The vision of the Supersonics Community is a future where fast air travel is available for a broad spectrum of the traveling public.

- Future supersonic aircraft will not only be able to fly overland without creating an “unacceptable situation” but compared to Concorde and SST will be efficient, affordable and environmentally responsible.
Outline

• Mission/Market Discussion

• Environmental Barriers

• Affordable Approaches to Landing/Take-Off (LTO) Certification
  Noise
2016 Global Demand Seat distribution (OAG+ 4793 Million Seats)

Within Region = 83%, Inter-Region = 17%
2036 Global Demand Seat distribution (OAG+ 9494 Million Seats)

Within Region = 85%, Inter-Region = 15%

- 22.0% NOA
- 4.8% SOA
- 2.0% EUR
- 20.8% SEA
- 4.3% JAK
- 2.5% SWP
- 4.3% AFR
- 2.5% SAS
- 3.3% MDE
- 0.6% EUR
- 0.4% CAR
- 0.6% SEA
- 4.8% SOA
- 2.8% AFR
- 0.6% MDE
- 0.4% SAS
- 2.5% SWP
- 4.3% JAK
- 0.6% CAR
Premium Seat Capture vs. Range and %Overland Distances

- Without waypoint diversions (GC distances only), most seat traffic is overland for year 2016 traffic data.
- Same is true for year 2036 traffic forecast.
• Without waypoint diversions (GC distances only), most city pairs include substantial overland distances

• Longer range missions generally offer greater opportunity for waypoint diversions to minimize overland distances between city pairs
1200<Range<2600 Nmi

<2600 Nmi
2600<Range<3800 Nmi

<3800 Nmi
3800<Range<4800 Nmi

<4800 Nmi
4800<Range<5400 Nmi

<5400 Nmi
Passenger Demand (based on Value Of Time) differs in Different Markets

Demand Analysis Steps:
1) Estimate aircraft lifecycle cost and minimum fare per pax mile.
2) Project future passengers / OD pairs
3) Filter out infeasible OD pairs
4) Compute historic distribution of fares for each route
5) Calculate time savings on each route
6) Adjust fare distribution based on VOT
7) Determine # of passengers willing to pay aircraft fare per pax mile
8) Case #1: 50% shift of remaining pax, Case #2: 100% shift of remaining pax
9) Determine flights/aircraft needed to fulfill passenger demand.

<table>
<thead>
<tr>
<th>Minimum fare per passenger mile</th>
<th>18 passenger</th>
<th>40 passenger</th>
<th>60 passenger</th>
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</thead>
<tbody>
<tr>
<td>Low-boom</td>
<td>$1.57</td>
<td>$0.81</td>
<td>$0.65</td>
</tr>
<tr>
<td>Non-low-boom</td>
<td>$1.50</td>
<td>$0.75</td>
<td>$0.61</td>
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</table>

Fare per Passenger Mile Paid ($/sm.)

LAX - Orlando

Narita – Dallas Fort Worth

One-way OD Pair: JFK - LHR

Fare Distribution Curve With VOT adjustment for supersonic cruise.
Premium Class Willingness to Pay (Supersonic %capture read from top down on CDF)

Demand Analysis Steps:

1) Estimate aircraft lifecycle cost and minimum fare per pax mile.
2) Project future passengers / OD pairs
3) Filter out infeasible OD pairs
4) Compute historic distribution of fares for each route
5) Calculate time savings on each route
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7) Determine # of passengers willing to pay aircraft fare per pax mile
8) Case #1: 50% shift of remaining pax, Case #2: 100% shift of remaining pax
9) Determine flights/aircraft needed to fulfill passenger demand.

One-way OD Pair: JFK - LAX
40 passenger SST example

Original Fare Distribution Curve

Non Low-boom Fare Distribution Curve
$M = 1.15$

Low-boom Fare Distribution Curve
$M = 1.4$

33% of passengers willing to pay more than $0.81 per passenger mile
41% of passengers willing to pay more than $0.75 per passenger mile

Fare per Passenger Mile Paid ($/mi)
Barriers to Practical Supersonic Commercial Aircraft

**Environmental Barriers**

**Sonic Boom**
- Design for low noise sonic boom
- Understand Community Response

**Landing/Take-Off Noise**
- Certification noise levels not louder than subsonic aircraft at appropriate airports

**Landing/Take-Off and High Altitude Emissions**
- Certification emissions levels
- Acceptable emissions at supersonic cruise altitudes

**Efficiency Barriers**

**Efficient Vehicles**
- Efficient airframe and propulsion throughout flight envelope

**Efficient Operations**
- Airspace-Vehicle interaction for full utilization of high speed

**Light Weight, Durable Vehicles**
- Low airframe and propulsion weight in a slender flexible vehicle operating at supersonic cruise temperatures
Environmental Acceptability

**Landing/Take-Off Noise**
- Integrated solutions including inlet and fan noise, innovative concepts, tools & techniques, and experimental validation
- Adverse impact to local property values
- Reduced O-D pairs due to local stringencies

**Landing/Take-Off & High Altitude Emissions**
- Engaging atmospheric science community to improve global high altitude emission models and study the impacts from future supersonic fleet scenarios
- Next-gen CMC combustor liner technologies to improve existing Rich-burn combustors while enabling future Lean-burn & staged injection with sustainable alternative fuels
- Adverse impacts to local & global environment are lasting
- Reduced O-D pairs due to local stringencies

