Ky-11 WarGator

GatorDomiNation

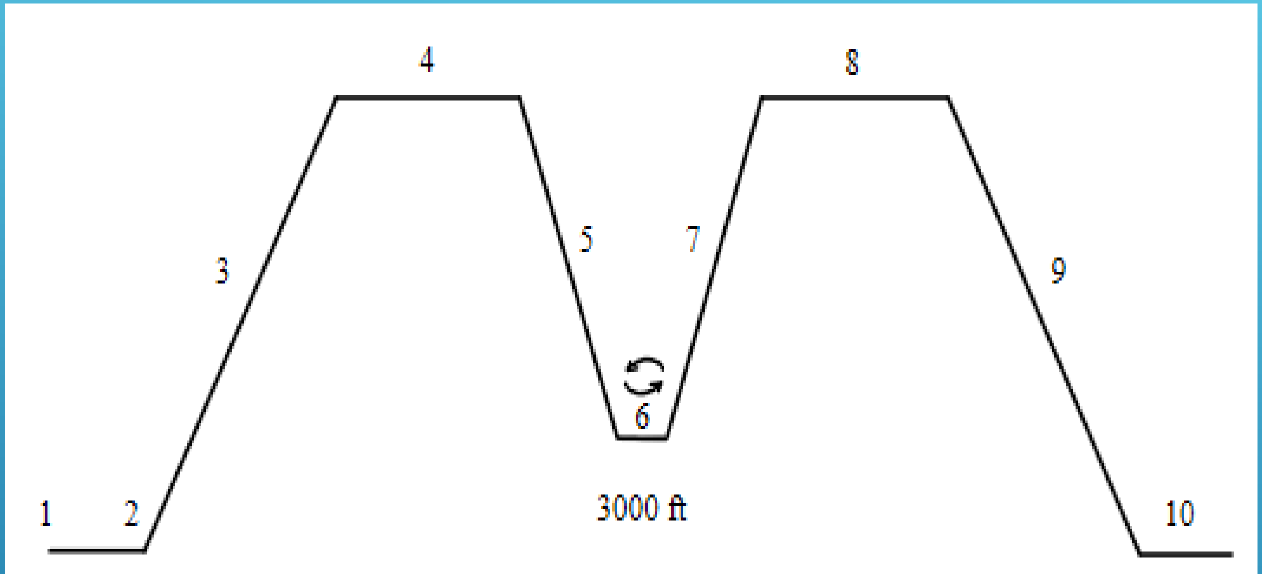
EAS4710 Group 3

Rendy Khairan, Matthew Lutton, Matthew Maddalon, Garrett Morgan, Ryan Mattson, Srajat Rastogi, Tiffany Ung

Competition Requirements

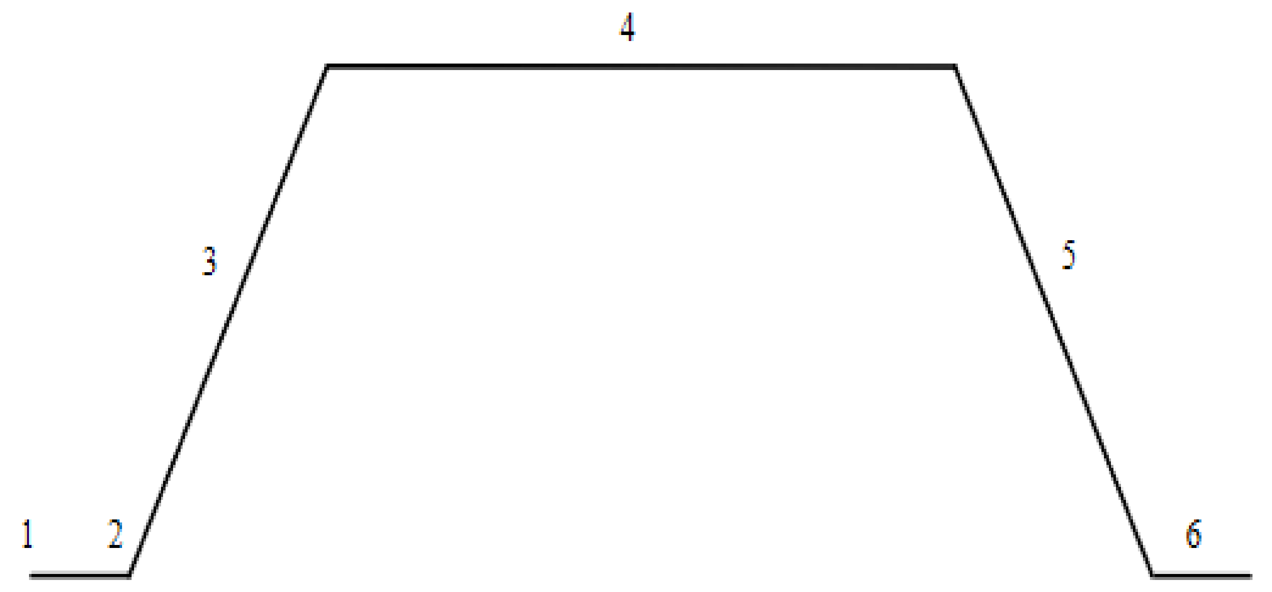
- Austere Field: Takeoff and landing over a 50 ft obstacle in less than 4000 ft
  - California Bearing Ratio of 5 - semi-prepared runway
  - Altitude up to 6000 ft
- Payload: 3000 lbs of armaments
  - 60% of payload for ferry mission
- Crew: Two-person seating, each with zero-zero ejection seats
- Service Ceiling: greater than 30000 ft
- Service Life: 15000 hours over 25 years
- Weapons: Integrated gun and variety of other weapons

Design Mission



1	Warm Up / Taxi	5 minutes
2	Take Off	Austere field, 50 ft obstacle, ≤ 4,000 ft
3	Climb	To cruise altitude, ≥ 10,000 ft; with range credit
4	Cruise	100 n mi
5	Descent	To 3,000 ft; no range credit; completed within 20 minutes of the initial climb
6	Loiter	On station, four hours, no stores drops
7	Climb	To cruise altitude, ≥ 10,000 ft; with range credit
8	Cruise	100 n mi
9	Descent / Landing	To austere field over 50 ft obstacle in ≤ 4000 ft
10	Taxi / Shutdown	5 minutes
11	Reserves	Sufficient for climb to 3,000 ft and loiter for 45 minutes

Ferry Mission



1	Warm Up / Taxi	5 minutes
2	Take Off	Austere field, 50 ft obstacle, ≤ 4,000 ft
3	Climb	To cruise altitude; with range credit
4	Cruise	At best range speed / altitude (≥ 18,000 ft), 900 n mi
5	Descent / Landing	To austere field over 50 ft obstacle in ≤ 4000 ft
6	Taxi / Shutdown	5 minutes
7	Reserves	Sufficient for climb to 3,000 ft and loiter for 45 minutes

Design Takeoff Weight Estimation

Propeller Aircraft vs. Jet Aircraft

Driving Equation: $W_0 = W_{payload} + W_{crew} + W_{fuel} + W_{empty}$ ⟶ $W_0 = \dfrac{W_{payload} + W_{crew}}{1 - \dfrac{W_{fuel}}{W_0} - \dfrac{W_{empty}}{W_0}}$

Fuel Weight Fraction

- Estimated the fraction of the weight at the end of the mission over the weight before the mission began
  - Warmup/takeoff, climb, descent, and landing weight fractions determined from historical data
  - Cruise and loiter weight fractions determined from Breguet range and endurance equations

$$\frac{W_f}{W_0} = 1.06\left(1 - \frac{W_i}{W_0}\right)$$

Empty Weight Estimation

- Obtained from trends of historical data

$$\frac{W_e}{W_0} = AW_0^C$$

	Propeller aircraft	Jet aircraft
Design mission	39601 lbs	25333 lbs
Ferry mission	13647 lbs	13164 lbs

Thrust to Weight Estimation

Takeoff: $\frac{T}{W_0} = \alpha M_{max}^{C}$ → $M_{max} = 0.85,\ \alpha = 0.488,\ C = 0.788$

