NASA Update

FAA REDAC E&E Subcommittee Meeting
September 16, 2020

Barbara Esker, Deputy Director, Advanced Air Vehicles Program
NASA Aeronautics Research Mission Directorate

NASA Aeronautics Strategies for Research

Safe, Efficient Growth in Global Operations
- Achieve safe, scalable, routine, high-tempo airspace access for all users

Innovation in Commercial Supersonic Aircraft
- Achieve practical, affordable commercial supersonic air transport

Ultra-Efficient Subsonic Transports
- Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy.

Safe, Quiet, and Affordable Vertical Lift Air Vehicles
- Realize extensive use of vertical lift vehicles for transportation and services including new missions and markets

In-Time System-Wide Safety Assurance
- Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

Assured Autonomy for Aviation Transformation
- Safely implement autonomy in aviation applications

ARMD Research Programs & Projects Aligned with ARMD Strategy

MISSION PROGRAMS

AIRSPACE OPERATIONS & SAFETY

AOSP

PROJECTS

- ATM Tech Demonstrations*
- UTM*
- ATM-X
- System-Wide Safety

ADVANCED AIR VEHICLES

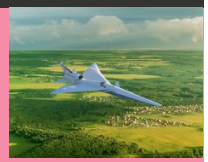
AAVP

PROJECTS

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

INTEGRATED AVIATION SYSTEMS

IASP



PROJECTS

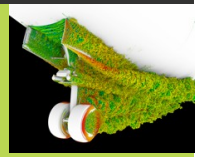
- UAS in the NAS*
- Flight Demonstrations and Capabilities
- Low Boom Flight Demonstrator
- Electrified Powertrain Flight Demonstration**
- Advanced Air Mobility

Integration and Flight

SEEDLING PROGRAM

TRANSFORMATIVE AERONAUTICS CONCEPTS

TACP



PROJECTS

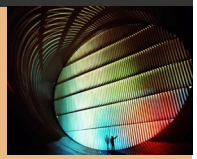
- Convergent Aeronautics Solutions
- Transformational Tools and Technologies
- University Innovation

