FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Aircraft Technology Modeling and Assessment

Project 10

FAA Project Manager: Rangasayi Halthore, Laszlo Windhoffer

Georgia Tech (Lead University): Dimitri Mavris (PI), Jimmy Tai (Co-PI)

REEs: Holger Pfaender, Mohammed Hassan

GRA Leads: Edan Baltman, Taylor Fazzini, Barbara Sampaio Felix, Rick Hong, Nikhil Iyengar, Kevyn Tran, Nathan Crane

October 22 & 23, 2019
Alexandria, VA

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 under the supervision of Rangasayi Halthore and Laszlo Windhoffer. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT
AVIATION SUSTAINABILITY CENTER

Team Approach to Tasks

Overall Objective: Investigating fleet impact of introducing supersonic transport (SST) in terms for fuel burn, emissions and noise, including sonic boom for various scenarios

Objective		Georgia Tech	Purdue
1	Fleet Assumptions & Demand Assessment	Expand Airline cost model: Capture vehicle performance sensitivities (passenger capacity, cruise Mach number); Evaluate which size vehicle the most likely to be able to close the business case	Airline fleet composition and network; Passenger choice for supersonic / subsonic demand; Effect of supersonic aircraft on subsonic aircraft operations and pricing
2	Fleet Analysis	Develop assumptions for supersonic scenarios relative to 12 previously developed subsonic focused fleet scenarios. Perform fleet analysis with the gradual introduction of SST vehicles into the fleet.	Develop assumptions for supersonic scenarios relative to 12 previously developed subsonic focused fleet scenarios; Perform fleet-level assessments, including additional SST vehicle types**;** Develop FLEET-like tool for supersonic business jet operations; Simple SST sizing to support FLEET development and studies
3	AEDT Vehicle Definition	Develop Methods to Model Supersonic Flights in AEDT	n/a
4	Support CAEP Efforts	FASST Vehicle Modeling: Develop additional SST class for 100 passengers; Develop AEDT coefficient generation algorithm for BADA3 supersonic coefficient; Perform trade studies to support CAEP Exploratory Study	Provide representative supersonic demand scenarios**;** Develop and assess airport noise model to account for supersonic aircraft
5	BADA4 Coefficient Generation	Develop, implement, and test BADA4 coefficient generation algorithms; Identify gaps and needs for BADA4 coefficient generation for SST	n/a
6	Coordination	Coordinate with entities involved in CAEP Supersonic Exploratory Study; Coordinate with clean-sheet supersonic engine design project	Coordinate with entities involved in CAEP MDG/FESG, particularly the SST demand task group**;** Maintain ability to incorporate SST vehicle models that use the engine design from ASCENT project 47 and / or NASA-developed SST models

Route Finder Algorithm

Specific Route: London-Dubai

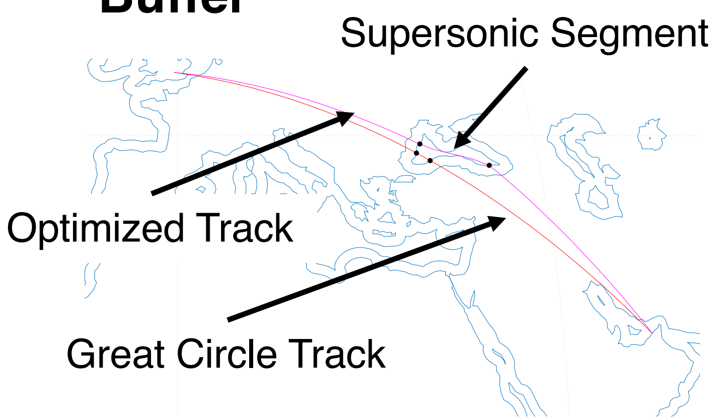
- Current high demand and even more so in the future
- Potentially complicated routing for overwater only supersonic flight

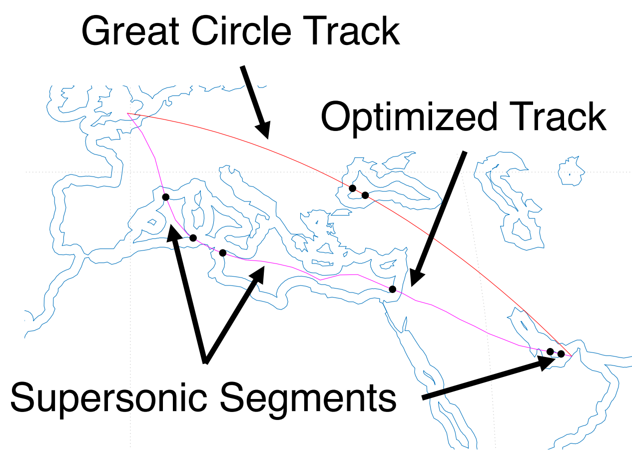
Testing algorithm capabilities

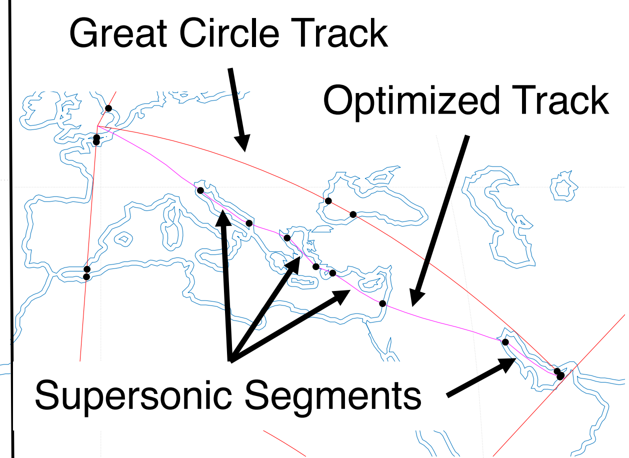
- Can it find a good optimum?
- Demonstrate cruise Mach sensitivity of optimum routing
- Number of total accelerations/decelerations
- Time saved compared to conventional subsonic
- -> Key for market demand

Route Variables: London-Dubai

	A	B	C
Speed	M1.4	M2.2	M2.2
Time Savings	1.2 hours	1.67 hours	2.1 hours
Accelerations	1	3	4
Coastal Buffer	100nmi	100nmi	50km/27nmi