Cruise: $\left(\frac{T}{W}\right)_{cruise} = \frac{1}{(L/D)_{cruise}}$ → $(L/D)_{cruise} = 15.588$

Climb: $\left(\frac{T}{W}\right)_{climb} = \frac{1}{(L/D)_{climb}} + \frac{V_{vertical}}{V}$ → $(L/D)_{climb} = 13.5\ ,\ \frac{V_{vertical}}{V} = 300\ \text{ft/nm}$

Critical Thrust Requirement: 11063 lbs

	Thrust to Weight Ratio
Takeoff	0.4367
Climb	0.1685
Cruise	0.1516

Wing Loading Estimation

Stall Condition: $\frac{W}{S} = \frac{1}{2} \rho V_{stall}{}^2 C_{L_{max}}$ → $V_{stall} = 150 \text{ ft/s}, C_{L_{max}} = 2.5$

Takeoff Condition: $\frac{W}{S} = (TOP)\, \sigma\, C_{L_{TO}} \left(\frac{T}{W}\right)$ → $TOP = 100, C_{L_{TO}} = 2.07$

Landing Condition: $\frac{W}{S} = \frac{(S_{landing} - S_a)\, \sigma\, C_{L_{max}}}{80}$ → $S_{landing} = 4000 \text{ ft}, S_a = 1000 \text{ ft}$

Critical Wing Area Requirement: 300 sq. ft

	Wing Loading
Stall	49.4 psf
Takeoff	66.7 psf
Landing	90.6 psf

Propulsion

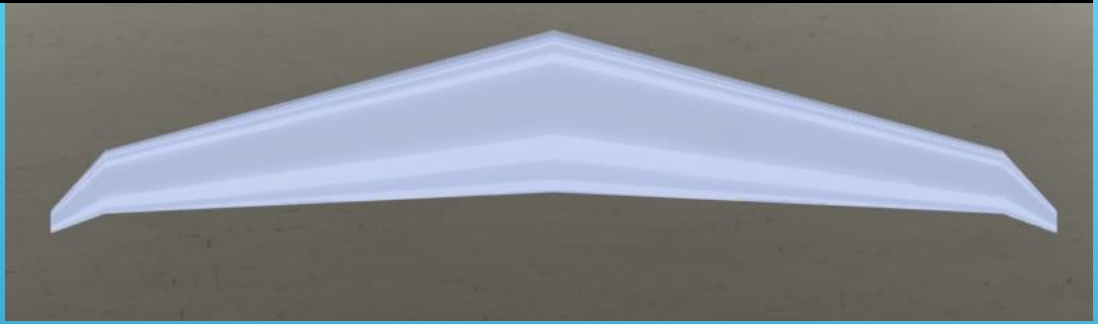
- Twin Honeywell F124 Low-Bypass Turbofan Engines
- Partially buried engines with armpit located, pitot inlets
- Fixed converging nozzles
- 110 ft^3 of JP-8 jet fuel held in self-sealing, bladder type fuel tanks
  - Located in wing and fuselage
  - Internal subdivisions in tanks to prevent sloshing

Installed Engine Parameters:

- $\% \, Thrust \, Loss = C_{ram}\left[\left(\frac{P_1}{P_0}\right)_{ref} - \left(\frac{P_1}{P_0}\right)_{actual}\right] \times 100\% = 2.7\%$
- $\% \, Thrust \, Loss = C_{bleed}\left[\left(\frac{bleed \, mass \, flow}{engine \, mass \, flow}\right)\right] \times 100\% = 2\%$
- Total Installed Thrust: 12,560 lbs. x 95.3% = 11,970 lbs.
- Specific Fuel Consumption = 1.25 $\times \, SFC_{dry}$ = 0.975

Wing Design

RAE 5212 Transonic Airfoil



Overall Dimensions

- 56 ft wingspan
- 9 ft root-chord, 3.5 ft tip-chord
- 312.5 ft^2 planform area

Geometry

- 15° leading edge sweep
  - Based on historic data
  - Prevents local shocks from forming on the wing, and the associated loss in lift
- -2.5° geometric twist
  - Ensures root stalls before tip
- Swept Back Wingtips
  - Reduces wingtip vortices

High Lift Devices

- Leading-edge slats
  - 17% chord
- Single-slotted flaps
  - 60% span
  - 25% chord

Aileron Dimensions

- 40% of span
- 25% of chord

Performance

		C_L	C_D
Cruise	(α=0°)	0.159	0.001
Takeoff	(α=15°)	1.368	0.072
Landing	(α=8°)	0.817	0.026

Vertical Tail Design

H-tail configuration

- Reduces side profile and radar cross-section of aircraft
- Keeps AC close to cg in vertical direction (reduced roll contribution from vertical tail)

Overall Dimensions

- 6.5 ft span
- 4.5 ft root-chord, 2.5 ft tip chord
- 45.5 ft^2 planform area, total

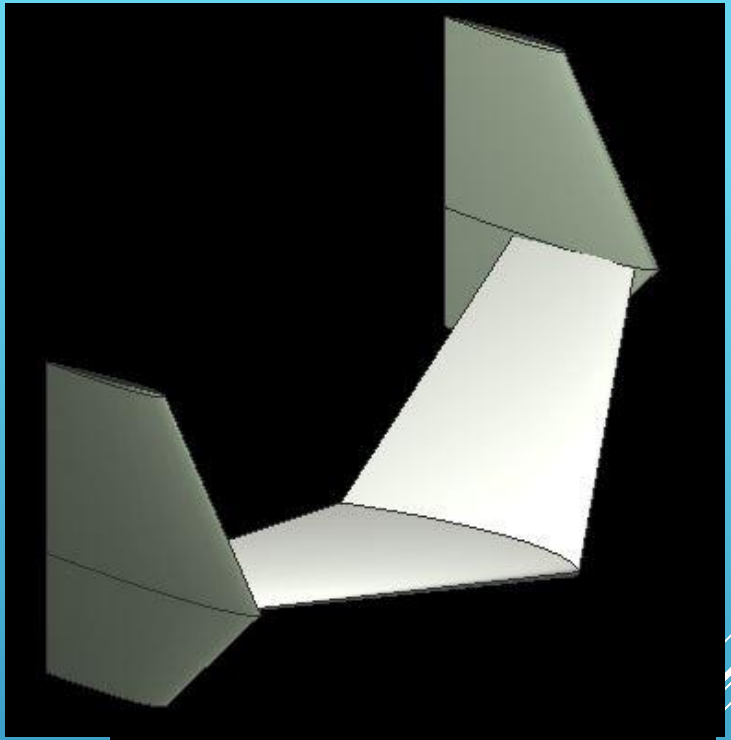
Rudder Dimensions

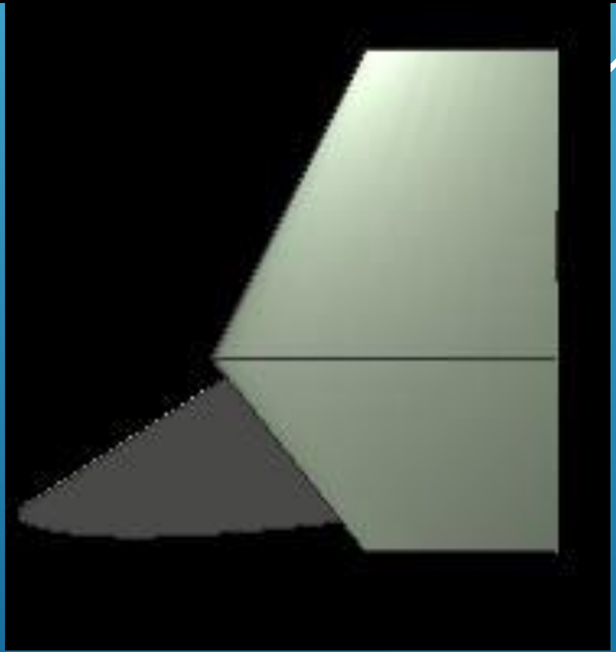
- 80% span
- 30% chord

Geometry

- Leading edge sweep to ensure straight trailing edge

NACA 0010 Airfoil





Horizontal Tail Design

<u>Overall Dimensions</u>

- 15 ft span
- 5 ft root-chord, 2.5 ft tip chord
- 56.3 ft^2 planform area
- 54.3 ft^2 projected area

