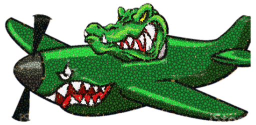
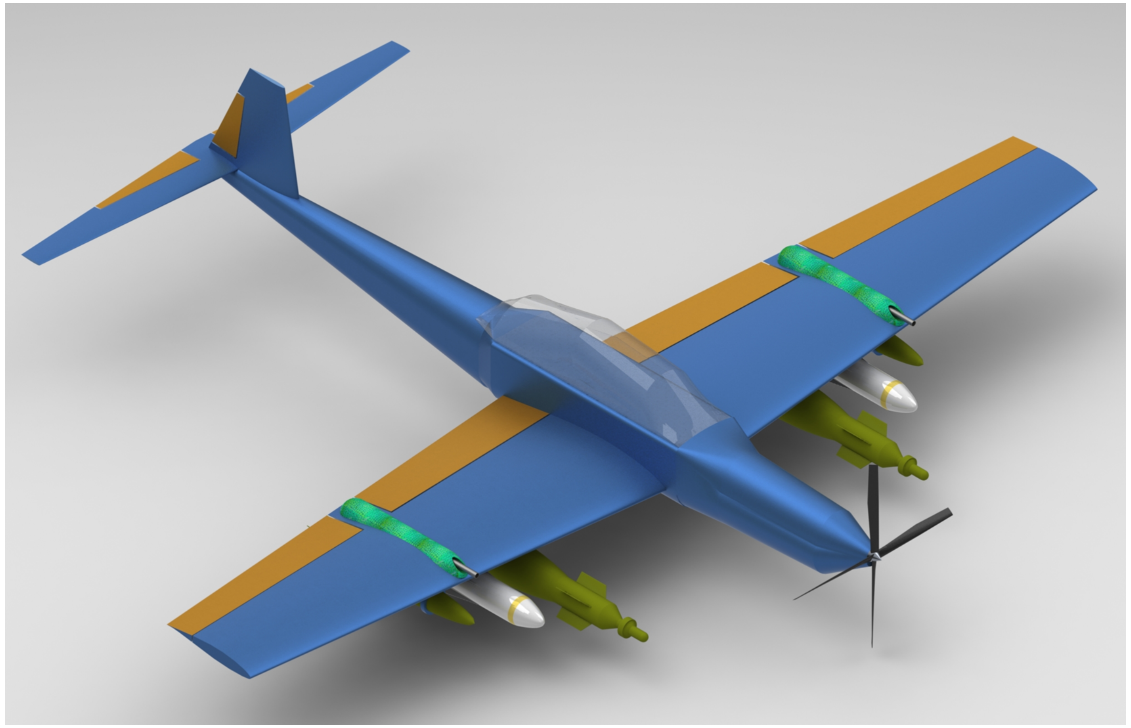
UF Herbert Wertheim College of Engineering
Department of Mechanical & Aerospace Engineering
UNIVERSITY *of* FLORIDA

Swamp Hopper

Light Attack Aircraft





EAS4710 - Group 2 – Spring 2021

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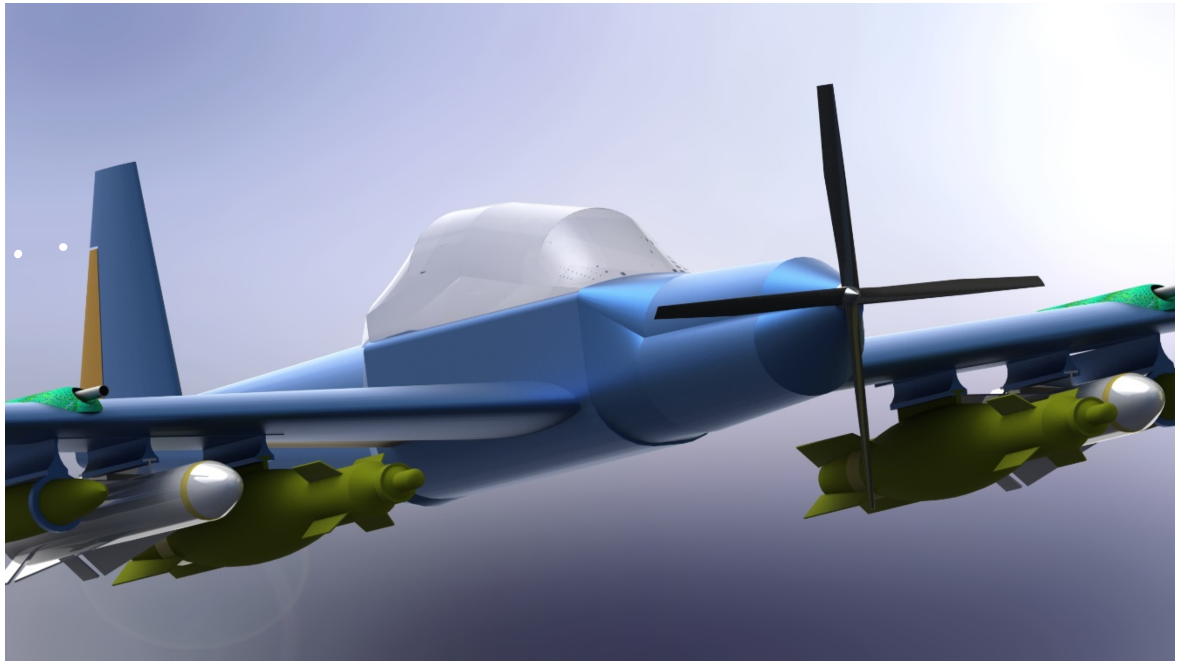
UF Mechanical & Aerospace Engineering

Overview

“The Swamp Hopper is an affordable light attack aircraft capable of austere field landing and can be strategically placed on the front lines to operate in roles previously only occupied by attack helicopters”



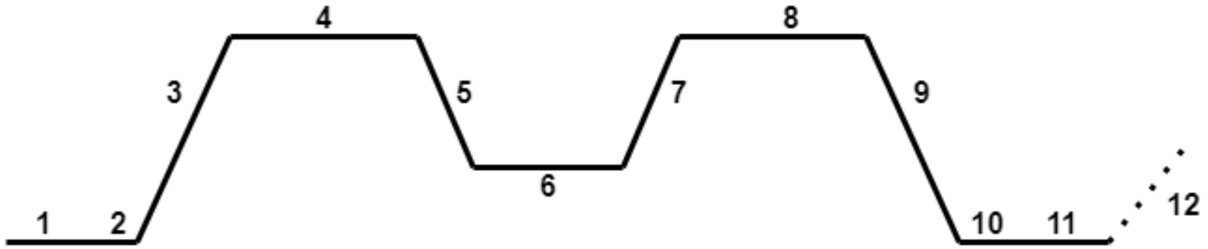
- Capabilities & Features:
  - Payload selection of up to 3,000 lbs.
  - Two integrated guns
  - 2 crew with zero-zero ejection seats
  - Service ceiling > 30,000 ft
  - Affordable

Case Study of Similar Aircraft & the Weight at Takeoff

Mission Outline

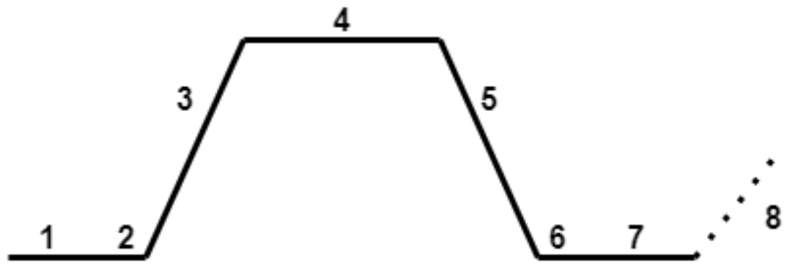
Design Mission

1. Warm Up / Taxi	7. Climb to ≥ 10000 ft; with range credit
2. Take off Austere field, 50 ft obstacle, ≤ 4,000ft	8. Cruise 100 n mi
3. Climb to ≥ 10,000 ft; with range credit	9. Descent
4. Cruise 100 n mi	10. Landing to austere field over 50ft obstacle in ≤ 4,000 ft
5. Descent to 3,000 ft; no range credit; completed within 20 minutes of the initial climb	11. Taxi/ Shutdown
6. Loiter for 4 hours on station	12. Reserves sufficient for climb to 3,000 ft and loiter for 45 minutes



Ferry Mission

1. Warm Up/ Taxi	5. Descent
2. Take off Take off Austere field, 50 ft obstacle, ≤ 4,000ft	6. Landing at austere field over 50ft obstacle in ≤ 4,000 ft
3. Climb To cruise altitude; with range credit	7. Taxi/ Shutdown
4. Cruise at best range speed / altitude (≥ 18,000 ft), 900 Nmi	8. Reserves Sufficient for climb to 3,000 ft and loiter for 45 minutes



Aircraft Characteristic Comparison

$$W_o = W_{payload} + W_{crew} + \left(\frac{W_F}{W_o}\right)W_o + \left(\frac{W_E}{W_o}\right)W_o$$

$$\frac{w_F}{w_o} = 1.06\left(1 - \left(\frac{w_i}{w_{i-1}}\right)_{TOTAL}\right)$$

Super Tucano

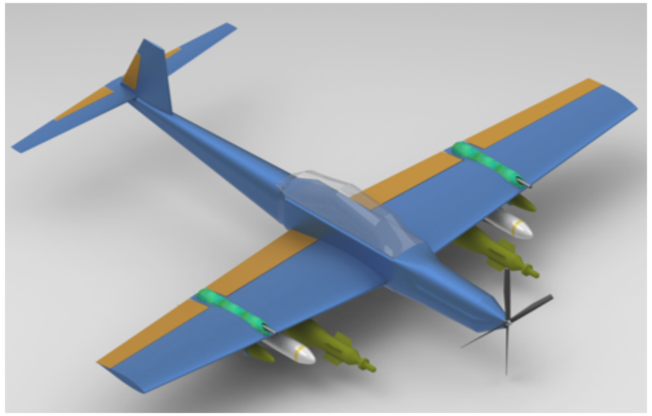
- Max Weight: 11,000 lbs.
- Max Payload: 3,300 lbs.
- Engine Power: 1,600 HP
- Maximum Fuel: 1,000 lbs.

Piper Enforcer

- Max Weight: 13,999 lbs.
- Max Payload: 5,680 lbs.
- Engine Power: 2,455 HP
- Maximum Fuel: 1,900 lbs.

AT6 Wolverine

- Max Weight: 10,000 lbs.
- Max Payload: 4,110 lbs.
- Engine Power: 1,600 HP
- Maximum Fuel: 2,908 lbs.



