SUSAN Single Aisle Market Analysis

ARMD Systems Analysis Symposium

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Subsonic **S**ingle **A**ft E**n**gine (SUSAN) Electrofan Overview

SUSAN uses a 20MW class Electrified Aircraft Propulsion system to enable advanced Propulsion Airframe Integration (PAI) in transport category aircraft. Alternative fuels will be used to reduce the amount of emissions per energy used. By combining these features there is the potential to reduce aircraft emissions by 50% per passenger/mile while retaining the size, speed, and range of large regional jets.

Problem: Aircraft emissions need to be reduced by at least a factor of two, with a goal of zero emissions.

Constraint: Must use existing airport infrastructure, be flight certifiable, and be more cost effective

Solution To Be Developed: Hybrid Electric Large Aircraft

Specific Concept To Be Developed: SUSAN Electrofan

- The SUSAN Electrofan Aircraft is a subsonic regional jet transport aircraft concept which utilizes Electrified Aircraft Propulsion (EAP) to enable propulsive and aerodynamic benefits to reduce fuel usage, emissions, and cost.
- Transformative concept: single engine transport aircraft. Four engine achieved in 1949, 3 engine in 1962, 2 engine in 1965. Five decades later we still have not achieved single engine transport
- The target market is the regional low cost carrier airline with mission specification: 180 passenger, design range of 2500 miles, economic range of 750 miles, speed of Mach 0.78.

SUSAN Market Analysis Outline

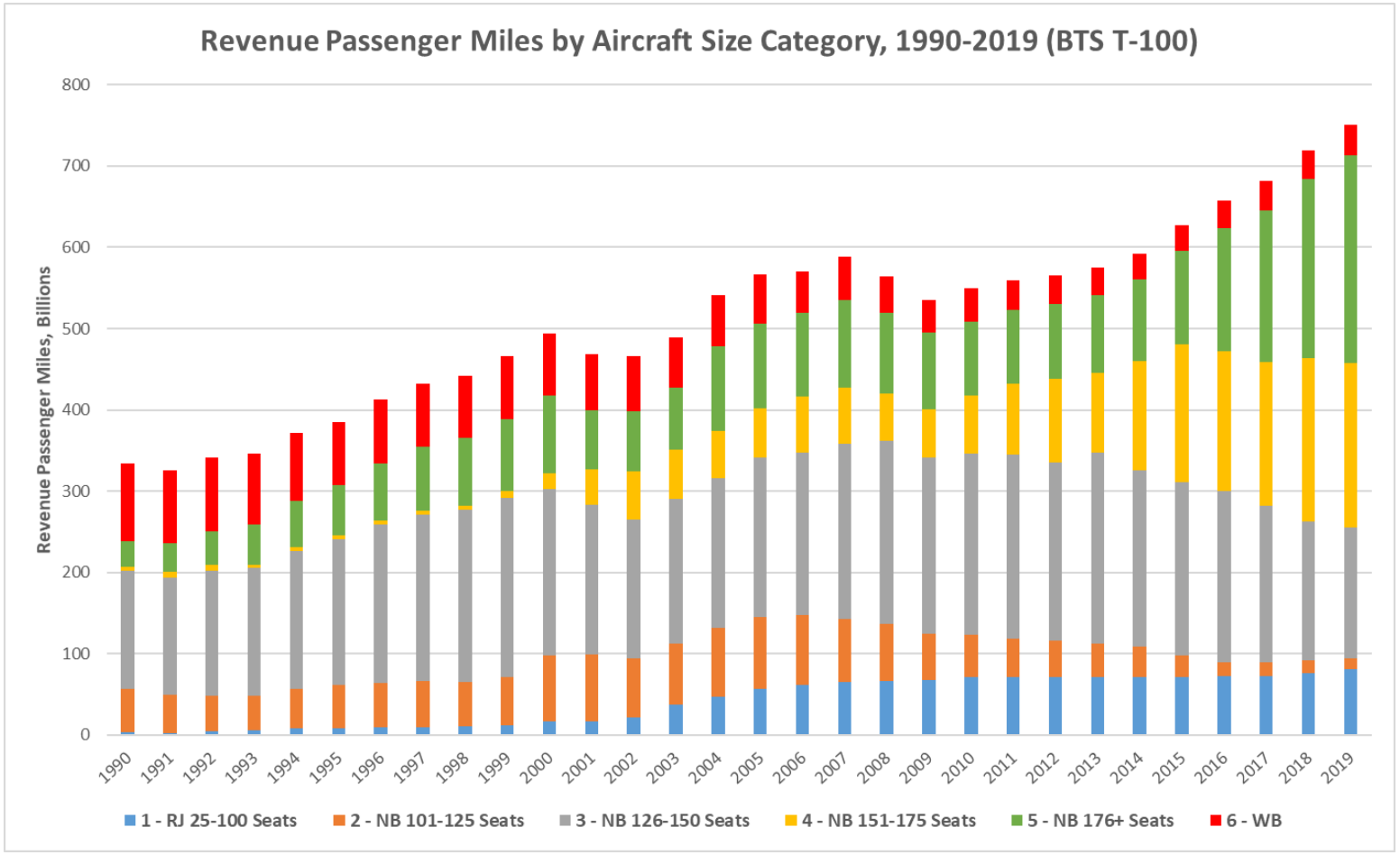
Extension of the trade space exploration of the SUSAN concept discussed in Jansen et al.[1], to analyze the current and future trends of the domestic US aviation market and the cost impacts from the introduction of the SUSAN aircraft. The market analysis focused on two areas:

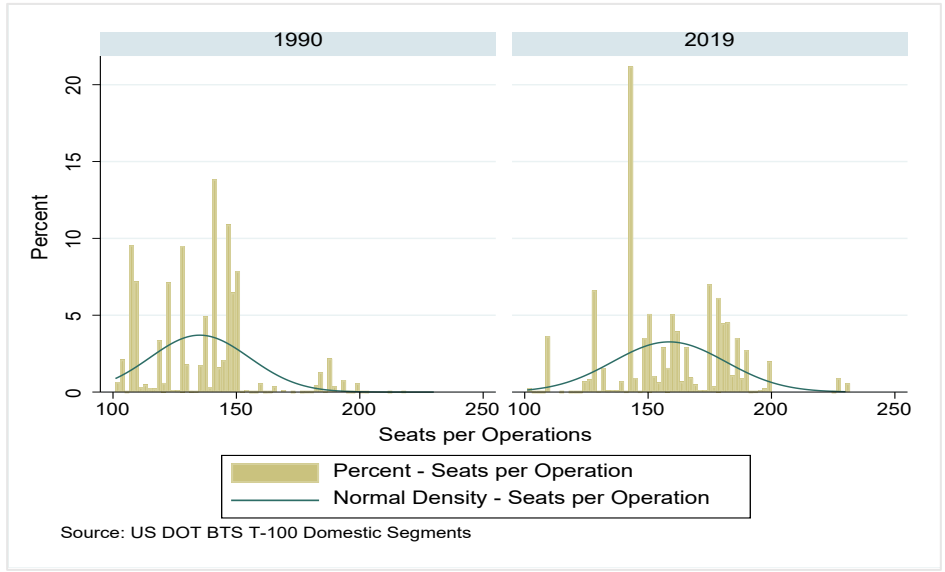
- Section 1 – Historical Trends and Fleet Forecasting
  i. Review of historical aviation trends in the U.S.
  ii. Long-run traffic and fleet demand forecasting
  iii. Fleet evolution analysis
- Section 2 – Future Market Cost Analysis
  i. Cost model development and analysis
  ii. Breakeven cost analysis

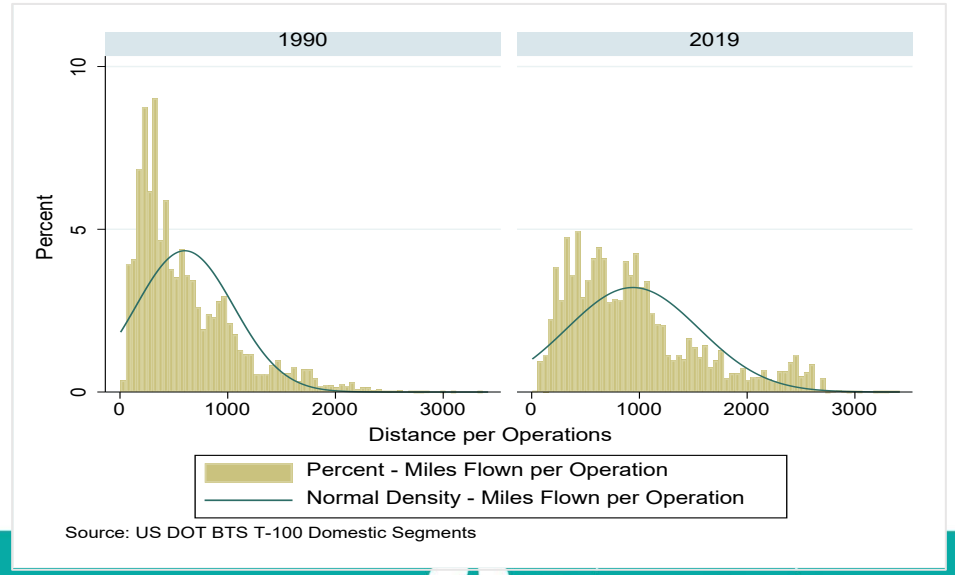
[1]Jansen, R. H., Kiris C. C., Mirhashemi, A., Denham, C. L., Heersema, N. "Subsonic Single Aft Engine (SUSAN) Transport Aircraft Concept and Trade Space Exploration." AIAA SciTech Forum and Exposition, San Diego, California, U.S.A., 2022. doi: 10.2514/6.2022-2179

