Solaris XIL-1

Team APPA (Foxtrot)

AE 420 Aircraft Preliminary Design

Meet the Team

Annabelle Stube
Project Engineer,
Stability Analyst

Kiana Arroyo
Cost & Aerodynamics
Analyst

Percy Solomon
Constraint &
Structures Lead

Kevin Nadolne
CAD & Simulation Lead

Alex Chidester
Performance Lead

Primary Mission

- Create the environmentally conscious aircraft of the future

- Stakeholders:
  - Fractional Owners and Operators

Primary Mission

Stakeholder Desires

Address gap in short range routes within the United States

Introduce competition and luxury options to train travel for short range routes in Europe

Improve fuel efficiency and reduce environmental impacts

Reduce maintenance and operational costs

Mission Requirements

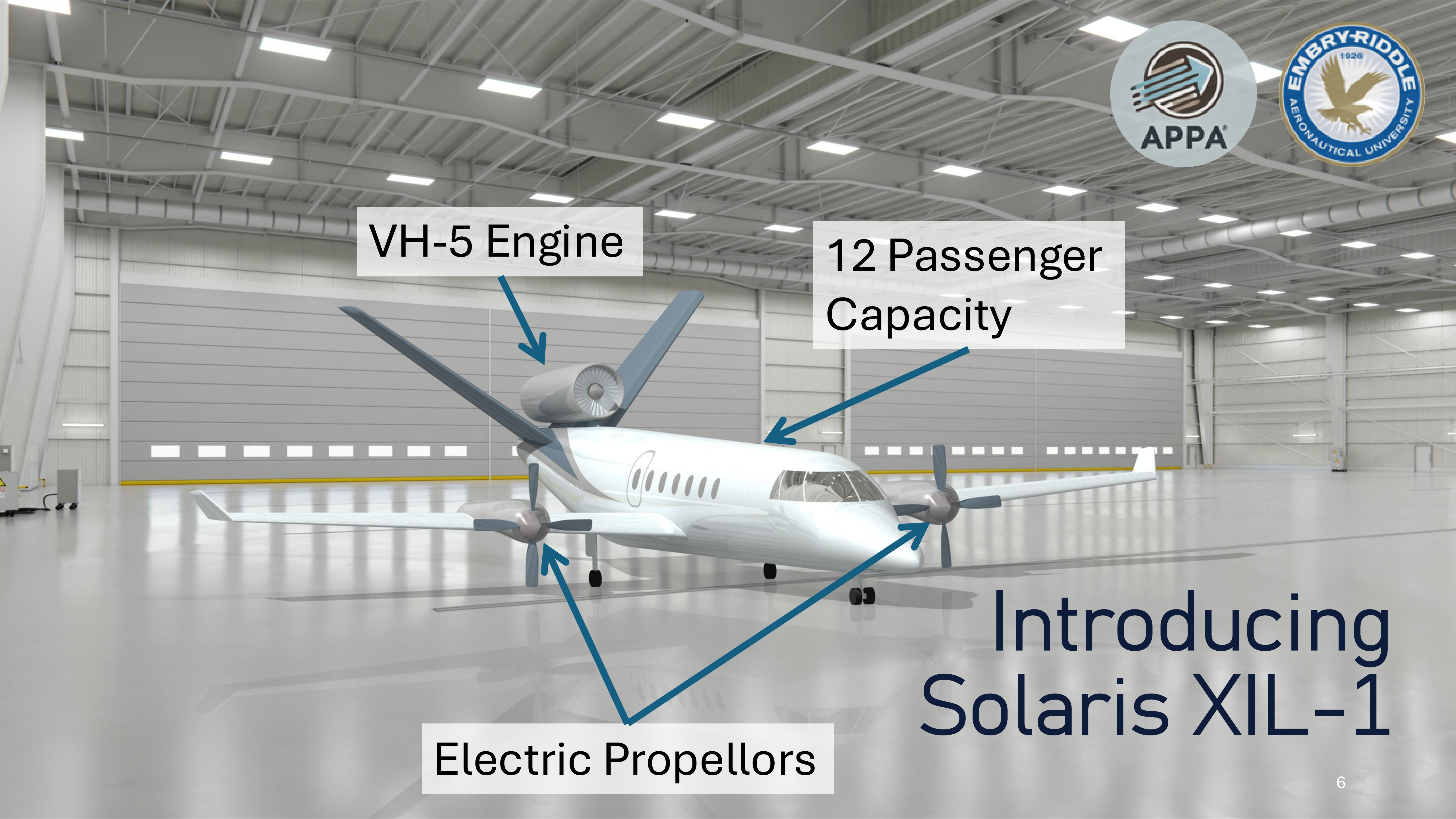
12 passenger capacity

Range of 1500 nm, optimized for 500 nm

Hybrid-electric design

Introducing Solaris XIL-1

Introducing Solaris XIL-1



Aircraft Regulations

- The Solaris XIL-1 is fully compliant with FAA 14 CFR Pt. 23, Level 4, High Speed
- Allows for faster flight and ensures stringent safety measures

14 CFR Part 23 Regulations [1]		Solaris XIL-1	
Level 4 Passenger Range	10 to 19	Passenger Capacity	12
MTOW	≤ 19,000 lbs	MTOW	18,900 lbs
High Speed Category	Max Speed ≥ 250 KCAS	Max Operating Speed	300 KCAS

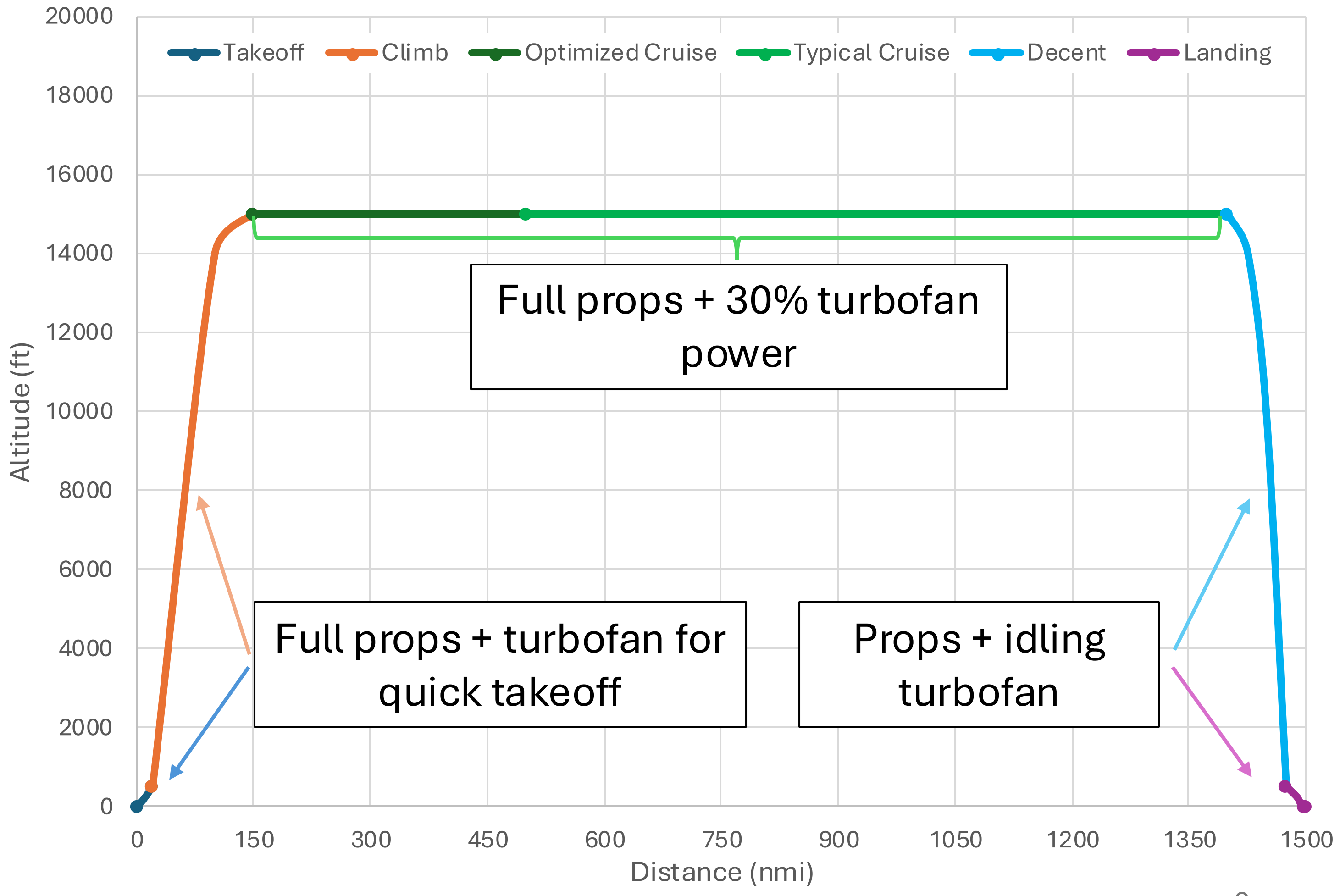
Requirements

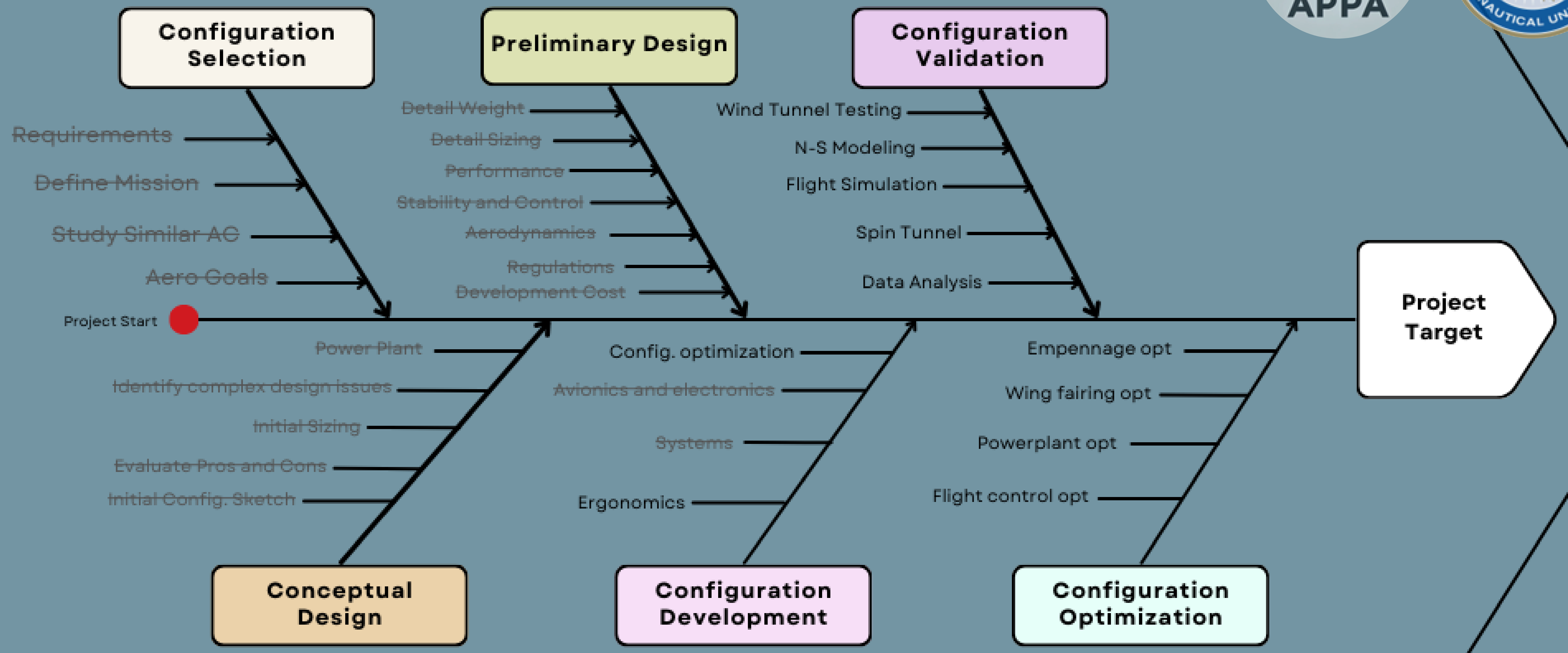
Requirements set by the team and their achievement:

Requirement	Met?	Design Achievements
Fully compliant with FAA regulations	Yes	FAA 14 CFR PT. 23 – Lvl. 4 High Speed
Environmentally conscious design	Yes	Hybrid – Electric Propulsion System
10 to 20 Passenger capacity	Yes	12 Passenger Capacity
Range of 1500 nm, Optimized for 500 nm	Yes	Achieved
Fully stable aircraft at all conditions	Yes	Achieved

Mission Profile

- Cruise altitude of 15,000 ft
  - Reduces climb and descent time
  - Improves fuel & propellor efficiency
- Optimizes for short-haul flight

