NASA Overview/Update
FAA ASCENT Meeting

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Brief Outline

- Global Growth in Aviation
- Emerging Markets – Integrated Challenges
- NASA Vision and Strategy
- FY2020 Budget request
- Subsonic Transport Technology Strategy
- Enabling U.S. Leadership in Subsonic Transport Markets
- Electrified Aircraft Propulsion Strategy
- Alternative Fuel Research – NASA
- Landing/Takeoff Noise and Emissions Procedures for Supersonic Transport

Global Growth in Aviation

2017

4 BILLION

PASSENGER TRIPS

2036

7.8 BILLION

PASSENGER TRIPS

41,030
New Aircraft Deliveries

$6.1 Trillion
Market Value

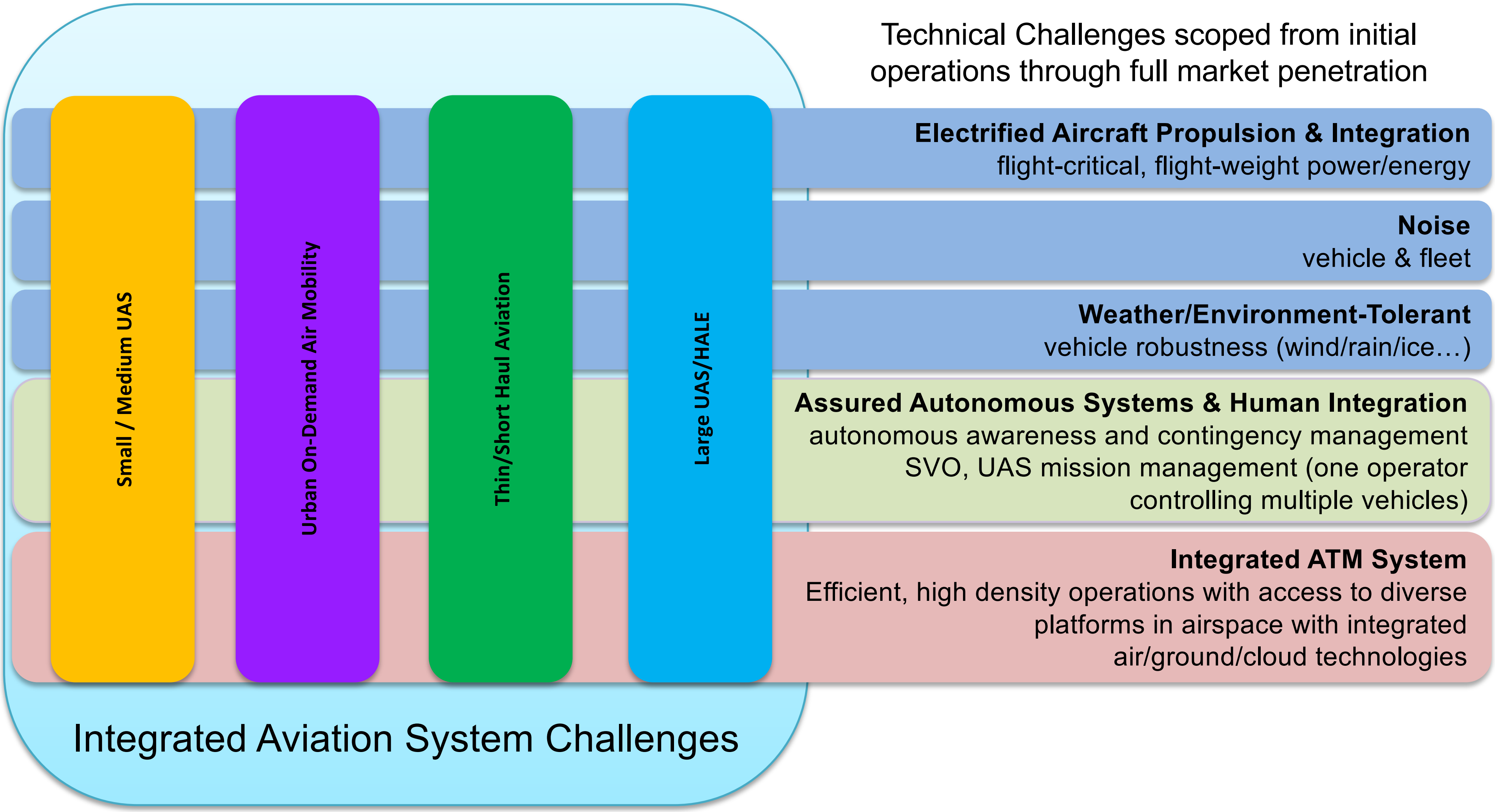
Asia-Pacific Market is Nearly **40%** of New Aircraft Deliveries

