



EXPLORE FLIGHT

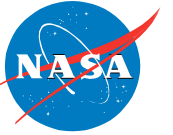
WE'RE WITH YOU WHEN YOU FLY

NASA Aeronautics Overview

FAA ASCENT Meeting
October 24-26, 2023

Cliff Brown
NASA Technical Lead for Subsonic Commercial Transport Noise
NASA Glenn Research Center

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



Safe, Quiet, and Affordable Vertical Lift Air Vehicles



Innovation in Commercial Supersonic Aircraft



In-Time System-Wide Safety Assurance



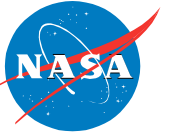
Ultra-Efficient Subsonic Transports



Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

Sustainability Exists at the Intersection of Economic, Environmental, and Social Forces



Aviation Economy



- 8.97 million flights by U.S. carriers worldwide in 2022
- 24 million tons of freight transported by U.S. airlines in 2022
- \$1.9 trillion total U.S. economic activity in 2019
- \$51.5 billion positive manufacturing trade balance in 2021
- 2.1 million aerospace/defense jobs; 575,000 in aeronautics/aircraft in 2021



U.S. Aviation Climate Action Plan



U.S. Aviation Climate Goal:

Net-Zero GHG Emissions* from the U.S. Aviation Sector by 2050**

"The United States believes that addressing the climate crisis through enhanced ambition is a defining priority of our time. This Aviation Climate Action Plan provides a whole-of-government approach and policy framework for the aviation sector to contribute to broader, economy-wide objectives."

- U.S. Aviation Climate Action Plan





ULTRA-EFFICIENT AIRLINERS



FUTURE AIRSPACE AND SAFETY



HIGH-SPEED COMMERCIAL FLIGHT



ADVANCED AIR MOBILITY



High-Speed Commercial Flight - Supersonics

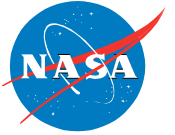


Advanced Air Mobility – Vertical Flight



Ultra-Efficient Transports - Subsonics

Quesst Mission Overview

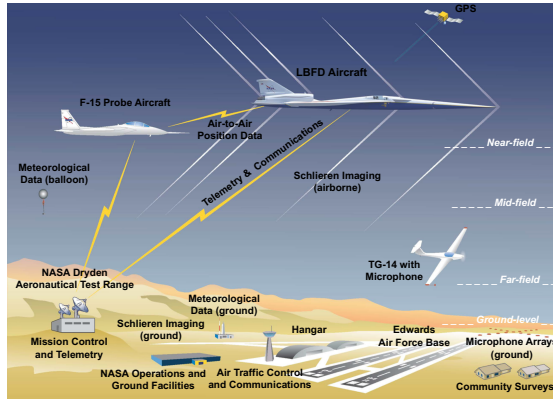


QUESST

Phase 1 – Aircraft Development

In progress (FY18-24)

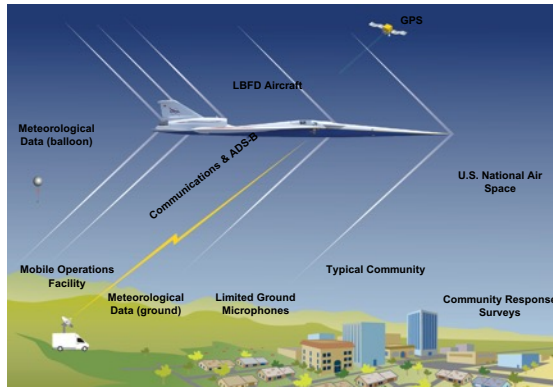
- Design, fabricate a quiet supersonic research aircraft
- Prove performance in test range flights
- Prove safety for flights in normal airspace



Phase 2 – Acoustic Validation

Preparation in progress (FY18-24), Execution FY24

- Prove the acoustic characteristics match design targets
- Detailed in-flight and ground measurements in test range



Phase 3 – Community Response Testing

Preparation in progress (FY19-23), Execution FY24-27

Conduct community tests

- Select communities
- Outreach and engagement (including STEM)
- Obtain necessary approval
- Plan surveys and recruit participants
- Collect ground measurements

**Systematic
Approach Leading
to Community
Testing**

Phase 1 X-59 Aircraft Development



Photos:
Lockheed Martin

- Progress continues, as do challenges
- All manufacturing and systems installation complete
- Aircraft moved from manufacturing facility to run-up stall on flight line

- Integrated structure and fuel systems checks underway
- First flight still targeted for the end of the year, but that date is at risk

Quesst Mission - Phase 2 and 3 Status



Acoustic Measurement

- Ground Recording System (GRS) being developed by Crystal Instruments, Inc
 - Ruggedization has been an ongoing challenge for these systems
- Next risk reduction test for Phase 2 logistics and GRS deployment planned for Oct
- Progress continues on airborne acoustic measurement systems



Community Test Planning & Execution

- Continued progress on test, exposure and survey plans
- Airfield and community selection process ongoing
- Test of survey methods in progress (no actual flights)
 - Including recruitment approach & survey questionnaires
- Addressing bias concerns in all levels of communication

