Boeing Dedicated Air Freighter

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INTRODUCTION

Problem Statement:

- Design a medium-sized, twin turboprop dedicated air freighter
- Expected to enter into service by 2029

Motivation/Background

- Fill the market gap for a regional turboprop freighter, with better versatility than existing civilian aircraft and less purchase and operational cost than military models

Mandatory Requirements per RFP:

- Capable of flying 750 nmi mission fully loaded
- Capable of flying 3,300 nmi mission when empty
- Cruise at 325 knots
- Take off from a 5,000' runway
- Turnaround time of 30 minutes

Tradable Requirements per RFP:

- Cruise at 375 knots
- Carry 30,000 - 40,000 lbs of payload
- Carry 20 LD-3 shipping containers
- Be capable of autonomous flight

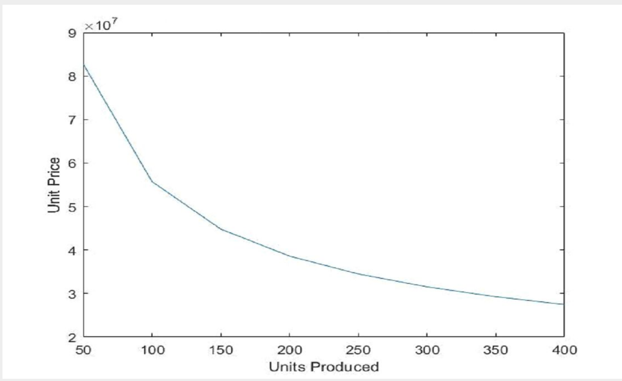
Bombardier Q400 - Civilian Aircraft

Airbus C295 - Military Aircraft

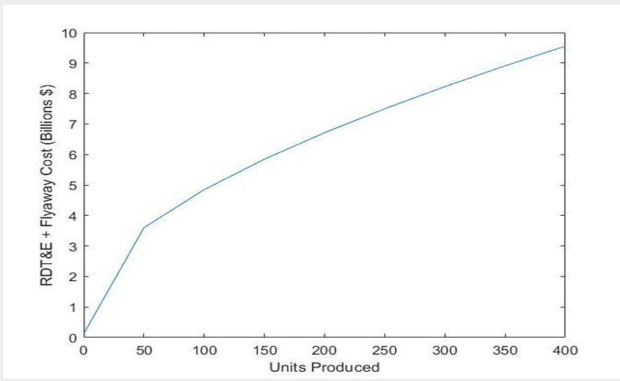
LD3 Cargo Containers

COST ANALYSIS

Inflation Adjusted Unit Cost (15% Profit)



Inflation Adjusted Production Cost



Yearly Cost of Operation and Maintenance ($$)	
Fuel	1,271,683
Crew Salaries	1,003,960
Maintenance	1,045,792
Depreciation	501,980
Insurance	41831
Total	**3,865,247**

Total Life-Time Cost ($$)	
Life Time O & M Cost + Unit Cost	**114,070,944**

Significant Driving Factors:

- Non-recurring development costs (engineering, FAA certification, unique production tooling, etc.)
- Necessary production rate to reach financial stability
- Changes in aircraft fuel costs over the operating years
- Civilian and military market analysis to determine project feasibility

