



NASA Aeronautics Research

Dr. Azlin Biaggi
Manager, Foundational Electrified Aircraft
Propulsion (FEAP) Sub-Project

Event: Presentation to Students
Location: University of Puerto Rico – Mayaguez Campus
Date: April 27, 2023



NASA Aeronautics is One of Five Mission Directorates



Aeronautics



NASA explores technologies that reduce aircraft noise and fuel use, get you gate-to-gate safely and on time, and transform aviation into an economic engine at all altitudes.

Space Technology



NASA technologies developed for spaceflight benefit our everyday life. The Artemis program proves and matures what those technologies can do and reduces risk for exploration of Mars and beyond.

Science



NASA and the nation's science community use space observatories conduct scientific studies of the Earth from space to visit and return samples from other bodies in the solar system, and to peer out into our galaxy and beyond.

Exploration Systems Development



NASA's Artemis program is defining and creating the steps path from Earth back to the Moon and on to Mars, including the Orion capsule, the Space Launch System, Exploration Ground Systems, the Gateway, and Human Landing System.

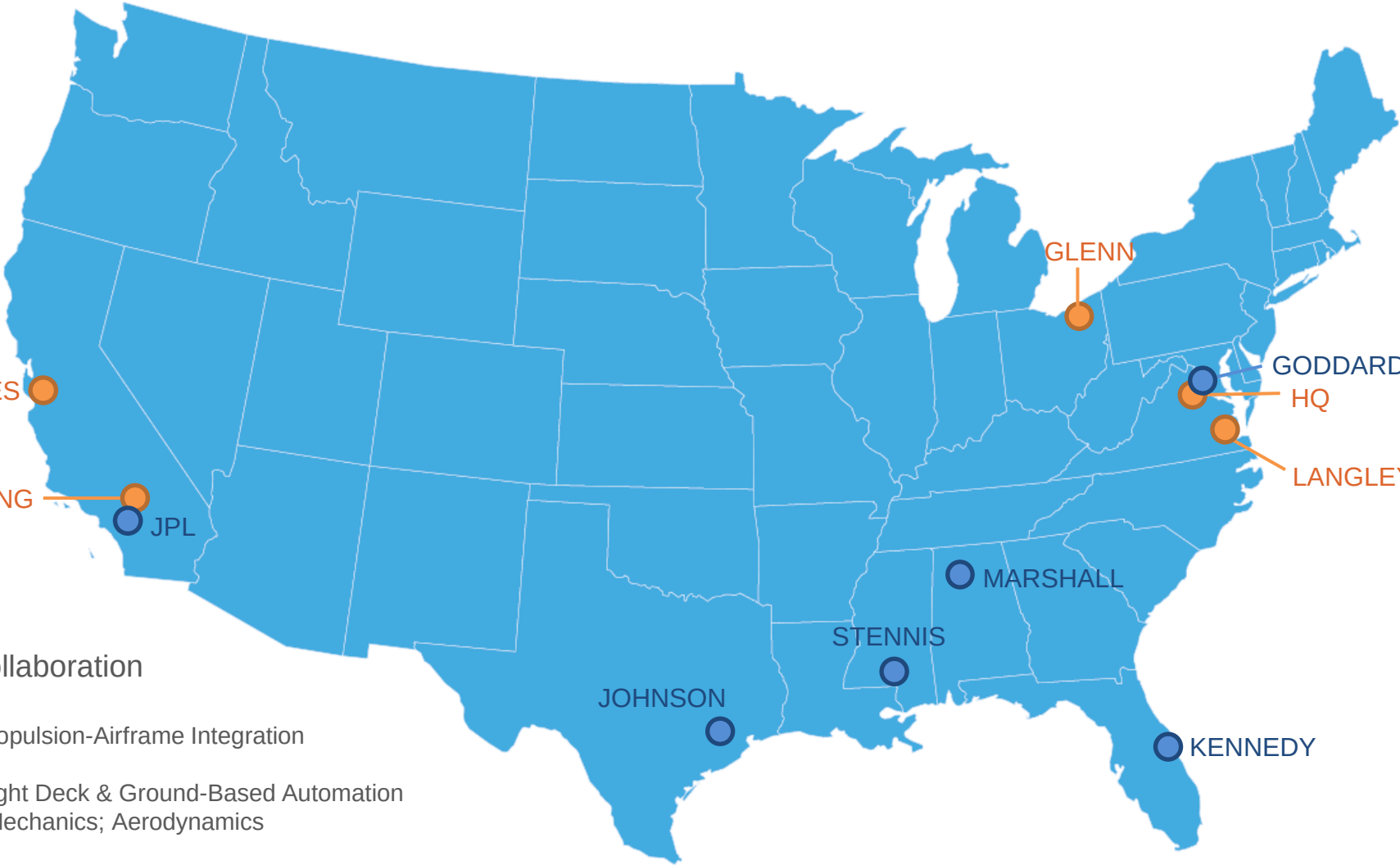
Space Operations



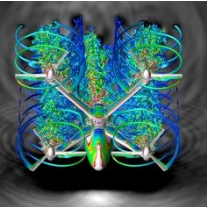
NASA's work in beyond low-Earth orbit includes commercial launch services to the International Space Station, exploration systems, space transportation systems, and broad scientific research on orbit.

Where Does NASA Aeronautics Research Happen?

Aeronautics research takes place at four of NASA's centers.



AMES



ATM Research and Technology & Integration

ARMSTRONG



Flight Research

GLENN



Propulsion Research and Technology

LANGLEY



Vehicle Research and Technology

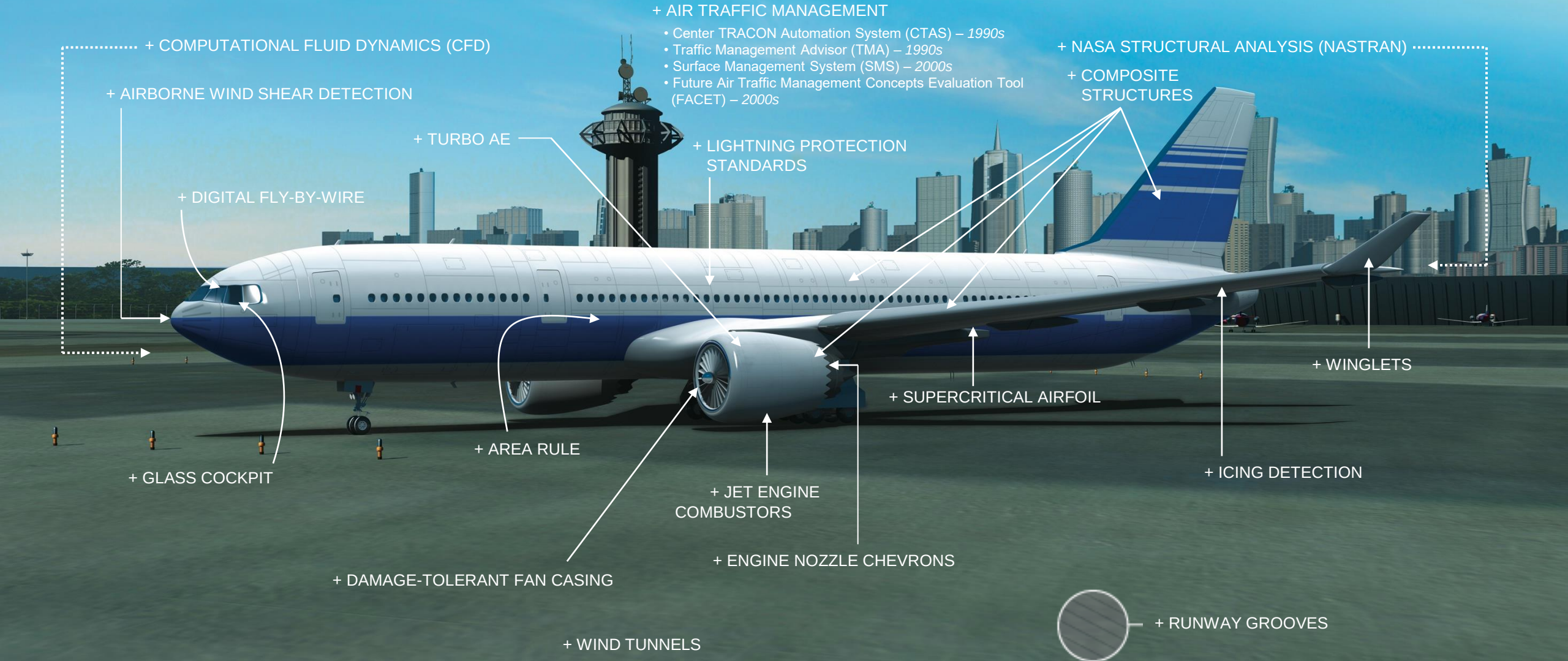
Major Areas of Inter-Center Collaboration

- Langley/Glenn:** Propulsion-Airframe Integration
- Ames/Langley:** Flight Deck & Ground-Based Automation Integration; Flight Mechanics; Aerodynamics
- Armstrong/Other Research Centers:** Flight Experiment Integration

NASA has Made Decades of Contributions to Aviation



NASA-developed technology is on board every U.S. commercial aircraft and control tower.