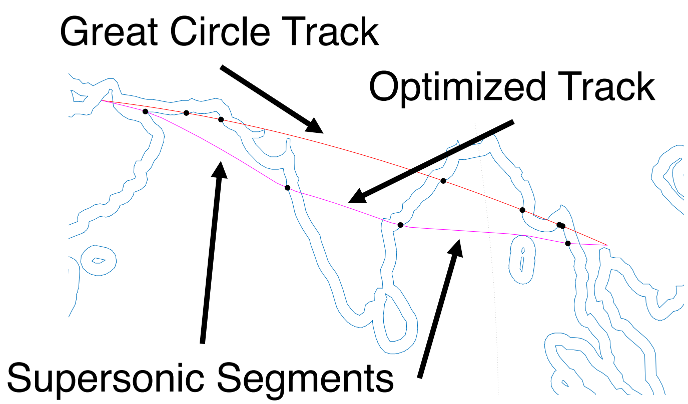


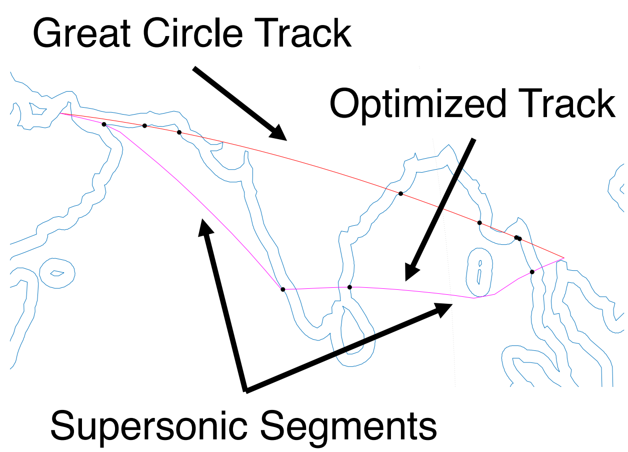


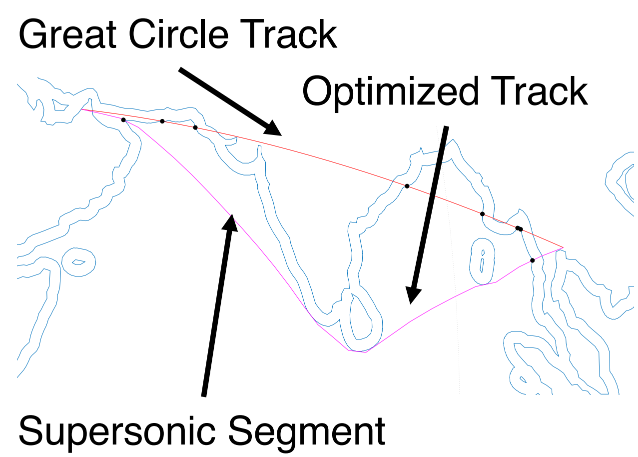
Buffer size matters quite a bit, at least on some routes
Accelerations could be quite fuel intensive
More than two could be prohibitive
Depends a lot on vehicle performance

Route Variables: Dubai-Bangkok

	A	B	C
Speed	M1.4	M2.2	M2.2
Time Savings	1.7 hours	2.6 hours	2.7 hours
Accelerations	2	2	1
Coastal Buffer	100nmi	100nmi	100nmi







Cruise Mach significantly changes optimum route

Potential trade between

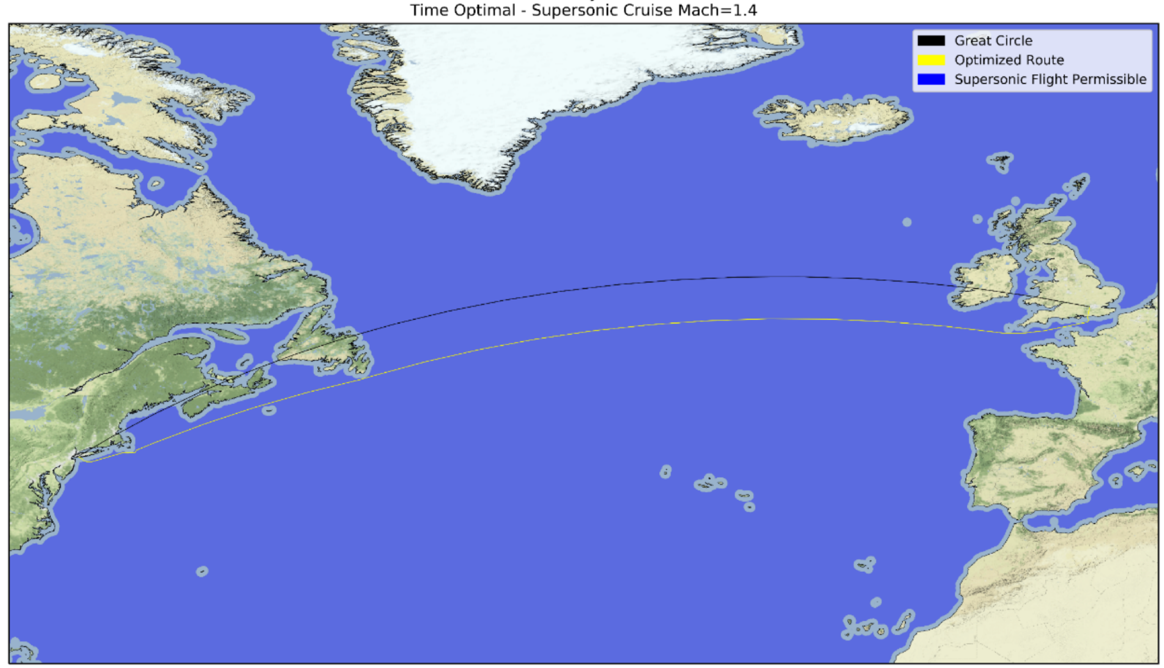
- Additional accelerations
- Additional ground track distance

Depends on vehicle performance and weather

Improved Routing Algorithm Detail

Route 8: WASHINGTON DULLES INTL to BENITO JUAREZ INTL
Time Optimal - Supersonic Cruise Mach=1.4

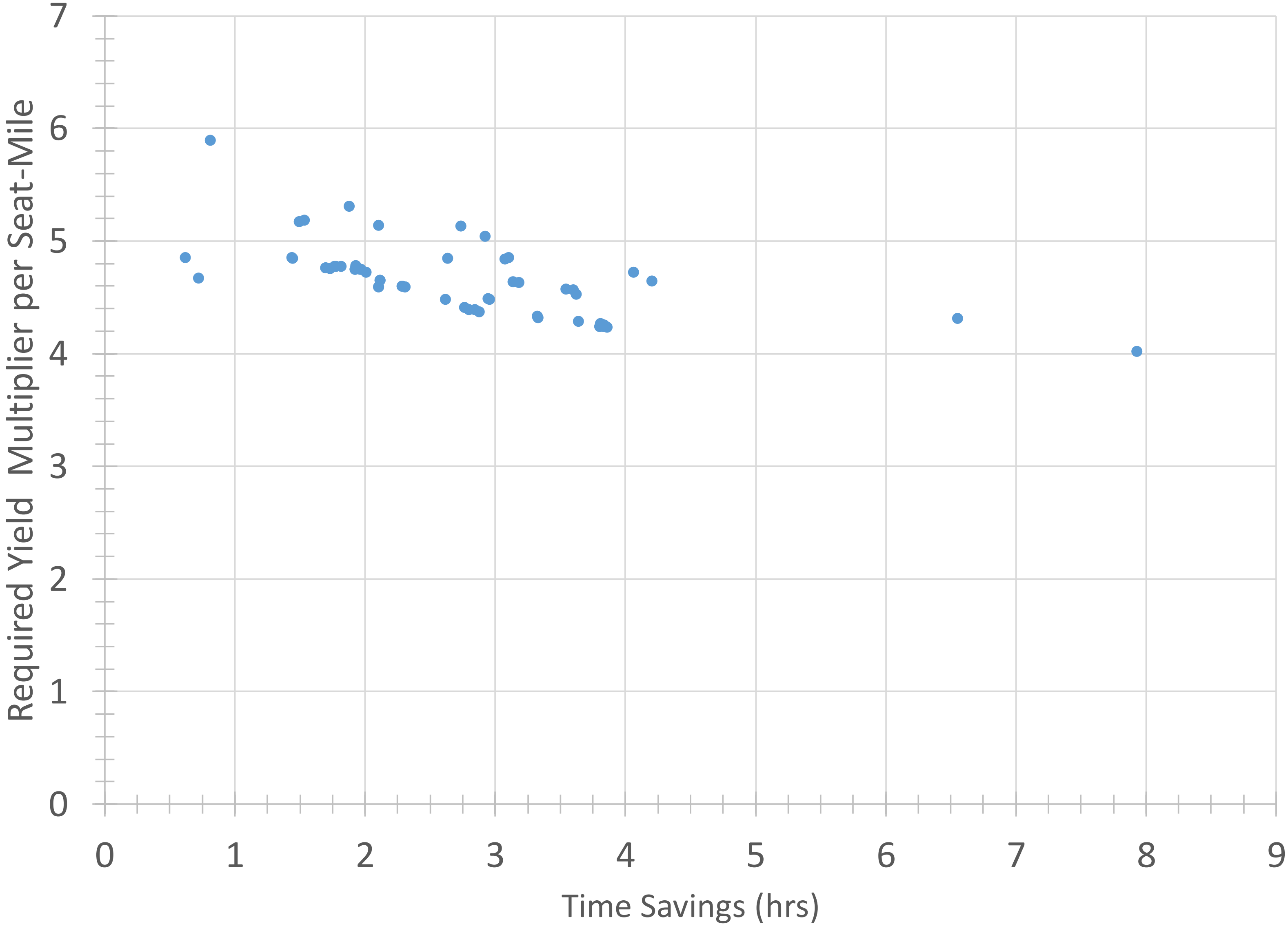
Route 5: HEATHROW to JOHN F KENNEDY INTL
Time Optimal - Supersonic Cruise Mach=1.4