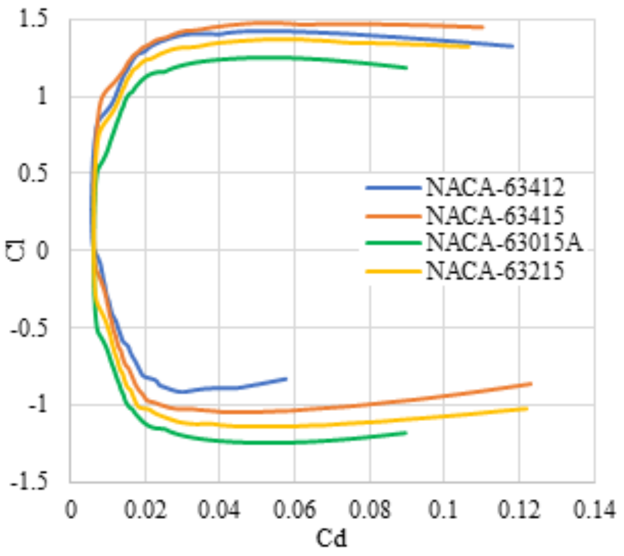
Swamp Hopper

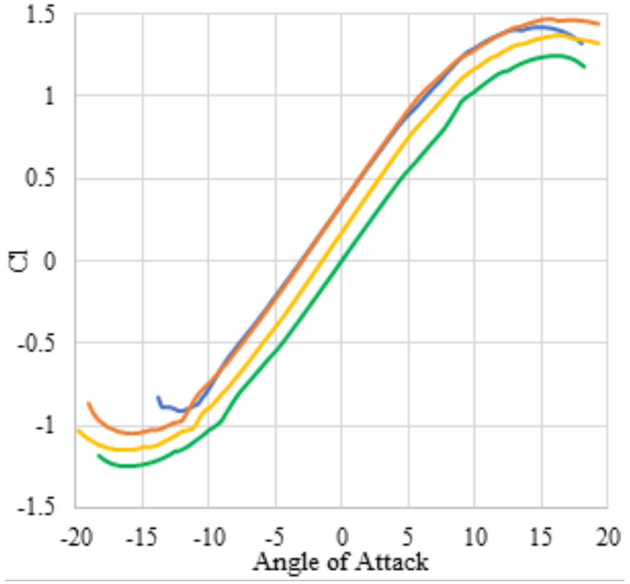
- **Max Weight: 10,615 lbs.**
- **Max Payload: 3,100 lbs.**
- **Engine Power: 1,600 HP**
- **Maximum Fuel: 3,190 lbs.**

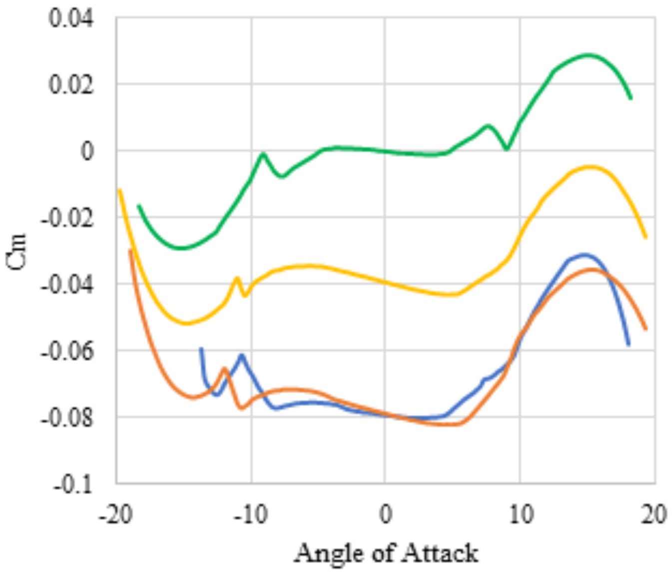
Airfoil Selection and Wing Geometry Design

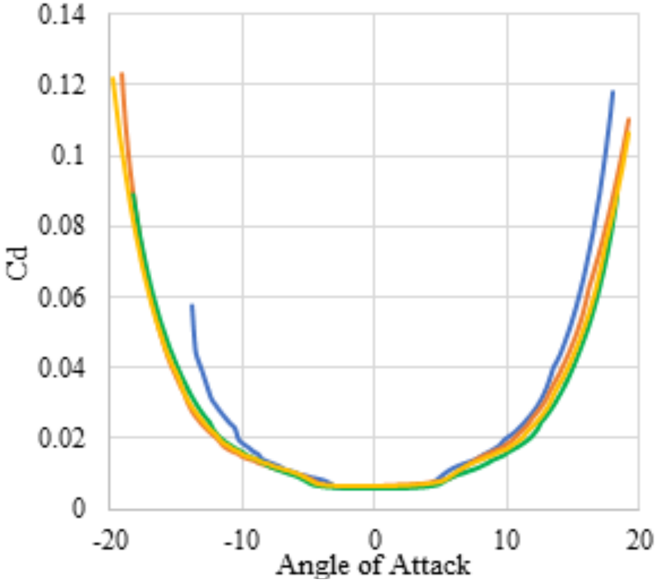
Airfoil Selection

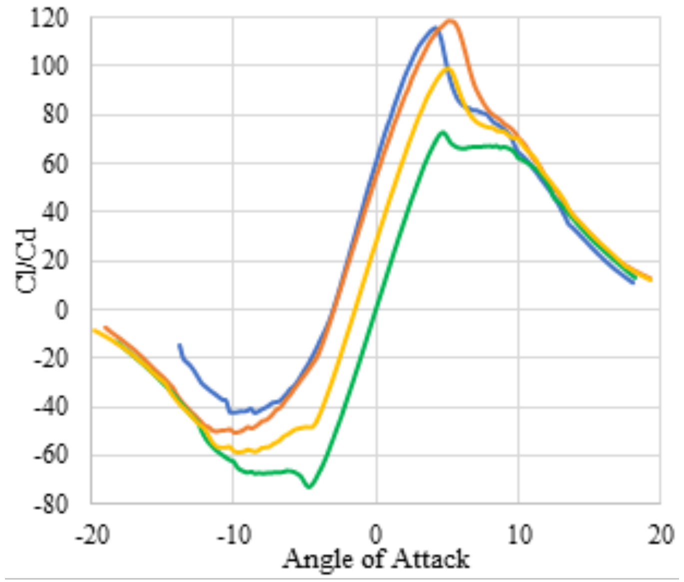
- Aerodynamic coefficients were compared for different airfoils
- **NACA** **63412** was chosen due to:
    - Higher lift at stall
    - Best lift to drag ratio
    - Smallest moment coefficient





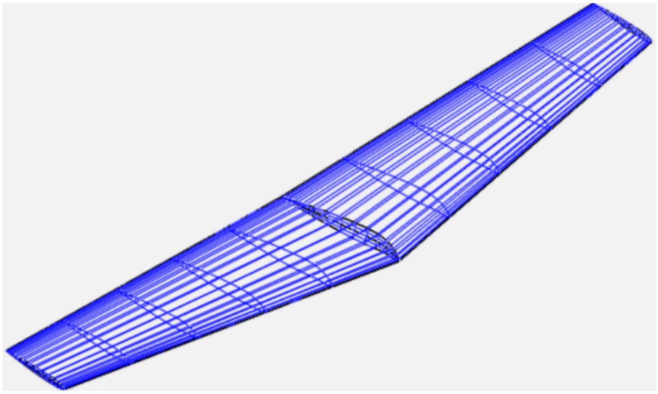






Wing Geometry Design

- Sweep
  - Ensures subsonic airflow during dive
  - Increases static stability
- Taper ratio
  - Creates elliptical lift distribution
  - Minimizes drag due to lift
- Low wing
  - Increases maneuverability
  - Landing gear storage
  - Clear overhead view
- Dihedral
  - Increases lateral static stability
- Cut-off wing tip
  - Increases lift and decreased drag.
- Incidence angle
  - Maximizes take-off lift
  - Minimizes cruise angle of attack.
- Twist
  - Prevents tip stall
  - Revises an elliptical lift distribution



Wing with NACA 64312 airfoil

Category	Symbol	Value
Span	B	38.0 ft
Total Wing Area	S	211 ft^2
Aspect Ratio	AR	6.61
Sweep	Λ	5°
Taper Ratio	λ	0.5
Wing Position	N/A	Low
Dihedral	Γ	4°
Wing Tip	N/A	Cut-off
Incident Angle	α_i	2°
Twist	β	-3°

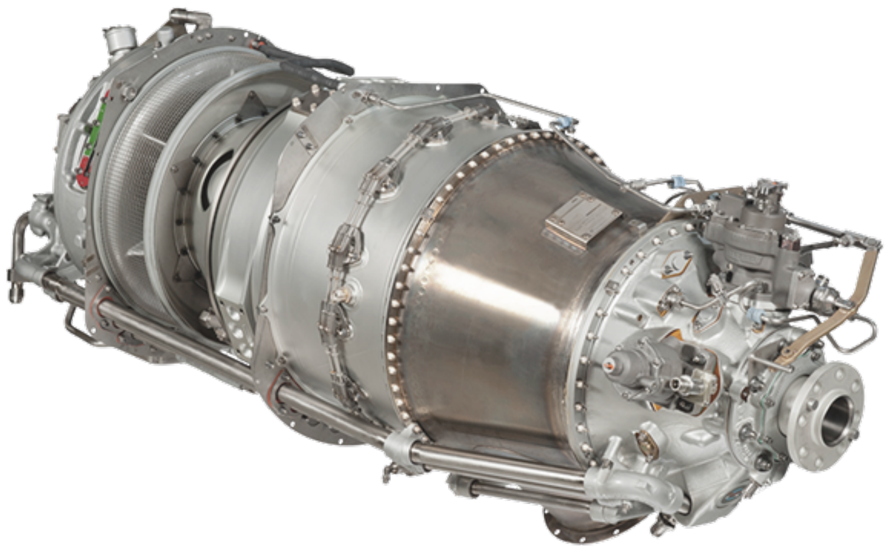
Propulsion

Propulsion

Why a Turboprop Engine?

- Higher efficiency than jet exhaust in denser air of low altitudes.
- More cost effective for short distances.
- Able to take off and land on shorter and non-concrete runways.
- Lower operation and maintenance costs.

Pratt & Whitney Canada
Une société de United Technologies



PT6A-68D

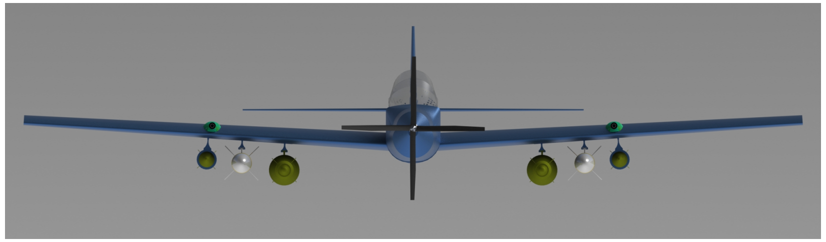
Chosen Engine: Pratt and Whitney Canada PT6A-68D
But why?

- Enough power for design and ferry mission.
- More versatility based on extra power.

