Project 10

Aircraft Technology Modeling & Assessment

Purdue University

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Cost Share Partner(s): Purdue University, OAG

Objective: Model and assess potential evolution of commercial airline fleet due to the introduction of future supersonic aircraft and how technology development could reduce the environmental impacts of aviation (e.g., fleet-level fuel burn, emissions and noise). ***The effort will examine several fleet-level impacts of supersonic aircraft operating in commercial service and business operations.***

Project Benefits: Provide an understanding of how introduction of new supersonic transports that could enter into commercial airline service and private use will affect fleet-wide fuel burn, noise and emissions.

Research Approach:

- Use FLEET to model airline operations and observe evolution of fleet utilization
- Purdue's five major tasks for current effort:
  - Generating supersonic and subsonic aircraft usage and allocation data
  - Modeling the impact if airlines use high-passenger-density subsonic aircraft in response to supersonic aircraft utilization
  - Analyzing impact of COVID-19 related demand slump on future fleet mix
  - Expanding FLEET's US-touching route network to a global network
  - Developing business jet analog to FLEET to analyze the fleet-level impacts of supersonic business jet aircraft

Major Accomplishments (to date):

- Completed the high-passenger-density subsonic aircraft utilization study
- Analyzed the impact of the COVID-19-related demand slump on fleet-level emissions and supersonic and subsonic aircraft operations
- Simultaneous supersonic and subsonic aircraft allocation approach revived

Future Work / Schedule:

- Conduct FLEET simulations based on a global route network (Jan '22)
- Integrate different types of SST aircraft in FLEET (Apr '22)
- Develop business jet analog to FLEET (Aug '22)

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Accomplishments to Date

- Introducing high-passenger-density subsonic aircraft on routes with SST aircraft allocations
- Impact of COVID-19 on future supersonic operations

Introducing High-Passenger-Density Subsonic Aircraft on Routes with SST Aircraft Allocations

- Motivation
  - To compensate for loss of revenue from premium passengers moved to supersonic aircraft, airlines might reconfigure subsonic aircraft with more economy seats
- Approach
  - Model high-passenger-density aircraft
  - Explore four ticket pricing strategies
  - Examine changes in aircraft utilization and fuel burn / CO_2 emissions
  - **Note: this study used pre-COVID travel demand predictions**
- Findings
  - Use of high-passenger-density subsonic aircraft may have a impact on total aviation emissions
  - Ticket pricing approaches lead to differences in subsonic aircraft allocation, fleet-level emissions, and overall airline profit

Introducing High-Passenger-Density Subsonic Aircraft on Routes with SST Aircraft Allocations

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- High-passenger-density aircraft modeling assumptions
  - Half of premium seats replaced with economy seats at ratio of 1:2
  - Constant aircraft empty weight
- Team developed four cases for airline ticket pricing relative to standard configuration aircraft:
  - Case 1: Maintain average ticket price
  - Case 2: Maintain ticket price for economy and premium seats
  - Case 3: Maintain trip margin
  - Case 4: Maintain ticket price margin
- Current modeling assumes that the premium class ticket costs twice as much as economy class tickets
- High-passenger-density subsonic aircraft operate on routes that have supersonic service

	Single-Aisle, SA (Class 3)		Small Twin-Aisle, STA (Class 4)		Large Twin-Aisle, LTA (Class 5)		Very Large, VLA (Class 6)	
Configuration	Standard	High-pax-density	Standard	High-pax-density	Standard	High-pax-density	Standard	High-pax-density
Max seat capacity [pax]	177 (165 + 12)*	**183 (177 + 6)***	261 (237 + 24)*	**273 (261 + 12)***	305 (227 + 78)*	**344 (305 + 39)***	417 (309 + 108)*	**471 (417 + 54)***
Pax capacity w/ 80% load factor	142	**147 (142 + 5)***	209	**219 (209 + 10)***	245	**275 (244 + 31)***	335	**377 (334 + 43)***

*seat capacity: economy class + premium (business and first) class

Introducing High-Passenger-Density (HPD) Subsonic Aircraft on Routes with SST Aircraft Operations

