Outline

• Context for briefing
• Background for Strategic Plan and Roadmaps
• Supersonic Thrust Introduction
• Thrust Outcomes & Research Themes
• Roadmap Details
• Community Development
• Risks & Opportunities
• Feedback Mechanisms
NASA has identified three Aviation Mega Drivers that will impact aviation community future needs.

**Traditional measures of global demand for mobility** - economic development and urbanization - are growing rapidly and creating transportation and competitive opportunities and challenges.

**Revolutions in the integration of automation, information, communication, energy, materials and other technologies** enable opportunity for transformative aviation systems.

**Large and growing energy and environmental issues** create enormous affordability and sustainability challenges.
NASA is developing Six Thrusts to focus research in response to mega-drivers. Fixed Wing and Vertical Lift are considered separately.

- **T1 Safe, Efficient Growth in Global Operations**
  - Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

- **T2 Innovation in Commercial Supersonic Aircraft**
  - Achieve a low-boom standard

- **T3A FW Ultra-Efficient Commercial Vehicles**
  - Pioneer technologies for big leaps in efficiency and environmental performance

- **T3B VL**

- **T4 Transition to Low-Carbon Propulsion**
  - Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

- **T5 Real-Time System-Wide Safety Assurance**
  - Develop an integrated prototype of a real-time safety monitoring and assurance system

- **T6 Assured Autonomy for Aviation Transformation**
  - Develop high impact aviation autonomy applications
Thrust Relationships

The six Thrusts are not independent. Dependencies exist between operations, vehicles and cross-cutting technologies like autonomy. Supersonic transports, subsonic transports and vertical lift vehicles have different strengths and research needs.

**What I Fly**

**MISSION CAPABILITY**

Combination of:
- Payload, Range, Speed,
- Field-Length, Hover, Endurance

Environmentally Friendly, (e.g. Noise, Emissions)
- Safety, Cost/Affordability

**How I fly**

**365/24/7 OPERATIONS**

Rules of the Road:
- Safe, Efficient, Flexible, Resilient

**Convergent Technology Opportunities**

- Low-Carbon Propulsion
- Real-Time System-Wide Safety
- Autonomy

**Supersonic Transports**

**Strength:** Speed 2X subsonic
**Need:** efficiency and environmental compatibility similar to subsonic transport

**Subsonic Transports**

**Strength:** Backbone of air transportation
**Need:** Environmental compatibility while reducing cost, increasing range, maintaining safety

**Vertical Lift**

**Strength:** Accessibility using Hover/Field Length
**Need:** more range, speed, payload, safety, comfort and less noise
The SIP contains information about Research Themes and System-Level Metrics for each Thrust. The SIP will be updated as part of developing roadmaps for each of the Thrusts.

Roadmaps for each of the six Thrusts in the SIP are being developed

- Update the SIP Outcomes, Research Themes and Metrics
- Drafts are being vetted for comments internal and external to NASA
Roadmaps are

- A high-level look at what technology is needed to accomplish the community outcomes
- A community roadmap; NASA does not expect to accomplish all roadmap goals within NASA programs
- Guidance for NASA project and NASA Centers for innovation and planning
- Part of the process to determine the strategic contribution of NASA portfolio investments in Technical Challenges in each project

Roadmaps ARE NOT

- A funded program or project plan
- A commitment by NASA to accomplish all roadmap objectives
- A determination of specific technology or investment

The Roadmaps will be updated with feedback received from internal and external sources.
ARMD Strategic Portfolio Model

The SIP and the Roadmaps are used to help guide NASA project planning. Feedback from partners and research results informs updates to the Thrusts and Roadmaps.