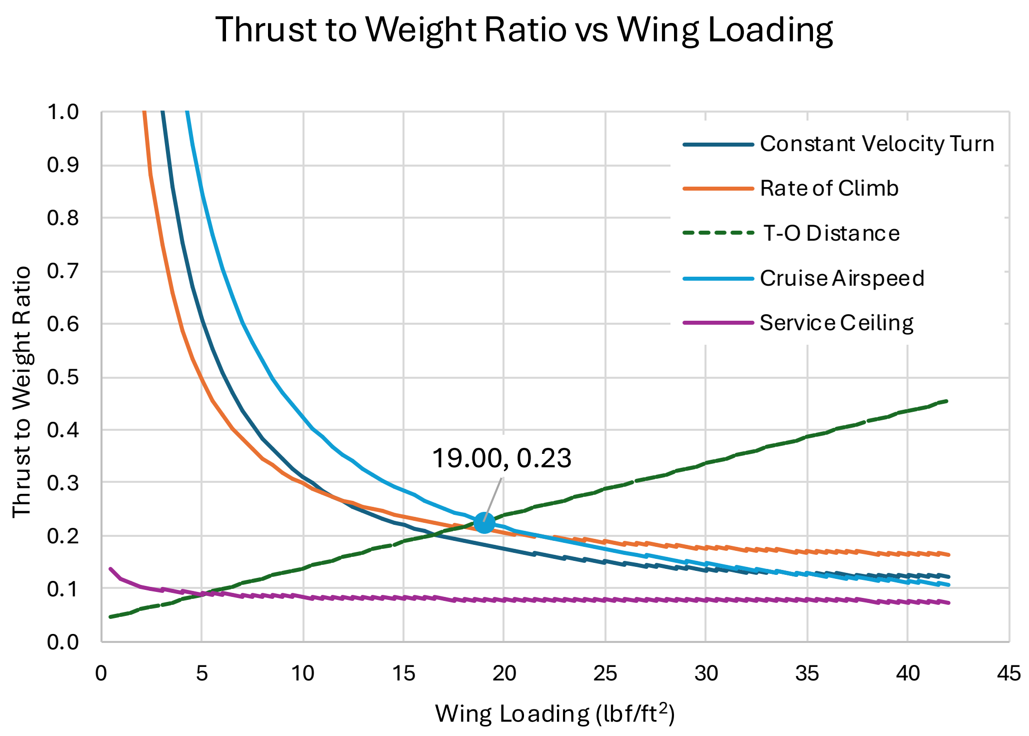




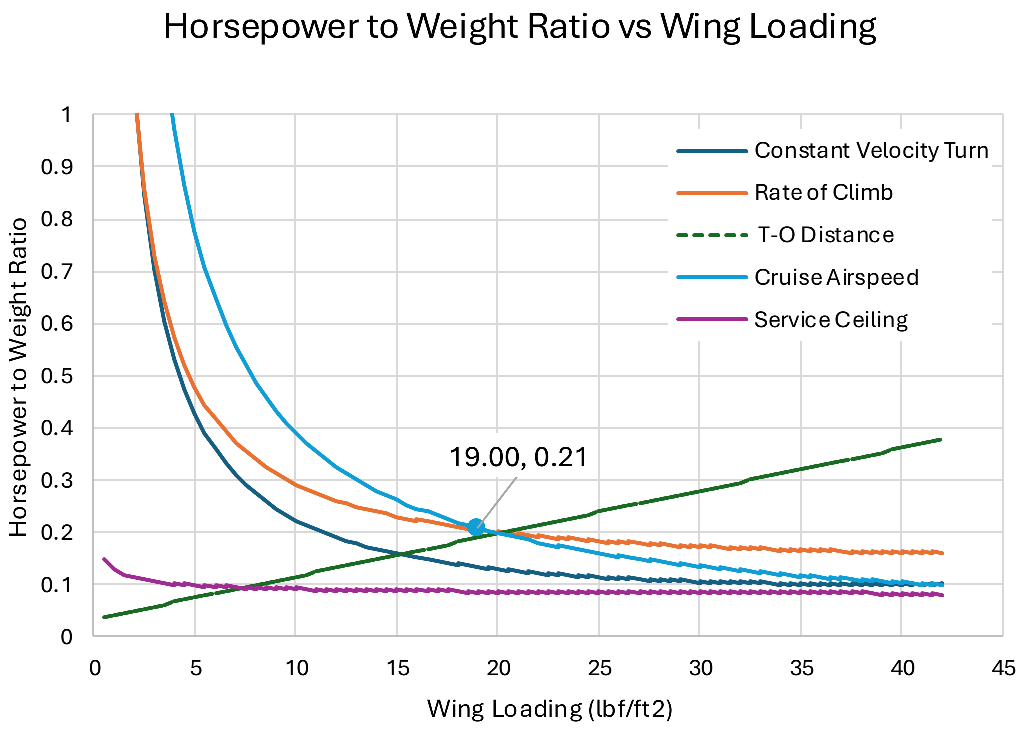
Configuration Selection
~~Requirements~~
~~Define Mission~~
~~Study Similar AC~~
~~Aero Goals~~
Preliminary Design
~~Detail Weight~~
~~Detail Sizing~~
~~Performance~~
~~Stability and Control~~
~~Aerodynamics~~
~~Regulations~~
~~Development Cost~~
Configuration Validation
Wind Tunnel Testing
N-S Modeling
Flight Simulation
Spin Tunnel
Data Analysis
Project Start
Project Target
~~Power Plant~~
~~Identify complex design issues~~
~~Initial Sizing~~
~~Evaluate Pros and Cons~~
~~Initial Config. Sketch~~
Conceptual Design
Config. optimization
~~Avionics and electronics~~
~~Systems~~
Ergonomics
Configuration Development
Empennage opt
Wing fairing opt
Powerplant opt
Flight control opt
Configuration Optimization

Constraint Analysis

Thrust wing loading

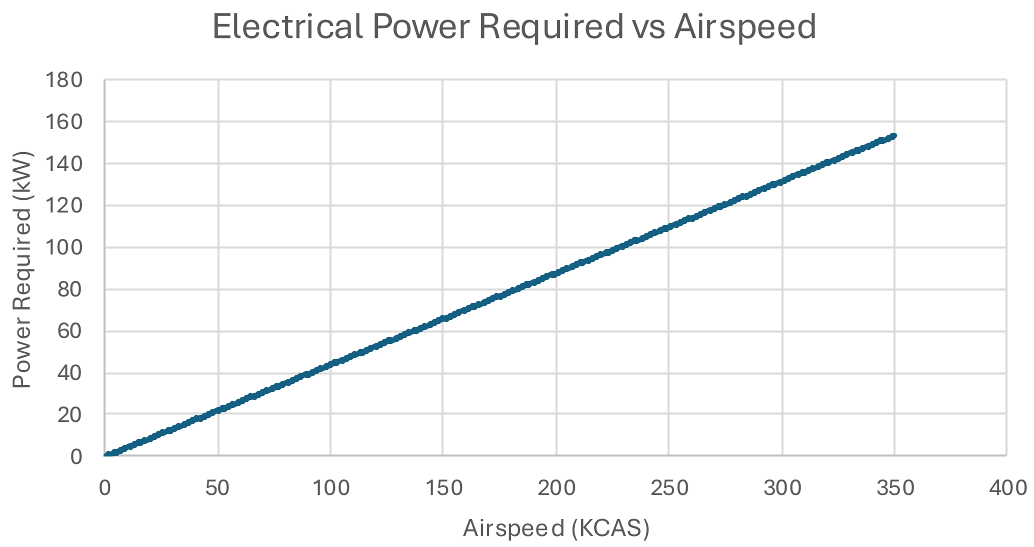


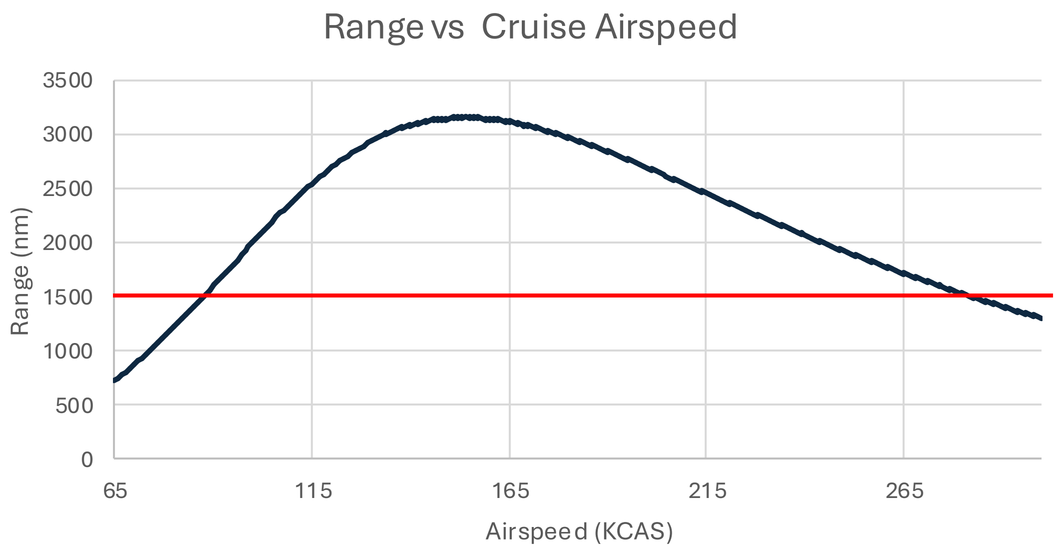
Power wing loading



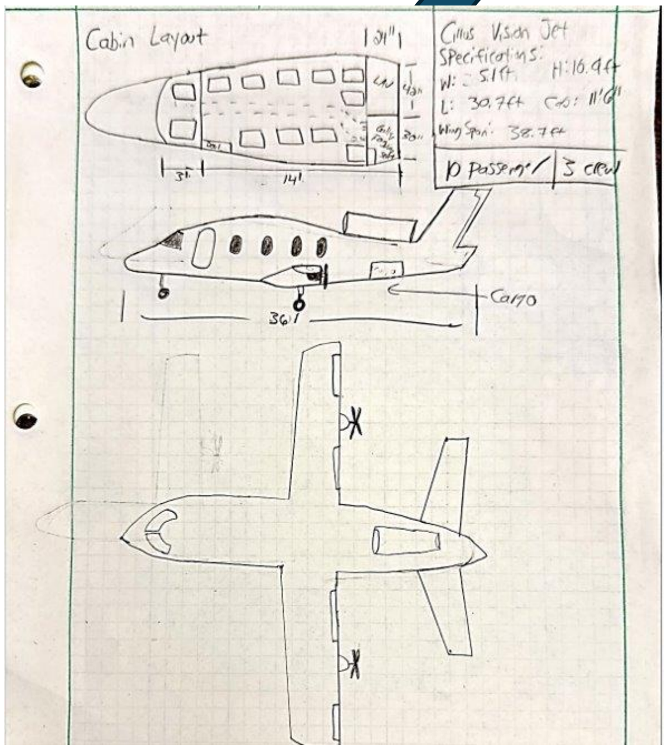
Trade Studies

- Analyzing the Effects of Cruise Airspeed on Range and Electrical Power Required

