ARMD Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft

Peter Coen for the Roadmap Team 2
Aeronautics R&T Roundtable, Washington DC
May 24, 2016
Outline

• Introduction
• Commercial Supersonic Community
• Outcomes, Benefits, Capabilities
• Strategies
• Research Themes
• Roadmaps
• Stakeholder roles, partnerships
• Risks and Opportunities
Introduction

Commercial supersonic flight represents a potentially large new market for aircraft manufacturers and operators world-wide

• Global demand for air travel is growing
  – The distance between some population centers is great (especially considering the growth in the Asia-Pacific region), which places a greater value on speed

• US leadership in the development of new products for this market will further support a positive balance of trade
  – Other countries have a significant need for high speed transport because it can connect them to Western markets more effectively.
  – There is new “wealth” in other regions (e.g. China and the Middle East) that could be spent on a new product built in the United States.

• New supersonic products lead to more high-quality jobs in the US.
  – Industry and NASA studies indicate a potential market for supersonic business aircraft (350+ aircraft) followed by supersonic commercial transports as technology matures. Supersonic civil aircraft market could grow to an estimated 1250-1700 aircraft where the US could potentially dominate the design & manufacture of these aircraft.
  – Technology leadership established through initial products will lead to development of larger, more capable airliners.

• Environmental impact of supersonic flight must continue to be a overarching consideration
  – Creates additional opportunities for technology and commercialization leadership
The Commercial Supersonic Community is global
- The majority of the community believes that current restrictions on supersonic overflight are a barrier to the creation of a market for supersonic airliners
- Small supersonic business class aircraft are recognized to be the most likely initial market entrants
  - Supersonic overflight is not universally perceived as a requirement for this market
- Large airframe manufacturers see larger supersonic airliners as potentially important products, but will likely wait until the market grows and technology improves before engaging
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<th>Outcomes</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
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<tbody>
<tr>
<td>Boom Noise</td>
<td>Supersonic Transports</td>
<td>Transport fleet</td>
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<tr>
<td>Rules preventing overland supersonic flight are replaced with noise</td>
<td>New market for fast point to point transportation is served by</td>
<td>A variety of air transportation markets will be served by supersonic</td>
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<tr>
<td>certification standards for en route supersonic noise. Market is</td>
<td>environmentally compatible small supersonic aircraft. New business</td>
<td>aircraft with capacities as large as 200 passengers. These aircraft</td>
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<td>opened for new supersonic aircraft</td>
<td>and job growth opportunities for manufacturers</td>
<td>will offer rapid travel with competitive economics and reduced</td>
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<td>Low boom design tools</td>
<td>Technologies enabling the first and second generations of supersonic</td>
<td>environmental impact</td>
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<td>Fundamental data on the characteristics of low noise waveforms</td>
<td>transports with emphasis on acceptable community and en route noise</td>
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<td>in real atmosphere</td>
<td>and high altitude emissions</td>
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<td>Scientifically valid data on community response to low noise supersonic</td>
<td>ATM technologies &amp; procedures for efficient supersonic &amp; terminal ops</td>
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<td>overflight</td>
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<td>Models for extrapolating community response to fleet impacts</td>
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<td>NASA Outputs/Capabilities</td>
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<td>• Low boom design tools</td>
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<td>• Range 4000 n.mi.</td>
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<td>• Mach 1.3-1.6 overland, higher over water</td>
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<td>• Passengers 100-200</td>
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<tr>
<td>• Sonic boom Noise 65-70 PNdB</td>
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<tr>
<td>• Business aircraft economics</td>
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<tr>
<td>• Cruise Noₓ Emissions &lt;5 g/kg fuel</td>
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<tr>
<td>• Reduced particulates &amp; H₂O vapor</td>
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Near term (2015-2025) – Overland Supersonic Flight

- Demonstrate supersonic overland flight without sonic boom noise and deliver scientifically valid data on community response to US and International Standard and Regulatory Organizations.
- Conduct fundamental research and demonstration in technology areas required to enable supersonic aircraft to meet existing certification standards with minimal performance impact.
- Conduct research and early flight validation of cockpit displays and flight management software that supports efficient supersonic flight operations with minimum en route noise.
- Conduct foundational research and explore new concepts for breakthrough improvement in supersonic cruise efficiency.

Mid term (2025-2035) – Environmental Compatibility

- Partner with industry on the development and integrated validation of technologies for reduced community noise and high altitude emissions in small overland flight capable supersonic aircraft.
- Partner with industry and Air Traffic Control organizations on the demonstration and validation of supersonic flight management and airspace operations software and procedures.
- Conduct fundamental research and demonstration of integrated airframe and propulsion technology for efficient supersonic cruise and off design operations.
- Conduct foundational research on new concepts and innovative approaches to reduce or eliminate supersonic en route noise for larger supersonic aircraft.

