Department of Mechanical and Aerospace Engineering

Responsive Aerial Fire Fighting Aircraft

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Group 2: Firefly

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Designing Fire Fighting Plane

- The majority of the aircraft currently in service for firefighting purposes are modified commercial or military airframes.

- Internal or external equipment is integrated onto the airframes, but compromises and inefficiencies are created.

Objectives

- Designing robust structural designs with easily repairable/replaceable structures at a potential weight savings.

Requirements

Fire Retardant Capacity

- 4,000 gal
- Multi-drop capable; minimum 2,000 gal per drop
- Drop speed <=150 kts
- Drop altitude <= 300 ft AGL

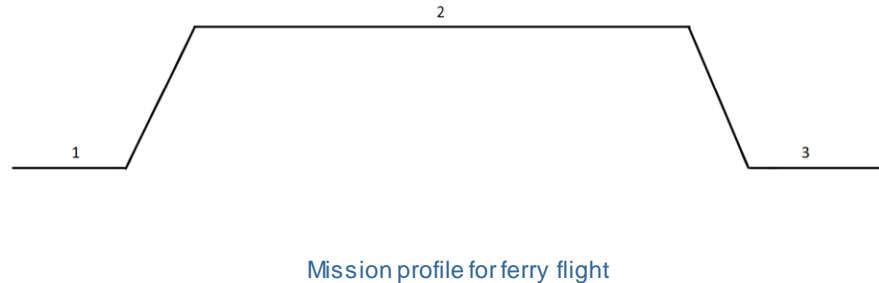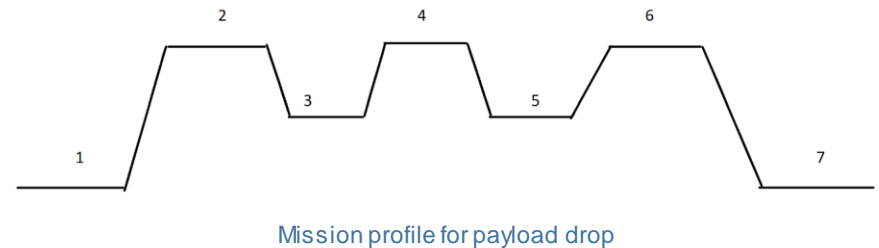Design

- Range 2,000 n mi (No Payload)
- Dash speed 300 kts

Mission Segments

- Mission 1: Payload drop

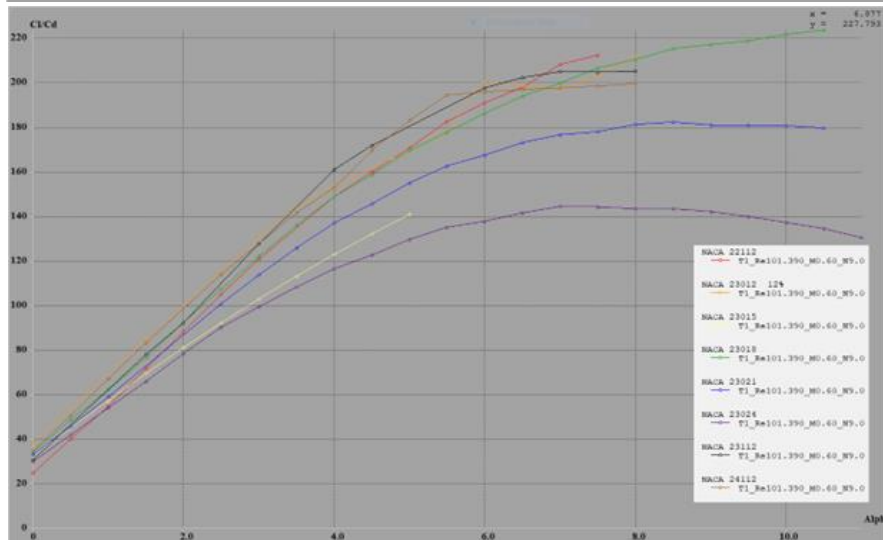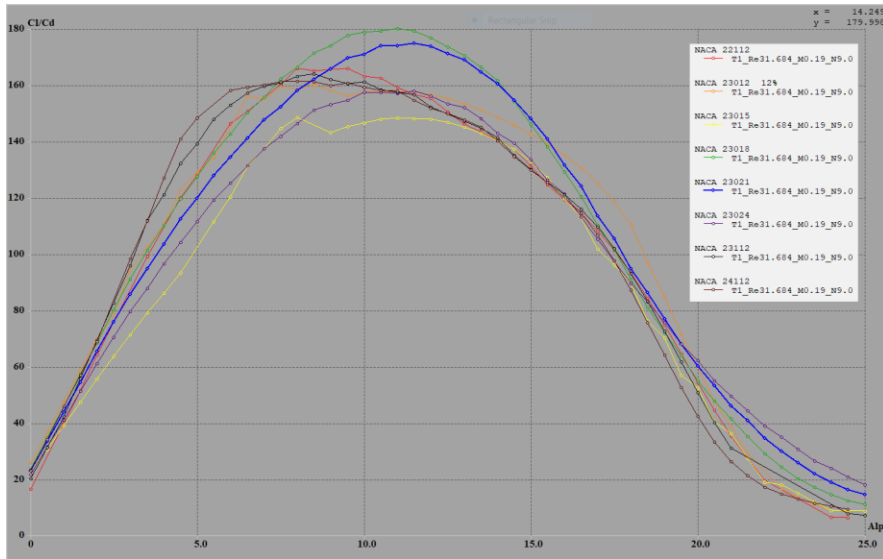1. Takeoff – 2. Cruise – 3. (1)Drop (Alt 300ft) – 4. Cruise – 5. (2)Drip – 6. Back to airport – 7. Landing