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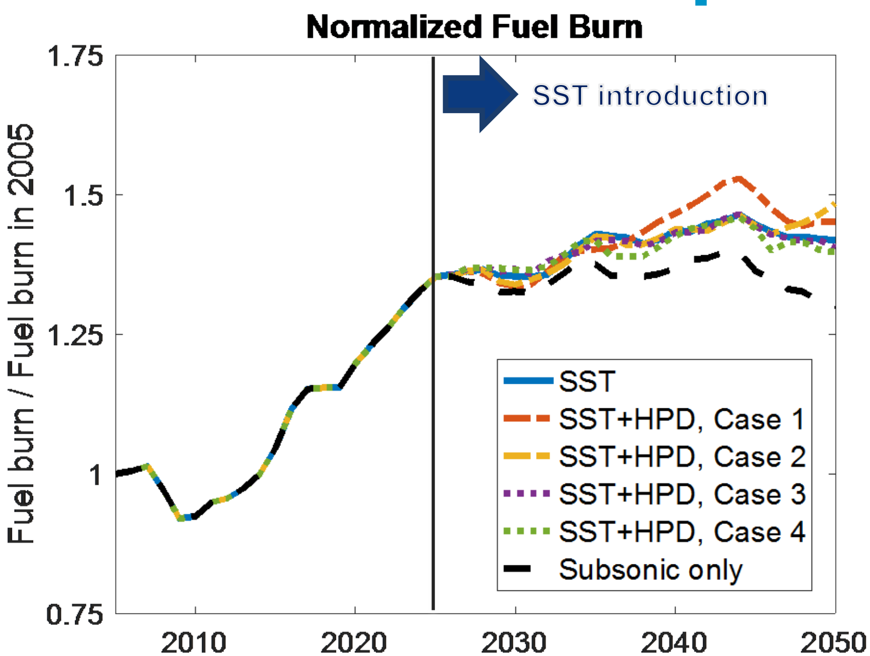

HPD: high-passenger-density

- Case 1 highest profit; highest fuel burn
- Case 2 (our team thinks most likely) and Case 3 little difference in fuel burn relative to standard passenger density subsonic operations
- Case 4 (least likely) lowest profit, lowest fuel burn
- Supersonic route numbers in 2050
  - With standard passenger density: 85 routes
  - Case 1: 87 routes
  - Case 2: 85 routes
  - Case 3: 86 routes
  - Case 4: 86 routes

Possible Airline Actions	Purdue Team's likelihood of pricing approach	Impact on Passengers (Ticket Pricing)			Impact on Emissions	Impact on Airline
		Average Ticket Price	Economy Ticket Price	Business Ticket Price	Fuel Burn	Profit
Case 1: Constant average ticket price	2	–	↑	↑	↑	↑
Case 2 : Constant ticket price	1 (most likely)	↓	–	–	↑ (slightly after 2046)	↑ (slightly)
Case 3 : Constant trip margin	3	↓	↓ (slightly)	↓ (slightly)	~ (similar)	↓ (slightly)
Case 4 : Constant ticket price margin	4 (least likely)	↓	↓	↓	↓ (slightly)	↓

Major Accomplishments to Date

- Introducing high-passenger-density subsonic aircraft on routes with SST aircraft allocations