Far Term (2035-2045) – Supersonic Airline Efficiency

- Partner with industry on the development and integrated validation of technologies to provide high cruise and off design efficiency yielding airline level operating economics for larger supersonic cruise aircraft.
- Continue fundamental research and demonstration of technologies and design approaches for a next generation of supersonic aircraft with the potential for the elimination of supersonic en route noise.
Strategic Thrust 2
Proposed Outcomes & Research Themes

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<th>2015</th>
<th>2025</th>
<th>2035</th>
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Research Themes/Sub-themes

Elimination of Environmental Barriers to Commercial Supersonic Aircraft
- Understanding and measuring community response to supersonic en route noise
- Minimizing the airport community noise impact of supersonic aircraft
- Reducing or Eliminating the impact of high-altitude emissions

Integrated Design and Efficiency
- Low boom design for certification
- Integrated design for efficiency, performance and weight reduction
- Airframe and propulsion technology for improved efficiency, performance and weight
- Sonic boom mitigation technology

Modeling & Simulation, Test Capability
- Integrated, physics bases models for aircraft design and analysis
- Quiet wind tunnel and acoustic test facilities

Efficient Supersonic Flight Operations
- Flight systems and cockpit displays for minimized impact of en route supersonic noise
- Operations for supersonic en route noise impact mitigation
- Airspace integration for maximum supersonic operational efficiency
Strategic Thrust 2
Roadmap Template

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<th>Outcomes</th>
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NASA Strategy

Overland Supersonic Flight

Environmental Compatibility

Supersonic Airline Economics

<table>
<thead>
<tr>
<th>Key Dates</th>
<th>2015</th>
<th>2025</th>
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<tr>
<td>LBF D 1st Flight</td>
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<tr>
<td>Ch 14 Noise Rule*</td>
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<tr>
<td>En Route Noise Standard</td>
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<tr>
<td>Efficient Multi-Mach Airliner</td>
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Research Themes

- Environmental Performance Barriers
- Vehicle Design & Efficiency
- ModSim & Test Capability
- Operational Efficiency (Thrust)

*Noise standards are periodically updated by the International Civil Aviation Org. (ICAO)
# Strategic Thrust 2

**NASA Near Term Strategy Overlay**

<table>
<thead>
<tr>
<th>Outcomes</th>
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<th>2025</th>
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<tbody>
<tr>
<td><strong>Overland Supersonic Flight</strong></td>
<td>Low Boom Demo</td>
<td>Sonic Boom Response Modeling</td>
<td>Data for de vel. Of Int'l Standard (w/FAA, ICAO)</td>
</tr>
<tr>
<td><strong>Environmental Compatibility</strong></td>
<td>Jet &amp; High-speed Fan/Inlet acoustics with airframe interactions</td>
<td>Combustor/cycle for LTO Certification/High Altitude Mitigation</td>
<td>Active Acoustic Control for Propulsion &amp; Airframe Sources</td>
</tr>
<tr>
<td><strong>Supersonic Airline Economics</strong></td>
<td>Low-boom design for full flight profile &amp; ops flexibility</td>
<td>Boom Reduction/Elimination for Large Civil Airliners</td>
<td>Second generation SS combustor: low emissions, particulate and water vapor</td>
</tr>
<tr>
<td><strong>Environmental Performance Barriers</strong></td>
<td>Inlet/Nozzle/PAL efficiency</td>
<td>Airframe materials &amp; structure for weight reduction, higher temp operation</td>
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<tr>
<td><strong>Vehicle Design &amp; Efficiency</strong></td>
<td>Low speed performance &amp; control</td>
<td>Advanced cycles &amp; prop. architecture</td>
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<tr>
<td><strong>ModSim &amp; Test Capability</strong></td>
<td>Light, durable high temp prop. materials</td>
<td>Light, durable high temp prop. materials</td>
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<tr>
<td><strong>Integ. Tools &amp; MDAO of OML</strong></td>
<td>Aeroservoelasticity, Advanced Flight Controls</td>
<td>Aeroservoelasticity, Advanced Flight Controls</td>
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<tr>
<td><strong>Operational Efficiency (Thrust 1)</strong></td>
<td>Extreme Aerodynamic Efficiency</td>
<td>Extreme Aerodynamic Efficiency</td>
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<tr>
<td><strong>Metered airspace ops &amp; fleet routes</strong></td>
<td>Dynamic, flexible a/c flight sim.</td>
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<tr>
<td><strong>Full Free Flight 4D Integration of supersonic aircraft</strong></td>
<td>Quiet flow facility for dev. &amp; validation of en route noise signatures</td>
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## Strategic Thrust 2

