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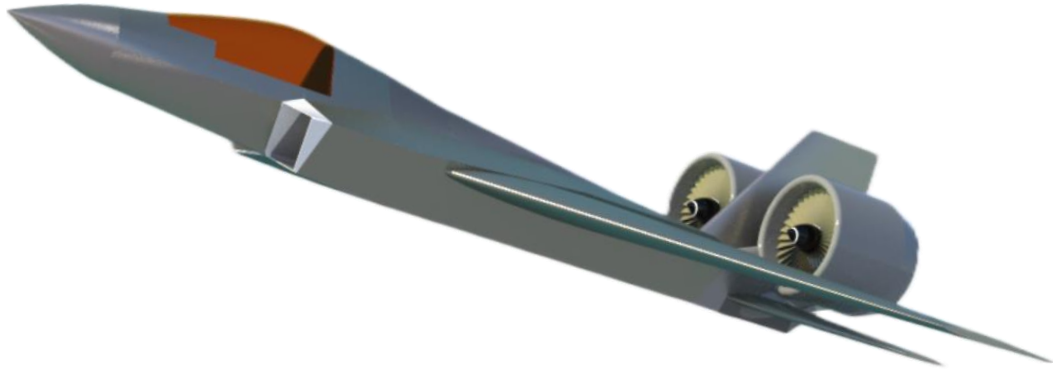


Harpy

George Apessos, Nahda Haikal, Brendan Harders, Robert Pan, Julian Peña, Abraham Yohannes

AIR VEHICLE DESIGN | 20 APR 2023

Design Requirements, Benchmarking, and Chosen Technologies

Benchmarking

Aircraft	F-35	Harrier II	A-10	A-37	SU-37	EMB 314
Role	Multirole, VTOL	Ground attack, VTOL	Close air support	Attack/COIN	Close air support	Attack/COIN
Year of Service	2006	1985	1972	1964	1978	2003
Wingspan (m)	10.7	9.25	17.5	10.9	14.4	11.1
Length (m)	15.7	14.1	16.3	8.62	15.5	11.4
Max Takeoff Weight (kg)	29,900	9,415 vertical 14,100 rolling	20,865	6,350	19,300	5,400
Combat Range (km)	1,239	556	400	740	750	550
Payload (kg)	8,200	4,200	7,260	1,800	4,400	1,550

Stakeholders

Direct Stakeholders:
- Department of Defense
- Military Pilots
- International Militaries
- Ground-based troops

Indirect Stakeholders:
- Environmental groups
- Military Contractors

Design Requirements and Tradeoffs

Requirement	Tradeoff
Vertical Takeoff/Landing	Large weight considerations, takeoff weight limited by max static thrust of engines
Small size (12m x 12m)	Limits payload capabilities
Moderate Range (2000–4000 km)	Limited max range. With low maximum takeoff weight, fuel supply will be relatively low
Low attack speed (100 m/s)	Limits maximum cruise speed. Likely limited to subsonic regime
Exclusively ground combat oriented	No air-to-air combat capabilities
Max Payload = 1200 kg	
Cruise speed = 270 m/s	
Operational Ceiling = 10,000 m	

Technology Readiness Level

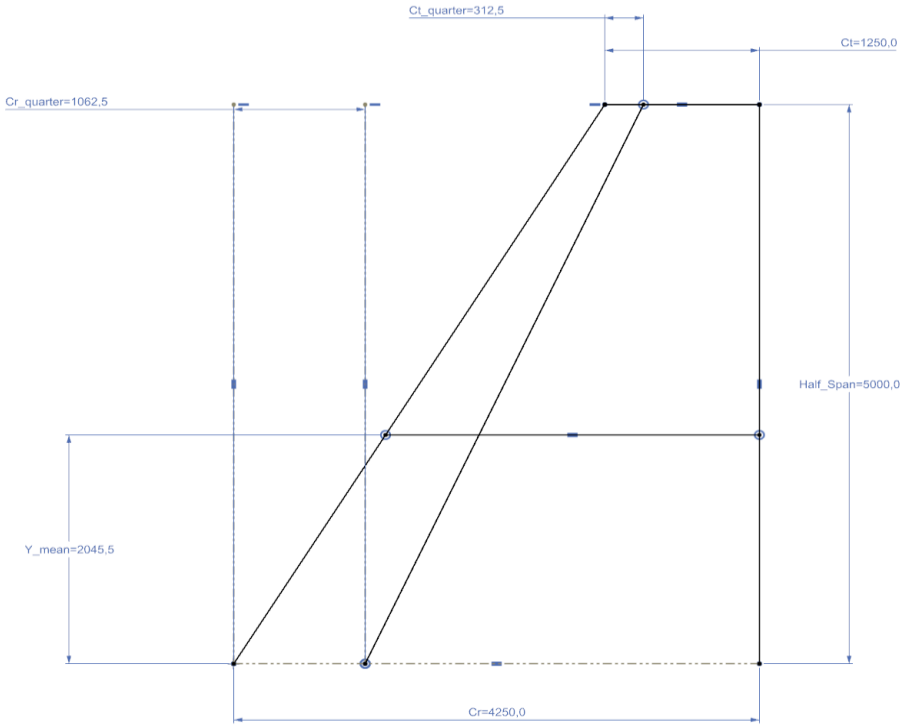
Subsystem	Propulsion system	Weapons systems	Avionics	Survivability systems	Control Systems
TRL	5	7	8	9	8

Sizing & Performance Estimation

Wing Geometry

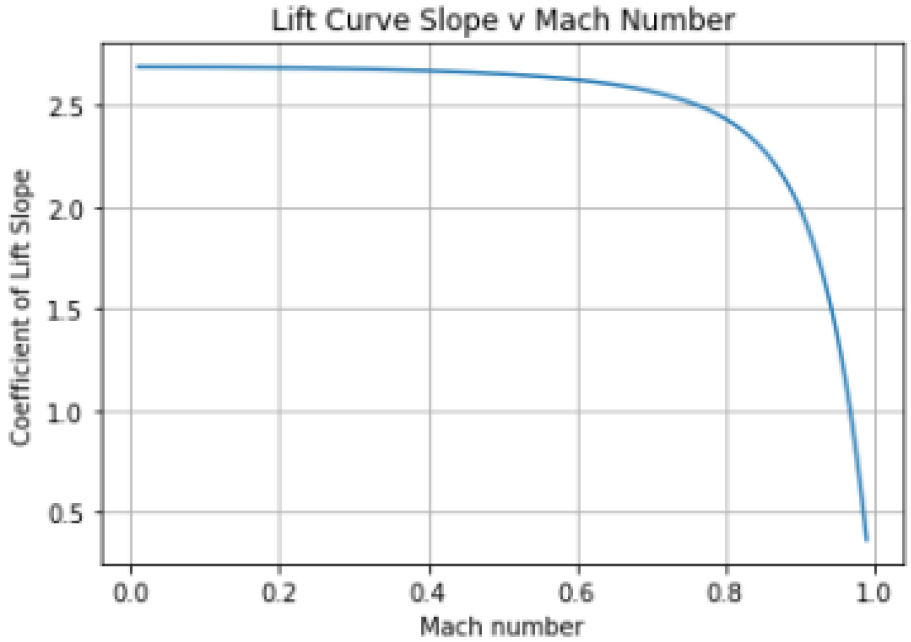
- Airfoil: 64A-204

Specification	Value
Area	27.5 m^2
Span	10 m
Aspect Ratio	3.64
Taper Ratio	0.294
Mean Chord	3.02 m
Leading Edge Sweep	31°



