Advanced Air Vehicles Program
Opening New Aviation Markets for U.S. Leadership

Jimmy Kenyon
Director, Advanced Air Vehicles Program

September 2019

NASA Aeronautics – Vision for Aviation in the 21st Century

ARMD continues to evolve and execute the Aeronautics Strategy *https://www.nasa.gov/aeroresearch/strategy*

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Transition to Alternative Propulsion and Energy
- Innovation in Commercial Supersonic Aircraft
- In-Time System-Wide Safety Assurance
- Ultra-Efficient Commercial Transports
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

Research Programs Align with Strategic Thrusts

MISSION PROGRAMS

Airspace Operations & Safety

AOSP

Safe, Efficient Growth in Global Operations

In-Time System-Wide Safety Assurance

Advanced Air Vehicles

AAVP

Ultra-Efficient Commercial Vehicles

Innovation in Commercial Supersonic Aircraft

Transition to Alternative Propulsion and Energy

Integrated Aviation Systems

IASP

Flight research-oriented, integrated, system-level R&T that supports all six thrusts

X-planes/ test environment

SEEDLING PROGRAM

Transformative Aeronautical Concepts

TACP

High-risk, leap-frog ideas that support all six thrusts

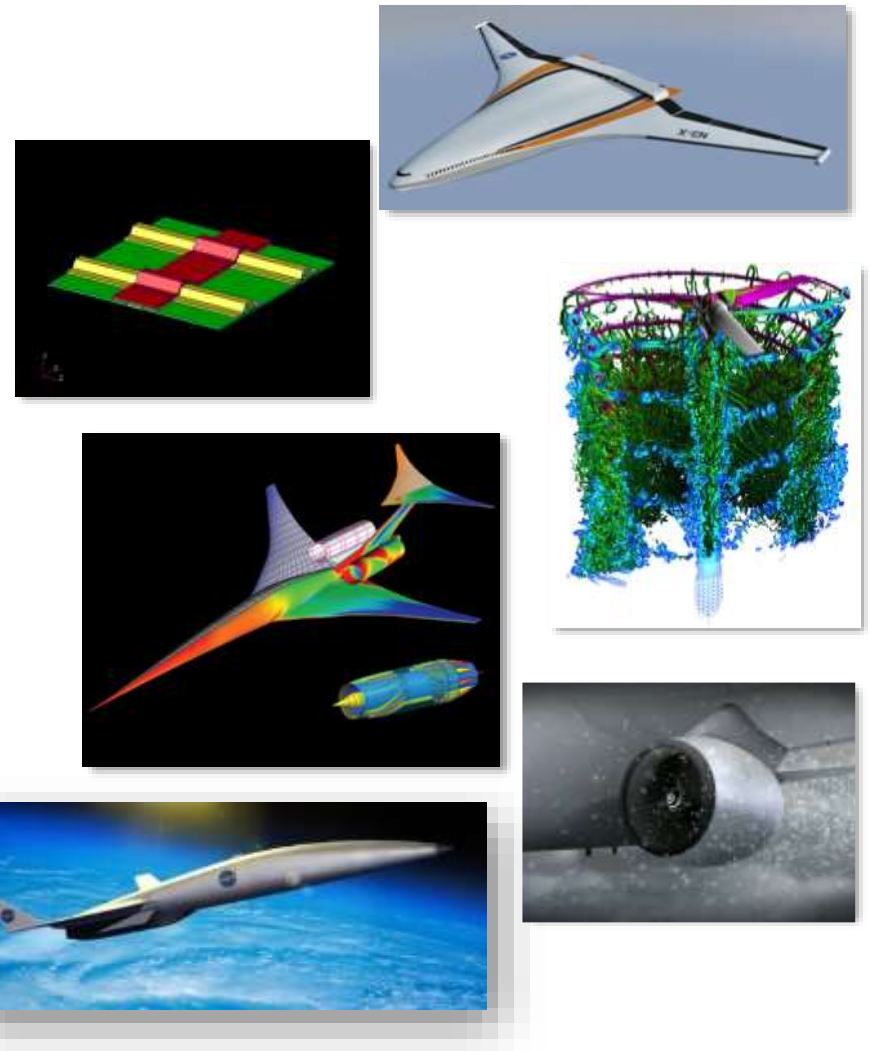
Critical cross-cutting tool development

Assured Autonomy for Aviation Transformation

Advanced Air Vehicles Program

Cutting-edge research that will generate innovative concepts, technologies, capabilities & knowledge to enable revolutionary advances for a wide range of air vehicles.