Airspace Operations and Safety Program



Advanced Air Vehicles Program



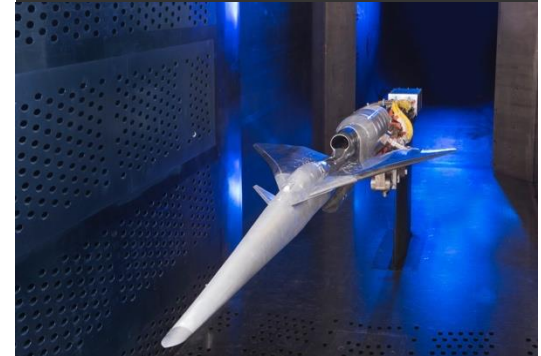
Integrated Aviation Systems Program



Transformative Aeronautics Concepts Program



Aerosciences Evaluation and Test Capabilities Portfolio



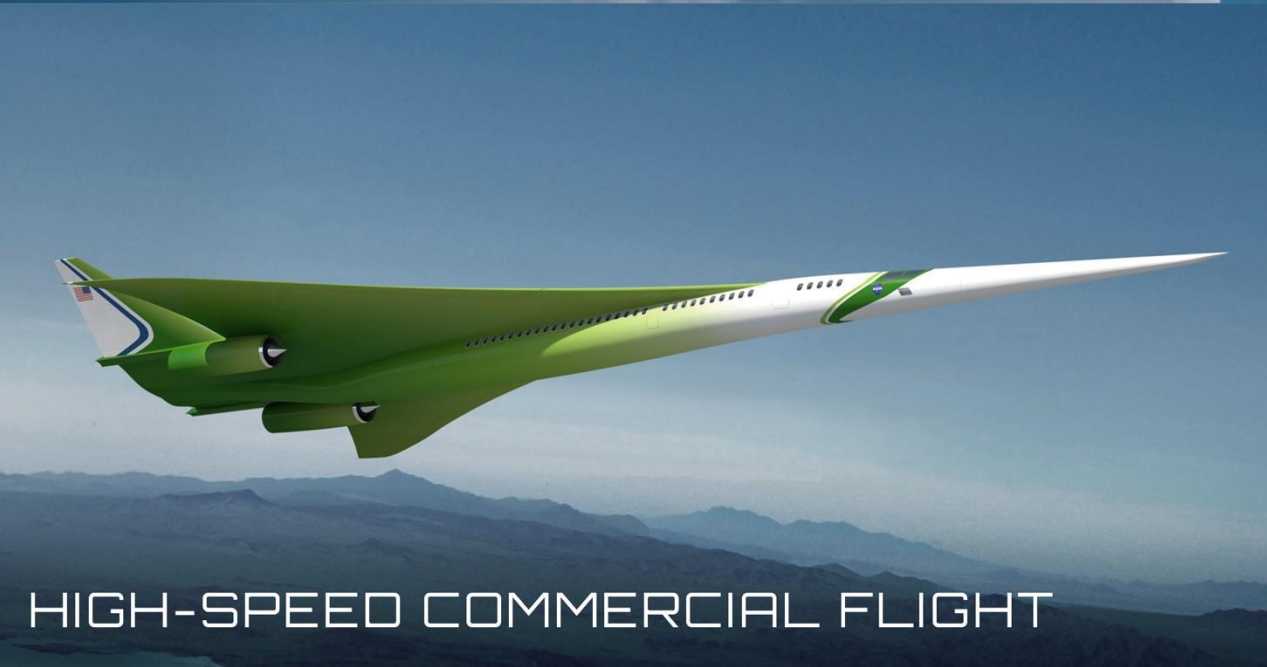
ARMD PROGRAMS



ULTRA-EFFICIENT TRANSPORT



FUTURE AIRSPACE



HIGH-SPEED COMMERCIAL FLIGHT



ADVANCED AIR MOBILITY

Aviation Pillars for a Sustainable Future

Global Aviation GOAL: net-zero carbon emissions by 2050



TECHNOLOGY



NASA = Primary Role

SUSTAINABLE
AVIATION FUEL



NASA = Supporting Role

OPERATIONS
AND INFRASTRUCTURE

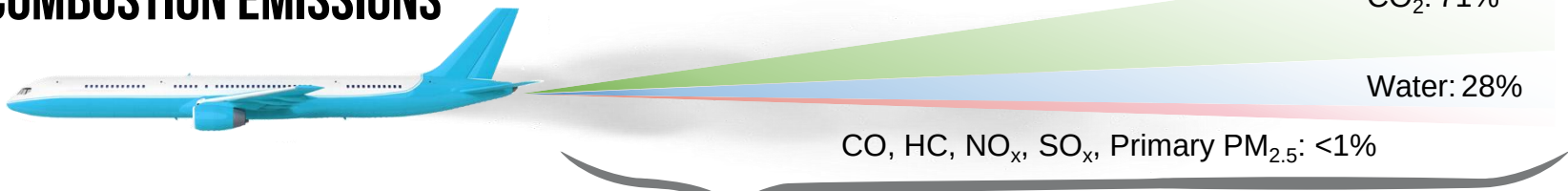


NASA = Primary Role

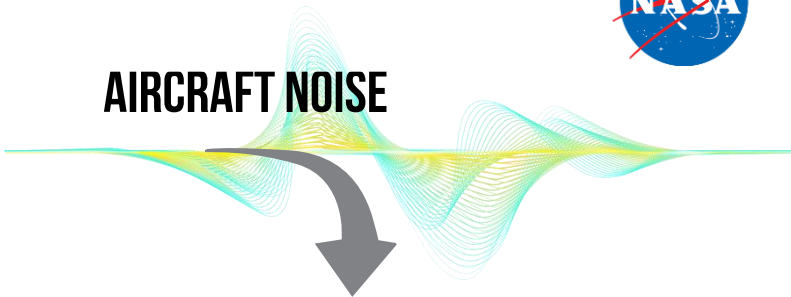
Environmental Impacts of Aviation



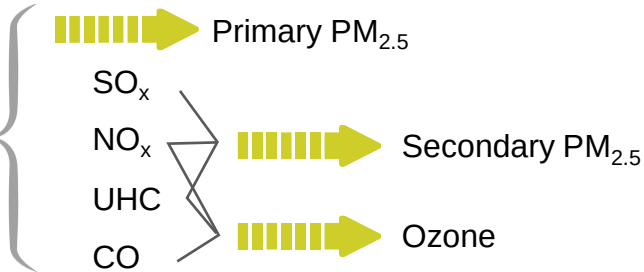
COMBUSTION EMISSIONS



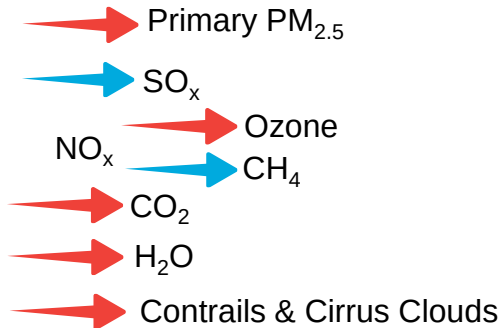
AIRCRAFT NOISE



ATMOSPHERIC CHEMISTRY & PHYSICS



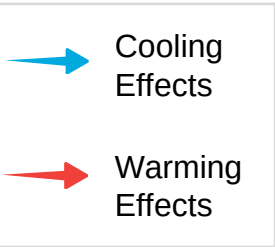
POPULATION
EXPOSURE
AND HEALTH
IMPACTS



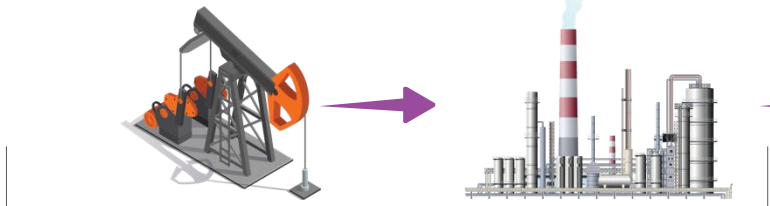
GLOBAL CLIMATE CHANGE



OZONE LAYER



EMISSIONS FROM FUEL PRODUCTION



CH₄, N₂O, CO₂

SUSTAINABILITY IMPACTS

Sustainable Flight National Partnership

Next-Generation Capability on the Path to Net-Zero Greenhouse Gas Emissions by 2050



Advance engine
efficiency and
emission reduction

Enable integrated
trajectory optimization



Advance airframe
efficiency and
manufacturing rate

Enable use of 100%
sustainable aviation fuels

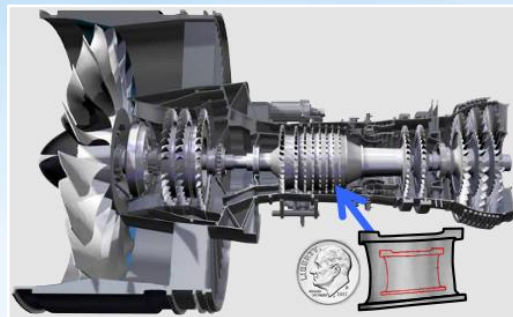
Accelerate toward net-zero greenhouse gas emissions by 2050 through 25-30% energy efficiency improvements in next-generation transports, 100% sustainable aviation fuel, and optimal trajectories.

Subsonic Transport Technologies

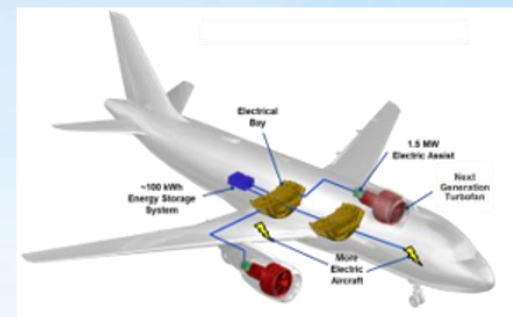
Ensure U.S. industry is the first to establish the new “S Curve” for the next 50 years of transports



Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit



Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit



High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Planning to Achieve a Sky for All

Imagining tomorrow's aviation system today



Sustainable Solutions

Seamless Skies



Ubiquitous and Resilient Operations

Operator Optimization



Learning-Based Systems and Communities

- NASA-led effort to gather inputs from the aerospace community and FAA
- Co-developed vision of a mid-21st century shared airspace that is agile, scalable, optimizable, increasingly diverse, and equitable
- Evolution from trajectory-based operations to collaborative and highly automated operations
- Sky for All results will inform ARMD research and development portfolio and collaboration with FAA

SKY^{for}ALL

High-Speed Commercial Flight

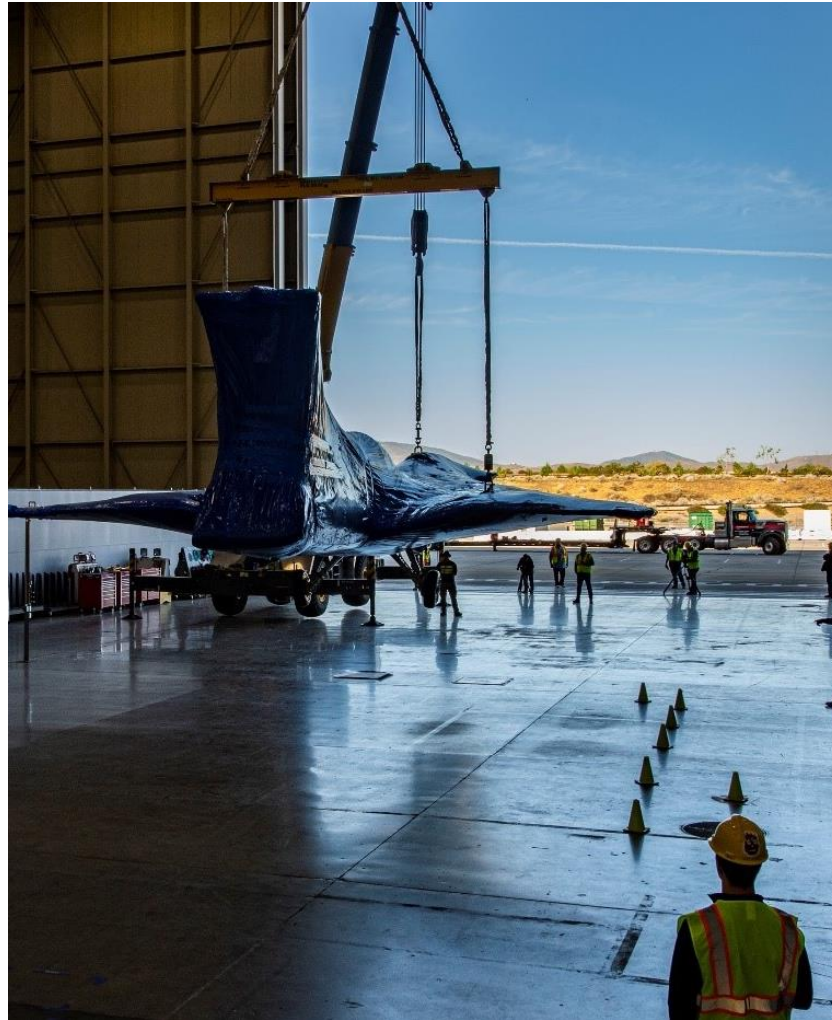
Sustainable transformation of the speed of air travel



Addressing the unique barriers to sustainable, environmentally responsible high-speed flight

The Quesst Mission generates key data to support development of en route certification standards based on acceptable sound levels

X-59 Construction and Testing



Complete X-59 Build in Fall 2022
Achieve First Flight in 2023

Advanced Air Mobility Missions are Emerging



CARGO
TRANSPORT



PUBLIC GOOD



CONSUMER/
ENTERPRISE
GOODS AND
SERVICES



PASSENGER
TRANSPORT



NASA's X-57 is Pathfinder for Electric Propulsion

First flight is early 2023



Enable new configurations



Ground and flight validation of electric motors, battery, and instrumentation

Share technical insights and lessons learned



LEAPTech experiment



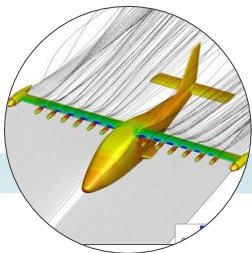
Wind-tunnel validation



Motor nacelle design & testing



Structural testing



Computational simulations



Operational checkouts

Inform Small Electric Aircraft Propulsion Standards and Certification

University Leadership Initiative (ULI) Engaging the University Community



5 rounds of solicitations
\$157M of awards

Seeking and awarding proposals
addressing all strategic thrusts
and special topics

- 23 awards with 64 universities
- 7 HBCUs and 10 other MSIs
- 406 proposals submitted
- 280 different proposing Principal Investigators
- 3189 team members
- 20–50 students per team

In ULI, the universities take the lead, build their own teams, and set their own research path.