- Impact of COVID-19 on future supersonic operations

Impact of COVID-19 on Future Fleet-Level Fuel Burn and Airline Operations

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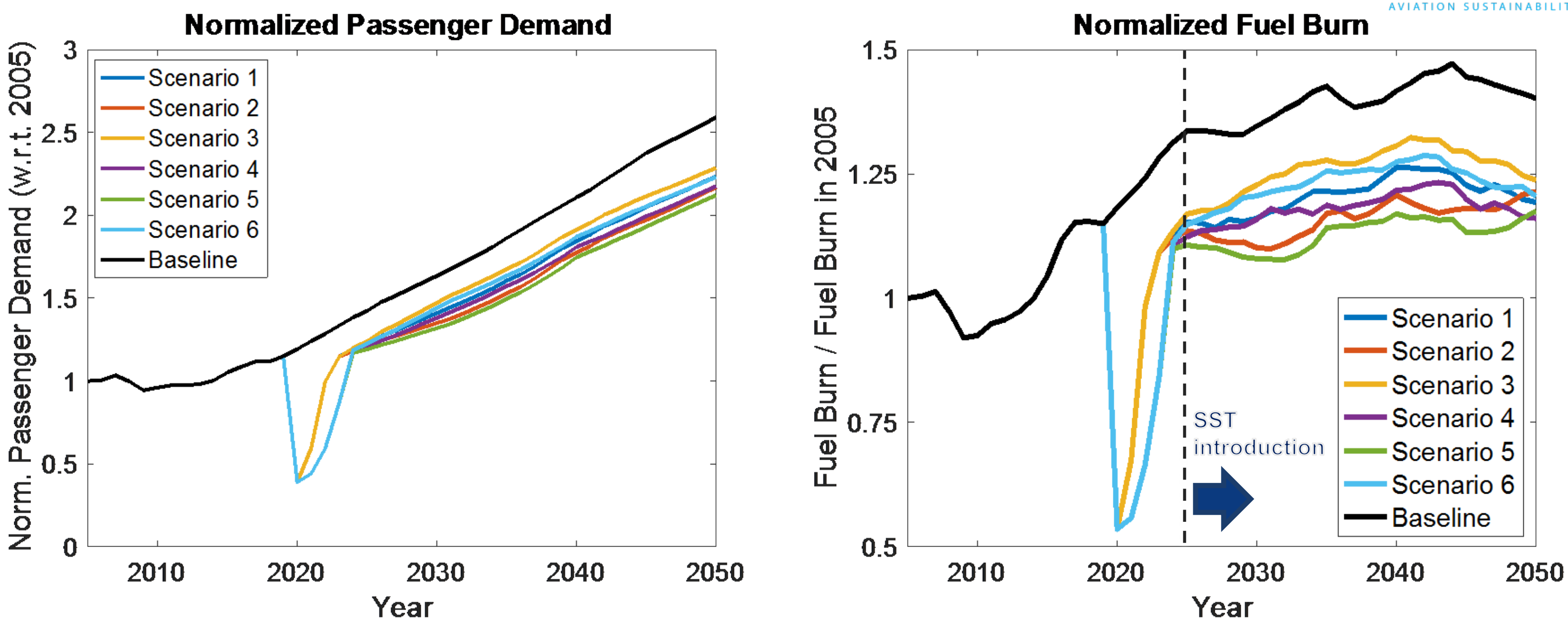
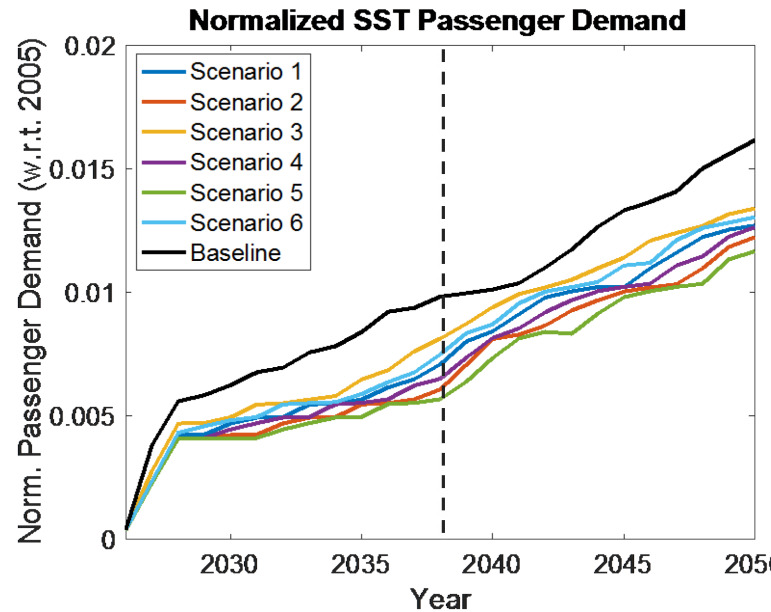
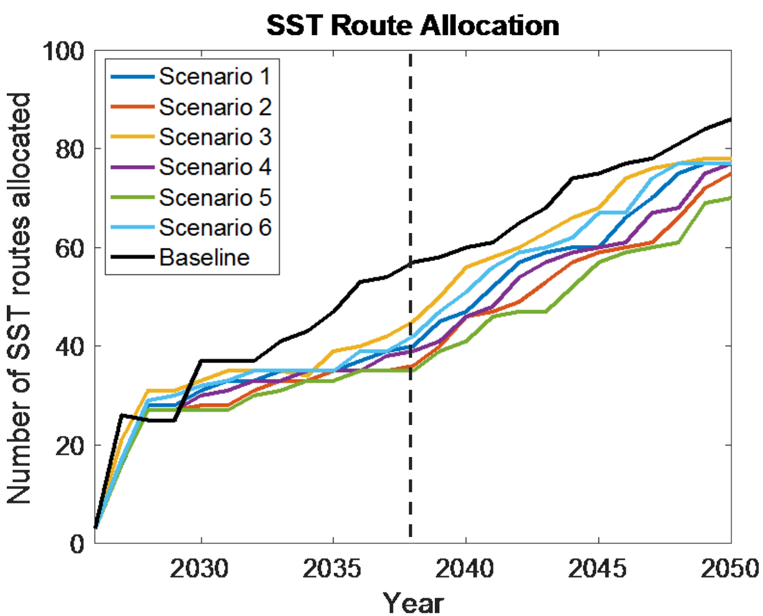