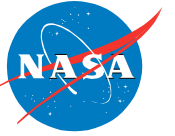


International Standards Development

- Continued engagement with FAA/AEE, ICAO/CAEP & international research community
- Working paper for October Steering Group meeting to address:
 - Quesst mission progress and challenges
 - Proposal to shift proposed supersonic en route standard to CAEP 15
 - Availability of information paper from NASA on potential international test collaborative framework



Commercial Supersonics LTO Noise & Prediction Uncertainty



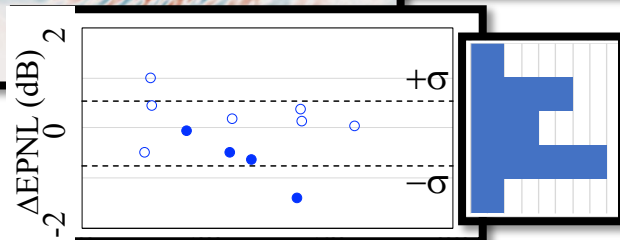
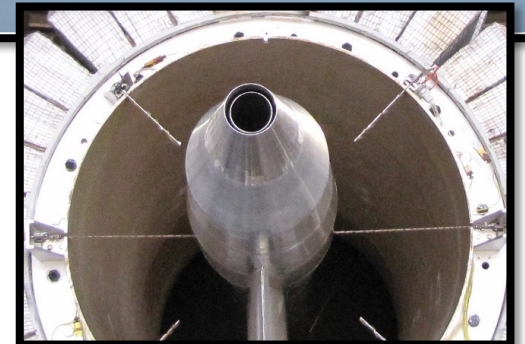
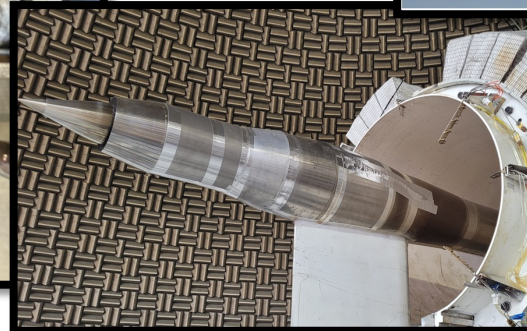
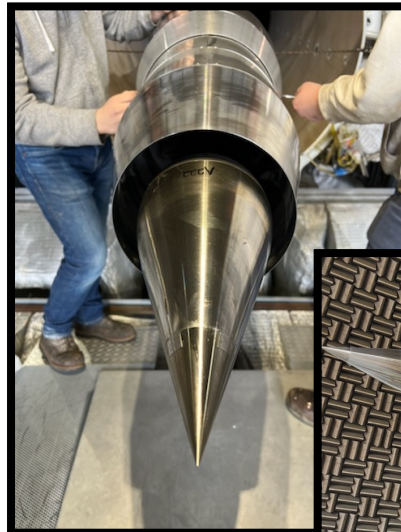
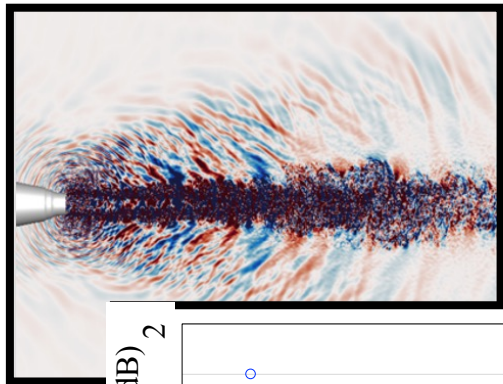
Improvements to noise prediction models used in studies of a supersonic market.

- Models based on current OEM-based aircraft designs for representative near-term aircraft.
- Data obtained by physics-based simulations, validated by model-scale tests which are validated by flight tests

Recent activities

- Working with OEM partners to create representative exhaust systems for final jet noise simulations.
- Working with FAA ASCENT #59 team to track anomalous noise sources in internal mixer nozzles.
- Simulating variations on OEM-designed two-stage fan to create required database for enhanced fan noise model.

➤ System level prediction uncertainty to be updated in October 2023.





