CONCEPTUAL DESIGN OF A QUIET SUPERSONIC TECHNOLOGY AIRLINER

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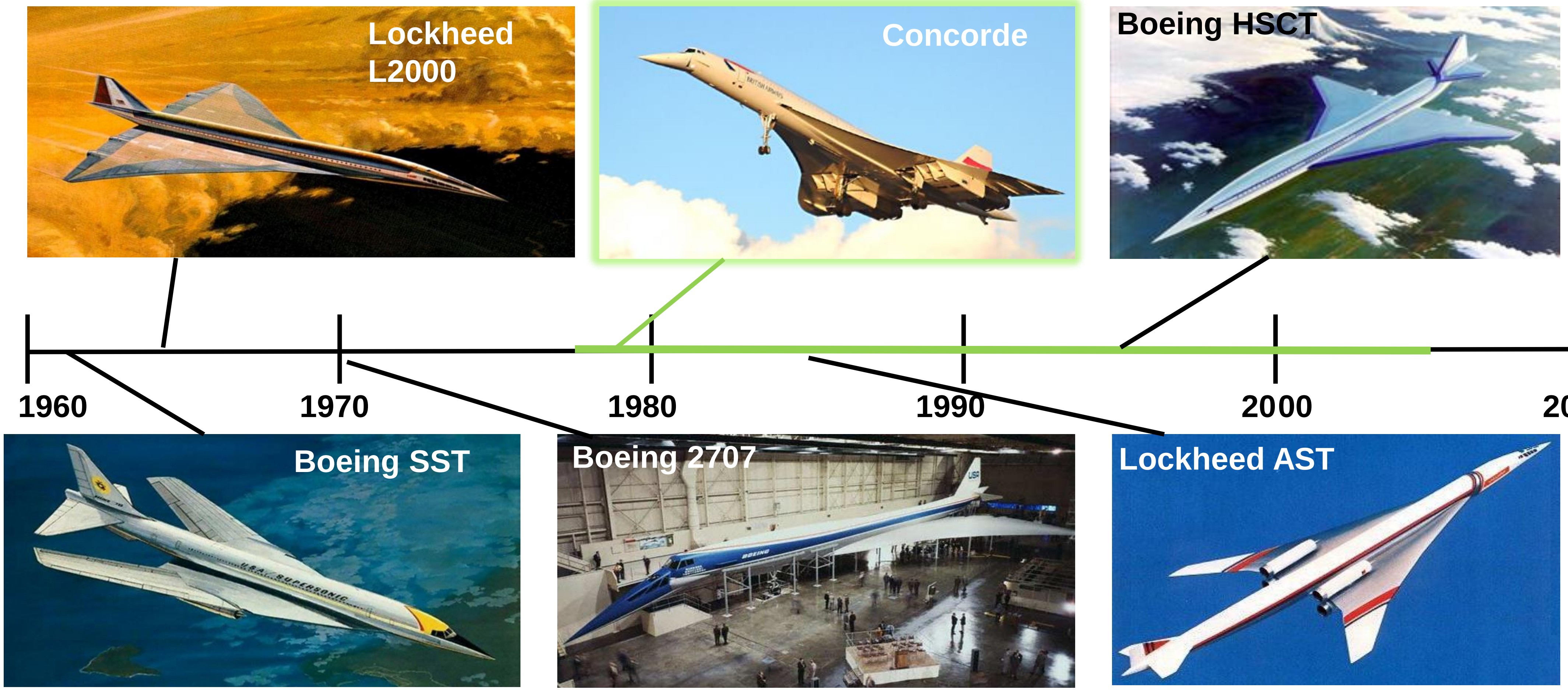
Air Vehicle Lead, X-59 Quiet Supersonic Technology X-plane

LOCKHEED MARTIN

OVERVIEW

- Background
- Requirements
- Enabling Technologies
- Configuration Overview
- Propulsion Integration
- Performance
- Summary

THE LONG QUEST FOR HIGH SPEED TRAVEL



After 6 Decades of R&D, only one Concorde and Tu-144 entered service with none remaining after Concorde's retirement in 2003

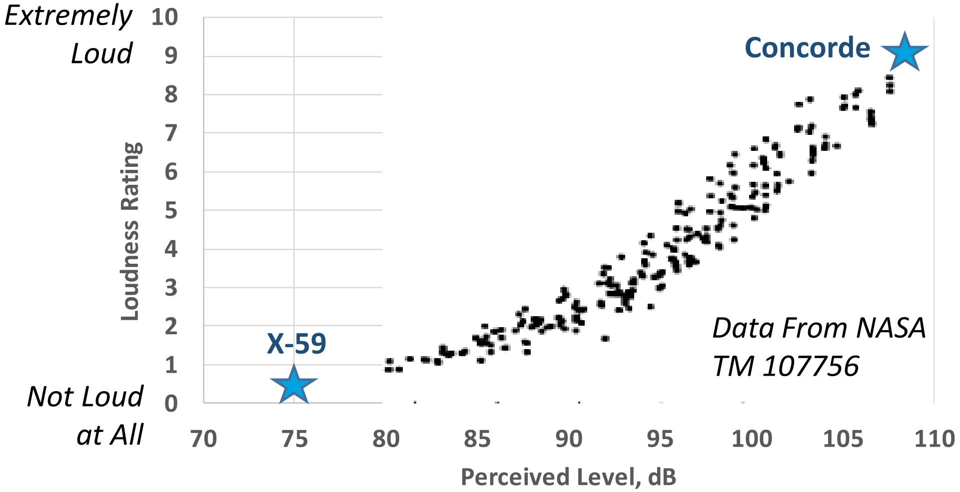
WHY ARE THERE NO COMMERCIAL SUPERSONIC AIRCRAFT TODAY?