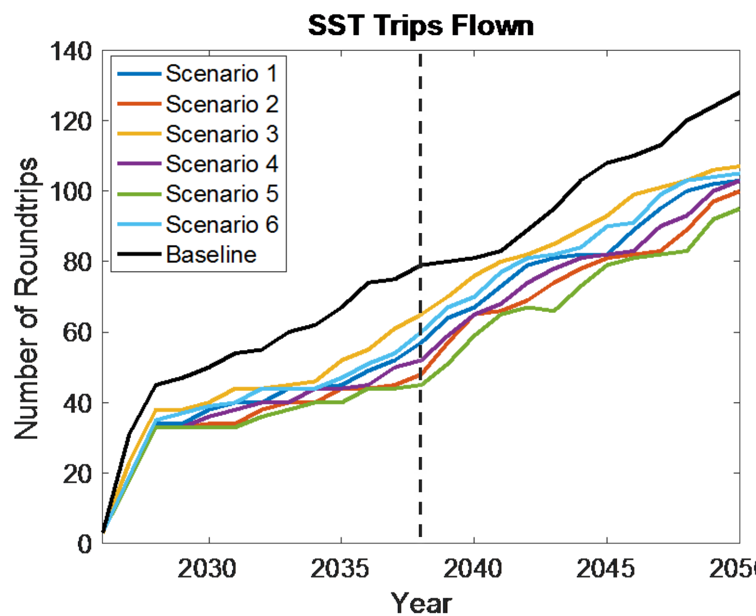
- Motivation
  - Represent impact of COVID-19 on air travel passenger demand in predictions
- FLEET implementation:
  - Model six possible paths to passenger demand recovery
  - Supersonic aircraft introduced in 2025 and 2038
  - Sequential allocation of aircraft; accommodating premium passengers on SSTs first
- Differences between COVID-19 scenarios and pre-COVID "baseline"
  - Lower passenger demand leads to lower total flights
  - Lower passenger demand initiates early retirement of less profitable aircraft

Impact of COVID-19 on Future Supersonic Operations

- The Purdue team provided SST operations to CAEP MDG/FSEG were for 2038 predictions using pre-COVID demand
- In 2038
  - 42% reduction in SST passenger demand from pre-COVID Baseline to COVID recovery Scenario 6
  - 39% reduction in number of SST routes allocated (57 to 35 routes)
  - 43% reduction in SST roundtrips flown per nominal day (79 to 45 trips)





