NASA Update

FAA ASCENT Fall Meeting
October 22, 2019

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

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

U.S. leadership for a new era of flight

NASA Aeronautics Research Programs

Aligned with Strategic Thrusts

MISSION PROGRAMS

Airspace Operations & Safety

AOSP

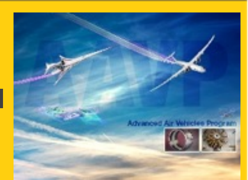
Safe, Efficient Growth in Global Operations

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

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..

Beginning in FY 2020, Aeronautics budget no longer includes the Aeronautics Evaluation and Test Capabilities (AETC) portfolio of approximately $56M. AETC was transferred to the Mission Support Directorate as Agency-level function.

supersonics

value via speed at cruise

vertical flight

value through accessibility

subsonics (transports)

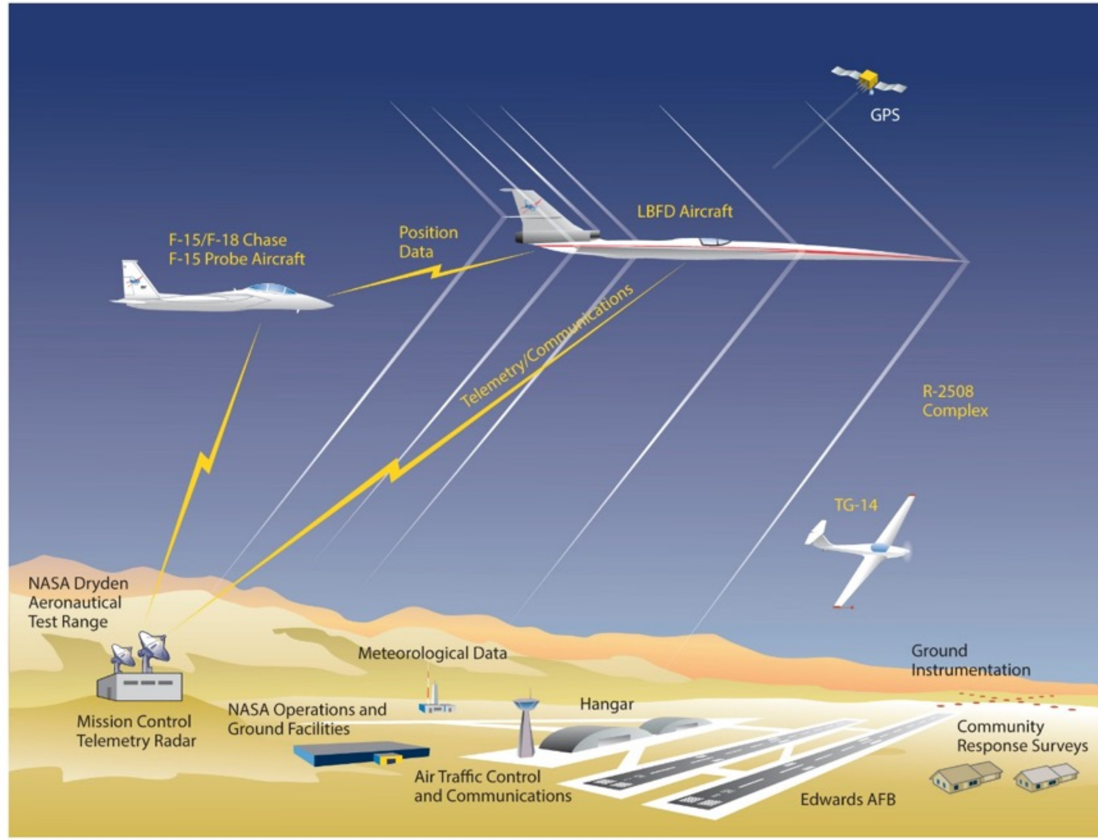
the 24/7 global backbone of air transportation
now and into the foreseeable future

Low-Boom Flight Demonstration Phases

Phase 1 - Aircraft Development
- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Envelope Expansion

Phase 2 – Acoustic Validation
- Measuring and characterizing the sonic ~~boom~~ thump

Phase 3 – Community Response
- Initial community response overflight study
- Multiple campaigns over representative communities and weather across the U.S.