Actual Time Savings

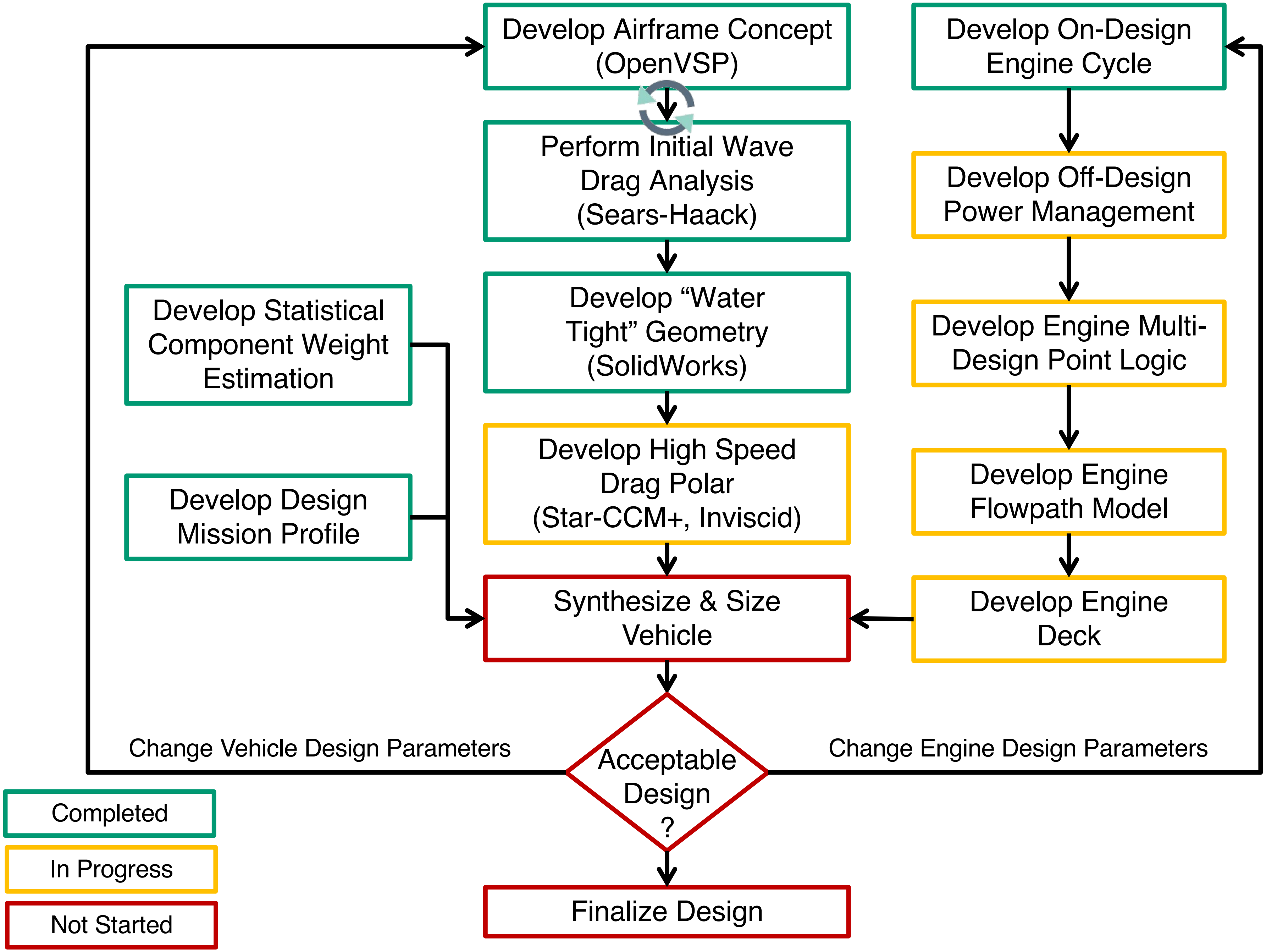
Top 2050 routes, M=2.2, 27nmi buffer

Required Yield vs Time Savings

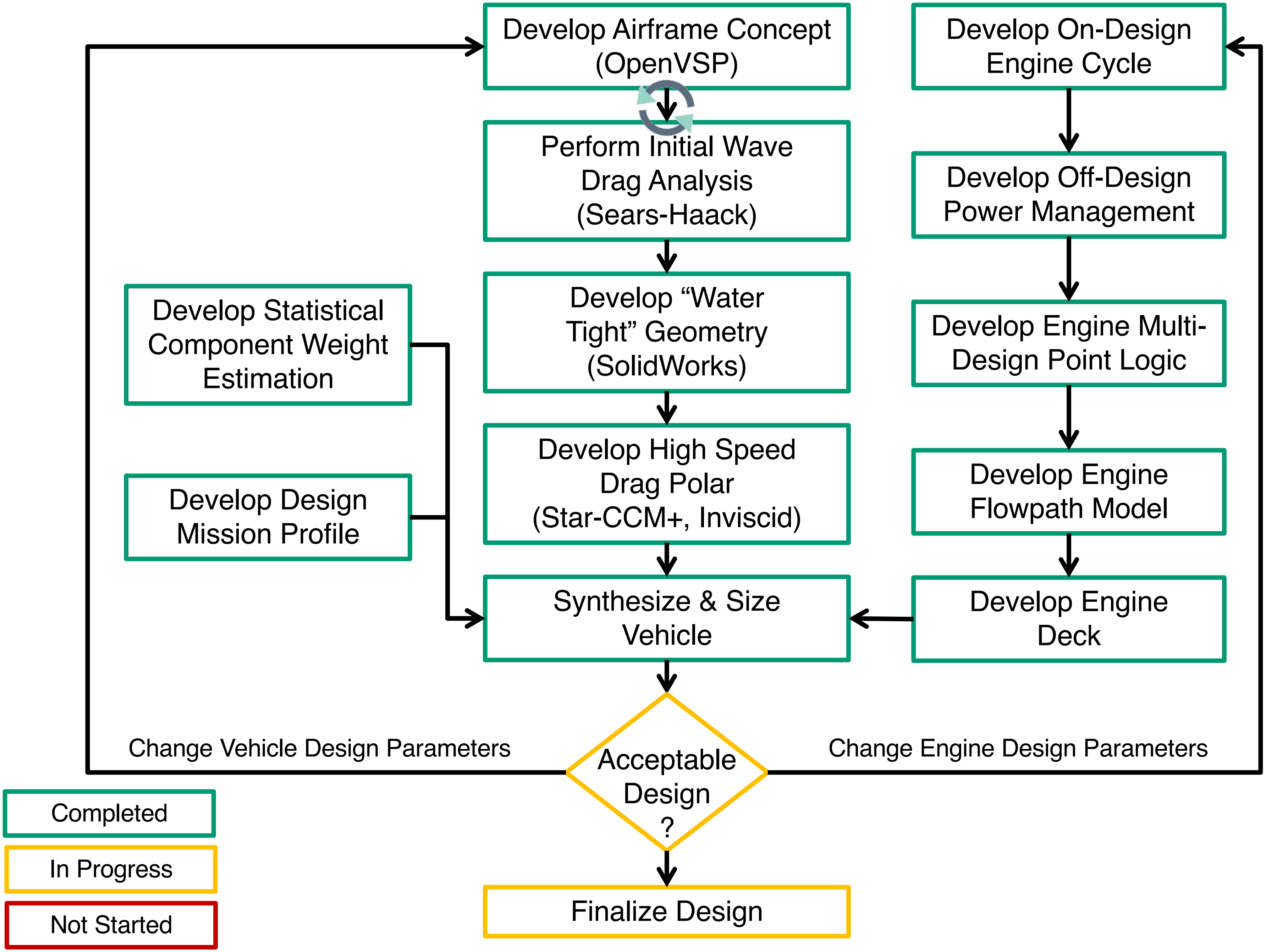


Top 2050 routes, M=2.2, 27nmi buffer, Concorde Efficiency (for now)