T³ Project Overview



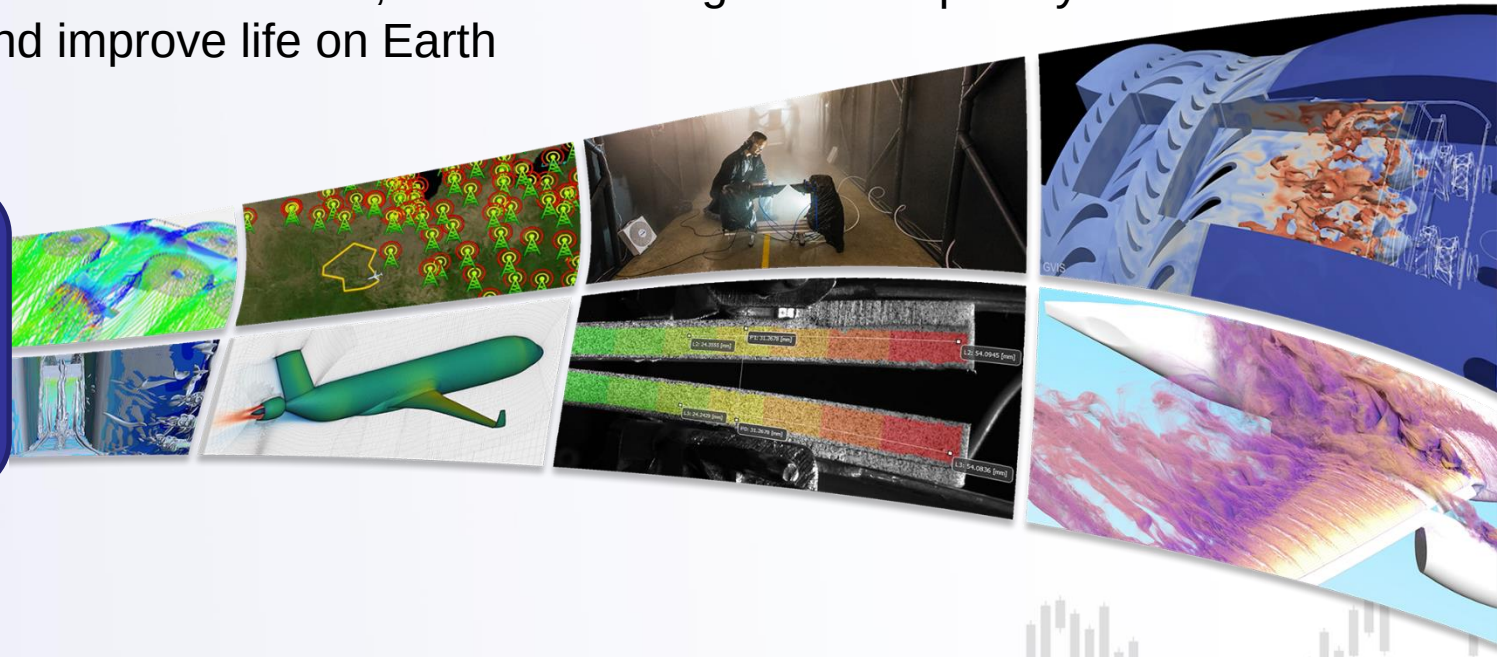
Transformational Tools & Technologies (T³) Project



Explores the unknown through foundational research that inspires innovation in aeronautics, delivering revolutionary advances in essential areas such as autonomy, certification by analysis, advanced materials, and sustainable aviation

- Conducts exploratory research with breakthrough potential to inspire the world through discovery
- Enables fast, efficient design and analysis of advanced aviation systems from first principles
- Develops innovative tools and technologies to revolutionize air transportation
- Sustains critical aeronautics core competencies for the nation, while delivering multidisciplinary system-level results that benefit humanity and improve life on Earth

Delivering cutting-edge research, leading community vision studies, and providing the community with valuable data and innovations that impact aeronautics research throughout the ARMD portfolio



T³ By The Numbers

**8 Enduring
Disciplines**



**9 PATENTS/
LICENSE**

**4 NASA
Centers**



**253
Publications**



**11 MISSION PROJECTS
SUPPORTED**

3 Sub-projects



37 AWARDS



\$62M BUDGET



**Over 90
Partnerships**



**187
FTEs**



284 Presentations

Continually Considering New Content & Fostering Innovation



T³ focuses on transformational cross-cutting foundational research

Vision Studies



AoA Studies



T³ supports all six ARMD Thrusts

Selection Criteria

- Foundational & Cross-cutting
- Potential Impact
- Supports Mission Projects
- Stakeholder Buy-in
- Transformational & Innovative
- Resource Constraints
- Center/Competency balance
- Labor/Procurement balance

Portfolio

Measures & Metrics

**TACP
Performance
Metrics**

**ARMD
Alignment**

Transformation

**Culture of
Innovation**

Agility

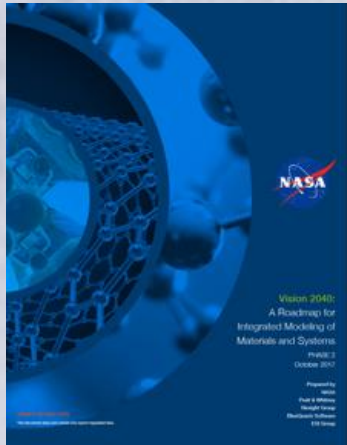
ARMD Strategic Portfolio
Management Review

Technical Community
(workshops, conferences, etc.)

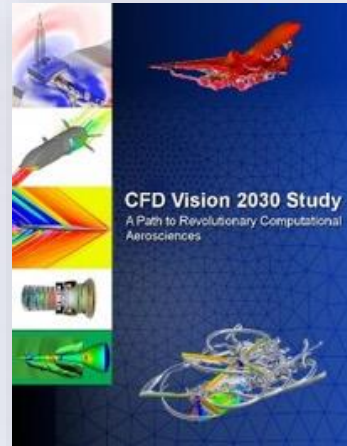
Encourage injection of new ideas, techniques, and approaches

T³

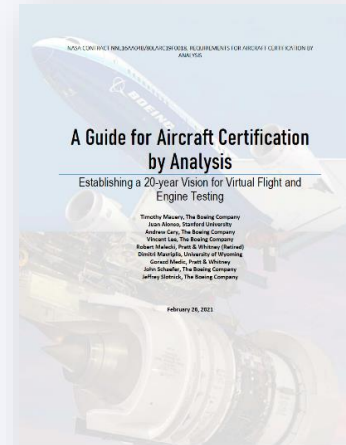
Community Visions and Analysis of Alternatives (AoA) Studies informing T³ activities



M&S 2040 - A Roadmap for Integrated, Multiscale Modeling & Simulation of Materials & Systems



CFD2030 – CFD Vision 2030 Study



A Guide for Aircraft Certification by Analysis – A 2040 Vision



AoA Study for Subsonic Transport Acoustics, Combustion/Emissions & Icing

Reports generate prioritized list of proposed high-value research appropriate for NASA with input from industry, academia, and OGAs in multiple sectors

Autonomy Verification & Validation Roadmap and Vision 2045

- Jointly funded with AOSP / SWS Project
- PI is Boeing lead for AI/Autonomy V&V technologies
- Technical Advisors from FAA, AFRL, NRL
- Draft final report submitted January 2023

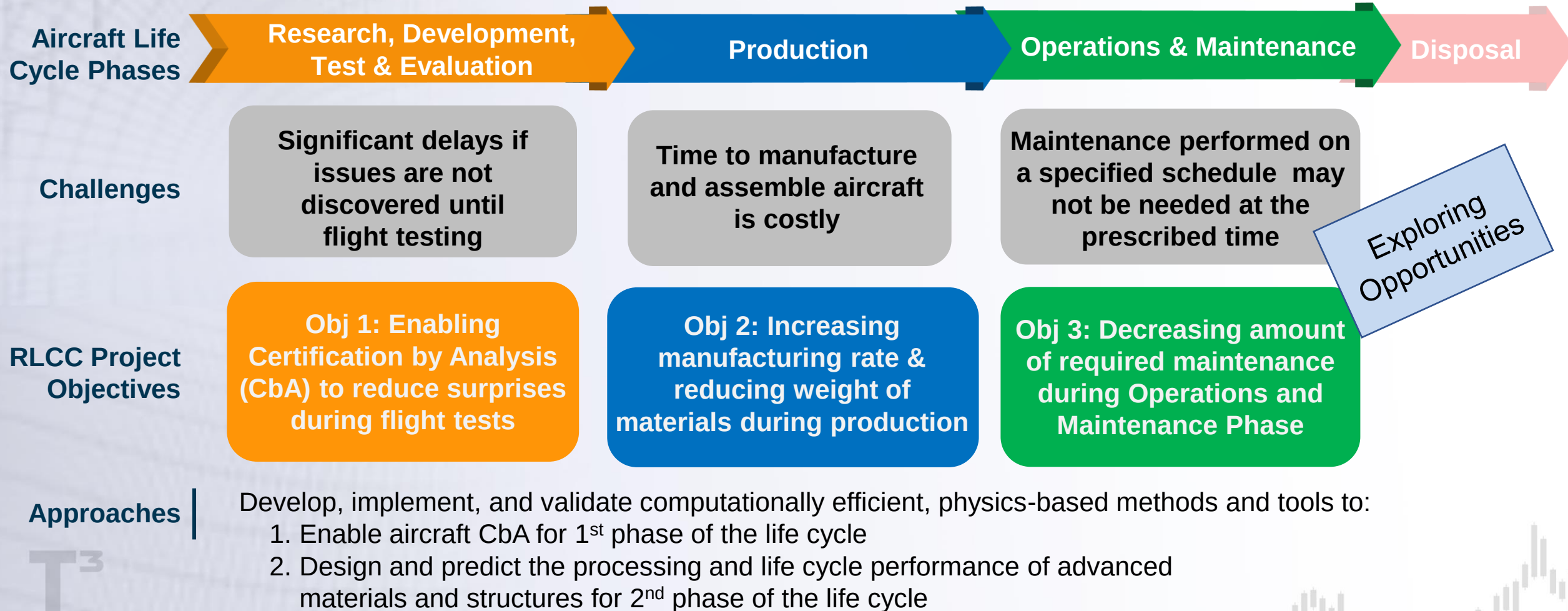


Reduced Life Cycle Cost (RLCC) Sub-project Overview



IM, RCA, Icing and M&S disciplines enable the RLCC sub-project

Purpose: Reduce the life cycle cost of aircraft to enable the U.S. aircraft industry to stay competitive worldwide