Overcoming the Barrier to Supersonic Overland Flight

Low-Boom Flight Demonstrator (LBFD) Project

Phase 1 – Aircraft Development

- Awarded design and build contract to Lockheed Martin
- Completed "Key Decision Point" major review to baseline project
- Initial fabrication underway
- Critical Design Review - September 9-13, 2019
- First Flight commitment is January 2022... planning to fly in FY 2021

Low-Boom Flight Demonstration Mission

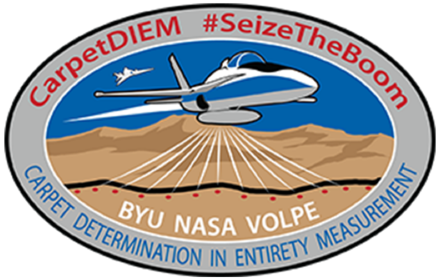
Phase 2 & 3 Related Activities

Community Test Risk Reduction – Quiet Supersonic Flights 2018 (QSF18)

- Initial data review complete, contractor report delivered and in preparation for release

Acoustic Validation Test Risk Reduction

- Carpet Determination In Entirety Measurements (CarpetDIEM)
  - Developmental test for measurement of wide sonic footprint of X-59
  - 25 n.mi wide microphone array (one half of full carpet)
  - Focus on land access and array deployment, microphone triggering
  - Second test planned for Summer 2020



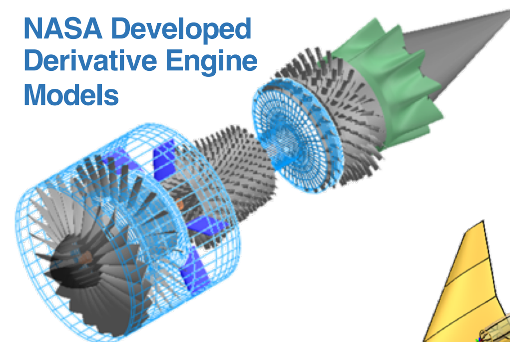
Community Test Methods Virtual Workshop

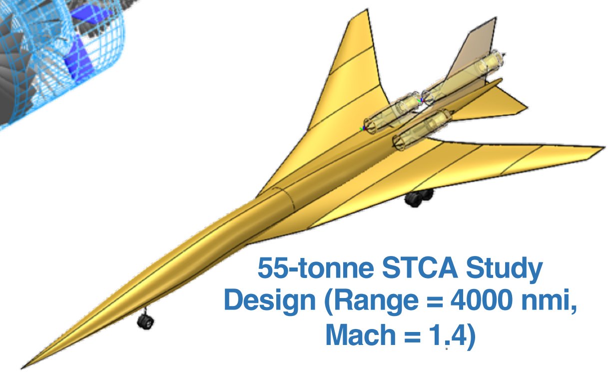
- Engage international research community in X-59 test preparation
- Present NASA approach and lessons learned for community testing during QSF18
- Follow on Face-to-Face Workshop planned for Fall 2020

Near-term efforts: ICAO/FAA Technical Support Landing/Takeoff Noise and Emissions Procedures for Supersonic Transports

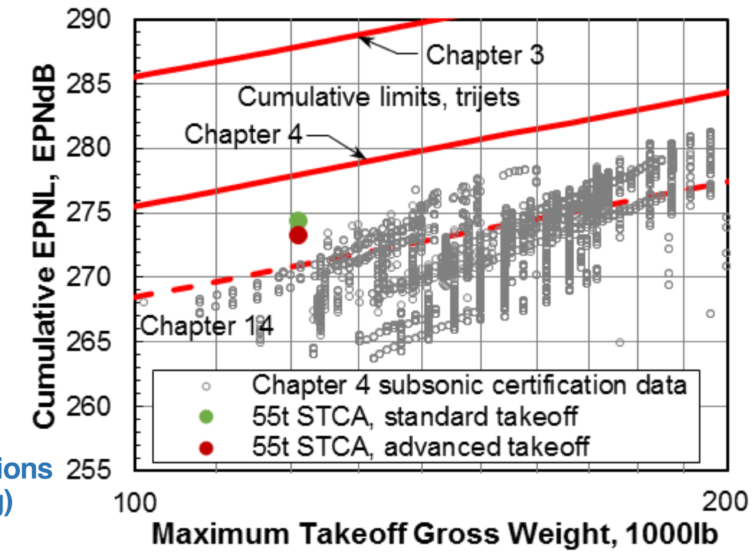
- Emergence of near-term market entrants has spurred a need for certification standards
- FAA and ICAO are engaged in parallel, coordinated processes
- In addition to company data, both organizations need independent analysis and trade study data to inform the standards process
- NASA is supporting this effort with the development of Supersonic Technology Concept Aeroplanes (STCA)
  - Effort is coordinated with Industry for consensus on methods and assumptions
  - Scope includes assessment of advanced procedures and technology/design trades
- NASA effort also includes targeted testing and analysis to reduce uncertainty in noise models
- **2020 AIAA SciTech Special Session "Community Noise Impact from Supersonic Transports"; this will be the public release of NASA's STCA design study, done for ICAO**