IMPACT

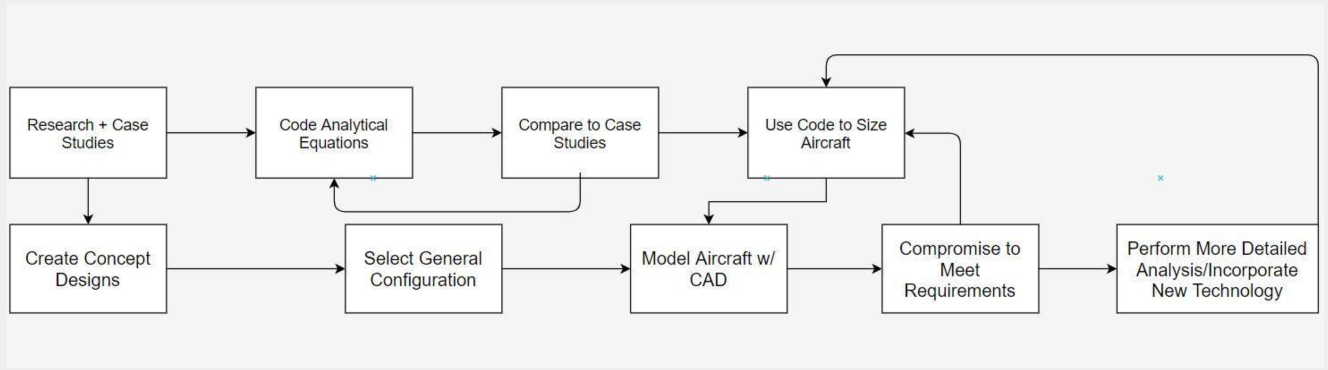
This aircraft will be state-of-the-art freighter airplane of its kind when launched into the market. It will be able to fly more cargo further than any medium sized turboprop currently existing. This platform will also travel faster than most aircraft of its payload capacity. With a significantly improved fuel efficiency, the operation cost will be far lower than aircraft currently in the civilian and military markets. The increase in speed will allow quicker turn-around times and a resulting increase in revenue. A decreased turn-around time improves customer satisfaction as they can transport more cargo that is time sensitive. The ramp door will allow longer freight to be loaded into the cargo bay compared to conventional aircraft side-doors. This design also reduces the need for heavy machinery to maneuver any cargo.

ETHICAL CONSIDERATIONS

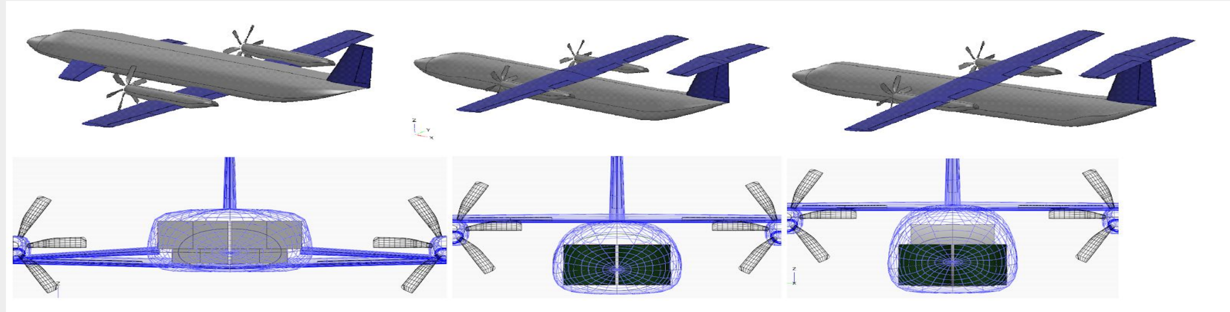
The largest positive impact that this design will have on the environment is its increased fuel efficiency. Since it will be the most fuel efficient aircraft of its type, it will release the least amount of greenhouse gasses into the atmosphere. This is an important step in reducing the carbon footprint of the rapidly growing cargo industry as, currently, aircraft account for 11% of U.S transportation emissions. The usage of composites materials decreases the aircraft's environmental impact as research suggest their lifetime impact (including energy expended in manufacturing as well as disposability) is less than that of conventional metals.