- ***Advanced Air Transport Technology Project (AATT)*** *Conducts fundamental research to improve aircraft performance & minimize environmental impacts from subsonic air vehicles*
- ***Revolutionary Vertical Lift Technology Project (RVLT)*** *Develops & validates tools, technologies & concepts to overcome key barriers, including noise, efficiency, & safety for vertical lift vehicles*
- ***Advanced Composites Project (AC)*** *Conducts research to reduce the timeline for development & certification of composite structures for aviation [Completing in early FY20]*
- ***Commercial Supersonics Technology Project (CST)*** *Develops tools & explores concepts for potential advanced capabilities & configurations for low boom supersonic aircraft.*
- ***Hypersonic Technology Project (HT)*** *Develops tools & technologies in the area of hypersonic flight*



A New Era of Flight Is Emerging

Opening new aviation markets for U.S. leadership

Electrified Aircraft Propulsion

Urban Air Mobility

Commercial Supersonic Flight

Hypersonic Flight

Potential Benefits of Electrified Aircraft Propulsion

Offer improvements to highly optimized aircraft like single-aisle transports

- Significant fuel burn reduction from alternative architectures & operational schemes
- Complement benefits from improved engine cores & airframe efficiencies

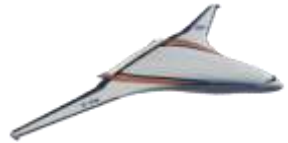
Help open Urban Air Mobility market

- Enable new VTOL configurations to transform transportation & services

Revitalize economic case for small short-range aircraft services

- Combine EAP & higher levels of autonomous operations to reduce operating costs of small aircraft
- Open access to community airports resulting in economically viable regional connectivity

Electrified Aircraft Propulsion – a 60,000 ft Perspective

	UAS	UAM	Small A/C	RJ	Single Aisle	Twin Aisle
Implementation Status	 All electric vehicles in operation	 All electric or hybrid applications being developed		 Potential for hybrid or turbo-electric within 10 years		 Significant progress needed for practical implementation
NASA Role	NASA research not needed	NASA focus on informing standards, regulations & design tools		NASA focus on enabling technologies, demonstrating benefits, addressing safety needs		Still too long term – not yet a NASA focus

Small Vehicle EAP

Energy & cost efficient, short range aviation

Transport Scale EAP

Energy & cost efficient, transport aviation

AATT/RVLT & IASP/X-57

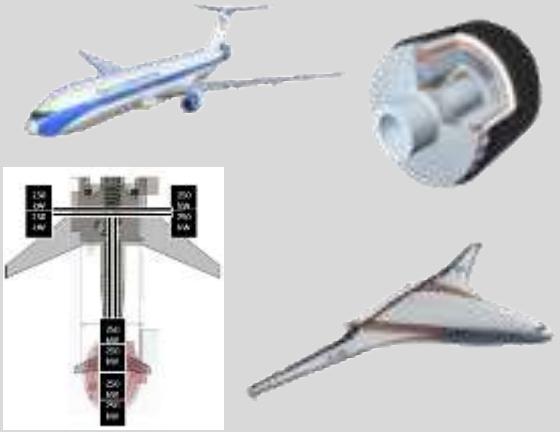
AATT/AAVP & UEST/EAP/IASP

Leverage learning at smaller size to inform scale-up

Fundamental challenges span range of sizes

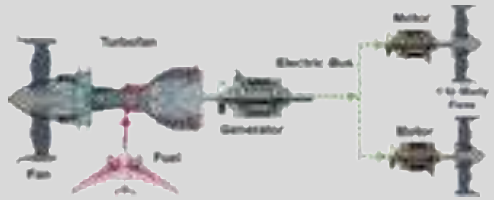
Advancing Technical and Integration Readiness

