ASCENT Project 10

Aircraft Technology Modeling & Assessment

Georgia Institute of Technology & Purdue University

PI: Dimitri Mavris, GT
William Crossley, Purdue

PM: Rangasayi Halthore
Maryalice Locke
Laszlo Winhoffer

Cost Share Partner: Boom Supersonics, Gulfstream, Georgia Institute of Technology, Purdue, OAG

Objective: Model and assess potential evolution of commercial airline fleet due to the introduction of future supersonic aircraft and how technology development could affect the environmental impacts of aviation (e.g., fleet-level fuel burn, emissions and noise). The effort will examine ***SST vehicle modeling (in support of CAEP Exploratory Study); fleet route simulation; fleet simulation, and AEDT supersonic modeling.***

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:

SST Vehicle Modeling:
- CFD based aero shaping; installed propulsion modeling; mission analysis; emissions and LTO noise analysis
- Perform design Mach trade study for three SST classes
- Model facsimile of OEM SST for CAEP E-Study

Fleet Route Simulation:
- Computing potential time savings per OD pair
- Computing value of travel time savings per OD pair
- Detailed SST aircraft performance on complex mixed missions

Fleet Simulation: See slide 4

AEDT SST Modeling:
- Generate performance data via aero and propulsion models
- Construct appropriate physics-rooted regression functions to model drag, thrust, and fuel-burn
- Fit regressions to performance data, predict, and validate

Major Accomplishments (to date):

SST Vehicle Modeling: Completed 7 SSTs for design Mach trade study; completed 3 OEM vehicles; completed study on VRNS impact on climb out NOx; completed nvPM study

Fleet Route Simulation: Developed flexible route optimization tool; Completed future SST demand study where demand depends on vehicle; Support for CAEP E-Study

Fleet Simulation: See slide 4

AEDT SST Modeling: Developed new approach for regressing SST aircraft data; completed data generation and initial model development for 2 SSTs; models demonstrate good predictive accuracy

Future Work / Schedule:

Complete modeling remaining SSTs (8/2021); complete design Mach trade study (5/2021); complete route simulations for OEM vehicles (5/2021); Check extensibility of SST performance modeling on all SSTs and OEM data (8/2021)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 10 through FAA Award Number 13-C-AJFE-GIT-006 under the supervision of Rangasayi Halthore, Maryalice Locke, and Laszlo Windhoffer. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

SST Vehicle Modeling

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Goal: Determine potential performance (fuel burn, emissions, noise) of future SSTs across a range of vehicle classes (Mach, Range, Pax) and support fleet level modeling

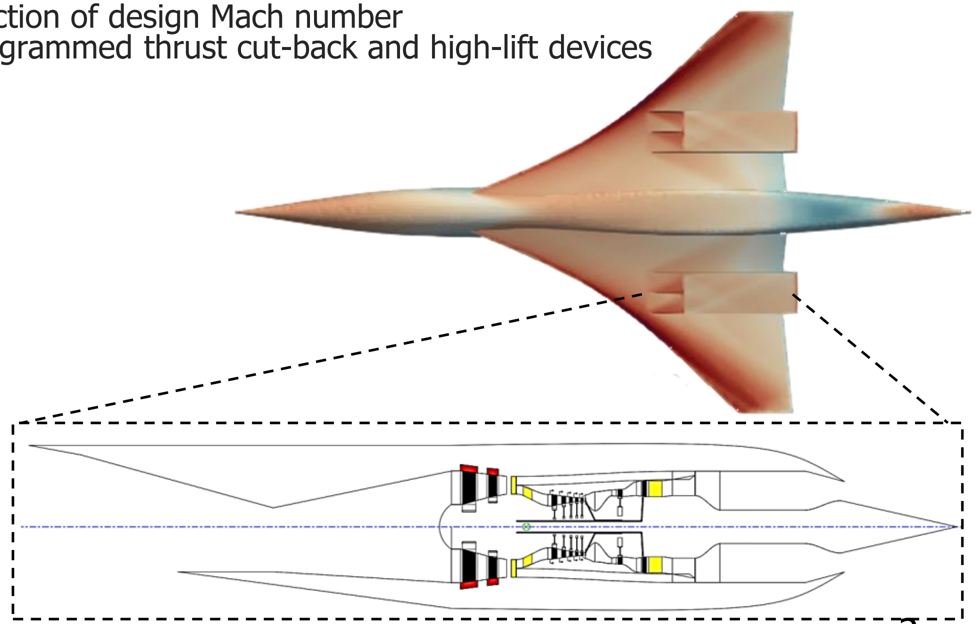
Approach: Utilize the FASST supersonic vehicle sizing environment to explore the design space conduct trade studies