High-Speed Commercial Flight - Supersonics

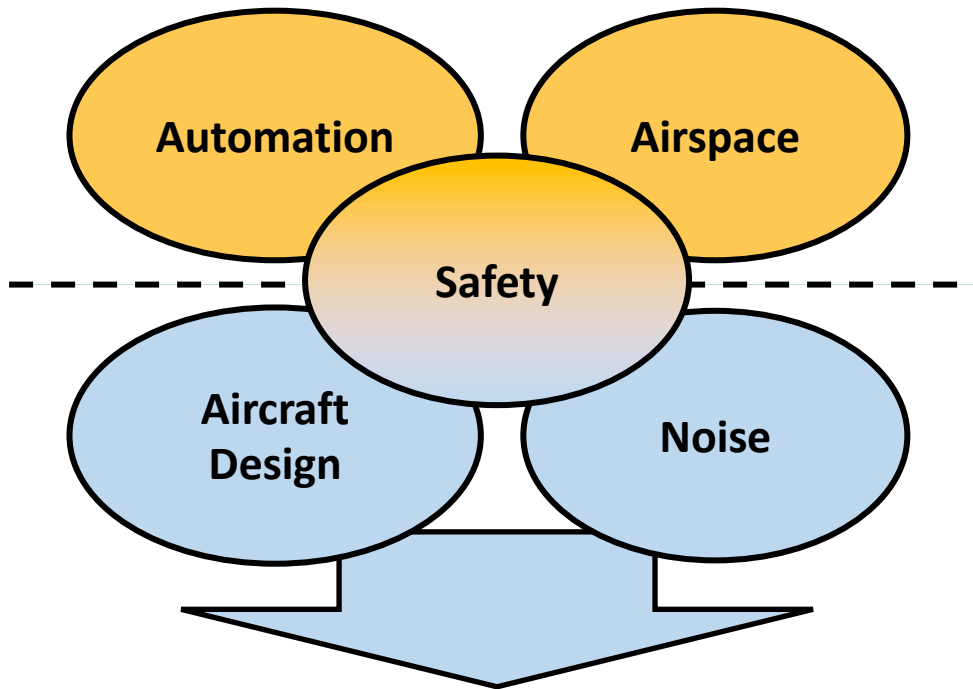


Advanced Air Mobility – Vertical Flight



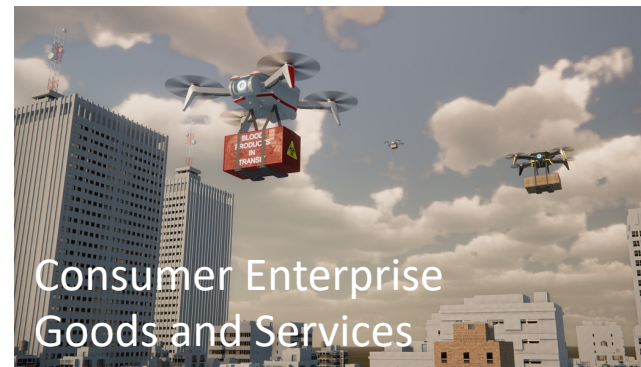
Ultra-Efficient Transports - Subsonics

Advanced Air Mobility Mission – Vision & Framework



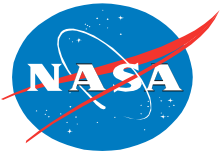
NASA AAM Vehicle Objectives:

1. Integrated Design and Operations for Noise
2. Integrated Aircraft Propulsion System Performance and Reliability
3. Weather Tolerant Aircraft Technologies
4. Survivability in Off-Nominal Conditions
5. Cabin Acceptability

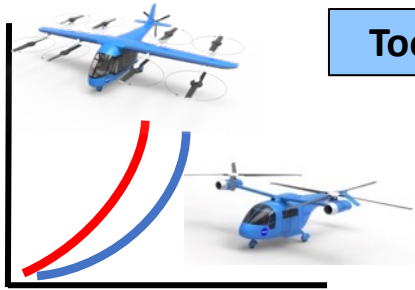


Revolutionary Vertical Lift Technology Project

Research Focus – Vehicle Noise and Safety; Overview and Objectives



Noise & Performance



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

- Validation experiments
- Efficiency & accuracy of conceptual design tools
- Design & analysis tools to OGA & US community

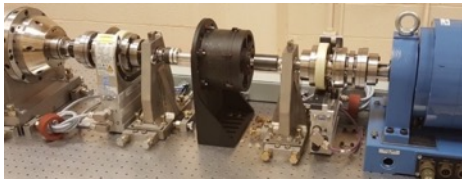
UAM Fleet Noise



UAM Operational Fleet Noise Assessment

- Noise Power Distance (NPD) database for several UAM ref. configurations & trajectories
- AEDT evaluation for UAM fleet noise assessments; provide feedback on findings & usage
- Empirical models for audibility & annoyance of UAM vehicles

Electric Powertrain Reliability



Reliable & Efficient Propulsion Components for UAM

- New labs for electric propulsion testing
- Tools to assess electric motor reliability & explore new design concepts
- Design & test guidelines for eVTOL propulsion & thermal components

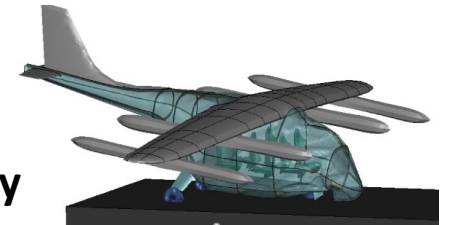
Handling & Ride Qualities



Acceptable Handling and Ride Qualities for UAM

- Human subject testing to assess handling & ride qualities
- Handling & ride qualities guidelines for UAM vehicles
- Flight dynamics & control modeling tools for conceptual design

Occupant Safety

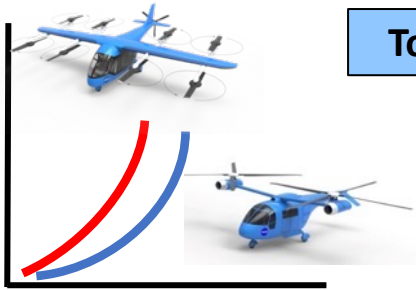
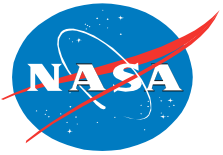