NASA Developed Derivative Engine Models





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



55t STCA EPNL Predictions (With Wing Shielding)

supersonics

value via speed at cruise

vertical flight

value through accessibility

subsonics (transports)

the 24/7 global backbone of air transportation now and into the foreseeable future

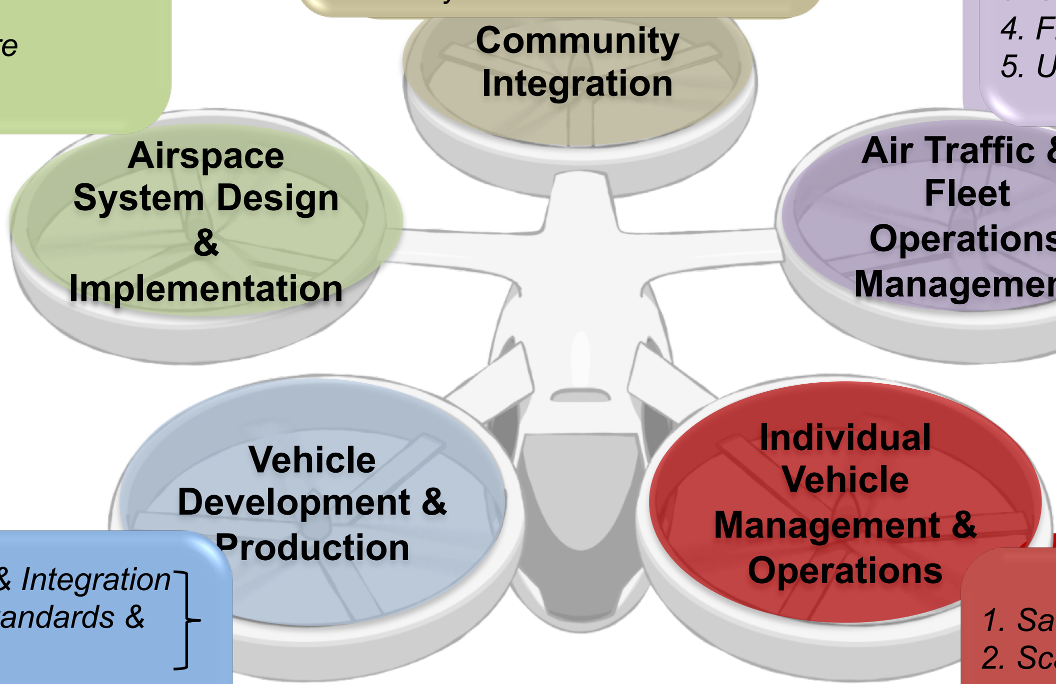
NASA UAM Vision, Framework, Barriers

Policy, Certification, and Technical Challenges for Operating in the NAS

1. Airspace Design
2. Operational Rules, Roles, & Procedures
3. CNS & Control Facility/Infrastructure
4. UAM Port Design

1. Public Acceptance
2. Supporting Infrastructure
3. Operational Integration
4. Local Regulatory Environment & Liability

1. Safe ATM Ops
2. Efficient ATM Ops
3. Scalable ATM Ops
4. Fleet Management
5. Urban Weather Prediction



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

1. Safe Urban Flight Management
2. Scalable Vehicle Ops
3. Certification & Ops Approval
4. Ground Ops & Maintenance

Urban Air Mobility (UAM) Vision

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

← "Development"