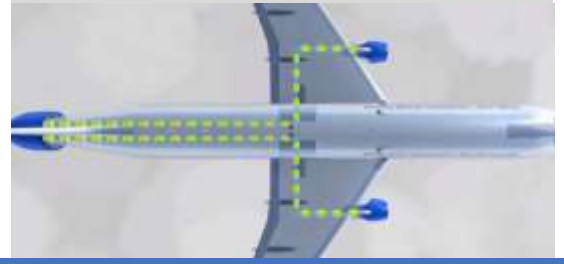
0 Early conceptualization & identification of KPP's/ technology gaps; component advancement; ground test capability gap assessment



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

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





3 Flight Experiments in relevant environment

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

U.S. currently has a lead since we are further in ground testing, but Europeans have already committed funding to progress through flight and could move ahead if we don't act

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

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

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

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

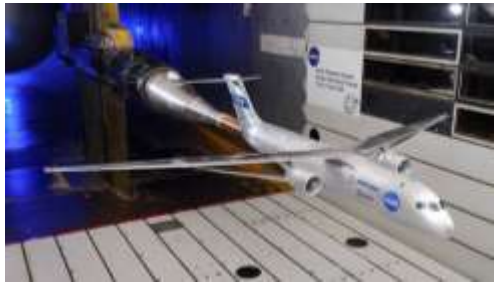
Adjacent Technology Development

Boundary Layer Ingestion

- Complementary to EAP architecture
- BLI fan successfully tested

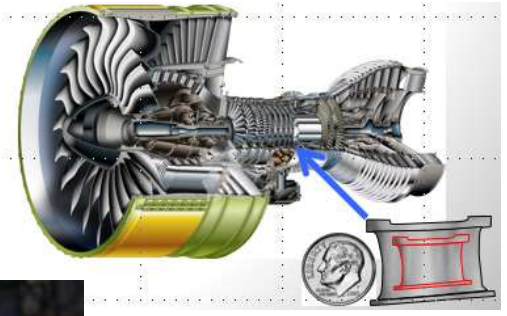
Transonic Truss Braced Wing

- High efficiency configuration relevant for future SA market
- Subscale wind tunnel testing on-going



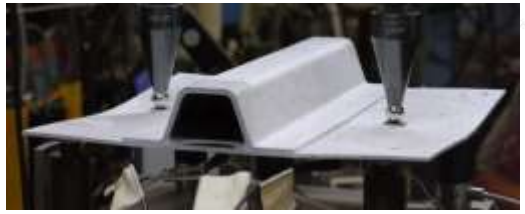
Small Core Engines

- Necessary for effective hybrid- and turbo-electric systems
- Component development underway



High Rate Composite Manufacturing

- Rate needed to enable new EAP-powered configurations
- Leverage ACP outcomes and M&S AoA