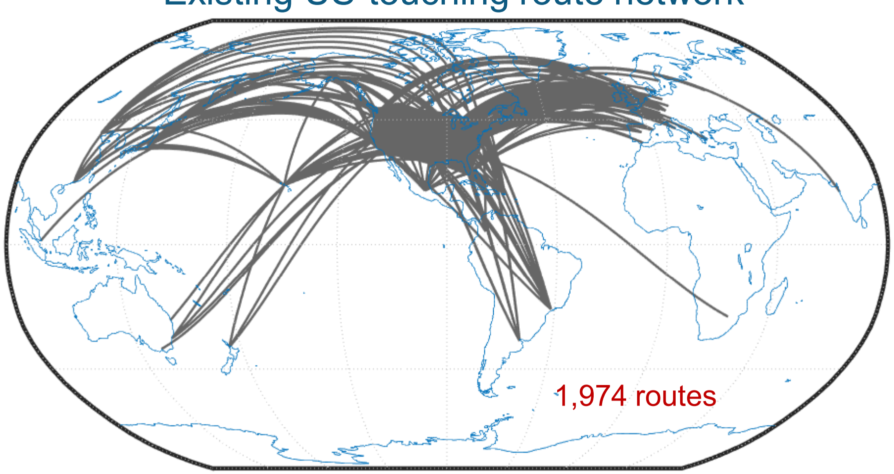


ONGOING AND FUTURE WORK

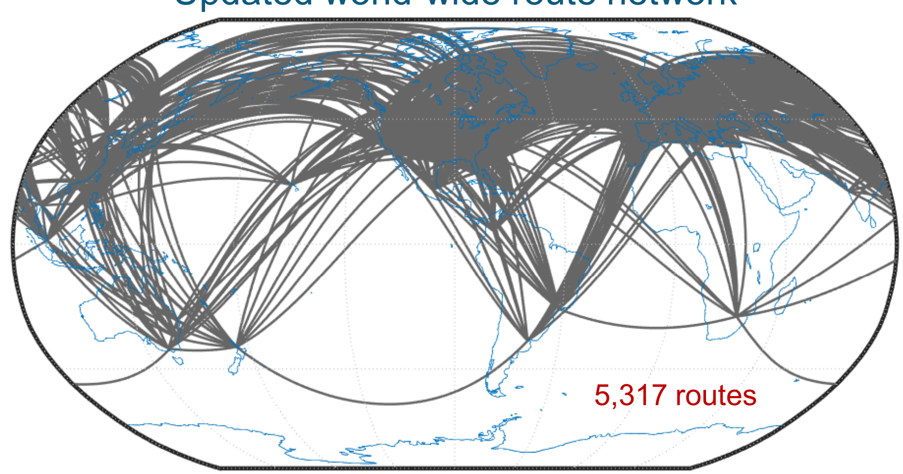
Expanding FLEET's US-touching route network to global network

- Capture all worldwide demand among WWLMINET 257 airports (Dec '21)
  - Purdue team purchased worldwide demand data from OAG for years 2011 to 2019
  - Currently identifying potential supersonic-eligible routes
- Update baseline fleet size and aircraft mix from a US-carrier fleet only in 2005 to a global fleet in 2011 (Jan '22)
  - Includes updating types of aircraft, number of aircraft, age of aircraft, technology "classes" of aircraft
  - Using BTS aircraft fleet data in 2011 and plan to adapt it to worldwide market

Existing US-touching route network



Updated world-wide route network



Work-in-progress

- FLEET update for simultaneous allocation of supersonic and subsonic aircraft (Dec '12)
  - Higher-fidelity fleet allocation
  - Enable capturing of noise and airport operations constraints
- Implementing other SST aircraft types in FLEET (Mar '22)
  - Will include different size and speed SST aircraft in FLEET simulations (25-pax, 75-pax, and 100-pax along with 55-pax SST aircraft)
  - Working to update potential supersonic-eligible routes identification approach in FLEET for all aircraft types
  - Will be followed by generating aircraft coefficients using FLOPS
- Developing a business jet analog for FLEET to study the fleet-level impact of supersonic business jets (Aug '22)
  - Allocation problem test run with hypothetical data complete
  - Looking to acquire credible business jet demand data