Certification by Analysis: Compliance Through Analytical Means

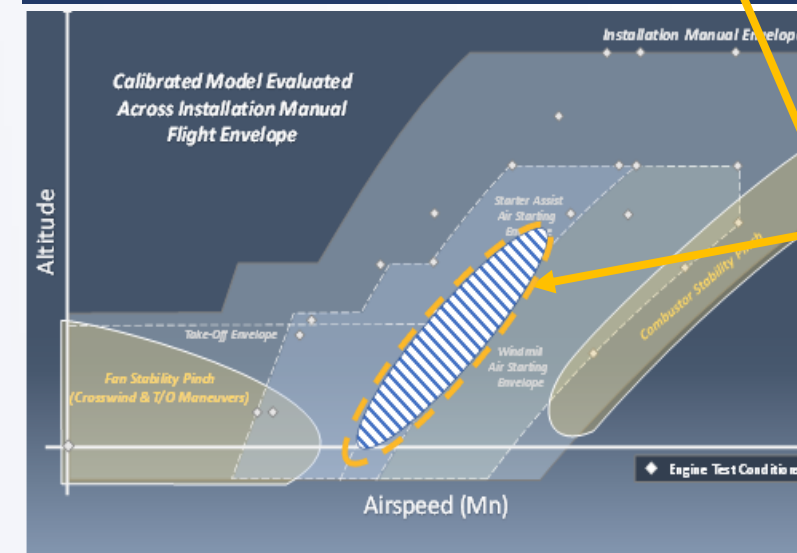
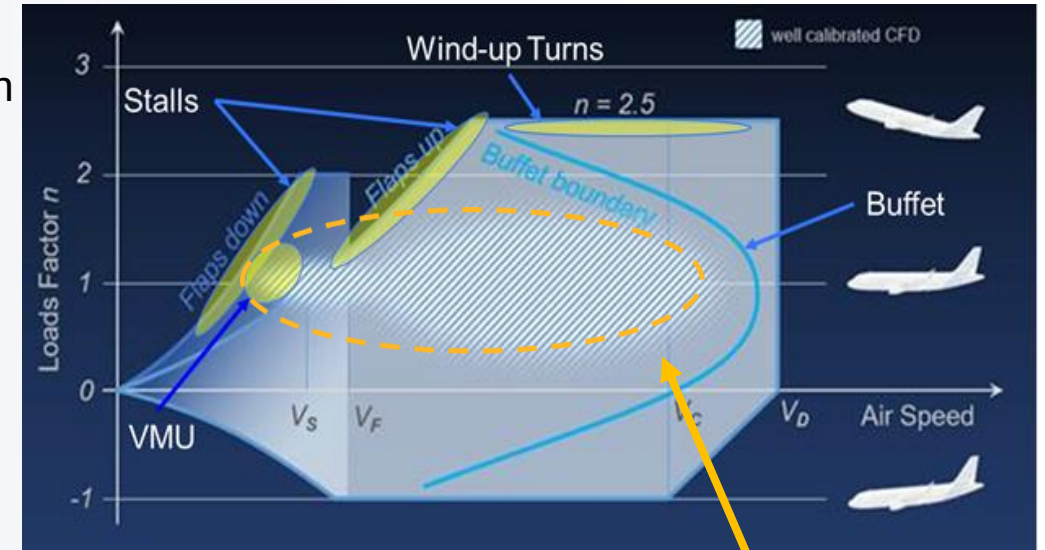


“Continued advances are required to address full-flight envelope predictions and propulsion system operating conditions, reduce design cost and cycle time, reduce ground and flight-testing, and **enable product certification through analysis (CbA)**...”

Recommendation of CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences

- **Regulatory Agencies (FAA, EASA) codify the standards and requirements for airworthiness**
 - Aircraft and engines must meet these requirements, before they can be put to service
- **Current compliance with the codes is through flight test for airframes and ground tests for engines**
 - Very time consuming and expensive endeavor
 - CbA is an alternate means of compliance for airplane and engine certification based on analysis

Ability to accurately predict complex turbulent flows involving separation is a key technical challenge



Limits of current CFD

Design and Execute CFD Validation Experiments



Testing of the CRM-HL models will expand the CFD validation database

Advancing the State of the Art of CFD to predict $C_{L,max}$

Challenge: To reliably predict the complex flow physics near $C_{L,max}$ and provide high quality experimental data that validates the CFD prediction of critical flow phenomenon.

Action: Conduct CFD validation experiments in different wind tunnels to add to the validation database in order to assess transition, turbulence models, and Reynolds number effect predictions.

Impact: Successfully completed first test of a new High Lift Common Research Model (CRM-HL) ecosystem model in the 14x22 wind tunnel.

- Completed the fabrication of a new 5.2% scale CRM-HL cryogenic model in August 2022.
- Executed a check out test of this new model in the NASA LaRC 14x22 wind tunnel facility in September 2022.
- Provided valuable information on installation and testing procedures for this new model before it is tested in other facilities.



BOEING



ONERA
THE FRENCH AEROSPACE LAB

Kawasaki



Partners in the CRM-HL Ecosystem Development Plan



New 5.2% scale CRM-HL model mounted in the 14x22 wind tunnel

Foundational Electrified Aircraft Propulsion (FEAP) Sub-project Overview



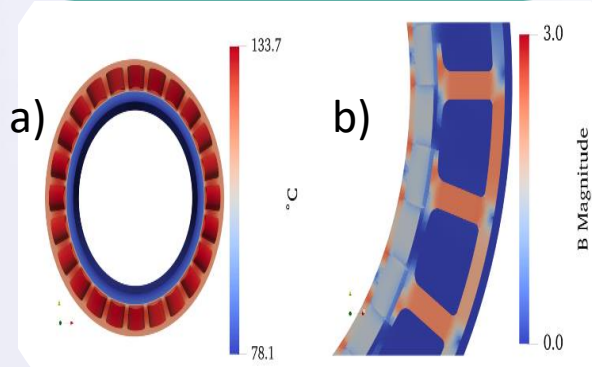
Enables the performance, reliability & durability of electrified propulsion systems by conducting enduring research & developing innovative materials, components, tools & methods that support needs in ARMD mission programs

Objective 1: Enable high voltage and high-power distribution for EAP Systems
(M&S)



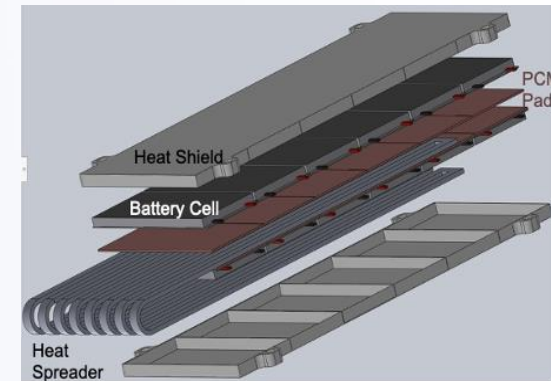
Power Cable Model For Electric Materials

Objective 2: Develop optimization tools and methods for electric and hybrid-electric vehicle design
(MDAO, Controls)



a) Electric Motor stator thermal analysis
b) Stator magnetic flux-density

Objective 3: Develop safe battery technologies to improve performance metrics for EAP
(M&S, MDAO)



Preliminary Battery Design Pack Configuration

Researching high voltage power cables to further sustainable aviation



Explore the unknown to develop robust, safe and reliable power cables for electric vehicle applications

Challenge

Sustainable aviation goals require efficient electric aircraft. High voltage operations with SOA cables need more insulation for higher voltage operation leading to increased weight and resulting in greater power needs.

Solution

Research viable materials to execute a multi-structural/layered approach that results in thinner, lighter, and longer lasting power cables.

Discovery Activities

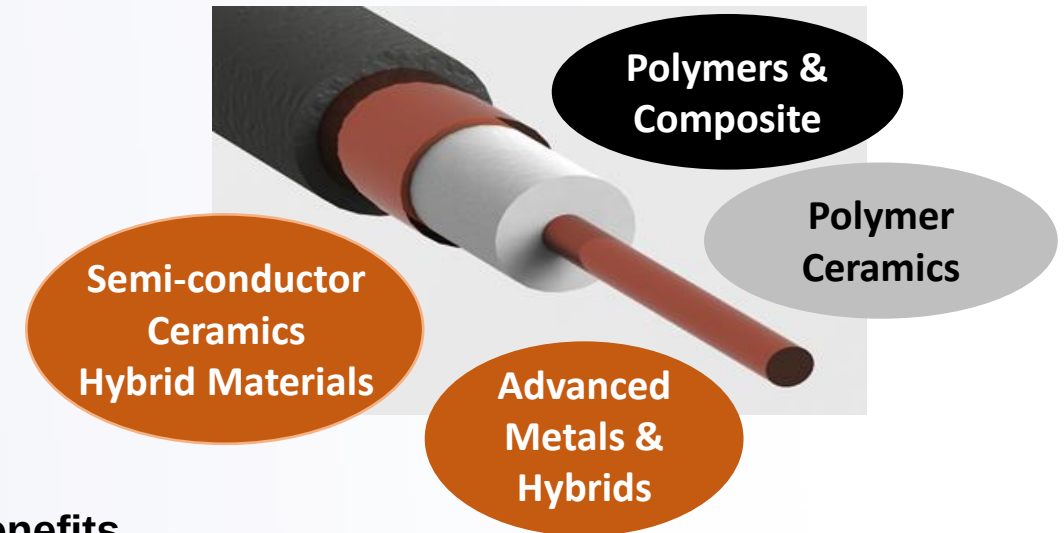
- Evaluating two multi-functional system insulations (MMEI, BNNS composites) and a conductor material (CNT/Cu composites)
- Exploring modelling research to predict properties and performance in terms of material composition, order of insulation stacking layers, and the structure of the system

Partners



Research sparked interest from ARMD and STMD Projects, DOE & SAE AeroTech

Cables with multi-prong redundant system to improve safety

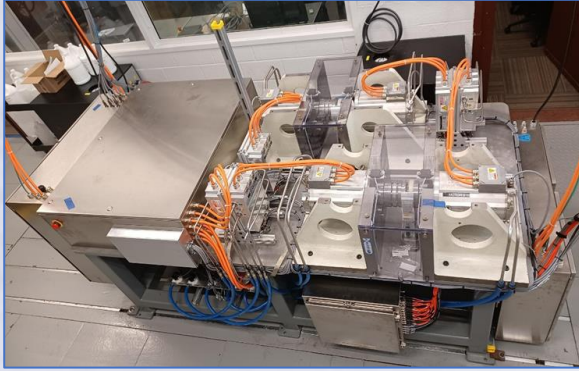


Benefits

- Thin, lightweight, and durable structures
- Reduce weight of cables while maintaining same performance outcomes as SOA cables.
- 20+ year insulation life will further sustainability goals and reduce maintenance costs for industry
- **Significant contributions to two SAE AE High Voltage coordinating and standards committees to shape future requirements.**

Propulsion Controls – *Energy Management Control Hardware-in-the-Loop*

Turbine Electrified Energy Management (TEEM) Control to enhance propulsion system stability in the hybrid-electric architecture



Accomplished Build Complete – Facility Operational (T³ and HyTEC Collaboration)