- In 1973, the FAA implemented FAR 91.817, which states that "No person may operate a civil aircraft ... at a … flight Mach number greater than 1" over land
- Concorde was only able to fly to a handful of coastal destinations due to the overland restrictions
- It was further limited by its loud noise and inability to fill its passenger capacity of 100+ people
- As a result, only 12 were built and entered service

Beautiful, but too loud and too big: Concorde was a technical marvel, but a business and environmental failure

QUIETING THE BOOM

- The prohibition on supersonic overland flight is the primary obstacle for re-introduction of commercial supersonic aircraft
- Under the Low Boom Flight Demonstration project, NASA is working to develop a community response dataset for shaped booms
- Leveraging the data, regulators may replace the ban with a standard for acceptable quiet supersonic overland flight



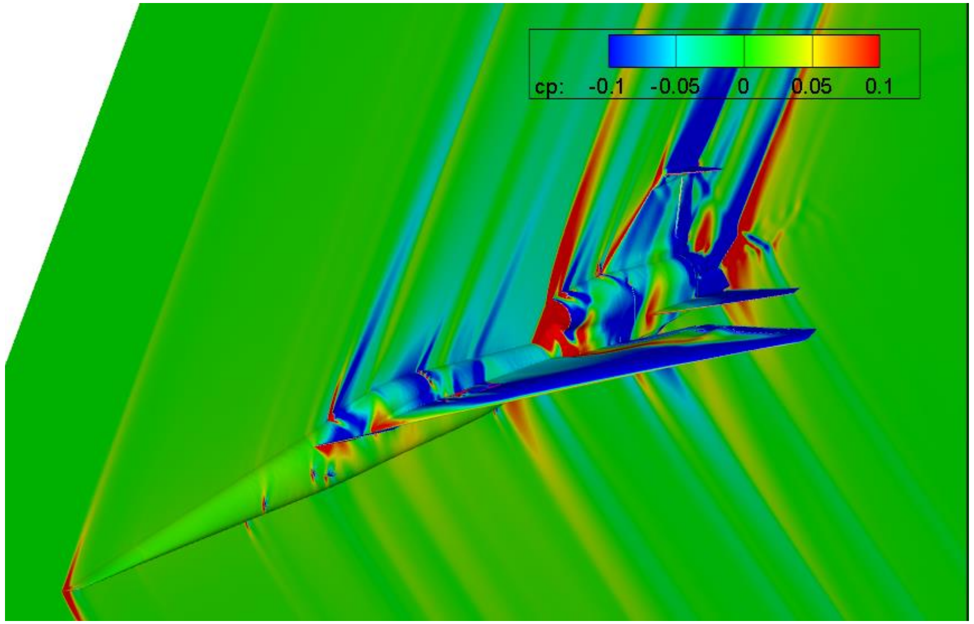
Success of the LBFD project could usher in a new age of high speed commercial air travel

FUTURE SST MARKET ANALYSIS AND REQUIREMENTS

Requirement	Threshold Value	Objective Value	Rationale
Range, plus IFR Reserves	4200 nm	5300 nm	4200 nm sufficient for most top destinations; 5300 nm allows nonstop trans-pacific routes
Takeoff Field Length (at SL, ISA, MTOW)	< 10,500 ft	< 9,500 ft	Most top destinations have large runways, and field performance for SSTs improves rapidly below MTOW
Passenger Capacity	19	40	Fewer than 19 would increase seat mile costs Greater than 40 limits economically viable city pairs
Loudness @ Start of Cruise	<80 PLdB	<75 PLdB	Values will depend on community acceptance testing but are believed to be in the 75-80 PLdB range
Overland Cruise Mach	> 1.6	> 1.7	Less than 1.6 Mach cruise adversely impacts utilization and cruise efficiency
Over Water Cruise Mach	> 1.7	>1.8	Faster Mach number permits more efficient utilization, but > 1.8 not feasible due to jet noise
Airport Noise	Consistent with future standards		Specific regulations for supersonic aircraft are being explored by the FAA and ICAO

ENABLING TECHNOLOGIES FOR ENVIRONMENTALLY RESPONSIBLE SUPERSONIC AIRCRAFT

- **Shaped boom design technology**
  - Integrated low noise propulsion
  - Swept wing supersonic natural laminar flow
  - External Vision System (XVS)



Flow Field around X-59

The same validated tools and methods that were used to design X-59 are applicable to larger commercial aircraft – permitting the design to be tailored for low boom while minimizing the impact to supersonic cruise efficiency