Propeller Design

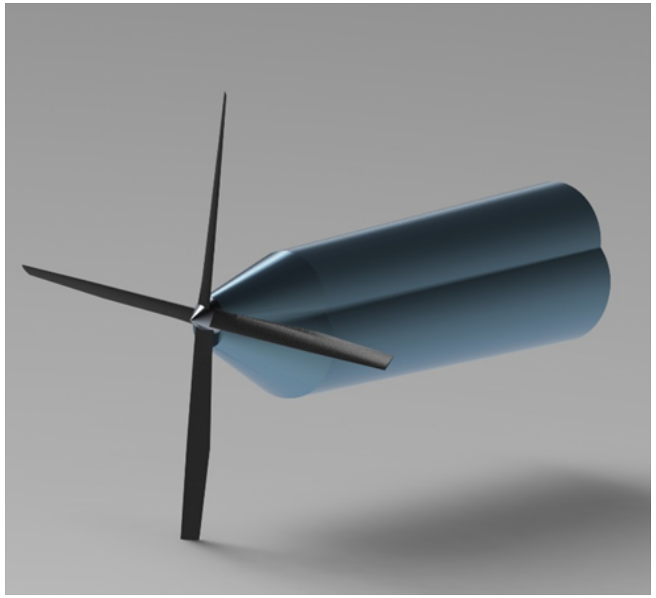
Design Decisions

- **NACA 4412** propeller airfoil.
- 4 blades.
- Puller configuration at nose of the aircraft.



Features

Variable	Name	Value
P	Power	1,600 hp
n	Rotation Speed	33.33 rev/s
D	Diameter	7.167 ft
$V_{tip,static}$	Static Tip Velocity	750.54 ft/s
$V_{tip,helical}$	Helical Tip Velocity	861.60 ft/s
J	Advance Ratio	1.771
C_p	Coefficient of Power	0.7412
C_t	Coefficient of Thrust	0.3347
N_p	Propeller Efficiency	0.80



Propeller and Engine Cowl

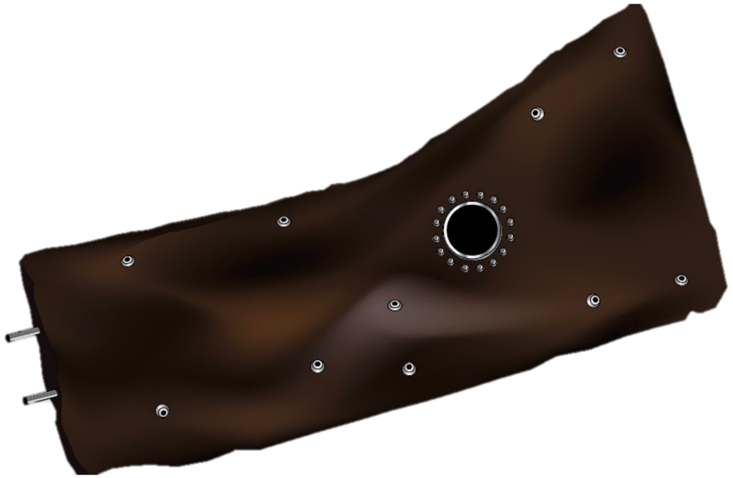
Fuel System

Design Requirements

- 1,700 liters of fuel needed for design mission with an extra 6% for reserved and trapped fuel.

Solution? No worries, we are engineers

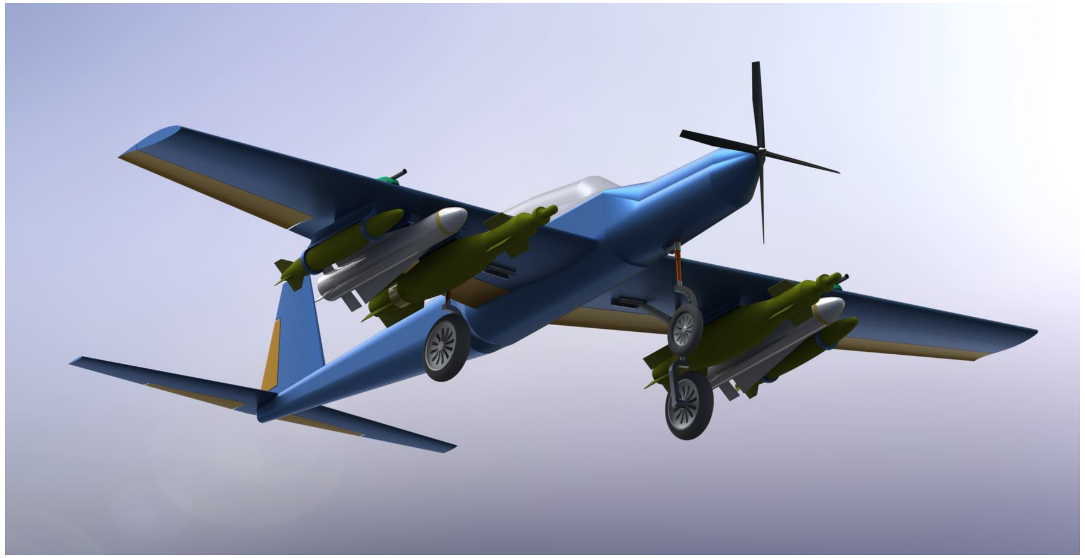
- Bladder tanks in the wings with 465 liters of capacity.
- Rigid tank in the fuselage with 1,235 liters of capacity.



Bladder tank for light aircraft

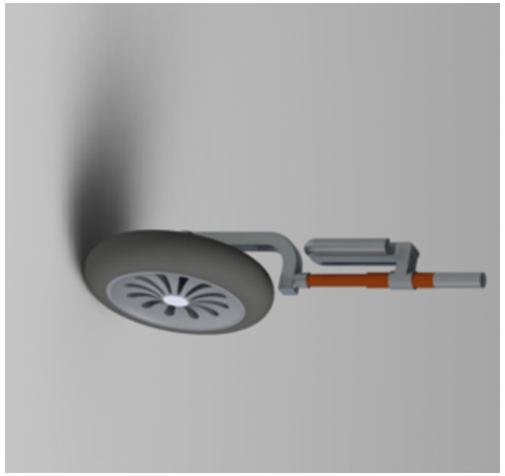
Landing Gear

Landing Gear Selection



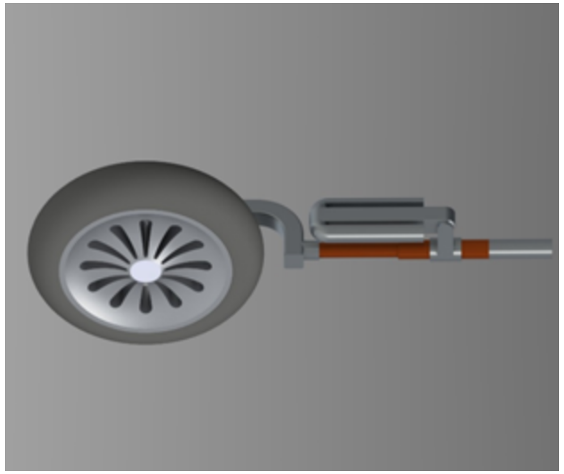
Bottom view of swamp hopper
with tricycle configuration

Auxiliary Tire



Landing Gear deployed on the left and stored on the right with the oleo struts highlighted in red

Main Tires



Static and Dynamic Loading Estimation

Load	Auxiliary Tire	Main Tires
Max Static Load [lbs.]	1,703.7	5,307.5
Min Static Load [lbs.]	908.6	-
Dynamic Braking Load [lbs.]	1,723.3	-

Total Kinetic Energy Calculated: 5,067,700 N•m/s

Tire Selection

Auxiliary Tire → Type VII Aircraft Rib 18 x 4.4 in.

Main Tires → Type VII Flight Leader DT 26 x 6.6 in.

Initial Calculated Tire Characteristics

Tire Distribution	Auxiliary Tire	Main Tires
Number of Tires	1	2
Weight Distribution	10%	90%
Diameter Distribution	70%	100%
W_w [lbs.]	1,062	4,780
Tire Diameter [in]	18.3	26.1
Tire Width [in]	5.21	7.44

Characteristics of Selected Tires

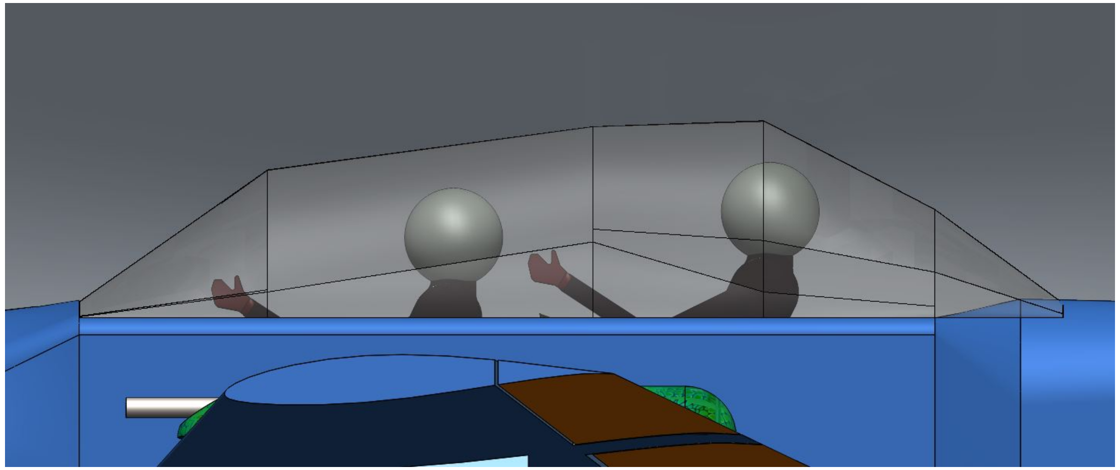
Parameter	Auxiliary Tire	Main Tires
Tread Design	Aircraft Rib	Flight Leader DT
Part Number	461B-2741-TL	226F02-6
Size [in.]	18 x 4.4	26 x 6.6
Rolling Radius [in]	7.9	11.2
Rated Load [lbs.]	2,100	6,900
Applied Load [lbs.]	1,723	5,307
Rated Pressure [psi]	100	155
Applied Pressure [psi]	76.5	97.9

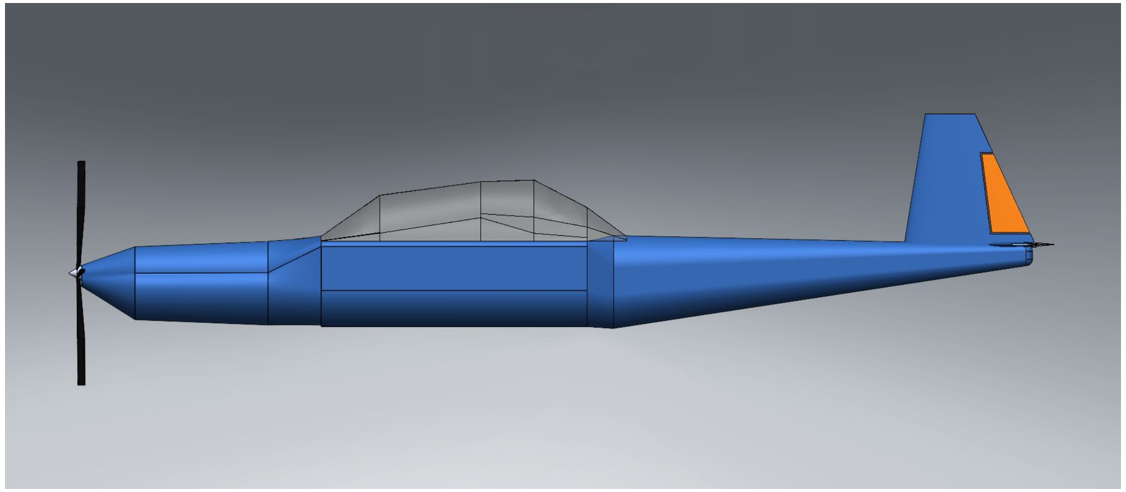
Model of the Tires

Fuselage, Crew Station Design, and Survivability Consideration

Crew Station and Design

- Fuselage:
  - Optimized fineness ratio for subsonic aircraft of 8.
  - Corresponds to a tip to tail distance of 30.75 ft.
  - Rounded contours to minimize radar footprint.
  - Turboprop allows for reduced IR signature.
  - Has both ECM and chaff countermeasures in case of detection.