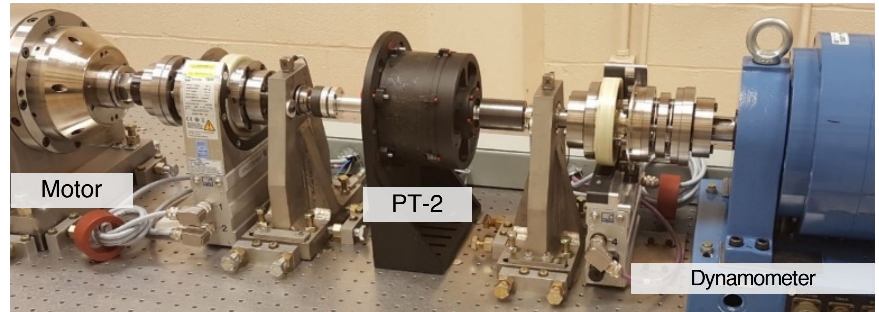
"Operations" →

UAM VTOL Vehicle – Propulsion and Noise

Propulsion barrier

Safe, reliable, low maintenance operations needed

- new electric propulsion architectures do not have proven in-flight experience
- thermal management will significantly impact the safety, reliability, life, and weight of the system
- need to inform design/test standards & have validated tools to support certification.



Test setup in the E-Drives Rig at GRC

What are we trying to do?

Develop design/test guidelines, acquire data, explore new concepts - to improve propulsion component reliability by several orders of magnitude over SOA technology for UAM electric & hybrid-electric VTOL vehicles.

Noise barrier

Noise likely a barrier to public acceptance of multi-rotor aircraft

- a validated/documented methodology for assessing noise/ efficiency tradeoffs needed
- will enable government & vehicle developers to assess vehicle noise impact on the community, explore feasible mitigation strategies for the different vehicles, or assess the performance reductions that are required to design a low-noise UAM vehicle.

Multirotor Test Bed Design

What are we trying to do?

Develop, demonstrate, validate, document a set of conceptual design tools capable of assessing the tradeoffs between UAM vehicle noise and efficiency.

UAM Reference Vehicle

The UAM "Grand Challenge" Series

- Challenging the industry to execute ecosystem-wide systems level safety and integration scenarios
- Raises the water level for all
- Builds knowledge base for requirements/standards
- No purse or prize money

Support requirements & system development for scalable, commercial UAM through integrated demonstrations of realistic safety/operational scenarios

Announcement of Opportunity posted to FedBizOpps on Oct. 10, 2019.

supersonics

value via speed at cruise

vertical flight

value through accessibility

subsonics (transports)

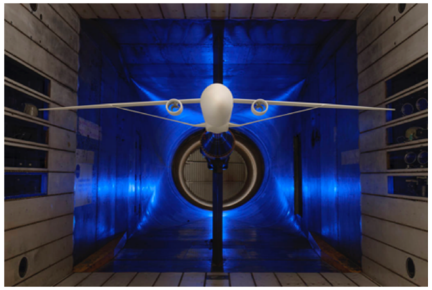
the 24/7 global backbone of air transportation now and into the foreseeable future

Subsonic Transport Technology Development

Suite of five Key Technologies coupled into transformative configurations will have a tremendous impact:

- Ultra-efficient wing
- Unconventional structure
- Novel propulsion airframe integration
- Electrified aircraft propulsion
- Small core gas turbine propulsion

ARMD is advancing these key technologies to create market opportunities



Very High Aspect Ratio Wing

Boundary Layer Ingestion

Electrified Aircraft Propulsion

Electrified Aircraft Propulsion – a 60,000 ft Perspective

(a range of vehicles and range of needs)

POTENTIAL IMPACT

Enable UAM market | **Help revitalize small, short-range aircraft** | **Enable alternative architectures**

	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

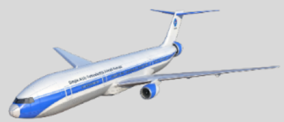
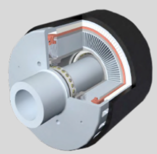
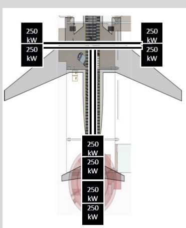
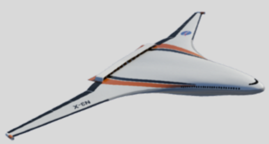
Energy & cost efficient, transport aviation