Airfoil Lift and Lift slope Calculations

- Airfoil lift coefficient
  - Cl = 1.9



Lift slope with respect to Mach

Moment and Drag Estimations

- Total Drag Coefficient: 0.03105
  - Engine housing
  - Fuselage
  - Wings
  - Horizontal and vertical tails

- Moment Coefficients:
  - C_{m_alpha} : 1.23
  - C_{m_zero} : 7.16

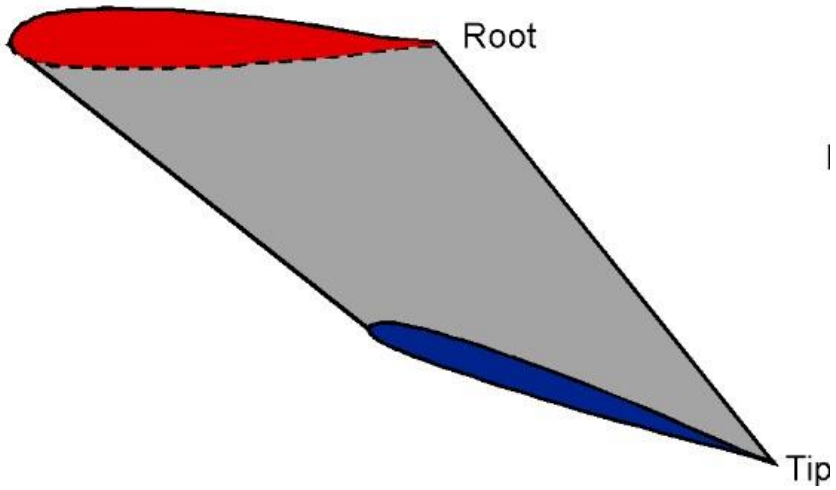
Stability Estimations

- Statically unstable in pitch
- Statically stable in yaw
- Statically stable in roll

Direction	Stability Coefficients
Pitch	$C_{M,\alpha CG} = 1.49$ $C_{M,0} = 7.16$
Roll	$C_{\mathscr{L},\beta} = -0.869$
Yaw	$C_{N,\beta} = 0.0834$

Geometric Parameters for Improved Aerodynamic Estimations

- Wing twist
  - Total: 2.16º
  - Geometric: 3.35º

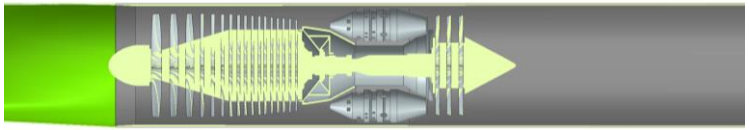


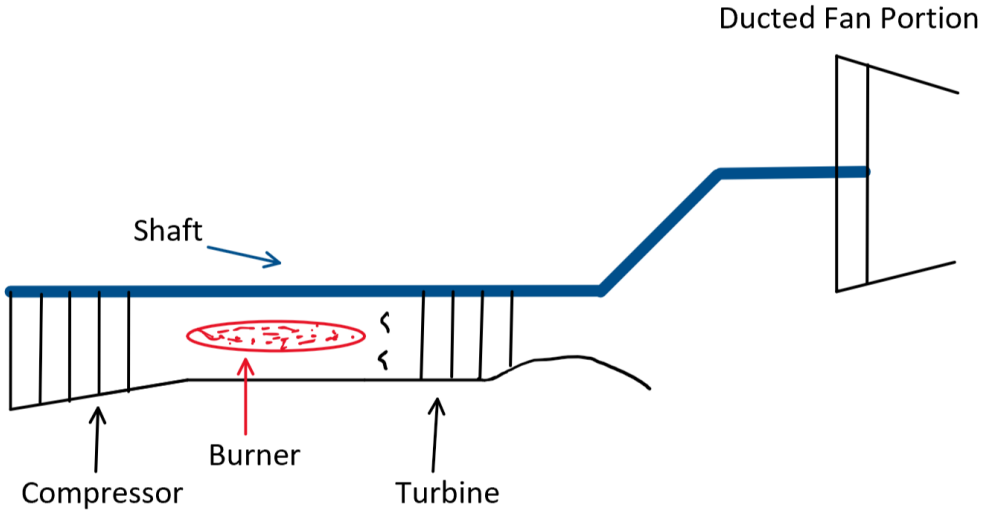
Tail Geometry

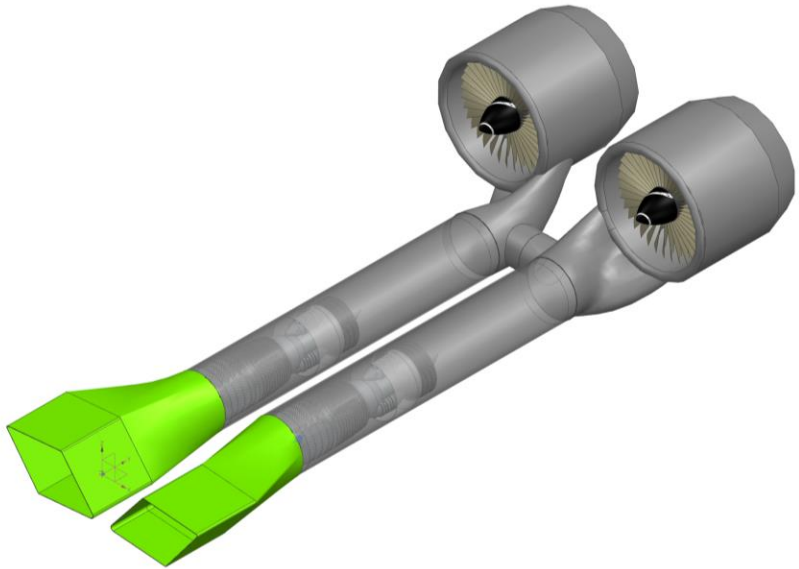
- Airfoils:
  - Horizontal Tail: NACA 0010
  - Vertical Tail: NACA 0009