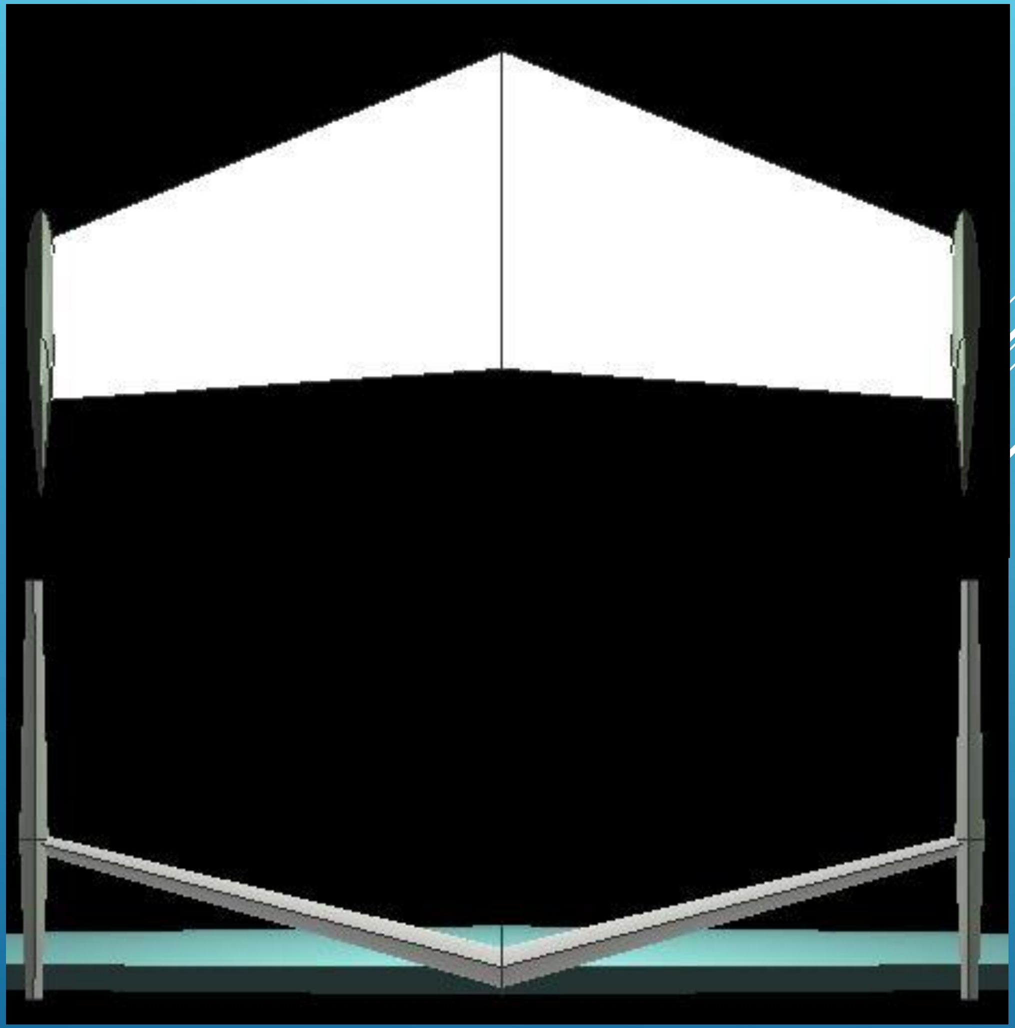
<u>Geometry</u>

- 22° leading edge sweep
- 15° dihedral
    - Prevents interference from engine exhaust jet

<u>Elevator Dimensions</u>

- 90% span
- 30% chord

<u>NACA 0012 airfoil</u>



Landing Gear Design

<u>General Dimensions</u>

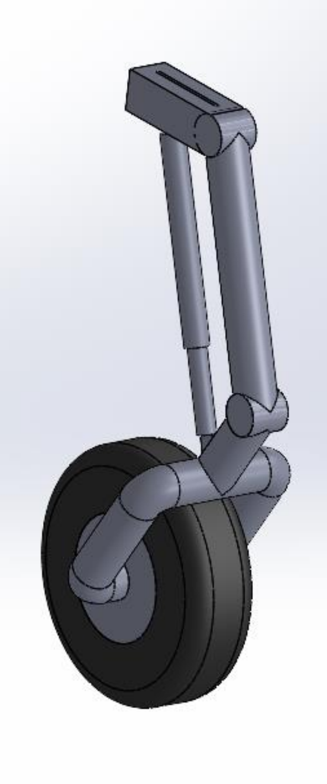
- Tricycle configuration chosen
- Sufficient clearance for fuselage, intakes, and ordnance
- 7 to 15 degrees tip-back angle
- 12.5 ft long wheelbase
- 9.5 ft wide wheelbase
- Trailing link oleo for all gear legs