ENABLING TECHNOLOGIES FOR ENVIRONMENTALLY RESPONSIBLE SUPERSONIC AIRCRAFT

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- **Integrated low noise propulsion**
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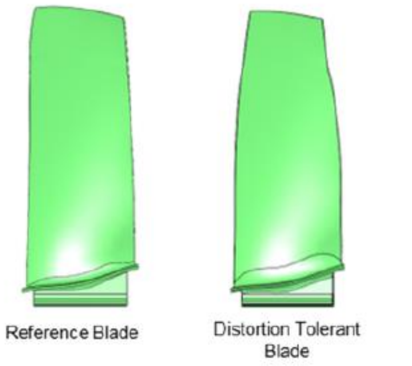
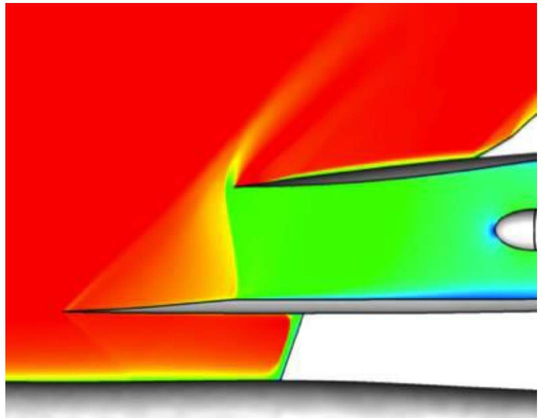
- External Vision System (XVS)

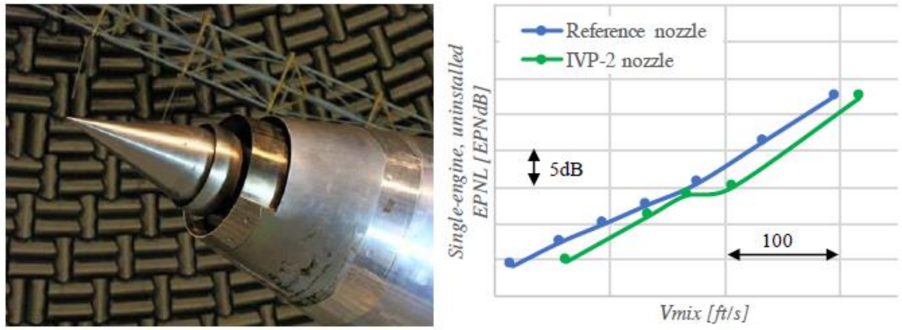
Recent innovations including advanced plug nozzles, the Streamline-Traced External-Compression (STEX) low-boom inlet, and noise shielding concepts enable efficient supersonic cruise with a low-boom compatible propulsion system that is no louder than today's existing subsonic fleet



Distortion-tolerant Fan Blades from AIAA 2017-5042



STEX Inlet from AIAA 2016-4050



Advanced Plug Nozzle from AIAA 2018-0265

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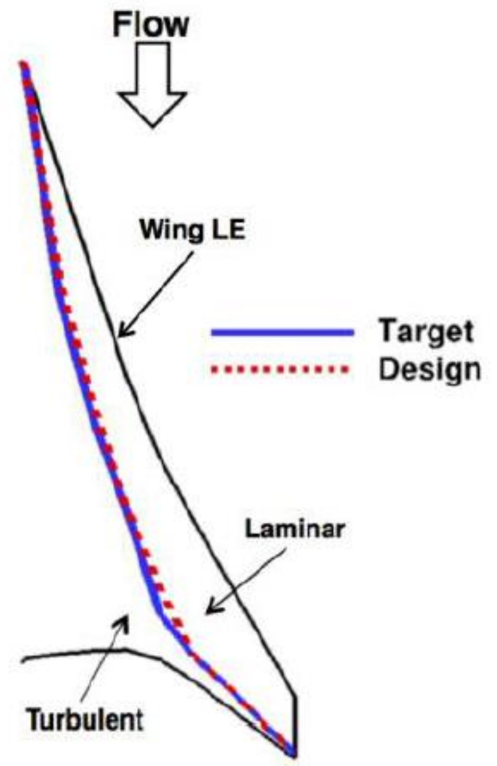
ENABLING TECHNOLOGIES FOR ENVIRONMENTALLY RESPONSIBLE SUPERSONIC AIRCRAFT

- Shaped boom design technology
- Integrated low noise propulsion
- **Swept wing supersonic NLF**
- External Vision System (XVS)

Research shows the potential to robustly decrease viscous drag by up to 10% without compromising wave drag or boom characteristics; improving fuel economy and opening up the potential for non-stop trans-Pacific range