Specification	Horizontal Tail	Vertical Tail
Area	4.156 m^2	4.125 m^2
Span	3.69 m	2.17 m
Aspect Ratio	3.28	1.14
Taper Ratio	0.286	0.267
Mean Chord	1.24 m	1.06 m
Leading Edge Sweep	36°	35°

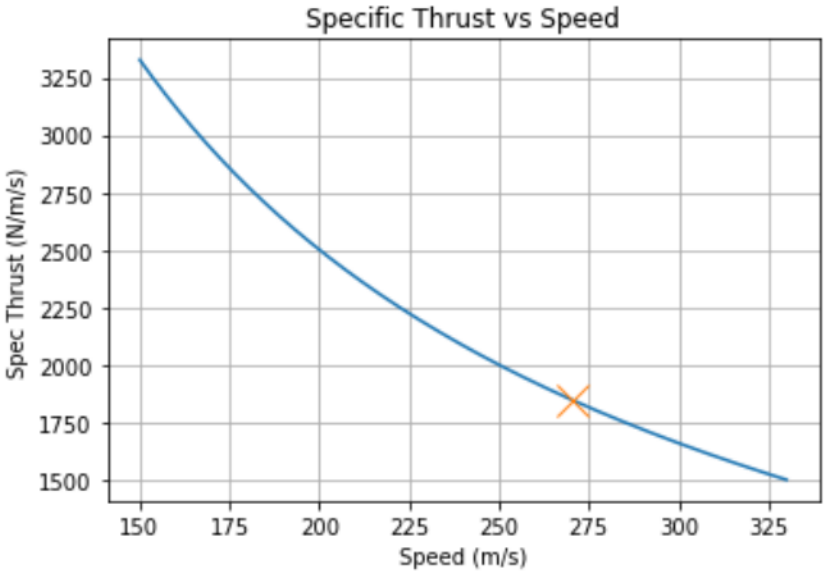
Powerplant Estimations

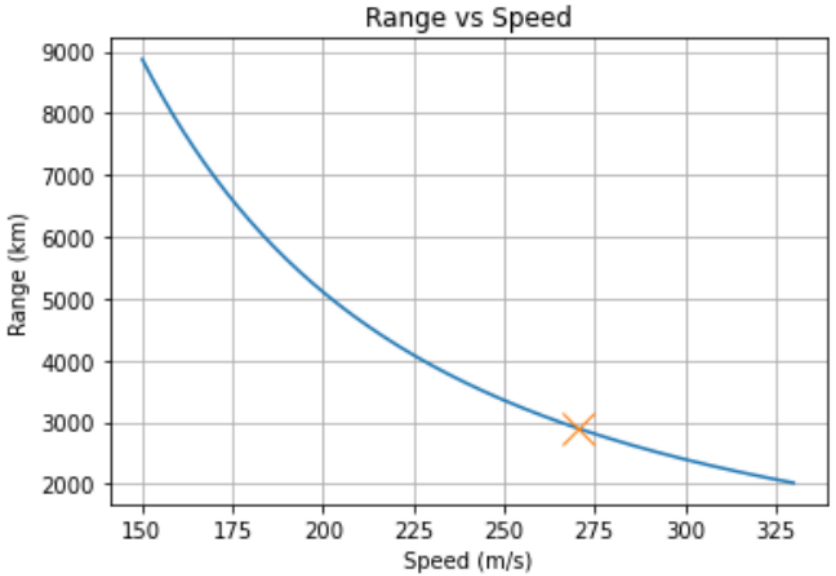






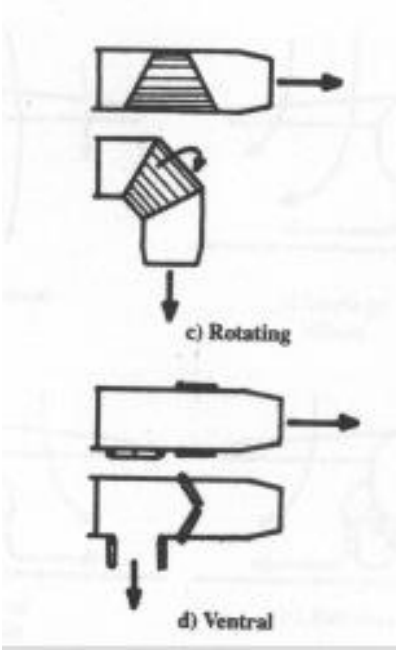
Powerplant Estimations

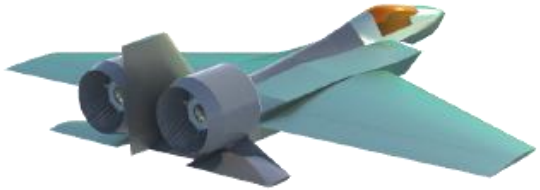




VTOL System

- Similar to Harrier VTOL system
- Hybrid system with both rotating engines and ventral bypass
- No Lift fan





Subsystem Estimations

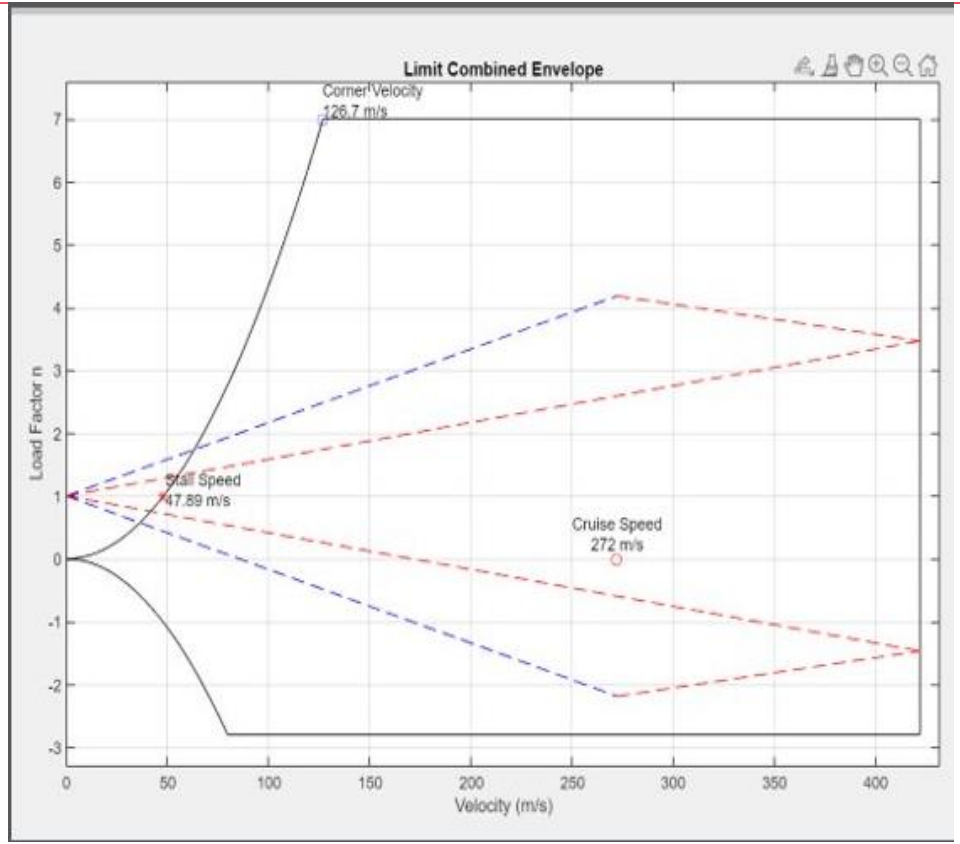
- Aerodynamic Control Surfaces
- Aircraft Propulsion System
- Aircraft Structural System
- Air Data and Flight Instrument
- Computer System
- Aircraft Pilots
- Intergration of Flight Systems
- Emergency Power