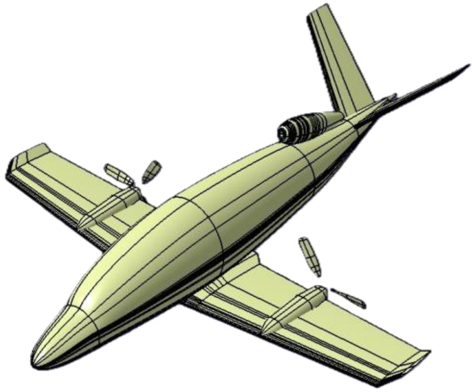




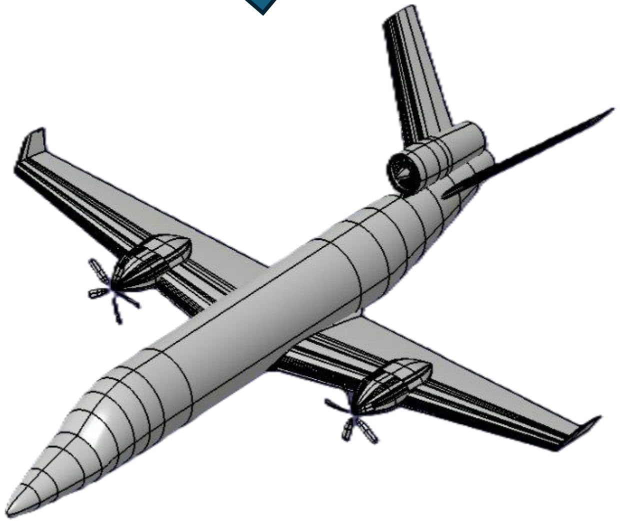
Configuration Progression



Initial Design



DR-01

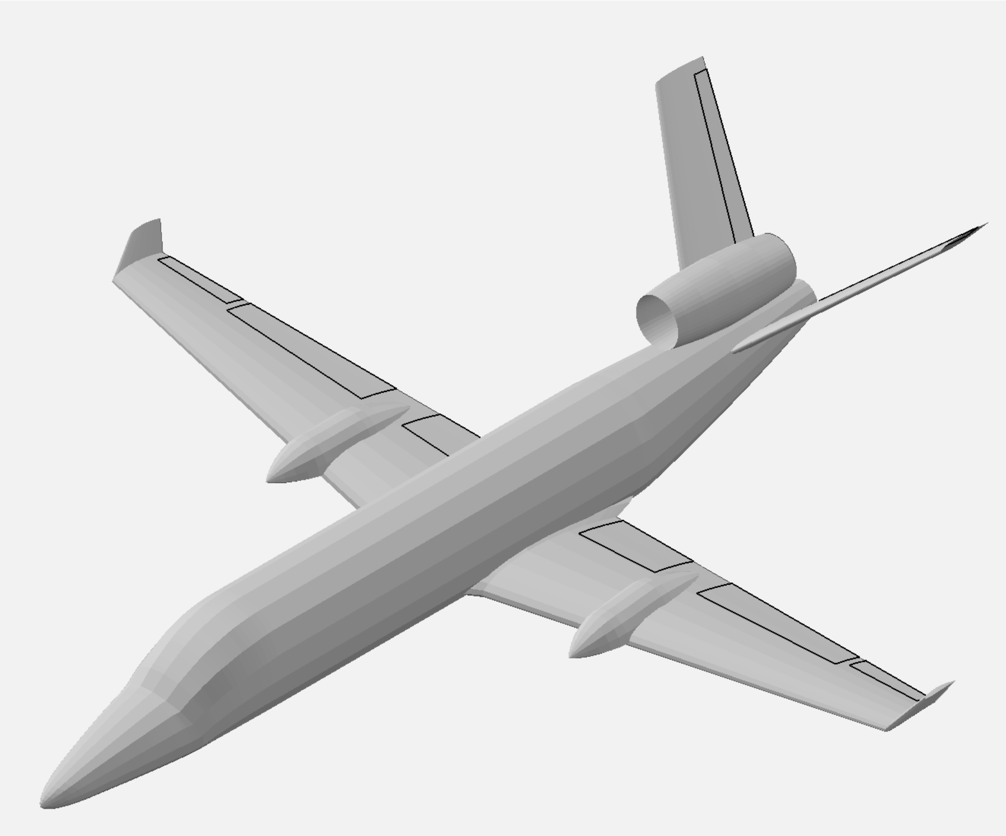


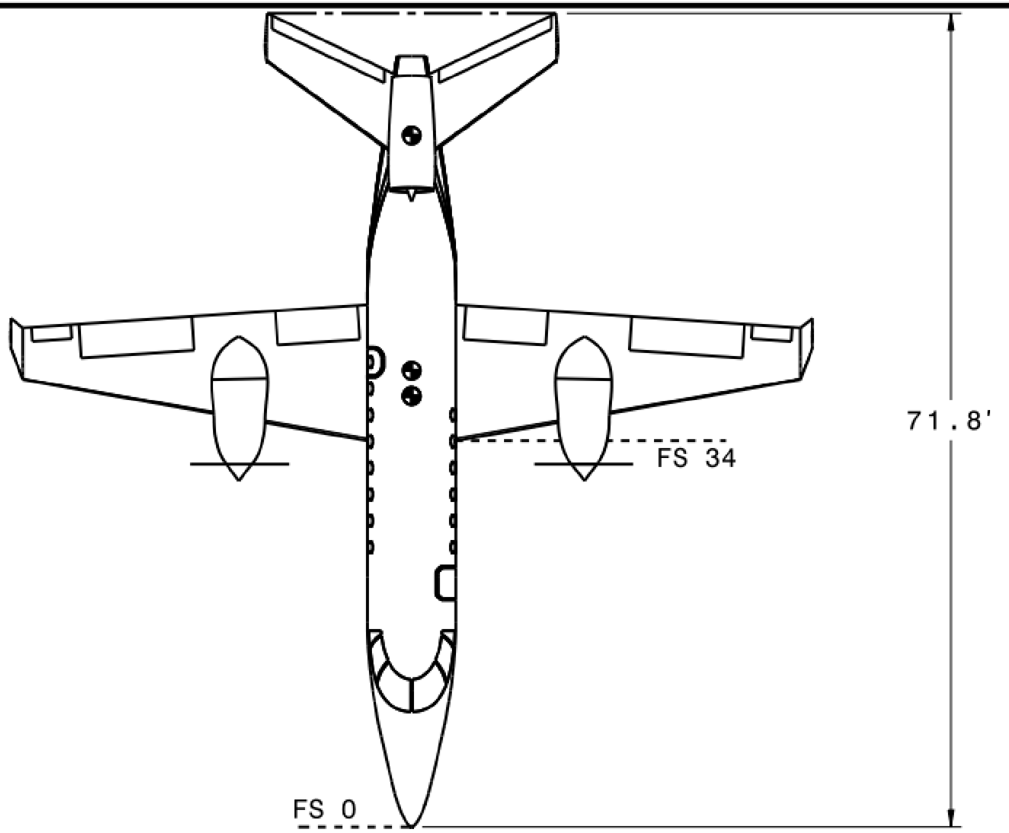
DR-02

Aircraft Modeling

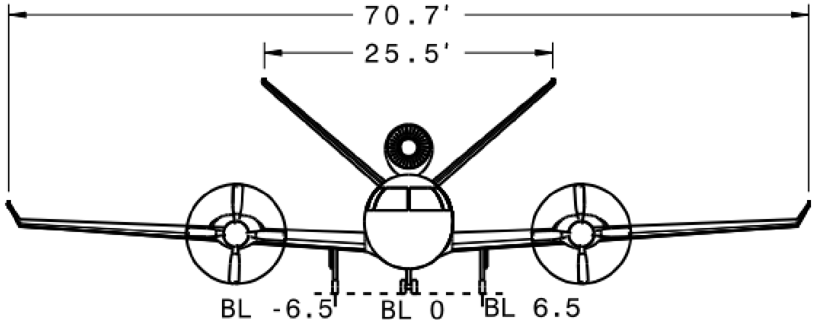
CATIA Rendering

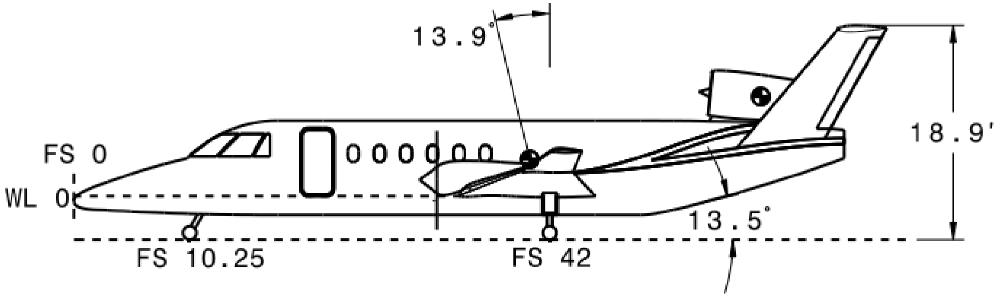
VSP Rendering





SURFACE	WING	V-TAIL
SPAN (FT)	70.7	33.0
AREA (FT^2)	476	194
MAC (FT)	7.36	6.0
ROOT CHORD (FT)	10	7.5
TIP CHORD (FT)	3.8	4.3
AIRFOIL	NACA 4415	NACA 0009





LONGITUDINAL M = 0.4 FL150	CL	CD	CLa	CDa	Cma	CLq	Cmq	CLM	CDM	CmM	CLde	CMde
	0.390	0.0196	6.67	0.220	-1.41	11.1	-10.8	0.22	0.0	0.0	-0.481	1.06

LATERAL M = 0.4 FL150	CyB	ClB	CnB	Clp	Cnp	Clr	Cnr	Clda	Cnda	Cydr	Cldr	Cndr
	-0.0664	-0.137	-0.059	-0.565	-0.015	0.179	-0.154	0.133	-0.0072	-0.0965	-0.0668	0.117

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY
DAYTONA BEACH, FLORIDA

TEAM NAME:	PART NAME:
APPA - FOXTROT	SOLARIS XIL-1

DRAWN BY:	CLASS SECT:	DATE:	SHEET
KEVIN NADOLNE	AE 420 - 02	04 - 13 - 2025	1/1

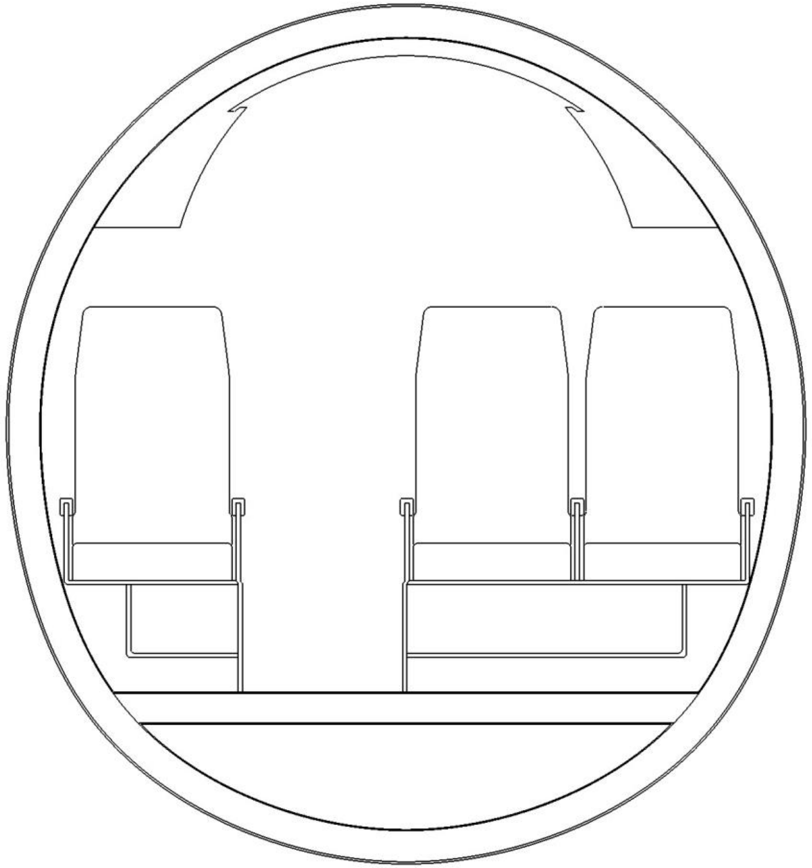
Economy Seating Layout

Cabin Cross Section

- Cabin Height – 74”
- Cabin Width – 85”

Economy 2x1:

- Seat Width – 18.3-18.5”
- Seat Pitch – 34”
- Aisle Width – 18.5”
- 12 seats

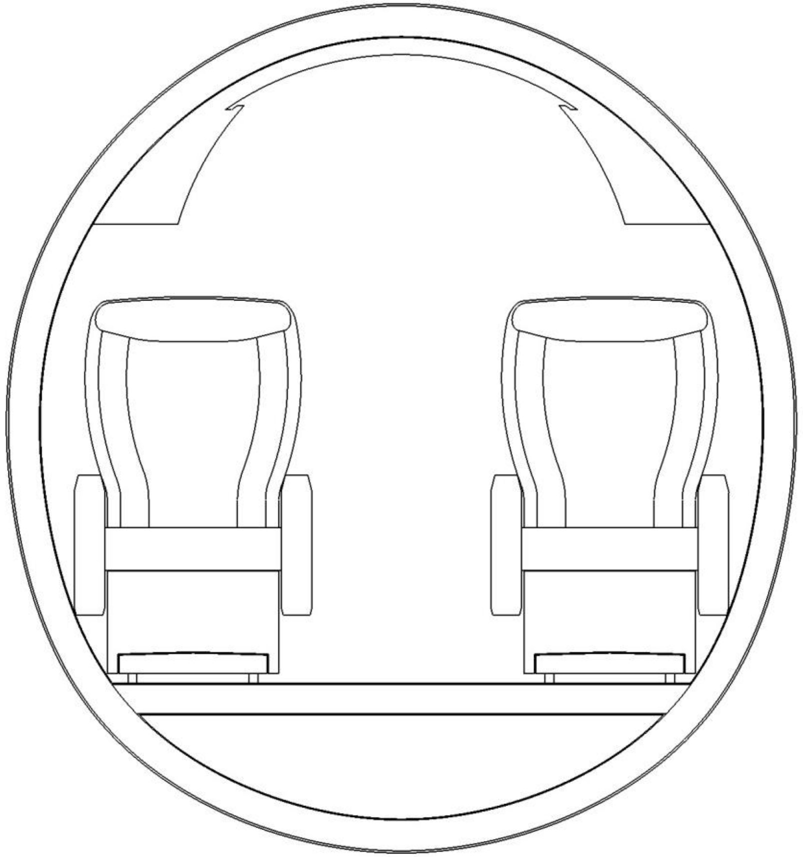


Business Seating Layout

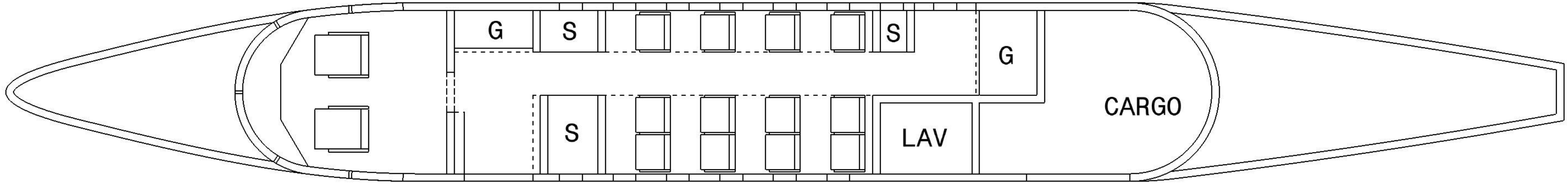
Business 1x1:

- Seat Width – 20.7”
- Seat Pitch – 43”
- Aisle Width – 21”
- 8 seats for Business
- 4 Seats for Combi

No Overhead Storage



Internal Layout



2 Pilot Seats

Jump Seat for Crew

12 Passenger Seats

G – Galley

S – Bag Storage

Lav – Lavatory

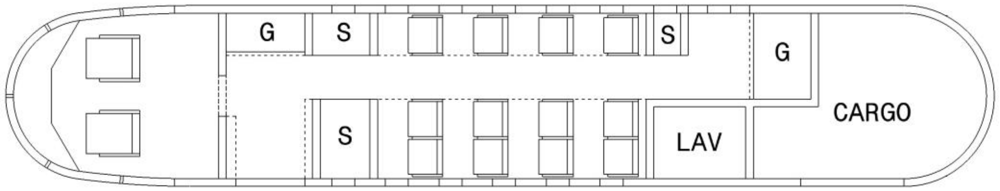
Cargo – No Cabin Access

Seat Pitch – 34" (Econ)

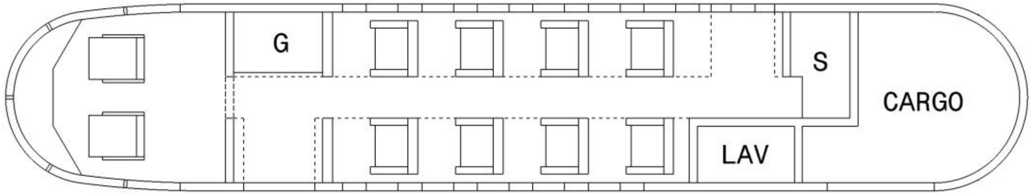
Cabin Length – 32'

Cargo Space – 156 cu ft (Econ)

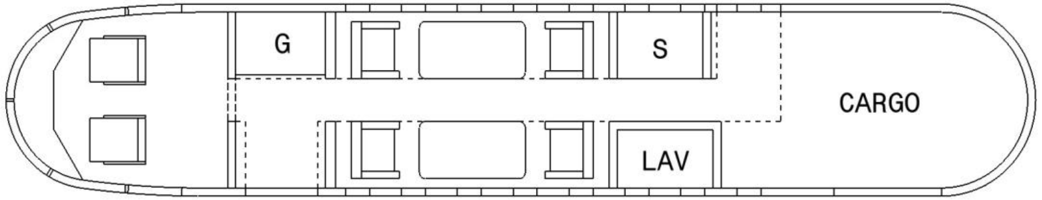
Internal Layout Configurations



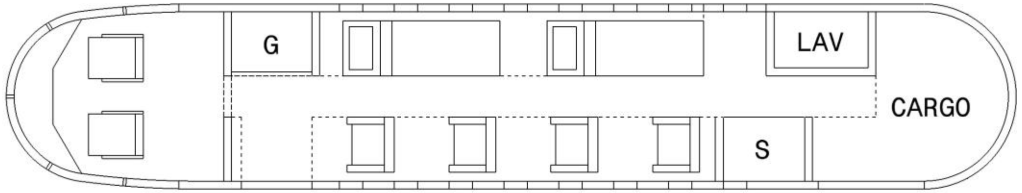
Economy – 12 PAX



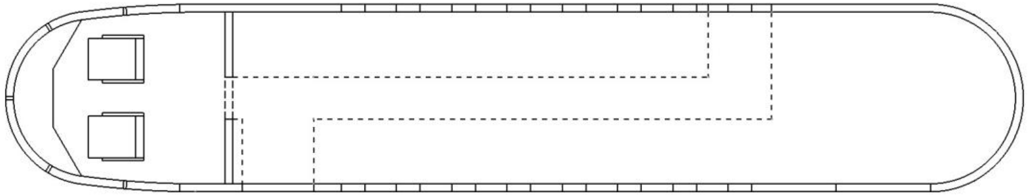
Business– 8 PAX



Combi – 4 PAX



MedEvac – 4 + 2 PAX



Cargo – 1152 cu feet

S – Storage
G – Galley
LAV – Lavatory

Weight Distribution

Battery

Passengers

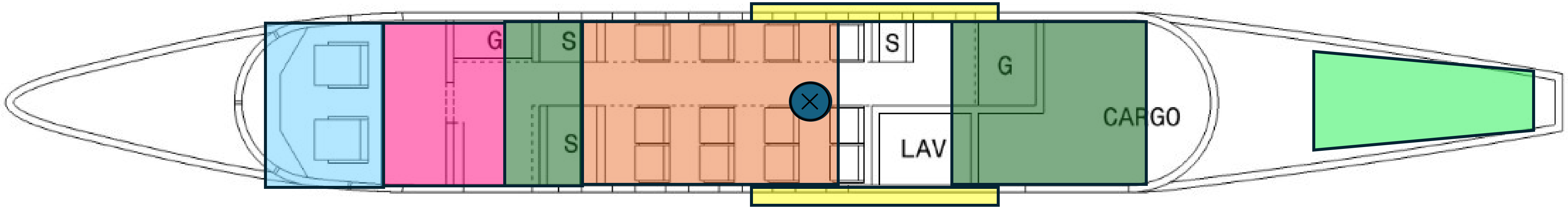
Fuel, Motors & Propellors

Crew

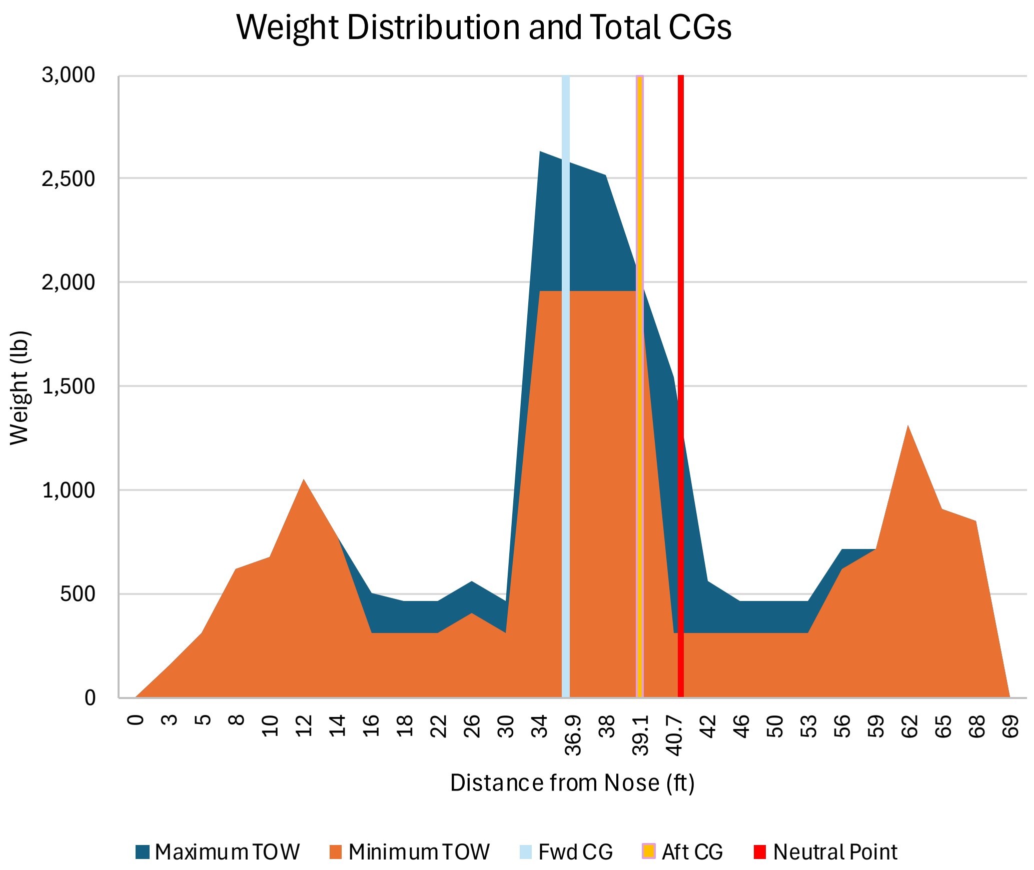
Cargo

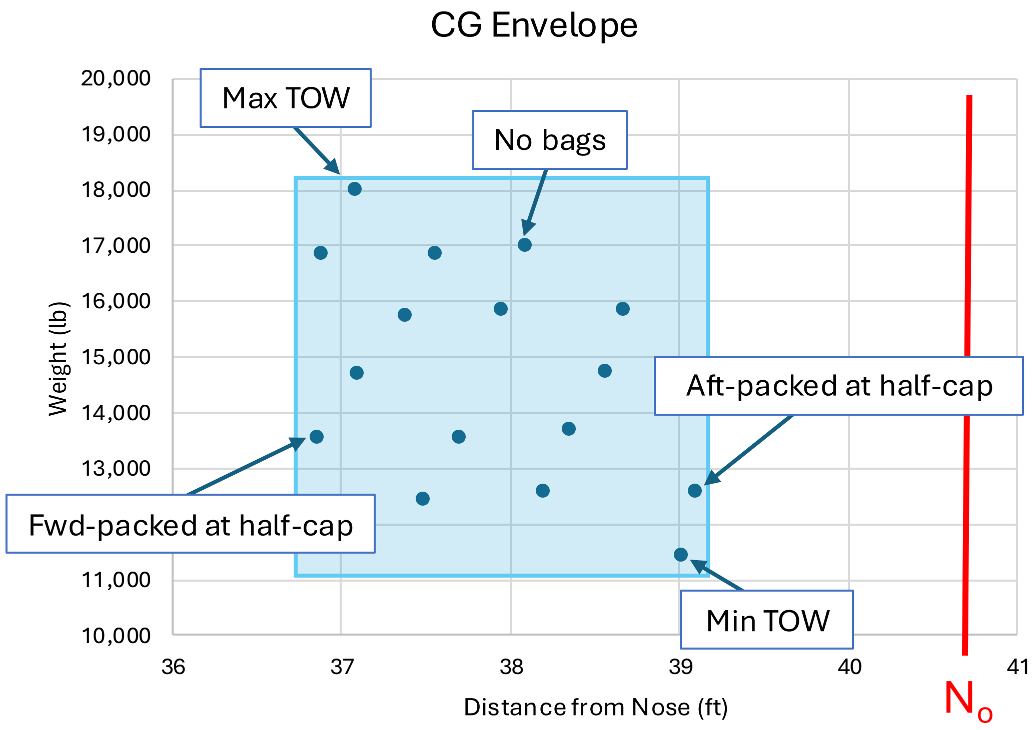
Turbofan

CG



Weight Distribution & CG Envelope



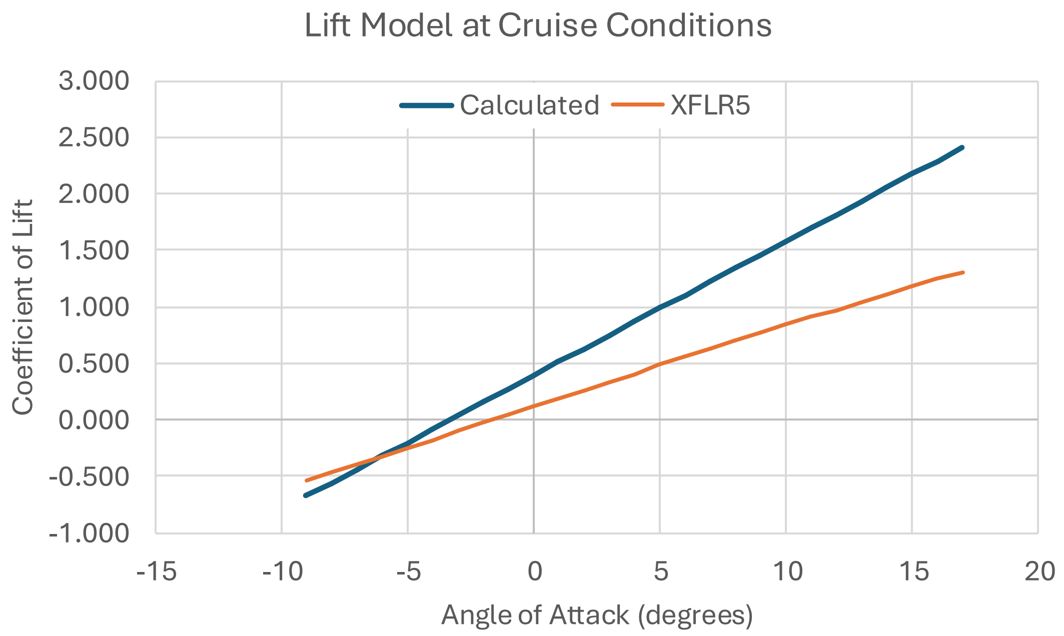


Weight Comparison

Component	Variable	**Solaris XIL-1**	Cessna Sky Courier [2]	Embraer Phenom 300 [3]	Beechcraft King Air-350 [4]
Empty	W_E	**10,875**	12,325	11,793	9,955
Payload	W_P	**3,030**	5,000	2,416	5,145
Design Fuel	W_F	**3,300**	1,519	4079	3,611
MTOW (lbs)	W_0	**18,900**	19,000	18,000	15,000