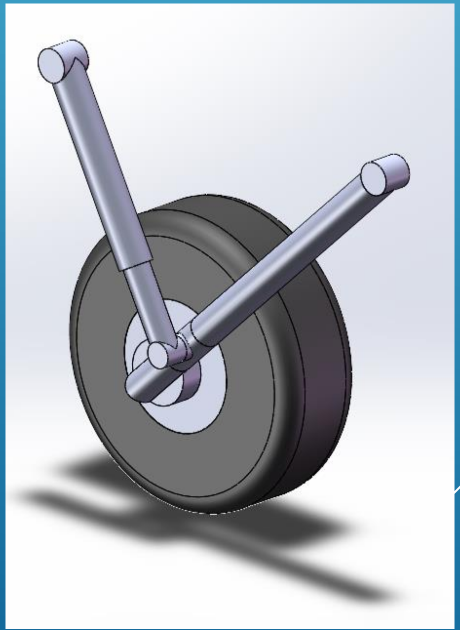
<u>Nose Gear Dimensions</u>

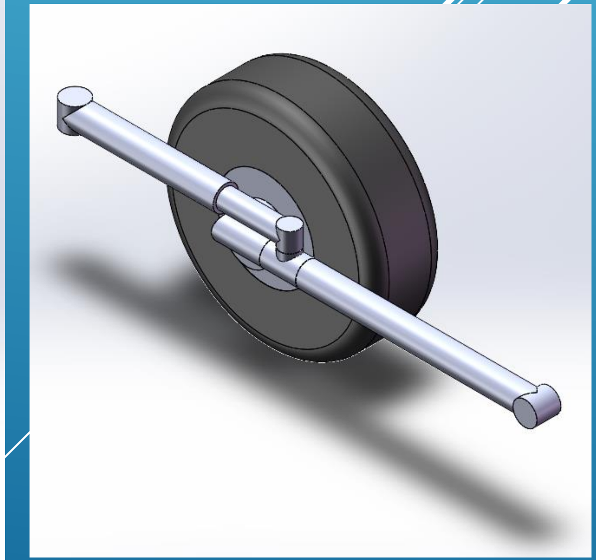
- 30.3 in diameter tire

<u>Main Gear Dimensions</u>

- 36 in diameter tire



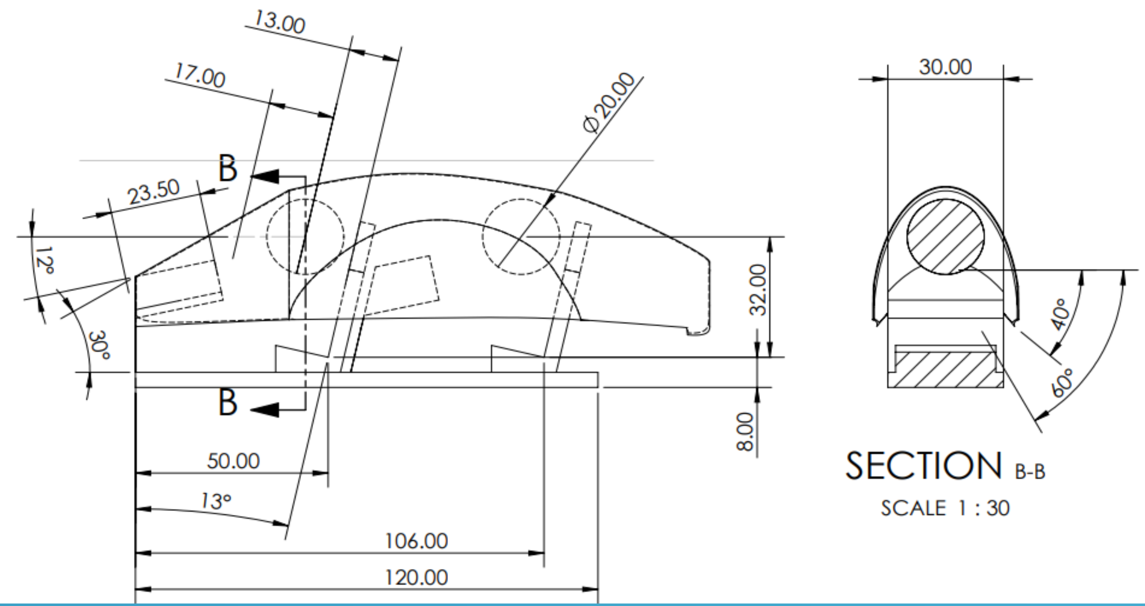




Fuselage/Cockpit Design

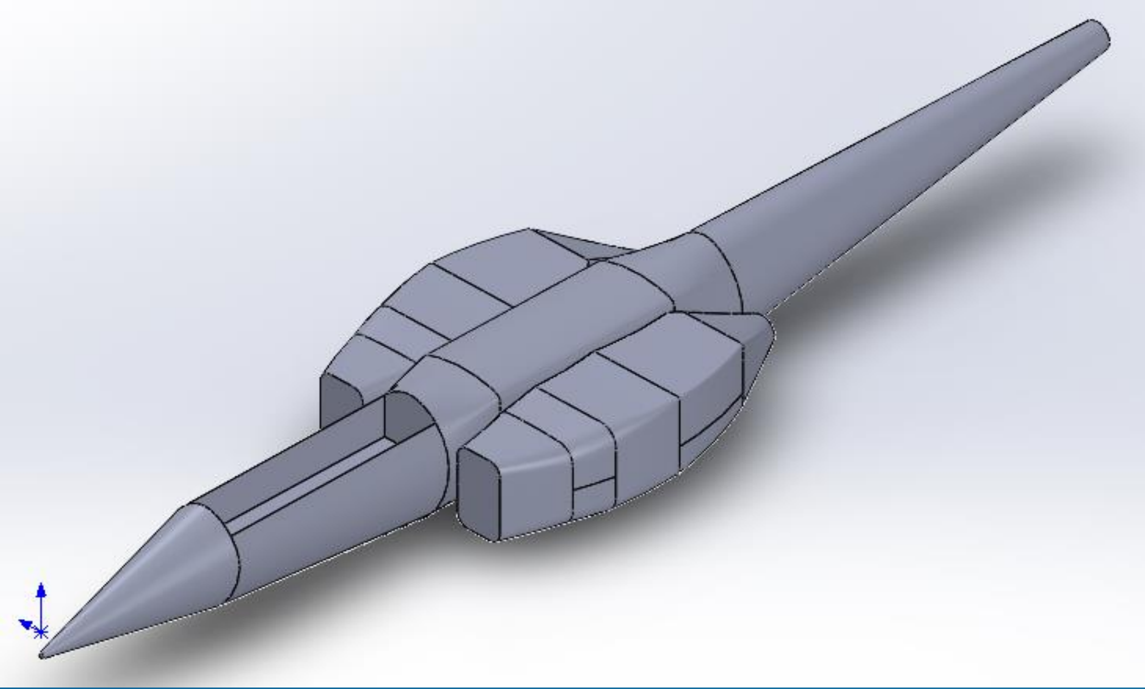
<u>Notable Specifications</u>

- 120x30-in two-person tandem cockpit w/ ejection seats
- 20-in diameter head clearance
- 13° seatback angle
- 30° transparency grazing angle
- Bullet-proof canopy
- Ceramic component cockpit armor



<u>Notable Specifications</u>

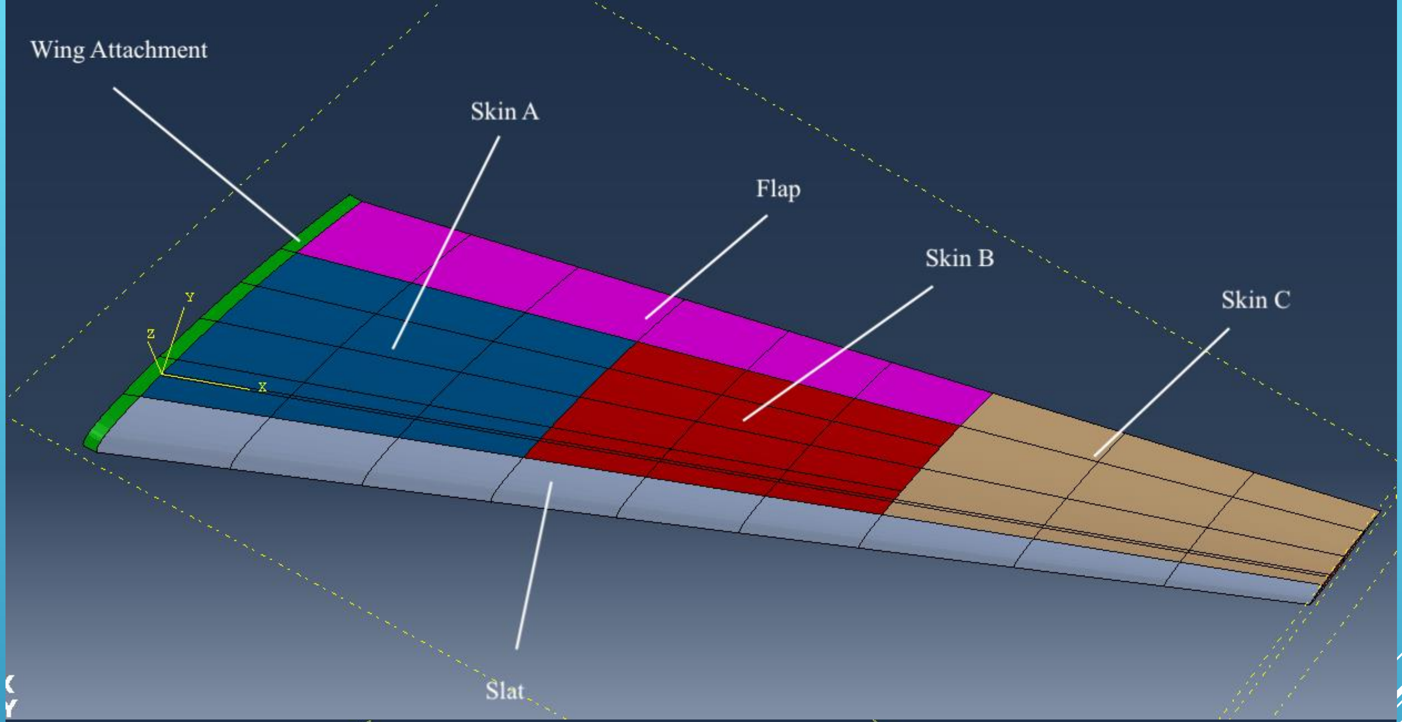
- 51.51 ft length
- 12.17 ft width
- 5.62 ft Length
- Fineness ratio: 4.2
- Over-nose angle: 17.9 degrees
- Heaviest components kept centered and high to keep close to wing aerodynamic center
- Fuselage shape designed to include internal components while preventing flow separation
- Ceramic component armor around engines