Leverage learning at smaller size to inform scale-up

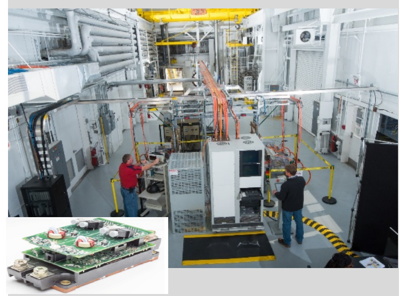
Fundamental challenges span range of sizes

Transport-Class
Advancing Technical & Integration Readiness

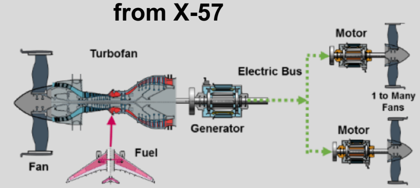
0 **Early conceptualization & identification of KPP's/ technology gaps; component advancement; ground test capability gap assessment**

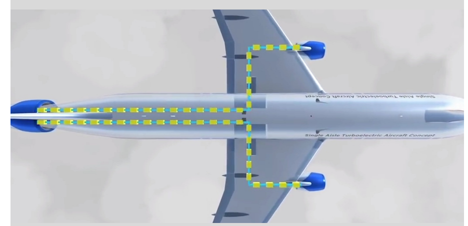





1 **Ground testing of Key electrical components (work is ongoing but must accelerate)**

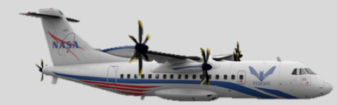


2 **Integrate in a flight system (likely existing airframe) – leveraging experience from X-57**





3 **Flight Experiments in relevant environment**



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

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

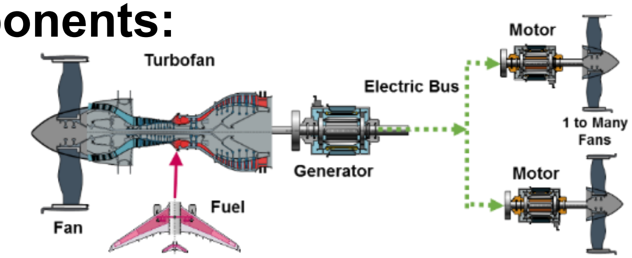
2016-2018+
TRL ~3
NASA in-house & industry efforts raise the TRL level of motors and inverters

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.

Multiple Aspects to Electrified Aviation Propulsion

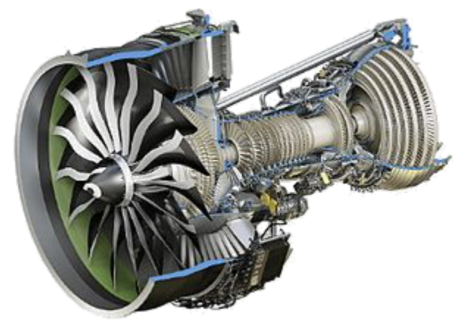
EAP encompasses more than just electrical components:

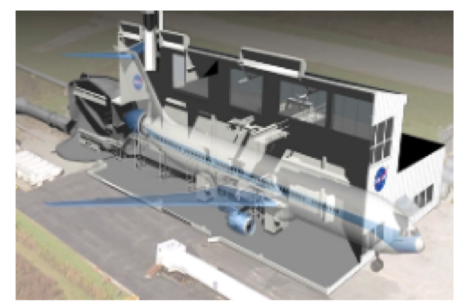


Electrical generation, storage and distribution
- Electrical power components (e.g. inverters, motors, generators & systems)
- Power storage
- Power extraction
- System architectures