Convergent Innovation and Revolutionary Analysis Tools

PORTFOLIO OFFICE

AEROSCIENCES EVALUATION & TEST CAPABILITIES

AETC



GROUND FACILITIES

Subsonic	Hypersonic
Transonic	Propulsion
Supersonic	Test Technology

* Projects end in FY 2020/21
** Projects start in FY 2021

FY 2021 Budget Request - Aeronautics

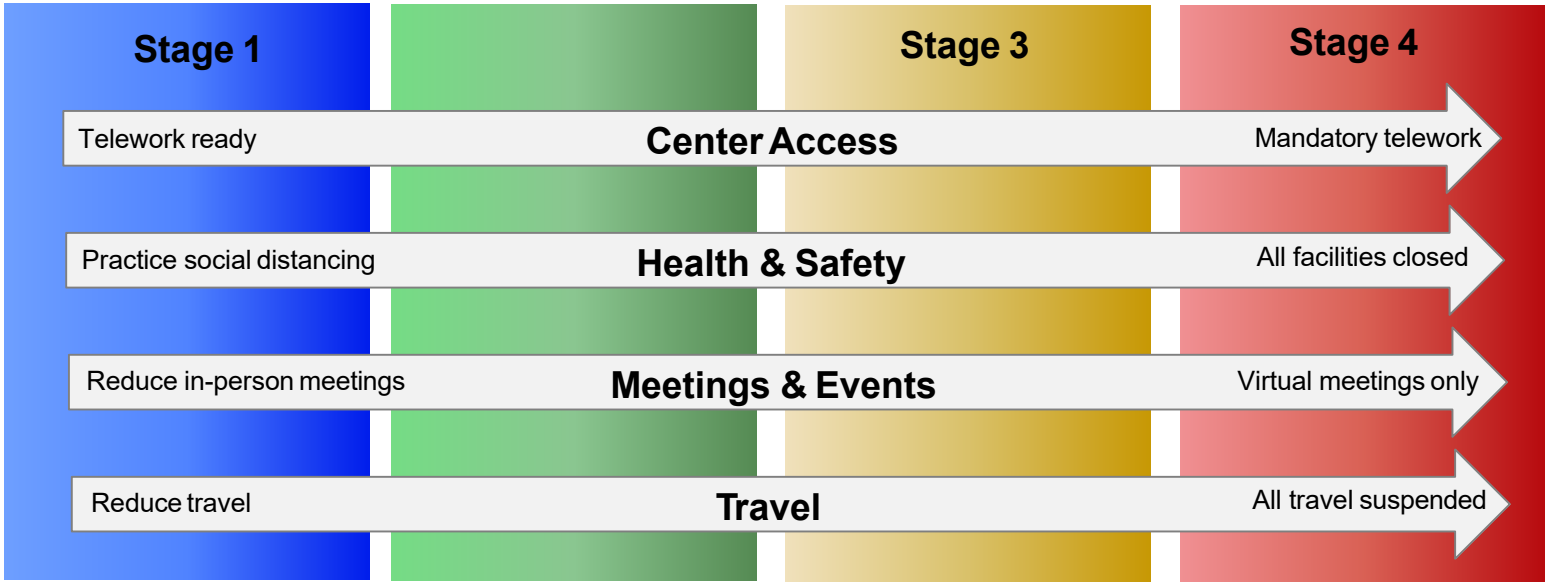
$ Millions	FY 2019	FY 2020*	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Aeronautics	**$724.8**	**$783.9**	**$819.0**	**$820.7**	**$820.7**	**$820.7**	**$820.7**
Airspace Operations and Safety	105.7	96.2	90.4	92.6	94.4	96.2	96.2
Advanced Air Vehicles	272.1	188.1	212.7	222.2	230.3	261.2	266.2
Integrated Aviation Systems	209.6	261.5	269.0	256.4	244.4	209.5	204.5
Transformative Aeronautics Concepts	137.4	121.1	129.9	132.3	134.6	136.7	136.7
Aerosciences Eval and Test Capabilities		117.0	117.0	117.1	117.1	117.1	117.1

* For consistency with FY21 budget structure, in FY20, the Advanced Air Mobility Project ($28.3M) is shown under IASP instead of AOSP.

The Aeronautics FY 2021 Budget Request supports critical needs of the U.S. aviation industry to maintain leadership in a new era of aviation

- Readies Low Boom Flight Demonstration Mission to achieve first flight in FY 2022 and deliver data that will support new noise standards
- Invests in critical needs for the emerging Advanced Air Mobility (AAM) market – building upon NASA's UAS technology development and airspace integration success
- Develops and matures technologies in time to support U.S. industry development of new subsonic aircraft by the early 2030s
  - Accelerates key enabling technology development: advanced aerodynamics, electrified aircraft propulsion, small core turbine engine technologies, and high rate production of composite materials
  - Demonstrates electrified aircraft propulsion via flight testing, first flight in FY 2023
- Invests in fundamental hypersonic research supporting DoD and commercial applications

NASA response to COVID
Health & safety of NASA workforce is paramount



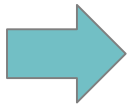
All research centers (Ames, Armstrong, Glenn, and Langley) went to Stage 4 (late spring/early summer) – all on-site research work stopped (wind tunnels, test facilities & laboratories); mandatory telework for all employees.

- Research centers are now in Stage 3 and in the process of carefully & systematically returning select persons and teams on-site - approving "Mission Critical" work packages that can be executed with necessary precautions (PPE & social distancing).
- Key facilities are coming on-line or being prepped to come on-line.

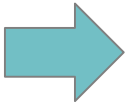
Supersonics

Vertical flight

Subsonics (transports)