Potential to integrate with EAP in multi-tech flight demo

UAM Vision and Framework

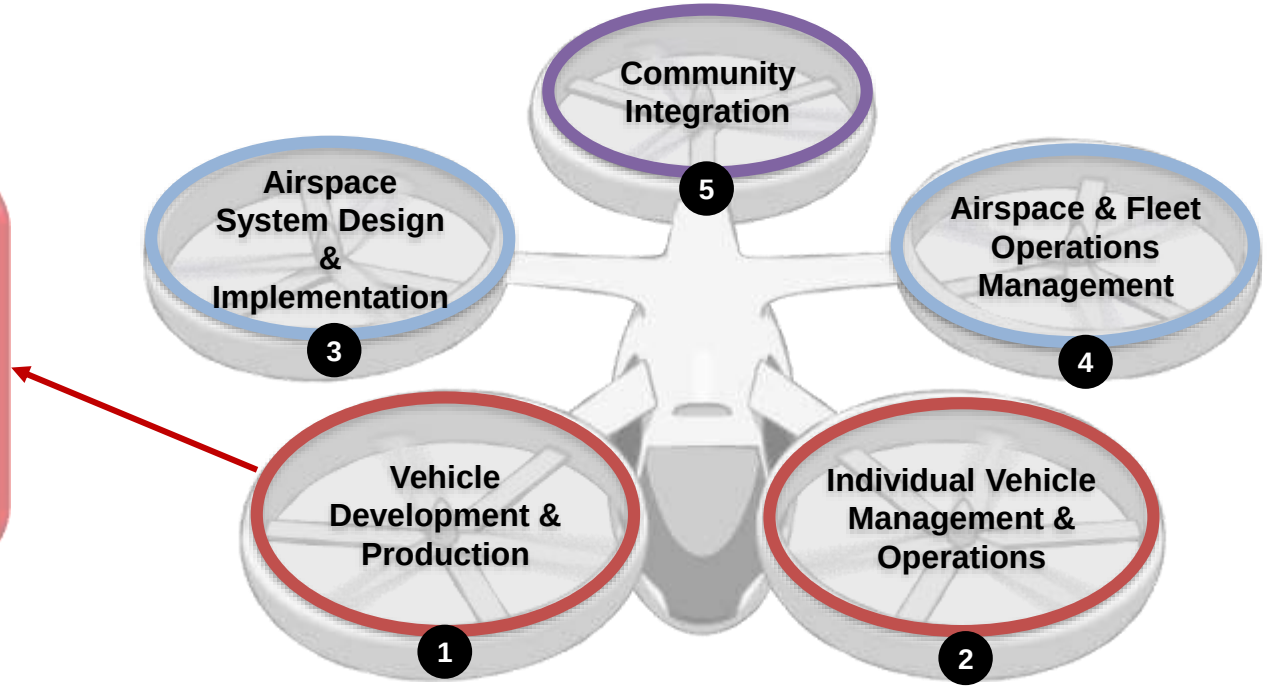
Urban Air Mobility (UAM) Vision

Revolutionize mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo

Focus Areas

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

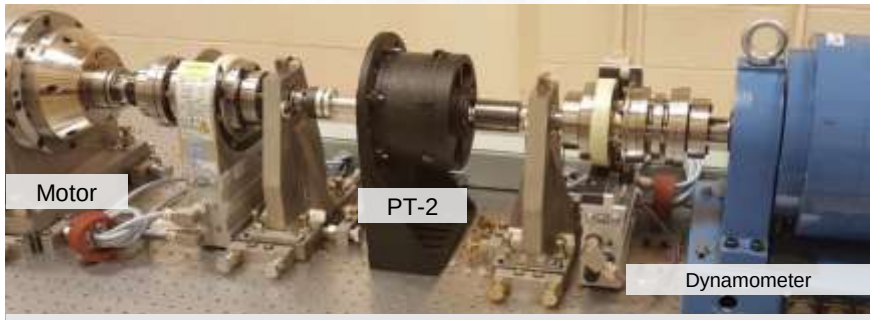
UAM Research Focus

eVTOL Concept Vehicles

- Pervasive technologies to focus work and conduct trade studies
- Widely shared, fully documented

Propulsion

- Design/test standards & validated tools needed to support certification
- Improve electric & hybrid-electric propulsion component reliability



Test setup in the E-Drives Rig at GRC

Community Noise

- Methodology for assessing noise/efficiency tradeoffs
- Assess community noise impact and explore mitigation strategies

