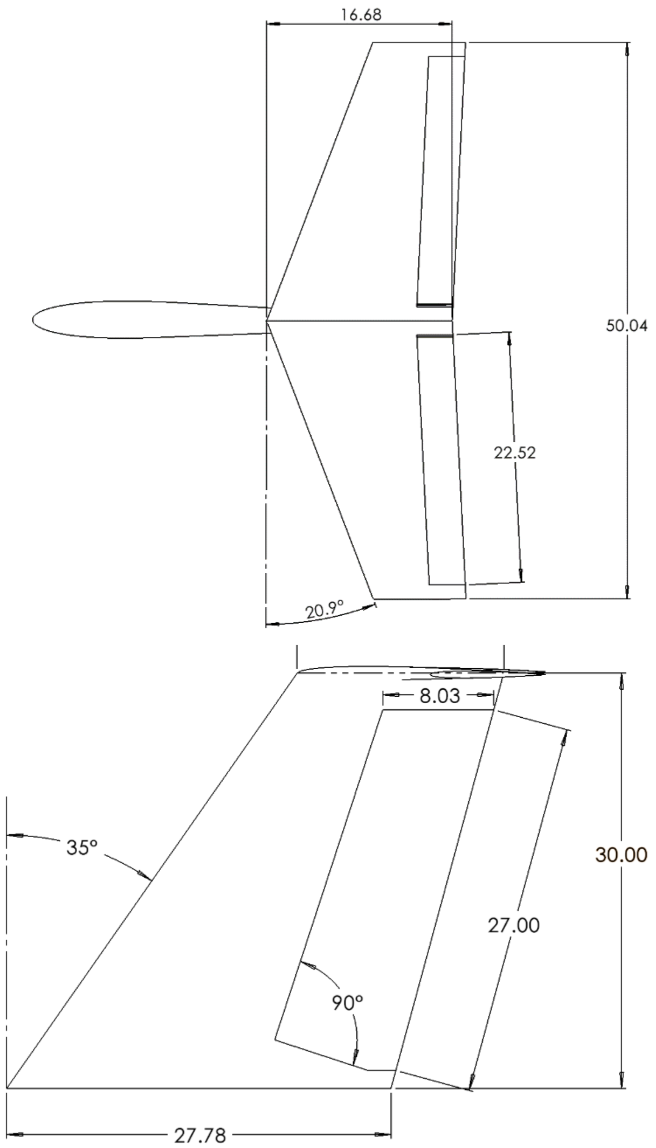
- Volume coefficient method used to provide minimum sizing for tails
  - Vertical tail also required to elevate the horizontal tail to avoid blanketing
- Designed to ensure higher critical Mach number than main wing
  - Increase sweep angle
  - Decrease thickness of airfoil

Parameter	Horizontal Tail	Vertical Tail
Wingspan (ft)	50.04	30.0
Mean Aerodynamic Chord (ft)	12.97	25.1
Root Chord (ft)	16.68	27.78
Tip Chord (ft)	8.34	22.22
Taper Ratio	0.5	0.8
Leading-Edge Sweep (deg)	25	35.0
Aspect Ratio	4	1.2
Total Area (ft^2)	626.1	750

Tail – Tail Control Surface Sizing

- Rudder and Elevators
  - Span is taken to be 90% of respective tail span
  - Chord is determined as a ratio to respective tail mean aerodynamic chord