Supersonic NLF Targets
From AIAA 2016-4327

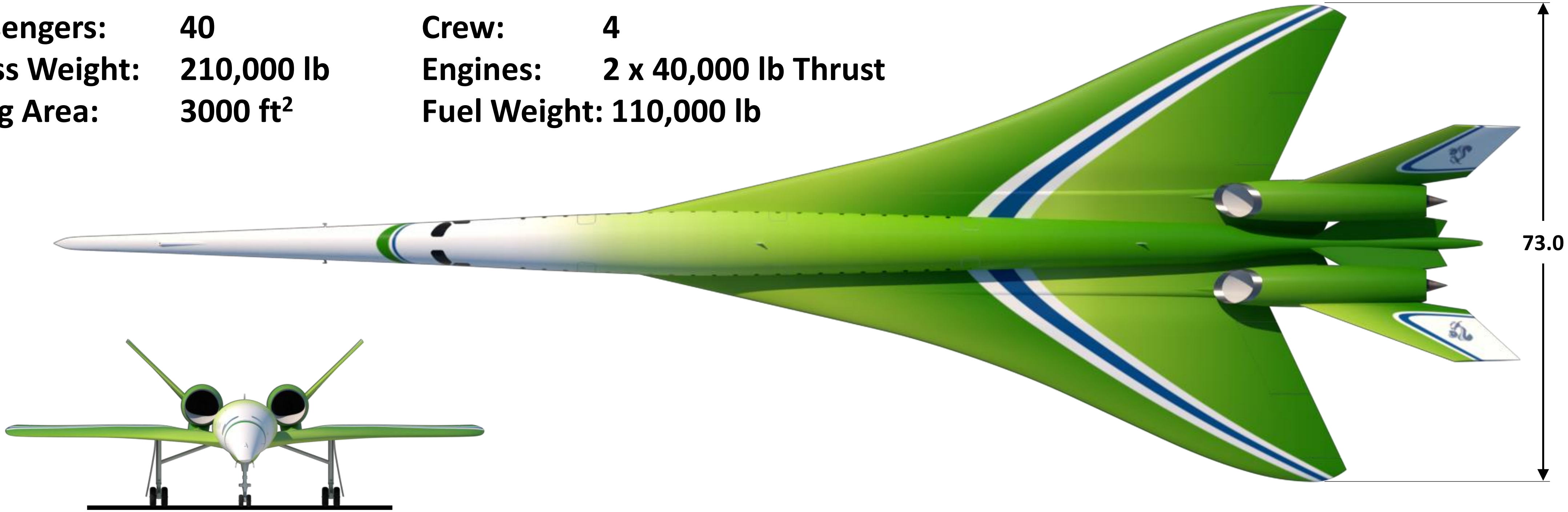
ENABLING TECHNOLOGIES FOR ENVIRONMENTALLY RESPONSIBLE SUPERSONIC AIRCRAFT

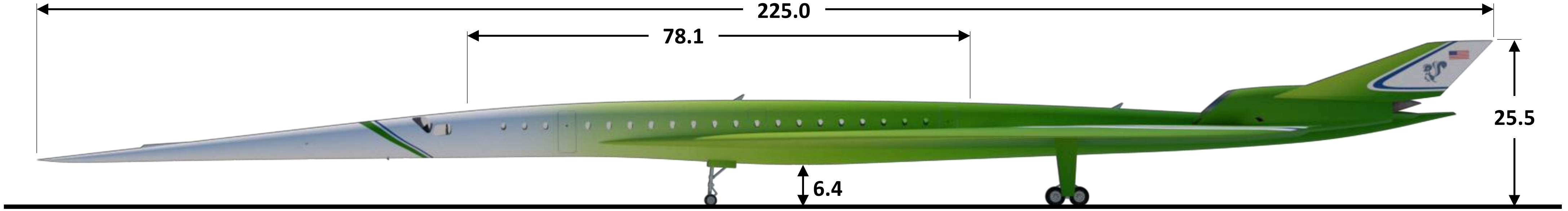
- Shaped Boom Design Technology
- Integrated low noise propulsion
- Swept wing supersonic natural laminar flow
- **External Vision System (XVS)**

A certified version of the Ultra High Definition XVS system being flown on X-59 will provide equivalent 20/20 natural visual acuity while avoiding the weight and complexity associated with the droop nose solution from Concorde

QUIET SUPERSONIC TECHNOLOGY AIRLINER (QSTA) 3-VIEW

Passengers:	40	Crew:	4
Gross Weight:	210,000 lb	Engines:	2 x 40,000 lb Thrust
Wing Area:	3000 ft^2	Fuel Weight:	110,000 lb