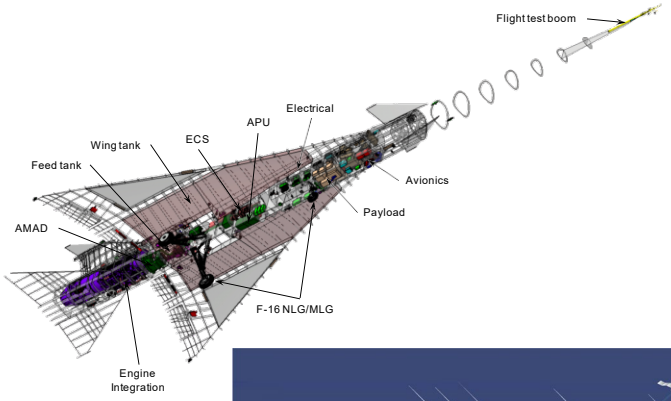


Hypersonics



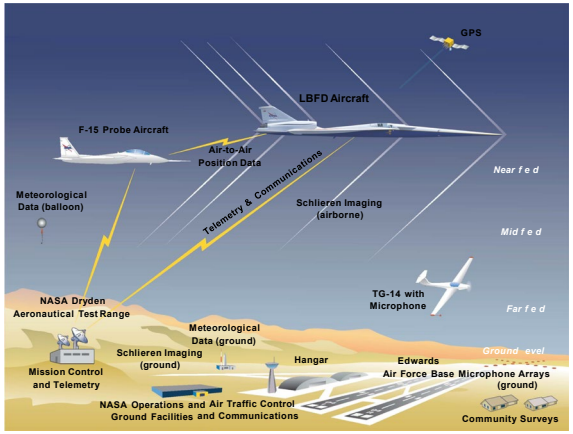
Foundational/convergent technology

Low Boom Flight Demonstration Mission Phases



Phase 1 – X-59 Aircraft Development – *In progress (FY18-23)*

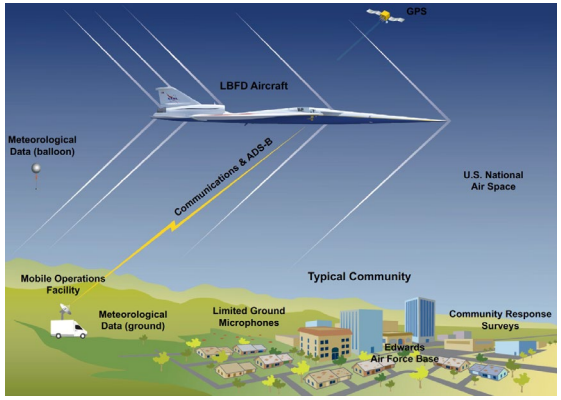
- Detailed design
- Fabrication, integration, ground test
- Checkout flights
- Subsonic and supersonic envelope expansion



Phase 2 – Acoustic Validation

In preparation, Execution FY 23

- Validation of X-59 acoustic signature and prediction tools
- Development of acoustic prediction tools for Phase 3
- Aircraft operations & support



Phase 3 – Community Response

In prepararation, Execution FY24-26

- Initial community response overflight study
  - Aircraft based at NASA AFRC
- Multiple campaigns (4 to 6) over representative communities and weather across the U.S.
  - Aircraft and test team deployed
- Data analysis and delivery to FAA and ICAO

Low-Boom Flight Demonstrator (LBFD) Project

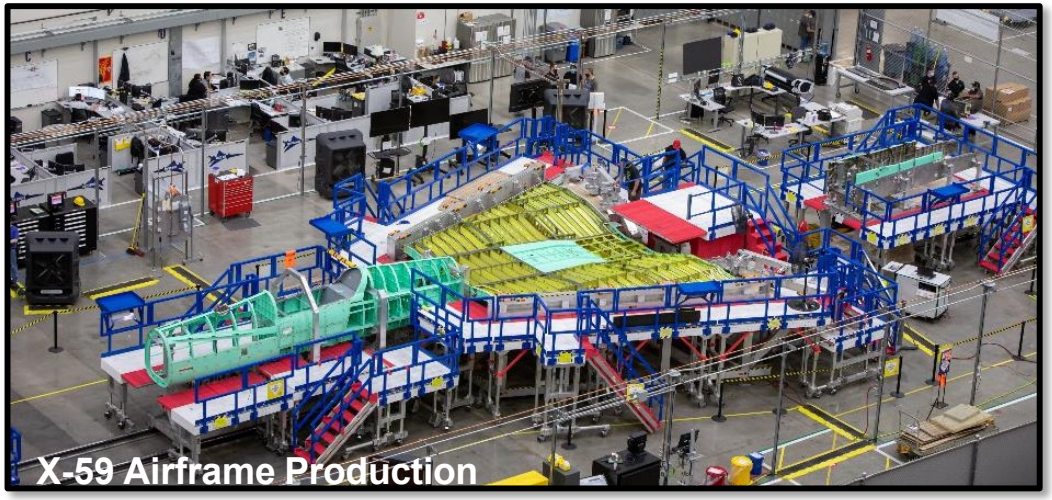
Phase 1 – Aircraft Development - X-59 Aircraft Build Progressing