Multirotor Test Bed Design

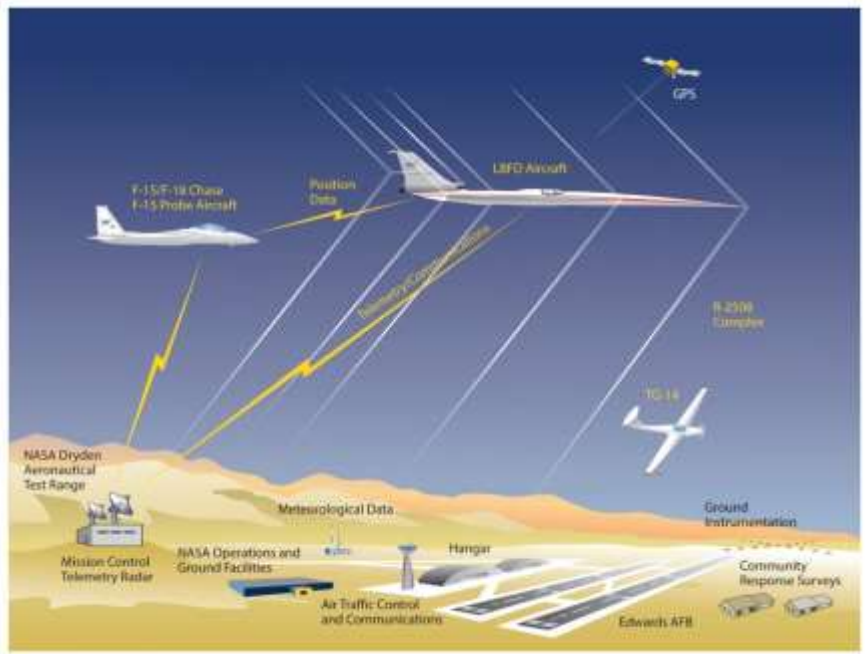
Commercial Supersonic Flight

X-59 Low Boom Flight Demonstrator

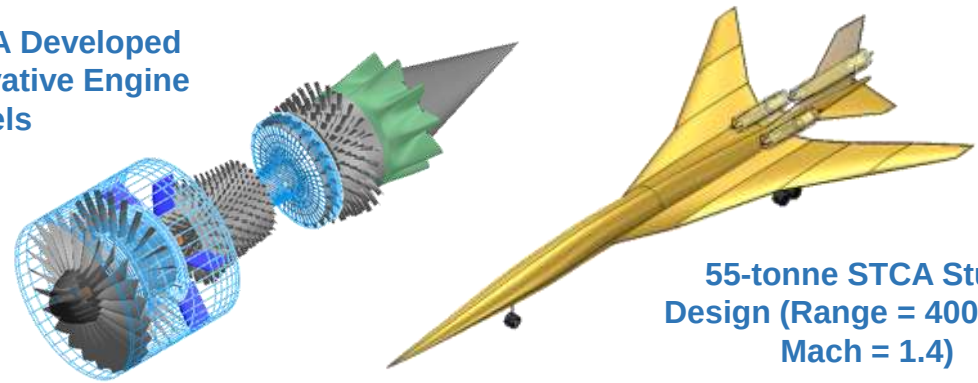
- Aircraft Development – design and fabrication
- Acoustic Validation – measuring and characterizing the ~~boom~~ thump
- Community Response – flight campaigns over representative communities and weather

Next up: LTO Noise and Emissions

- FAA and ICAO engaged in parallel, coordinated processes
- NASA supporting Supersonic Technology Concept Aeroplanes (STCA)
  - Consensus on methods and assumptions
  - Advanced procedures and technology/design trades



NASA Developed Derivative Engine Models



55-tonne STCA Study Design (Range = 4000 nmi, Mach = 1.4)

Overcoming Key Barriers to Supersonic Commercial Flight

NASA Hypersonic Research

Enable routine, reusable, airbreathing hypersonic flight

Emerging vision for future point-to-point transport

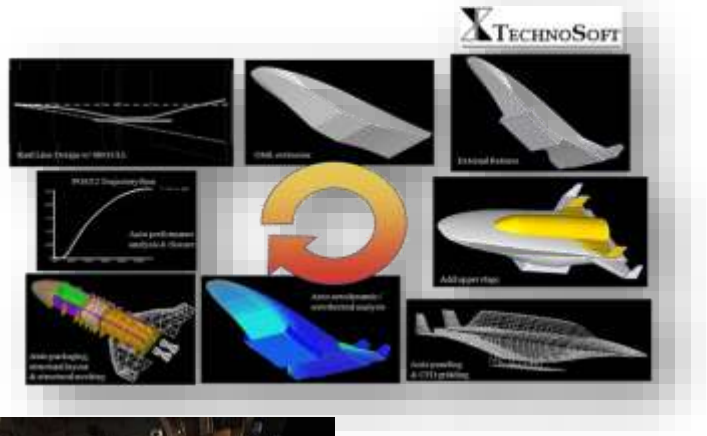
Multiple challenges but propulsion is the tallest pole

- NASA focused on mode transition between a turbine and scramjet
- Creating a design capability, not a point solution
- Recent testing shows a viable path forward

NASA leveraging advances in other communities

- NASA leveraging comprehensive DoD ground and flight tests
- High priority area where industry needs help

Unique NASA testing capability and analysis provides a National resource



Advanced Air Vehicles Program Summary

Breaking down barriers to open new markets, advance U.S. competitiveness, and make air travel better for all Americans and for people around the world

- Highly efficient electrified aircraft – to make air travel cleaner, quieter, and more affordable (AATT)
- Urban air mobility – to allow people to move about major population centers more easily (RVLT)
- Commercial supersonic flight – to make air travel faster (CST)
- Hypersonic flight – to enable a future vision for hypersonic transport (HT)