UAM Crashworthiness & Occupant Protection

- Full-scale & component level tests
- Test guidelines, modeling best practices, & vehicle technologies for crash mitigation
- Crash & impact data to consensus standards organizations

Revolutionary Vertical Lift Technology Project

Research Focus – Vehicle Noise and Safety; Recent Progress

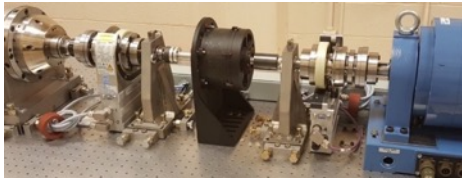


Noise & Performance

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

- Held Conceptual Design Toolchain Workshop #4 in August
- Completed rotor hover validation test and side-by-side rotor performance test acquiring data for toolchain validation

Electric Powertrain Reliability



Reliable & Efficient Propulsion Components for UAM

- Acquired data for high voltage DC power quality standard.
- Established methodology for motor reliability prediction.
- Concluded concept design of fault-tolerant modular motor.

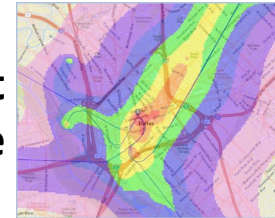
Handling & Ride Qualities



Acceptable Handling and Ride Qualities for UAM

- Completed 2nd generation flight dynamics & control models.
- Conducted handling qualities test in the Vertical Motion Simulator establishing a baseline design criteria for flight control systems.

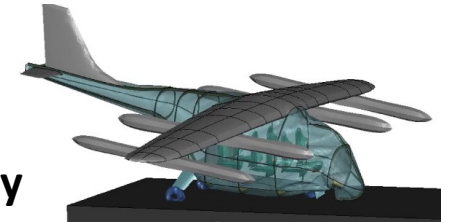
UAM Fleet Noise



UAM Operational Fleet Noise Assessment

- Preliminary recommendations for AEDT modifications to support UAM with FAA/AEE.
- Completed psychoacoustic test assessing multiple flyover events relative to annoyance.
- Measured Moog SureFly acoustics in hover for validation of acoustic predictive models

Occupant Safety

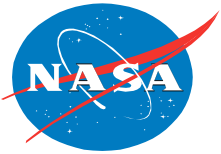


UAM Crashworthiness & Occupant Protection

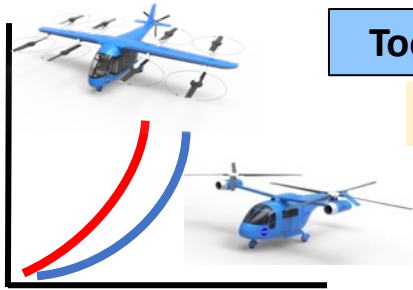
- Completed full-scale composite cabin drop test.
- Developed validated LS-DYNA model of Lift-plus-Cruise configuration.
- Developed plan for batter pack drop testing.

Revolutionary Vertical Lift Technology Project

Research Focus – Vehicle Noise and Safety; **FAA & Standards Org Interactions**



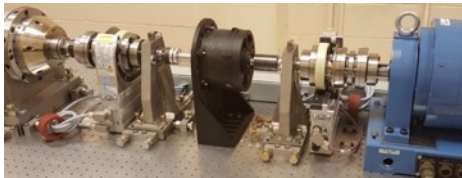
Noise & Performance



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

- NASA/FAA UAM Aircraft Design & Development Working Group

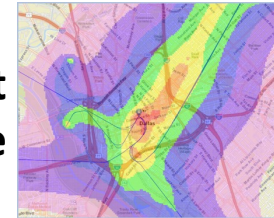
Electric Powertrain Reliability



Reliable & Efficient Propulsion Components for UAM

- SAE AE-7 Aerospace Electrical Power & Equipment Committee
- AE-7A AS-8441 Permanent-Magnet Propulsion Motors & Drives
- AE-7C AS-7499 High Voltage DC Power Quality

UAM Fleet Noise



UAM Operational Fleet Noise Assessment

- Agreement with FAA/AEE on UAM community response test planning
 - ICAO WG1 N.06 ETA Subgroup
 - SAE A-21 development of noise sphere guidance

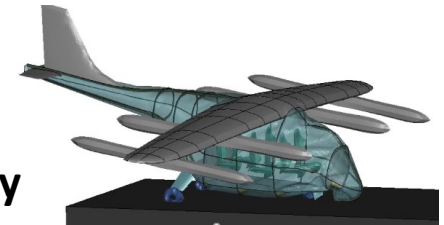
Handling & Ride Qualities



Acceptable Handling and Ride Qualities for UAM

- NASA/FAA UAM Aircraft Design & Development Working Group

Occupant Safety



UAM Crashworthiness & Occupant Protection

- ASTM D30 Committee on Composite Materials
- ASTM F44 WK68781 Means of Compliance for Dynamic Response
- ASTM F44 WK68805 Bird Strike Requirements
- SAE G-28 Simulants for Impact & Ingestion Testing