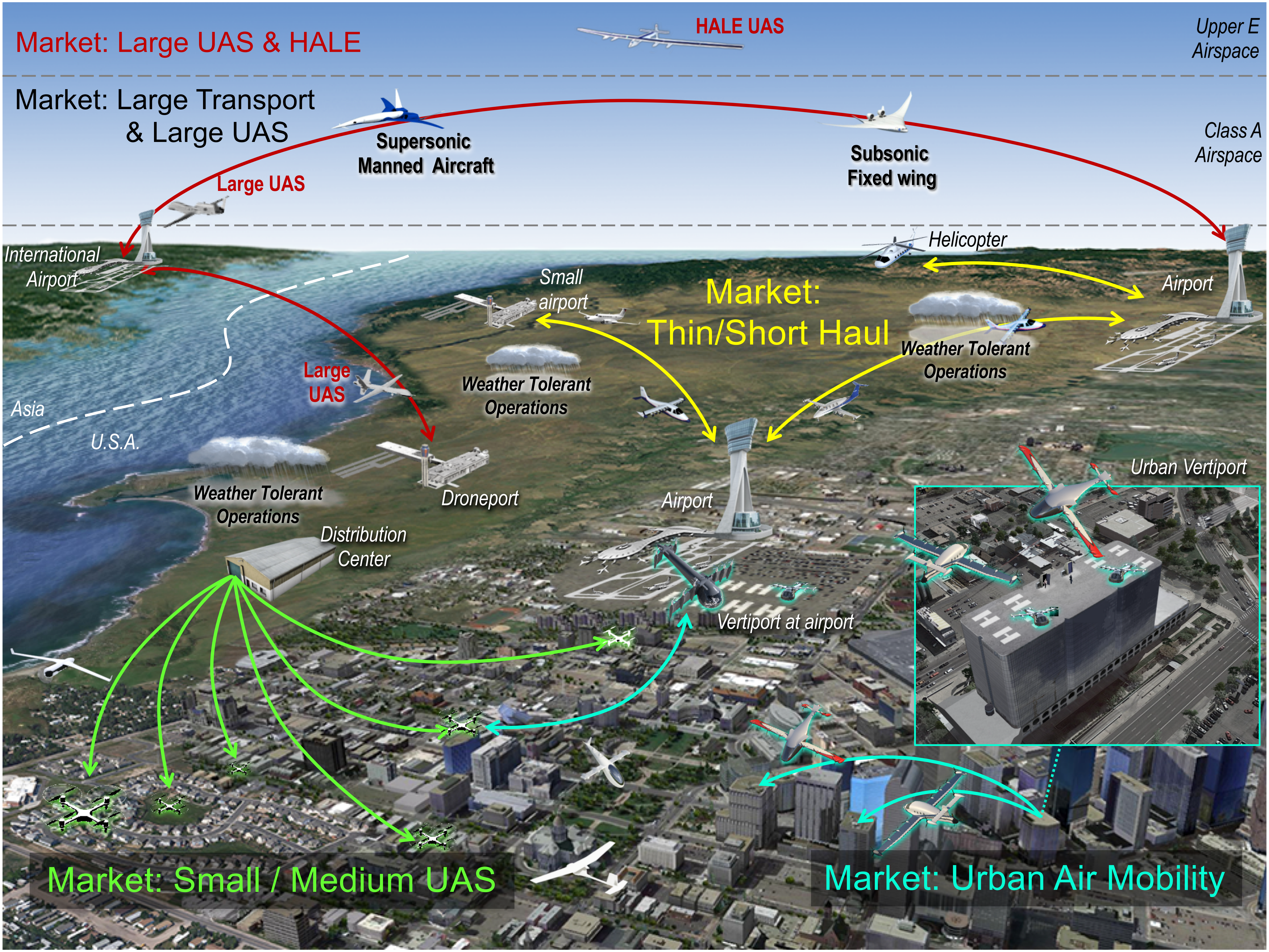
78% of New Aircraft Deliveries are Single Aisle Class (including Regional Jets)

