CONCEPTUAL DESIGN OF A QUIET SUPersonic TECHNOLOGY AIRLINER

Michael Buonanno
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

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

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

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

- Shaped boom design technology
- Integrated low noise propulsion
- Swept wing supersonic natural laminar flow
- 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.
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.
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  
Gross Weight: 210,000 lb  
Wing Area: 3000 ft²  
Crew: 4  
Engines: 2 x 40,000 lb Thrust  
Fuel Weight: 110,000 lb
QSTA KEY FEATURES

- Extended, equivalent area – matching nose shapes forward shock
- Fixed STEX inlet directs shock upward
- Medium bypass, non-afterburning turbofan engines
- Lifting, all-flying V-tail increases aft equivalent area, reducing signature
- XVS/EFVS systems provide forward visibility
- Swept supersonic laminar flow for increased range and reduced emissions
- Wing shielding eliminates inlet spillage contamination to signature
- Accommodations for up to forty passengers – every seat is both a window and an aisle seat
- Fixed STEX inlet directs shock upward
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QSTA INTERNAL ARRANGEMENT

XVS/EFVS systems provide forward visibility

Accommodations for up to forty passengers – every seat is both a window and an aisle seat

Medium bypass, non-afterburning turbofan engines

Baggage Compartment

Wing Fuel

Aft Body Fuel

APU / Equipment Bay
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

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<td>&gt;1.8</td>
<td>1.8</td>
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<tr>
<td>Airport Noise</td>
<td>Consistent with today’s subsonic fleet</td>
<td></td>
<td></td>
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**Diagram:****
- **Loudness Rating:**
  - Extremely Loud
  - Not Loud at All
- **Ground Overpressure (psf):**
  - X-59 75PLdB
  - QSTA 80 PLdB
  - Concorde 108 PLdB

**Data From NASA TM 107756**
- **Concorde:**
  - Extremely Loud
  - Not Loud at All
- **QSTA:**
  - PLdB
The combination of long range, high speed, and overland capability provides great utility and dramatically reduces trip times.

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