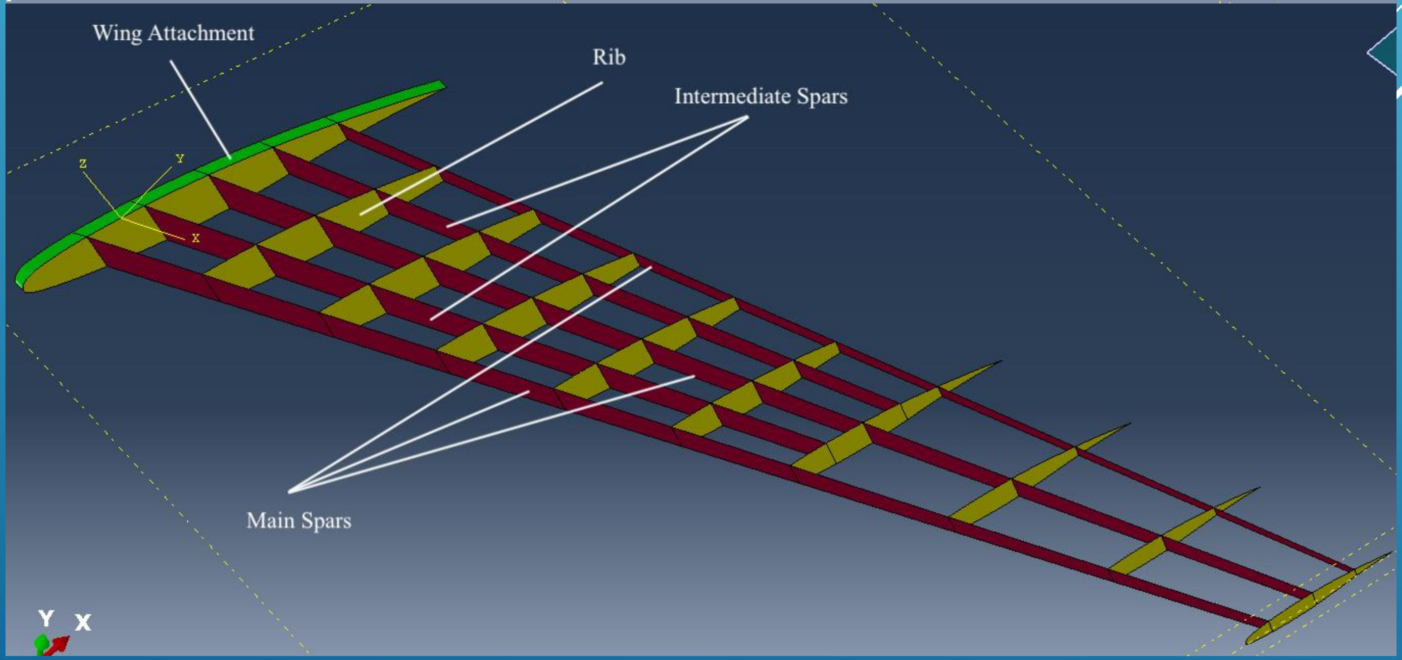


Wing Structure

<u>Ribs and Spars Arrangement</u>

- Skin A (0.16 in), Skin B (0.12 in), and Skin C (0.08 in)
- Skins further away from the root experience less loading, thus reduced thicknesses
- Ribs shaped after the chosen RAE5212 airfoil with decreasing sizes
- Three main spars run from wing root to tip, two intermediate spars run from wing root to the seventh rib
- All spars designed to be 0.82-inch thick
- More spars are constructed closer to the wing root to support the larger loading
- All wing structures except wing attachment: graphite-epoxy composites
- Wing attachment: Titanium

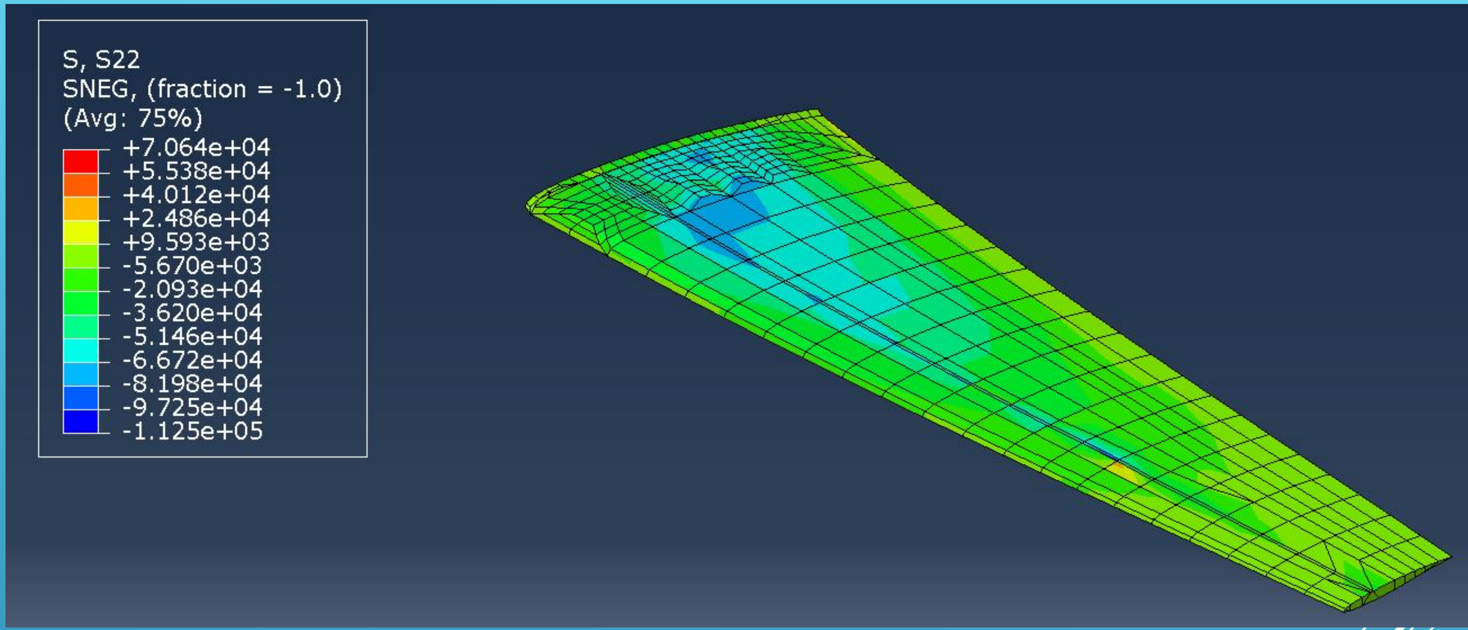




Wing Structure

<u>Finite Element Analysis</u>

- Elliptical lift distribution acting along wing quarter chord
- Factor of safety of wing: 1.6 (ultimate tensile strength vs absolute max principal stress)
- Maximum vertical displacement: 25.4 inches
- Stringers would be introduced at the high stress regions
- Flanges will also be used to help connect the spars to the skin
- At wing root, spars are 15 in from each other
- Stringers and flanges are spaced out by 5 in
- Thicknesses of the stringers and flanges are both 0.1 in



Fuselage Structure

Components: Semi-monocoque structure made up of frames, bulkheads, stringers, and skin