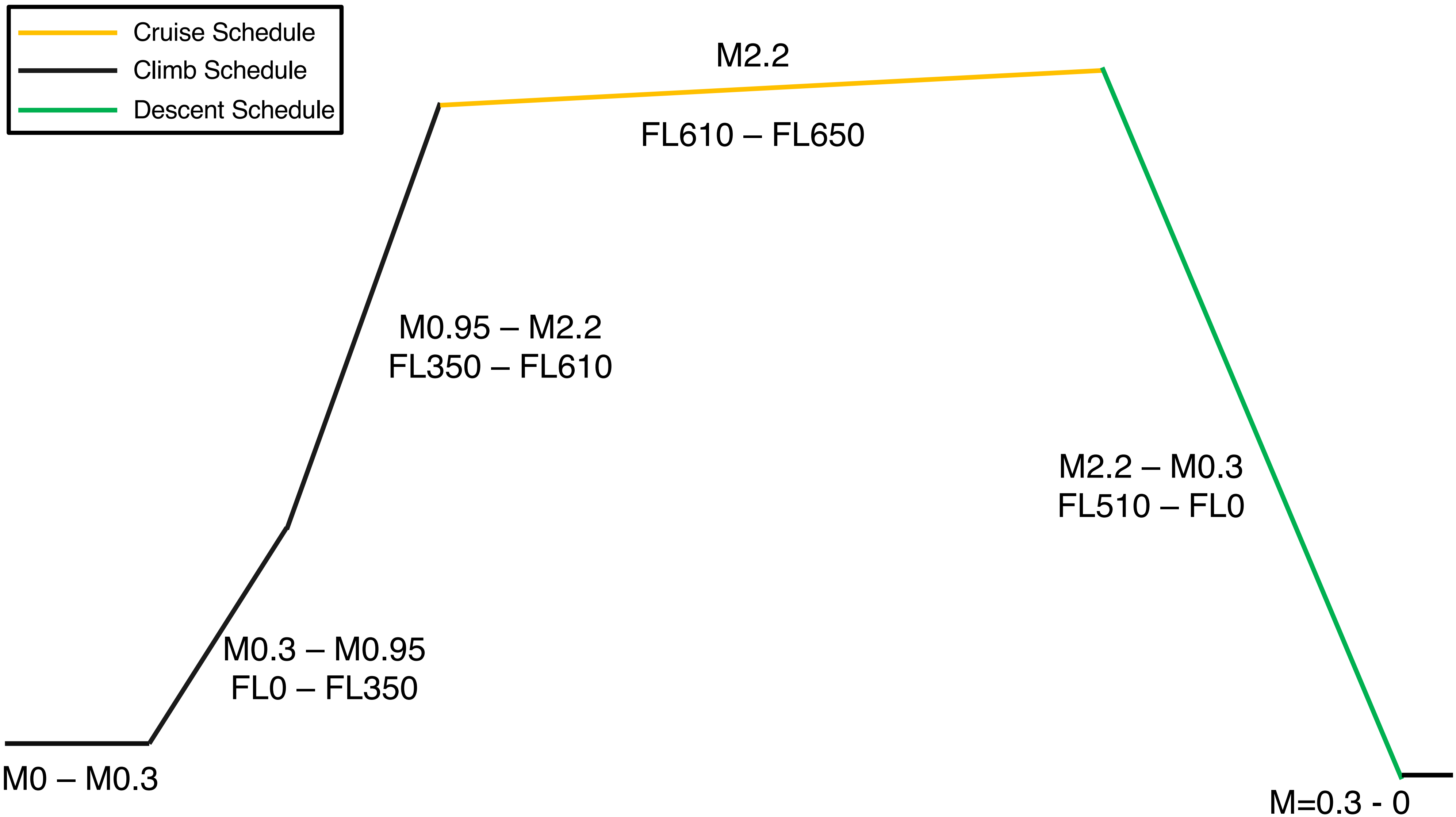
Supersonic EDS Vehicle Modeling – Spring 2019



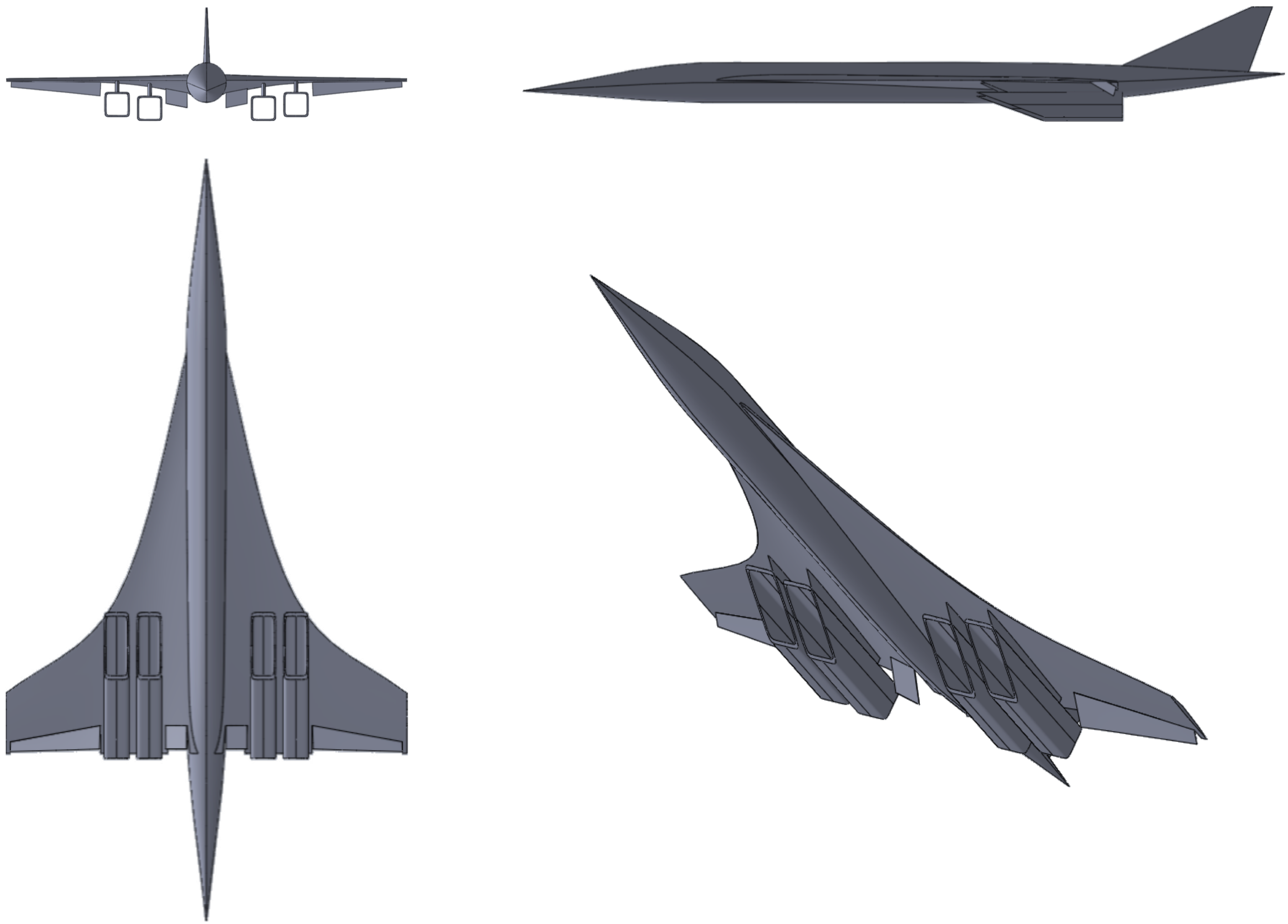
Supersonic EDS Vehicle Modeling – Fall 2019