- Aerodynamic Analysis: CART3D inviscid CFD with viscous correction
  - automated and parallelized analysis procedure (geometry, meshing, analysis, post-processing)
  - heuristic design constraints enforced to avoid infeasible designs
- Mission Analysis and Vehicle Sizing: NASA FLOPS
- Propulsion Analysis: NPSS and WATE++
  - cycle design study to determine best cycle for each airframe
  - parametric loss models and maps for engine components
- LTO Noise analysis: ANOPP
  - assess tradeoffs and in fuel burn and noise as a function of design Mach number
  - optimize trajectory for each vehicle using VNRS (programmed thrust cut-back and high-lift devices

Number of Supersonic Transports Modeled

	M1.4	M1.6	M1.8	M2.0	M2.2
8pax (STCA)	4243	4243	4243		
25pax	4243	4243	4243		
55pax			4500	4500	4500
75pax			4500	4500	4500
100pax		5000	5000	5000	

Ranges (nmi) for each pax and Mach class

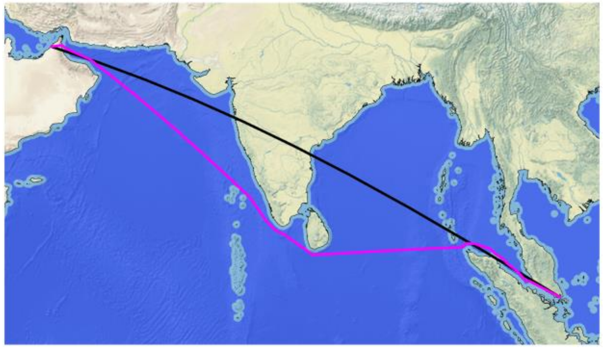


Fleet Demand Route

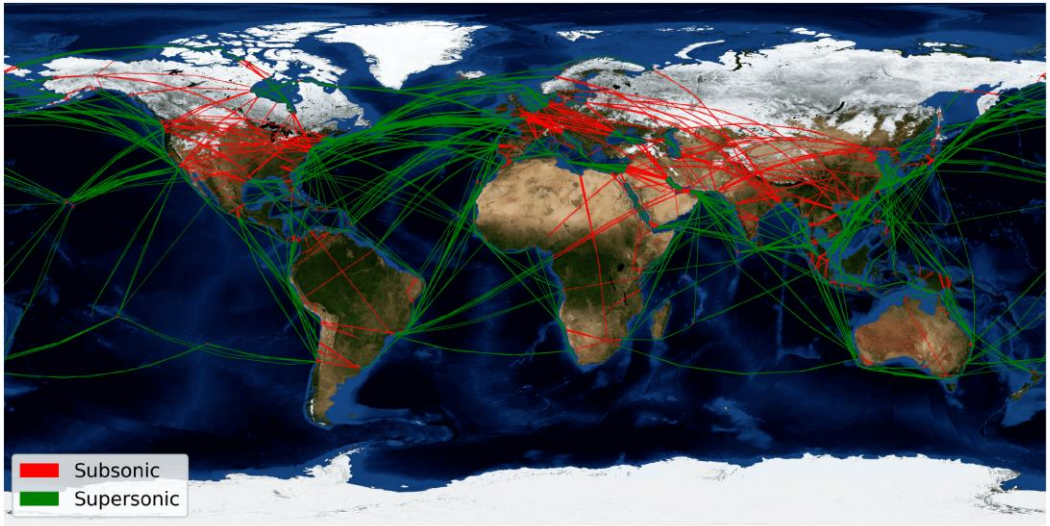
Goal: Determine potential SST demand globally in the future and estimate fuel burn and emissions