DESIGN PROCESS

Iteration Process:

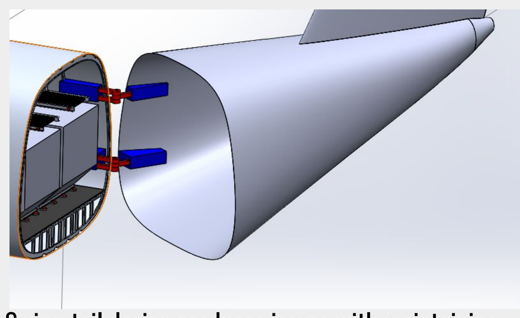


Fuselage Trade study:

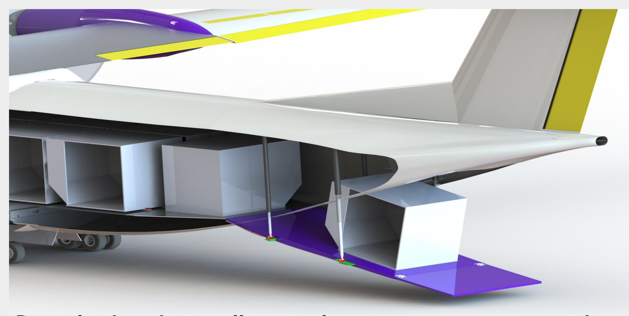


Inefficient nose and tail taper | Best compromise between cargo volume and fuselage drag | Fuselage too large and drag inducing

Cargo Loading Trade study:

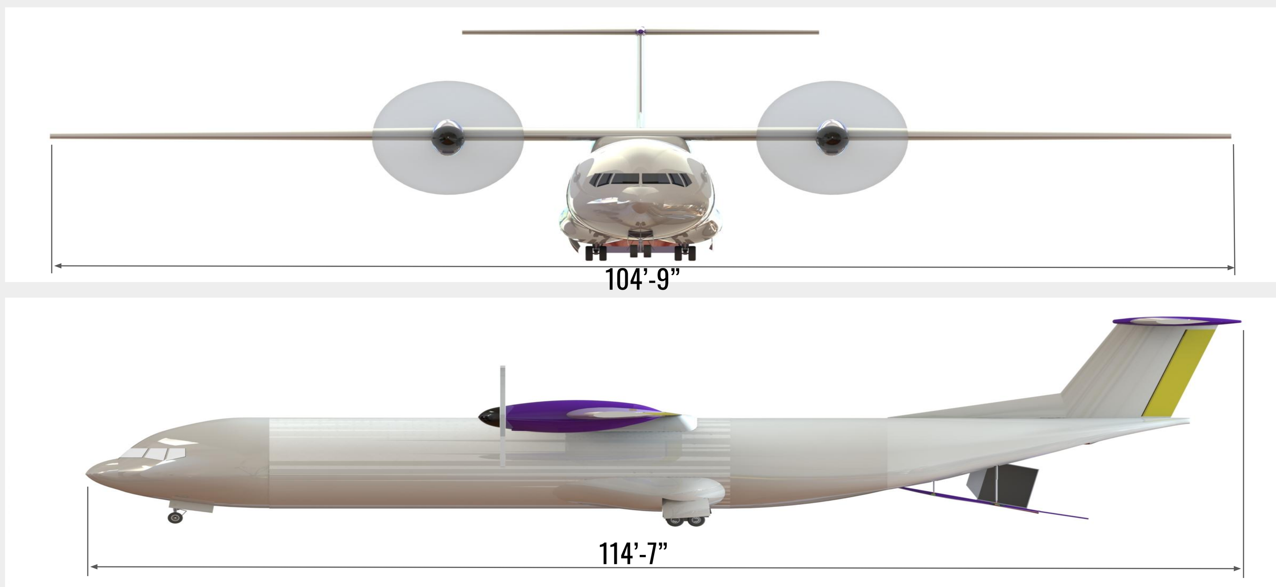


Swing-tail design produces issues with maintaining electrical, hydraulic, and fuel connections