Frames

- Spacing: 19-24 in.
- Depth: 2 in.
- Material: High-strength graphite epoxy

Bulkheads

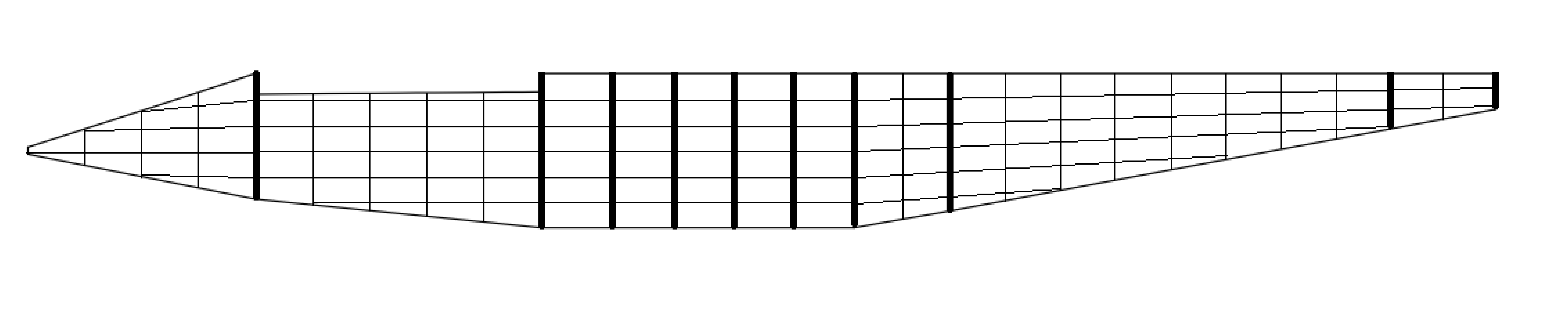
- Placed in parts of the fuselage experiencing large amounts of load

Central Fuselage

- Titanium alloy for bulkheads (Ti4Al4Mo2Sn)
- Al 7050 for skin
- Steel for engine mounts

Stringers

- Z-type cross-section
- Spacing: 10-12 in.



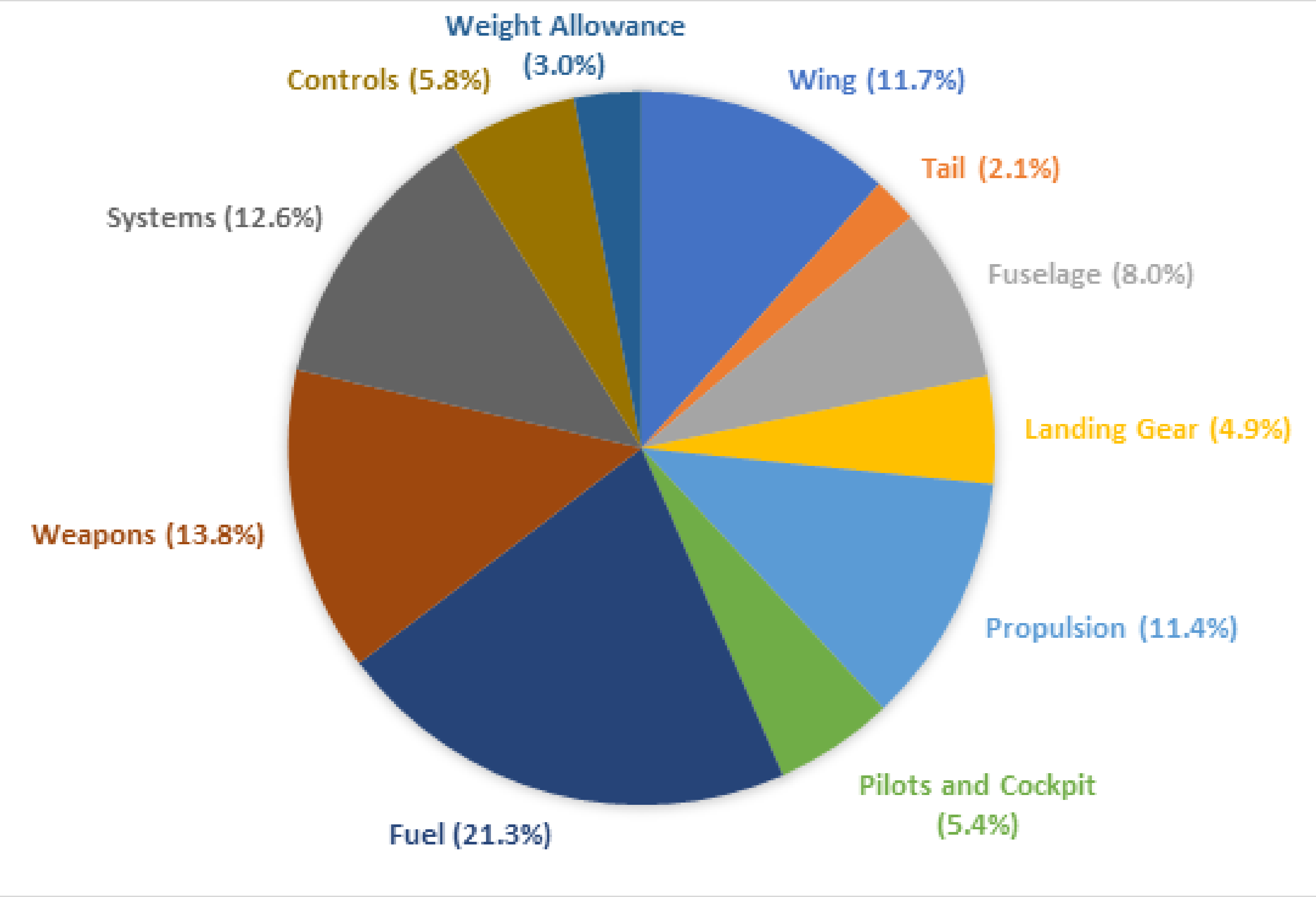
Refined Weight Approximation

Methodology: Raymer's statistical weight formulas for attack/fighter aircrafts

Maximum Takeoff Weight: 24266 lbs

Empty Takeoff Weight: 15643 lbs

Fuel Weight: 5162 lbs



Weapons

Weapon Selection

1. Gatling Gun
   - M61A1
2. Missiles
   - Air-to-air missile
     - AIM-9
   - Air-to-ground missiles
     - AGM-65 Maverik D-Variant
     - AGM-114 Hellfire (3)
3. Bombs
   - GBU-12
   - GBU-39 (4)
4. Air-to-ground rocket
   - Hydra 70 (7 or 19)

Weapon Release Mechanisms

1. Rail Launch
   - LAU-127
   - LAU-117/A
   - COBRA Single Rail Launcher/AGML III
2. Ejection Launch
   - IOMAX HSP Bomb Rack Unit
   - BRU-6/A
3. Rocket Launch
   - LAU32
   - LAU51