Emerging Markets - Integrated Challenges

NASA ARMD Programs pivoting to address complex challenges

ARMD has developed a holistic understanding of the challenges for enabling the enormous potential of emerging aviation global market opportunities




Market: Large UAS & HALE
HALE UAS
Upper E Airspace
Market: Large Transport & Large UAS
Supersonic Manned Aircraft
Subsonic Fixed wing
Class A Airspace
Large UAS
International Airport
Helicopter
Small airport
Market: Thin/Short Haul
Airport
Weather Tolerant Operations
Large UAS
Weather Tolerant Operations
Asia
U.S.A.
Weather Tolerant Operations
Droneport
Airport
Urban Vertiport
Distribution Center
Vertiport at airport
Market: Small / Medium UAS
Market: Urban Air Mobility

NASA Aeronautics Strategic Implementation Plan

Continues to Guide NASA Aeronautics Investment

Key Trends (Not Exhaustive)	Aviation Mega-Drivers	Analysis & Community Dialogue	Strategic Thrusts	Community Vision

Key Trends (Not Exhaustive)

Increasingly Urbanized World

Rising Global Middle Class Driven by Asia-Pacific

Urban Transportation Increasingly Congested

Aviation Mega-Drivers

Key Trends (Not Exhaustive)

Continuing Pressure to Reduce Noise and Local Air Quality Impacts

Aviation Industry Sets Challenging CO_2 Reduction Goals through Mid-Century

Aviation Mega-Drivers

Key Trends (Not Exhaustive)

Networked Com and Sensors, Embedded Artificial Intelligence, and Big Data Converging with Traditional Systems and Technologies

On-Demand Service Models Disrupting Traditional Industries

Aviation Mega-Drivers

Analysis & Community Dialogue

Industry / Gov't Execs What's Needed?

Industry / Gov't SMEs What's Possible?

Systems Analysis

Strategic Thrusts

1. Safe, Efficient Growth in Global Operations
2. Innovation in Commercial Supersonic Aircraft
3. Ultra-Efficient Commercial Aircraft
4. Transition to Alternative Propulsion and Energy
5. In-Time System-Wide Safety Assurance
6. Assured Autonomy for Aviation Transformation

https://www.nasa.gov/aeroresearch/strategy

ARMD Research Programs & Strategic Thrusts

MISSION PROGRAMS

Airspace Operations & Safety

Projects
- Airspace Technology Demonstrations
- UAS Traffic Management
- System-Wide Safety
- ATM-X

Advanced Air Vehicles

Projects
- Advanced Air Transport Technology
- Advanced Composites
- Revolutionary Vertical Lift Technology
- Commercial Supersonic Technology
- Hypersonic Technology

Integrated Aviation Systems

Projects
- Unmanned Aircraft Systems Integration in the National Airspace System
- Flight Demonstrations and Capabilities
- Low Boom Flight Demonstrator

SEEDLING PROGRAM

Transformative Aeronautical Concepts

Projects
- Convergent Aeronautics Solutions
- Transformational Tools and Technologies
- University Innovation