- SIP Outcomes Drive Top-Down Planning
- Roadmaps Provide Guidance for NASA Project / Center Innovation and Planning

Partnerships & Performance Create a Feedback Loop

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Innovation in Commercial Supersonic Aircraft
- Ultra-Efficient Commercial Vehicles
- Transition to Low-Carbon Propulsion
- Real-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation
Introduction to Strategic Thrust 2

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
### Community Outcomes, Benefits and NASA Outputs

#### Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft

<table>
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<tr>
<th>Outcomes</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
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<th>Benefits</th>
<th>2015</th>
<th>2025</th>
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<tr>
<td>Rules preventing overland supersonic flight are replaced with noise certification standards for en route supersonic noise. Market is opened for new supersonic aircraft</td>
<td>New market for fast point to point transportation is served by environmentally compatible small supersonic aircraft. New business and job growth opportunities for manufacturers</td>
<td>A variety of air transportation markets will be served by supersonic aircraft with capacities as large as 200 passengers. These aircraft will offer rapid travel with competitive economics and reduced environmental impact</td>
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<tr>
<th>NASA Outputs/Enabled Capabilities</th>
<th>2015</th>
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<td>• Low boom design tools&lt;br&gt;• Fundamental data on the characteristics of low noise waveforms in real atmosphere&lt;br&gt;• scientified data on community response to low noise supersonic overflight&lt;br&gt;• Models for extrapolating community response to fleet impacts</td>
<td>Technologies enabling the first and second generations of supersonic transports with emphasis on acceptable community and en route noise and high altitude emissions&lt;br&gt;ATM technologies &amp; procedures for efficient supersonic &amp; terminal ops&lt;br&gt;Vehicle Capabilities&lt;br&gt;• Business aircraft economics&lt;br&gt;• Mach 1.6-1.8&lt;br&gt;• Range 4000 n.mi.&lt;br&gt;• Passengers 6-90&lt;br&gt;• Sonic boom Noise 70-75 PldB&lt;br&gt;• Airport noise: ICAO Ch. 14 w/margin&lt;br&gt;• Cruise NOx Emissions &lt;10 g/kg fuel</td>
<td>Technologies enabling supersonic transports that are competitive in airline market with emphasis on high efficiency and light weight for improved economics&lt;br&gt;Tech. for supersonic airline ATM&lt;br&gt;Vehicle Capabilities&lt;br&gt;• Airline economics&lt;br&gt;• Mach 1.3-1.6 overland, higher over water&lt;br&gt;• Range 4000 -5500 n.mi.&lt;br&gt;• Passengers 100-200&lt;br&gt;• Sonic boom Noise 65-70 PldB&lt;br&gt;• Airport noise: 15 EPNdB below Ch. 14&lt;br&gt;• Cruise NOx Emissions &lt;5 g/kg fuel&lt;br&gt;• Reduced particulates &amp; H2O vapor</td>
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NASA Commercial Supersonics: Research Strategy, 2015-2035+

NASA has a strategy that supports each of the three Community Outcomes (2015-2025, 2025-2035, 2035+) of the SIP. The strategy for commercial supersonic research, with examples of recommended NASA technology investments, is described on the next few slides.

**COMMUNITY OUTCOMES**

**2015**
- **Supersonic Overland Certification Standard**
  - Based on Acceptable Sonic Boom Noise

**2025**
- **Introduction of Affordable, Low-boom, Low-noise, and Low-emission Supersonic Transports**

**2035**
- **Increased Mission Utility and Commercial Market Growth of Supersonic Transport fleet**

**NASA Strategy**

- **Focus investment on**
  - the development of low boom design, flight validation and community response

- **Focus on key technologies that ensure that**
  - supersonic aircraft will be environmental good neighbors and meet standards similar to latest subsonic aircraft

- **Focus on capabilities and technologies that enable airline compatible operating economics for supersonic aircraft**
Strategic Thrust 2
Commercial Supersonics Strategy

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
These are the proposed Research Themes for the Commercial Supersonics Thrust. Research Themes are long-term research areas that will enable the SIP Community Outcomes.

**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
In this chart, the new Community Outcomes are located across the top and the new Research Themes are located to the left.