Parameter	Elevators	Rudder
Total Span (ft)	45.04	27
Chord (ft)	3.24	8.03



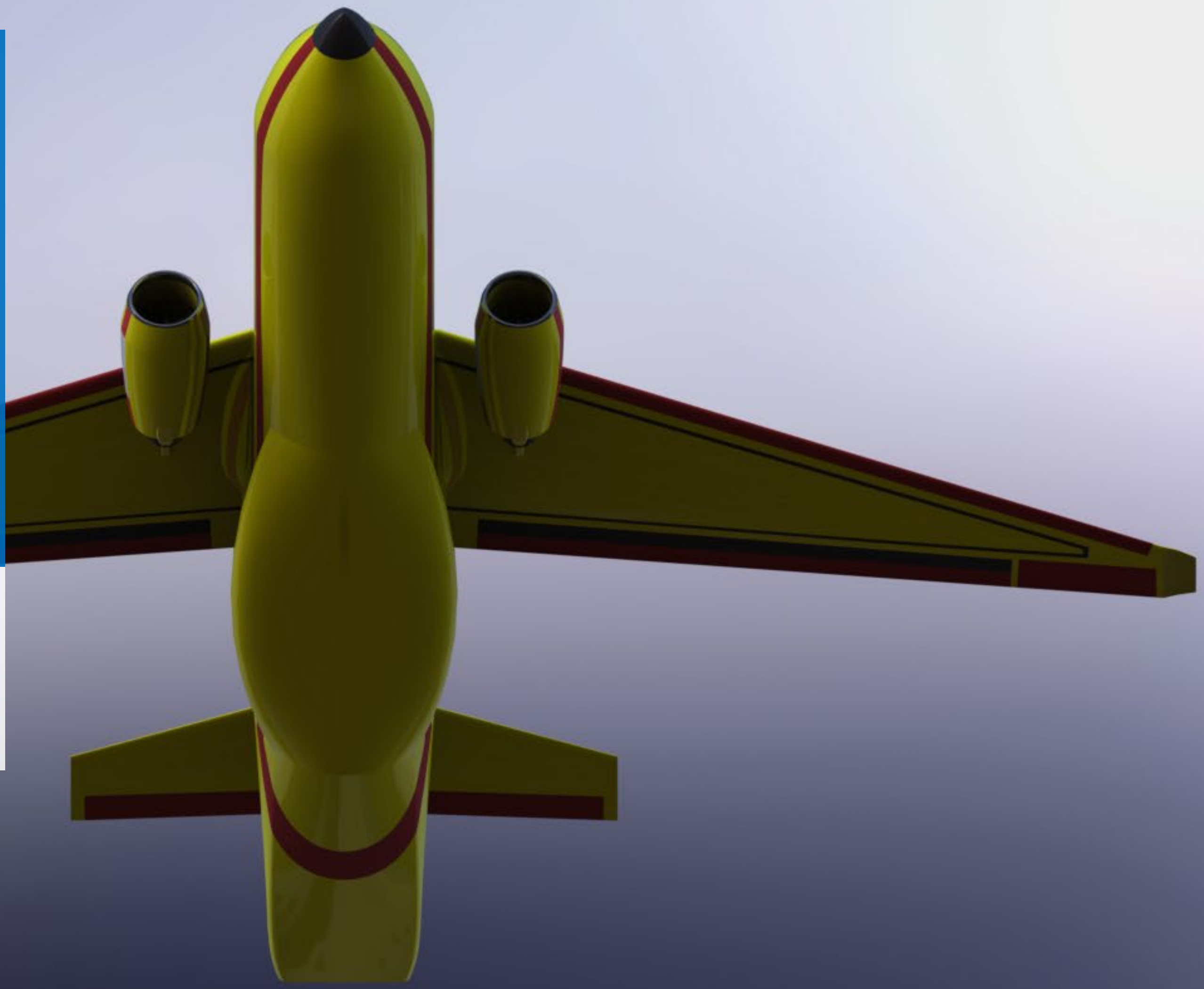
Tail – Wing Control Surface Sizing

- Ailerons and Spoilers
  - Aileron sized using historical relations between aileron chord ratio and span ratio to the main wing
  - Ailerons possible were not large enough by themselves
  - Spoilers used to supplement roll control at low velocities

Parameter	Aileron	Spoiler
Span (ft)	20	20
Spanwise Start Position (ft)	45	24.5
Spanwise End Position (ft)	65	44.5
MAC (ft)	3.24	4.28
Chordwise Start Position (% chord from LE)	70	45
Chordwise End Position (% chord from LE)	100	70