High-Speed Commercial Flight - Supersonics



Advanced Air Mobility – Vertical Flight



Ultra-Efficient Transports - Subsonics

Subsonic Airliner Technologies

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

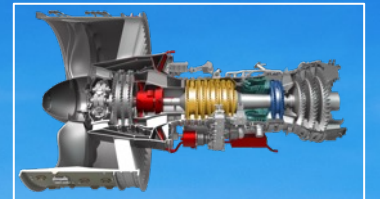
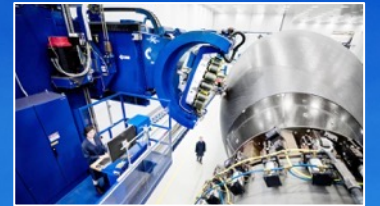
Integrated Aircraft System Efficiency
Propulsion Airframe
Integration Opportunity

Aerodynamic Efficiency
Transonic Truss-Braced Wing
(5-10% fuel burn benefit)

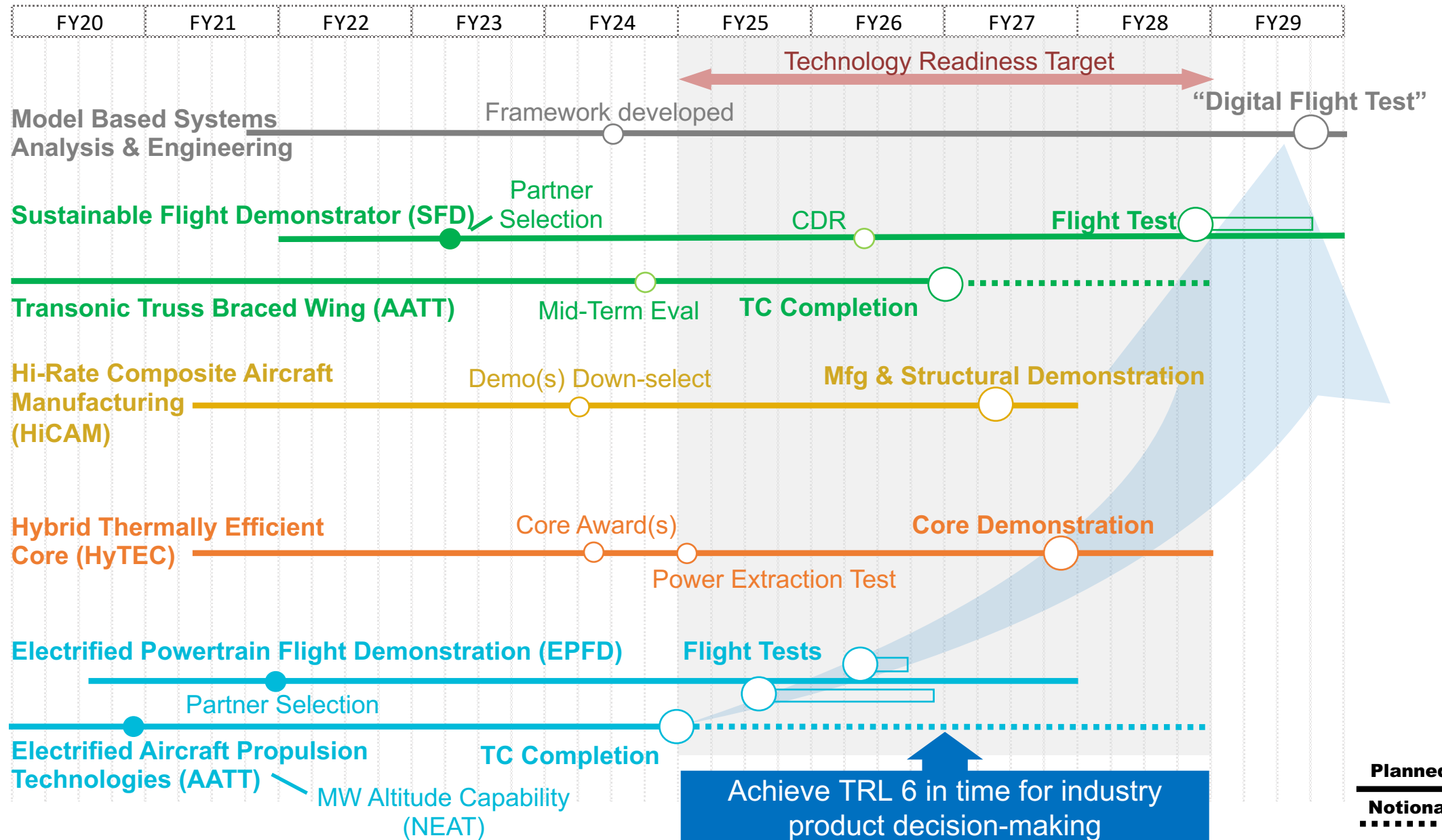
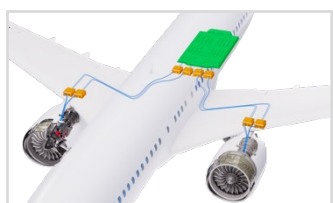
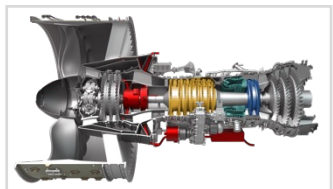
Weight
High-Rate Composites
(4-6x manufacturing increase)