- Crew station
  - Equipped with Two Zero-Zero Ejection seats for both pilots
  - Canopy and cockpit geometry is optimized for 95th percentile pilot
    - Allows for optimal visibility
  - Firewalls installed around fuel tanks and crew compartment

Weapons Carriage

Deployable Bombs and Missiles:

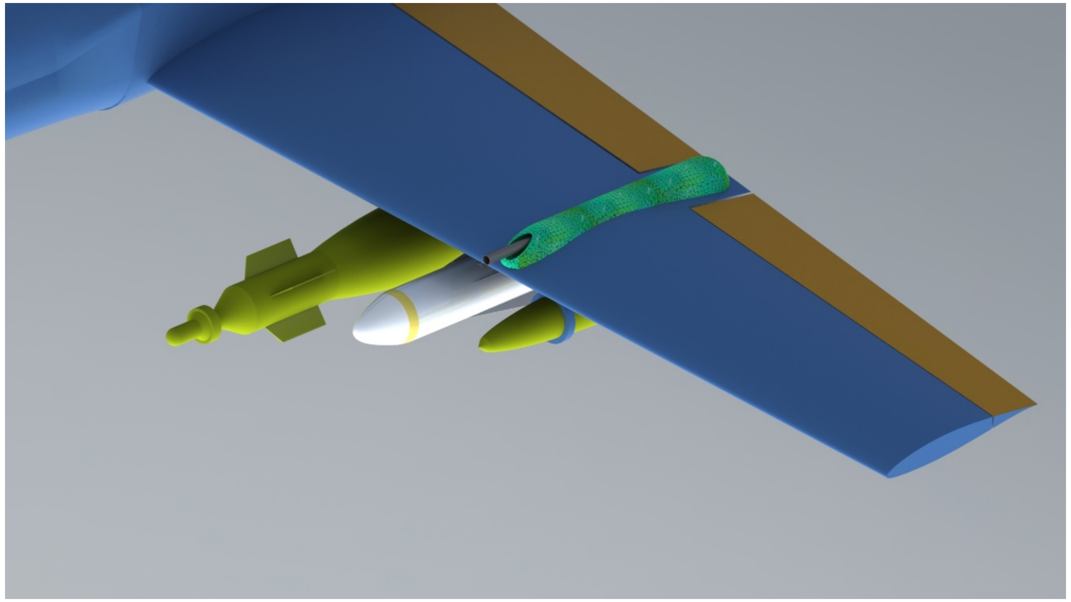
- Mark 82 Unguided bombs

- GBU 12 Pathway II Guided Bombs

- AGM 25 Guided Missile

- Mounted Gun: The FN M3P .50 caliber machine gun.

- Mounted on each wing as to not cause a moment due to recoil when firing.
- Gun placement behind engine eliminates recoil smoke interfering with combustion

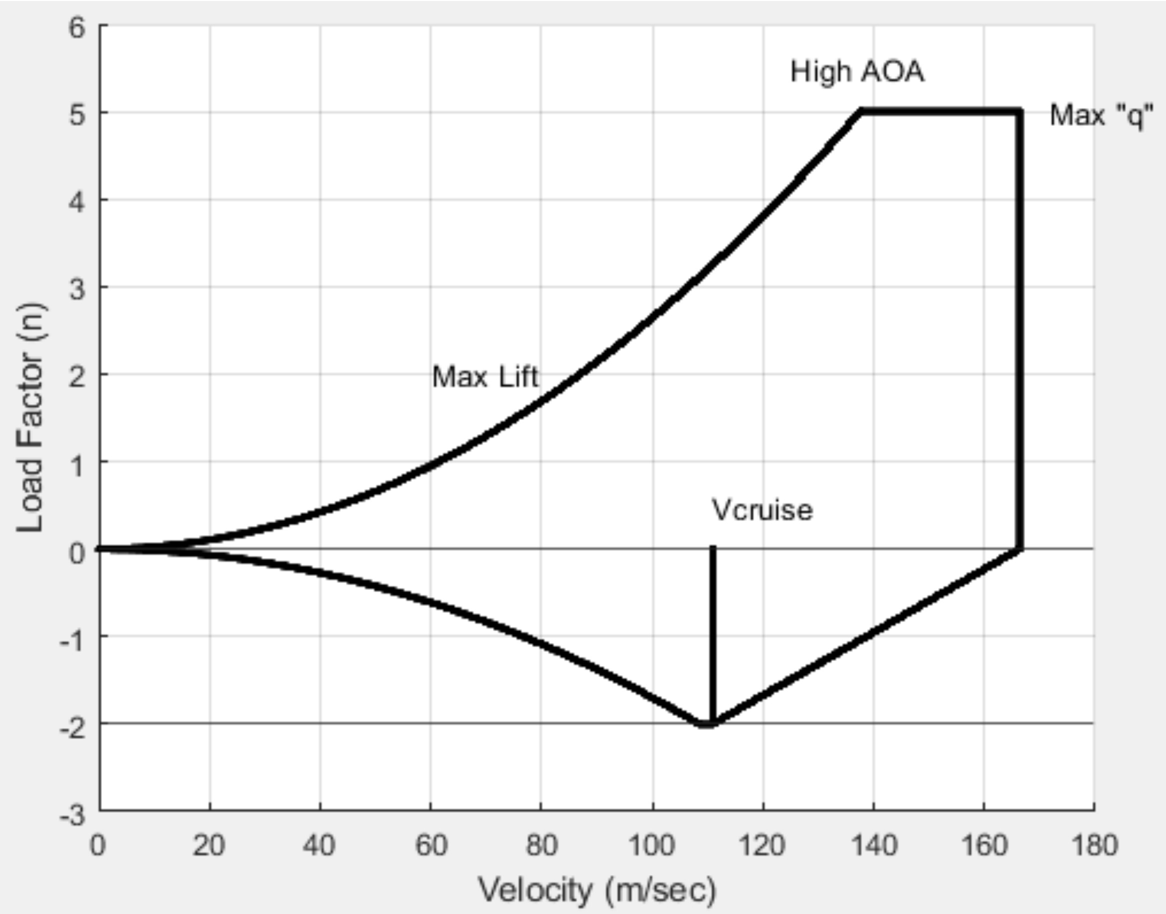


- Bombs and missiles are stored under each wing, and the guided munitions use a rail launch mechanism.
- A total of 6 deployable ordinances are used to fulfil the 3,000lb armament package requirement outlined by the RFP.
- External mounting allows for modular armament swapping

Structure

V-n Diagram

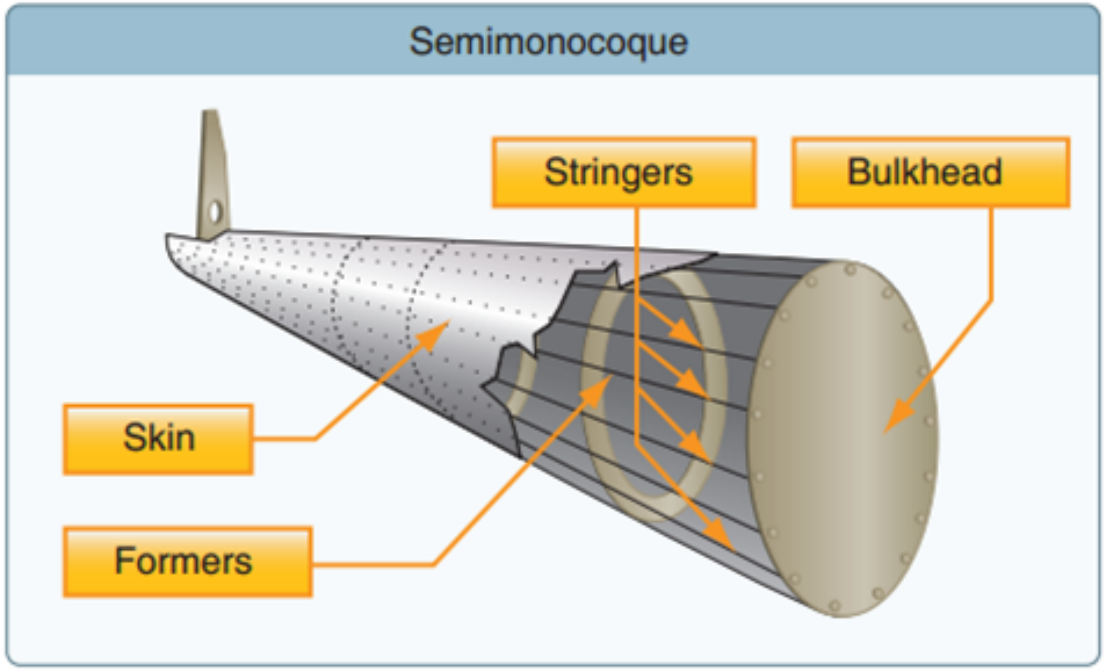
- Variation in load factor as a function of EAS (Equivalent Airspeed)
- Load factor indicates maneuvering of aircraft of as a multiple of standard acceleration due to gravity
- EAS – proportionality between TAS (True Airspeed) and square root of density ratio