Section 1 – Historical Trends and Fleet Forecasting

Historical Trends in U.S. Domestic Aviation







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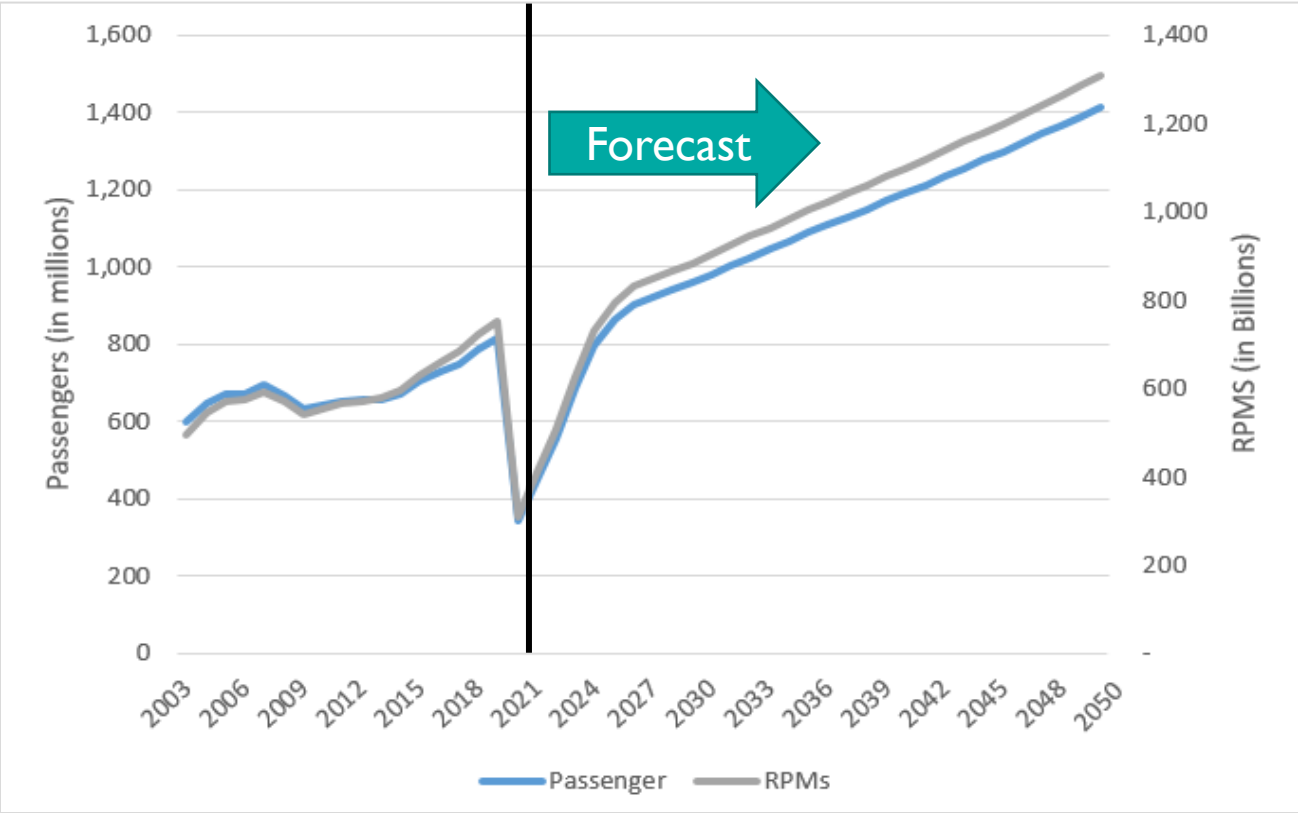
Traffic and Fleet Forecasting (1/2)

Long-run U.S. Domestic Traffic Forecast

- Exogenous forecast of traffic sourced from FAA's Terminal Area Forecast (TAF) program. Origin-destination airport pair forecasts cover 99% of total commercial domestic traffic.