Design Mission Profile: All Supersonic



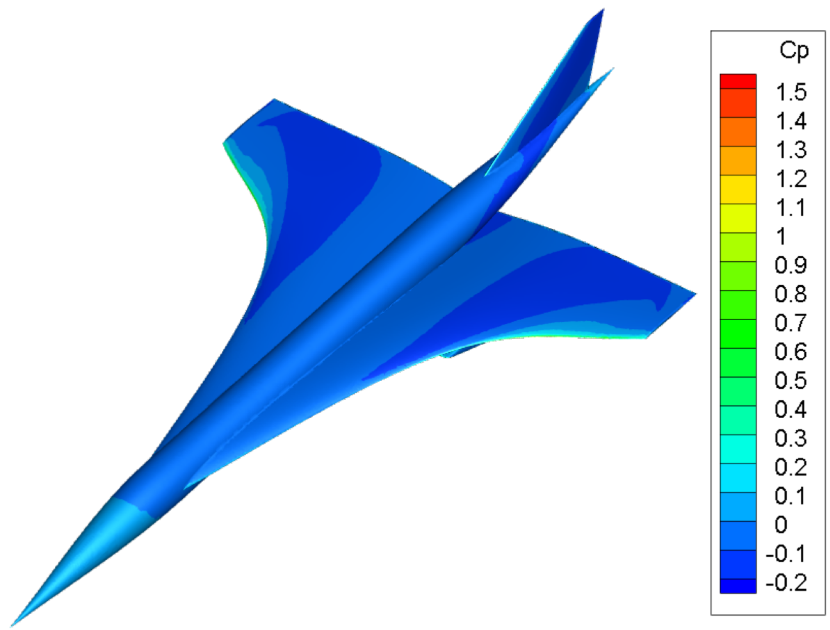
GT Medium SST (Flap Configuration)



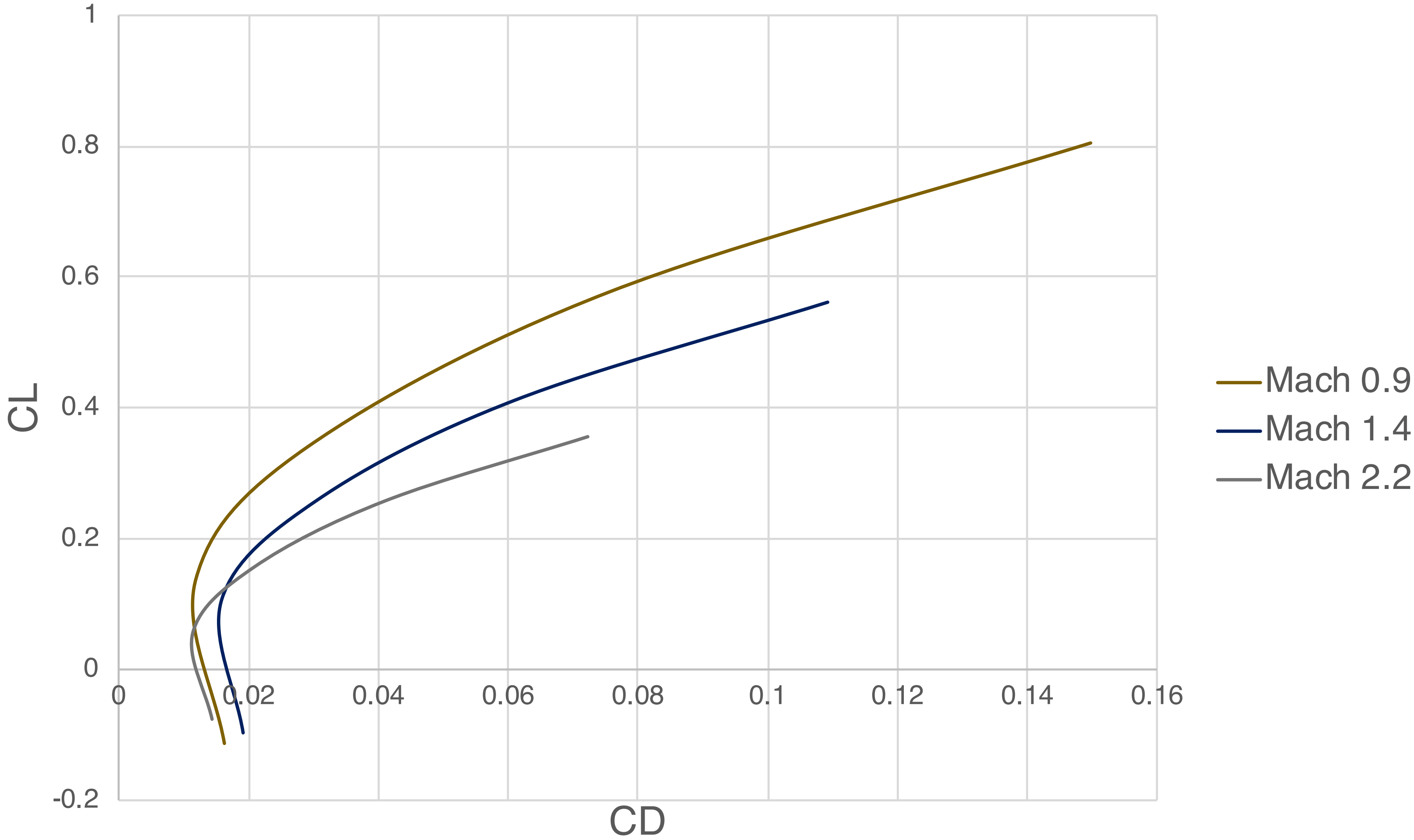
GT Medium SST Converged Solution (4 Engines)

- Converged Design Parameters:
  - Thrust-to-Weight = 0.367
  - Wing Loading = 92.2 psf
  - Empty Weight = 128,411 lb
  - Fuel Weight = 158,773 lb
  - Takeoff Gross Weight = 298,733 lb
  - SLS Thrust = 27,430 lb
  - Range = 4500 nmi

- Configuration Specs:
  - Cruise L/D: 7.52
    - M2.2, Alt. 65K, W = 192,000 lb
  - 4500 sq. in capture area engines
  - Wing area: ~3240 sq. ft
  - Tail area: ~365 sq. ft