Fuselage & Wing Structure Type

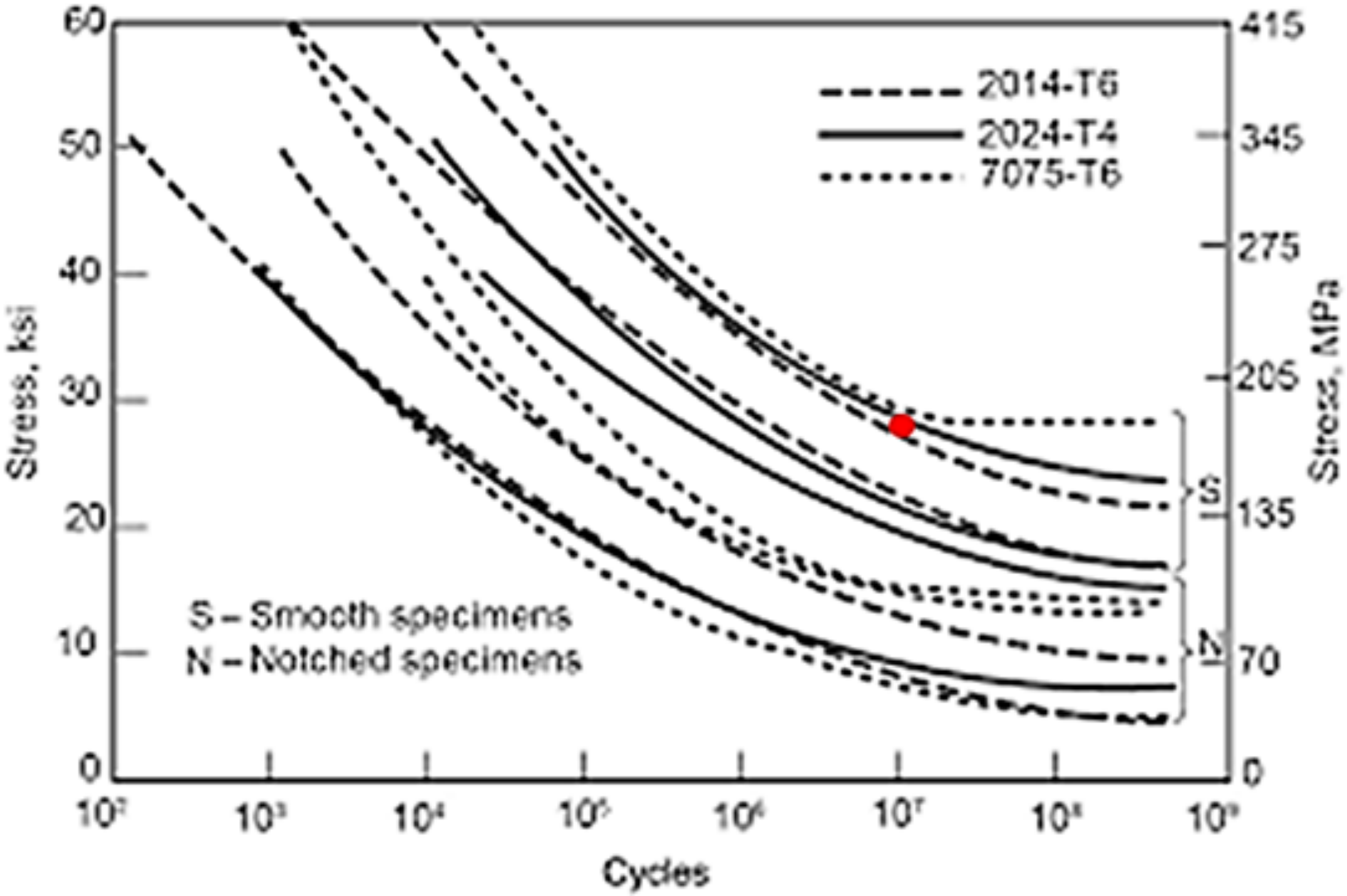
- Fuselage Types (Truss, Monocoque, Semi-Monocoque)
  - Selected Fuselage Type = Semi-Monocoque
    - Uses stringers which takes some of the bending stress away from the fuselage
    - Creates a barrier for further crack propagation
    - Many structural members --> Increases strength and rigidity

- Wing Structure Types (Mono-Spar, Multi-Spar, Box Beam)
  - Selected Wing Structure Type = Multi-Spar
    - Similar aircraft (Embraer Super Tucano)
    - Landing gear & mounted gun location



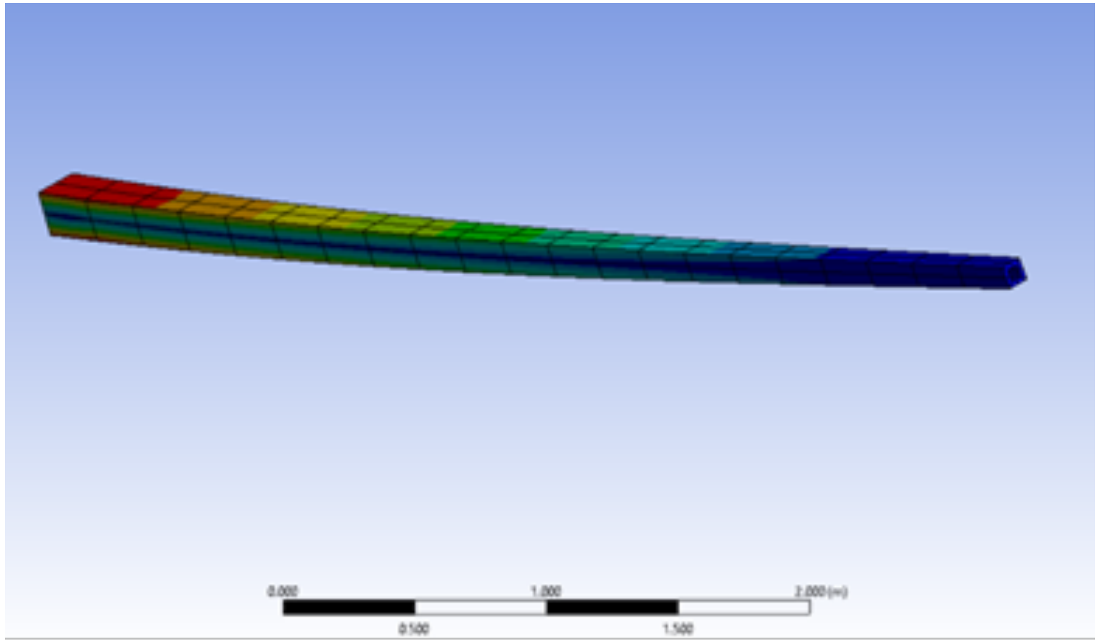
Material Selection

- Material Selected for Swamp Hopper
  - Aluminum 2024-T42
- Material Properties
  - Density = 0.100 lb./in^3
  - Ult. Tensile Strength = 57.3 ksi.
  - Yield Strength = 37.7 ksi.



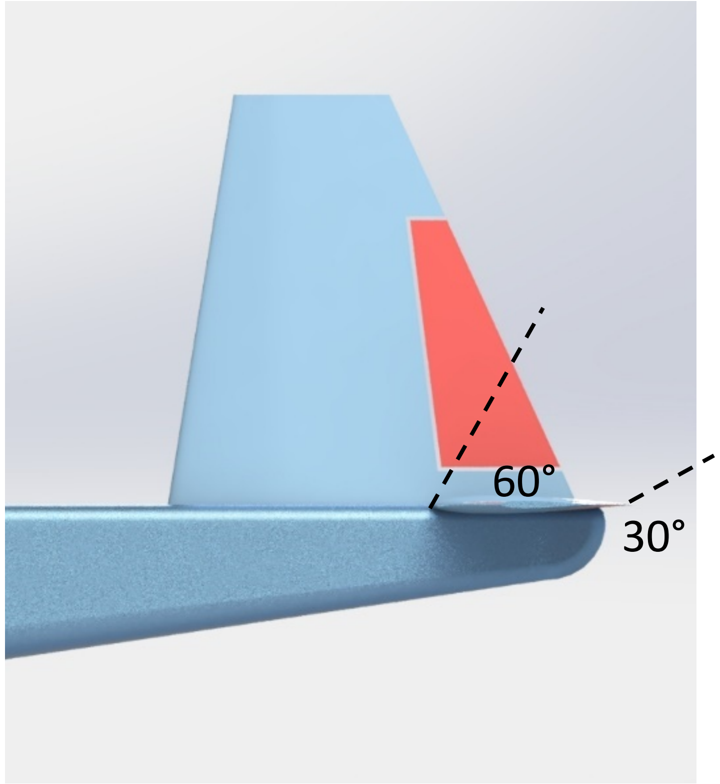
Structural Analysis

- Structural Analysis Results (ANSYS Software)
- Load was applied with a safety factor of 1.5
- Von Mises from ANSYS = 30.8 ksi
- Von Mises from principal stresses = 25.2 ksi
  - Both less than yield strength of 37.7 ksi
  - Number of cycles is 10 million



Tail Design, Systems, Weight, and CG Estimation

Conventional Tail Design

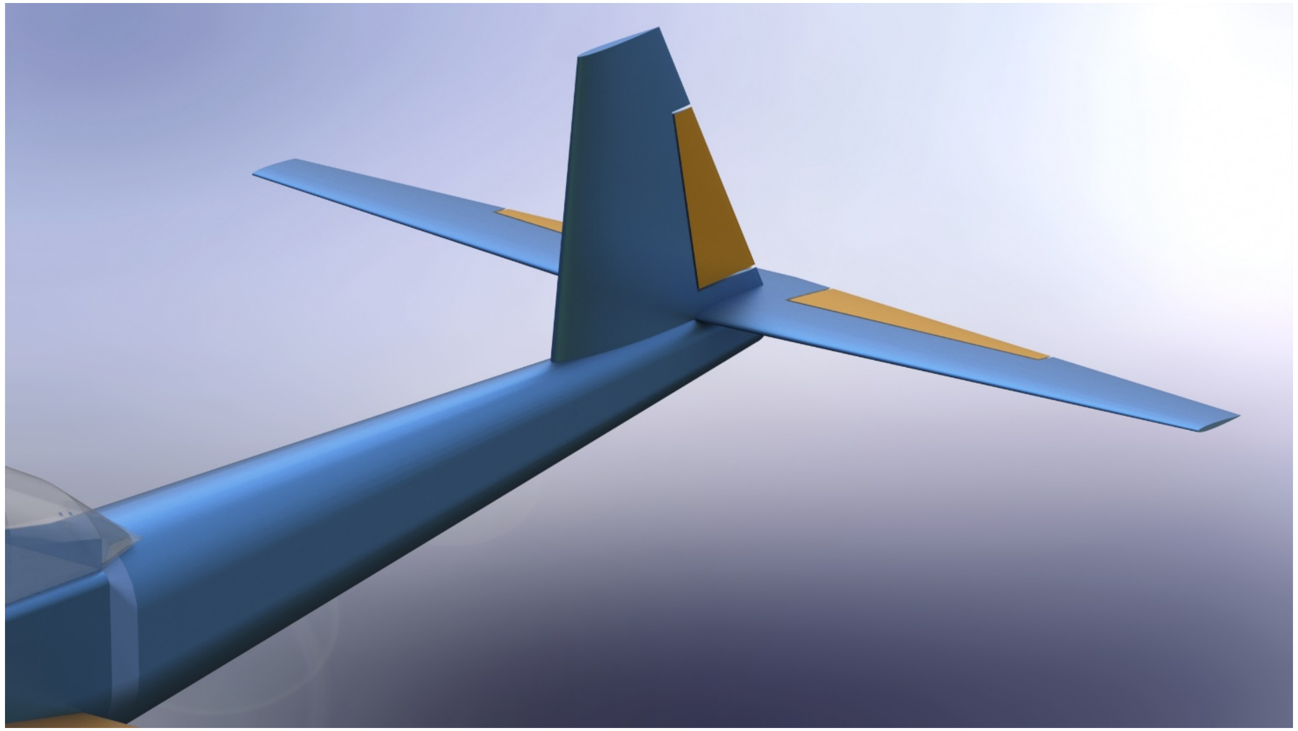


Properties	Horizontal Tail	Vertical Tail
Tail Volume Coefficient	0.70	0.06
Tail Arm, L	19.5 ft	19.5 ft
AR	4.0	1.0
λ	0.4	0.4
Sweep Angle	10°	10°
Airfoil	NACA 0009	NACA 0009
Tail Area	42.5 ft^2	24.7 ft^2