- Forecast from 2021-2050, including recovery from COVID-19 pandemic downturn.
- Traffic forecast compound annual growth rate (2019-2050) = 1.8%, compared to 1.6% over the historical period (2000-2019).

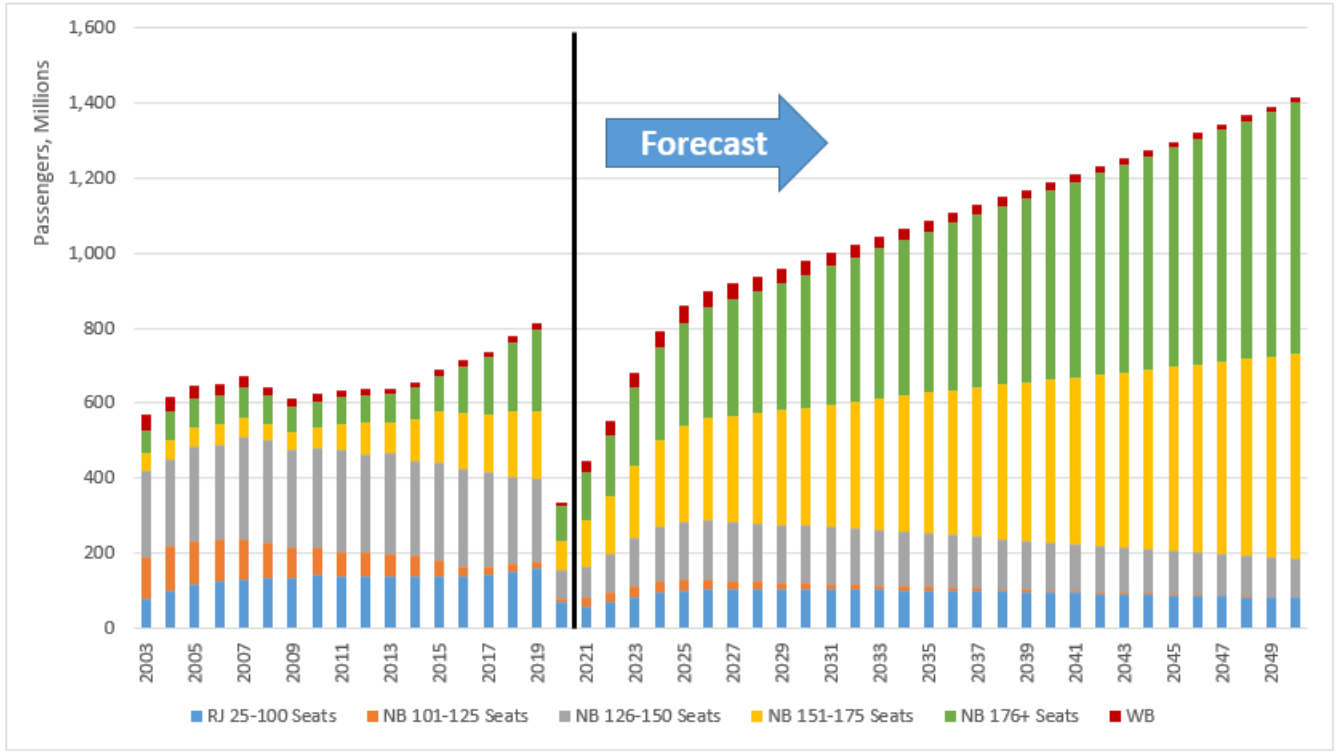
Traffic and Fleet Forecasting (2/2)