Mission profile for payload drop

- Mission 2: Ferry flight

1. Takeoff – 2. Cruise – 3. Landing
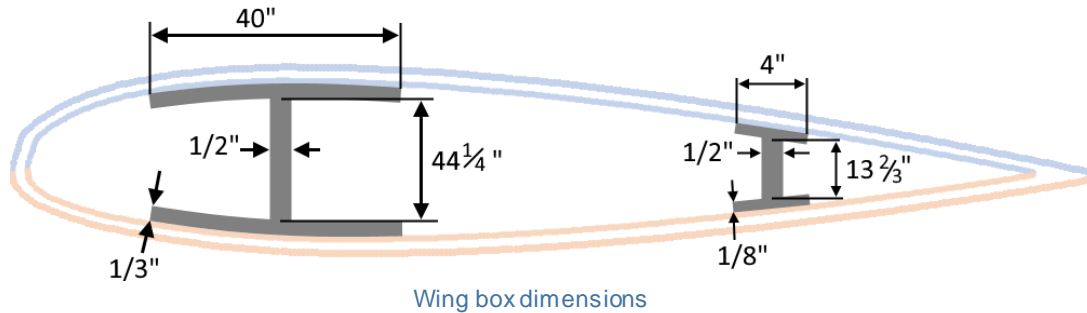
Mission profile for ferry flight

Airfoil

- NACA 23018
  - Highest aerodynamic efficiency at angle of attack of 10.5 degrees
    - Dash speed
  - Smaller drag coefficient at higher Reynold's numbers
  - Thickness
    - Moderate for maneuverability
    - Tolerate high load factor
    - Enter climb at drop speed
    - Lighter wing-box spars
  - Largest L/D ratio

Wing Structure

Wing box dimensions

- Wing box
  - Spars: fuselage to tip
    - Discrete bars with I-beam profiles
    - Main spar at aerodynamic center
    - Rear spar is attachment point for flaps
  - Ribs
- Wing tips (Hoerner-style wing tip)

Wing tip

Isometric view of wings

- Material
  - Leading edges: cladded aluminum
  - Skin: aluminum
    - Polyurethane top coat and primer
  - Frame: 2017 T4
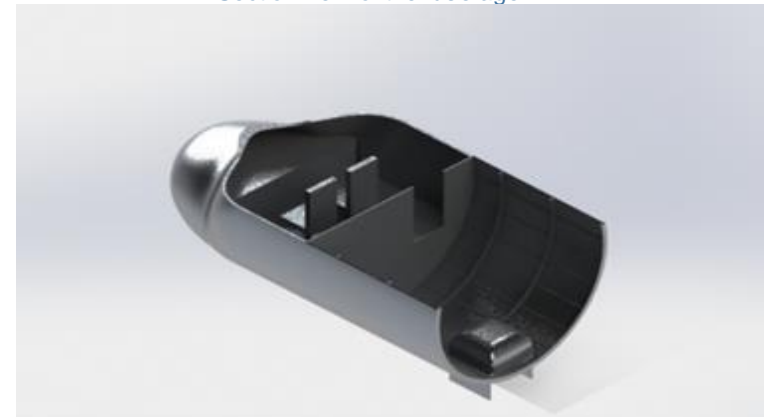
Fuselage