Lift Model

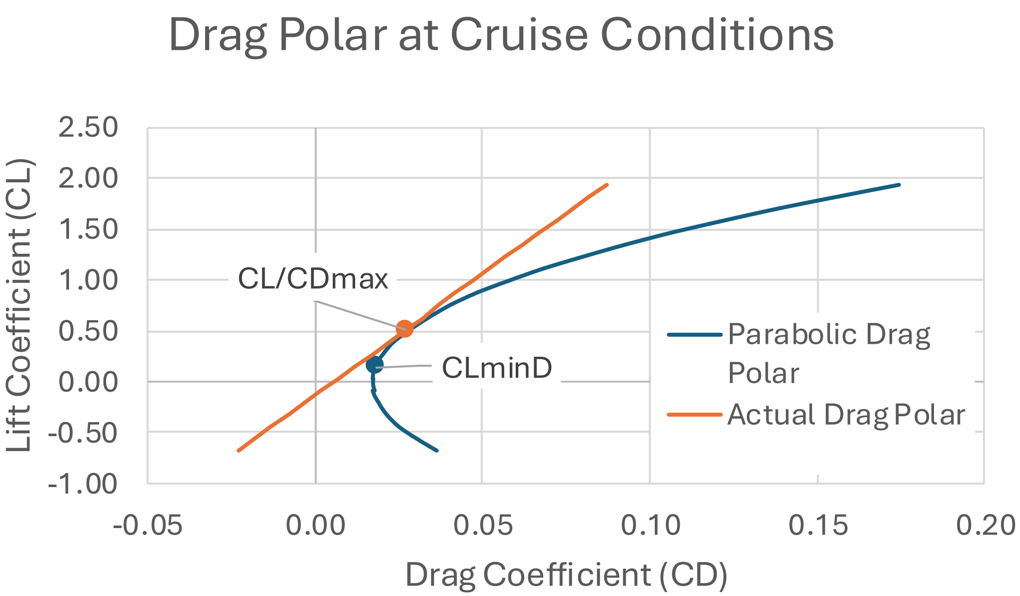
- Utilizing Gudmundsson's Wing and Lift Enhancement
  - Wing: NACA 4415
  - Flaps: Clark Y
    - Fixed-slot airfoil for ailerons
    - Single-slotted fowler flap configuration for elevator



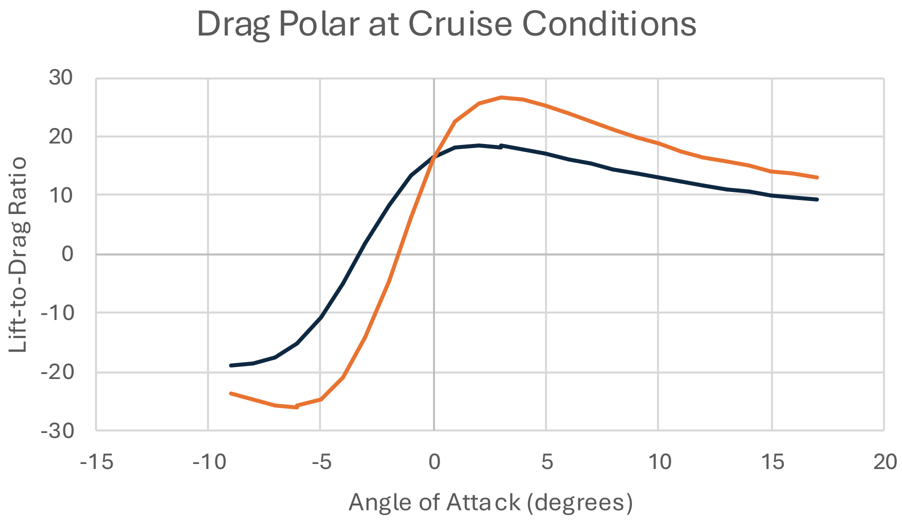
S_w	α_c	α_{stall}	C_L	C_{Lc}	C_{LT-O}	α_{T0}	$C_{L,LDG}$	Weight	Total Lift
476.1ft^2	0º	21º	0.260	0.190	1.50	5.1º	1.60	18,875 lb	18,973 lb

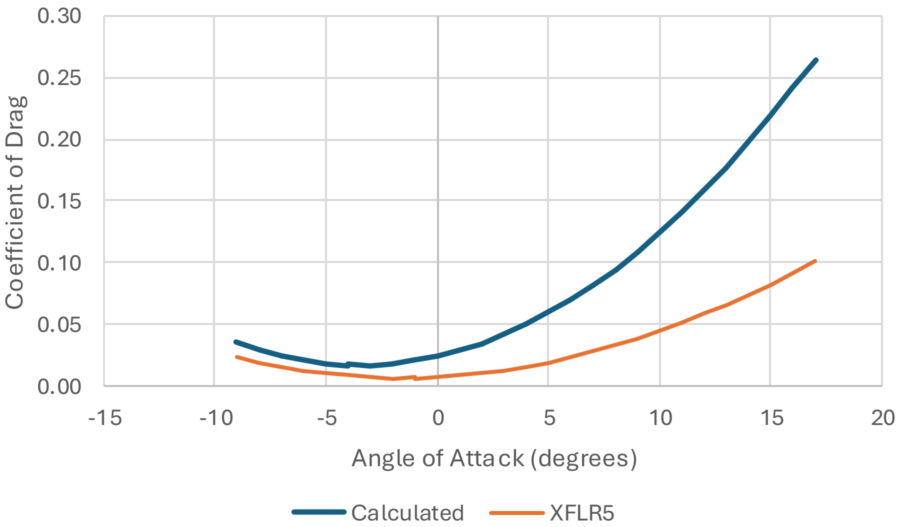
For the entire Aircraft at cruise conditions

Drag Model



Variable	Value
CL_{minD}	0.10
CD_{o}	0.02





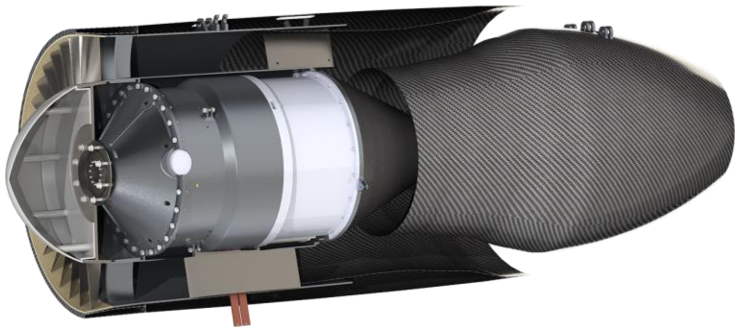
Powerplant Decision Matrix

VerdeGo Aero VH-5 selection

- Met Power and Thrust required
- Low SFC
- Exceptional Electrical Power capabilities
- Sustainability and environmental benefits

Feature	**Weight** 1-5	**Configuration Score** 1- Poor, 2- Ok, 3-Preferred			
		VH-5	TFE731-60	Williams FJ44-4	PW306B
Complexity	3	**2**	2	1	1
Electric Power Generated	5	**3**	1	1	1
Max Thrust	5	**3**	3	2	3
TSFC	4	**3**	2	2	2
Engine Size and Weight	3	**2**	3	2	2
Reliability	3	**3**	2	3	3
Maintenace	2	**2**	3	3	3
Noise	3	**3**	2	2	2
Redundancy	3	**3**	2	2	2
Total	**31**	**85**	**67**	**59**	**64**

Selected Powerplant



Combined Thrust of 5600lbs at SSL

- 40% more then required, allows excellent takeoff performance

VerdeGo Aero VH-5

- Weight (lb): 2100
- Max Rated Thrust (lbf): 3600
- Max Electric Power (MW): 1.5
- TSFC (lb/lbfhr): 0.34

Advantages

- Hybrid Electric
- Low TSFC/PSFC
- Generates Power in series and/or parallel
- Forward Thrust and electrical power during cruise

MAGIDRIVE Model - 500

- Dry Weight (lbs): 220 x 2
- Max Rated Power (KW): 500 x 2

McCauley 4 - Bladed Constant Speed

- Diameter (in): 105
- Propeller Efficiency: 0.85
- Dry Weight (lbs): 100 x 2

Advantages

- Integrated Motor provides less power loss
- High Motor Efficiency (96%)
- Propellers will be able to be feathered
- Large Propellers provide high efficiency

Selected Wiring & Battery

Amprius SiMaxx - High Power
- Power Capacity (kWh): 200
- Battery Weight (lb): 1100lb
- Energy Density (Wh/Kg): 400
- Discharge Rate: 10C
- Cycle Life: >500

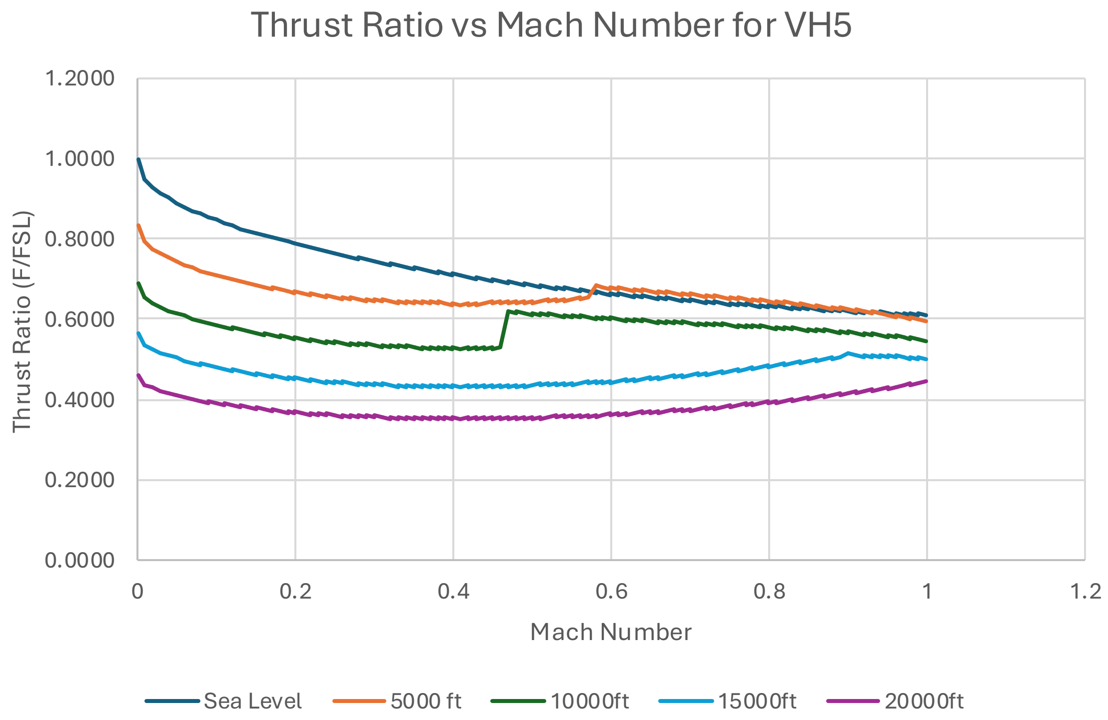
*anticipated by 2040

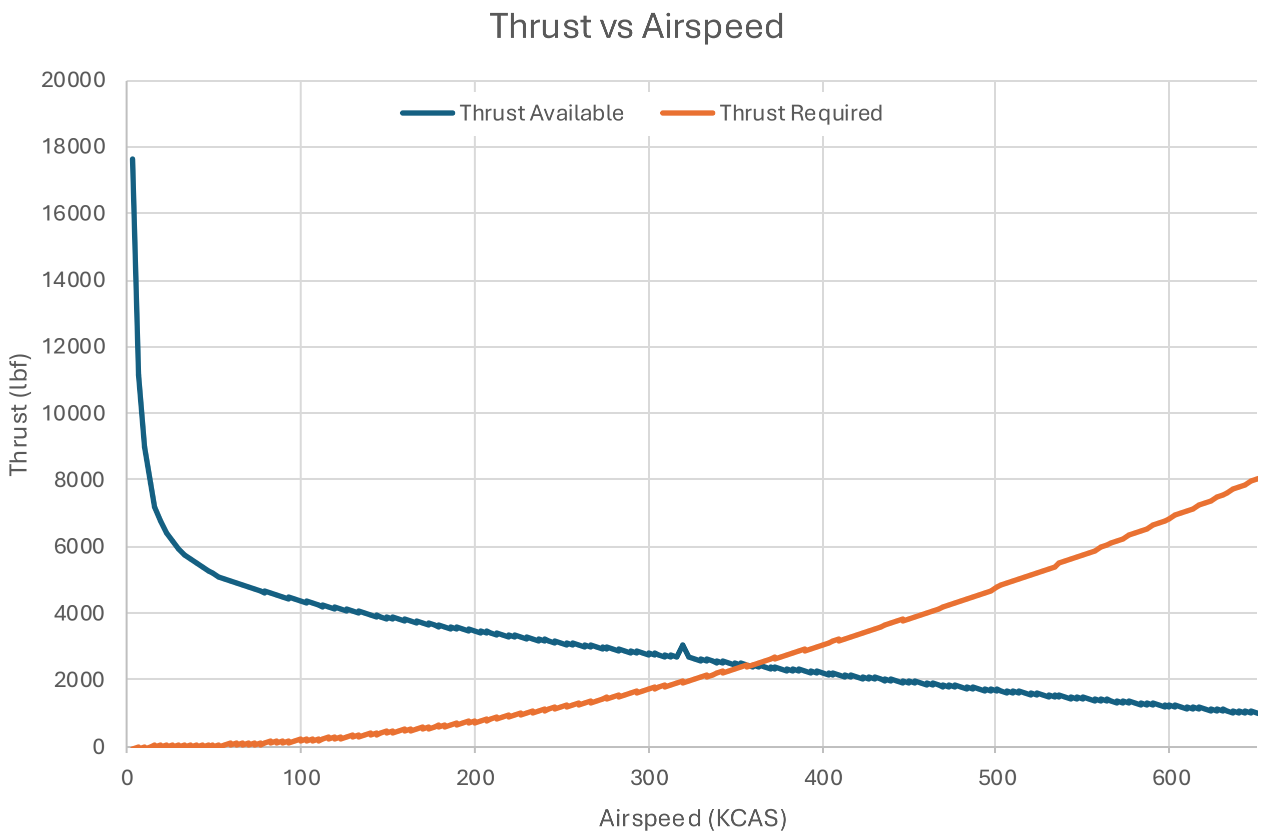
Wiring: Turboflex AWG G961-003
- Length Required (ft): 96.5
- Diameter (in): 0.431
- Weight (lbs): 40.7
- 0.005 V drop/ft
- VAC (volts): 3000
- Material: Copper