- Good progress being made, with some challenges encountered
  - Engineering details of a complex, clean sheet design
  - COVID-19
- Schedule updates implemented in August
  - Integrated ground testing targeted to start August 2021
  - First flight targeted for summer 2022


X-59 GE-414-100 Engine


X-59 Engine at NASA AFRC

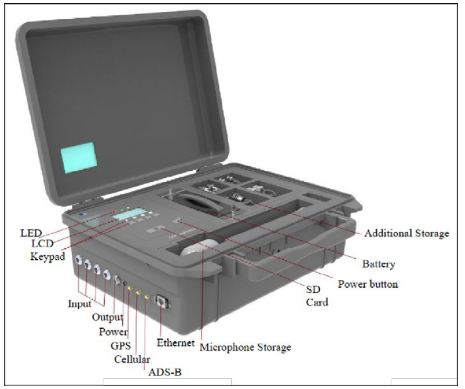
X-59 QueSST (Quiet SuperSonic Technology)


X-59 Airframe Production

LBFD Mission - Phase 2 and 3 Status

Acoustic Measurement

- Awarded contract for development of Ground Recording System
  - New system meets challenging requirements for X-59 mission
  - Phased delivery of 125+ units to support Phase 2 & 3 measurement
- Progress continues on airborne acoustic measurement systems
  - CoVID-19 is slowing effort, but not yet impacting milestones

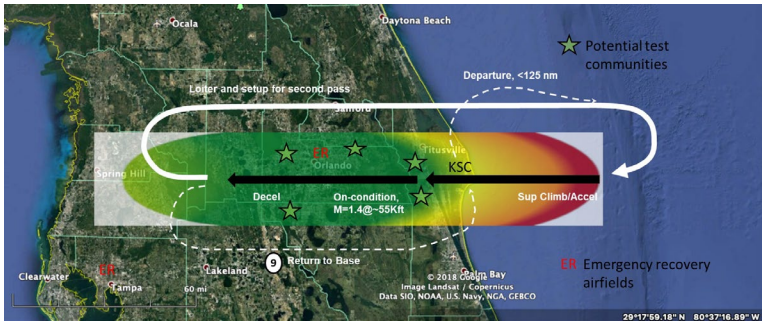


Community Test Planning

- Community Test Planning/Execution team established
  - Test airfield selection process underway
  - Test Support Team contract solicitation in progress

International Standards Development

- Continued engagement with ICAO CAEP and international research community
- COVID-19 impacting international workshop schedule

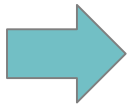


Representative Mission for Potential Airfield/Community Selection Studies

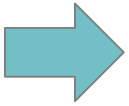
Supersonics

Vertical flight

Subsonics (transports)