- Structure
  - Semi-monocoque
- Material
  - Aluminum Alloy: 2017 T4
  - Skin: aluminum
    - Polyurethane top coat and primer
    - Epoxy coating (for area exposed to fire retardant
- Design
  - Fineness ratio: 7.4
  - Radome Design
  - Cockpit similar to A350

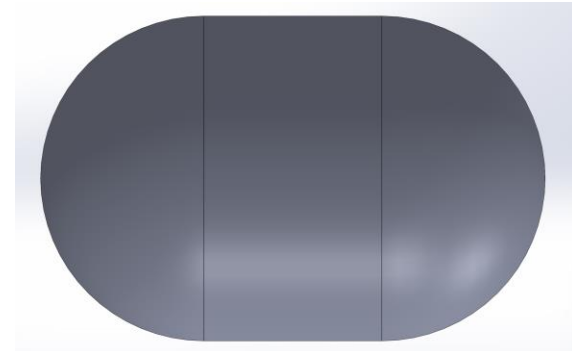Mid and Tail section of the fuselage

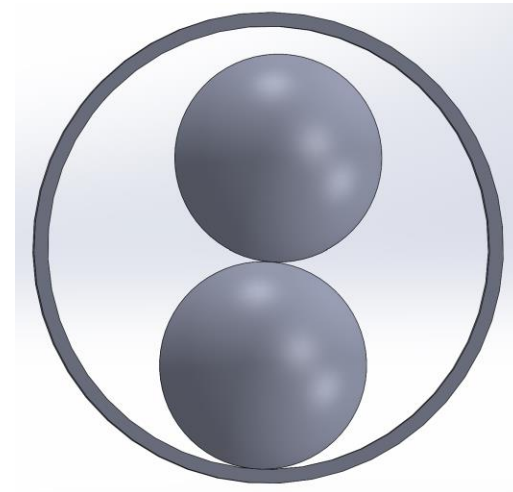Section view of the fuselage

Section view of the fuselage(front)

Fire Retardant Tanks

- Two tanks, each with 3,002-gallon capacity
- Each tank has a 7.5 ft diameter, length of 139 inches
- Compressed air
- Sloshing
  - Top then bottom tank emptied
- Placed at center of gravity
- Retardant refill
  - Manual
  - Using pumps

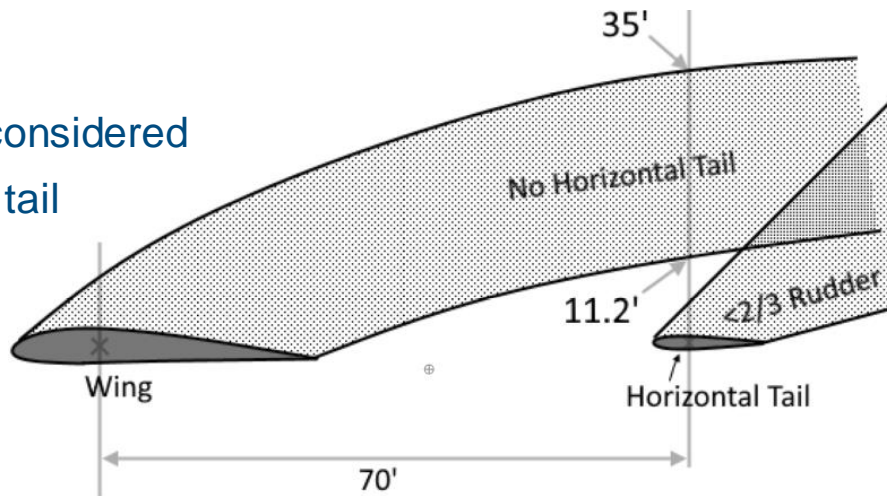Side view of the one fire retardant tank

Cross section of the fuselage with the two fire retardant tanks stacked

Tail Design

- Configurations considered
  - Conventional tail
  - Cruciform tail
  - T-tail
  - H-tail