NASA Aeronautics Vision for Aviation in the 21st Century

ARMD Strategy
https://www.nasa.gov/aeroresearch/strategy

FY 2020 Budget Request - Aeronautics

$ Millions	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Aeronautics	**$690.0**	**$725.0**	**$666.9**	**$673.6**	**$680.3**	**$587.1**	**$587.0**
Airspace Operations and Safety	118.7		121.2	130.6	133.5	136.2	138.9
Advanced Air Vehicles	237.7		188.1	203.3	212.2	219.3	224.2
Integrated Aviation Systems	221.5		233.2	209.4	202.2	97.1	87.2
Transformative Aeronautics Concepts	112.2		124.4	130.3	132.3	134.6	136.7

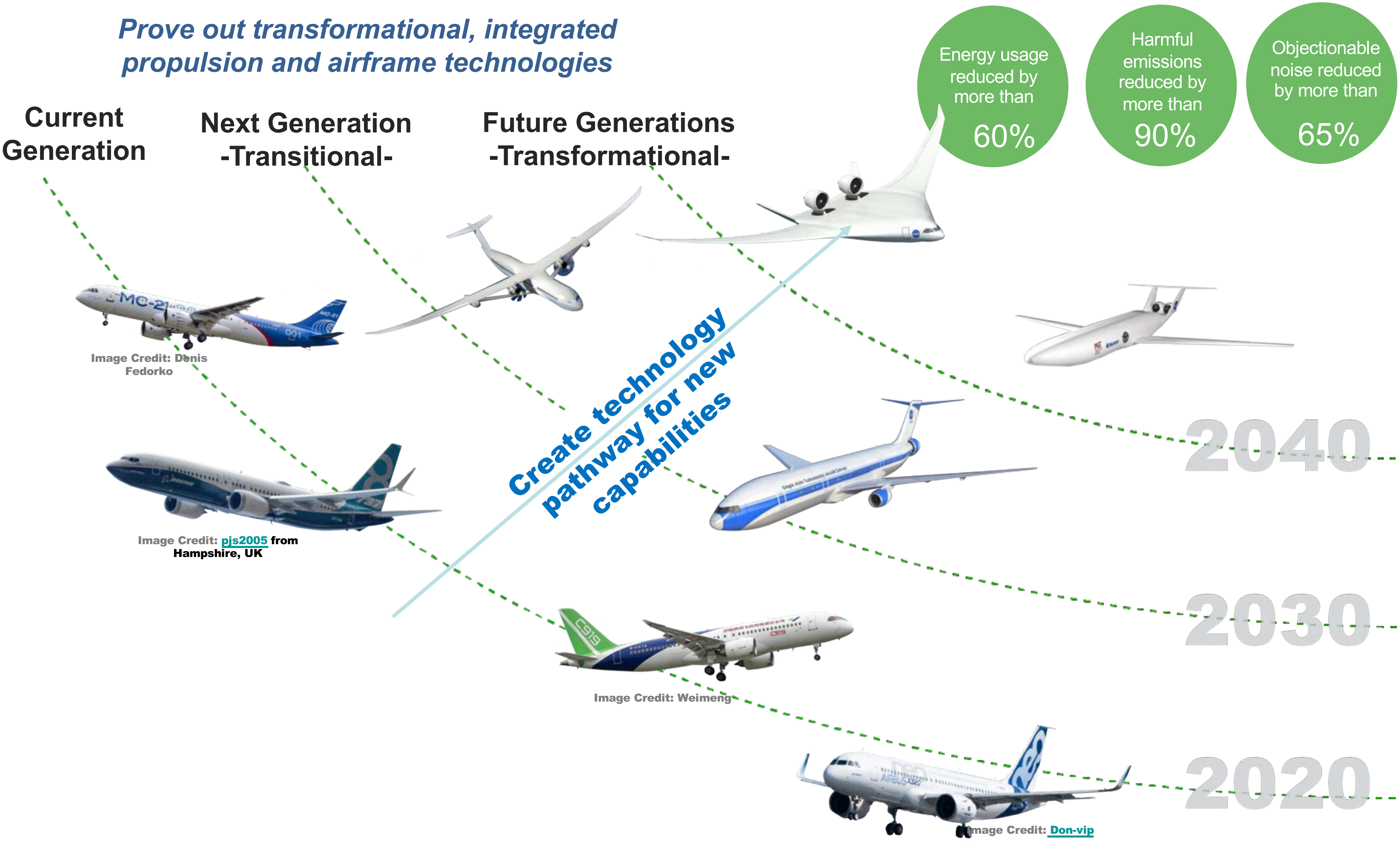
FY 2018 reflects funding amounts specified in Public Law 115-41, Consolidated Appropriations Act, 2018, as adjusted by NASA's FY 2018 Operating Plan.