8. Weight and Stability

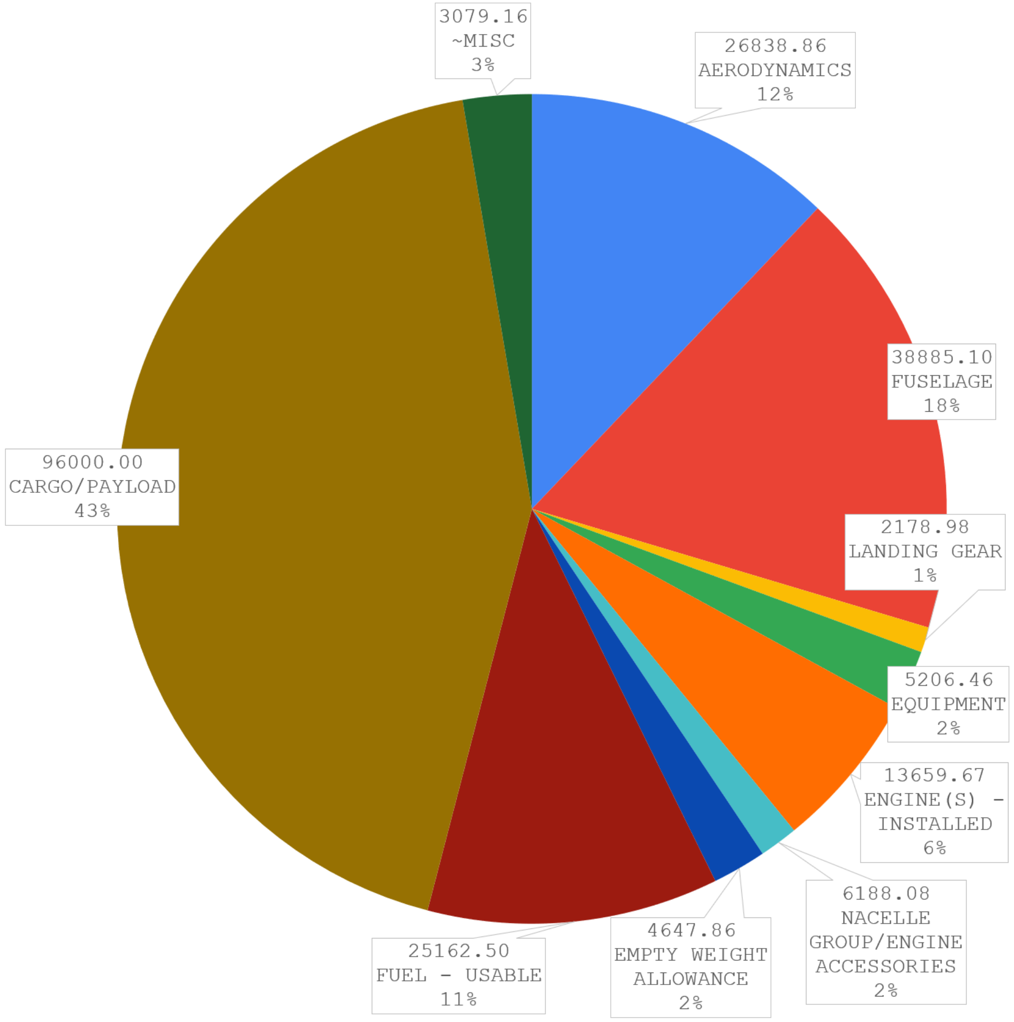
Weight Estimation, CG, Stability



Weight Budget

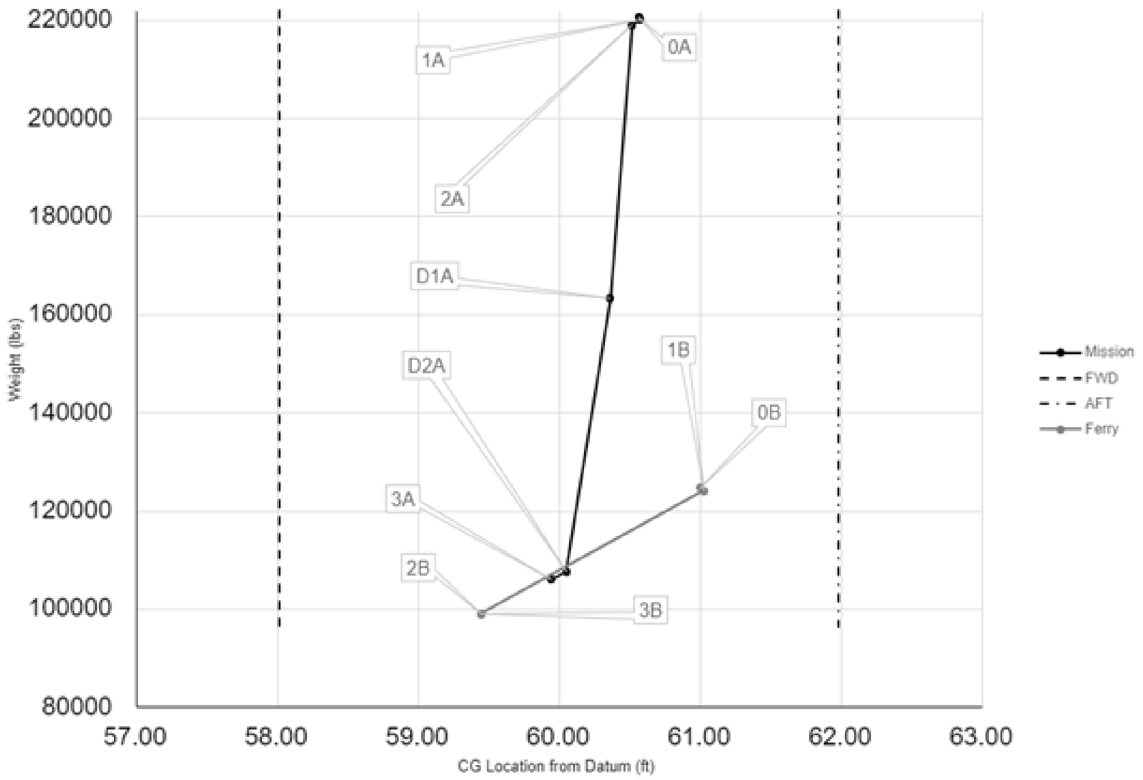
- Used Raymer's statistical weight formulas for transport aircrafts

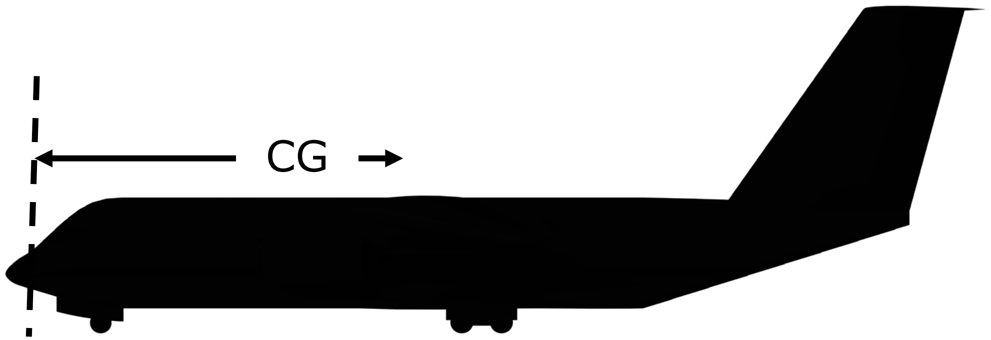
Weight	Value (lbs.)
MTOW	221846.7
Empty Weight (W_e/W_0)	97605.0 (0.44)
Payload	96000.0
Fuel (W_f/W_0)	25162.5 (0.113)



CG Estimations

- Firewall Datum Chosen (4ft from nose tip)
- Calculated Weight and Balance at all points of missions