- Why Conventional?
  - Weight
  - Rudder Control: Vertical tail blanketing
  - Elevator Control: Horizontal tail blanketing
  - Possible H-tail reevaluation

35'

No Horizontal Tail

11.2'

<2/3 Rudder

Wing

Horizontal Tail

70'

Probable turbulent wakes, which will 'blanket' tail surfaces in a stall.
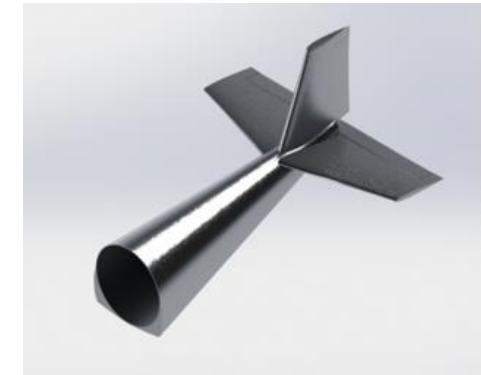
Isometric view of the tail assembly, including the control surfaces
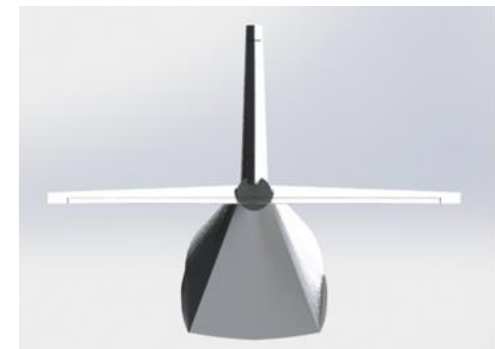
Rear view of the tail and fuselage assembly

Flight Controls

- Aileron
  - NACA 23018
  - Taper Ratio: 0.45
  - Mean chord: 3.77 ft
  - 50%-90% span of wing
- Elevator
  - NACA 0008
  - Mean chord: 4.22 ft
  - 10%-90% span of horizontal stabilizer
- Flaps
  - 0%-40% depth
  - ~50 ft
- Rudder
  - NACA 00018
  - Mean chord: 3.97 ft
  - 0%-90% span of vertical stabilizer

Initial design of wing with flap

Fuel System

- One tank in each wing
- Within the wing box
- 8,163-gallon total fuel capacity per tank(2)
- JPA1 Jet Fuel (most readily available)
- Maintain flight time of 7.5 hours
- 14,600 lb/hr of fuel burn

Truck carrying Jet A-1 Jet Fuel at airport

Landing Gear

Side view of the aircraft assembly

- Type VII 34 x 11 tires for main tires
  - 8 tires
  - 122.87 in^2 contact area
  - 13.95 in rolling radius
  - Load: 19,400 lbs per tire
- Type VII 30x8.8 tires for the nose
  - 2 tires
  - 83.09 in^2 contact area
  - 12.95 in rolling radius
  - Load: 14,000 lbs per tire
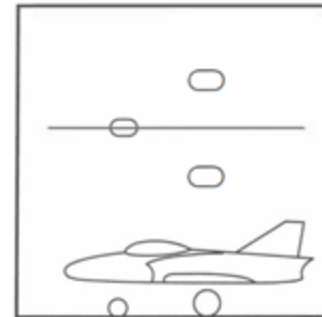
Tricycle landing gear configuration

Oleo strut

SIZE	CONSTRUCTION			SERVICE RATING				TREAD DESIGN/ TRADEMARK	PART NO	WEIGHT (LBS)
	PLY RATING	TT OR TL	RATED SPEED (MPH)	RATED LOAD (LBS)	RATED INFLATION (PSI)	MAXIMUM BRAKING LOAD (LBS)	MAXIMUM BOTTOMING LOAD (LBS)			
30x8.8	16	TL	225	14,200	200	21300	42600	Flight Leader	309F62G1	53.1
34x11	22	TL	225	20,500	185	30750	61500	Flight Leader	341F22-2	81.4