Component	Weight (kg)
Avionics	53.00623999
Pilot Control	
Ejection Seat	170.8782645
Radar	15.14203491
GPS/surveillance	
Fire Control system	
Flight Computer	6.40606275
Hydraulic	171.2767336
Main Cannon	
Electrical Control System	
Upper Body Fuel Tank	559.6143224
In-Wing Fuel Tank	519.1935094
Inner Body Fuel Tank	166.088372
Engine Control	142.4325769
Electric Power Generation	
Forward Landing Gear	57.4034
Rear Landing Gear	115.4149
Backup Power	42.8085917
Redundant Control System	
Redundant Electrical System	

Flight Envelope

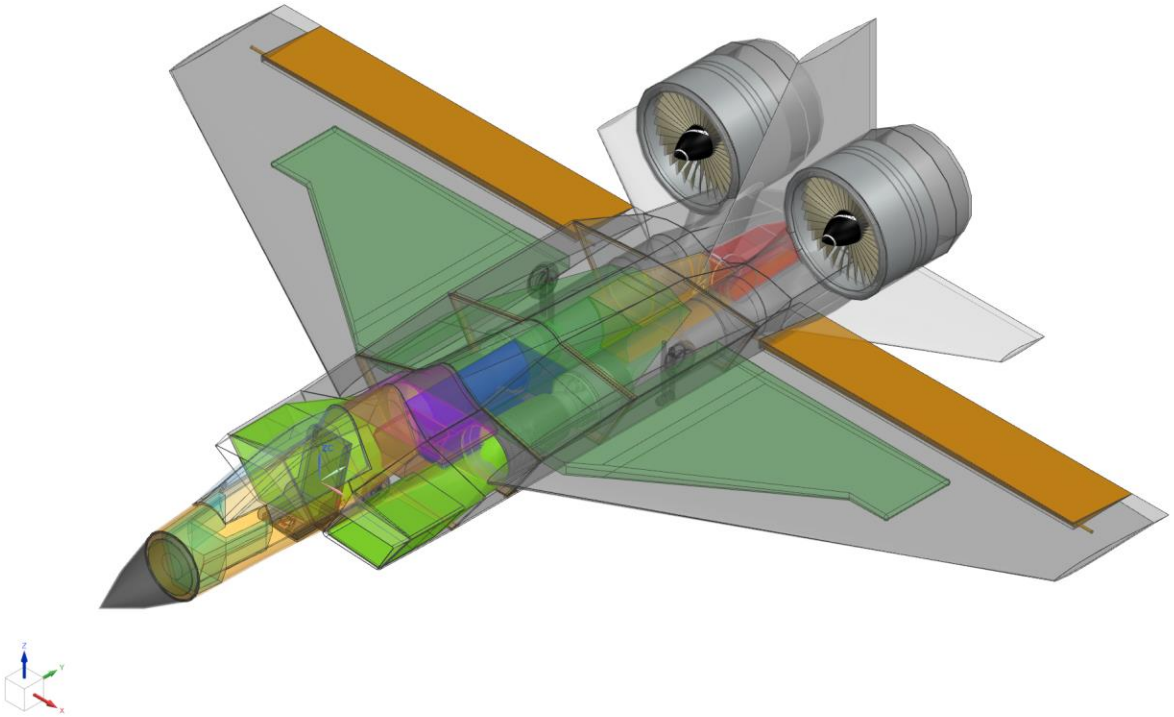
- V-n Diagram
  - Gust diagram included
  - Min. Load Factor = -2.8G
  - Max Load Factor = 7G

Velocities	Value (m/s)
Stall Speed	47.89
Maneuvering Speed	126.7
Cruise Speed	272
Design Dive Speed	380.8
Demonstrated Dive Speed	421.6
Never Exceed Speed	342