Deep Stall and Spin Recovery Considerations:

- Height of the aft tail aligned with the wing/fuselage AC
- >1/3 of the rudder is out of the horizontal tail wake region

Tail Control Surfaces



Rudder

- 30% of the vertical tail chord
- Same taper ratio as vertical tail
- 50% of the vertical tail span

Elevator

- 30% of the horizontal tail chord
- Same taper ratio as horizontal tail
- 50% of the horizontal tail span

Flight Control System

Primary Control System

Fly-by-wire (FBW) control system

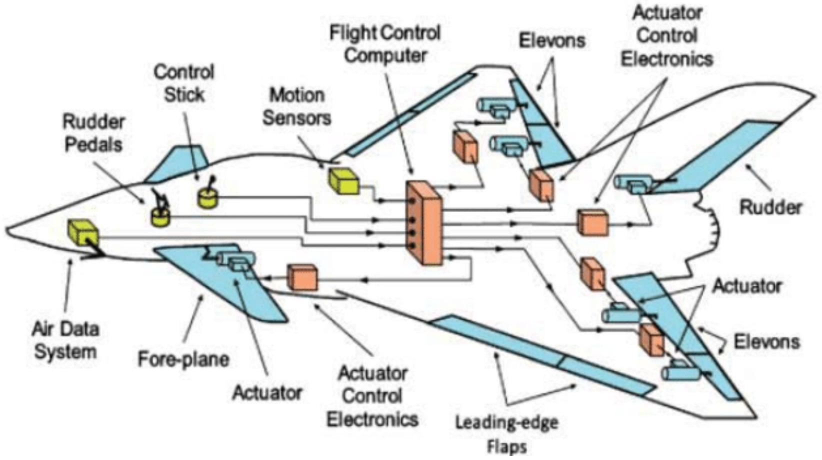
Secondary Control System

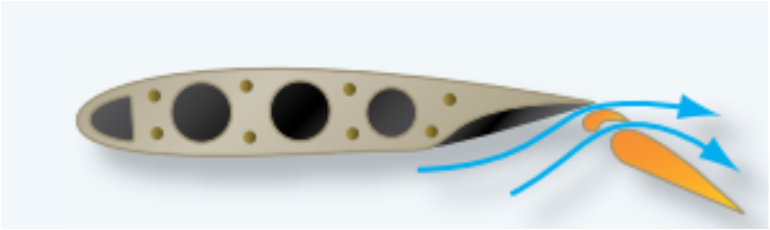
Slotted fowler flaps as the trailing edge high lift devices

Engine Control System

Full authority digital engine control (FADEC) system

- Better fuel economy
- Automatic engine monitoring
- Diagnostic processes





Subsystems

Hydraulic Systems

- AeroShell 31 synthetic hydrocarbon-based fluid

Electrical

- Turboprop generator
- Nickel-cadmium (NiCad) battery
- Wiring system
  - > 10 gauge: aluminum
  - < 10 gauge: copper

Pneumatics

- Pressurization
- Anti-icing
- Engine starting
- Environmental control

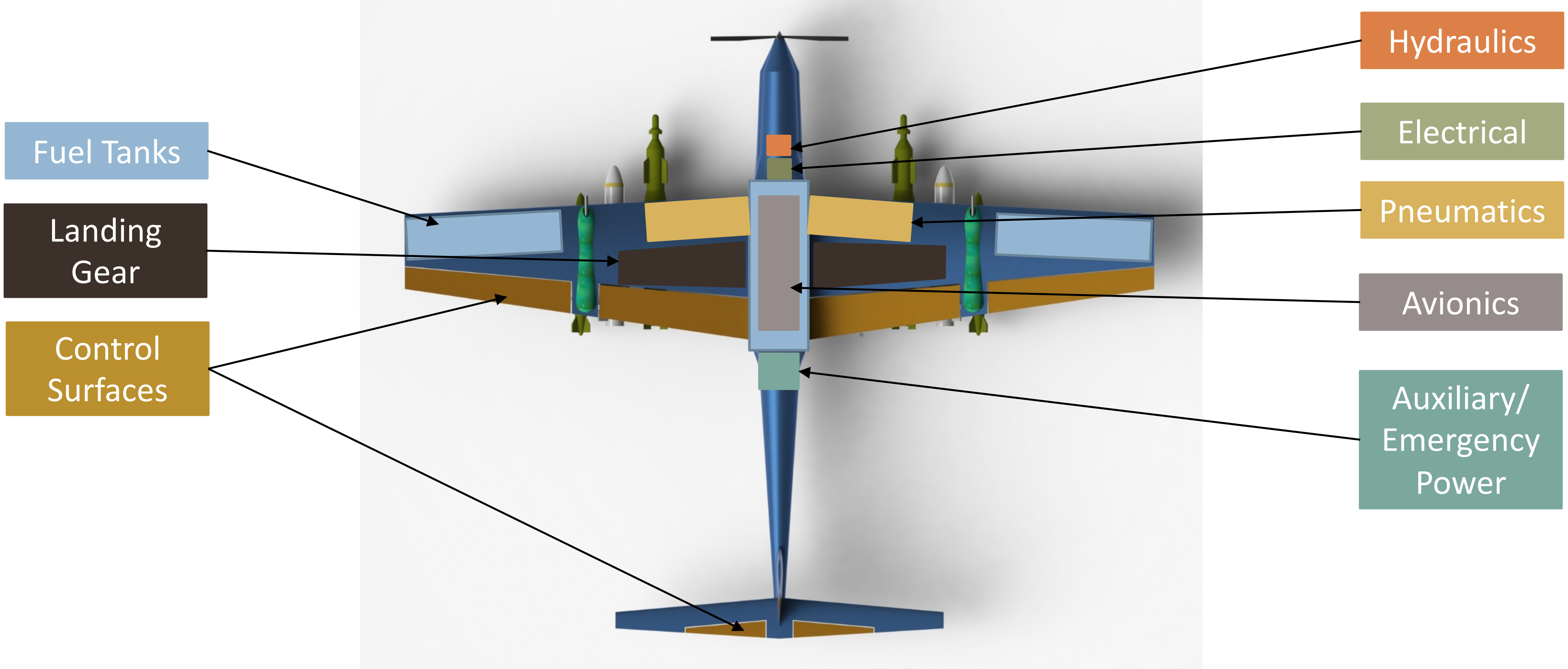
Auxiliary/ Emergency Power

- Jet-fuel auxiliary power unit (APU)

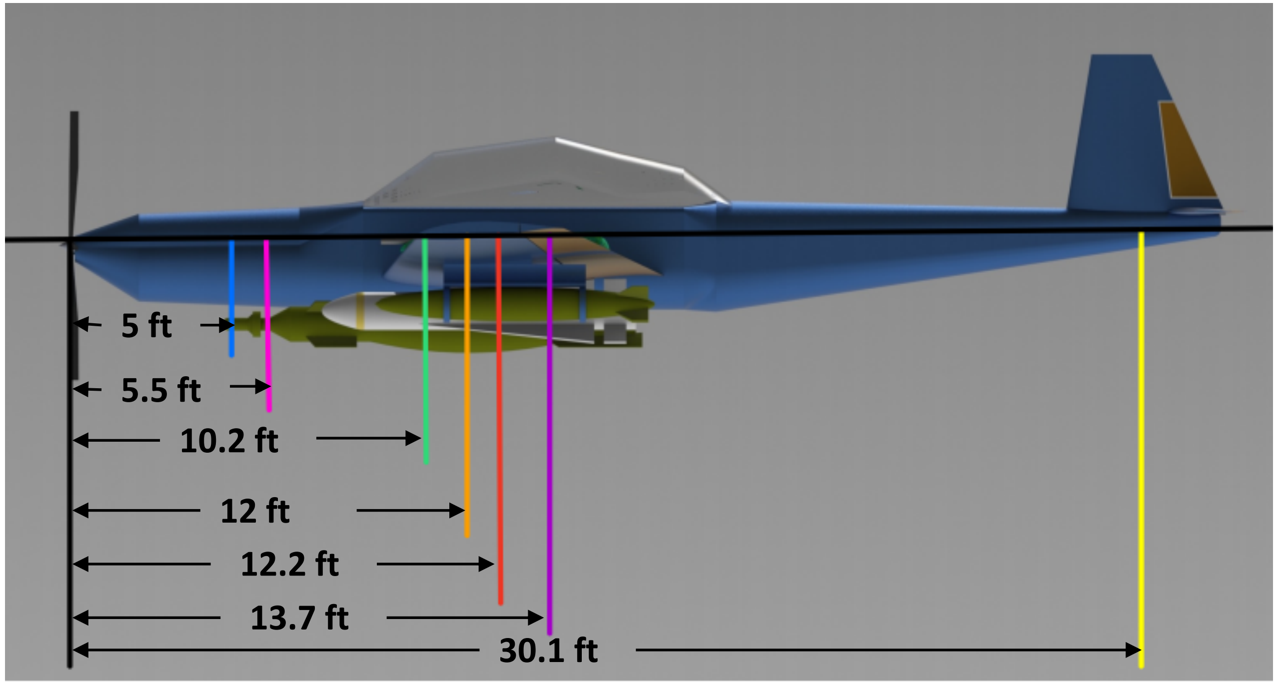
Avionics

- Electronic Countermeasure (ECM)
- Infrared Jammer
- Infrared search and track (IRST) system
- IR Jammer
- Communications and navigations system