Fleet Forecasting

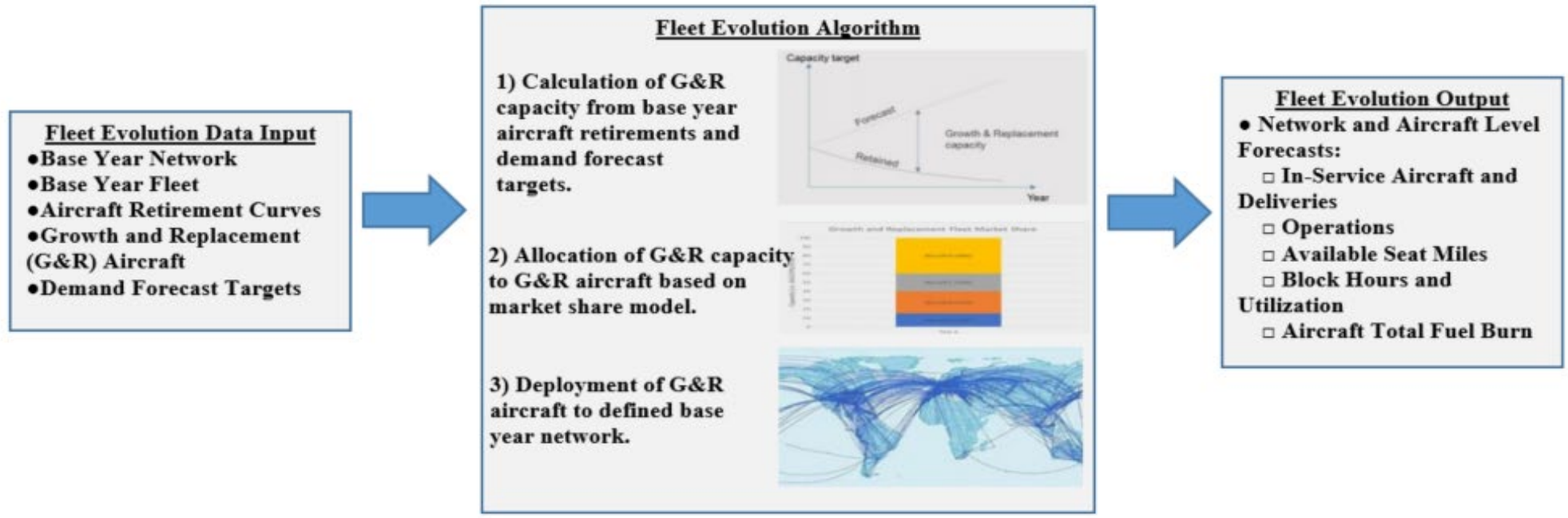
- Combined exogenous traffic demand forecast with a multinomial logit (MNL) discrete choice model to predict future aircraft size categories.
- MNL model estimated on historical segment and aircraft level data sourced from BTS T-100 from 2003-2019.
- In-sample model predictions closely match actual RPM shares by a/c category in 2019.

In-Sample MNL Model Predictions – Share of RPMs by Aircraft Category		
Aircraft Seat Class Category	**Actual 2019 Passenger Share**	**Predicted 2019 Passenger Share**
Piston/Turbo Prop ≤ 100 Seats	1%	2%
Regional Jets 25-100 Seats	19%	17%
Narrow Bodies 101-125 Seats	2%	4%
Narrow Bodies 126-150 Seats	27%	27%
Narrow Bodies 151-175 Seats	22%	23%
Narrow Bodies 176+ Seats	26%	23%
Wide Bodies	2%	4%

- Fleet-wide category forecasts show significant growth in market share for the two largest narrow body categories (151+ seats).
- Share of total passengers for these two categories increases from 49% in 2019 to 86% by 2050.



Fleet Evolution



- Incorporated traffic and fleet forecast results to model the retirement and replacement process of the future fleet.
- Requires inputs and assumptions on aircraft retirement curves, base year fleet and network, list of growth and replacement aircraft, and market shares for newly delivered future aircraft.
- Baseline results without the SUSAN concept can be compared directly to alternative scenarios with SUSAN being introduced at different rates of market diffusion.

Section 2 – Future Market Cost Analysis

Future Market Cost Modeling

- To determine the cost requirements for the SUSAN aircraft, two modeling approaches were taken:
  - Cost analysis over the entire narrow body fleet
  - Breakeven analysis at the individual aircraft level

Fleet Cost Model

- Measure the fleet-wide effects of introducing SUSAN aircraft beginning in 2040.
- Requires assumptions on aircraft delivery market shares and operating/capital costs.
- Parametrically adjust cost inputs to measure the full range of impacts.

Breakeven Analysis

- Comparison of lifecycle costs of individual aircraft to determine cost equivalence.
- The breakeven point for the SUSAN aircraft is identified as the level at which cost decreases from one source balance cost increases from another, relative to a comparison aircraft.

Future Market Cost Analysis: Fleet Cost Model (1/2)

Cost Model Estimates Two Scenarios for the Domestic Narrow Body Market

- Costs in baseline US market with no SUSAN aircraft
- Costs in US market with SUSAN aircraft