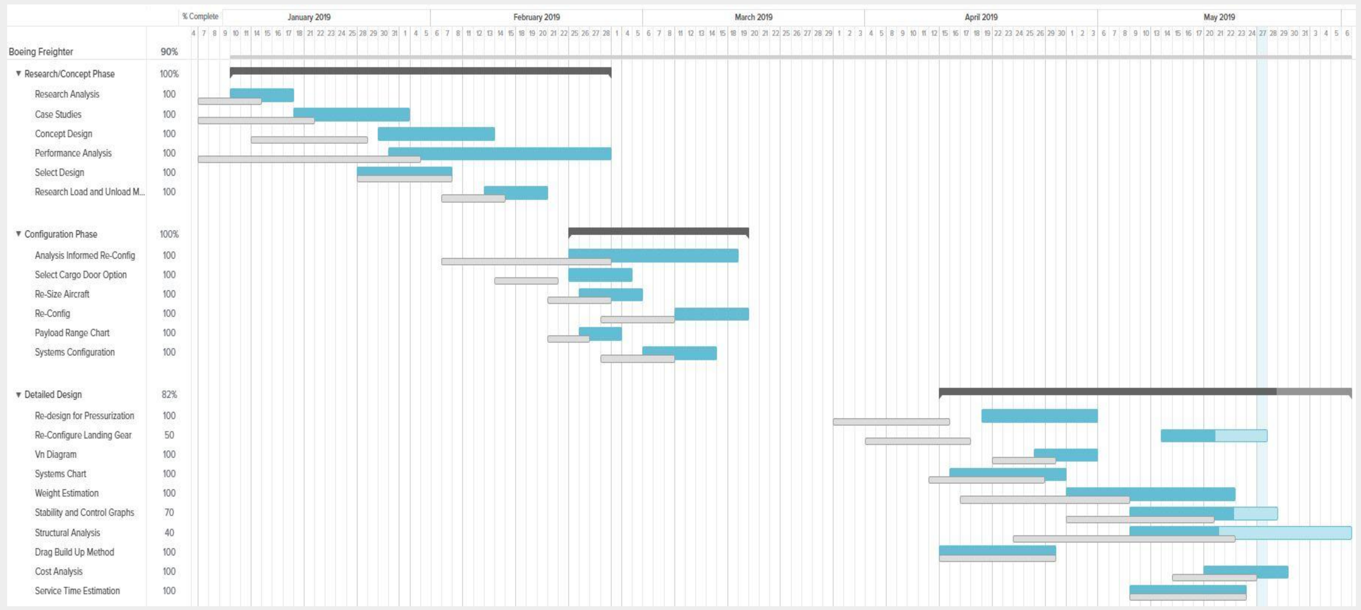


Ramp loading design allows for longer cargo containers without relying on scissor lifts

Final Aircraft Model:



SCHEDULE



CONCLUSION

Accomplishments

- Sized the aircraft to fit 17 LD-3 containers
- Met all performance requirements per the RFP
- Performed detailed weight estimation
- Conducted stability and control analysis
- Sized to carry 30,000 lbs of payload

Next Steps

- Finish structural and aerodynamic analysis of the aircraft
- Perform further market research and financial analysis for cargo load optimization
- Produce the resulting model iteration of design

Lessons Learned

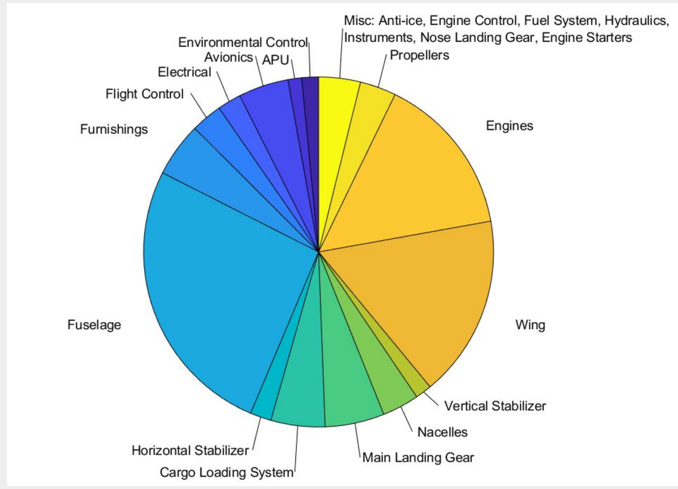
- Communication between sub-teams was critical to ensure objectives were up-to-date
- Decisions made regarding aircraft design and analysis were highly cyclical and dependent on each other (difficult to break the loop)
- General information on existing civilian and military aircraft is often publicly available
- Understanding the governing FAA regulations helped set project constraints