Weapons

Possible Mission and Weapon Configurations

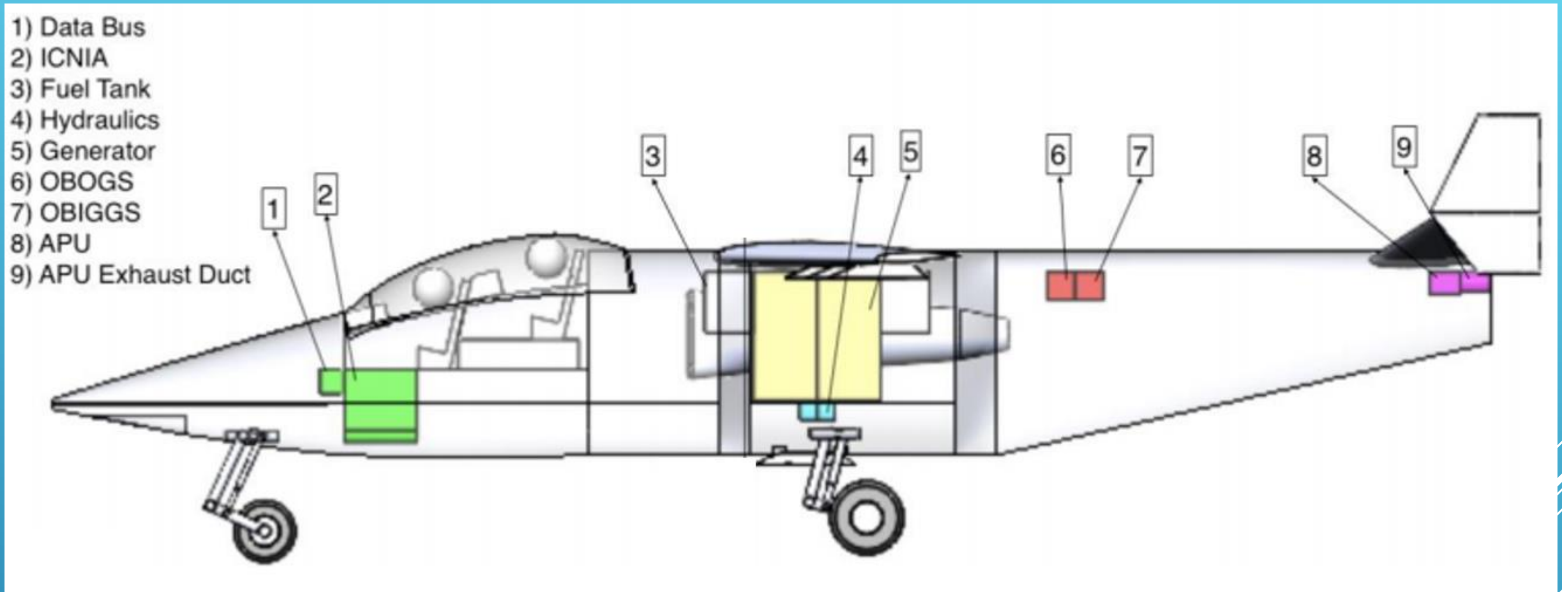
1. Anti-armor
   - 2 AIM-9 missiles, 4 AGM-65D missiles, 6 AGM-114 missiles
   - Payload: 2962 lb
2. Heavy bombing
   - 2 AIM-9 missiles, 2 AGM-114 missiles, 4 GBU-39 bombs, 2 GBU-12 bombs
   - Payload: 3011 lb
3. Anti-personnel
   - 38 Hydra 70 rockets, 2 GBU-12 bombs, 2 AGM-114 missiles, 2 AIM-9 missiles
   - Payload: 3020 lb
4. General purpose
   - 2 AIM-9 missiles, 14 Hydra 70 rockets, 2 GBU-12 bombs, 10 AGM-114 missiles
   - Payload: 3012 lb

Visual of Mission 4 Configuration

Subsystems

The subsystems in the KY-11 include:

- A data bus, head-up display, and an ICNIA unit to relay and display flight information
- Two centrally located 210 kg/cm^2 hydraulic pumps
- Two 30kVA electric generators supplying 115/200v at a frequency of 400Hz
- OBIGGS and OBOGS units which form the environmental control system and receives pressurized air from a pneumatic system to control the environment within the cockpit
- An APU unit that will supply the hydraulic pumps with pressurized air and start the engines via power from DC batteries in case of failure



- The avionics found in the KY-11 include the navigational subsystems and radios, which are within the cockpit.
- Additional subsystems, which are typical for jet fighters, are used to allow the pilot to control the aircraft

Stability Analysis

Longitudinal Static Stability

- Neutral Point: 302.03 in
- Static Margin: 5.05%
- Pitch Moment Derivative: -0.4187

Trim Analysis

- Takeoff
  - Angle of Attack: 15°
  - Flap Deflection: 20°
  - Elevator Deflection: 18-18.5°
- Cruise
  - Angle of Attack: 0°
  - Flap Deflection: 0°
  - Elevator Deflection: 2-2.5°
- Landing
  - Angle of Attack: 8°
  - Flap Deflection: 30°
  - Elevator Deflection: 10-10.5°

Lateral Static Stability

- Wing Contribution: -0.0516
- Tail Contribution: -0.0271
- Roll Moment Derivative: -0.0787

Trim Analysis

- Aileron Control Power: 0.0119

Directional Static Stability

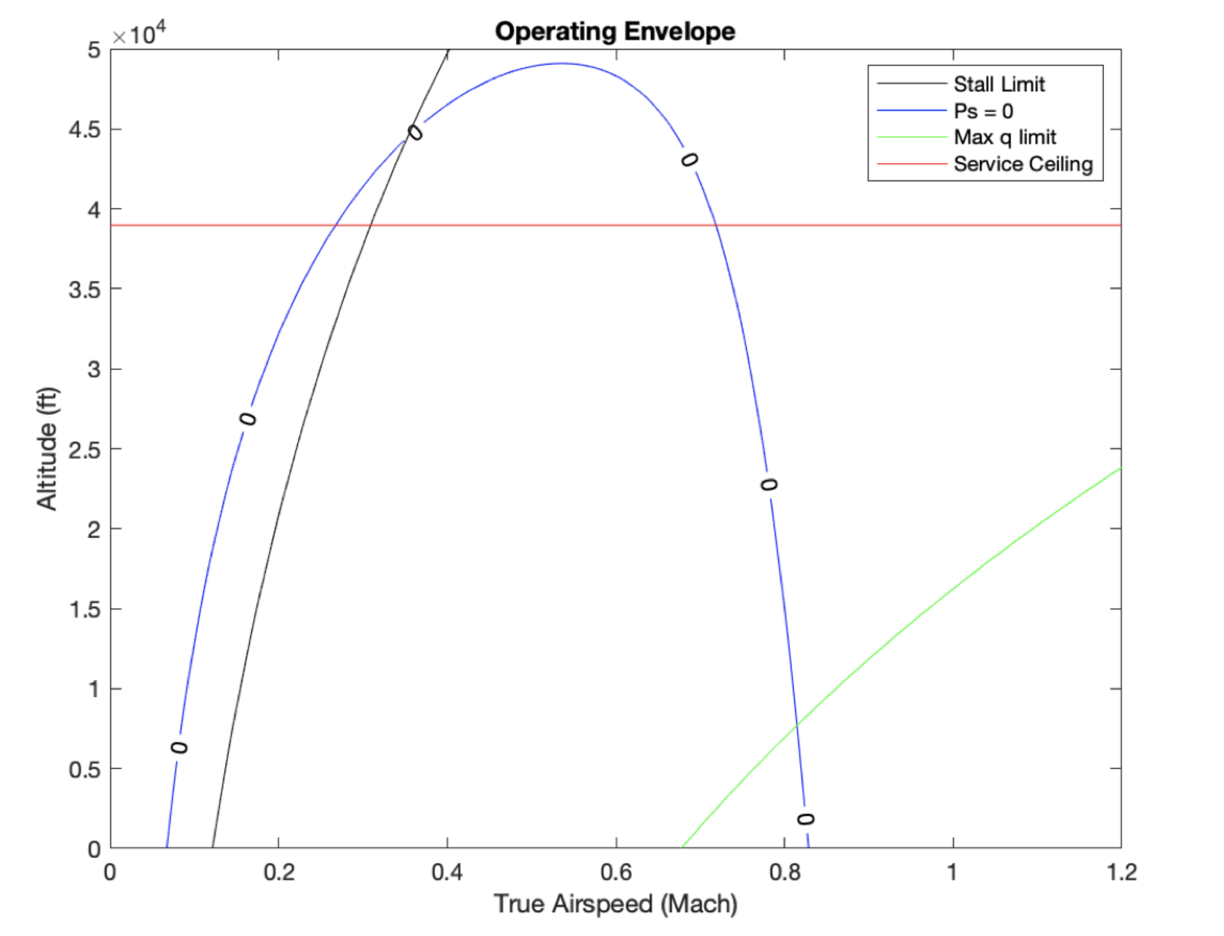
- Yaw Moment Derivative: 0.1875

Trim Analysis

- *Engine Out Case*
  - *Yaw Moment Coefficient: 0.606*
- *Crosswinds-Landing Case*
  - *Yaw Moment Coefficient: 0.0370*