Advantages
- Can be charged to 80% in 6 mins
- Provides 15 min of independent Endurance at 100% power
- Can Handle up to 1.2 MW of power
- Durable

Thrust Model

- Analyzed using the Mattingly Model of thrust at cruise
- Maximum Speed ~300kts





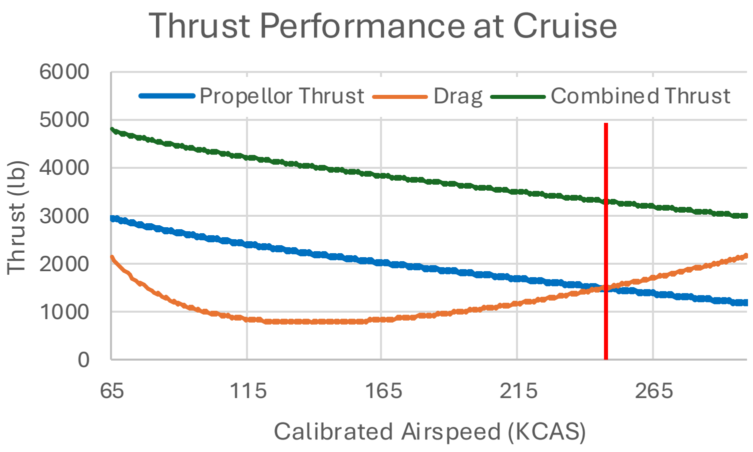
Performance

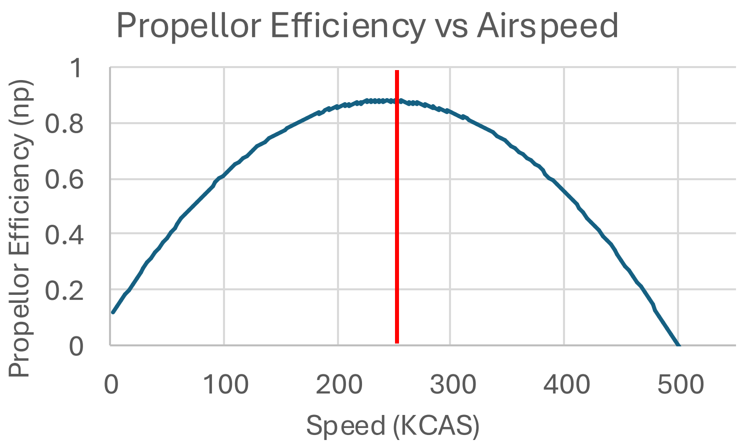
Takeoff	
T/W	0.3
MTOW	18,800 lb
Ground Roll	1,731ft
Takeoff Distance	3,194 ft
Liftoff Speed	98 kts

Climb	
Rate of Climb	2,744 ft/min
Max Climb Angle	10.3 deg
Time to Cruise	7 min
Climb Velocity	190 kts

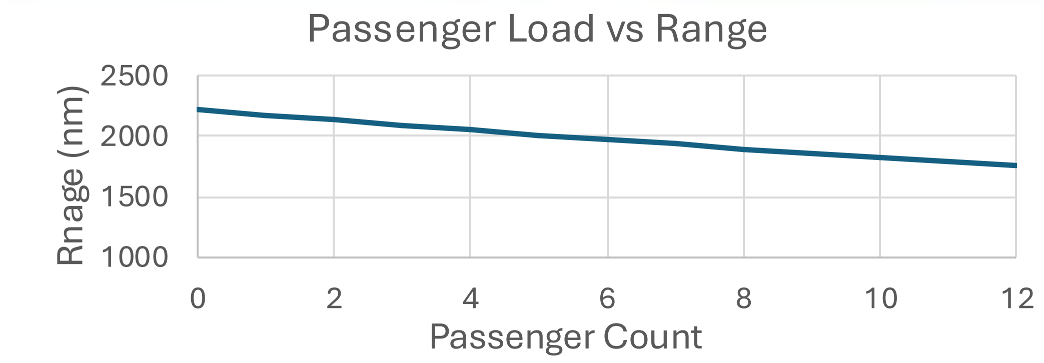
Cruise	
VCruise	250 KCAS
L/D	11.7
Ceiling	22,000 ft
Thrust Required	1,907 lbf
Thrust Available	3,126 lbf

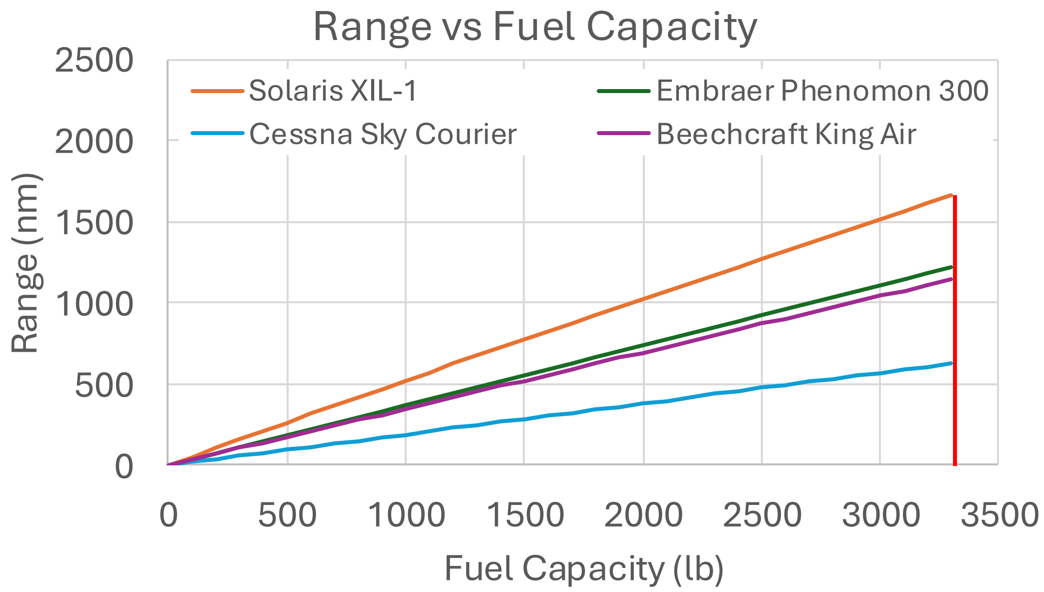
Landing	
Rate of Descent	1,156 ft/min
Min Angle of Descent	2.5
Landing Distance	1,900 ft
Glide Speed	182 kts
Landing Speed	101 kts





Range

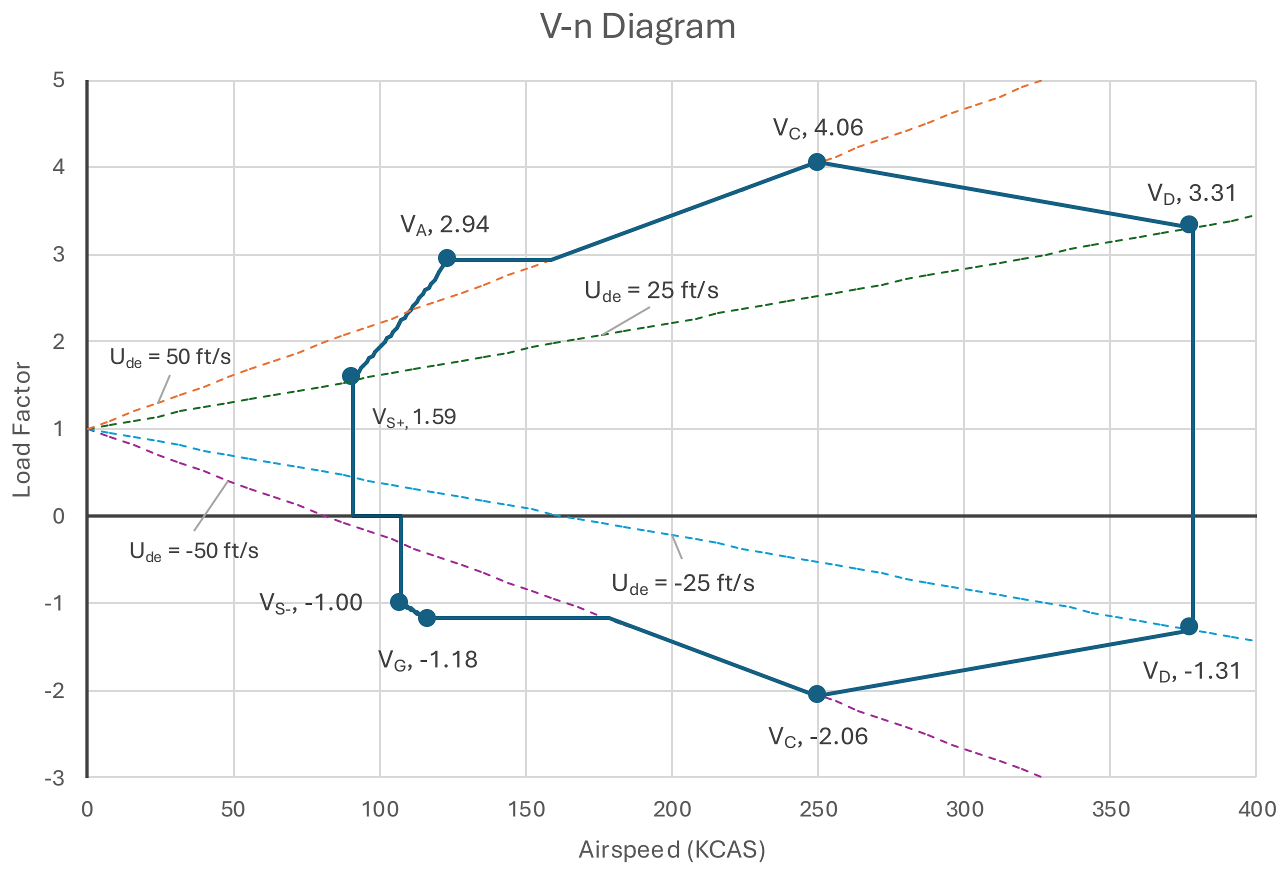




Rival Aircraft	**Solaris XIL-1**	Cessna Sky Courier	Embraer Phenom 300	Beechcraft King Air-350
Range (nm)	**1,500**	900	1,971	1,806
Cruise Speed (KCAS)	**250**	210	464	303
Ceiling (ft)	**22,000**	25,000	45,000	35,000
Fuel Capacity (lb)	**3,300**	4,826	5,353	5,192
Passengers	**12**	19	9	11

- 15 mins Battery Power and 300 lb of fuel for redundancy
- 2200 nm of Ferry Range