Hypersonics



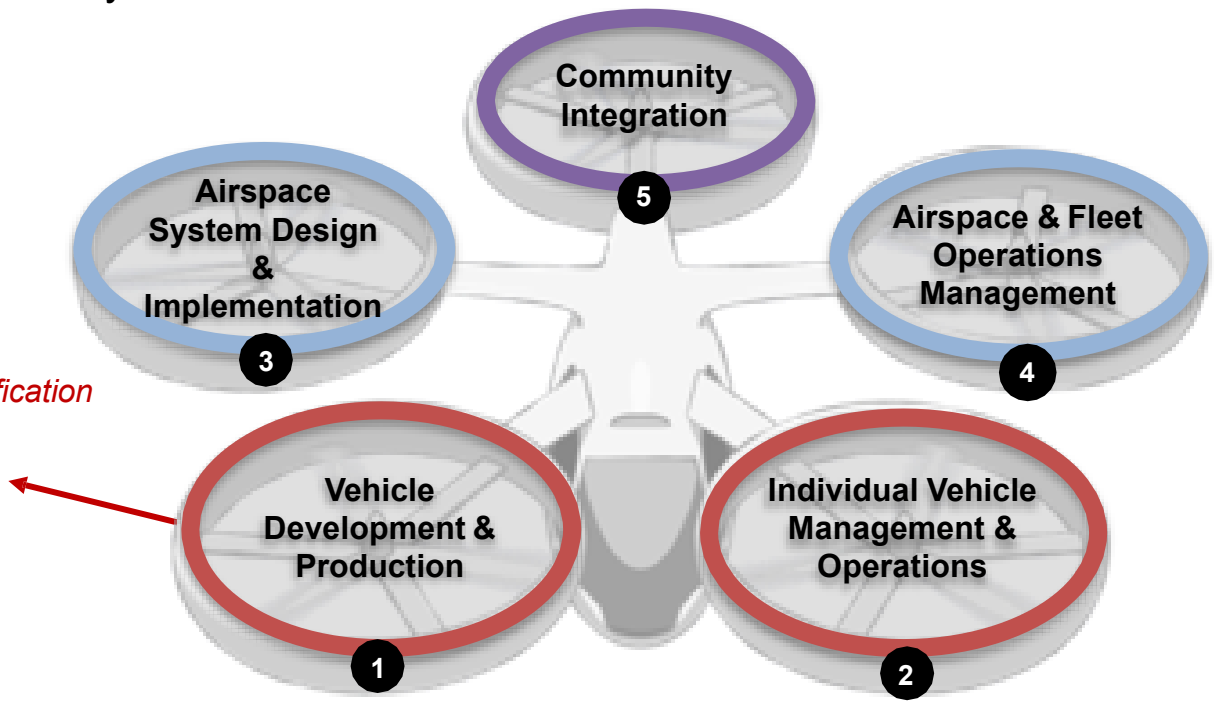
Foundational/convergent technology

Advanced Air Mobility Mission Vision and Framework

Advanced Air Mobility (AAM) Vision -
Revolutionize mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers & cargo

Challenges:

1. *Vehicle Design & Integration*
2. *Airworthiness Standards & Certification*
3. *Manufacturing*
4. *Vehicle Noise*
5. *Weather-Tolerant Vehicles*
6. *Cabin Acceptability*

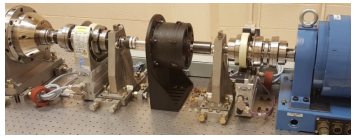


NASA providing community leadership to advance safe, community-friendly UAM system integration

Revolutionary Vertical Lift Technologies
Near Term Plans for Technical Challenges, FY20-FY22

Reliable and Efficient Propulsion Components for UAM

Vehicle Propulsion Reliability



- Re-configure laboratories for electric propulsion testing
- Conduct initial single string tests
- Develop tools to assess motor reliability
- Develop high reliability conceptual motor design

Goal: Improve propulsion component reliability for UAM electric & hybrid-electric VTOL vehicles using a pre-competitive approach to address safety for full UAM market

- Integrated approach between mechanical, electrical, & thermal disciplines for reliability improvements

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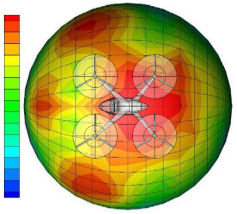
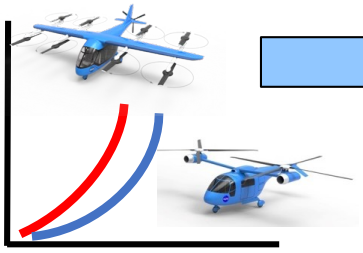
Human Response to Noise



UAM Operational Fleet Noise Assessment

- Calculate Noise Power Distance (NPD) for several UAM reference configurations to represent ATM-X trajectories
- Conduct Gen-1 and Gen-2 Fleet Noise assessment
- Initiate psychoacoustic testing to assess human response to UAM vehicles

Source & Fleet Noise



Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles

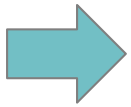
- Plan and conduct validation experiments
- Improve efficiency and accuracy of conceptual design tools
- Conduct high-fidelity configuration CFD for validation and reference
- Improve community transition and training for analysis tools

Goal: Develop, validate & document methodologies needed for assessing noise/efficiency tradeoffs and assess vehicle noise impact on the community and explore feasible mitigation strategies

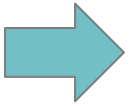
Supersonics

Vertical flight

Subsonics (transports)