Specifications of tires from GoodYear

Goodyear (https://www.aps-aviation.com/wp-content/uploads/goodyear-aircarft-tire-data.pdf)

Powerplant and Propeller Design

- Europrop TP400-D6
- 4 total
- 14,850 Shaft Hp each
- Dash speed 400 kts
- Range 3086 nm (4,800 nm from operating base)
- Power to weight ratio:4.41 kW/kg
- Dry Weight: 1,900 kg (4,189 lb)
- TSFC: 0.175-0.561
- Can take Jet A, Jet A1, Jet B, JP4, JP5, JP8
- # of blades: 8
- Length of blade: 15.64 ft

Picture of the three-shaft turboprop Europrop TP400 engine

8-bladed propeller configuration

Economics

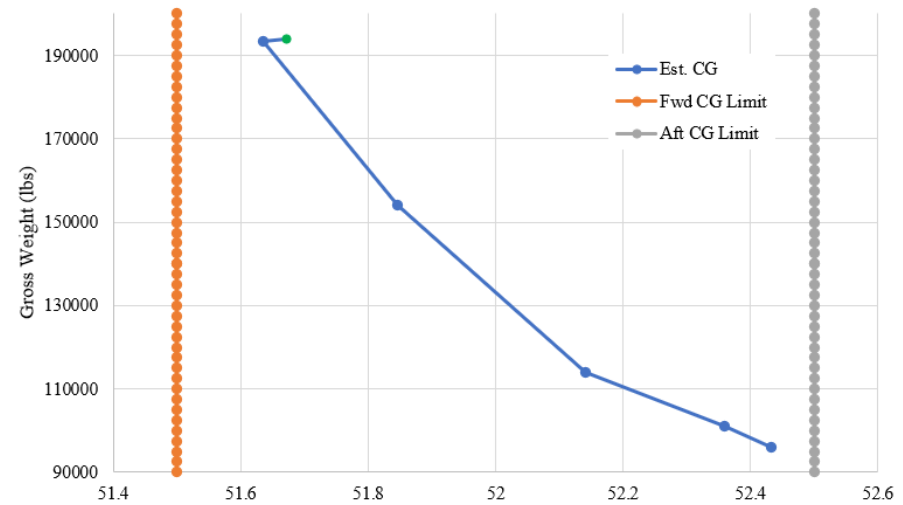| $905	$568	$92M
Crew (three)	Material (per fh)	Manufacturing
$1.5M	$445	$6.2B
Powerplant	Maintenance (per cycle)	Total

Break Even Price: $123.5M

(for a 50 aircraft production run)

Weight Estimation

- Total Takeoff Weight: 193,719 lbs

- After drop 1: 154,047 lbs

- After drop 2: 114,101 lbs
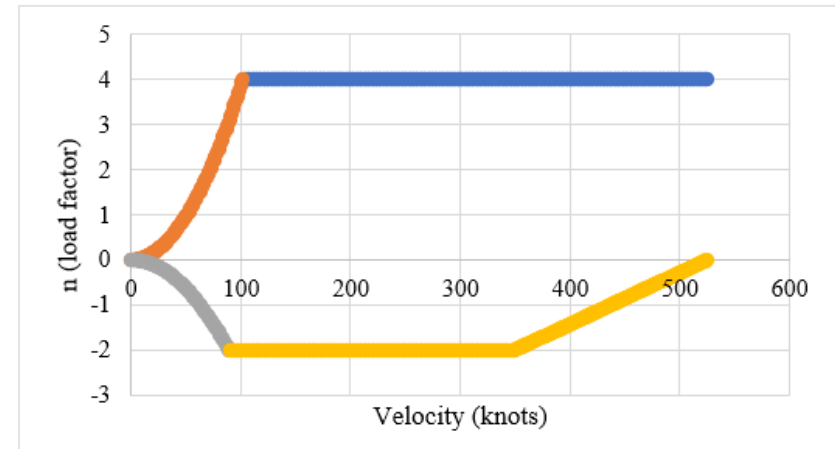
- Total Empty Weight: 90,578 lbs