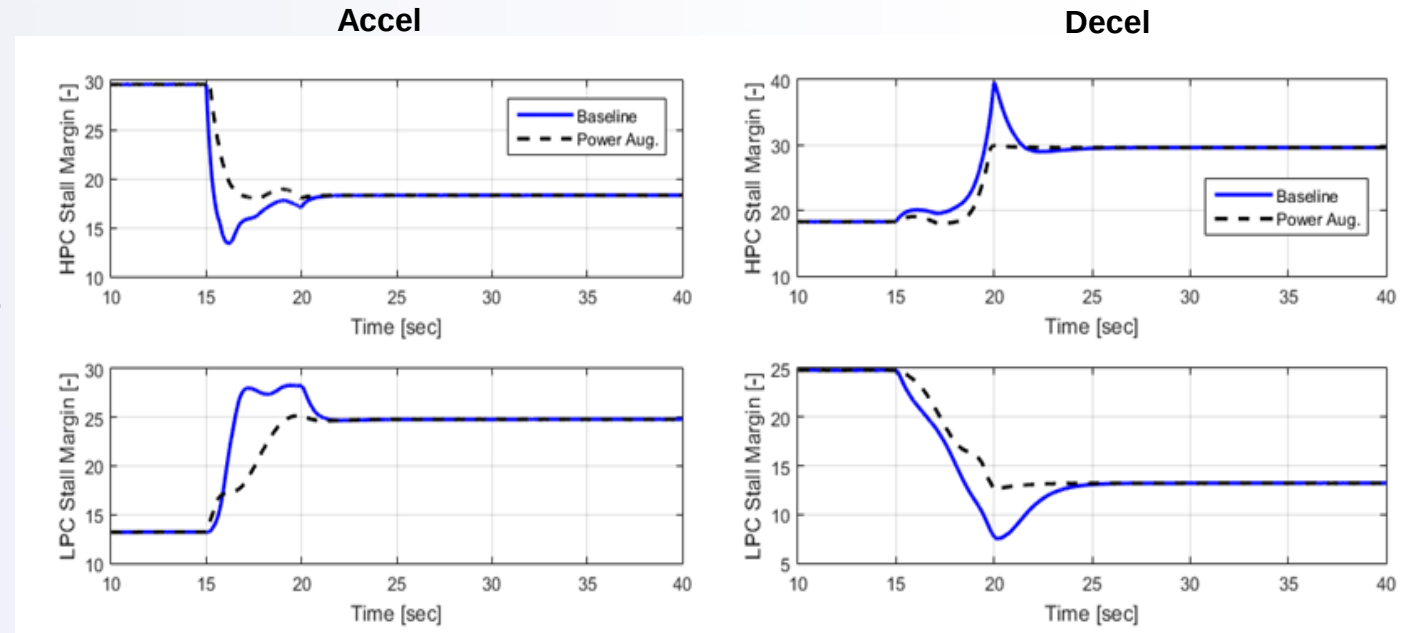
- An agile testbed specifically for propulsion dynamics, control, operability, and energy management technology development.
- All classes of propulsion architecture accommodated using a **novel method** of scaling power and inertia via software.
- Includes power extraction and thrust augmentation with supercapacitor energy storage and dynamically variable loading.
- Operates in the 100kW power flow class and is instrumented to capture turbine - power system interactions and propulsion dynamics **in a flexible, low-cost environment**.

TEEM test article at High Performance Electromagnetic Rig (HiPER) Lab in SE-17

Importance

- Addresses the increased complexity of Electrified Propulsion Systems and energy flows across the vehicle, especially dynamic interactions.
- Provides opportunity for injecting controls into the conceptual design process – *Operability Influenced Design*.
- Agile platform for collaboration with external partners.

Risk reduction platform for investigating advanced concepts, fault management, and real-time model performance



AVIARY – Integrated Multi-Center Aircraft Design & Mission Analysis Code Development

Single aircraft design and sizing tool with new capabilities for unconventional vehicle designs



Problems: MDAO state of the art has advanced beyond the state of adoption; Existing aircraft design capabilities are severely limited in their ability to provide meaningful trends for hybrid-electric and all-electric aircraft

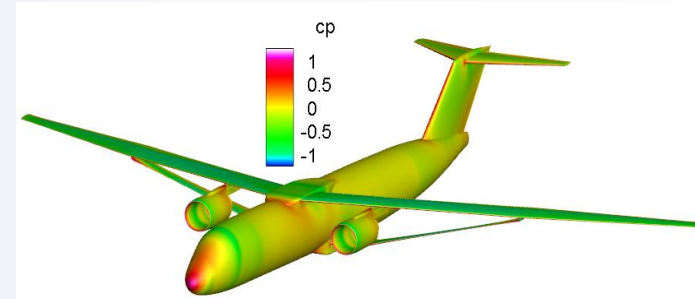
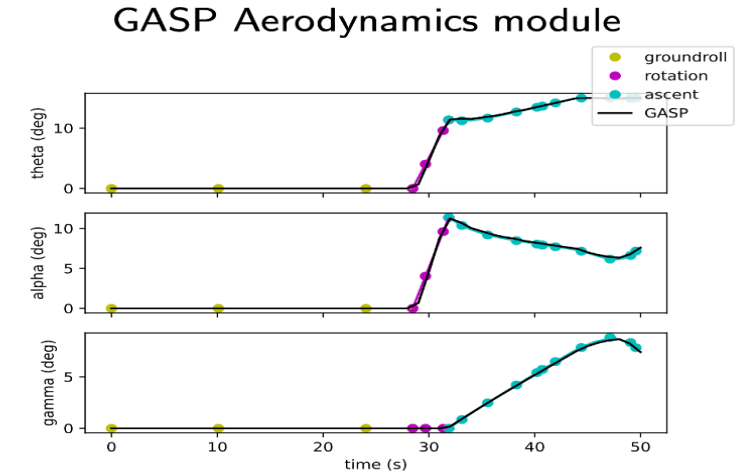
Project Goals: Develop Next Generation Aircraft Design Tools for RVLT, EPFD, AATT and other stakeholders. Embed efforts and associated milestones with ARMD. Broaden impact by releasing open-source codes with low barriers for adoption. Enable conceptual design of N+4 aircraft considering such systems as hydrogen propulsion.

Details: Reimplemented legacy aircraft sizing codes using state of the art numerical methods

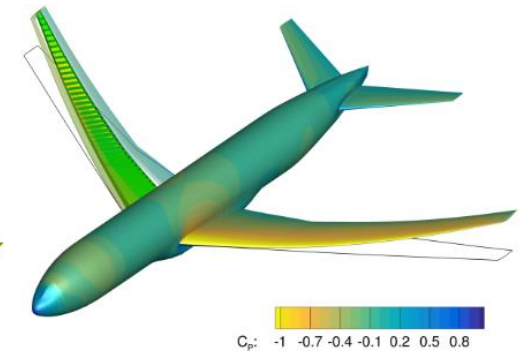
Impact: Integrating disparate co-development efforts across centers and coalescing around a single composite aircraft design and sizing tool for the agency that will be:

- More sustainable
- Ensure commonality
- Avoid duplication

Partners: Academia, Industry, Government Labs



Unconventional Vehicle Design and Analysis



Tightly Coupled Aerostructural Optimization

Co-funding activities with AATT, EPFD, and SFD. Laying the foundation for SFNP's Model-Based Systems Analysis and Engineering (MBSA&E) effort.

Overview of Battery Research Area

Battery Architecture Modeling and Testing



Problem: Significant uncertainty exists around thermal management system performance, battery pack level integration, and pack life in aviation applications. What is the effect of cyclic loading and high strain on packs that are built into flexible structures?

Project Goals: Demonstrate a battery pack can survive 100 loading cycles derived from turbulence in a highly flexible wing and still maintain thermal performance under nominal conditions and safe shutdown under cell failure.

Details: Runaway events are extremely energetic and destructive. Initial testing carried out in FY22 using a partially degraded cell was still powerful enough to damage a protective lens cover on the experimental camera. No thermal-runaway data is available for these high specific energy cells.

Impact: The data collected in these tests can be made publicly available and will be critical for designing TMS systems that can handle runaway events. Develop relationships for thermal management weight as a function of battery architecture, size and composition

Partners: Amprius

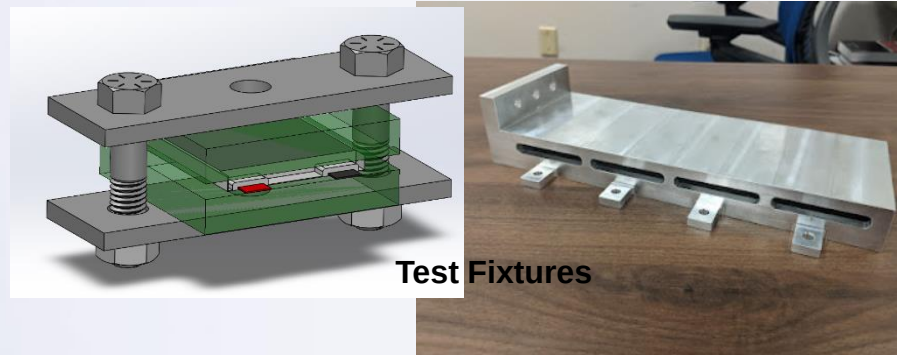


787 Wing Flex During Testing



Thermal Runaway Testing

Battery system architecture on UAM/AAM aircraft lacks significant data. Fundamental research will provide valuable insight



Test Fixtures



Revolutionary Aviation Mobility Sub-Project



Overview

Supports ARMD mission programs by providing a pipeline of solutions and knowledge for **foundational challenges in enabling an AAM market.**

Enables increasingly autonomous transportation in the **UML-4+ timeframe**

Content supports ARMD Strategic Thrusts 1, 4, 5, and 6



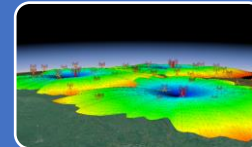
GOAL

Provide leading edge tools, technologies, and research findings to enable increasingly autonomous AAM transportation in the UML-4+ timeframe

OBJECTIVES



Enable scalable operations for AAM through development of an m:N operational approval roadmap supported by community coordination and critical tool and technique research (TC/FY27) {AS}



Explore and develop airspace management and operations architectures and tools in expectation of increased heterogeneous air traffic {AS, CNS, MDAO}



Develop modeling, performance, and control tools & techniques for advanced urban capable aircraft {Controls, MDAO, AS}



Explore and demonstrate approaches for scaled vehicle production {M&S}

RAM Portfolio Overview

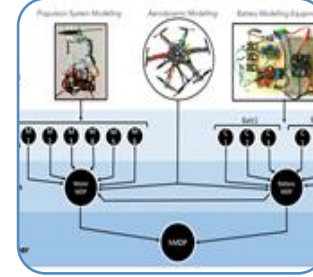
Multidisciplinary approach to tackling the fundamental challenges for ubiquitous AAM



Human Autonomy Teaming

As autonomy increases, need to carefully consider human behavior. It'll require humans and machines to work and think together in new and different ways.

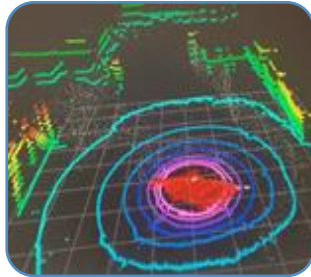
Activities: Research tools & sims with partners, community working group



AutoMitigate Assurance Efficacy

Need to understand the limitations and evidence required for auto-mitigation functions to enable the functions in SWS' In-time Aviation Safety Management System.

Activities: Arguments & artifacts for acceptance of auto-mitigate functions, flight validation



Distributed Sensing

Replacing the "pilot's eyeballs" is no easy feat. Distributed sensing provides a more comprehensive knowledge of the environment, increasing safety and capability of the system.

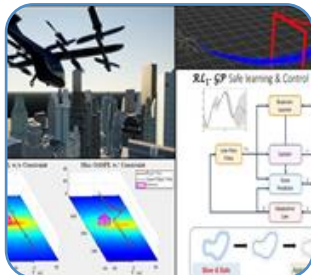
Activities: Common perception framework with distributed info sources; flight demos



Communication, Navigation & Surveillance

As air traffic density increases, new strains on the system will occur, such as increased comm interference and spectrum demand.