FY 2019 reflects funding as enacted under Public Law 116-06, Consolidated Appropriations Act, 2019

Note: PBR FY20 and beyond budget decrease relative to FY19 is result of AETC transfer out of ARMD

Subsonic Transport Technology Strategy

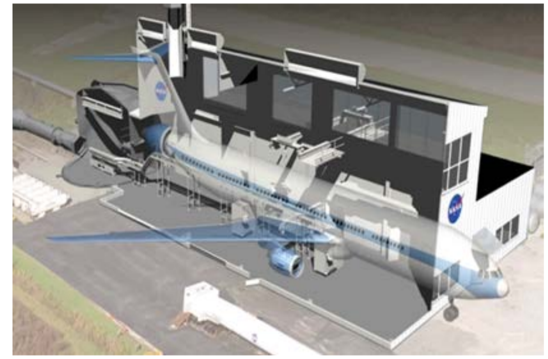
Prove out transformational, integrated propulsion and airframe technologies



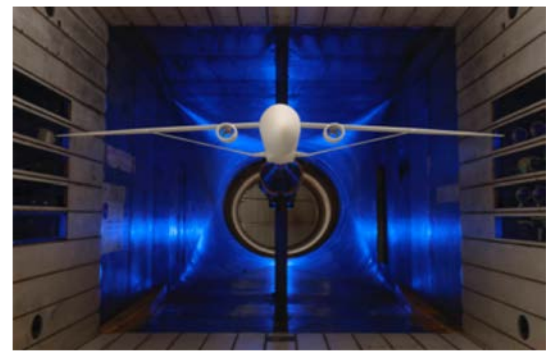
Enabling U.S. Leadership in Subsonic Transport Markets

- Suite of 5 key technologies coupled into transformative configurations will win the subsonic transport future
  - Light Weight, Very High Aspect Ratio Wings
  - **Propulsion – Airframe Integration, especially Boundary Layer Ingestion**
  - Tailored Non-Circular Fuselage
  - **Electrified Aircraft Propulsion**
  - **Small Core Turbine Engines**

- ARMD is advancing these key technologies to create market opportunities

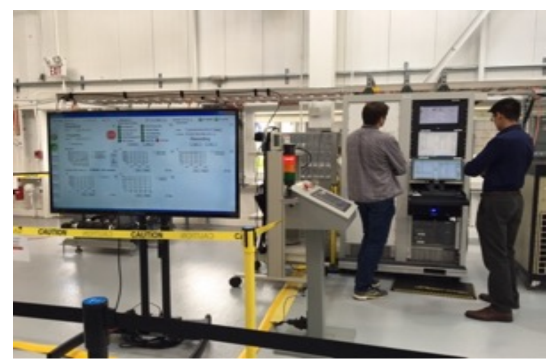


NASA Electric Aircraft Testbed (NEAT) Facility



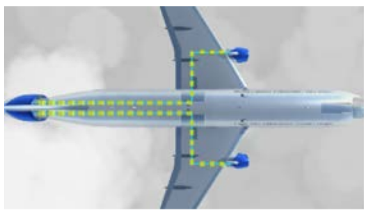
Very High Aspect Ratio Wing

Boundary Layer Ingestion



Hybrid Electric Propulsion

Electrified Aircraft Propulsion Strategy for Single Aisle Aircraft



Initial Focus on Turboelectric Aircraft

- Concept definition & system analysis
- Novel integration and BLI
- MW flight-weight electrical component development
- Integrated system testing
- Advanced cores with large power extraction