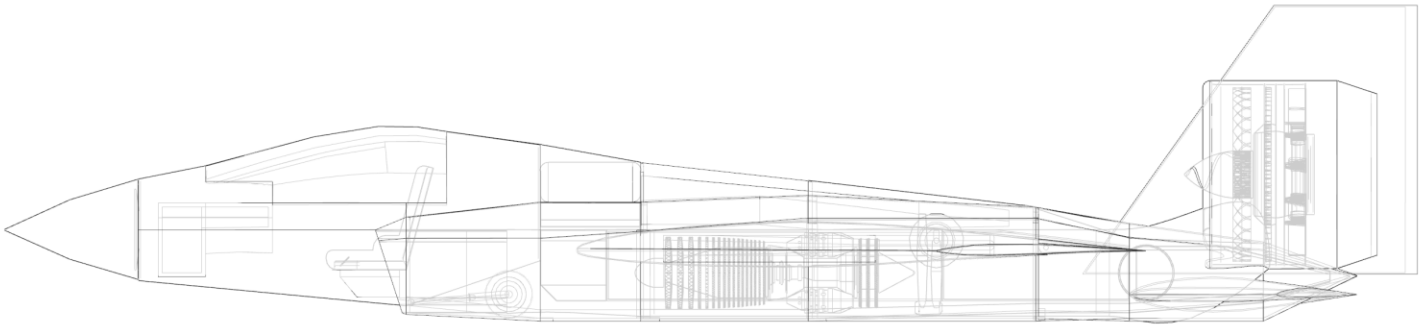


Final Design

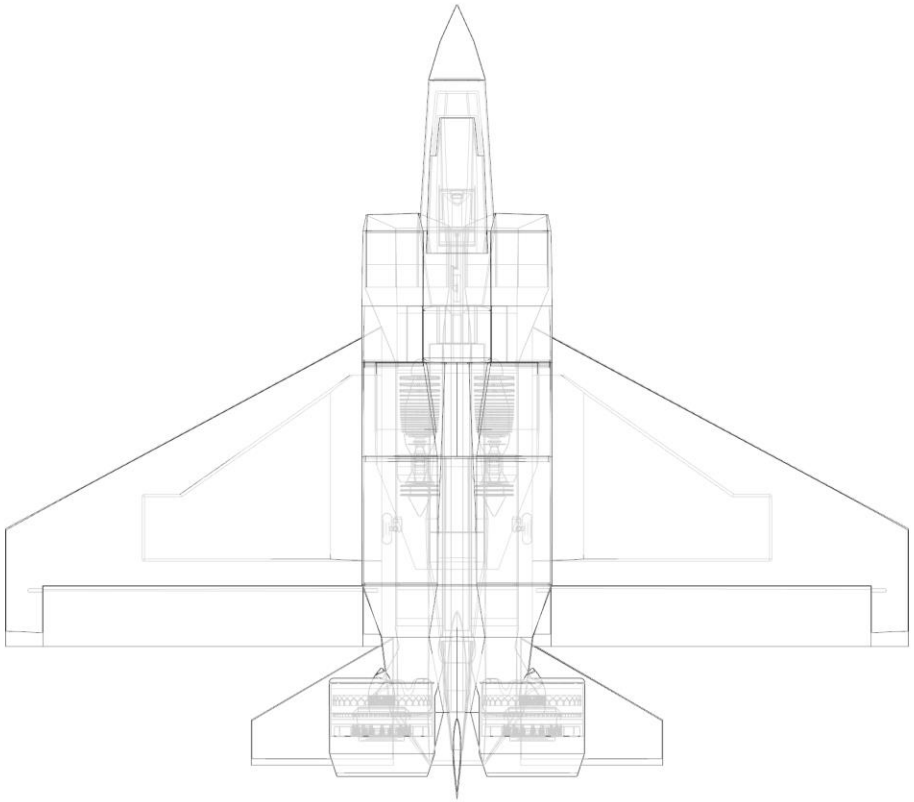
CAD Drawings



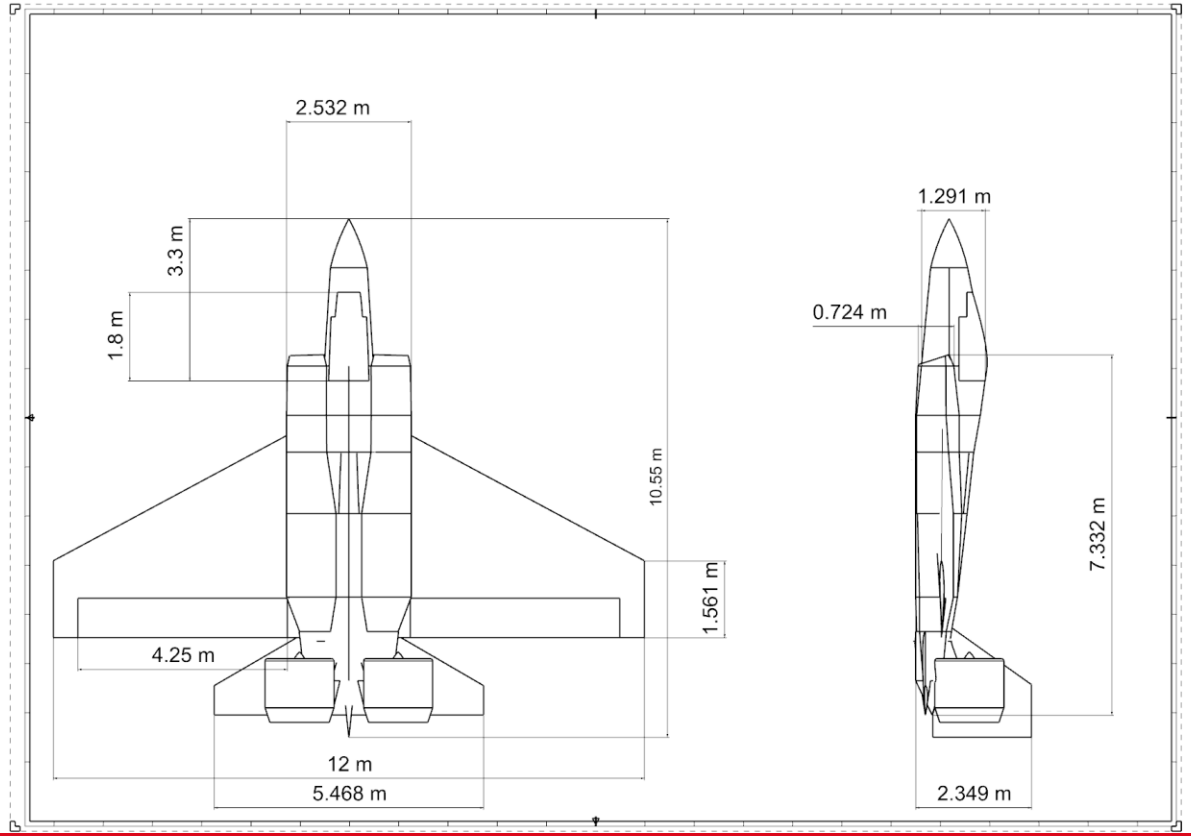
CAD Drawings



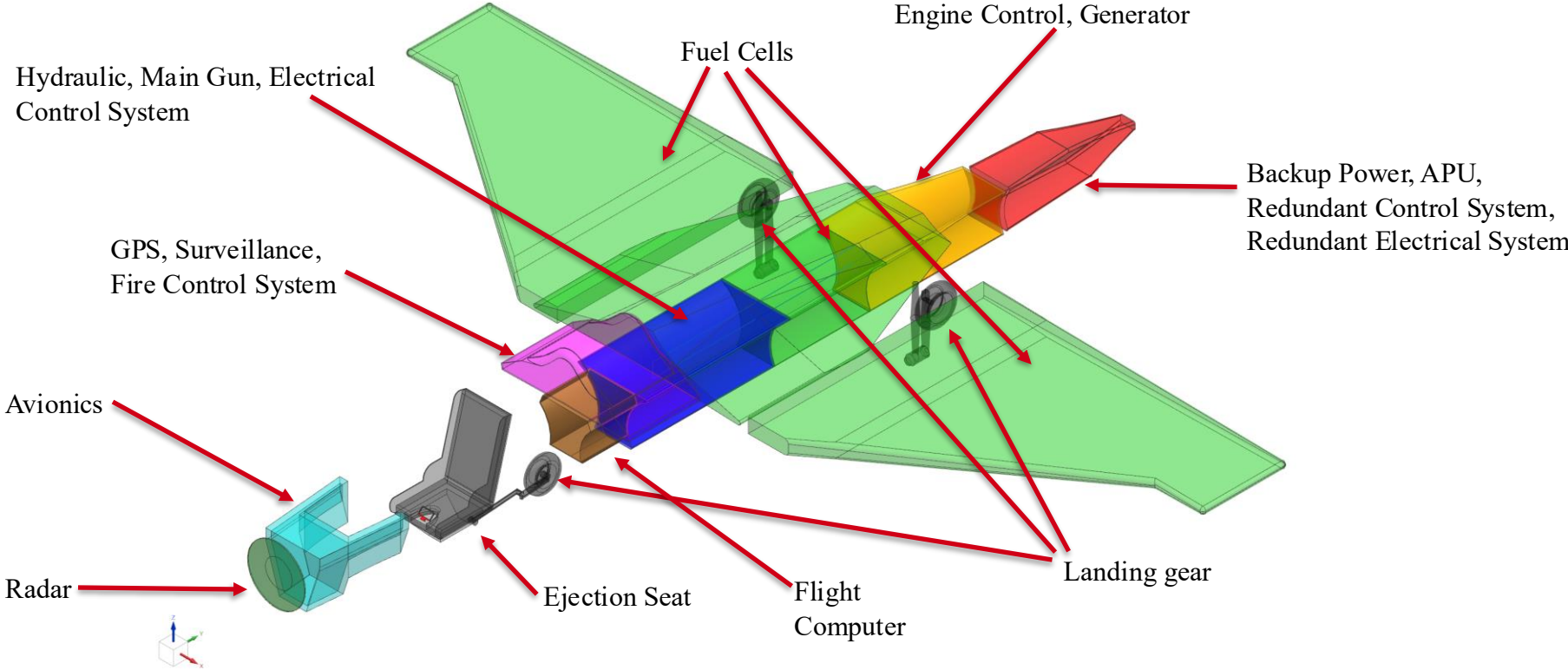
CAD Drawings



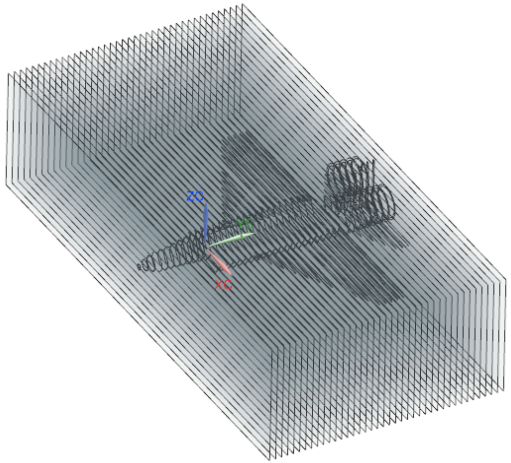
CAD Drawings



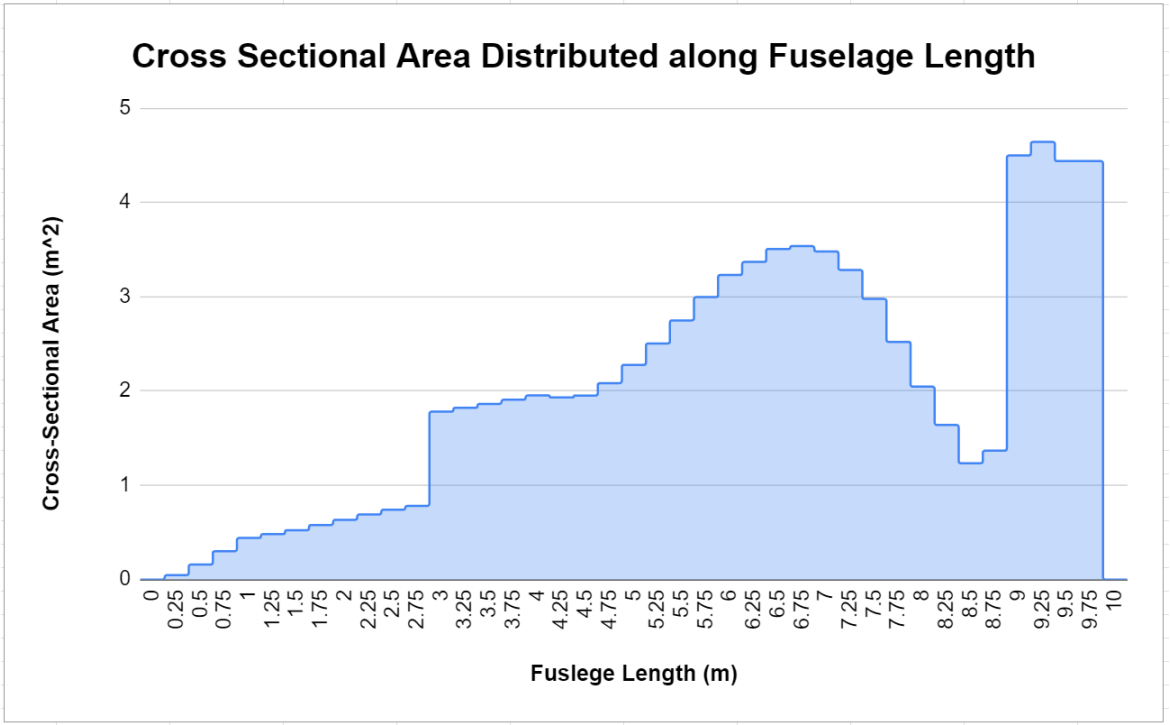
Subsystem Diagram



Cross Sectional Area

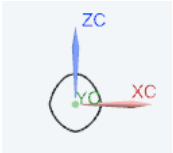


Cross Sectional Area Slicing

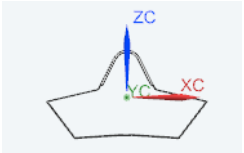


Important Cross Sectional Areas

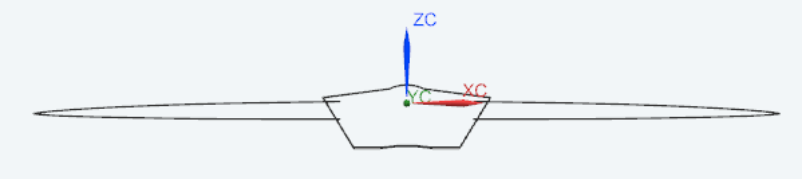
Fuslege Length (m)	Cross Sectional Area (m^2)
0	0
1.5	0.5235026456
3	1.78057533
4.5	1.95205643
6.75	3.536294335
8.5	1.233809465
9.25	4.640461295
10	0