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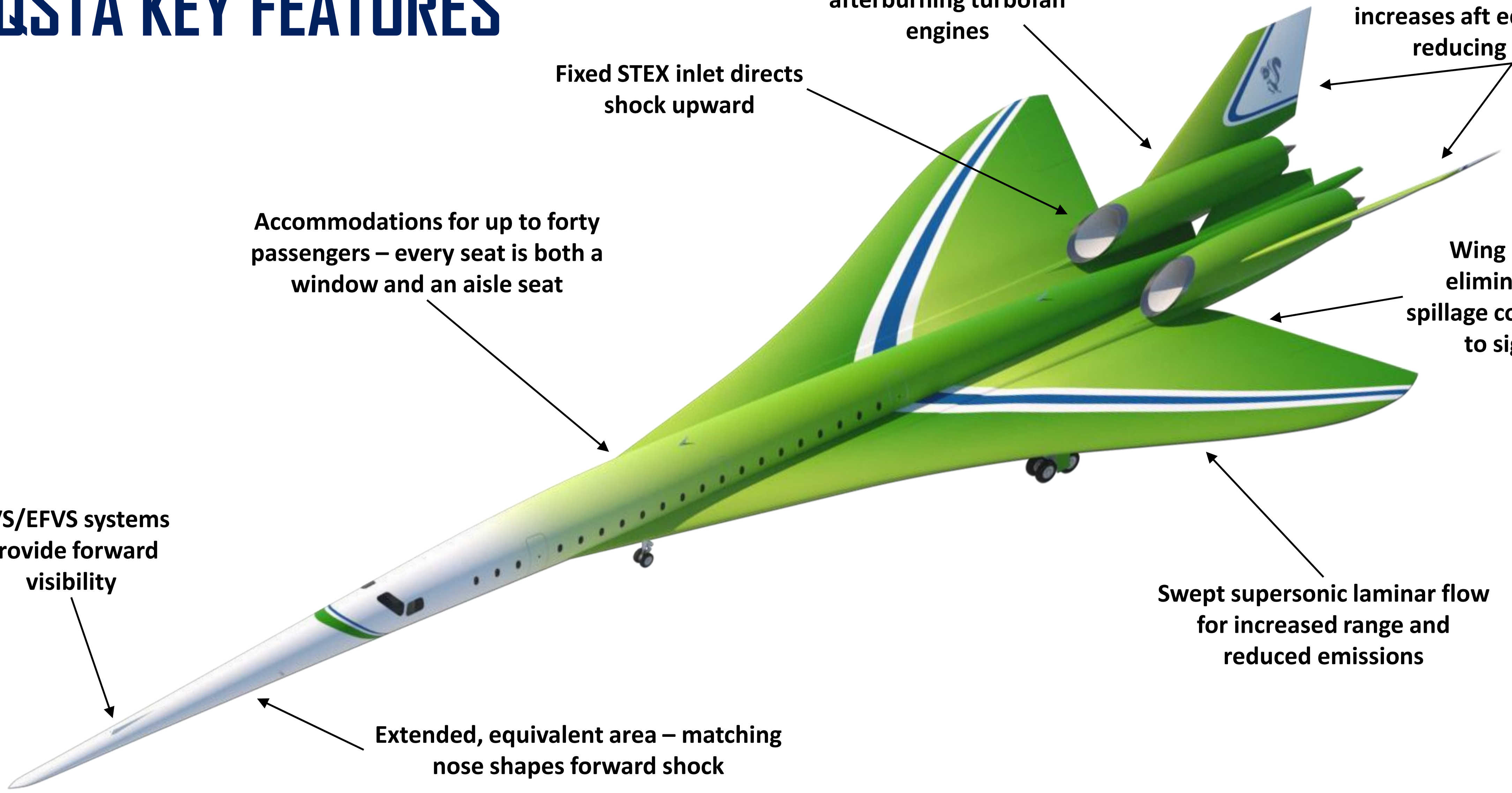
QSTA KEY FEATURES