Activities: Autonomous spectrum allocation, self-optimizing phased array antennas



Intelligent Contingency Management

Need advances in state-of-the-art autonomous vehicle systems. Vehicles will need to deal with predictable and unpredictable scenarios without human intervention.

Activities: Learning-based approaches to handle off-nominal conditions, autonomous decision tools



Efficient design & testing of AAM vehicles

AAM eVTOL vehicles are very complex, resulting in increased time and expense to design and test.

Activities: Novel methods for efficient flight and ground testing; perception-influenced design of propeller blades

Multi-Vehicle (m:N) Operations Research

Informing the design of a scalable, profitable AAM future

Challenge: To achieve scalable, profitable AAM operations, multi-vehicle or m:N ops is required, where a small number, m , of ground operators manages a large number, N , of highly autonomous aircraft

Action: Collect critical human autonomy teaming data that supports safe, efficient command & control of multiple UAS (m:N ops).

Results/Impacts

- Studied trust in human-autonomy teams by collecting and analyzing human factors data from mission project flight tests on CERTAIN range
- Supplied knowledge gained to update ground control station and ops for improved flight-testing capability for mission project goals
- Most recently, worked with MaRERA to achieve multi-vehicle flight capability with 1 remote operator supervising 2 live aircraft with handoffs between operators
- Won ARMD AA Award for Technology and Innovation Group
- Engaged students via internships, dissertation committee service & Center visits

Developing the foundation of human-autonomy teaming for increasingly autonomous systems by leveraging mission project flight tests



Remote Operations for Autonomous Missions (ROAM) lab with 3 active ground operators

*Joint funding for ROAM;
provide ops for human
factors study in T³*

AAM-HDV,
CAS-STEReO, MaRERA,
future: SWS TC-5, ACERO

CERTAIN Range



*Collaboration on GCS
design for m:N ops
(in discussion)*

Boeing/Wisk
American Robotics

*Collaboration on
human-in-the-
loop studies*

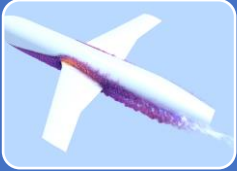
The logo for Old Dominion University (ODU), featuring a crown above the letters 'ODU'.

T³

National Aeronautics and Space Administration

POC: Eric Chancey/LaRC

Enduring Disciplines Overview



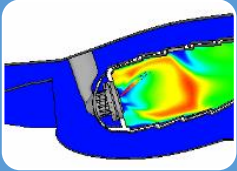
Revolutionary Computational Aerosciences
(algorithms, meshing, transition, AI/ML)



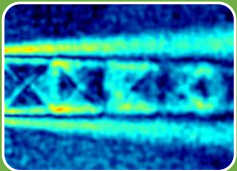
Materials & Structures
(EBC/CMC, SMAs, part of High Temp Alloys)



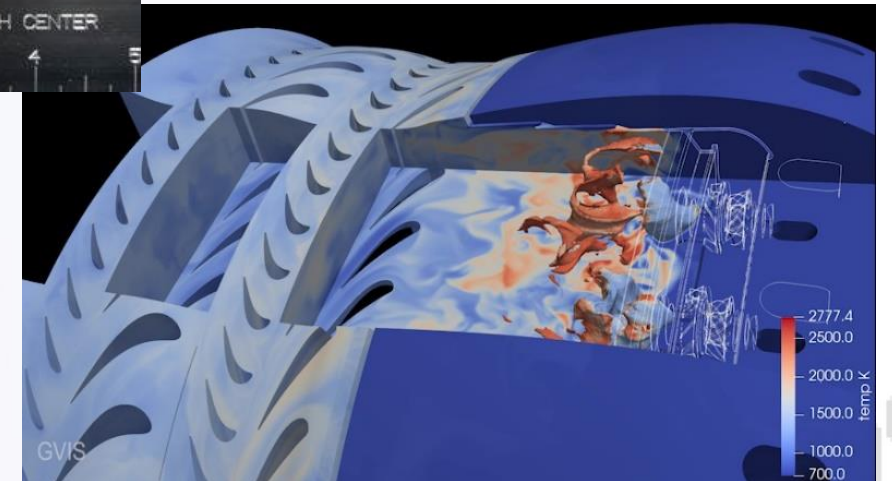
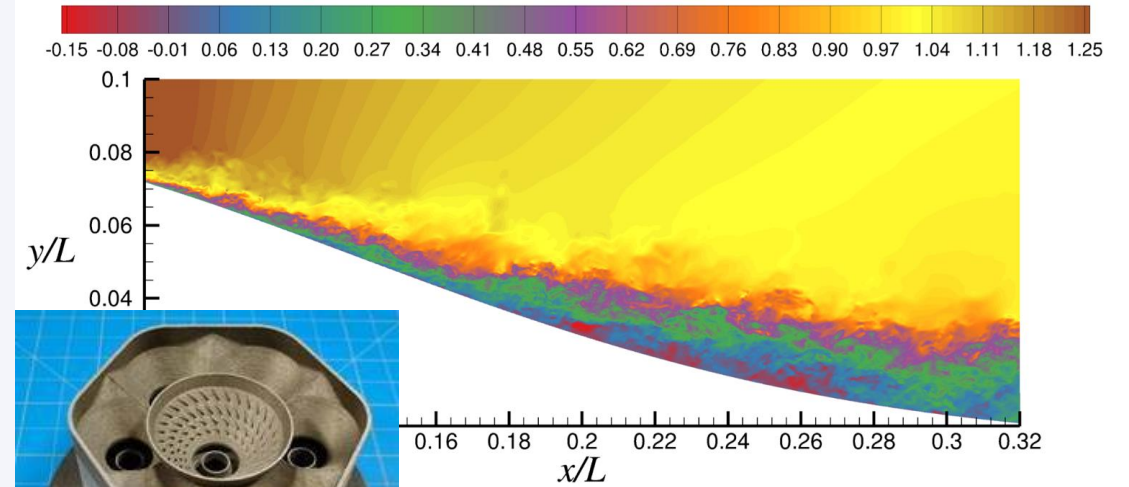
MDAO
(Enduring tools, uncertainty)



Combustion
(Modeling and Experiments)



Innovative Measurements
(Cutting-edge measurement techniques)

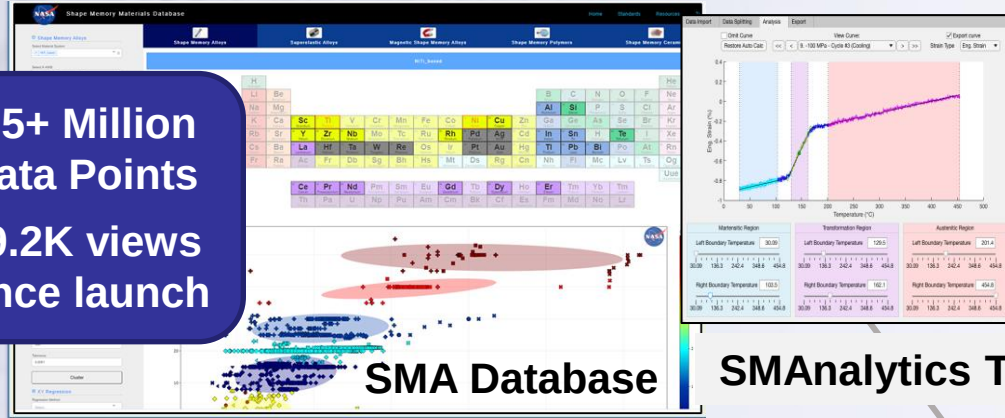


World's Largest Shape Memory Alloy (SMA) Database Enables Development of Two New Alloys in One Year

Dissemination of Information

Technology Demonstration

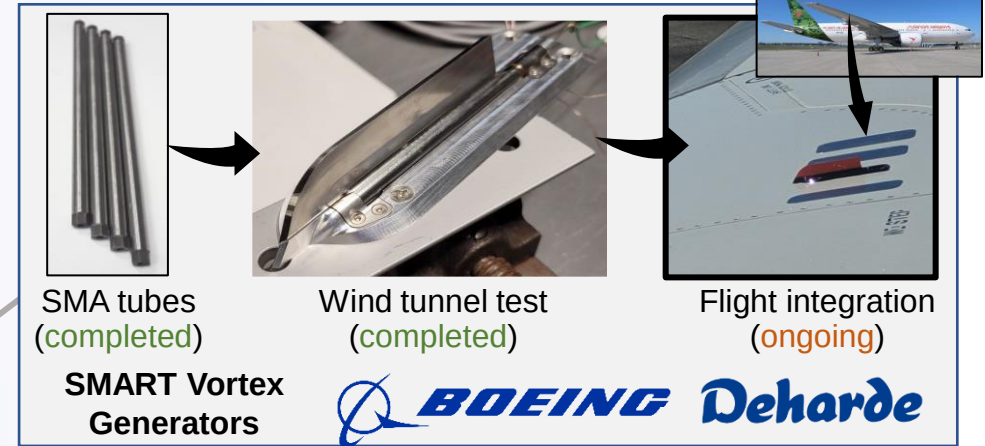
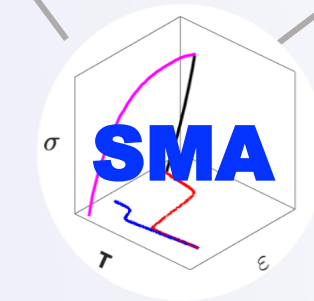
1.5+ Million
Data Points
59.2K views
since launch



SMAAnalytics Tool

Launched Shape Memory Materials Database & Analysis Tool via a web portal

- Completed the database functionality for ALL materials category
- Impact:** Enable faster, **efficient**, accurate design of SMAs (in line with Vision 2040)
- Tool publicly launched via a web application
- Impact:** Promote database growth and data mining via direct scientific community contributions



Developed TWO new experimental alloys for FY22 Boeing ecoDemonstrator flight test with two key advancements

- Alloy properties: Improvements in activation temperatures and hysteresis
 - Impact:** Expand applicability beyond “standard day” flight profile
- Production methods: Newly developed tube production methods helped for fast turnaround (using melt suction casting)
 - Impact:** Seamless transition to high volume production levels

T³ established a new FY23 Annual Performance Indicator (API)
23-3.2.3.5 for SMART VGs testing and benefits assessment

NASA's High-Temperature Superalloy: GRX-810



An Additively Manufactured (AM) Oxide Dispersion Strengthened (ODS) Breakthrough

Problem

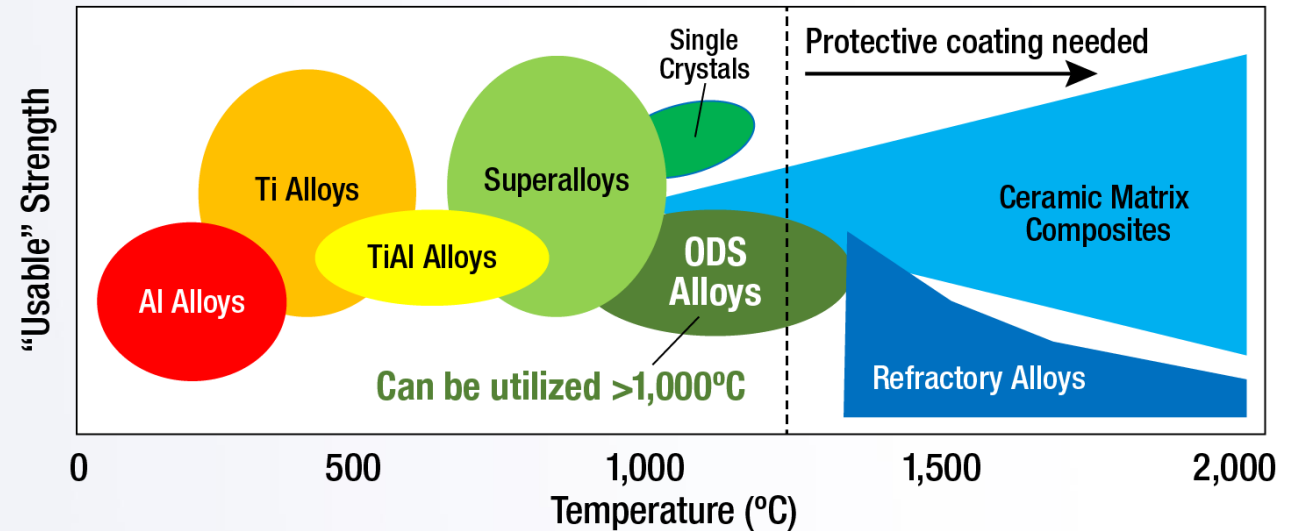
Conventional materials and processing limit the design and operating temperature of aerospace components.