Performance Analysis

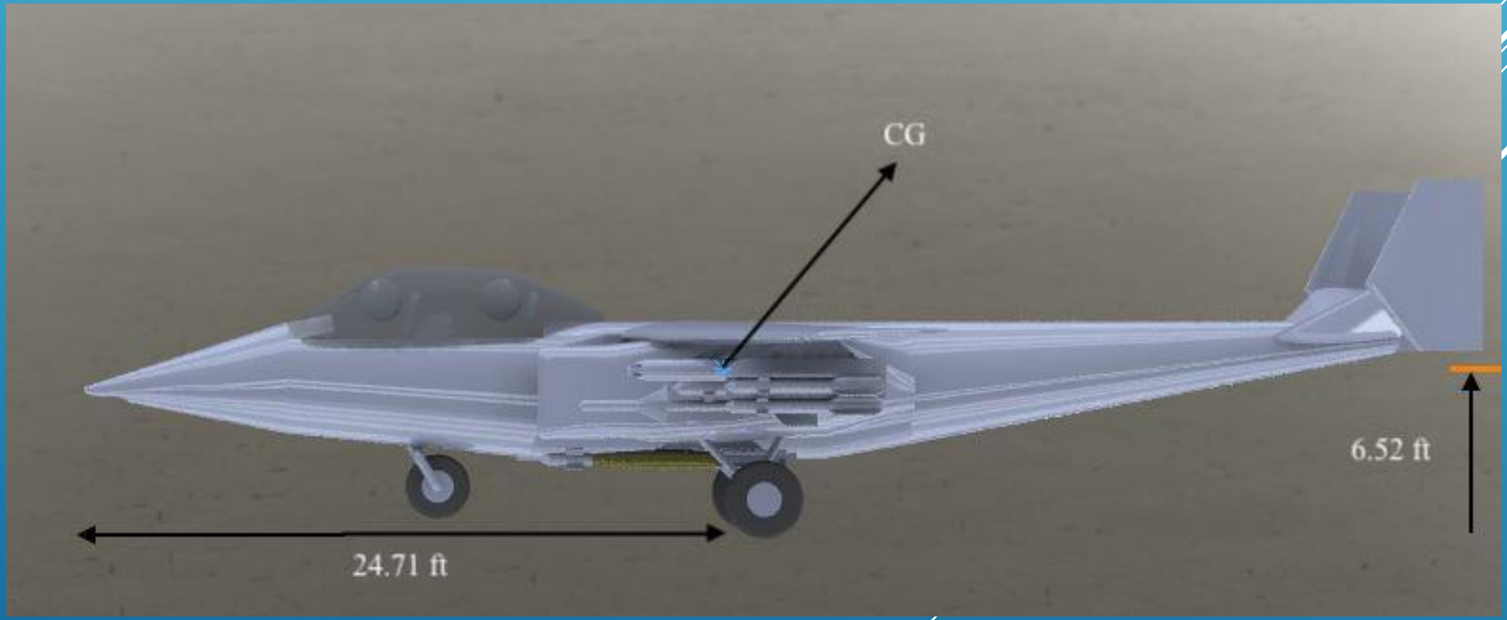
- Top speed: 629 mph (Mach 0.82)
- Cruise speed: 537 mph (Mach 0.7)
- Service ceiling: 38,979 ft
- Range: 2,363 nmi.
- Total Endurance:
  - 5.85 hrs. for design mission
  - 4.43 hrs. for ferry mission
- Takeoff Distance: 3,600 ft
- Landing Distance: 2,294 ft
- Limit load factor: +9/-3 g



Weights

Center of Gravity (CG)

- X-direction (along fuselage): 24.8 ft aft of nose
- Y-direction: Along fuselage centerline due to symmetry
- Z-direction (vertical): 6.52 ft from ground

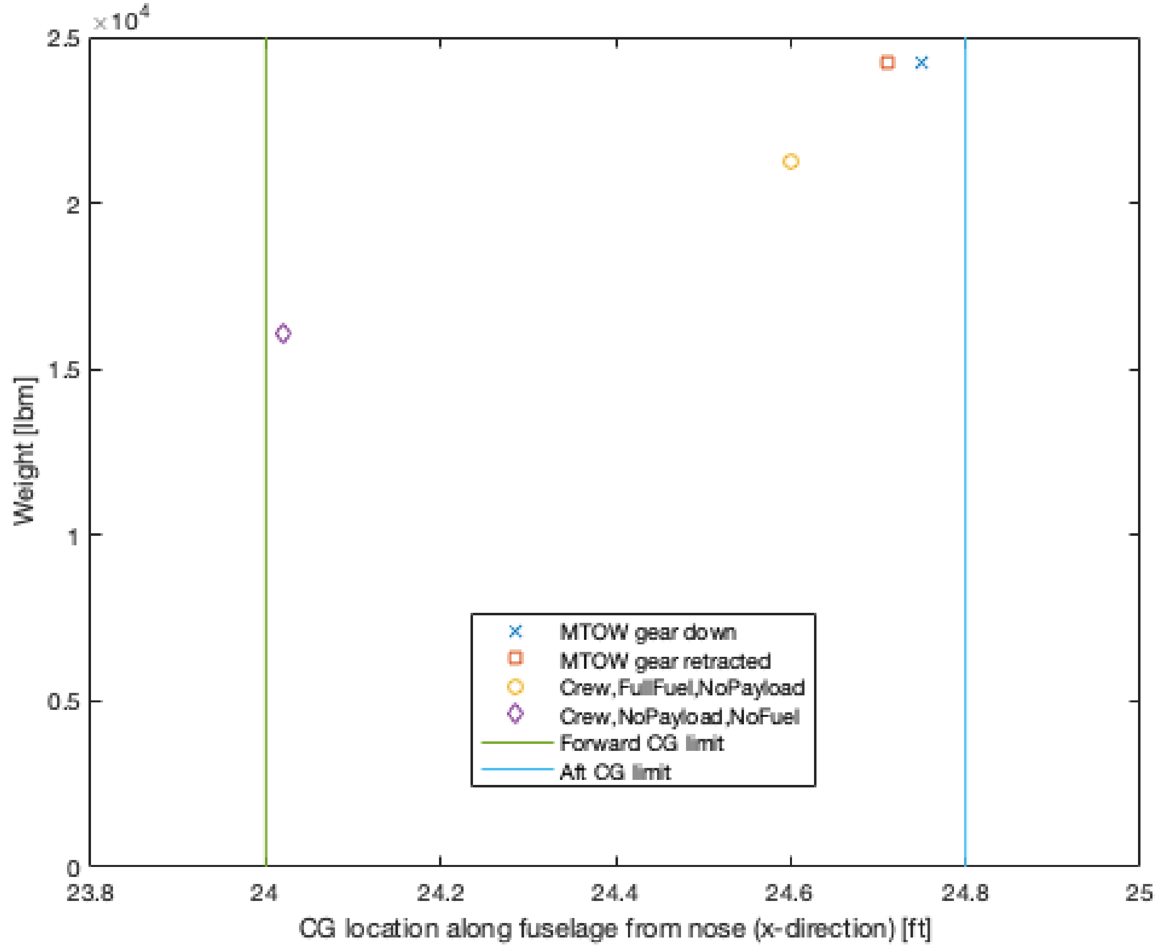


CG Location

Weights

CG Envelope

- Forward and aft CG limits dictated by landing gear geometry
- Distance between forward and aft limits is 10.9% MAC (slightly higher than typical jet)
- KY-11 CG envelope shows that various CG's are within the forward and aft CG limits
- CG of the aircraft moves aft as mission progresses, making the aircraft more stable



Cost

The cost is broken down into three types of expenses:

- Non-recurring: initial, fixed costs
- Recurring: costs associated with the production of each unit
    - The recurring costs posted are the total values for the production of 50 units
- Operation and Maintenace: occur with each flight cycle

The unit cost is simply the sum of the non-recurring and the recurring costs, divided by the number of units going into production, which is 50.

- **Unit cost: $60.5 Million**

Non-Recuring Costs	
Development	$165,281,928
Testing	$1,165
Engineering	$601,657,379
Tooling	$318,661,894
Total	**$1,085,602,366**

Recurring Costs	
Manufacturing	$562,191,200
Quality Control	$824,011,673
Material	$204,004,358
Engine	$250,000,000
Avionics	$100,000,000
Total	**$1,940,207,231**

Operations and Maintenance	
Maintenance	$996.09
Fuel	$1,165.14
Oil	$5.83
Total	**$2,167.06**

Questions?