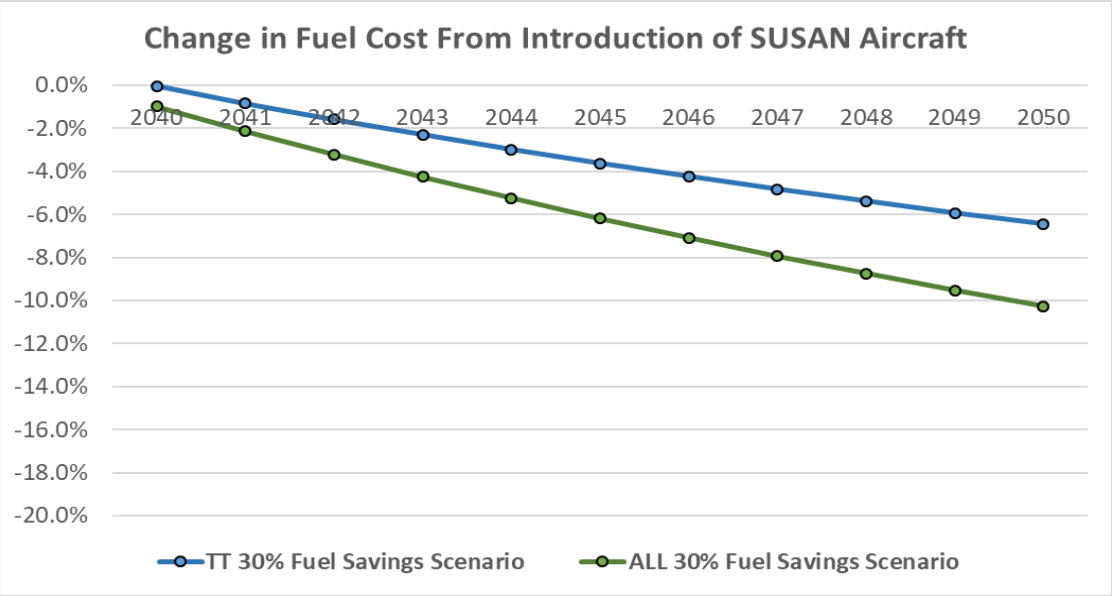
Fleet Cost Model Assumptions

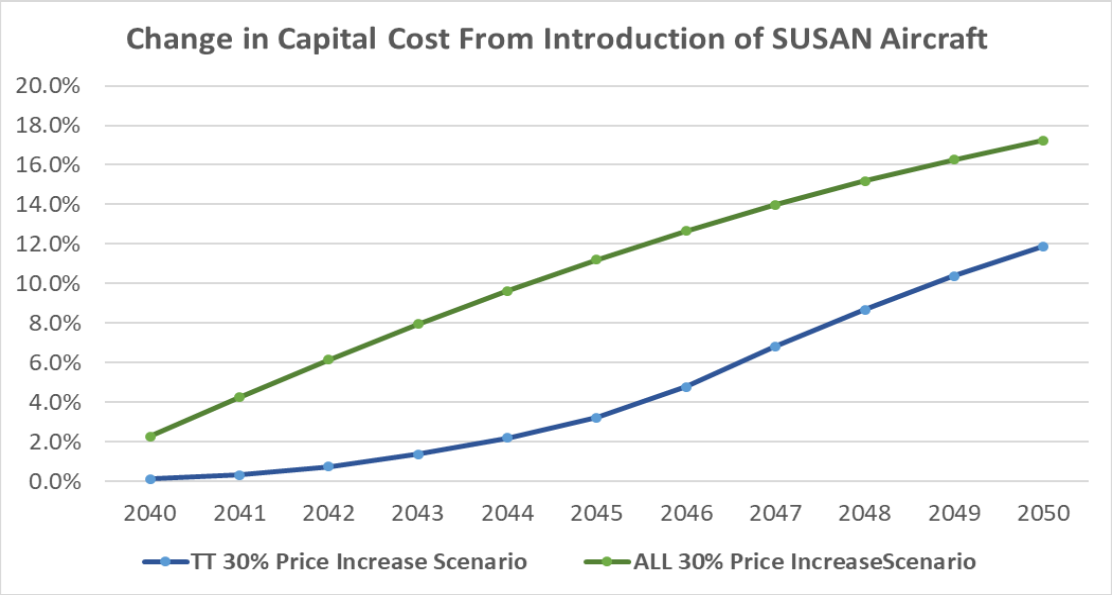
- SUSAN is assumed to enter the market in 2040 with two market share approaches:
  - Immediate entry with 100% share of new deliveries ('ALL' scenario)
  - Gradually increasing market share up to 100% by 2047 ('TT' scenario)
- Costs are calculated in 2018$
- Fuel burn (decrease) and aircraft price (increase) for SUSAN aircraft adjusted parametrically to bound costs.