RESULTS

General Characteristics	
Wing Area	1,000 sq ft
Wing Span	104.8 ft
Payload	30,000 lbs
MTOW	72,905 lbs
Empty Weight	36,452 lbs
Fuel Capacity	17,000 lbs
Power Plant	Pratt & Whitney 2025
Power	6,200 eshp (each)
Propeller	DOWTY R408 6-blade composite

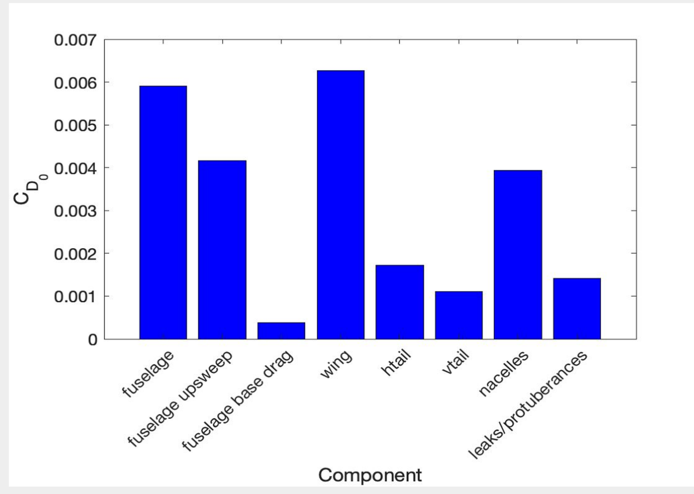
	Performance	Requirements
Max Payload Range	752 nmi	750 nmi
Ferry Range	3,303 nmi	3,300 nmi
Max Cruise Velocity	353.5 knots	N/A
Cruise Velocity	325 knots	325 knots
Service Ceiling	27,000 ft	N/A
Take Off Distance (SL)	3,050 ft	5,000 ft
Landing Distance (SL)	2,400 ft	5,000 ft

Weight Distribution by System/Component



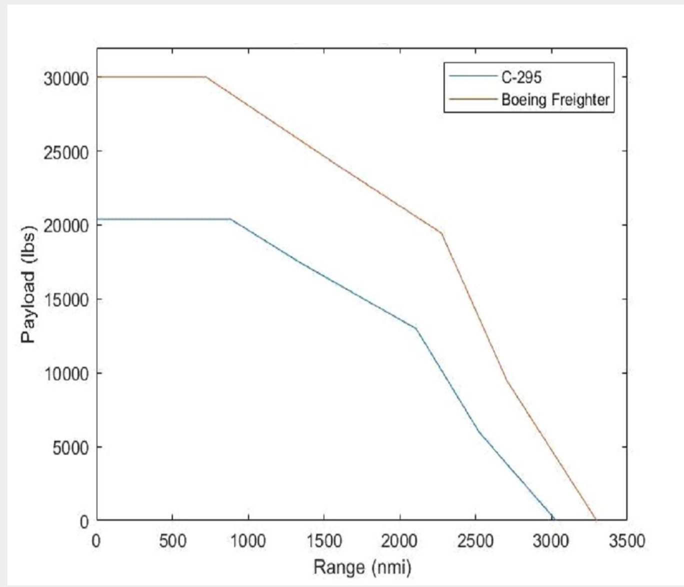
Distribution of weight based off of each major component or category of components in the aircraft. This was generated using a statistical method from Daniel Raymer's book on aircraft design