Research activities in each theme (shown on next charts) represent areas of investment focus, not necessarily all research.
Outcomes

2015
Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise

2025
Introduction of Affordable Low-boom, Low-noise, & Low-emission Supersonic Transports

2035
Increased mission utility and commercial market growth of Supersonic Transport fleet

Key Dates and EIS

Chapter 14 Noise Rule in effect
Chapter XX Noise Rule in Effect
En Route Noise Standard

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
- Jet & High-speed Fan/Inlet acoustics with airframe interactions
- Global emission impact assessment
- Combustor/cycle for LTO Certification/High Altitude Mitigation
- Low-Boom Design for Certification
- Low boom design for full flight profile & ops flexibility
- Inlet/Nozzle/PAI efficiency
- Airframe materials & structure for weight reduction, higher temp operation
- Advanced cycles & prop. architecture
- Light, durable high temp prop. materials
- Aeroservoelasticity, Advanced Flight Controls
- Extreme Aerodynamic Efficiency

Vehicle Design & Efficiency

- ModSim & Test Capability
- Integ. Tools & MDAO of OML
- MDAO of OML and Structure, integ. prop. and aeroservoelastics
- Dynamic, flexible a/c flight sim.
- Physics Based acoustic phenomena & source modeling
- Quiet flow facility for development & validation of en route noise signatures

Operational Efficiency (Thrust 1)

- Metered airspace ops & fleet routes
- Flight Ops for Boom Mitigation
- Full Free Flight 4D Integration of supersonic aircraft

Research Themes

- Environmental Performance Barriers
- Vehicle Design & Efficiency
- ModSim & Test Capability
- Operational Efficiency (Thrust 1)
Strategic Thrust 2
Roadmap Version 1.1

Outcomes

2015
Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise
LBFD 1st Flight

2025
Introduction of Affordable Low-boom, Low-noise, & Low-emission Supersonic Transports
Supersonic Bus. A/C
Small SS Airliner

2035
Increased mission utility and commercial market growth of Supersonic Transport fleet
Efficient Multi-Mach Airliner

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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
Jet & High-speed Fan/Inlet acoustics with airframe interactions
Combustor/cycle for LTO Certification/ High Altitude Mitigation
Response Models & Standards for Airline Ops (w/ FAA, ICAO)
Active Acoustic Control for Propulsion & Airframe Sources
Second generation SS combustor: low emissions, particulates and water vapor
Strategic Thrust 2
Roadmap Version 1.1

Outcomes

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Small SS Airliner
Efficient Multi-Mach Airliner

Key Dates and EIS

Research Themes

Vehicle Design & Efficiency

Low-Boom Design for Certification
Low boom design for full flight profile & ops flexibility
Boom Reduction/ Elimination for Large Civil Airliners
Airframe materials & structure for weight reduction, higher temp operation

Inlet/Nozzle/PAI efficiency
Low speed performance & control
Advanced cycles & prop. architecture
Light, durable high temp prop. materials
Aeroservoelasticity, Advanced Flight Controls
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Strategic Thrust 2 Roadmap Version 1.1
Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise

Introduction of Affordable Low-boom, Low-noise, & Low-emission Supersonic Transports

Increased mission utility and commercial market growth of Supersonic Transport fleet

Outcomes

2015

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2025

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Research Themes

Operational Efficiency (Thrust 1)

Metered airspace ops & fleet routes

Flight Ops for Boom Mitigation

Full Free Flight 4D Integration of supersonic aircraft

Roadmap Version 1.1
# Strategic Thrust 2

## Evolution of Stakeholder Community

<table>
<thead>
<tr>
<th>FY15</th>
<th>FY25</th>
<th>FY35</th>
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**FY25**

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

**FY35**

- 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
Give Us Feedback!

• Download this presentation from the NARI website
  – Identify gaps or areas that are missing from the roadmap (the roadmap is rolled up to a high level, so we are looking for general categories, not specific technology)
  – Identify additional high level risks or dependencies that are not captured
  – Identify areas that are currently on the roadmap that you believe do not require further investment and should be removed

• Two ways to provide feedback:
  1) Email to peter.g.coen@nasa.gov with subject line FEEDBACK
  2) Give feedback in person to NASA representatives at the upcoming AIAA Aviation Meeting (June 13-17)
Concluding Remarks

• NASA Aeronautics has developed a Strategic Implementation Plan (SIP) that contains Community Vision, Community Outcomes, Research Themes, and System Metrics for each of the six Thrusts

• Each Thrust has a roadmap planning exercise underway. Thrust 2 is directed exclusively at Commercial Supersonic Flight

• The NASA Thrust 2 Roadmap team is seeking your comments and input on the draft roadmap

• Feedback may be through email or in-person communications at upcoming conferences and events