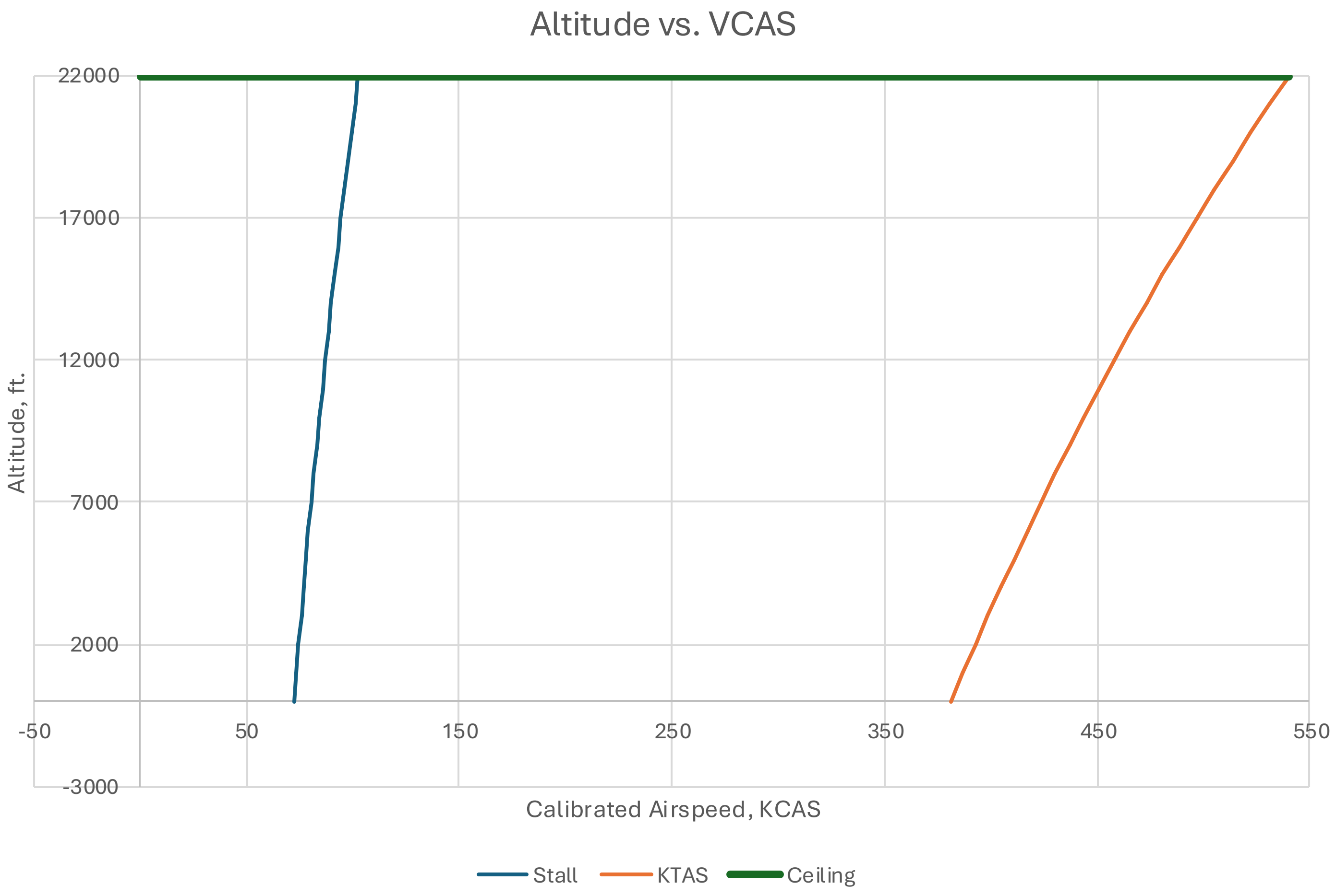
V-n Diagram



Parameter	Value	Unit
Positive Load Factor	2.94	g
Negative Load Factor	-1.18	g
Positive Stall Speed	90.66	knots
Negative Stall Speed	107.28	knots
Manuevering Speed	155.46	knots
Negative Maneuvering Speed	196.44	knots
Cruise Speed	250	knots
Dive Speed	378	knots

Flight Envelope

- Max weight
- Maximum altitude 22,000 ft



Stability and Controls

- Aiming for stable cruising conditions
- Decreased maneuverability for increased stability
- Increased passenger comfort and safety
- Higher controllability

Type	Variable	Analytical (per °)	VSP (per °)	Stable?
Longitudinal	$C_{M\alpha}$	-0.0321	-0.0478	Yes
Sideslip	$C_{Y\beta}$	-0.0079	-0.0113	Yes
Directional	$C_{N\beta}$	0.0026	0.0025	Yes
Lateral	$C_{L\beta}$	-0.0017	-0.0019	Yes

Mode	Natural Frequency (1/s)	Damping Ratio
Short Period	8.95e-4	1.25e4
Phugiod	0.335	1.04e-2
Dutch Roll	3.4e-4	2.2e2
Spiral Stability	Spirally Stable	

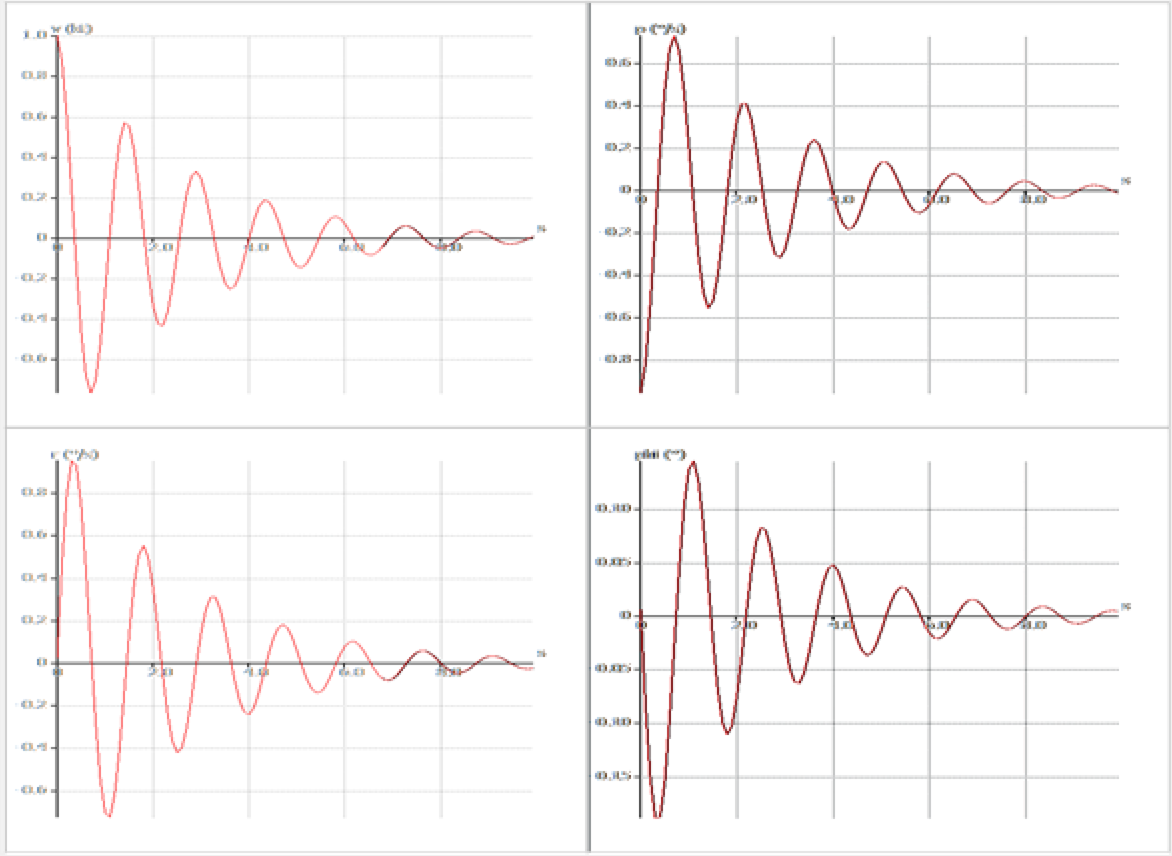
Cruise Stability Specifications

Description	Variable	Value	units
Neutral Point	X_{neu}	40.4	ft
Static Margin	SM	0.016	-
Steady-State Roll Rate	$p_{s.s.}$	14.5	deg/s
Max Lift Coefficient	$C_{L,max}$	2.22	-
Stall Speed	V_S	72.6	kts
Trim AoA	α_{trim}	-1.7	deg
Ruddervator Deflection	δ_v	2.4	deg
“Elevator” Deflection	δ_e	1.7	deg

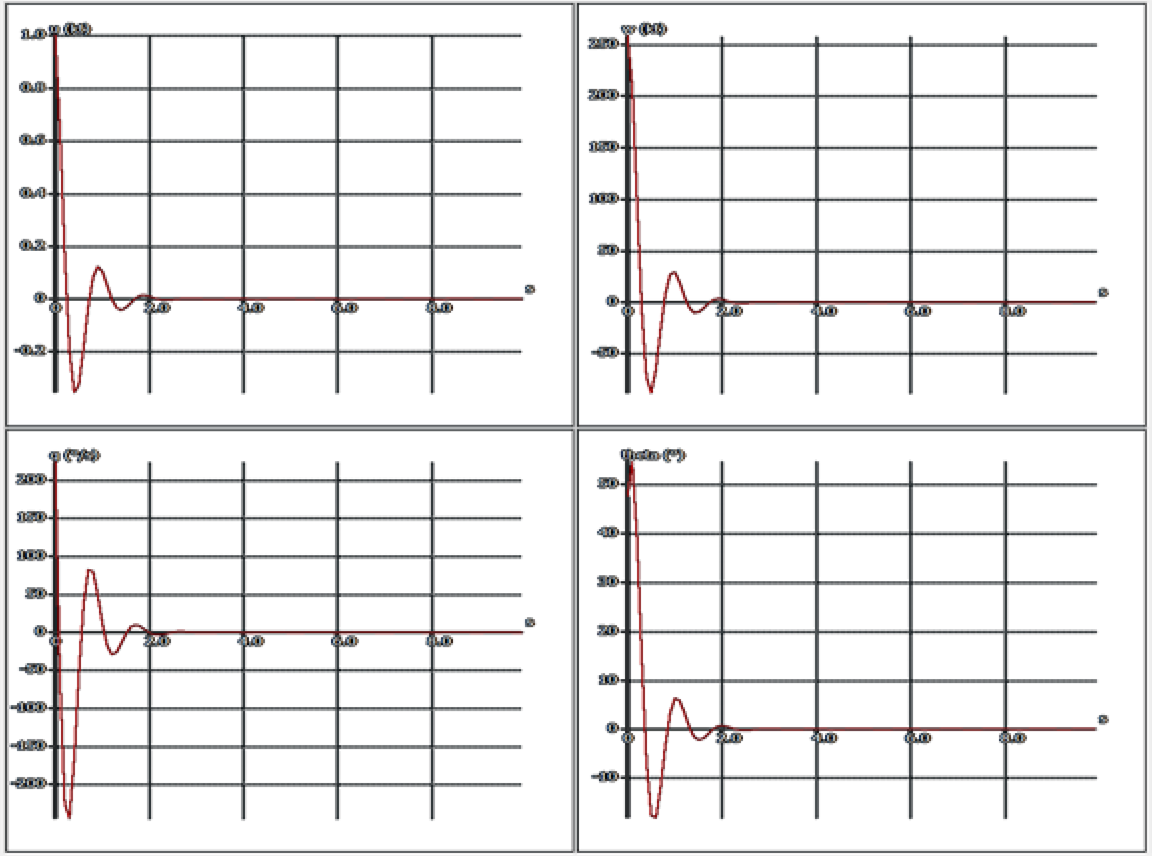
The aircraft is stable and maneuverable during a steady level cruise