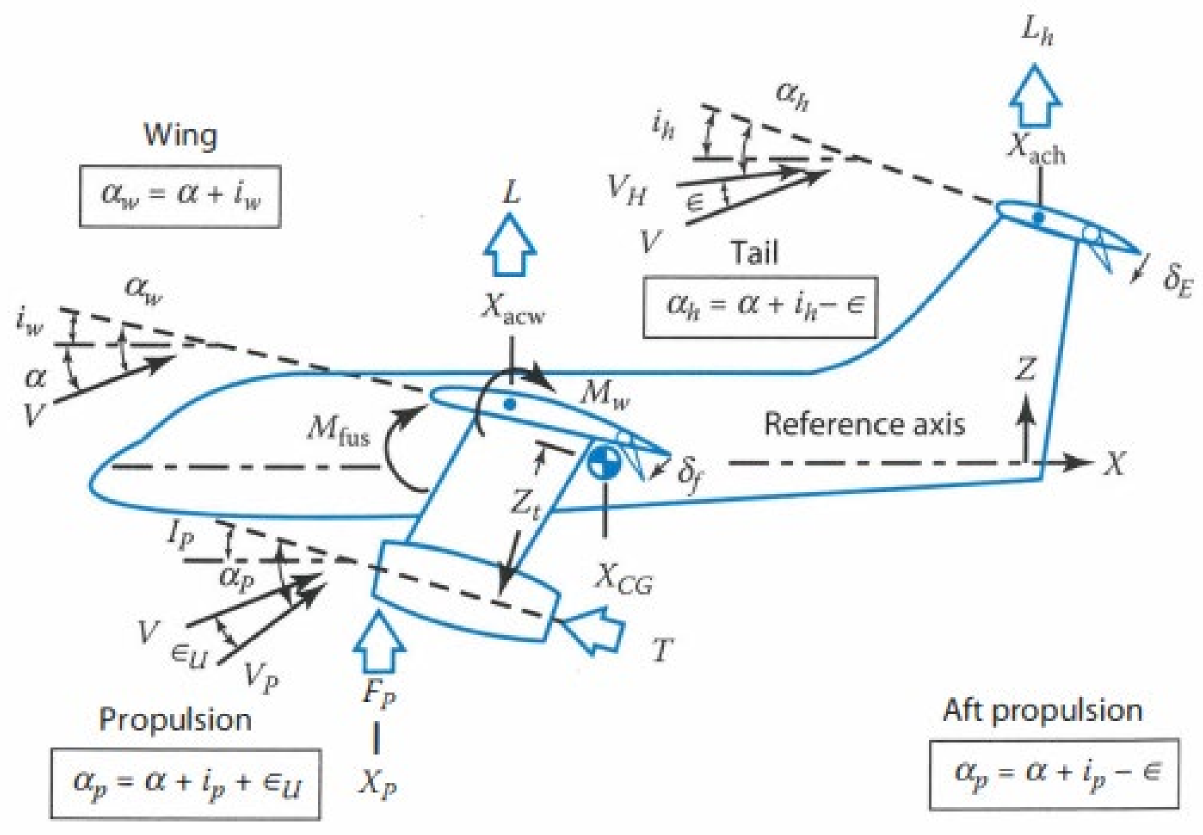




Stability

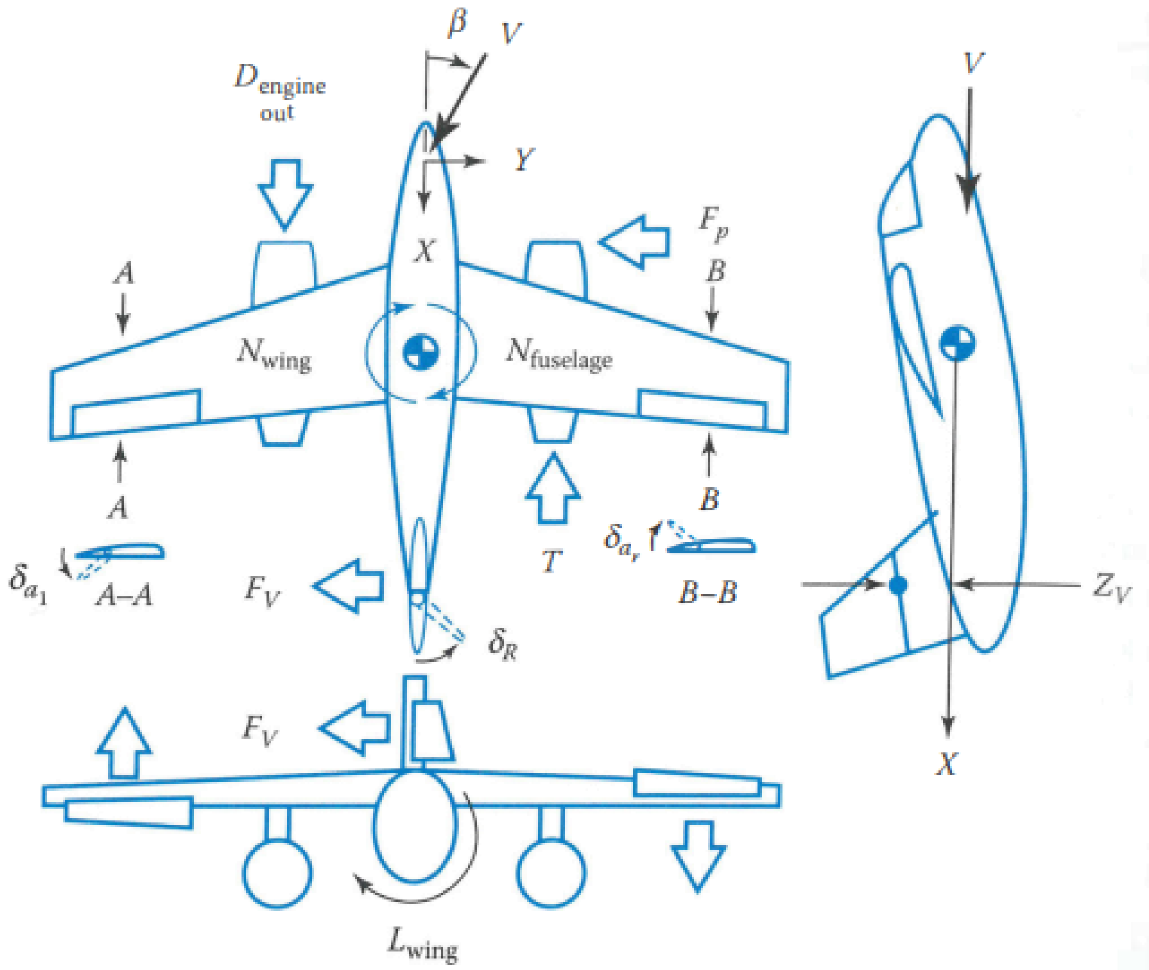
- Longitudinal
  - Pitching Moment Coefficient
  - $C_{m_\alpha} = -1.22$