Cost Model Inputs

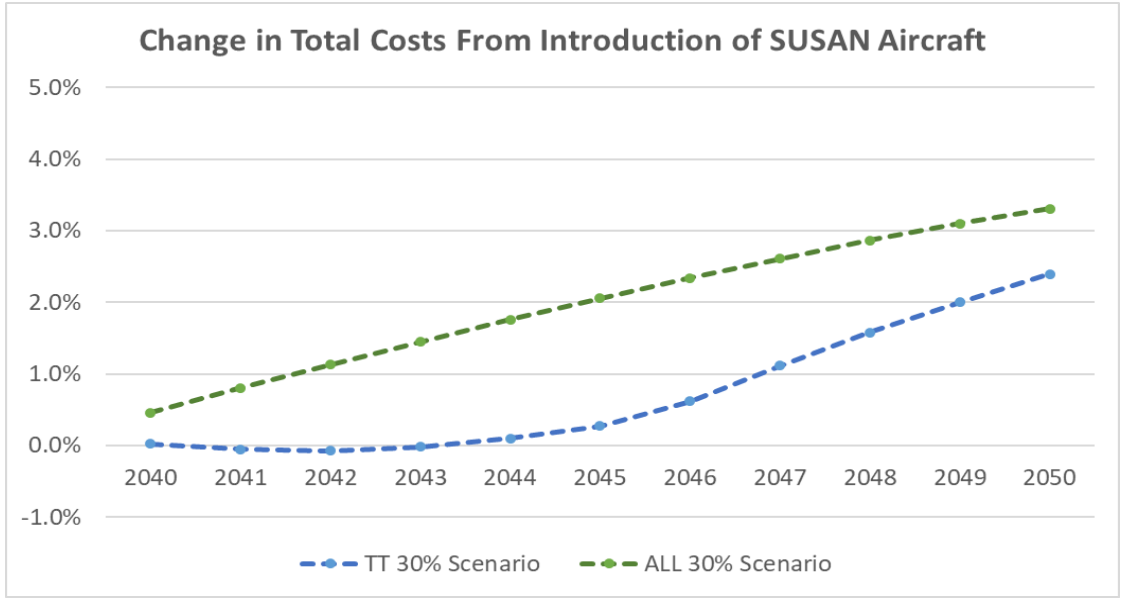
Data Type	Input For	Data Source/Value
Total Deliveries	Capital cost calculation	Fleet forecasting, specific to each aircraft type
Total Block Hours	Operating cost calculation	
Fuel Burn (kg)	Fuel cost calculation	
Cost of Fuel	Fuel cost calculation	$2.18/gallon (2018$) (source: EIA)
Maintenance Cost Per Block Hour	Operating cost calculation	Sourced from FAA BCA guidance – varies by aircraft size
Crew Cost per Block Hour	Operating cost calculation	Sourced from FAA BCA guidance – varies by aircraft size
Purchase Price	Capital cost calculation	50% of list price, specific to each aircraft type (source: OEMs)
Finance Rate	Capital cost calculation	7.2% (source: IATA's weighted average cost of capital)
Depreciation Rate	Capital cost calculation	3.4% (source: airline financial annual reports)

Future Market Cost Analysis: Fleet Cost Model (2/2)





- Cost model outputs for a 30% decrease in fuel burn and 30% increase in aircraft price for SUSAN aircraft.
- **'TT' Scenario:** incremental market diffusion of SUSAN aircraft
- **'ALL' Scenario:** 100% market share starting in 2040



Future Market Cost Analysis: Breakeven Analysis (1/2)