Subsystem Locations



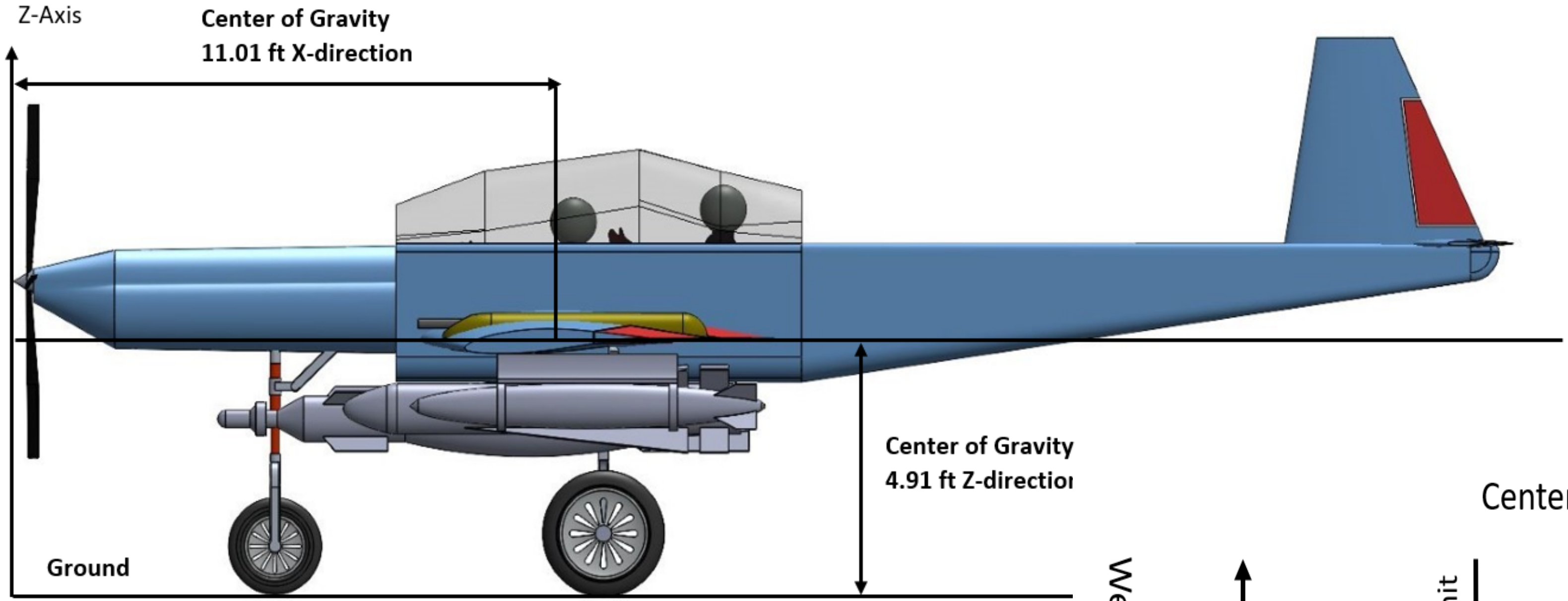
Weight and Moment Estimations

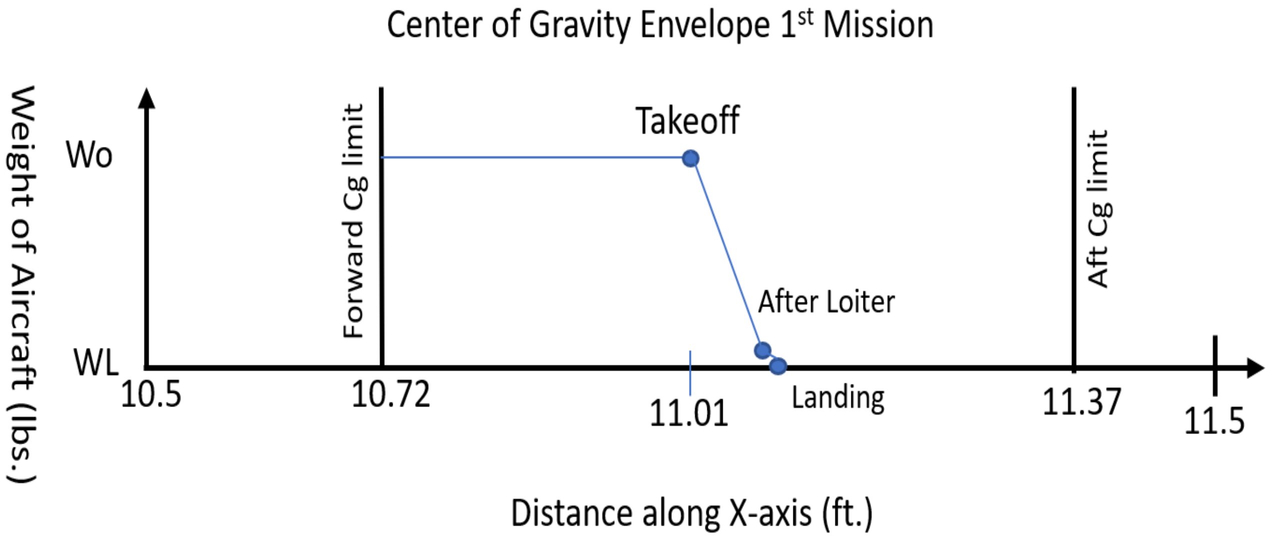


Component	Weight (lbs.)	Moment (ft-lb)
Payload	2,994	35,299
Crew	400	4,800
Engine	578	2,088
Usable Fuel	3,161	32,113
Trapped Fuel	32	324
Two Wings	1,971	20,025
Tail	130	3,912
Main Landing Gear	514	6,274
Nose Landing Gear	91	495
Fuselage	960	13,152

Total Weight: 10,830 lbs.

CG (Center of Gravity) Estimation





Stability and Control

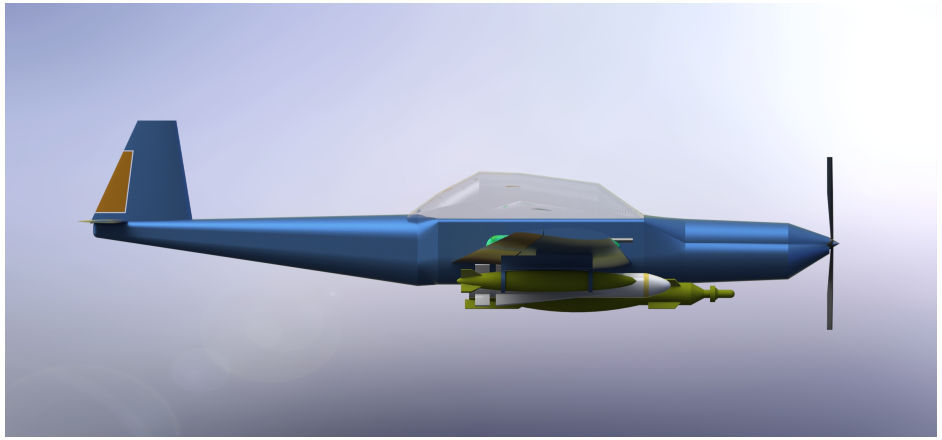
Longitudinal Static Stability

Requirement:

- $C_{m_{cg}} = 0$
- $C_{m_\alpha} < 0$

Main Contributions:

- Wing
  - Largest destabilizing contribution
- Flap
- Fuselage
- Horizontal Tail
  - Largest stabilizing contribution
- Engine



Name	Value
C_{m_α}	-0.648
$C_{m_{cg}}$	-0.044
Neutral Point	2.05
Static Margin	0.119

Lateral-Directional Static Stability

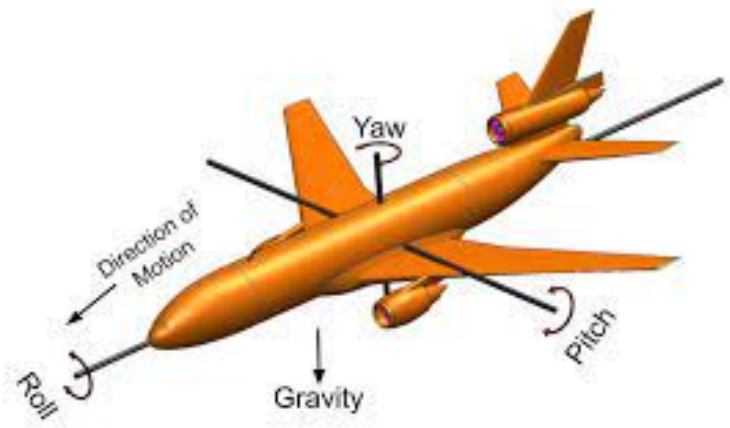
Name	Value
Roll Moment Coeff.	-0.138
Yaw Moment Coeff.	0.138

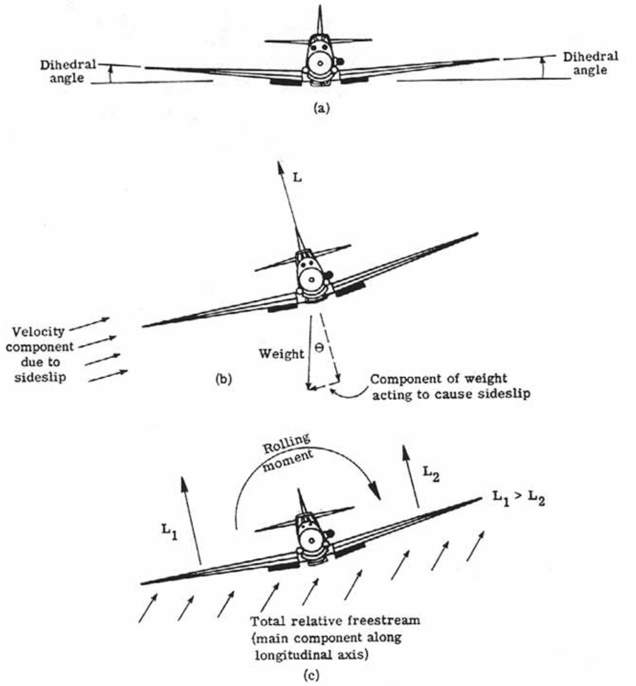
Roll Moment Major Contributors

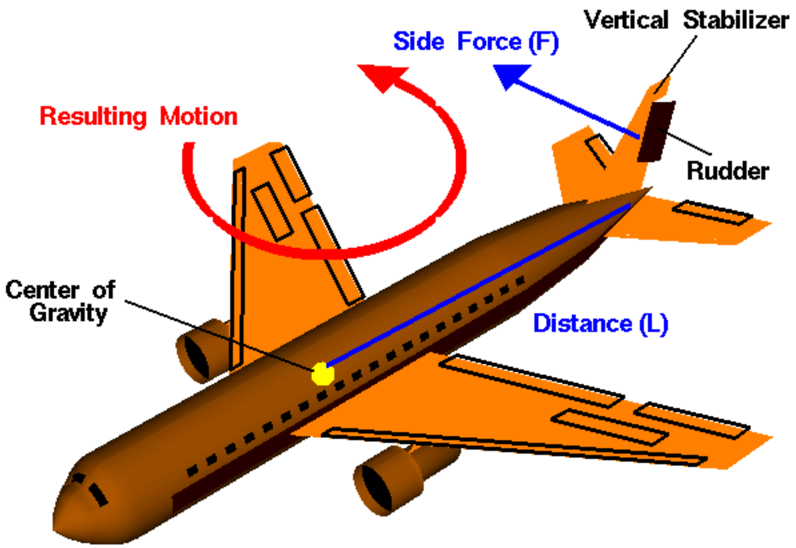
- Wing Sweep
- Wing Placement
- Dihedral

Yaw Moment Major Contributors

- Vertical Tail
- Wing Sweep
- Dihedral







Performance Analysis

Range & Endurance Analysis

Range Analysis Values

- Cruise 1: 1,307 miles
- Cruise 2: 1,307 miles
- Loiter: 273 miles
- **Total Range:** 2,887 **miles**