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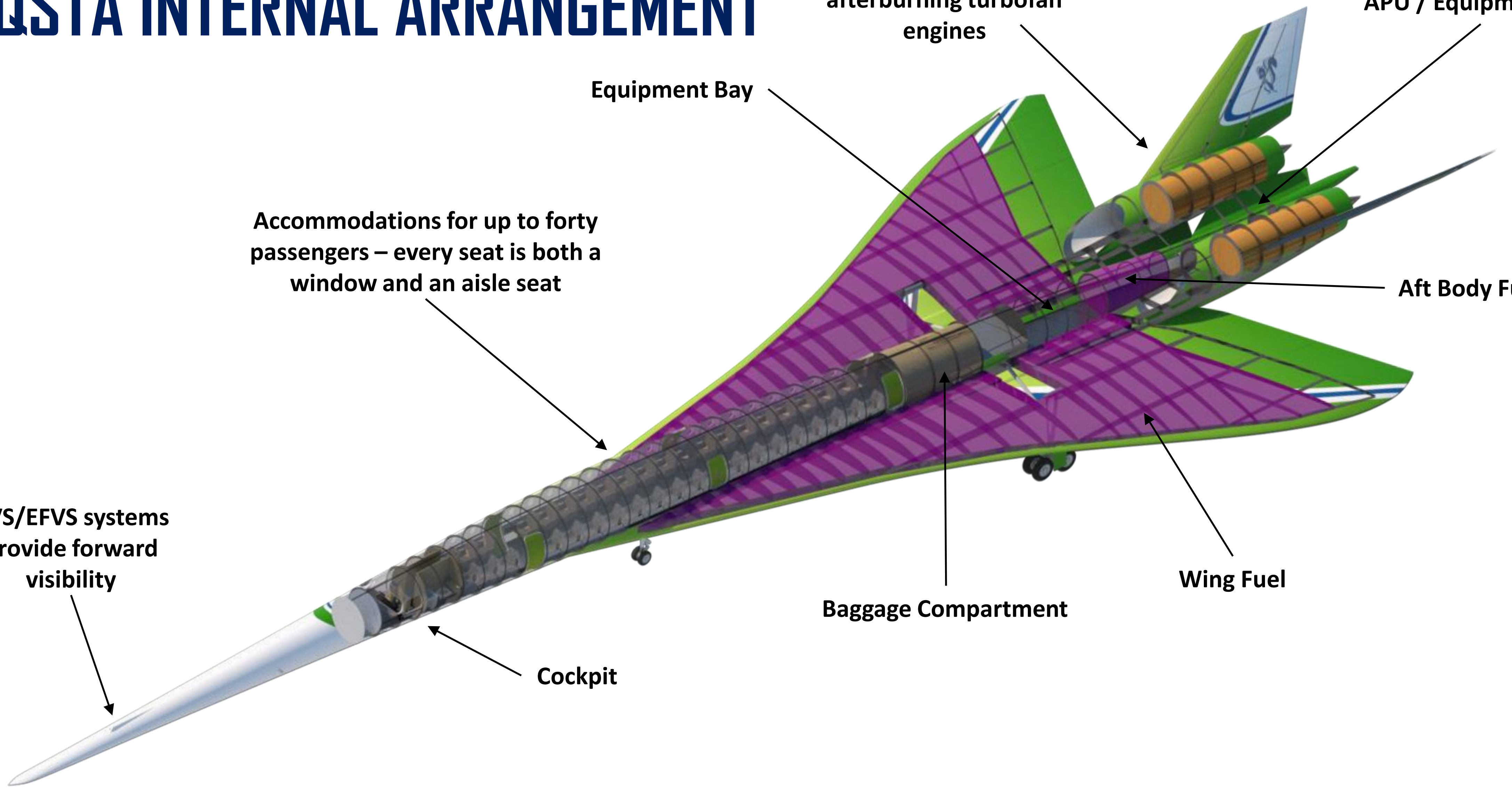
QSTA INTERNAL ARRANGEMENT



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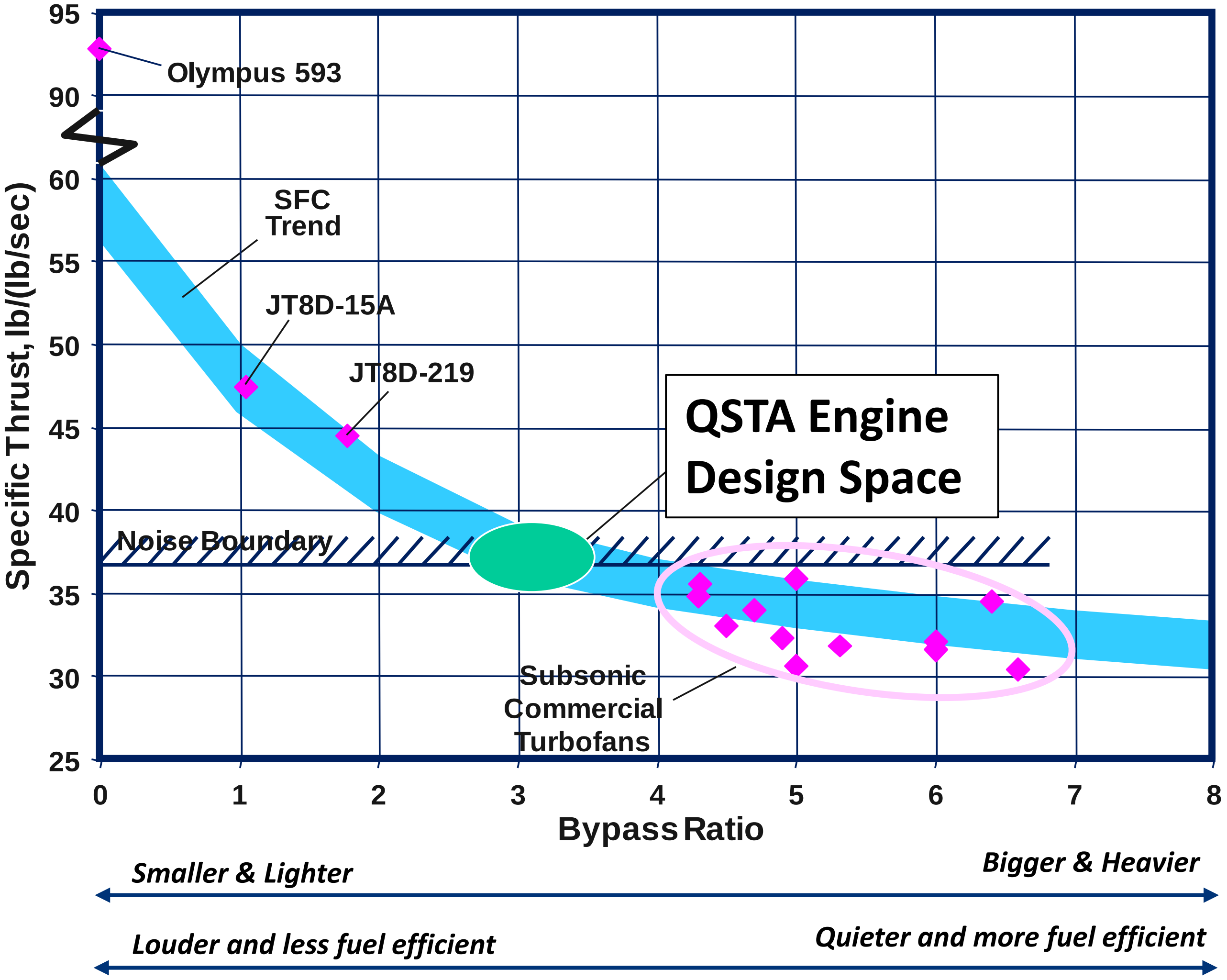
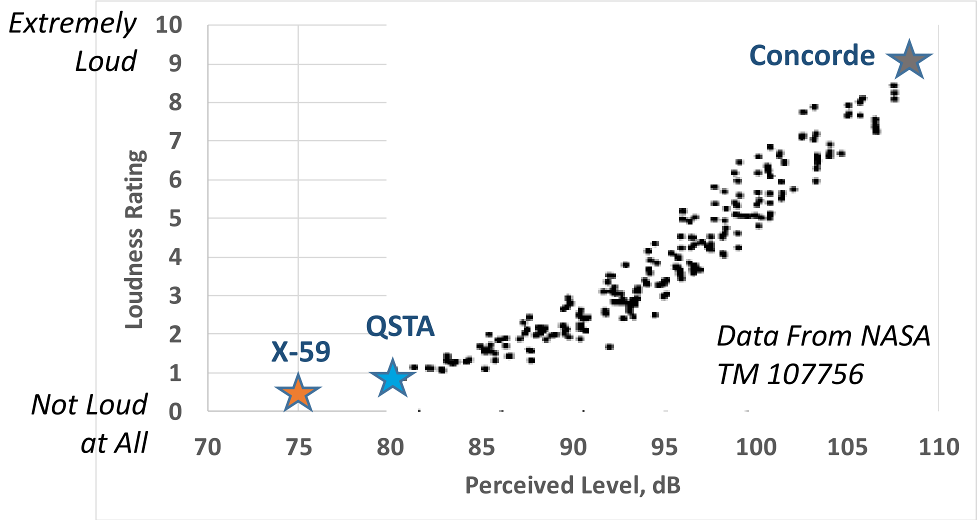
ENGINE SELECTION & PROPULSION INTEGRATION