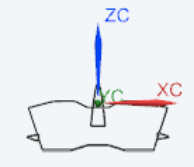
1.5 m



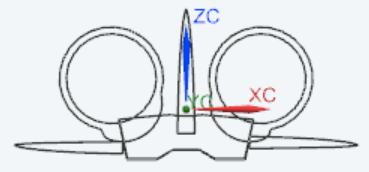
3.0 m



6.75 m

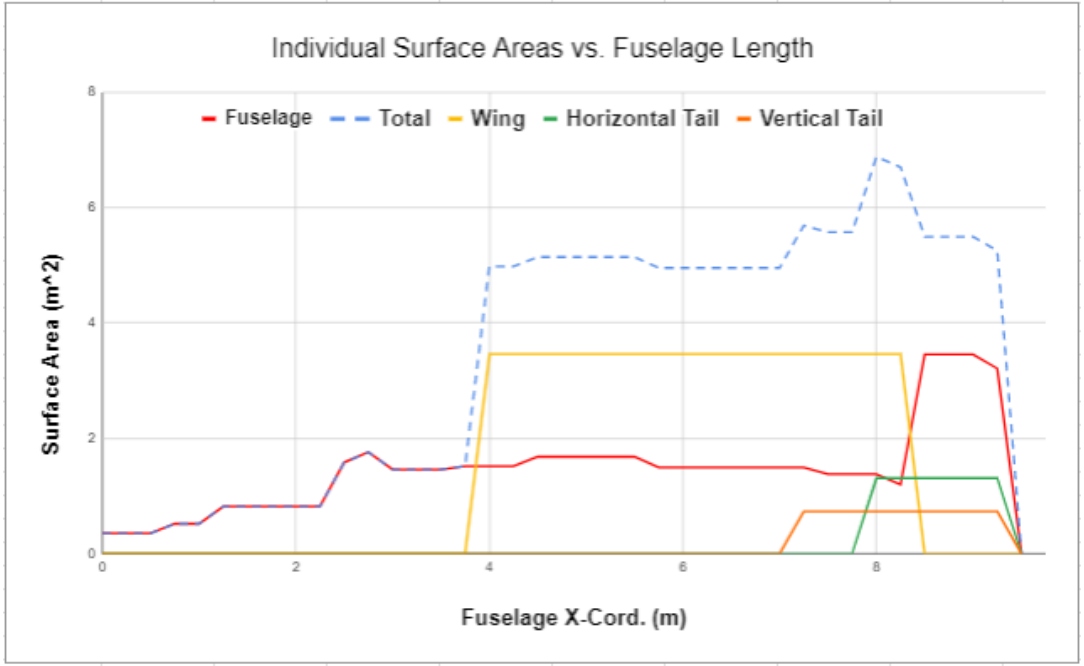


8.5 m



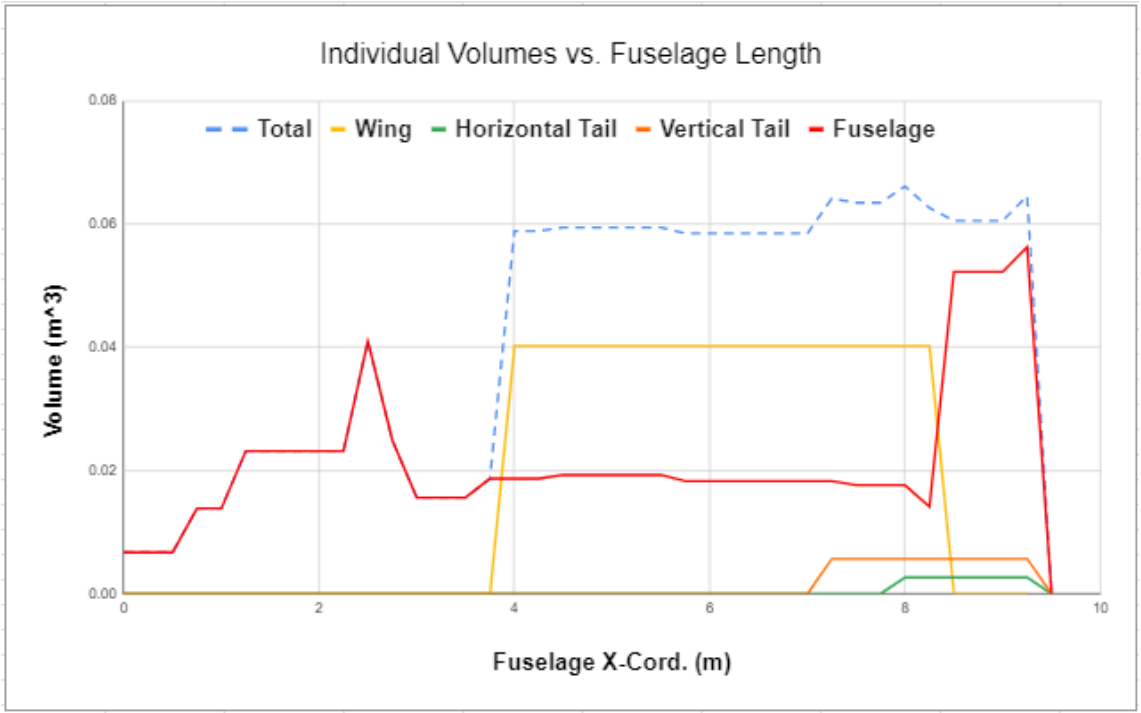
9.25 m

External Surface Area Distribution



Total External Surface Area: 133.64 m^2

Volume Distribution



Total Shell Volume: 1.656 m^3

Material Selection

Material	Density (kg/m^3)	Aircraft Component
Carbon Fiber M55J	1710	- Fuselage Shell - Fuselage Ribs - Propulsion System Intake - Cockpit Cell Top
Carbon Fiber M55lt	1600	- Wing Shell - Vertical Tail Shell
Forged Light Weight Carbon Fiber	1800	- Aileron - Horizontal Tail - Rudder
Molybdenum Mo Al203 Composite	550	- Internal Engine Housing - External Engine Housing
Titanium	4420	- Cockpit Cell base - Fuselage Structural Beams
Acrylic	1180	- Cockpit Window

Total Weight and Center of Gravity

Aircraft Component	Mass (kg)
Fuselage	1,724
Wing	914
Horizontal Tail	151
Vertical Tail	127
Propulsion System	884
Subsystems	791
Fuel Weight	2,500
Payload	390
Empty Weight:	4,591
Total Weight: *Including Fuel and Payload Weight*	7,481