Approach: Vehicle capability based time savings and cost per route to estimate demand and aircraft performance

- Developed SST route optimization tool that takes aircraft specific performance into account and allows trading off time savings and fuel efficiency
- Developed link to feed optimized routes and run performance in FLOPS to create full flight fuel burn and emissions
- Support for CAEP E-Study
- Developed detailed global emissions dataset for Projects 22 and 58



Example: Dubai – Singapore



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Purdue University

Research approach:

- Use FLEET to model airline operations and observe evolution of fleet utilization
- Purdue's four major tasks for current effort:
  - Generating supersonic and subsonic aircraft usage and allocation data
  - Studying the impact on fuel burn 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

Major accomplishments:

- Identified profitable SST routes and fuel burn impact
- Developed approach to examine airlines increasing passenger density of subsonic aircraft on SST routes
- Modeled potential of COVID-19 to change introduction of new technologies and reduce fleet size

2038 FLEET aircraft allocation on selected supersonic routes - demonstration:

- With current modeling
  - Airline serves 57 routes with supersonic aircraft in year 2038
  - FLEET results provide detailed supersonic and subsonic aircraft allocation data, including number of daily roundtrips, number of roundtrip passengers carried, etc.
  - This FLEET run has no constraints on number of airport operations
  - The number of round trips reflects US flag carriers only

Route Information		FLEET Allocation Information			Number of Daily Roundtrips for different A/C Size and Generation						
Airport A	Airport B	Allocation Model	Fuel Stop	Distance Flown (nmi)	New-in-Class 3	Future-in-Class 3	Best-in-Class 4	New-in-Class 4	New-in-Class 5	Future-in-Class 5	Best-in-Class SST
JFK	LHR	*Supersonic*		3150.63	0	0	0	9	1	0	2
		Subsonic-only		2991.45	0	1	0	10	0	0	
LAX	HNL	*Supersonic*		2225.47	0	0	0	18	4	0	4
		Subsonic-only		2217.99	1	0	0	22	1	0	
DFW	NRT	*Supersonic*	HNL	6619.53	0	0	0	6	0	0	1
		Subsonic-only		5573.40	0	0	0	4	0	2	

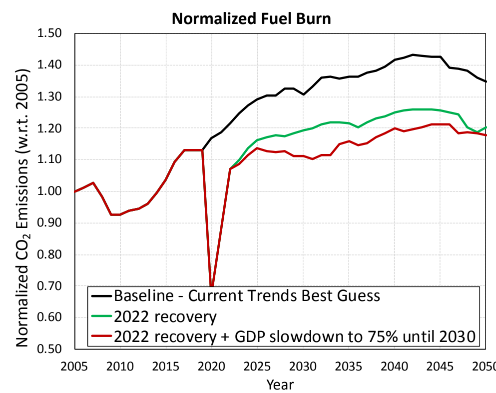
Introducing High-Passenger-Density Subsonic Aircraft on Routes with SST Aircraft Allocations:

- Model what airlines might do if the SST takes away the "premium" paying passengers that might be subsidizing some of the economy class passengers
- Airlines may convert "no-longer-needed" business class seats into economy seats increasing aircraft seat density – high-passenger-density
- Aircraft modeling approach assumes that empty weight remains constant, and one business-class seat is replaced by two economy-class seats

Example Coefficients for Class 3 Aircraft on JFK-LHR route	Standard Config.	High-Pax-Density Config.	Increment
Max seat capacity [pax]	177	183	6 pax
Fuel burn [lbs.]	31,663	32,825	3.7 %
Indirect operating cost [$]	19,966	20,338	1.9 %

Future fleet-level impact of COVID-19:

- Considers two future demand scenarios of COVID-19-related passenger demand recovery
- Current work considers subsonic aircraft only
- Results show future fleet-level fuel burn using the projected demand scenarios are lower compared to the baseline (no COVID-19) case for all years from 2022 to 2050
- Airline fleet size is about 25% smaller than the baseline case fleet size by 2050