Electrified Aircraft Propulsion
~5% fuel burn and
maintenance benefit

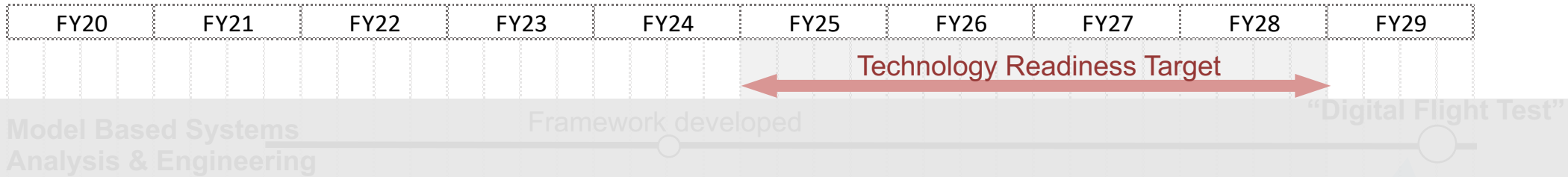
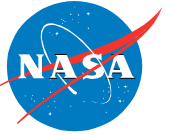
Engine Efficiency
Small Core Gas Turbine
(5-10% fuel burn benefit)



Subsonic Airlines: Integrated Technology Development



Subsonic Airlines: Integrated Technology Development



EPFD:

- GE Aviation and magniX USA Inc. contracts are in place to mature MW-class hybrid electric propulsion systems & demonstrate flight readiness for single-aisle and regional aircraft, respectively.
- GE CDR is planned for 2Q FY2024. The magniX PDR will be conducted in 2Q FY2024.

AATT/Electrified Aircraft Propulsion:

- Prototypes complete and TRL-6 tests ongoing for MW-class GE inverter and circuit breaker technology with 3 partners – Navy, GE, and Raytheon – as part of EAP Fault Management contracts
 - Results very favorable and highly relevant for flight applications
- Coordinated with ULI to test MW motor-inverter at NEAT.
 - Preparing for two additional tests in FY24 (magniX and 2-MW Industry Partner) followed by test support for ARPA-E ASCENT motors

Electrified Powertrain Flight Demonstration (EPFD)

Flight Tests

Partner Selection

Electrified Aircraft Propulsion Technologies (AATT)

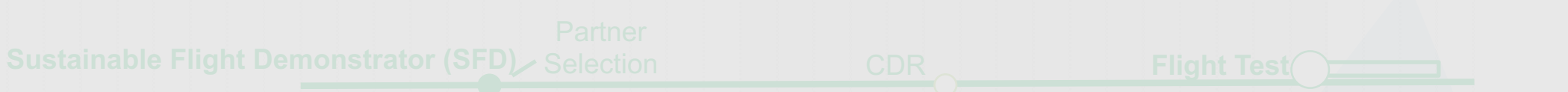
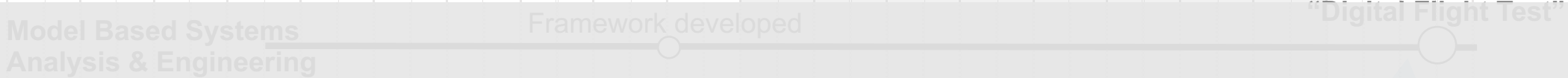
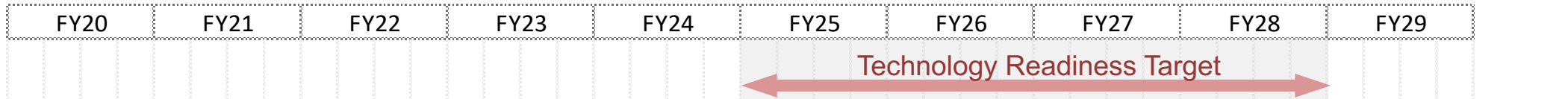
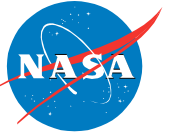
TC Completion

MW Altitude Capability (NEAT)

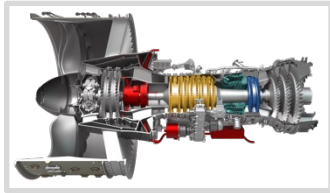
Achieve TRL 6 in time for industry product decision-making