- Trim Scenarios
  - Takeoff, Cruise, Landing



Stability

- Lateral/Directional
  - Roll Moment Coefficient
  - $C_{l_\beta} = -0.56$
  - Yaw Moment Coefficient
  - $C_{n_\beta} = 0.34$
- Trim Scenarios
  - Engine out, Crosswind Landing



9. Performance

Range, Operating Envelopes,
Balanced Field Length, V speeds

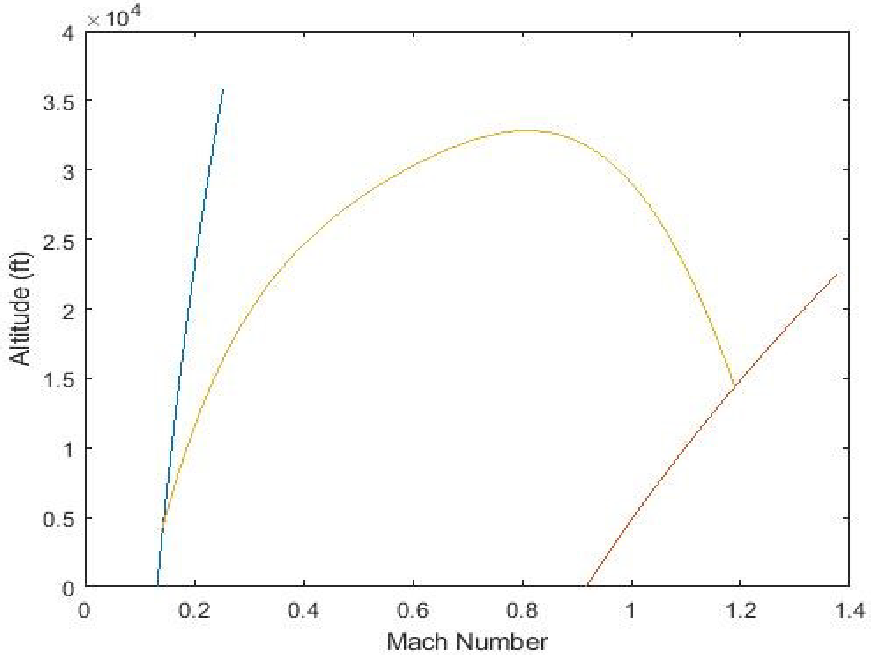
Performance – Range

- Values assume velocity, specific fuel consumption, and L/D are kept constant
  - Ranges obtained from the Breguet Range Equation
- R_{Loiter} - 1811.33 mi radius
  - Wi/Wf - 0.8502
- $R_{NoCargo}$ - 3323.14 nautical miles
  - Wi/Wf - 0.7425
- Complies with mission requirements

Variable	Value
V (mph)	430
C (1/hr)	0.47
K	0.057
C_L	16.97
C_{Do}	0.015
R_{Loiter} (mi)	1811.33
$R_{NoCargo}$ (nmi)	3323.14

Performance - Operating Envelope

- Envelope highlights V_{stall}, q_{max}, and P_s=0 lines
  - Range of altitudes calculated through standard atmospheric density conditions
- Stall limit is far enough away from cruise conditions at M=0.75

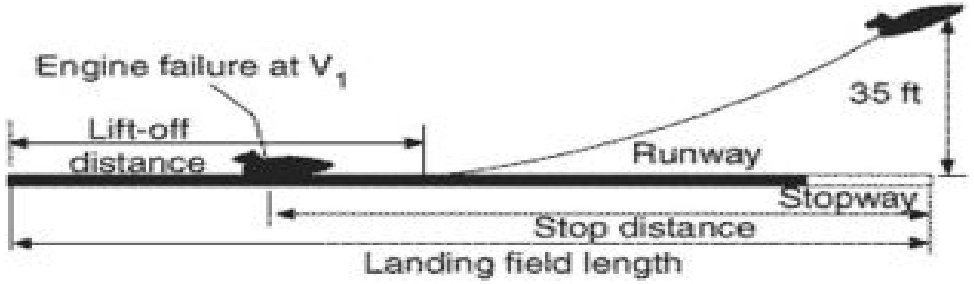


Parameter	Color
V_{stall}	Blue
Q_{max}	Red
P_s=0	Yellow

Performance – Balanced Field Length (BFL) Analysis

- Takeoff distance required to clear a 35-ft. obstacle
  - BFL distance - 6523.5 ft
  - Less than the required 8000 feet
  - Complies with FAA FAR 25

- Total drag (D_{skin} + D_{wing}) at climb – 1587.24 lbs



Performance- V Speeds Summary

- Useful/Important speeds to the operation of the aircraft
- All speeds calculated assuming Standard Day at MTOW