BACKUP SLIDES

Possible Airline Actions when Introducing High-Passenger-Density (HPD) Aircraft on Routes with SST Service

- Current Trends Best Guess scenario from previous subsonic-only ASCENT 10 work
  - Supersonic aircraft introduced in **2025 and 2038**
  - Supersonic allocation before subsonic; accommodating premium passengers first

- Case 1 (constant avg ticket price)
  - Airline adjust ticket prices of economy and premium passengers to maintain the same average ticket price
  - Airline favors larger aircraft, to maximize $/trip; higher class 5 and 6 aircraft utilization means higher fuel burn
  - <u>Expected impact:</u> slight change in demand; allocation changes significantly
- Case 2 (constant ticket price)
  - Airline does not change ticket price (per passenger)
  - Airline favors smaller aircraft, to minimize "loss" of business class revenue
  - <u>Expected impact:</u> no change in demand; slight changes in allocation
- Case 3 (constant trip margin)
  - Airline adjust ticket prices to maintain the same profit margin per trip
  - Airline favors smaller aircraft, to minimize "loss" of business class revenue
  - <u>Expected impact:</u> slight change in demand; allocation changes a bit
- Case 4 (constant ticket price margin)
  - Airline adjusts ticket prices to maintain a constant ticket price margin (per passenger)
  - Airline favors smaller aircraft, to minimize "loss" of business class revenue; lower class 4 and 5 aircraft utilization means lower fuel burn
  - <u>Expected impact:</u> slight change in demand; allocation changes significantly

Impact of COVID-19 on future fleet-level emissions and airline operations

- Future Demand Scenarios
  - Two different scenarios for airline operations recovery to pre-COVID-19 levels (2019)
  - Three different GDP growth scenarios from the year of passenger demand recovery to pre-COVID-19 levels (2019) to the year 2030
  - Leads to a total of six scenarios

Scenario #	Description	Passenger Demand (% of pre-COVID-19 levels)					GDP Growth Rate (as % of 'Nominal')
		2020	2021	2022	2023	2024	
1	2023 recovery	34%	52%	88%	100%	--	No change
2	2023 recovery + GDP slowdown to 75% until 2030	34%	52%	88%	100%	--	75% (- 25%)
3	2023 recovery + GDP inflation to 125% until 2030	34%	52%	88%	100%	--	125% (+25%)
4	2024 recovery	34%	38%	50%	75%	100%	No change
5	2024 recovery + GDP slowdown to 75% until 2030	34%	38%	50%	75%	100%	75% (- 25%)
6	2024 recovery + GDP inflation to 125% until 2030	34%	38%	50%	75%	100%	125% (+25%)

Impact of COVID-19 on future fleet-level emissions and airline operations

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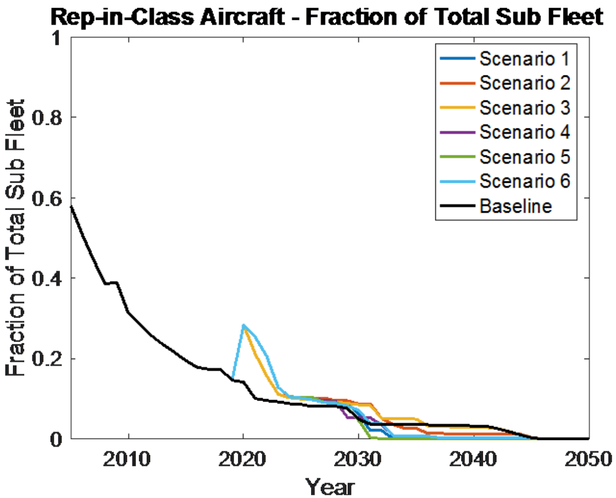