**Support of FAA/ICAO studying operations & regulatory impacts**
- Supersonic Technology Concept Aeroplane (STCA), Market, Noise, Emissions trades
55t STCA Business Jet Concept

- Max gross weight: 55t (121klb)
- Passengers: 8
- Cruise Mach: 1.4
- Engines (x3): CFM56-derived
- Length: 135ft
- Span: 67.3ft
- Reference area: 1619ft²
- Aspect ratio: 2.7
- Taper ratio: 0.09
- Wing loading: 74psf
- Wing fuel: ~24klb
- Fuselage fuel: ~36klb
- Fuel fraction: ~0.50

Differs from 2018 STCA; improvements with help from NASA Langley
Supersonic Derivative Engine

• Analytical redesign of CFM COTS CFM56-7B27 low-pressure spool
• CFM56 core began as the GE F101-102, for the B-1A supersonic aircraft;
• Numerical Propulsion System Simulation (NPSS) software
• Model design changes:
  - High spool components held constant
  - Translating centerbody inlet
  - Booster removed
  - Revolutionary Turbine Accelerator fan
    • GE57 single-stage fan; PR 2.2, $\eta$ 0.87
    • Perhaps representative of what might be used by a major engine maker in a supersonic refan application
  - Redesigned low turbine
  - Forced lobed mixer
  - Axisymmetric, single-stream, variable-geometry, convergent-divergent plug nozzle

• Predict thrust & fuel flow across flight envelope; use in performance analysis
Noise Type-Certification Process

Effective Perceived Noise Level:
- Sources at flight conditions
- Propagation and ground effects
- Noy-weighted summation
- Tone content penalties

Result:
Ground observer noise vs. time history

International Standards and Recommended Practices –
Environmental Protection, Annex 16 to the Convention on
International Civil Aviation, Vol. I

U.S. Code of Federal Regulations, Title 14,
Chapter I, Part 36
Profiles for Noise Certification: Selected LTO Flight Conditions

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<th>Point</th>
<th>DFBR, ft</th>
<th>Altitude, ft</th>
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<th>Thrust, lb</th>
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</table>

*Approach point (glide slope is 3 degrees)
Advanced takeoff uses (1) V2+35kn climbout and (2) 10% programmed thrust lapse. 1.6 EPNdB cumulative margin to Chapter 4.
EPNL Sensitivities Due to Uncertainties

Sensitivity bars represent two standard deviations of Monte Carlo experiment histograms (i.e., 95% of samples fall in band)
Source Noise and Operational Uncertainties

- Airframe noise source uncertainties
  - Effects of higher TO speed on constituent sources (landing gear, flaps/slats, etc)
  - Shielding for supersonic geometries
- Propulsion noise source uncertainties
  - High pressure fan, ~low/modest bypass ratio
  - High speed jet and shock-cell noise
  - Inlet geometries & suppression effects, liners, aux door noise radiation
  - Nozzle geometries (e.g. non-axi exit areas, plug nozzles, etc.)
- Operational uncertainties
  - Ground and refraction-scattering effects
    - Accurate predictions of lateral system noise are critical, especially for supersonic transports exploiting lateral attenuation using programmed thrust lapse procedures

55t STCA Engine Variants

**NASA CFM56-7B27 model:**
Commercial subsonic off-the-shelf separate flow turbofan

**NASA 55t STCA engine (2017):**
High-TRL, mixed flow turbofan with redesigned low-pressure spool for supersonic application

**Variant engine (2018):**
- Excursion in bypass ratio.
  High-TRL, mixed flow turbofan with lower fan pressure ratio and higher bypass ratio

**Variant engine (2018):**
Nozzle chevron study
55t STCA: Takeoff Profiles of Engine Variants

- Advanced takeoff procedures held constant
- **Baseline vs. higher bypass engine:** Thrust lapses differently for higher BPR variant
- **Baseline vs. chevron-equipped engine:** Thrust penalty due to chevrons
- But departure profiles are nearly unchanged
55t STCA: Higher Bypass Engine Variant

Cumulative EPNL benefit of higher bypass cycle: 5.3 EPNdB (4.1% range penalty)
Cumulative EPNL benefit of chevrons: 2.7 EPNdB (2.8% range penalty)
Summary

• Sufficient premium seat traffic exists at Mach~1.6 to support commercial production rates
  - Aircraft capacity appears to favor <<100 passengers (to maintain load factors & reasonable production rates)
  - Most O-D pair routes have substantial overland fractions without GC diversions

• Environmental impacts must be addressed for certification, regardless of cruise mission
  - LTO noise is more economically impacting
  - LTO & cruise emissions are more lasting; limiting cruise altitudes and speed to achieve acceptable levels

• Studies indicate affordable noise reductions are ~small for acceptable range penalties (fuel burn), and procedural choices have strong influence on both performance and noise
  - Operational procedures (PLR, high TO speeds, etc.)
  - Enhanced jet/ambient mixing (Chevrons, etc.)
  - Uncertainty reductions for supersonic geometries needed, otherwise large noise margins

• Longer mission ranges from higher cruise efficiency will require more robust acoustic technology investment
  - Suppressor nozzles
  - Multi-stream engine/nozzle systems