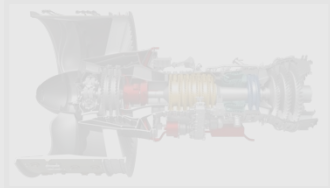
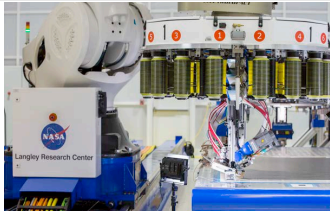
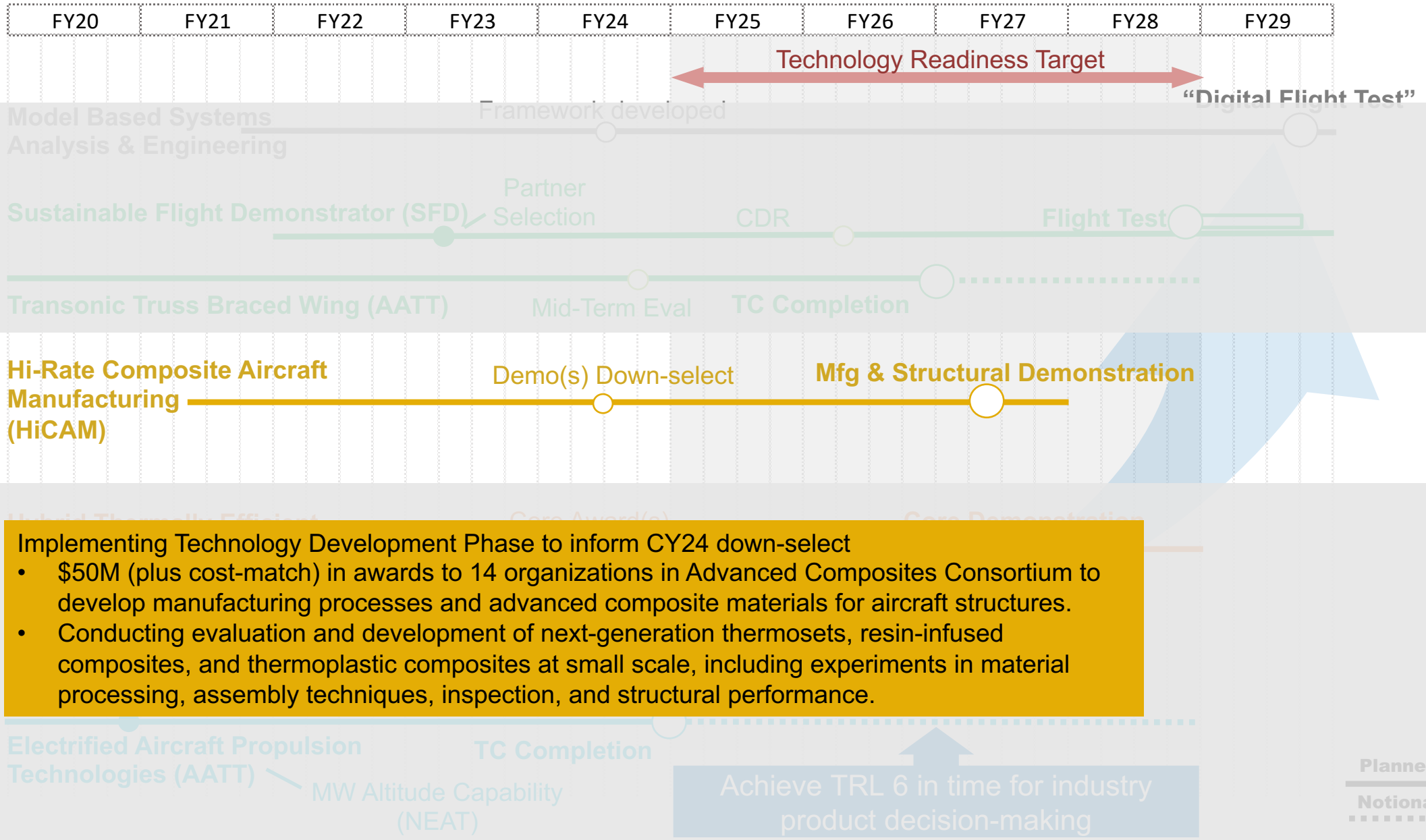
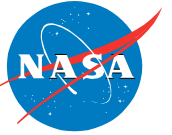
Subsonic Airlines: Integrated Technology Development



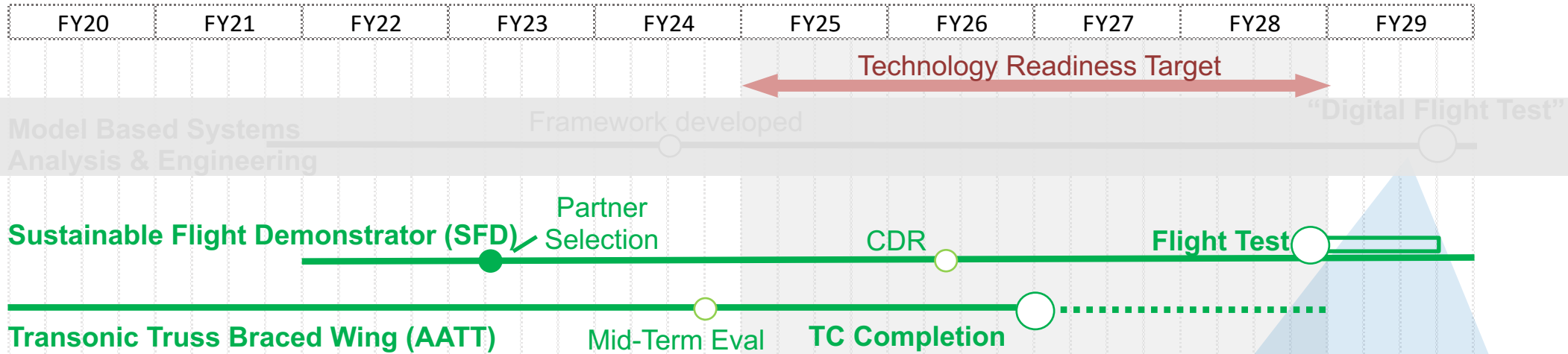
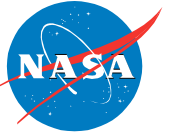
- Phase 1 small core technology development contracts are progressing toward TRL 4/5 with most planned to complete in 2024
- Phase 2 Engine Core Development solicitation proceeding as planned; contract award expected by Jan. 2024
- Completed initial systems analysis modeling with the new Model Based Systems Analysis framework to estimate the Phase 1 results against project technical metrics; projections are promising.