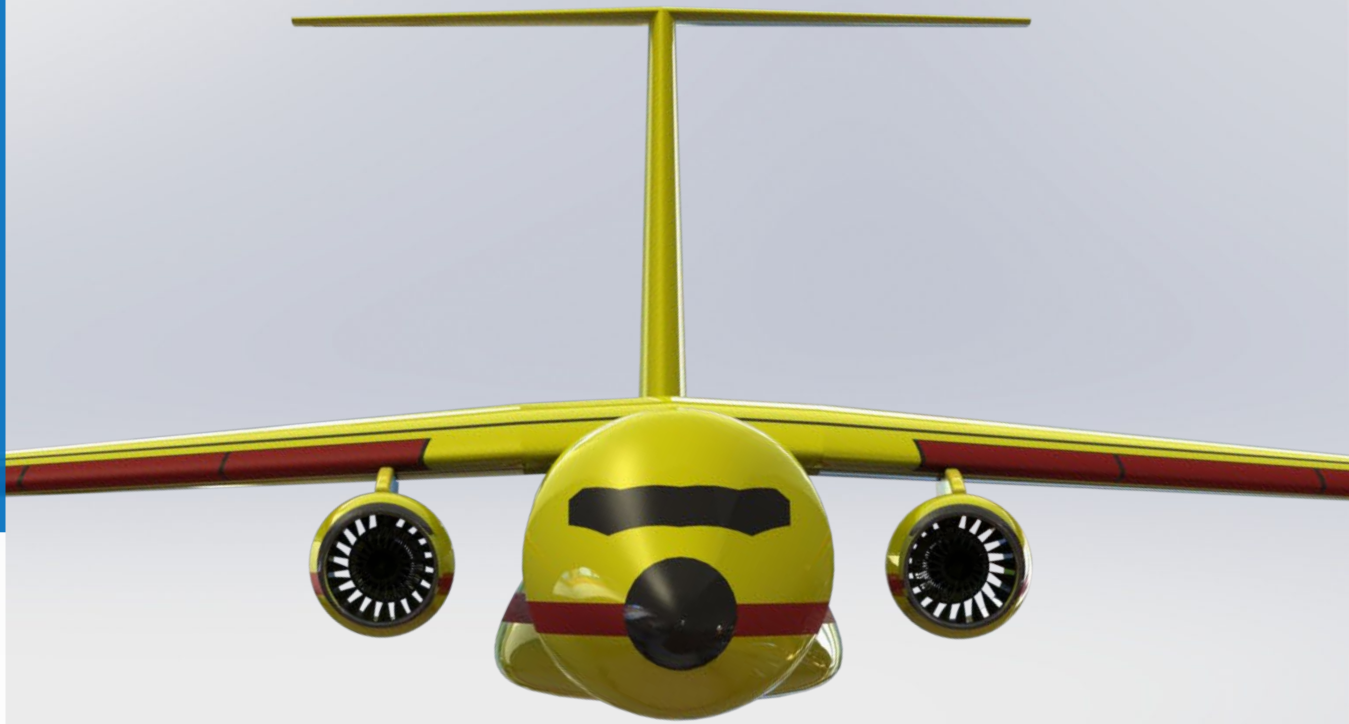
*V_G shown at 20k ft @ 75% MTOW

- Best climb angle – 15.5 degrees at 196.2 kts

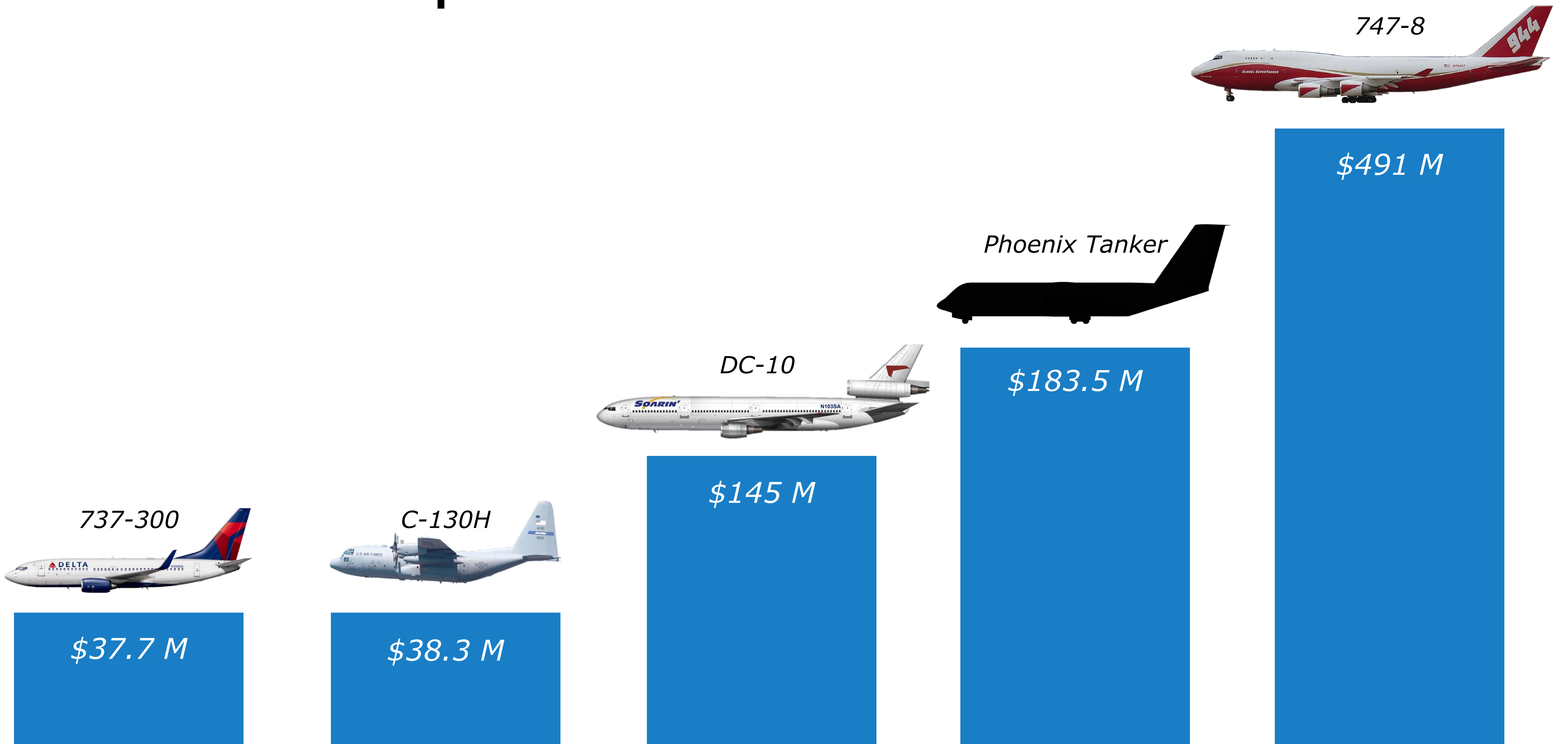
V Speed	Value (kts)
V_A	232
V_C	430
V_D	645
V_G	176*
V_{NE}	645
V_{NO}	530
V_R	121
V_S	127
V_{S0}	98
V_X	196
V_Y	332.5