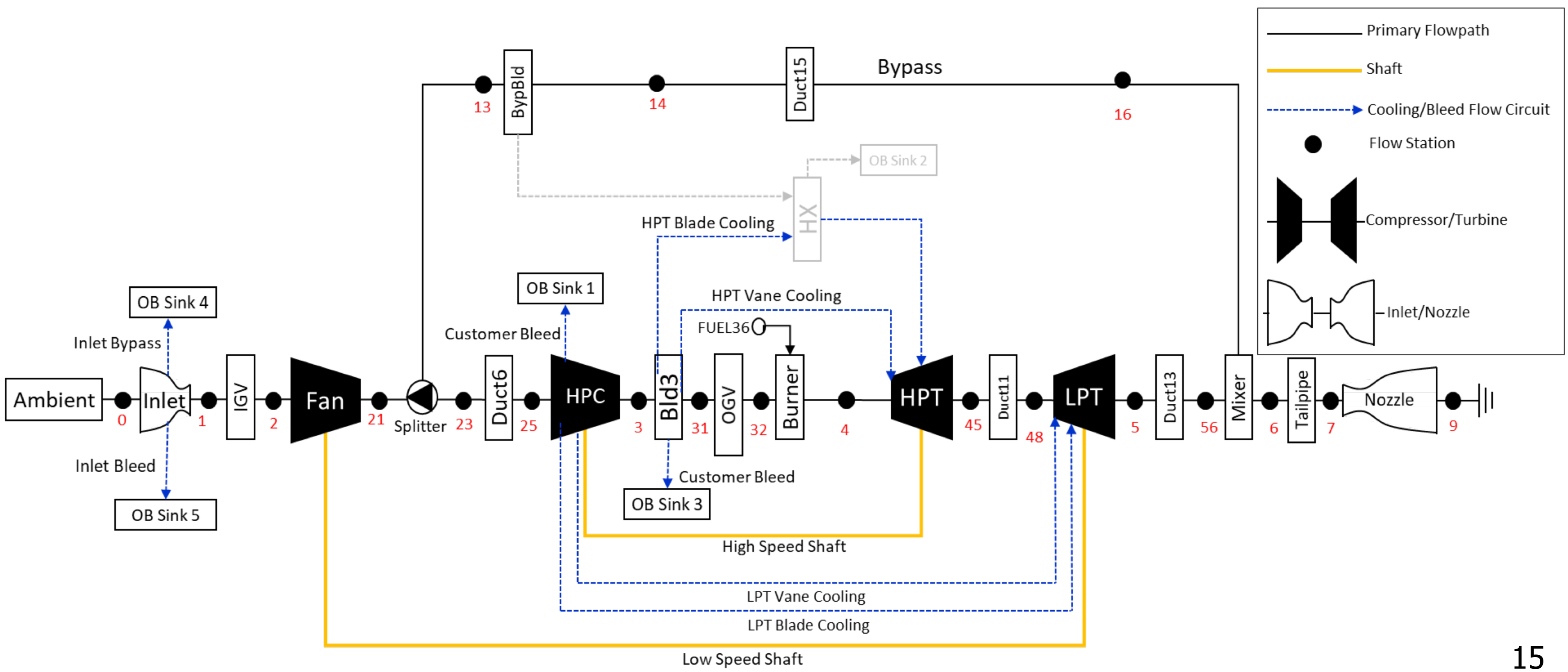


High Speed Drag Polar



Engine Architecture

- Mixed Flow Turbofan
  - Improved specific thrust (thrust per unit airflow) to control thrust lapse
  - 2 stage fan
  - Cooled turbines
  - 2D inlet
  - Axisymmetric CD nozzle



Cabin Layout – Summary

VIP Class

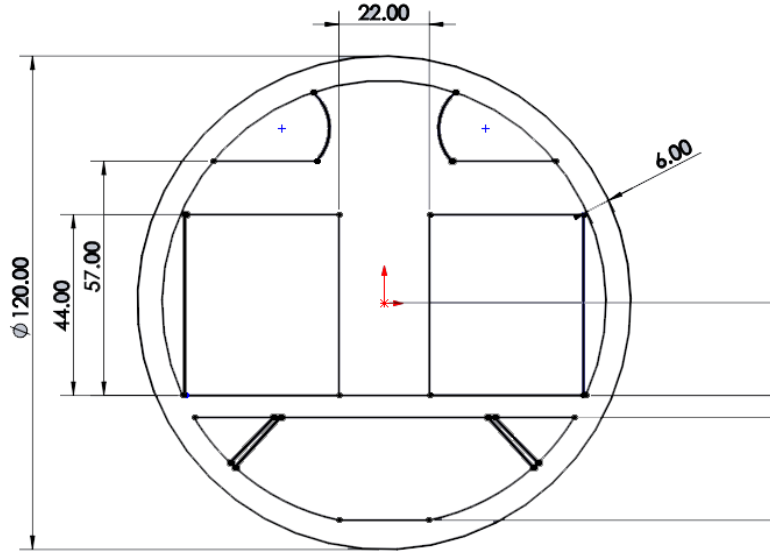
- Seat pitch: 45 in
- Seat Width: 24 in (31 in w/ arm rest)
- Isle width: 22 in

First Class

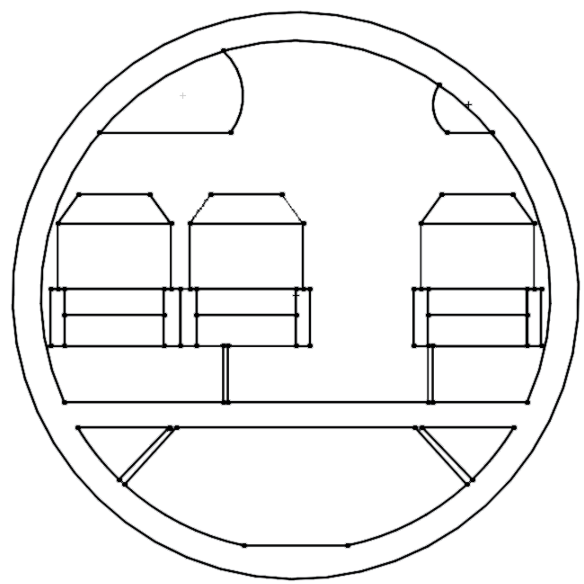
- Seat pitch: 37.5 in
- Seat width: 21 in (27 in w/ arm rest)
- Isle width: 22 in