→ Potential Flight Demo → Potential single aisle aircraft

Hybrid electric option to be considered with advances in battery technology

MW-level High Efficiency/Power Density Electric Machines & Flight-weight Power System/Electronics

– Explore conventional & non-conventional topologies; Integrate novel thermal management; Demonstrate component maturation
– Develop/demonstrate powertrain systems and components; High voltage, MW power electronics, transmission, protection

Enabling Materials

– Insulators & conductors for high power & altitude components; Nanocomposite magnetic materials for targeted machines and drives

Integrated Subsystems

– Explore component interactions, power management, & fault management

Alternative Jet Fuel Combustion Research at NASA

TTT

- Fuel Sensitive Chemistry Models
- Fuel Sensitive simulation capability for Lean Blowout (LBO) and Ignition
- Improved Soot Models
- Testing with alternative fuels

Instantaneous temperature contours from LES of Referee Rig at near LBO condition

NJFCP

- Provided experiments enabling development of chemistry models for conventional and alternative jet fuels
- Provided LBO and Ignition experiments with multiple fuels for development and validation of fuel sensitive CFD models

AATT

- Testing with alternative fuels (100% and blends)
- Flow reactor network for assessing fuel impacts over large range of geometries/conditions than practical with detailed CFD simulations

NASA Test Cell Ce-5 Stand 1 tested N+3 combustor with JetA and alternative fuel blend

CST

- Fuel impacts on soot emissions
- Fuels optimized for flame stability and lower emissions

AATT-CGT: N+3 Low Emissions – Fuel Flexible Combustor Concept

Problem
Fuel flexible, Small Core, High OPR (50+) engines present greater challenges to combustor emissions and operability

Objective
Develop and demonstrate (to TRL 3) a low-emissions, fuel-flexible, small-core compatible combustor architecture that reduces LTO NOx 80% below CAEP/6 and cruise NOx 80% below 2005 best-in-class.

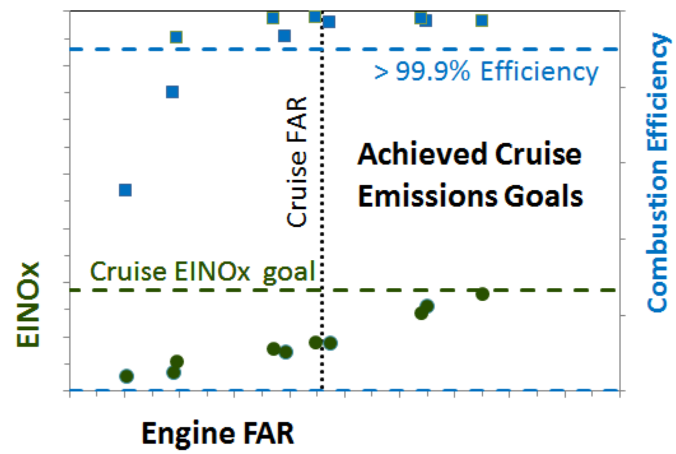
Results
- Developed small-core lean-burn combustor technology for propulsion engines in efficient N+3 aircraft such as the D8 concept aircraft.
- Completed emissions testing of small core combustor in CE-5 covering LTO and cruise conditions.
- Completed testing using Jet-A and a 50/50 blend of Jet-A / Alternative fuel (Gevo Alcohol-to-Jet). Demonstrated equivalent combustor performance and the effect of fuel composition on non-volatile particulate matter emissions.
- Demonstrated LTO NOx emissions >80% below CAEP6 in UTRC single-sector tests of small-core N+3 combustor.