**NASA Mid Term Strategy Overlay**

### Outcomes

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### NASA Strategy

#### Overland Supersonic Flight

#### Environmental Compatibility

#### Supersonic Airline Economics

### Research Themes

**Environmental Performance Barriers**
- Low Boom Demo
- Sonic Boom Response Modeling
  - Data for devel. of Int’l Standard (w/FAA, ICAO)
- Nozzle/cycle Cum. Noise Certification
- Global emission impact assessment

**Vehicle Design & Efficiency**
- Low Boom Design for Certification
  - Low boom design for full flight profile & ops flexibility
  - Inlet/Nozzle/PAI efficiency
  - Low speed performance & control
    - Advanced cycles & prop. architecture
    - Light, durable high temp prop. materials
    - Aeroservoelasticity, Advanced Flight Controls
    - Extreme Aerodynamic Efficiency
- Boom Reduction/Elimination for Large Civil Airliners
- Airframe materials & structure for weight reduction, higher temp operation

**ModSim & Test Capability**
- Integ. Tools & MDAO of OML
- MDAO of OML and Structure, Integ. Prop. and aeroservoelastic
- Physics Based acoustic phenomena & source modeling
- Dynamic, flexible a/c flight sim.
- Quiet flow facility for dev. & validation of en route noise signatures
- Extreme Aerodynamic Efficiency

**Operational Efficiency (Thrust 1)**
- Metered airspace ops & fleet routes
- Flight Ops for Boom Mitigation
- Full Free Flight 4D Integration of supersonic aircraft
## Strategic Thrust 2

### NASA Far Term Strategy Overlay

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<th>Outcomes</th>
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### NASA Far Term Strategy

#### Overland Supersonic Flight

**Environmental Compatibility**

- **Low Boom Design for Certification**
  - Inlet/Nozzle/PAI efficiency
  - Low speed performance & control
- **Boom Reduction/Elimination for Large Civil Airliners**
  - Advanced cycles & prop. architecture
  - Light, durable high temp prop. materials
  - Aeroservoelasticity, Advanced Flight Controls
  - Extreme Aerodynamic Efficiency
- **Response Models & Standards for Airline Ops (w/FAA, ICAO)**
  - Nozzle/cycle Cum. Noise Certification
  - Global emission impact assessment
- **Jet & High-speed Fan/Inlet acoustics with airframe interactions**
- **Active Acoustic Control for Propulsion & Airframe Sources**
  - Second generation SS combustor: low emissions, particulate and water vapor

### Research Themes

- **Environmental Performance Barriers**
  - Sonic Boom Response Modeling
  - Data for devel. of Int'l Standard (w/FAA, ICAO)
  - Low Boom Demo

- **Vehicle Design & Efficiency**
  - MDAO of OML and Structure, integ. Prop. and aeroservoelasticity
  - Dynamic, flexible a/c flight sim.

- **ModSim & Test Capability**
  - Integ. Tools & MDAO of OML
  - Physics Based acoustic phenomena & source modeling

- **Operational Efficiency (Thrust 1)**
  - Metered airspace ops & fleet routes
  - Flight Ops for Boom Mitigation
  - Full Free Flight 4D integration of supersonic aircraft
Strategic Thrust 2
Evolution of Stakeholder Community

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- ICAO, FAA
- Limited U.S. Airframe Manufacturers
- Unscheduled airlines
- Business Jet Operators & Passenger

- ICAO, FAA, IATA
- U.S. Airframe Manufacturers
- U.S. Engine Manufacturers
- Narrow-spectrum scheduled airlines
- Premium-class passengers

- ICAO, FAA, IATA
- U.S. Airframe Manufacturers
- U.S. Engine Manufacturers
- Foreign manufacturing subsidiaries enabling market growth
- Broad-spectrum scheduled airlines
- Multi-class passengers
Strategic Thrust 2
External Risks/Opportunities

• Risks
  – Certification Standards process is delayed by demand for large global community response
database or political/social complications – Market development delayed
  – New environmental standards for community noise and emission exceed the capability of the
technologies envisioned in the community strategy – New technology will need to be developed,
delaying availability for products in mid and far term outcomes
  – Integrated technology for efficiency in community strategy insufficient for the demands of
supersonic airliner economics – Longer technology development cycle pushes date of introduction
of supersonic airliners beyond 2040
  – Global airline business case evolves to favor a model where first class, high value fares are
required to support low cost high volume passenger service.
  – Demand for larger, higher capacity aircraft may reduce or eliminate supersonic airliner market
• Opportunities
  – International interest in collaborative effort for data collection and standards development –
opportunity to leverage investment
  – Supersonic business aircraft use of alternative low emission fuel could spur development of
needed infrastructure
  – Development of subsonic airliner manufacturing business overseas may drive shift of US industry
to innovative new configuration developments
  – Advances in alternative fuels and propulsion (Thrust 4) may yield significant improvement for
supersonic flight, and reduce the impact of the energy penalty of high Mach flight