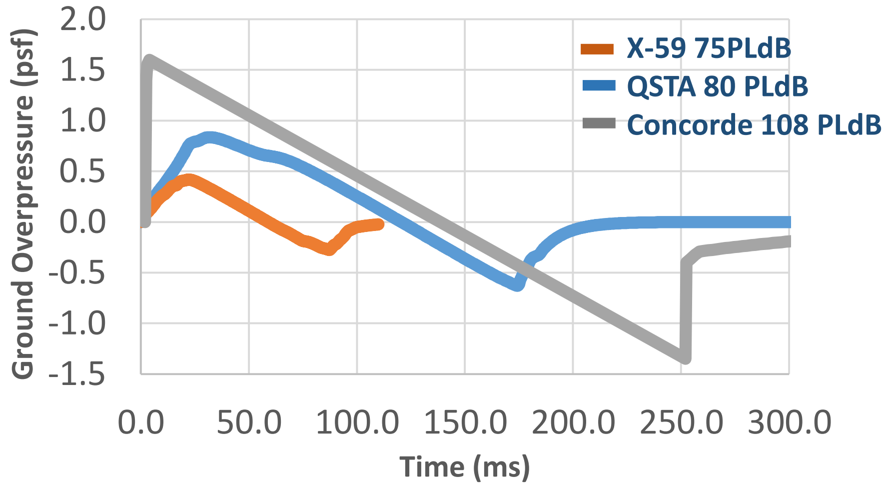
- Engine design for commercial supersonic aircraft is a balance of meeting high speed efficiency and low speed noise requirements
  - No existing Off The Shelf engine is suitable to balance these two conflicting objectives
- The QSTA engine uses a cycle consistent with today's existing widebody cores in conjunction with a clean sheet low pressure spool with a moderate Bypass Ratio of ~3
- Advanced Propulsion-Airframe Integration and Advanced Takeoff Procedures are used to reduce noise while mitigating the aerodynamic and shaped boom impact on the vehicle