Hypersonics



Foundational/convergent technology

Four Key Subsonic Transport Technologies

Create new “S” curve for the next 50 years of subsonic transports

Electrified Aircraft Propulsion

- Improved efficiency/emissions
- Mild hybrid systems promising for early 2030s

Small Core Gas Turbine

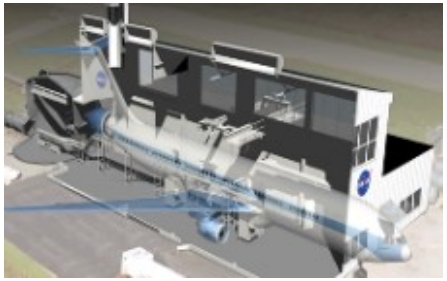
- Increased gas turbine efficiency
- Facilitates airframe integration – conventional or EAP

Transonic Truss-Braced Wing

- Increased aerodynamic and structural efficiency
- Propulsion system integration and high rate production

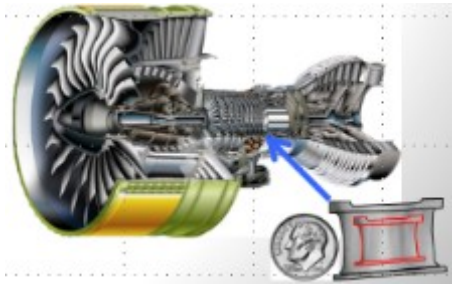
High Rate Composites

- Critical to U.S. competitiveness via reduced delivery time
- Reduced time/cost to market with increased performance

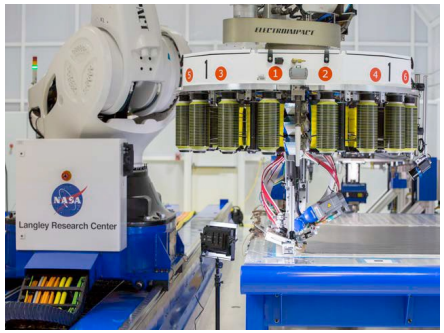


Electrified Aircraft Propulsion

synergistic



Small Core Gas Turbine



High Rate Composites

synergistic

Transonic Truss-Braced Wing

ARMD is advancing these key technologies to create market opportunities

Subsonic Transport Technology

NASA Aeronautics Vision and Strategy Established

2008-2013	2014 - 2019	2020-2025

Subsonic Concept/Technology Studies
Electric Aircraft Propulsion, Transonic Truss Braced Wing

Environmentally Responsible Aviation (ERA) Project

Flight Demonstrator Studies

Advanced Composites (ACP)