Dynamic Stability

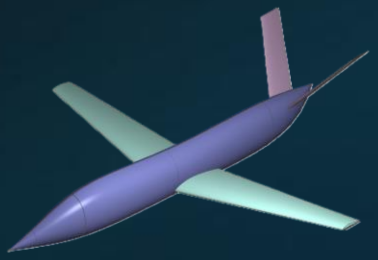
Lateral

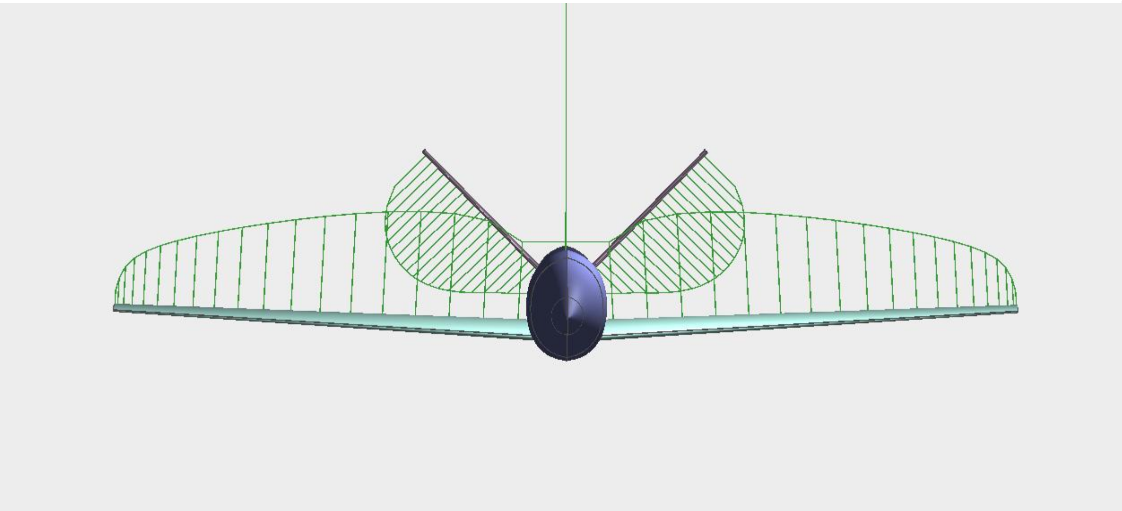


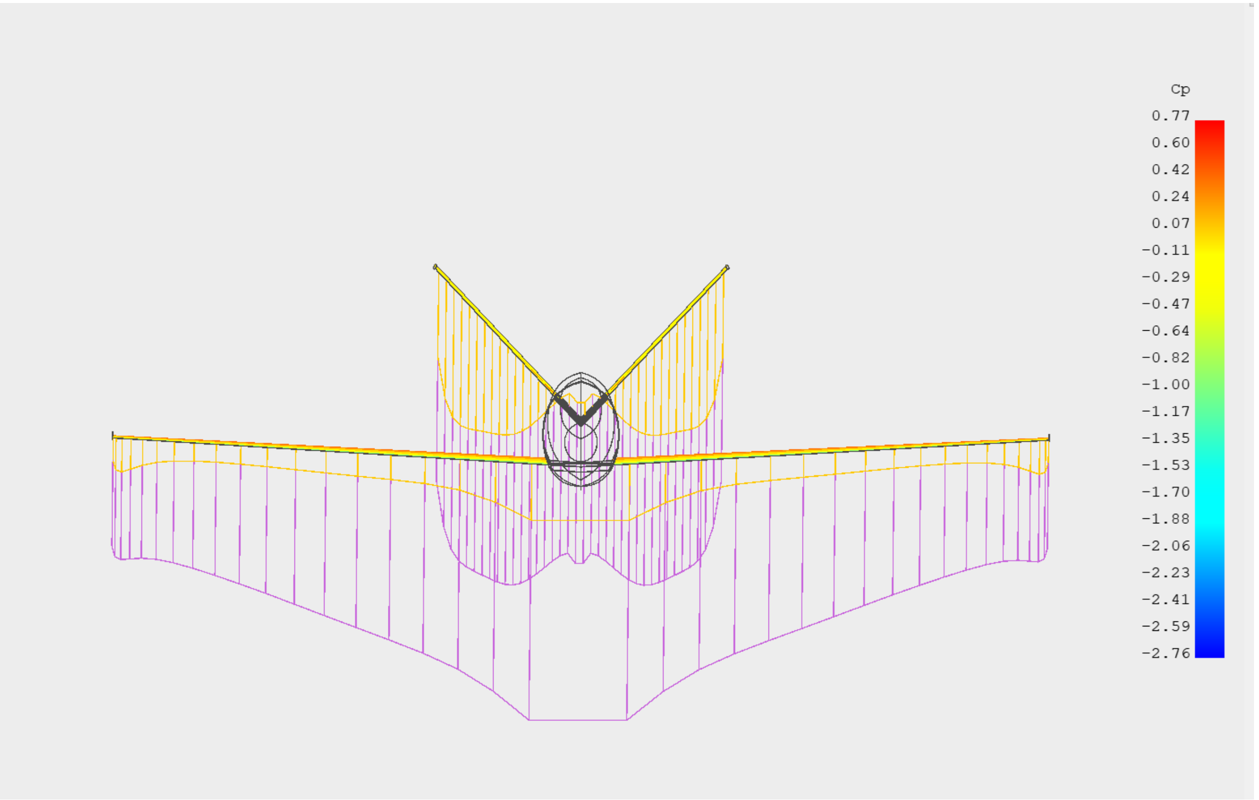
Longitudinal



XFLR5 Simulation







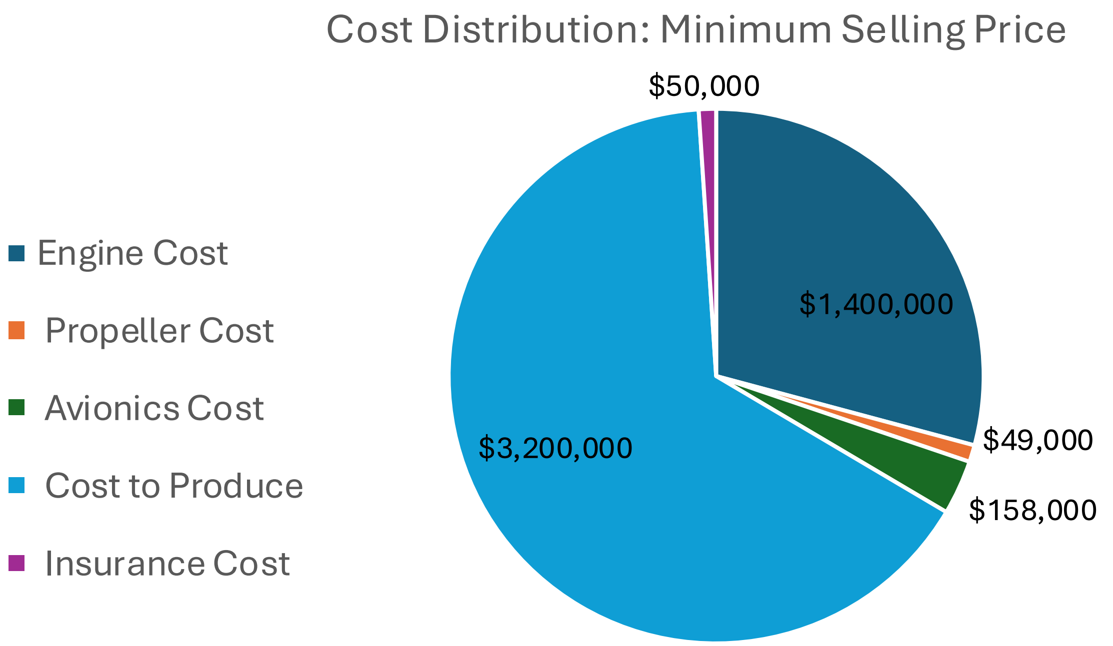
— Lift
— Induced Drag
— Viscous Drag

Cost Analysis

For a fleet of 500 AC to be produced in a 10 year timespan and a quality discount factor of 0.63

Development Cost	Manufacturing Cost	Certification Cost
$15,000,000	$421,000,000	$207,000,000

Minimum selling price of $4.8 million



Utilizing Gudmundsson cost analysis method.

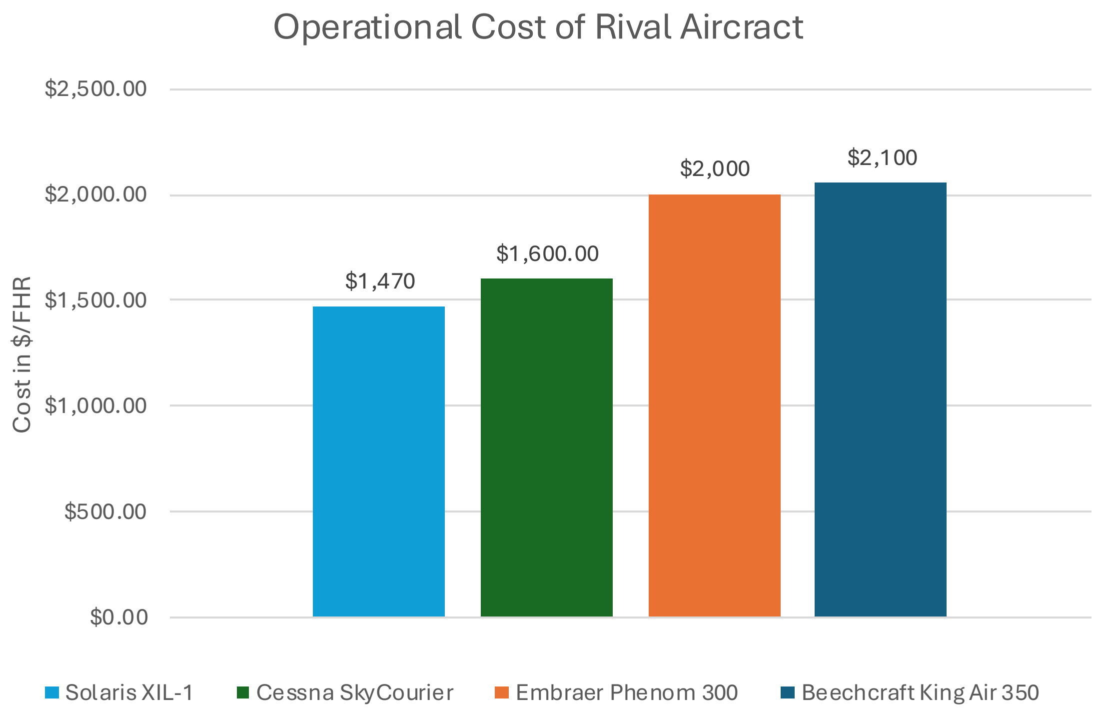
Cost Analysis

- Passenger aircraft that have similar design concepts, capacity, or propulsion configuration

Operational Cost	
Maintenance cost, per year	$7,920
Storage cost, per year	$3,000
Other. (per year)	~$700,000
Cost per FH, $/hr	**$1,470**

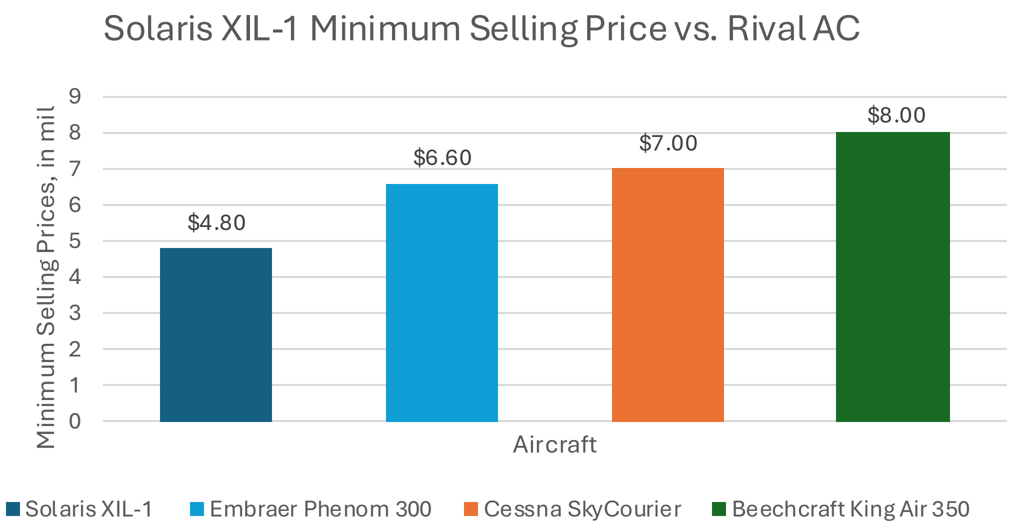
Assuming an average of 550 flight hours per year

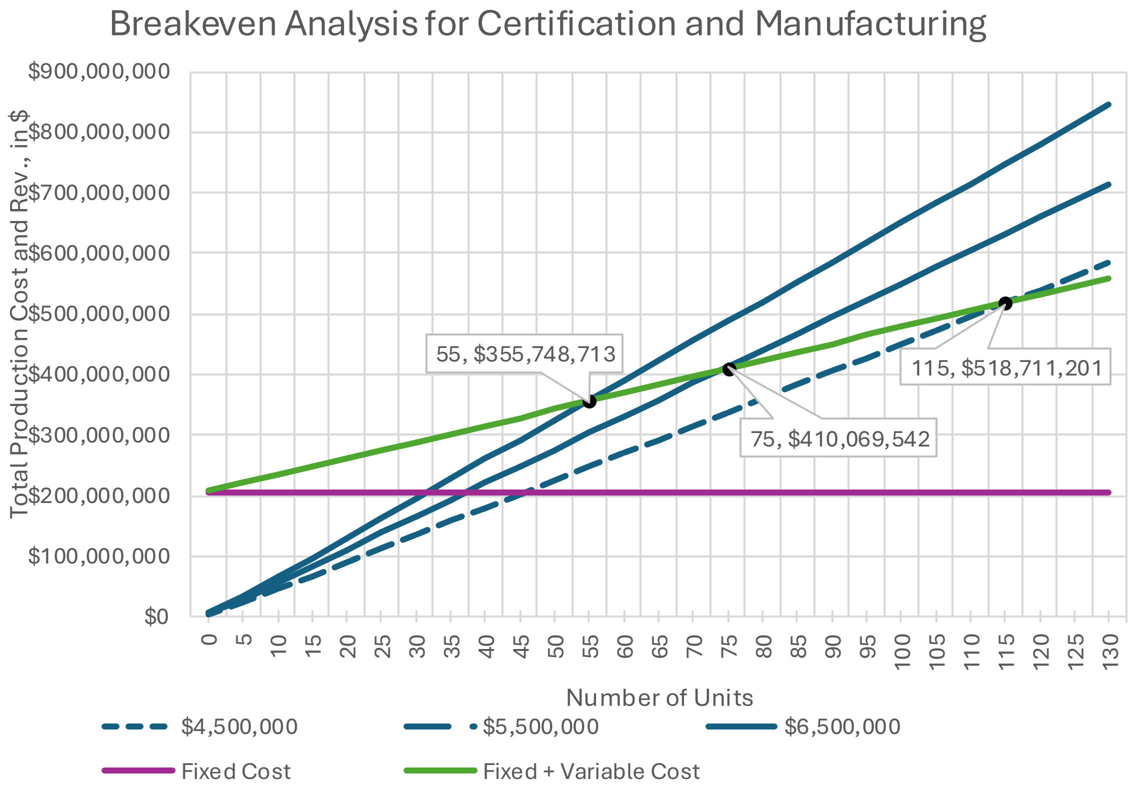
Utilizing Gudmundsson cost analysis method.



Cost Analysis

Break even point: 100 units at minimum selling price





Environmental Impacts

Energy

- 46% total energy required reduction [6]
  - Combination of power required to charge batteries and fuel

Noise

- 50% reduction in perceived noise [6]
- >10 dB reduction in maximum sound pressure level at takeoff

Emissions

- 73% reduction in CO_2 emissions [7]
  - Using Swedish power grid

Conclusion

- Highlights new hybrid-electric propulsion system for high-power aircraft
- Can be easily controlled to optimize power or environmental considerations
- Most efficient at cruise speed
- Requires less fuel weight for longer ranges compared to conventional or full-electric aircraft
- In the future, consider distributed propellers to further noise reduction

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Questions?