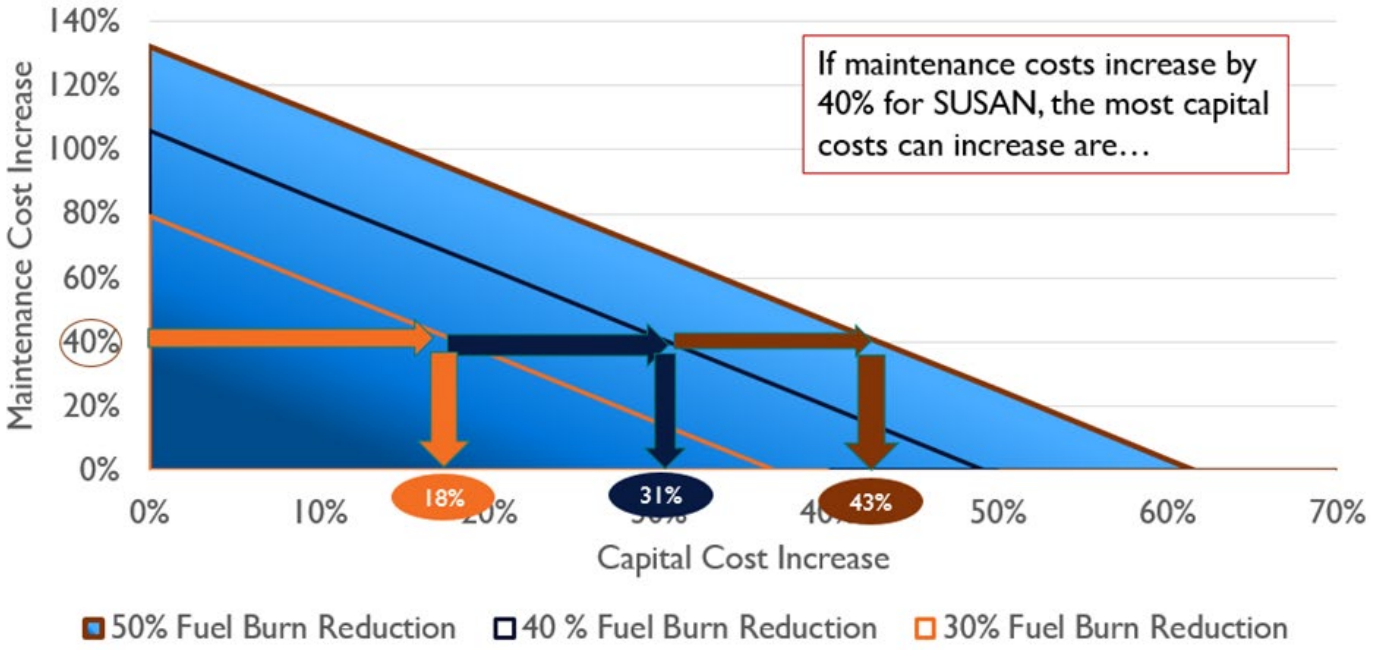
The breakeven analysis identifies the point at which overall SUSAN costs are equivalent to the overall costs of a comparison aircraft.

Breakeven Analysis Assumptions

- 25-year useful life
- Equivalent seat capacity and utilization rates.
- All costs are assumed constant between aircraft, except for capital costs, maintenance cost per block hour, and fuel burn.
- Boeing 737-8MAX and -9MAX used as the comparison aircraft.

Breakeven Analysis Inputs		
Data Type	**B737-8 and 9 MAX**	**SUSAN**
Total Deliveries	Fleet forecasting	Fleet forecasting
Total Block Hours	Fleet forecasting	Fleet forecasting
Average Block Hours per Aircraft	Assumed 4,000, based on average fleet forecasting	Assumed 4,000, based on average fleet forecasting
Fuel Burn (kg)	Fleet forecasting	Fleet forecasting
Total Cost of Fuel Burn	Fuel Burn converted to gallons and combined with price estimate of $2.18/gallon	Fuel Burn converted to gallons and combined with price estimate of $2.18/gallon
Cost of Fuel Burn Per Block Hour	Total Cost of Fuel Burn divided by Total Block Hours	Total Cost of Fuel Burn divided by Total Block Hours
Maintenance Cost Per Block Hour	$574.40 – sourced from FAA BCA guidance, reduced by 20%	Varies based on breakeven test
Purchase Price	One-half of list price, $59.7 (-8 MAX) and $63.3 (-9 MAX) million in 2018$	Varies based on breakeven test
Finance Rate	7.2%	7.2%
Depreciation Rate	3.4%	3.4%

Future Market Cost Analysis: Breakeven Analysis (2/2)



Breakeven Analysis Rate Table		
Fuel Burn Reduction	**Purchase Price Increase**	**Maintenance Cost Increase**
30% Reduction	20%	36%
30% Reduction	30%	15%
40% Reduction	20%	63%
40% Reduction	40%	20%
50% Reduction	20%	90%
50% Reduction	50%	25%

- Future work will expand the evaluation to include potential purchase and maintenance cost reductions compared to the baseline aircraft

Findings Summary

- Baseline market analysis predicts continued and significant growth in the large (151+ seat) narrow body market domestically.
  - Increase in total share of passenger enplanements up to 86% by 2050.
- SUSAN aircraft could serve majority (about 70%) of the future domestic market in terms of capacity and distance range capabilities.
- Fleet-wide cost model analysis shows SUSAN aircraft reducing fuel burn/cost significantly, with marginal increases in total cost due to capital cost increases.
- Breakeven analysis provides additional evidence that the SUSAN aircraft can be economically viable and cost effective under a range of fuel burn reduction scenarios.

Next Steps

- **Next steps for FY23 include:**
  - Paper presentation at SciTech (January 2023)
  - Further refinement of SUSAN concept (NASA team)
  - Volpe – refinement of sensitivity to cost metrics to bound the cost requirements for SUSAN
  - Volpe – regional market study and cost sensitivity analysis with both passenger and freight considerations

Q+A Session

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