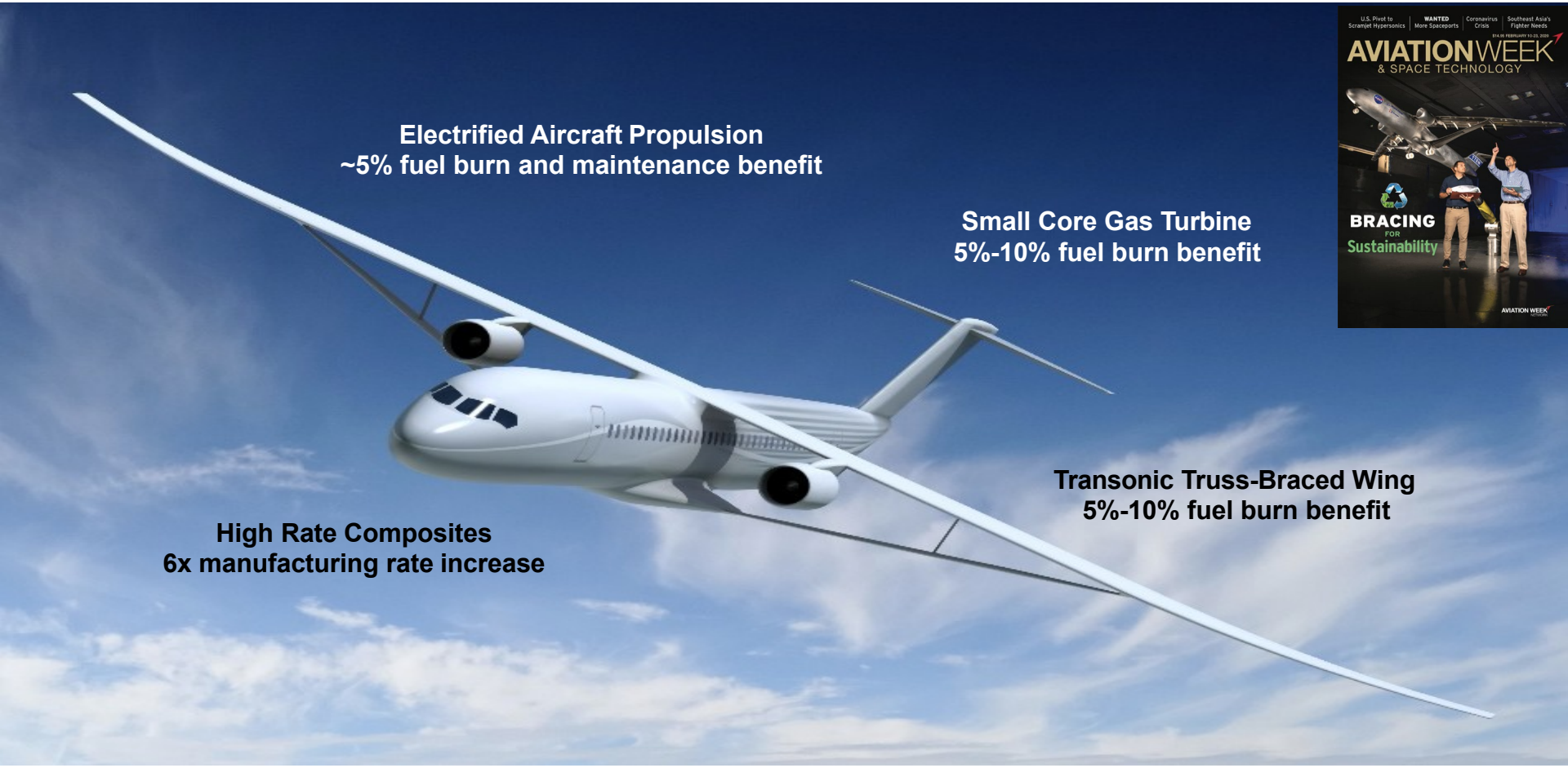
Next Step

Maturation and Integration of Four Key Technologies that will Create a New "S Curve" for Future Subsonic Transports

FAA CLEEN I	FAA CLEEN II	FAA CLEEN III

ARMD Subsonic Transport Strategy Based on over a Decade of Research, Concept and Technology Development, and Partnership

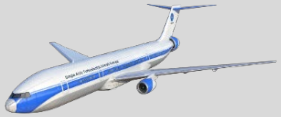
Subsonic Transport Technology

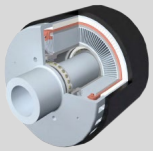


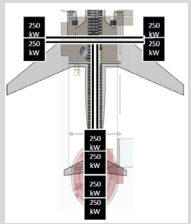
Assessing the potential of the combination of these four technologies to establish a new S-curve for future subsonic transports

Transport-Class
Advancing Technical & Integration Readiness

0 **Early conceptualization & identification of KPP's/ technology gaps; component advancement; ground test capability gap assessment**

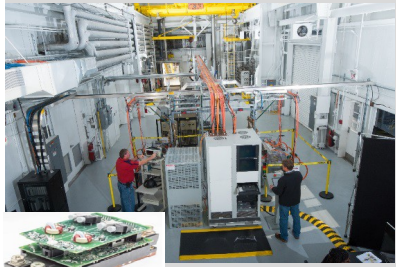






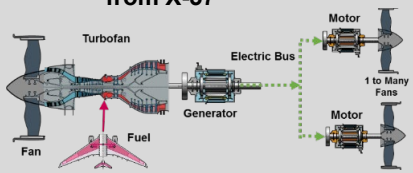
2009-2015
TRL 1-2
NASA in-house & NASA-sponsored university/industry efforts advancing MW motors & inverters for EAP

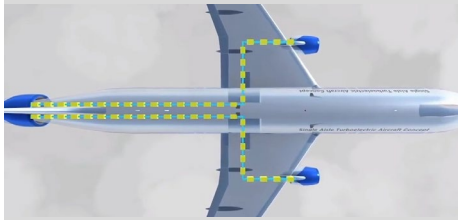
1 **Ground testing of Key electrical components (work is ongoing but must accelerate)**



2016-2018+
TRL ~3
NASA in-house & industry efforts raise the TRL level of motors and inverters

2 **Integrate in a flight system (likely existing airframe) – leveraging experience from X-57**





2018-2020
TRL ~4
NASA in-house & industry efforts leading to ground demo of TRL 4 level end-to-end power system

3 **Flight Experiments in relevant environment**

- **Key data informing product decisions**
- **Knowledge to support certification**
- **Learning to inform further fundamental research**

2021-2023
TRL 5-6
Flight demo of end-to-end MW EAP power system with application to transport aircraft.