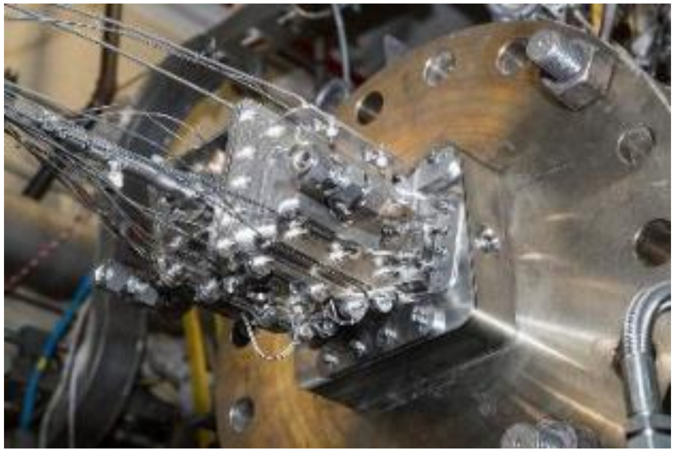
Significance
Lean Burn combustor concept shows potential to meet/exceed NASA's Far Term LTO NOX goal. But further investigation of dynamic characteristics of the combustor concept are required to ensure good operability over the flight conditions

Emissions goals achievable with small core compatible combustor with Alternative Fuels

Summary of Emission Results

Flight Condition	EI NOx
Takeoff (100%)	5.01
Climbout (85%)	3.81
Approach (30%)	10.60
Idle (7%)	4.40
Dp/Foo	8.37 g NOx/kN
% Below CAEP/6 Stringency:	88.2
% Below CAEP/8 Stringency:	86.6





AATT.03.L1.CGT.41.007, POC: C. Chang

ICAO/FAA Interaction and Technical Support

Landing/Takeoff Noise and Emissions Procedures for Supersonic Transport

Objective

- Analyze representative near-term commercial supersonic design space to inform CAEP regulators with LTO performance for use in Type Certification process.

Approach

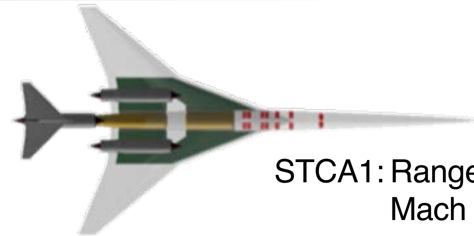
- Use conceptual supersonic derivative mixed flow turbofan based on CFM56-7B and down-sized Boeing N+2 vehicle.
- Assess certification margins using conventional & advanced procedures for noise (WG-1).
- Assess certification margins using current Rich-Burn & advanced Lean-Burn combustor emissions for both conventional & advanced takeoff procedures (WG-3)
- Interact with industry for consensus on methods/assumptions

Status

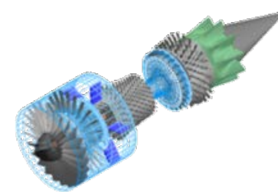
- Advanced takeoff procedures will be helpful in achieving Chapter 4 noise levels, but will require departures from subsonic standards/ reference procedures
- Existing subsonic CAEP/4 levels of LTO emissions appear achievable near-term, depending on regulation times-in-mode for take-off, climbout, approach, taxi.

Significance

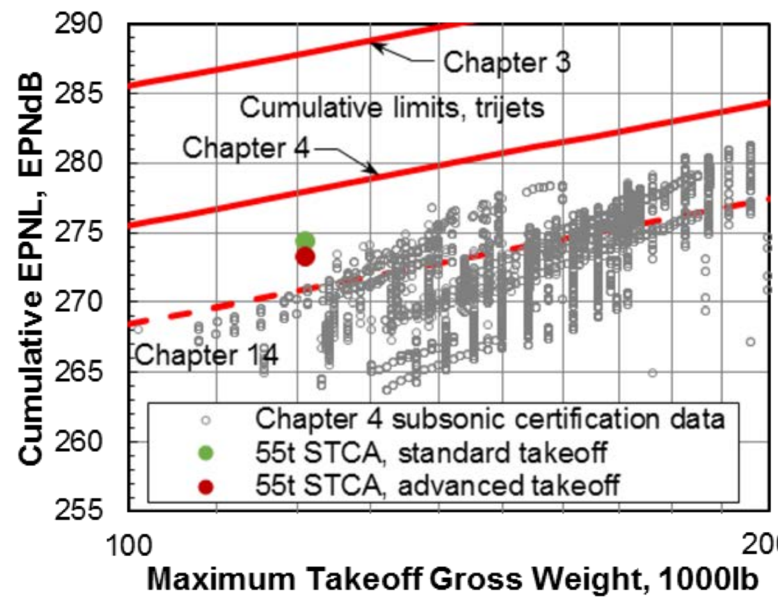
- NASA results are key to moving forward with CAEP gap analysis