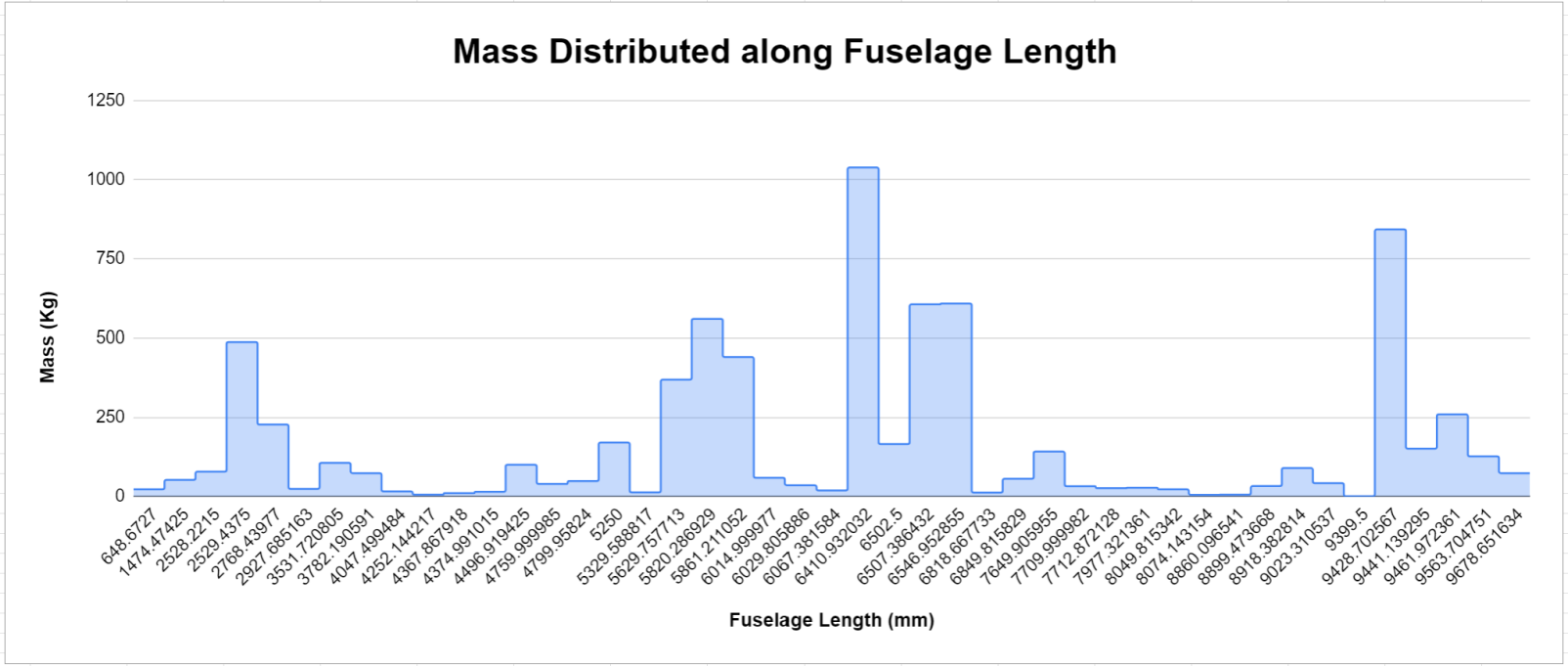
Total Weight CG

Center of Gravity X-cord. (mm)	Center of Gravity Y-cord. (mm)	Center of Gravity Z-cord. (mm)
6,174.8	0	-130.5

Empty Weight CG

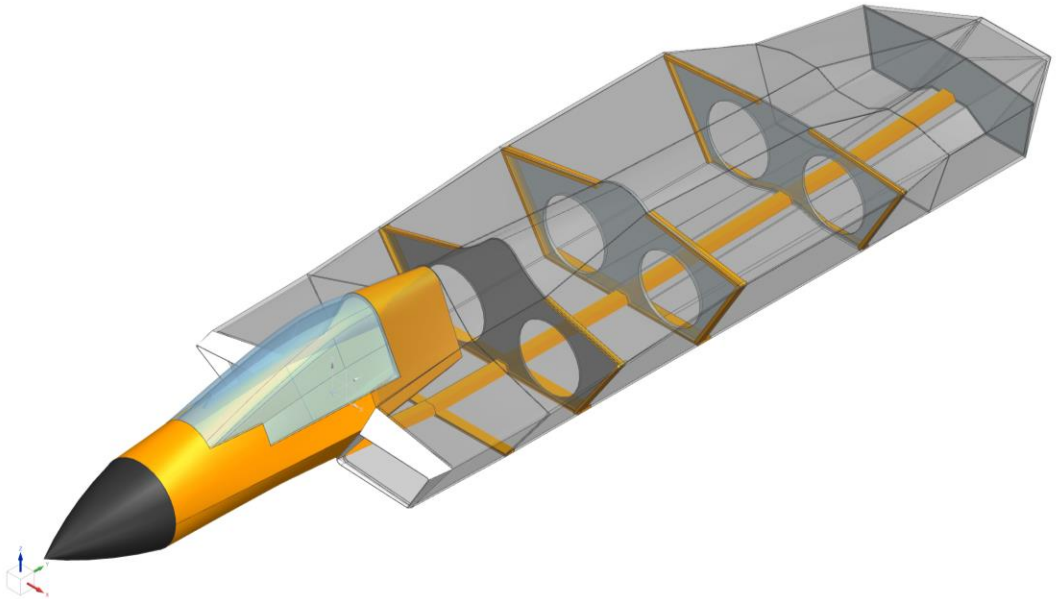
Center of Gravity X-cord. (mm)	Center of Gravity Y-cord. (mm)	Center of Gravity Z-cord. (mm)
6,115.5	0	-167.1

Weight Distribution



- Titanium
- Carbon Fiber M55J

- Cockpit cell uses titanium on the base and carbon fiber on the top layer



Serviceability, Maintenance Considerations, Cost

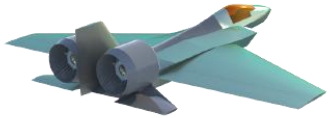
DAPCA IV MODEL

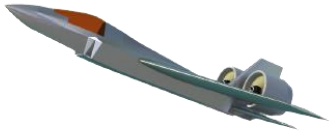
B	C
Inputs	
We (kg)	4691
V (km/h)	979.2
Q	1
FTA	2
Neng	2
Tmax (kN)	18.47
Mmax	0.95
Tturbine inlet (K)	1423.15
Cavionics ($)	11900
Labor rates (2023)	
RE ($)	153.14
RT ($)	157.13
RQ ($)	143.82
RM ($)	130.5

	mks	*Fudged*
Eng hours (HE)	1740772.579	1914849.837
Tooling hours (HT)	620521.6473	682573.812
Mfg hours (HM)	301445.4368	331589.9805
QC hours (HQ)	0.133	0.1463
Devel support cost (CD)	107075459.2	
Flt test cost (CF)	20196206.69	
Mfg materials (CM)	5404072.915	
Engine production (Ceng)	2047038.434	
RDT&E+flyaway	540204843.5	

- RDT&E+ Flyaway Cost = **$540,204,843.5**

DAPCA IV MODEL





- Operations and Maintenance Cost = **$22,036,445.02**
  - Fuel Cost (per year) = $3,595,475.18
    - DLA Energy: $3.88 per gallon of JAA Petroleum Oil
    - Fuel Rate = 0.17 kg/s
    - 15% of cost
  - Crew Salaries (per year) = $7,422,747.33
    - Per block hour = $600 for each crew member
    - 35% of cost
  - Maintenance = $11,018,222.51
    - 50% of cost
    - Same as all labor costs

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