Proposed Solution

Develop a material that can be AM and operate in temperatures above 2,000°F (1,093°C).

Discovery and Development

Used computational tools to discover the optimal alloy composition and 3D printing to create an ODS alloy.



Performance

vs. current state-of-the-art superalloys

2x Strength

3.5x Ductility

1,925x Creep Rupture Life

Benefits

- ODS alloys offer higher-temperature capabilities vs. Ni-base superalloys.
- Thermodynamic model predictions reduce time and cost to produce results.
- Coated metallic powder technique enables efficient production of complex 3D-printed ODS components.

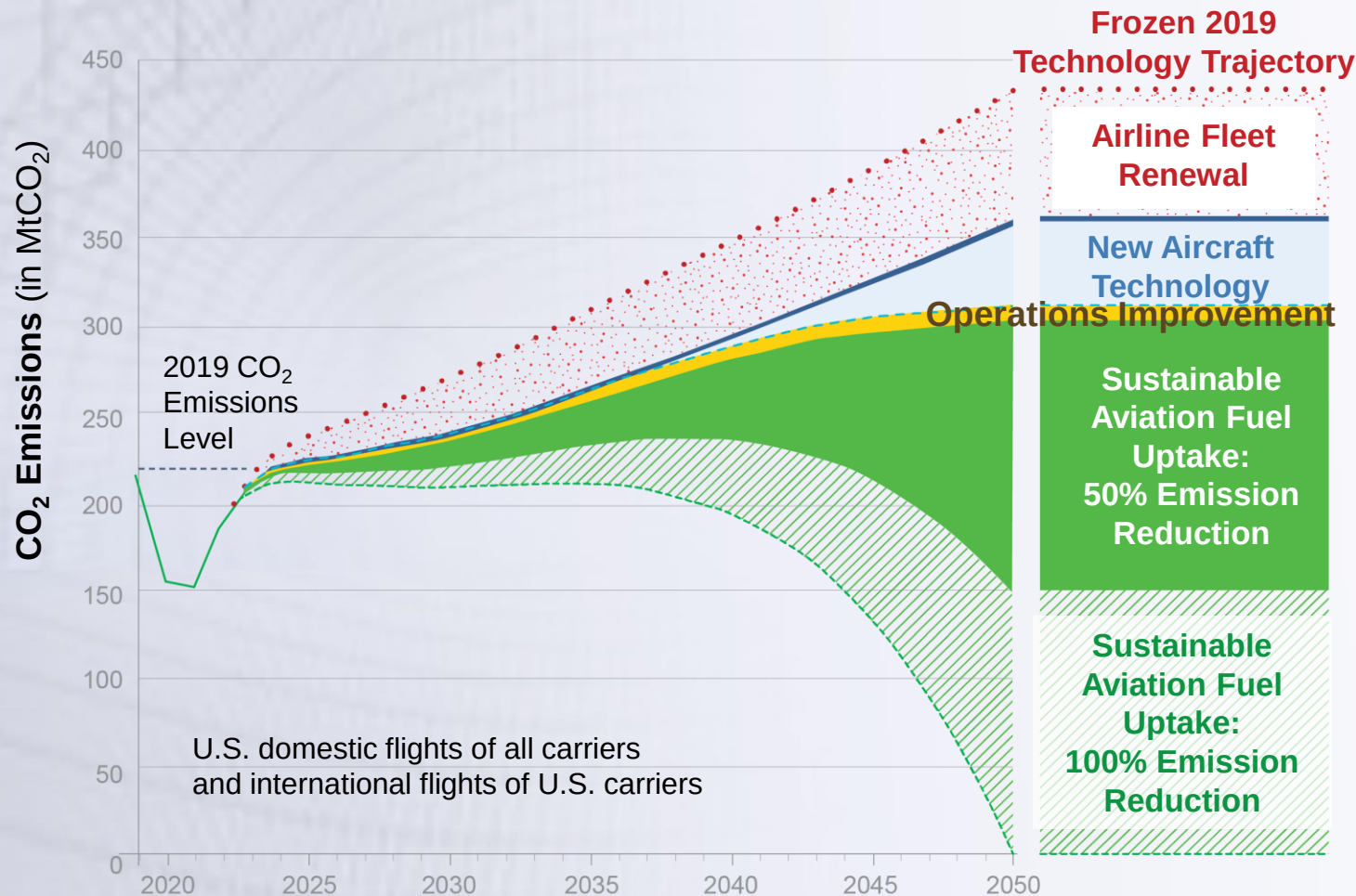
3D-printed ODS Combustor Dome



U.S. Aviation Climate Action Plan – T³ Contributions



Global Context for Sustainable Aviation



Insert new technologies into the fleet and accelerate certification

- Improve fuel efficiency
 - Aerodynamic efficiency
 - Engine fuel burn
 - Reduced weight materials & structures
- Certification by Analysis
 - Non-conventional configurations
 - Greater portion of flight envelope
 - Icing
 - Additive Manufacturing

Alternative Power and Propulsion

- Sustainable Aviation Fuels
 - Combustion and Emissions
- Enable more (hybrid) electric aircraft
 - Power cables, batteries
 - Control algorithms

The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 using a common basket of measures

T³

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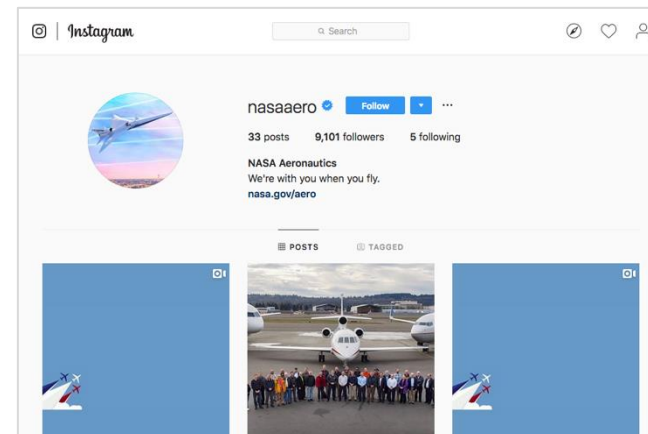
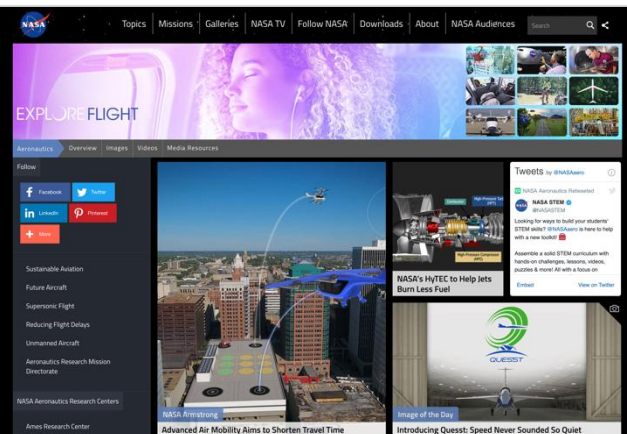
@NASAAero



@NASAAero



@NASAAero



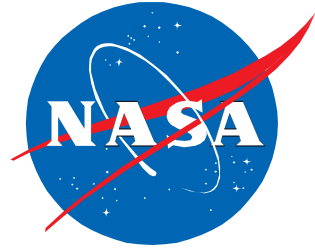
www.nasa.gov/aeroresearch/strategy

www.nasa.gov/aeroresearch/solicitations



Antes, Ahora y Siempre...¡COLEGIO!

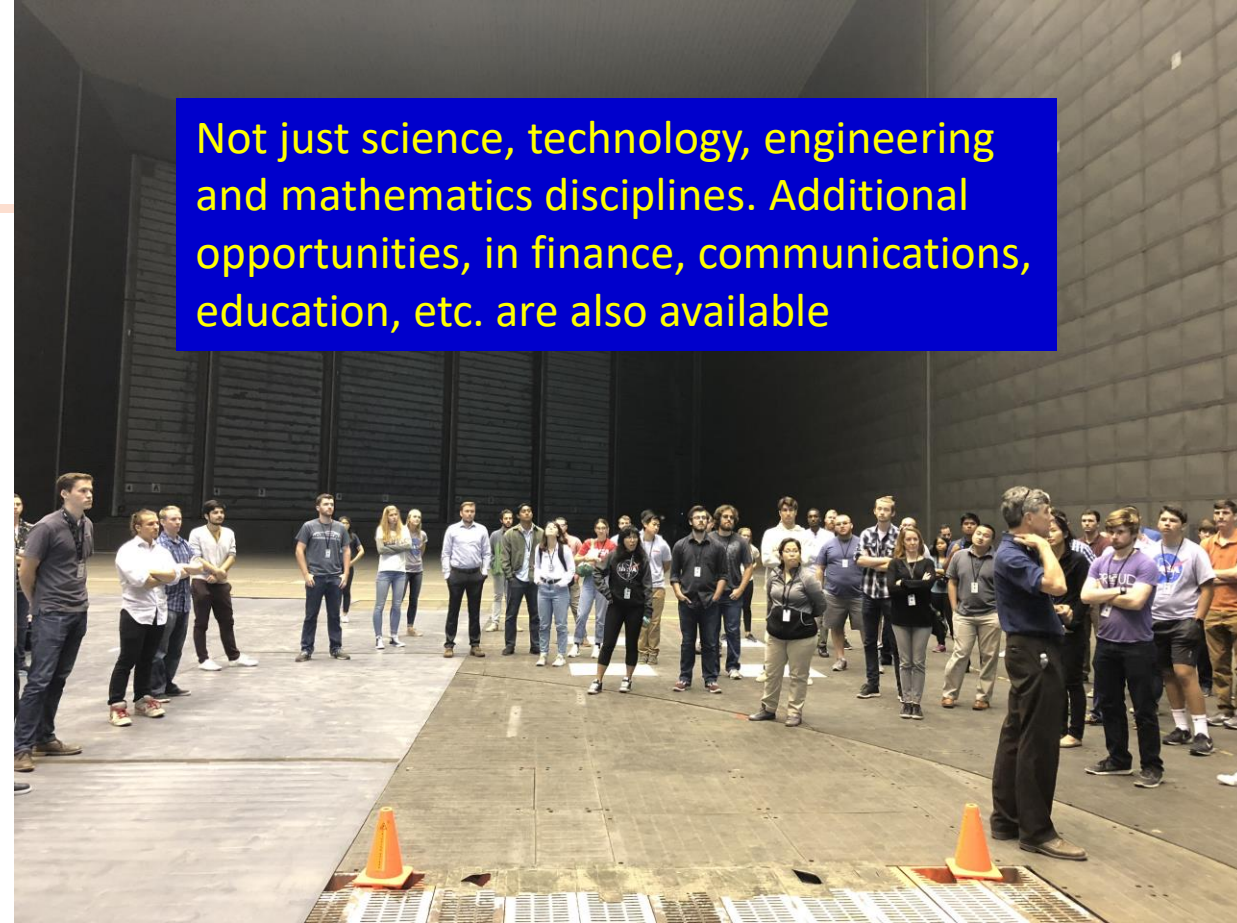




NASA Internship Program

- Summer (10 weeks)
 - Full time at NASA Center (40 hours/week)
 - High School Seniors through Post-Docs
- Fall and Spring (16 weeks)
 - Part to Full time at NASA Center
 - Undergraduates through Post-Docs
- Apply at <https://intern.nasa.gov/>
 - Example deadlines to submit internship applications:
 - Spring 2023: late November (session starts late-January)
 - Summer 2023: end February (session starts early June)
 - Fall 2023: mid July (session start late August)
 - Most projects start being posted ~1 month prior to deadline
 - Resumes and applications can be updated and submitted at any time