Drag Build-up



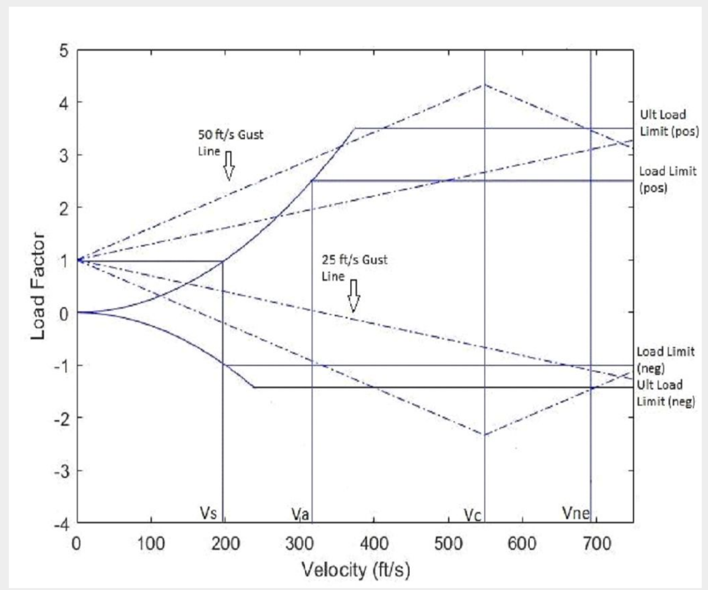
A breakdown of the parasitic drag contribution for each major aerodynamic component of the aircraft is shown above. The zero-lift drag does not include drag generated by 3-D effects.

Payload Range Chart



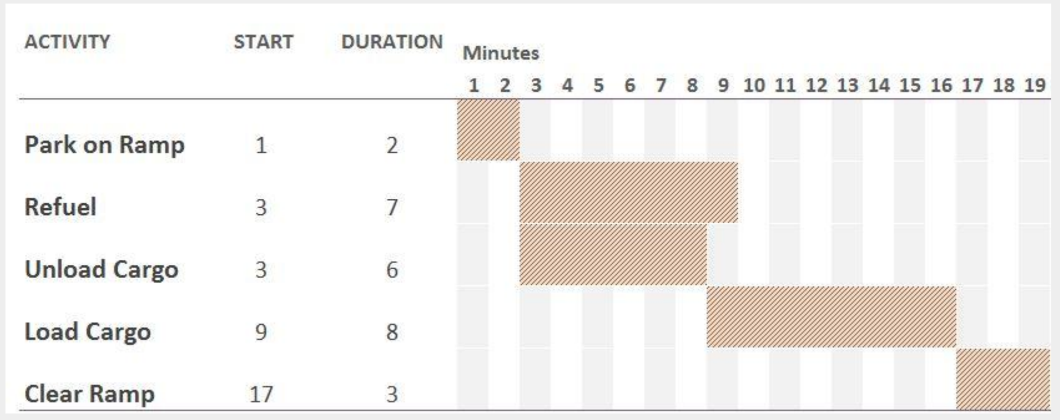
This chart shows the range and payload trade-offs that are feasible for our Boeing aircraft. It is compared to a C-295 which is a military turboprop cargo aircraft similar to our design.

V/n Diagram



The graph above shows the flight envelope of the Boeing freighter aircraft. Once pushed outside of the bounds of these lines, the aircraft will either stall or sustain structural damage.

Turn Around Time



The breakdown of the time on the aircraft must spend on the ground between missions can be seen in the above graph. A major goal of this project was to keep this turn-around time as low as possible so that the short range Boeing freighter aircraft can be in operation more frequently for revenue purposes.

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