Expand FLEET's network to global network:

- Increase FLEET demand representation to capture all demand among WWLMINET 257 airports
- Using the OAG database to retrieve necessary data

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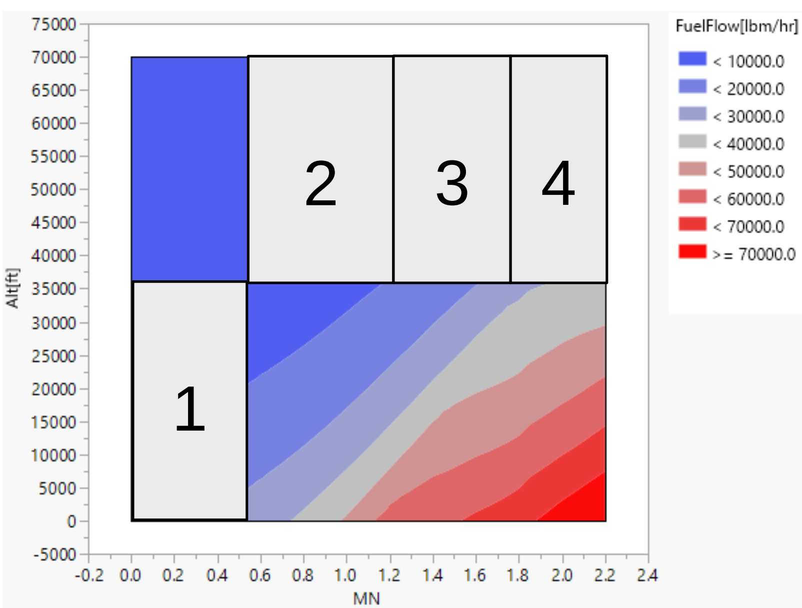
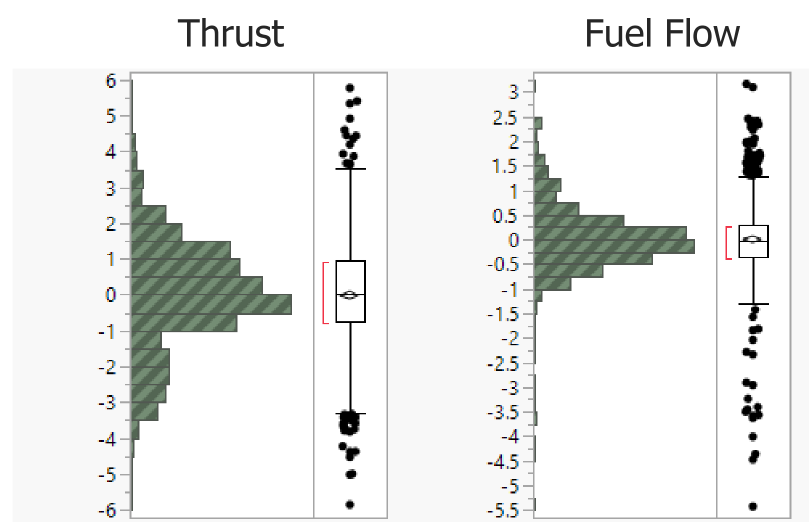
AEDT SST Modeling

Goal: Develop & validate approach for modeling SST aerodynamics & propulsion performance within AEDT

Approach:

- Generate performance truth data for SST aircraft concepts
  - Aerodynamic Analysis: CART3D inviscid CFD with viscous correction
  - Propulsion Analysis: NPSS
- Fit using standard activation function, generate coefficients, and assess accuracy
- Develop new regression equations to model both supersonic and subsonic regimes
  - Physics-rooted functional forms
  - Focus on maximizing parsimony (minimal number of coefficients) while minimizing prediction errors
- Fit truth data to physics-rooted functional forms, quantify errors and propagate through aircraft mission
  - Region of validity for regressions extracted from notional SST missions
  - Fit several regressions using identical functional forms; applicable within specified envelope, i.e., region of validity
  - Assess prediction errors and propagate through simulated mission(s)
- Provide implementation plan to incorporate models within AEDT





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