QSTA PERFORMANCE OVERVIEW

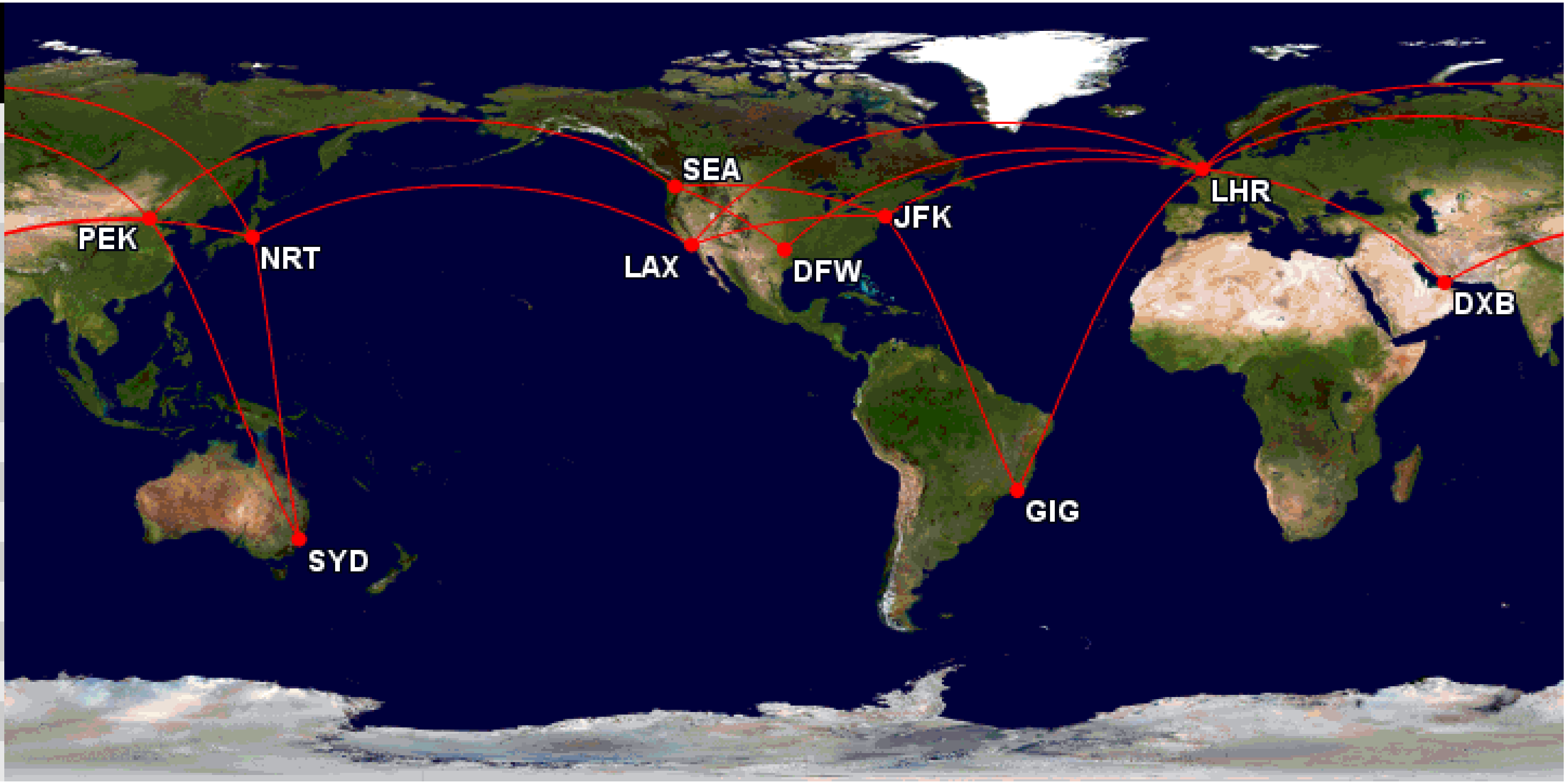
Requirement	Threshold Value	Objective Value	Status Performance
Range, plus IFR Reserves	4200 nm	5300 nm	5200 nm
Takeoff Field Length (at SL, ISA, MTOW)	< 10,500 ft	< 9,500 ft	9,600 ft
Passenger Capacity	19	40	40
Loudness @ Start of Cruise	<80 PLdB	<75 PLdB	80 PLdB
Low Boom Cruise Mach	> 1.6	> 1.7	1.6
Over Water Cruise Mach	> 1.7	>1.8	1.8
Airport Noise	Consistent with today's subsonic fleet		





QSTA RANGE MAP

City Pair	Air Distance (nm)	Time Savings (hours)
DFW-SEA	1,440	1.2
JFK-SEA	2,110	1.8
JFK-LAX	2,150	1.8
DXB-LHR	2,970	2.5
JFK-LHR	3,000	3.0
DXB-PEK	3,160	2.7
DFW-LHR	4,130	3.9
GIG-JFK	4,160	3.9
NRT-SYD	4,210	4.2
DXB-NRT	4,320	3.7
LHR-PEK	4,410	3.8
SEA-PEK	4,700	4.6
LHR-LAX	4,740	4.5
LAX-NRT	4,740	4.8
PEK-SYD	4,820	4.7
GIG-LHR	4,980	5.0
LHR-NRT	5,190	4.5



The combination of long range, high speed, and overland capability provides great utility and dramatically reduces trip times

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SUMMARY

- **Technological advances over the past decade show potential for addressing the shortcomings of prior supersonic commercial development aircraft programs**
- **Success of LBFD and a repeal of the prohibition on overland supersonic flight enables a future where environmentally responsible supersonic flight is commonplace**

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