Not just science, technology, engineering and mathematics disciplines. Additional opportunities, in finance, communications, education, etc. are also available



Eligibility Requirements

- US Citizen
- 3.0 GPA on a 4.0 scale
- At least 16 years of age
- Enrolled in a degree program at accredited college or university

Tips for Summer Internship

- For summer internships, remember to apply early (in February)
 - Include all your skills in your resume and application
 - Be specific about your experience and knowledge
 - When applying to an advertised NASA opportunity, share how your skills and interests fit the project description
 - Keep visiting the internship website as more project opportunities are opened
- Have a question?

Contact the NASA Center where you want to intern. See contacts at <https://www.nasa.gov/offices/education/contacts/centers/index.html>



NASA Pathways Program

Many in NASA are former pathways interns who were converted to full-time employees

- NASA Pathways Intern Employment Program
 - Work at NASA when not in school
 - Opportunity to rotate through many different areas
 - U.S. citizen pursuing a degree or certificate, enrolled on at least a half-time basis

Look for opportunities and apply at:
<https://www.usajobs.gov/>
- NASA Pathways Recent Graduates Program
 - Recent graduate appointee is placed in a one-year career development program
 - Apply within two years of completing a degree at a qualifying educational institution
 - U.S. citizen

Look for opportunities and apply at:
<https://www.usajobs.gov/>
- NASA Pathways Presidential Management Fellows (PMF) Program
 - Qualifying masters, doctorate or professional degree within the last two years

Look for opportunities and apply at:
<https://www.pmf.gov/>

Acronym List



Acronym	Definition
AAM	(IASP) Advanced Air Mobility
AATT	(AAVP) Advanced Air Transport Technology
AAVP	Advanced Air Vehicles Program
ADaPT	Antenna Deployment and oPtimization Technologies
AePW	Aeroelastic Prediction Workshop
AERoBOND	(CAS) AdhEsive fRee BONDing of Complex Composite Structures
AETC	Aerosciences Evaluation and Test Capabilities
AFRL	Air Force Research Lab
AI	Artificial Intelligence
AI/ML	Artificial Intelligence/Machine Learning
AIT	Adaptive Icing Tunnel
AM	additive manufacturing
AMEL	Automated Materials Experient Lab
AMIO	AAM Mission Integration Office
ANL	Argonne National Laboratory
AoA	Analysis of Alternatives
AOSP	Airspace Operations and Safety Program
ARMD	Aeronautics Research Mission Directorate
AS	Autonomous Systems
ASNP	air service navigation providers
ATAG	Air Transport Action Group
ATM-X	(AOSP) Air Traffic Management eXploration Project
ATTAM	Advanced Turbine Technology for Affordable Missions
AUVSI	Association for Unmanned Vehicle Systems International
AVSI	Aerospace Vehicle Systems Institute
BNNS	Boron Nitride Nanosheet
BOS	Background Oriented Schlieren
BVLOS	beyond visual line of sight
C2QA	Co-design Center for Quantum Advantage
CAS	(TACP) Convergent Aeronautics Solutions
CAS MART	Consortium for the Advancement of Shape Memory Alloy Research and Technology
CbA	certification by analysis
CFD	Computational Fluid Dynamics
CLAS-ACT	(CAS) Conformal Lightweight Antenna Structures for Aeronautical Communication Technologies

Acronym	Definition
Clmax	the maximum lift coefficient of the airfoil
CM4QC	Computational Materials for Qualification and Certification
CMC	Ceramic matrix composite
CMH	Composite Materials Handbook
CNS	Communication, Navigation & Surveillance
CST	(AAVP) Commercial Supersonic Transport
DASC	Digital Avionics Systems Conference
DCB	Double Cantilever Beam
DECWG	Distributed Engine Control Working Group
DFT	Density functional theory
DNW-NWB	German-Dutch wind tunnels
DoE PNNL	(DoE) Pacific Northwest National Laboratory
DTU	technical university of Denmark
EAP	Electrified Aircraft Propulsion
EBC	Environmental Barrier Coatings
EPFD	(IASP) Electrified Powertrain Flight Demonstration Project
ESDMD	Exploration System Development Mission Directorate
ESI	early stage innovation
eVTOL	electric vertical takeoff and landing vehicles
FAA	Federal Aviation Administration
FDC	(IASP) Flight Demonstrations & Capabilities Project
FEAP	Foundational Electrified Aircraft Propulsion
HATTB	Human-Autonomy Teaming Task Battery
HDV	High Density Vertiplex (aka the AAM Subproject)
HECC	High Efficiency Centrifugal Compressor
HENAAC	Hispanic Engineer National Achievement Awards Corporation
HiCAM	(AAVP) Hi-Rate Composite Aircraft Manufacturing Project
HiPER	High Performance Electromagnetic Rig
HiPot	high potential
HITL	Human in the Loop
HL-CRM	High-Lift Common Research Model
HLPW4	High-Lift Prediction Workshop – 4
HPC	High performance computing



Acronym List (cont.)

Acronym	Definition
HRLES	Hybrid Reynolds-Averaged Navier-Stokes and Large Eddy Simulation
HT	high temperature
HTP	(AAVP) Hypersonic Technology Project
HV	high voltage
HyTEC	(AAVP) Hybrid Thermally Efficient Core
IASP	Integrated Aviation Systems Program
ICAO	International Civil Aviation Organization
ICCCRD	Interagency Coordinating Committee on Ceramic Research and Dev.
ICME	Integrated computational materials engineering
IFAR	International Forum for Aviation Research
IHMC	Institute for Human & Machine Cognition
IM	Innovative Measurements
IML	inner mold line
L2	level 2 milestone
LBFD	(IASP) Low Boom Flight Demonstration
LOFTID	Low-Earth Orbit Flight Test Inflatable Decelerator
LSAWT	Low Speed Aeroacoustic Wind Tunnel
LSHR	low solvus high refractory
LxC	Likelihood x Consequence
M&S	Materials & Structures
m:N	m is a small number of operations. N is a large number of aircraft
MACCCR	Multi-Agency Coordinating Committee for Combustion Research
MaRERA	Multi-aircraft Remote Emergency Response Assessment
MBSA&E	(AATT) Model-Based Systems Analysis & Engineering
MCAAD	Modeling and Control of Agile Aircraft Development
MDAO	Multidisciplinary Design, Analysis & Optimization
MDM	Material Data Management
MDMC	Material Data Management Consortium
MEC	Multidisciplinary Engineering Challenge
MMEI	Micro-Multi-Layered Electrical Insulation
MPATH	Measuring Performance for Autonomy Teaming with Humans
MPEAs	multi-principal element alloy
MSFC	Marshall Space Flight Center

Acronym	Definition
NESC	NASA Engineering and Safety Center
NETL	National Energy Technology Laboratory
NJFCP	National Jet Fuels Combustion Program
NRA	NASA Research Announcement
NREL	National Renewable Energy Laboratory
NRL	Naval Research Laboratory
NTR	New Technology Report
ODS	oxide dispersion strengthened
ODU	Old Dominion University
OFAT	one-factor-at-a-time
OGAs	other government agencies
OH PLIF	hydroxyl radical planar laser-induced fluorescence
OML	outer mold line
ONR	Office of Naval Research
OPO	optical parametric oscillator
PAAV	Pathfinding for Airspace with Autonomous Vehicles
Pcard	NASA credit card user
PD	partial discharge
PEASA	Power Electronics for AeroSpace Applications
PI	Polyimide
PIV	Particle Imaging Velocimetry
PLGRM	Portable Laser Guided Robotic Metrology
PNNL	Pacific Northwest National Laboratory
PPSA	Propulsion and Power Systems Alliance
PSP	Pressure Sensitive Paint
PSPP	Process-structure-property-performance
PTI	Programmed Test Inputs
Q&C	qualification and certification
RAM	Revolutionary Aviation Mobility
RANS	Reynolds Averaged Navier-Stokes
RAVEN	Research Aircraft for eVtol Enabling technologies
RCA	Revolutionary Computational Aerosciences
RD&P	research development & deployment

Acronym List (cont.)



Acronym	Definition
RFI	radio frequency interference
RFI	request for information
RLCC	Reduced Life Cycle Cost
ROAM	Remote Operations for Autonomous Missions
RSM	Response Surface Modeling
RTRC	Raytheon Technologies Research Center
RVLT	(AAVP) Revolutionary Vertical Lift Technology
SAA	Space Act Agreement
SABERS	(CAS) Solid-state Architecture Batteries for Enhanced Rechargeability & Safety
SAF	sustainable aviation fuel
SBLI	shock/boundary-layer interaction
SFD	(IASP) Sustainable Flight Demonstrator
SFNP	Sustainable Flight National Partnership
SFW	subsonic fixed wing
SiC	silicon carbide
SLS	Space Launch System
SMA	Shape Memory Alloys
SMART-VG	Shape Memory Alloy Reconfigurable Technology-Vortex Generator
SMMD	shape memory materials database
SMST	Shape Memory and Superelastic Technologies
SPARRCI	(CAS) Sensor-based Prognostics to Avoid Runaway Reactions & Catastrophic Ignition
STEREO	(CAS) Scalable Traffic Management for Emergency Response Operations
STMD	Space Technology Mission Directorate
SUSAN	Subsonic Single Aft Engine
SWS	(AOSP) System-Wide Safety
T ³	Transformational Tools & Technologies
TACP	Transformative Aeronautics Concepts Program
TDT	Transonic Dynamics Tunnel
TEEM	Turbine Electrified Energy Management
THX	turbulent heat flux

Acronym	Definition
TIM	Technical Interchange Meeting
TomoBOS	tomographic BOS
ToR	Terms of Reference
TQR	Technical Quality Review
TSNA	Transformation Strengthened NASA Alloys
TTBW	(AATT) Transonic Truss-Braced Wing
TWGs	technical working groups
UI	(TACP) University Innovation
UIUC	University of Illinois Urbana-Champaign
uPSP	Unsteady Pressure Sensitive Paint
UQ	uncertainty quantification
uRANS	unsteady RANS
USDC	University Student Design Challenge
V&V	verification & validation
VEATE	Versatile Electrically Augmented Turbine Engine
VLPNT	vertical lift propeller noise
WG	working group
WMLES	Wall-modeled Large Eddy Simulation
WPAFB	Wright Patterson Air Force Base
ZOB	Cleveland Air Route Traffic Control Center