Coupled turbine systems
- Small core turbomachinery
- New material systems

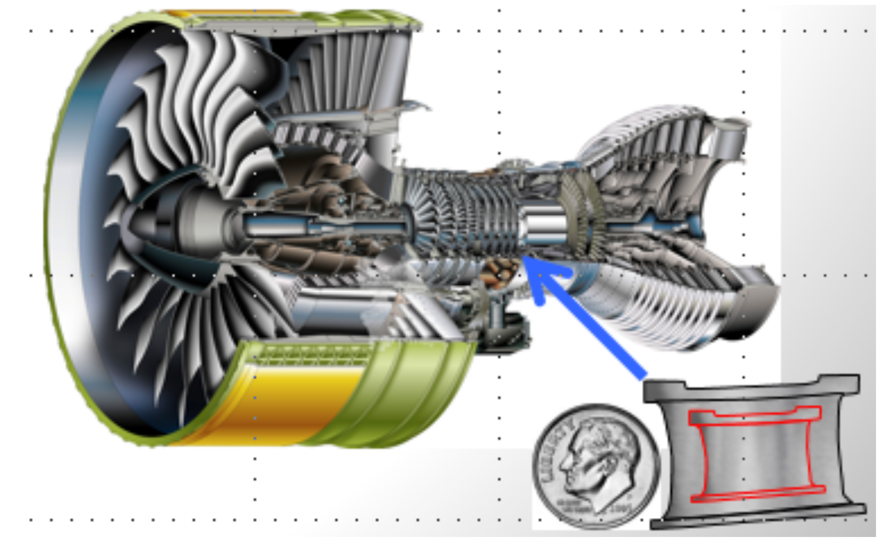
System benefits
- Novel propulsion airframe integration
- Systems analysis tools
- Test capabilities



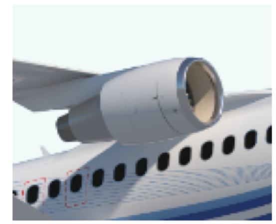


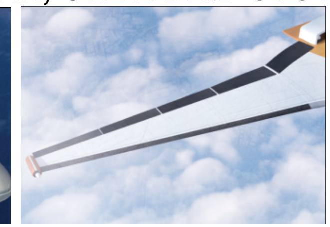
Electrified Aircraft Propulsion (EAP) – the suite of technologies and capabilities that will enable air vehicles to leverage benefits of electricity in their propulsion systems.

Small Core Gas Turbine Propulsion



APPLIES TO DUCTED FAN, OPEN FAN, OR HYBRID SYSTEM





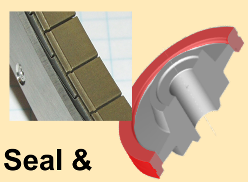
LOW NOx COMBUSTOR

NASA CE-5 Combustor Sector test:

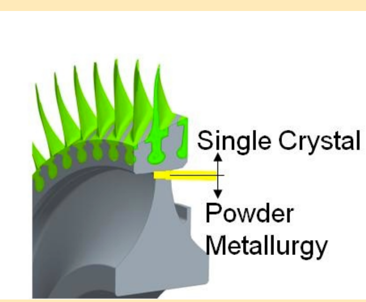
- *Single-cup sector; 265 psia, 1150 F inlet to rig*
- *Alternative-fuel blending at rig*

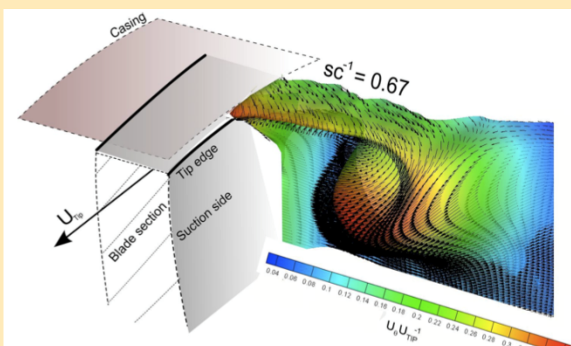
Demonstrated low-emission fuel-flexible combustor concept for emission reduction to 80% below CAEP6 at TRL 3 – combustor concept, design approach, test & analysis results. Preferred concept recommended for higher fidelity research

HIGH EFFICIENCY COMPRESSOR



1500F Seal & Hybrid Disk





Wu et al. Exp. Fluids, 2010, 1011
Miorini et al., J. Turbomachinery 2012, AIAA Journal 2012

Tip/Endwall Aerodynamic Loss Mitigation

Advanced casing treatments can improve compressor stall margin by +10%. Gain can be traded for efficiency improvement. Significance: Improve small core engine compressor efficiency contribute to overall fuel burn reduction.

Other Important Items

- Overall strong support from key stakeholders
- On the verge of completing several projects – outreach and communications on results is on-going
  - Advanced Composites
  - UAS in the NAS
  - Airspace Demonstrations
- Continued support for our larger testing facilities at the Agency level
- NASA Aeronautics leadership changes:
  - Dr. Jaiwon Shin – retirement (Aug. 2019)
  - Mr. Bob Pearce named Acting Associate Administrator (Sep. 2019)
  - Dr. Jimmy Kenyon selected as Program Director, Advanced Air Vehicles Program (July 2019)

Thank you