Center-of-gravity envelope diagram

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Final Design

- Length: 136.84 ft
- Height: 38 ft
- Wingspan: 200 ft
- Gross Weight: 192,712 lbs
- Engines: 4 Europrop T400
- Crew: 3
- Balanced Field Length: 5,000-8,000 ft
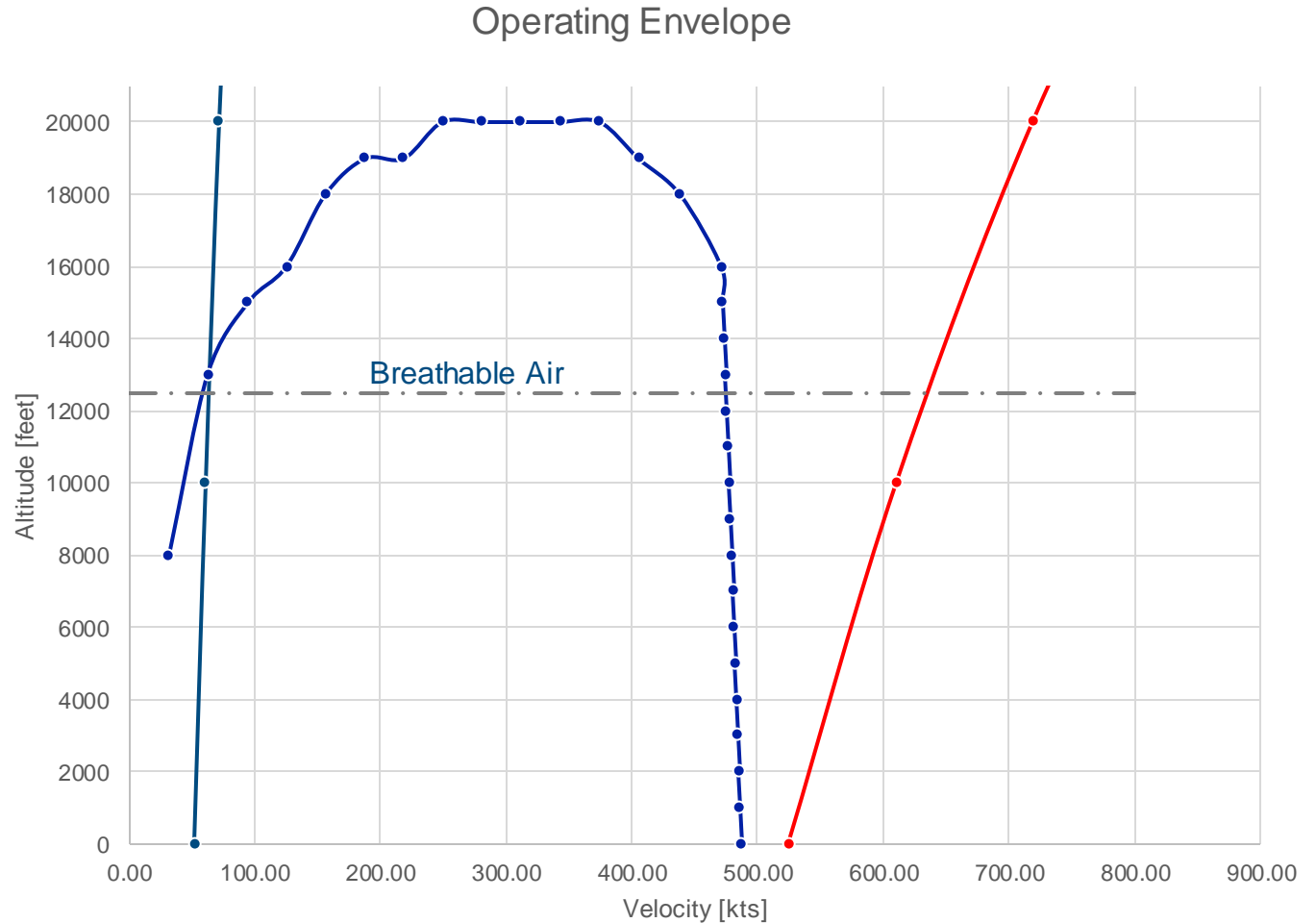- Ferry Range: 3,096 Nautical Miles

V-n diagram using calculated based on the values

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Operating Envelope

- Air breathability
- Ps=0
- q-limit
- Stall limit
- Dash speed

Operating Envelope

FIREFLY

THANK YOU