Length of passenger cabin: 80 ft

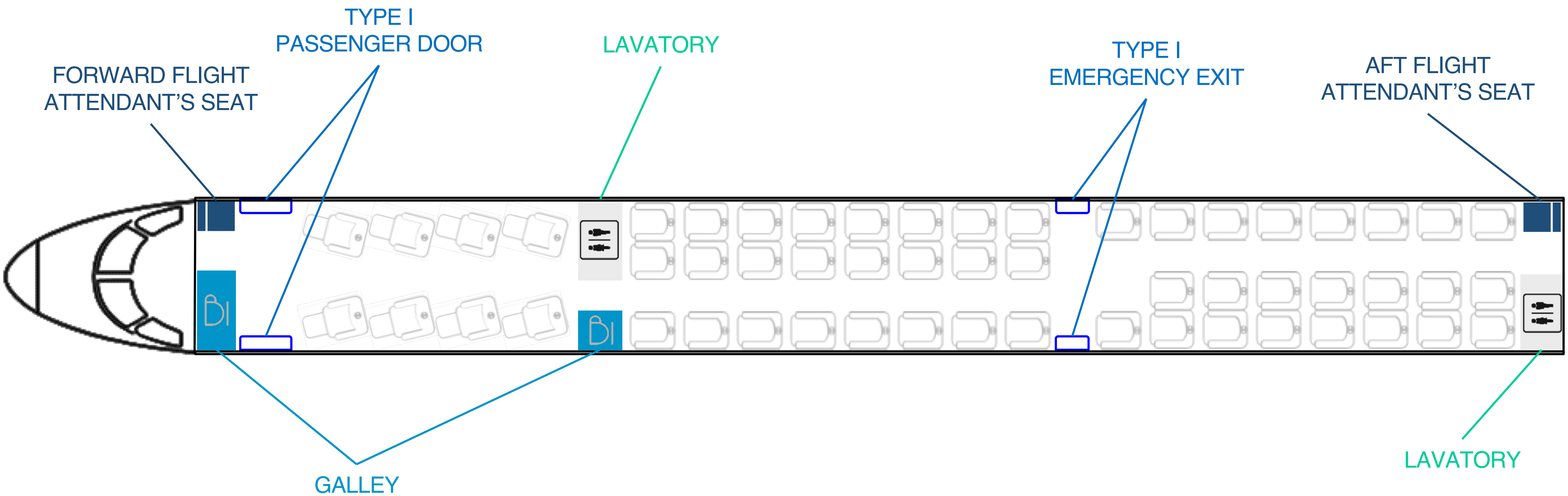
VIP Class

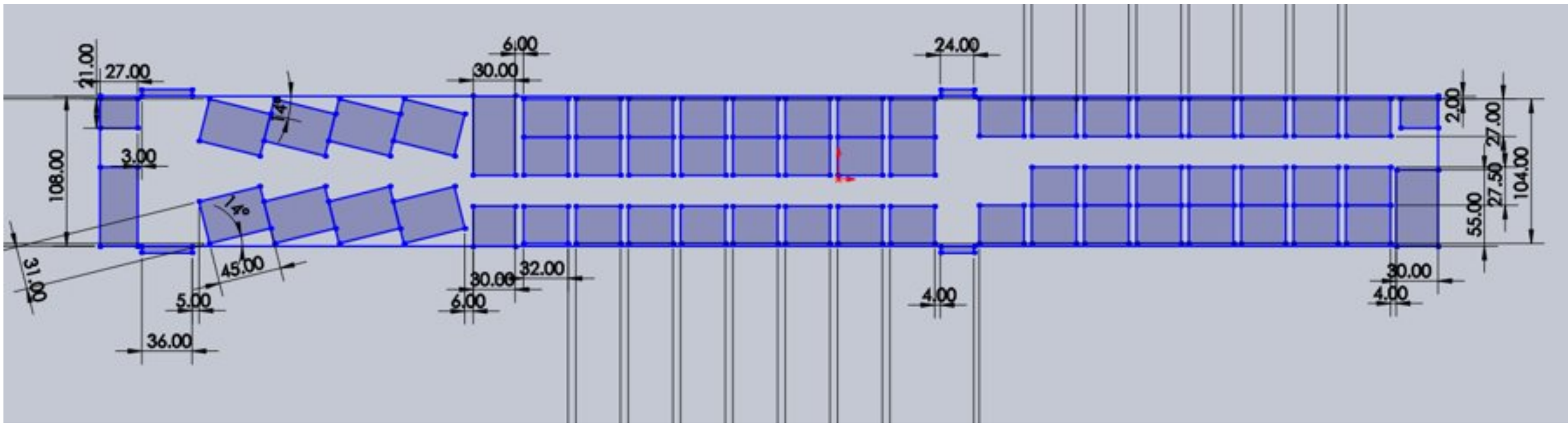


First Class



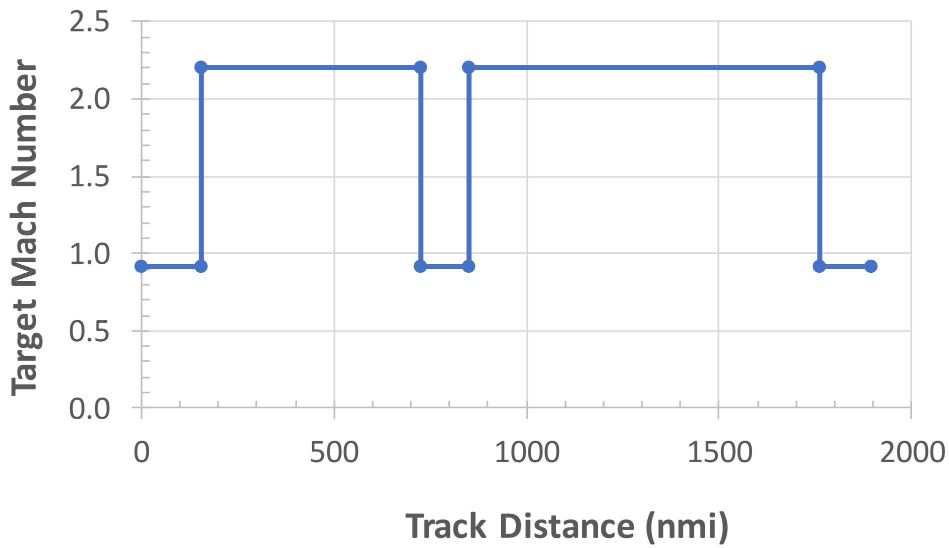
Cabin Layout

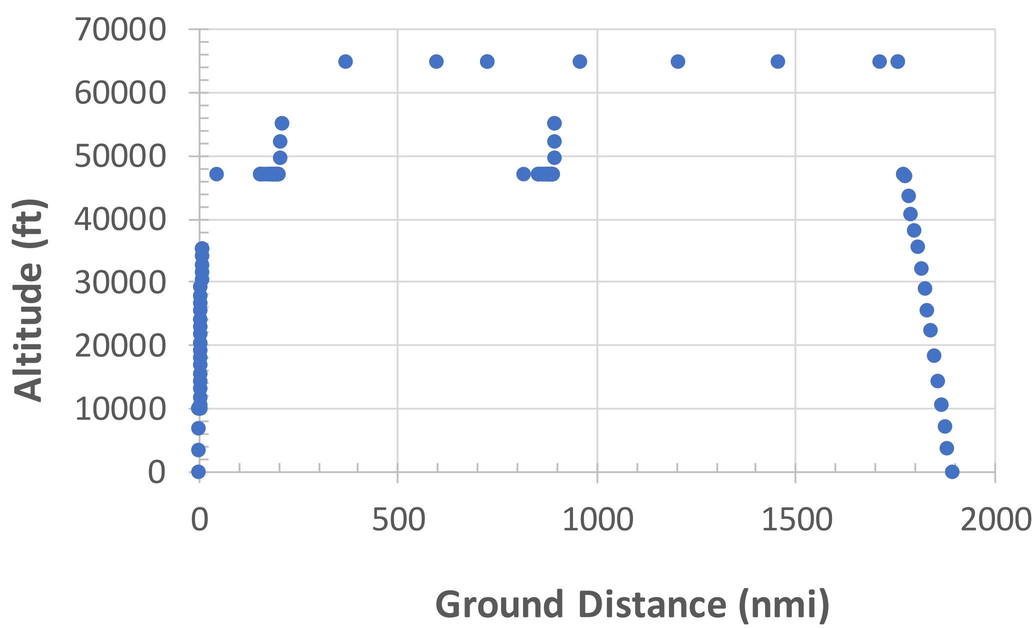




Sample Route: IAD – MEX (Medium SST Results)

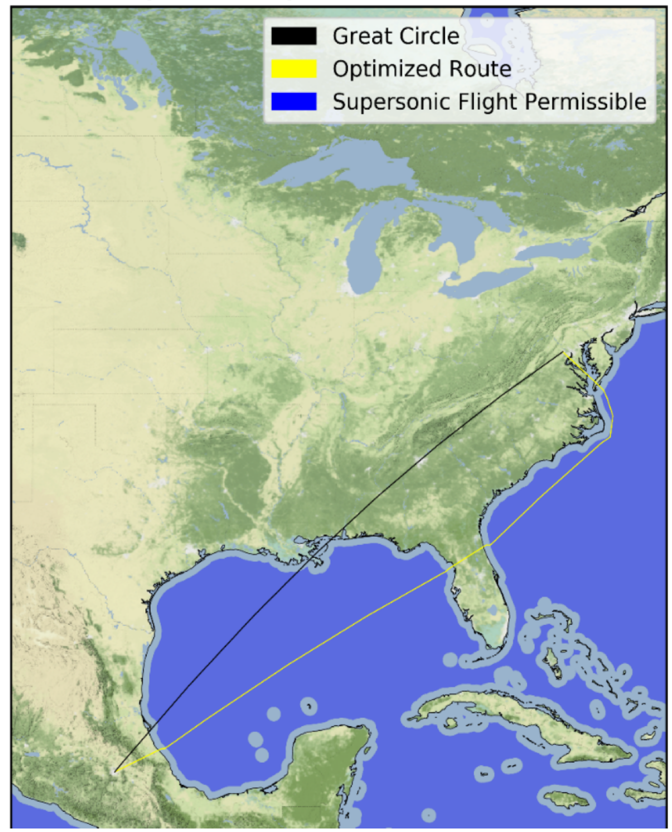
- GT Medium SST flown following target Mach profile