STCA1: Range = 4000 n.mi.
Mach = 1.4

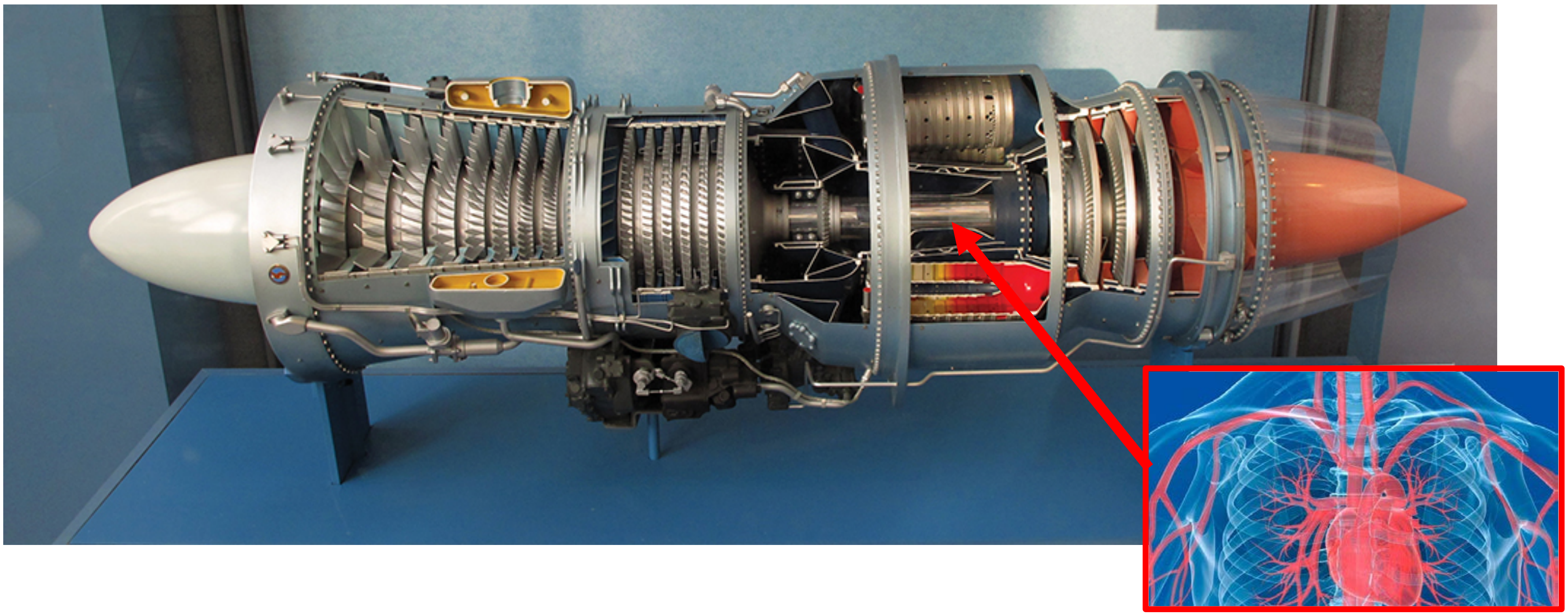


Redesigned CFM56-7B low-pressure spool for supersonic application



55t STCA EPNL predictions (with wing shielding) compared to Chapter 4 data.

Every engine has a heart



Loss of sight in the importance of the combustor is like forgetting about ones heart that supplies our entire body with the energy we need to get up every day.
Not an option.