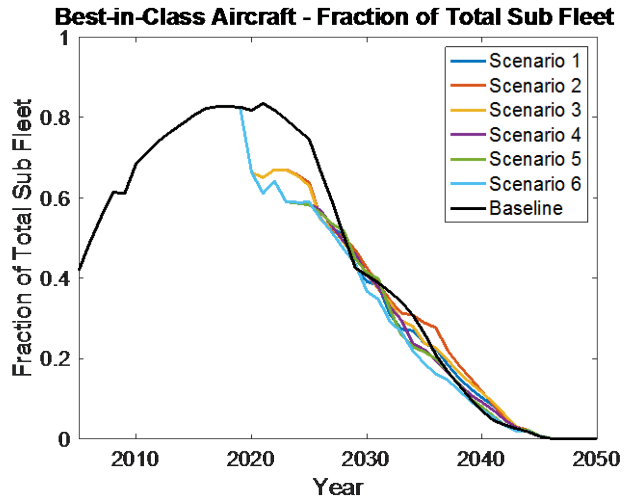

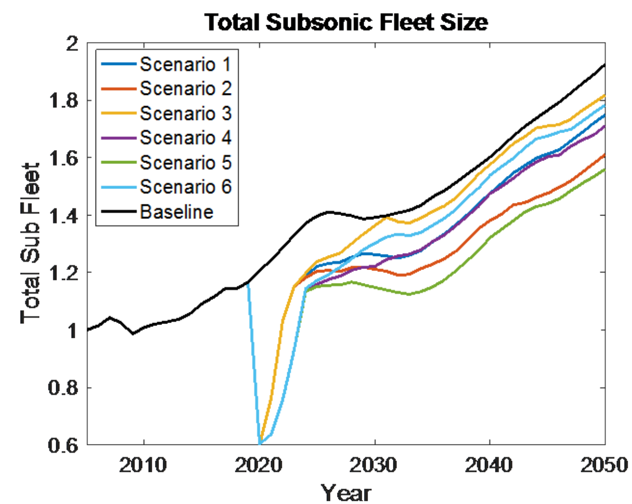

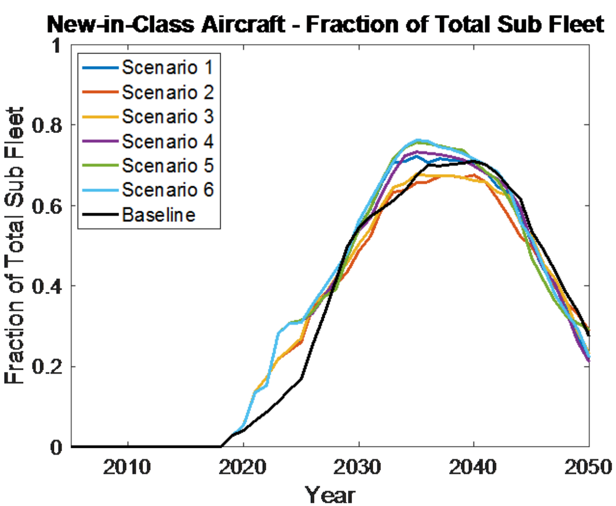

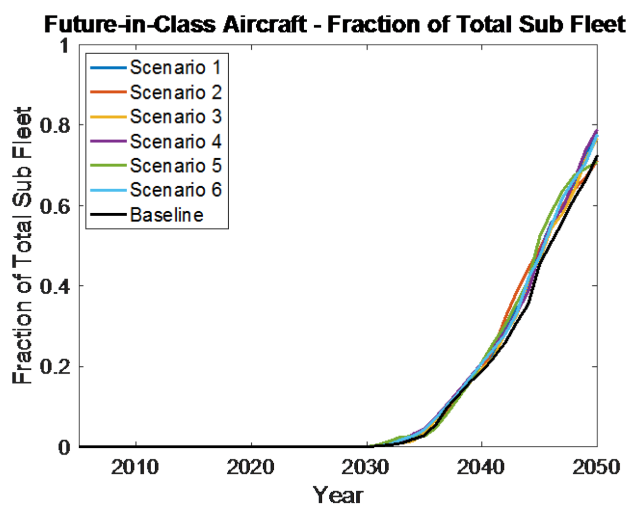

- Less profitable aircraft are retired during the low demand period
- More profitable (more fuel-efficient) aircraft introduced during recovery