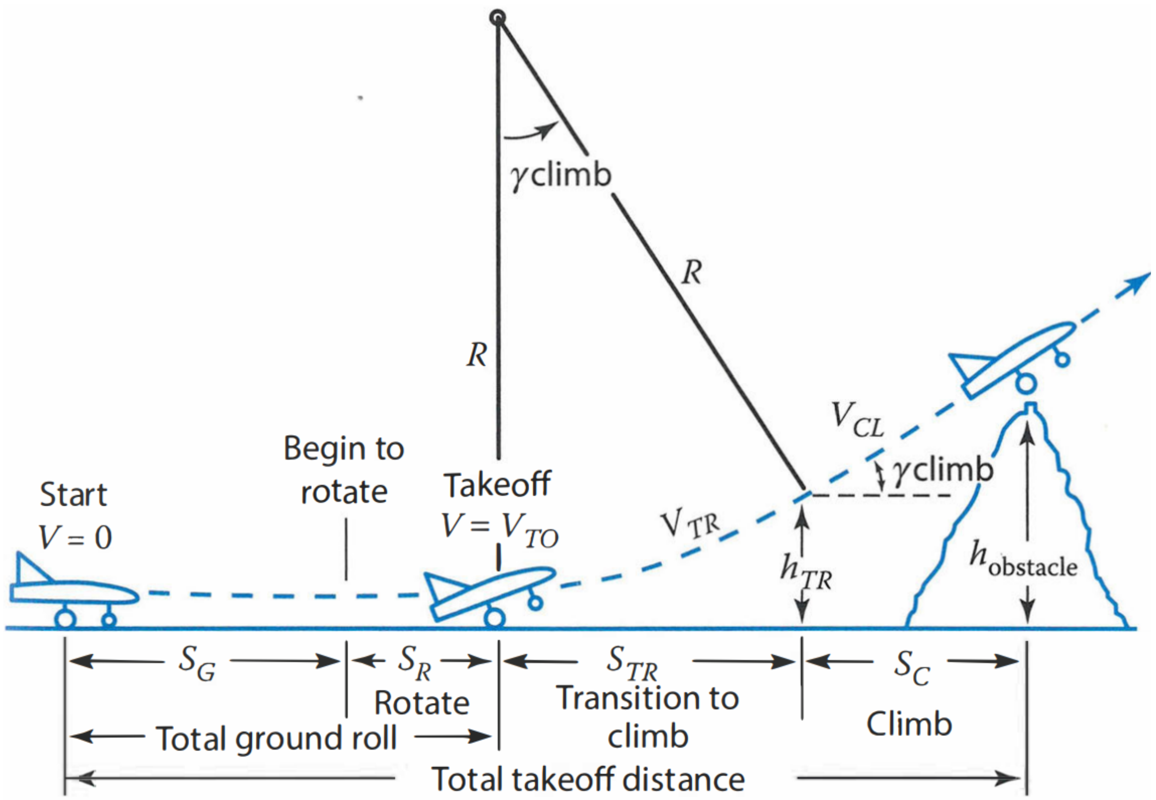
Endurance Analysis Values

- Fuel Used: 1,095 lbs.
- **Endurance: 6.05 hours**

Variable	Cruise 1	Cruise 2	Loiter
W_i	10,830 [lbs.]	9,300 [lbs.]	9,300 [lbs.]
W_f	9,300[lbs.]	7,990 [lbs.]	8,900 [lbs.]

Variable	Description	Value [Units]
Wi	Initial Weight	7,800 [lbs.]
Wf	Final Weight	6,710 [lbs.]
E	Endurance	6.05 [hr.]

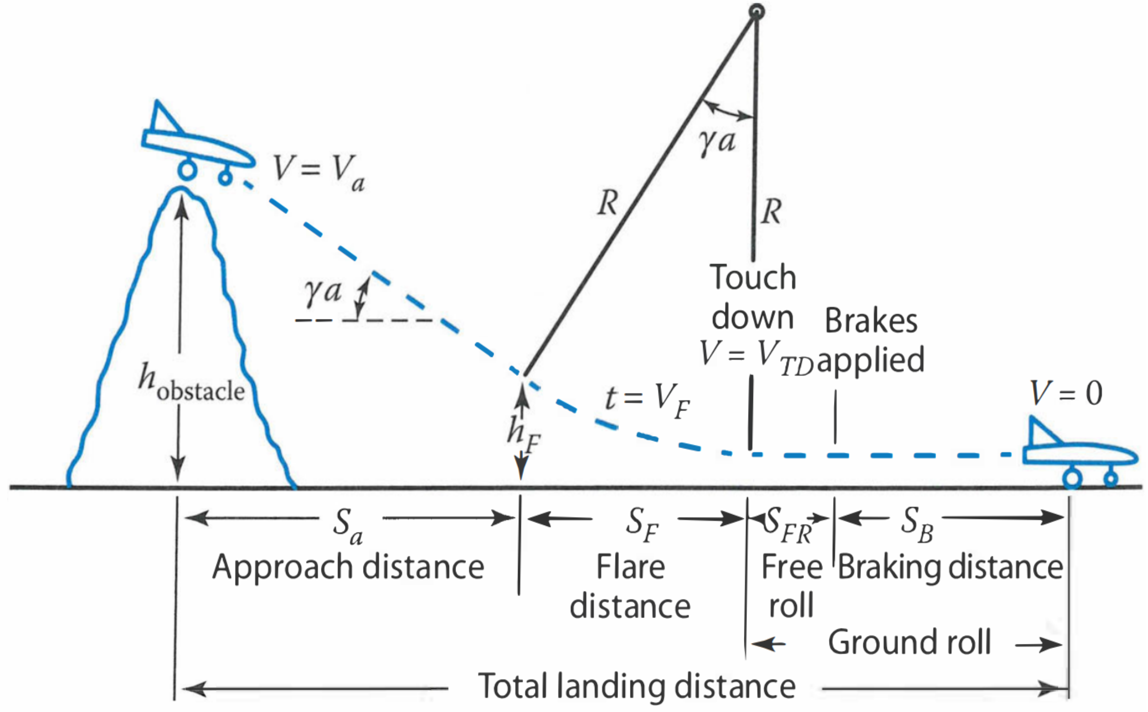
Take-off Performance



Variable	Description	Value
V_{stall}	Stall velocity	151 ft/s
V_g	Ground roll velocity	166 ft/s
V_{tr}	Transition to climb velocity	1,734 ft/s
V_{cl}	Climb velocity	181 ft/s
a	Takeoff acceleration	2.91 ft/s^2
γ	Climbing angle	4.83°
h_{tr}	Transition to climb altitude	16.6 ft
S_g	Horizontal ground roll distance	1,967 ft
S_{tr}	Horizontal transition to climb distance	395 ft
S_c	Horizontal climb distance	395 ft
S_{tot}	**Total horizontal take-off distance**	**2,757 ft**

Design Requirement: $S_{tot} \leq 4{,}000$ ft

Landing Performance



Variable	Description	Value
μ	Rolling resistance with brakes on	0.2
$\gamma_{approach}$	Approach angle	4.77°
$V_{approach}$	Approach velocity	190 ft/s
h_F	Flare height	16.2 ft
V_{TD}	Touchdown velocity	166 ft/s
S_a	Approach distance	405 ft
S_F	Flare distance	390 ft
S_g	Horizontal landing ground roll distance	2,355 ft
S_{FR}	Horizontal free roll distance	332 ft
S_B	Horizontal braking distance	2,022 ft
S_{tot}	**Total horizontal landing distance**	**3,150 ft**

Design Requirement: $S_{tot} \leq 4{,}000$ ft

Cost Estimation

Research, Development, Testing and Evaluation (RDT&E) Cost Estimation

RDT&E Cost per Unit

Description	Cost
Engineering	$4,260,00
Tooling	$2,310,000
Manufacturing	$3,960,000
Quality Control	$580,000
Total RDT&E Cost	**$11,100,000**

Fly Away Cost Estimations

Fly Away Cost per Unit

Description	Cost
Development Support	$1,170,000
Flight Test	$899,000
Manufacturing Materials	$1,060,000
Engine Production	$4,900
Total Flyaway Cost	$**3,120,000**

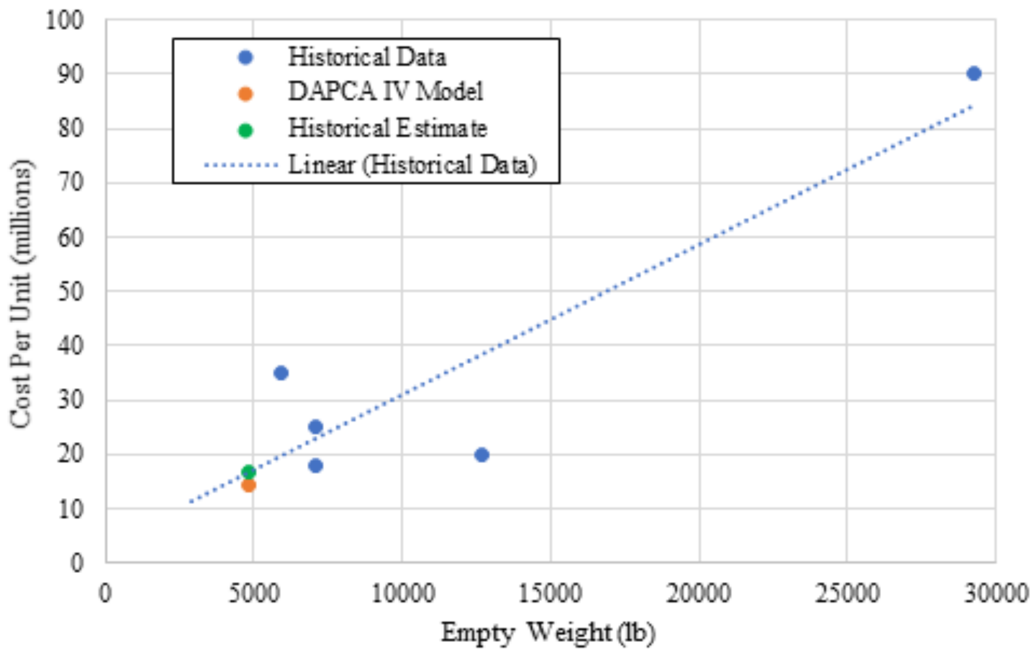
Research, Development, Testing and Evaluation and Fly Away Cost Estimations

RDT&E and Flyaway Costs at Different Production Quantities

Quantity of Aircraft [5 years]	Total RDT&E Cost [$]	RDT&E Cost Per Unit [$]	Total Flyaway Cost [$]	Flyaway Cost Per Unit [$]
50	556,000,000	11,100,000	171,00,000	3,420,000
500	1,510,000,000	3,000,000	562,000,000	1,120,000
1000	2,150,000,000	2,150,000	932,000,000	932,000
2000	3,110,000,000	1,558,000	160,000,000	803,000

Values were calculated by using a Development and Procurement Costs of Aircraft (DAPCA) model

Empty Weight vs Unit Cost



Operational Cost for 1200 Flight Hours

Operations and Maintenance Cost per Year

Variable	Cost per year
Fuel Maintenance	$39,000
Crew Salaries	$745,000
Maintenance	$1,290,000
Total Operations and Maintenance Cost	**$2,434,000**

- Maintenance Hours: 3 man-maintenance hours/flight hour
- Cost per Maintenance Hour: $358/flight-hour

Total Cost Per Year for 1,200 Flight Hours

Variable	Cost per Year
Operations and Maintenance	$2,430,000
Tires	$6,000
Brake System	$10,000
Oil	$1,500
Insurance	$24,000
Total Cost for 1,200 Flight Hours	**$2,470,000**

Thanks For Your Attention

Any Questions?