10. Cost Analysis

Flyaway Cost, Operational Costs, Aircraft Comparisons



Cost Comparison



Cost – Operational Cost Estimations

Flight-Hours per Year	700 Hours	1000 Hours	1400 Hours
Fuel	$14,150,432.19	$20,214,903.13	28,300,864.38
Crew	$503,436.37	$719,194.82	$1,006,872.75
Maintenance Crew	$224,000.00	$320,000.00	$448,000.00
Maintenance Materials	$1,108,082.36	$1,582,974.81	$2,216,164.73
Depreciation	$10,476,700.11	$10,476,700.11	10,476,700.11
Insurance	$446,336.06	$637,622.94	$892,672.11
Total Operation	**$26,908,987.10**	**$33,951,395.81**	**43,341,274.08**

Phoenix Tanker

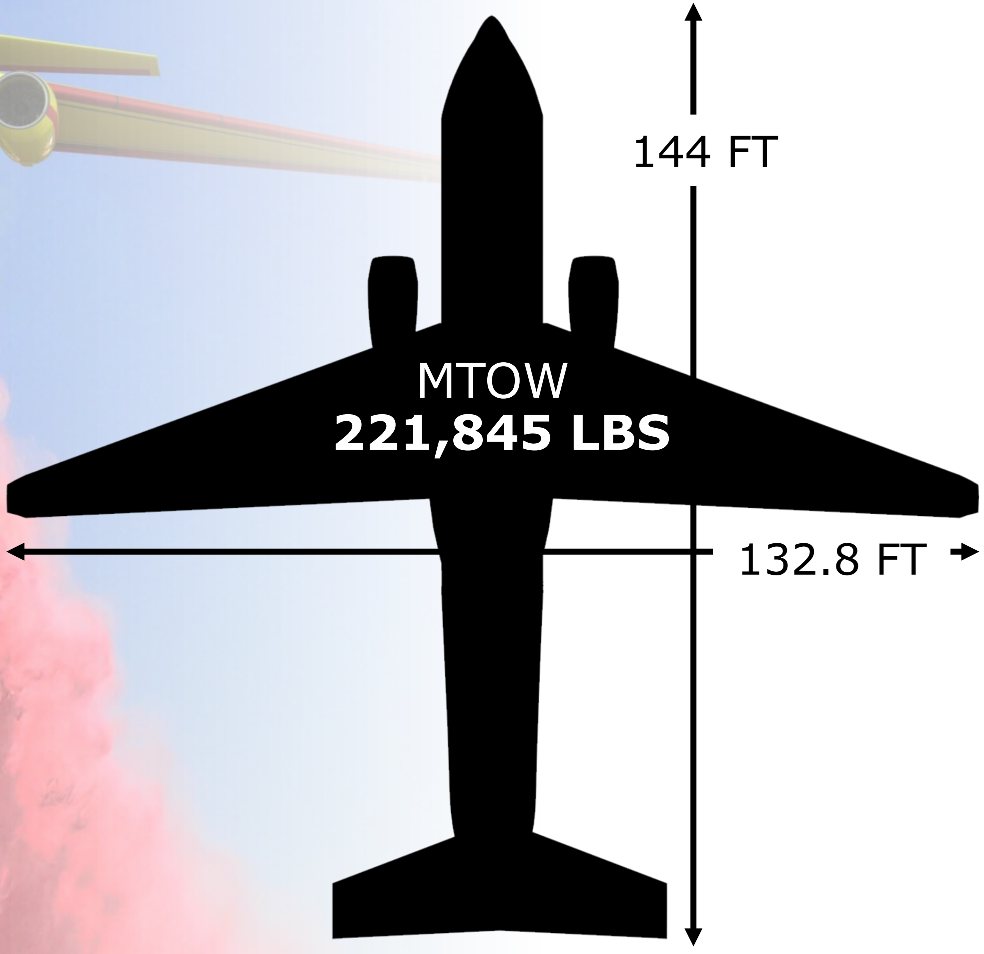
PAYLOAD CAPACITY
8000 GAL

MISSION RANGE
1811 NMI

FERRY RANGE
3320 NMI

DROP SPEED
<150 KTS

DROP HEIGHT
300 FT



CREW
2 PILOTS

ENGINES
2 PW1133G/2-JM (2024)