New project: Electrified Powertrain Flight Demonstration (EPFD) Project
To reduce the technology risks of a MW-class electrified powertrain by demonstrating key elements in a relevant flight environment

Project planning and formulation efforts underway

Acoustic Measurements on 787 ecoDemonstrator

Breaking News:

- NASA-Boeing ecoDemonstrator flight testing completed on Sep. 2, 2020 at Glasgow, Montana.
- Data taken on SOA aircraft – measurements on fuselage and via ground array.
  - 214 on-aircraft microphones
  - 962 phased array microphones (with 4 miles of fiber optic cable, 20 miles of coax cable)
- Early data analysis is very encouraging – deeming the test highly successful. Full data analysis on-going - for awhile...

Link to video: https://advocate.socialchorus.com/boeing/BNN/articles/what-s-all-the-noise-about-boeing-nasa-test-fly-a-787-to-find-out-1

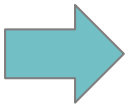
Array of on-aircraft acoustics sensors

"More to come" on engagement with FAA on data and learnings...

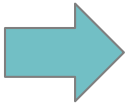
Supersonics

Vertical flight

Subsonics (transports)



Hypersonics



Foundational/convergent technology

Jan. 2020 Commercial Hypersonic Workshop Follow-Up

Continued research focus: Enable Routine, Reusable, Airbreathing Hypersonic Flight

Opportunities/needs from industry included:

- Independent market study
- Regulatory concerns
- International partnerships
- Data protection concerns (export control, classified, CUI, etc.)
- Integration into NAS - CONOPS for hypersonic aircraft integration into NAS
- Hypersonic ground & flight test capability
- Technology development thru collaborative agreements

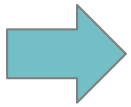
Status: Six different studies underway including two independent market studies.

- Business case that makes development of this vehicle economically viable?
- Market segment? Value of the market? Potential for a fleet?
- Economic sensitivity based on cruise Mach, range, passengers/payload, route (city pairs)?
- Factors most influencing direct operating cost (DOC)?
- Barriers/challenges with potential new market?
- What is the intrinsic value of time (e.g., transpacific in a day) for traveler?
- Enabling technologies? Estimated R&D investment cost?
- Economic benefit for operator (sortie rate) being able to turn two flights in a day?
- Impact to market due to increased telework capabilities/comfort level with collaboration tools?
- Potential certification issues?

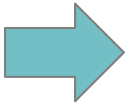
Supersonics

Vertical flight

Subsonics (transports)



Hypersonics



Foundational/convergent technology

NASA Aeronautics Flow of Revolutionary Ideas and Tools

University Leadership Initiative
Diverse Teams Addressing Aviation Challenges

3 rounds of solicitations – ARMD award of $93M:

- 13 awards with 47 universities
- 5 HBCUs and 5 MSIs
- 240 proposals submitted
- 191 different proposing Principal Investigators
- 1631 team members
- 1170 different people
- 20-50 students per team

Other Important Items

- Overall support from key stakeholders is strong
- Have completed several projects – outreach and communications on results will be on-going
  - Advanced Composites
  - UAS in the NAS
  - Airspace Demonstrations
- Have green light for starting new Electrified Powertrain Flight Demonstration (EPFD) Project
- Research centers are working the processes to safely restart key, mission-critical test facilities on-site. Progress is being made.
- NASA Aeronautics leadership changes:
  - Mr. Steve Clarke named Deputy Associate Administrator (was previously Mr. Bob Pearce)
  - Dr. Ron Colantonio selected to lead the Aeroscience Evaluation& Test Capabilities Portfolio
  - Newly defined roles: Mr. Peter Coen, Mission Integration Manager for Low Boom and Mr. Davis Hackenberg as Mission Integration Manager for Advanced Air Mobility

Thank you