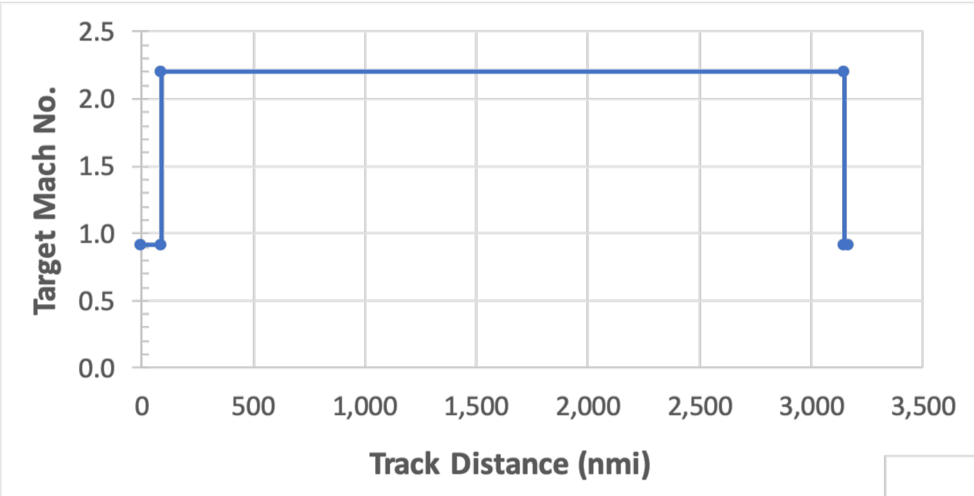
OPERATING WEIGHT EMPTY	128411	LB
PAYLOAD	11550	LB
MAXIMUM FUEL	65217	LB
GROSS WEIGHT	205177	LB
REFERENCE WING AREA	3239.34	SQ FT
WING LOADING	63.34	LB/SQ FT
THRUST PER ENGINE	27430	LB
THRUST-WEIGHT RATIO	0.535	
RANGE	1894	NMI
BLOCK TIME	2.41	HOURS
BLOCK FUEL	60175	POUNDS

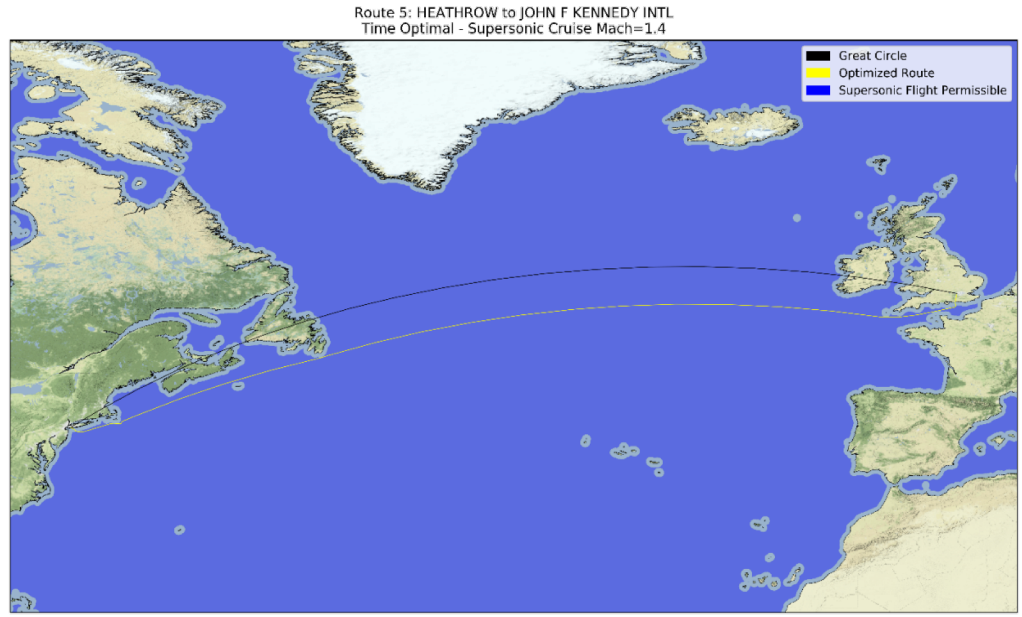
Route 8: WASHINGTON DULLES INTL to BENITO JUAREZ INTL
Time Optimal - Supersonic Cruise Mach=1.4



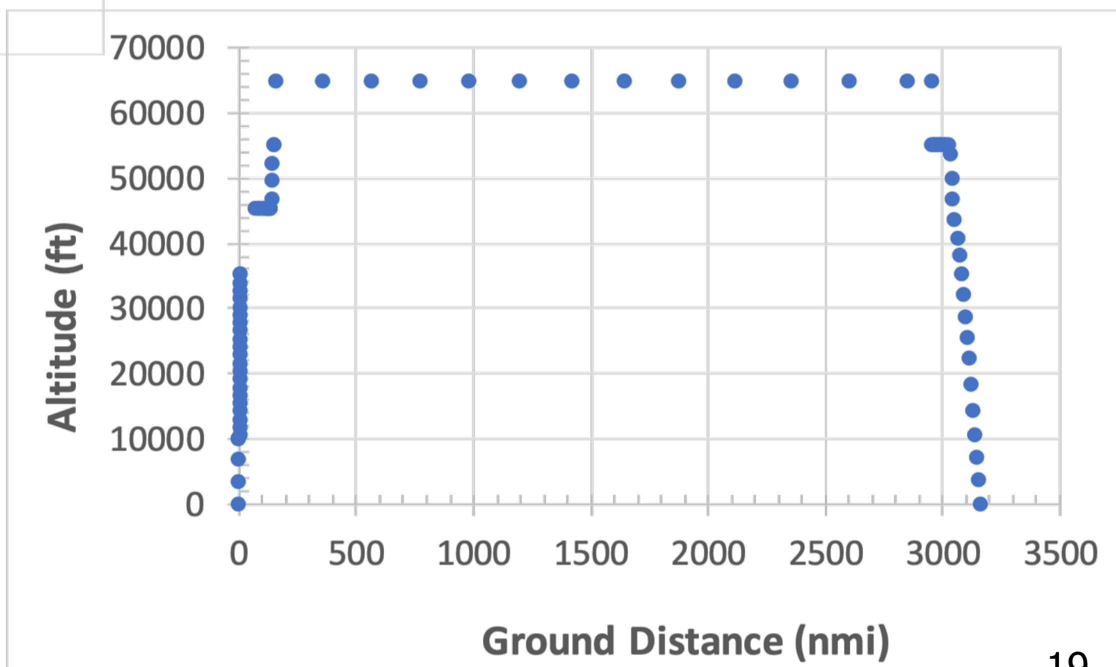
Sample Route: LHR – JFK (Medium SST Results)

- GT Medium SST flown following target Mach Profile





OPERATING WEIGHT EMPTY	128411	LB
PAYLOAD	11550	LB
MAXIMUM FUEL	103274	LB
GROSS WEIGHT	243235	LB
REFERENCE WING AREA	3239.34	SQ FT
WING LOADING	75.09	LB/SQ FT
THRUST PER ENGINE	27430	LB
THRUST-WEIGHT RATIO	0.451	
RANGE	3167.2	NMI
BLOCK TIME	3.21	HOURS
BLOCK FUEL	94773	POUNDS



Summary Remarks & Next Steps

- Developed constrained optimization algorithm for modeling routes
- Completed preliminary FASST development
- Converged GT Medium SST
  - 55 passenger
  - Mach 2.2
  - 4500 nmi design range
- "Flew" both NASA STCA and GT Medium SST on two sample routes
- Next steps:
  - 100 passenger SST
  - AEDT supersonic modeling
  - Continual support of CAEP SST Exploratory Study