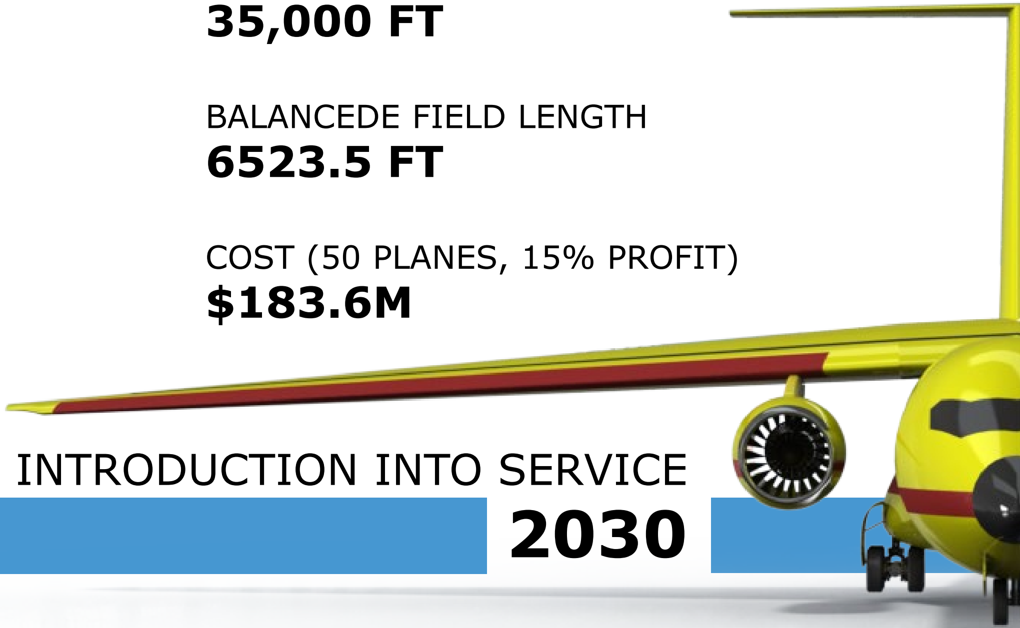
THRUST
36,580 LBF (PER ENGINE)

CRUISE SPEED
430 KTS

CRUISE ALTITUDE
35,000 FT

BALANCEDE FIELD LENGTH
6523.5 FT

COST (50 PLANES, 15% PROFIT)
$183.6M



INTRODUCTION INTO SERVICE
2030

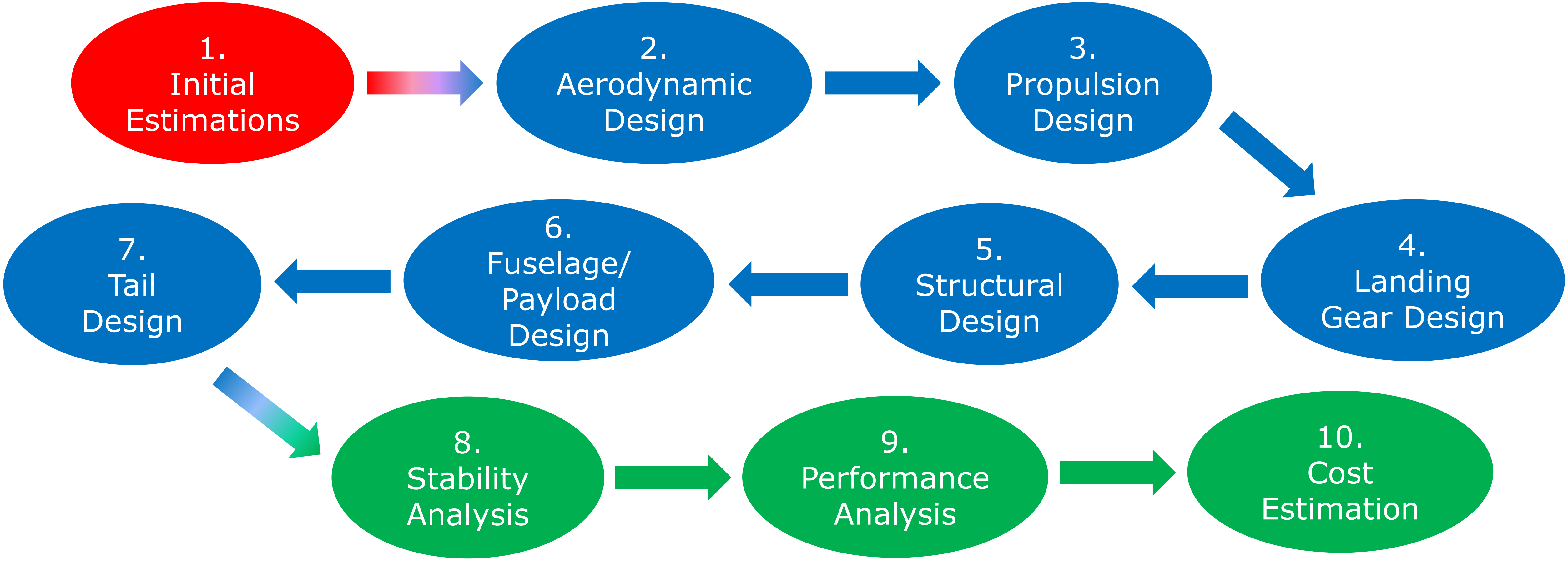
The Next Generation Medium Firefighting Tanker

Appendix

Additional Charts, Graphics, and Info

Outline

How did we go about constructing our *Phoenix Tanker?*



GAT-AIR AID

The Next Generation Medium Firefighting Tanker