Subsonic Airlines: Integrated Technology Development



Subsonic Airlines: Integrated Technology Development



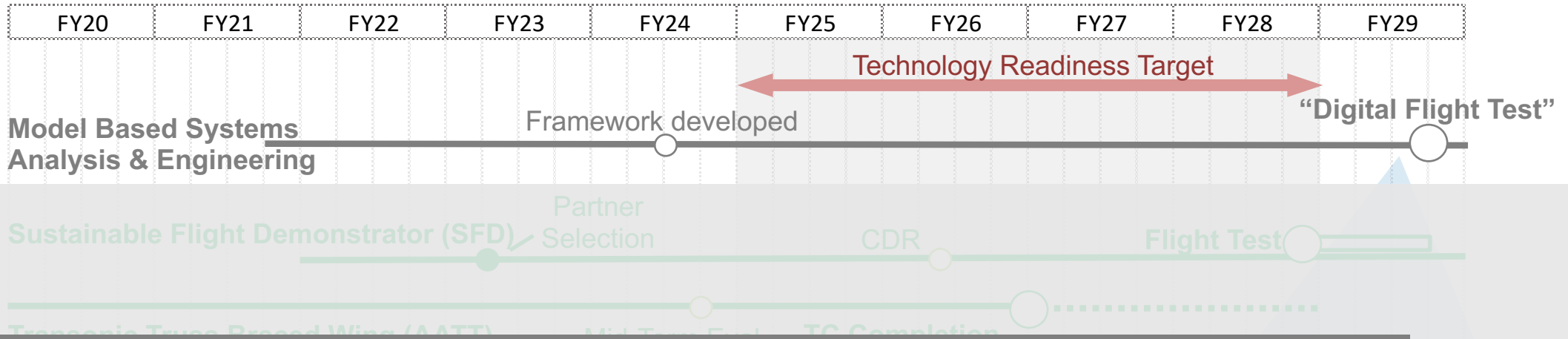
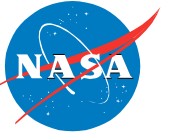
Sustainable Flight Demonstrator:

- Funded Space Act Agreement awarded to Boeing in Jan 2023 and kickoff meeting completed in Feb 2023.
- Upcoming 2023 milestones include Concept Design Review and Systems Requirements Review.
- First flight of a TTBW-based demonstrator aircraft with associated technologies planned for late Sept 2028.
- June 2023 announcement of Sustainable Flight Demonstrator's new X-66A designation
 - July 2023 livery announced at OshKosh

AATT/Ultra Efficient Wing (TTBW):

- SUGAR TTBW Phase VI-A contract task awarded to Boeing in April 2023 with 7-month POP.
 - Phase VI-B cooperative agreement in process – expect award in Sept./Oct. 2023
- Test planning/model fabrication initiated for Deep Stall Risk Reduction Test at NASA Langley 12-ft Tunnel in October/November 2023.
- TTBW Wing-Truss-Junction (WJT) model design completed/fabrication initiated for testing in the NASA Glenn Icing Research Tunnel in FY24.

Subsonic Airlines: Integrated Technology Development



AATT/Systems Analysis & Integration:

- Established NASA internal SFNP MBSAE Working Group to digitally integrated research progress across SFNP (March 2023)
- Integrating propulsion, geometry, aerodynamics, structures, and cost disciplinary analysis tools within the MBSAE framework
- Industry/Academia proposals received 4Q FY2023 on development of the MBASE framework, methods, tools, and models
 - Awards planned for 1Q FY2024

Hybrid Thermally Efficient

Core Award(s)

Core Demonstration

Transformative Tools & Technologies Project:

- Completed development of Aviary v0.1.1 in Sep. 2023
 - Anticipate public release in 1Q/2Q FY2024
- Aviary integrates previous disparate tools for vehicle sizing and mission analysis into a singular code base while retaining the capability to execute legacy tool input files.

Electrified Aircraft Propulsion Technologies (AATT)

TC Completion

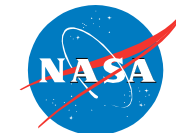
MW Altitude Capability (NEAT)

Achieve TRL 6 in time for industry product decision-making

Planned

Notional

TC 19.1: Efficient Quiet Integrated Propulsors (EQuiP)



Objective

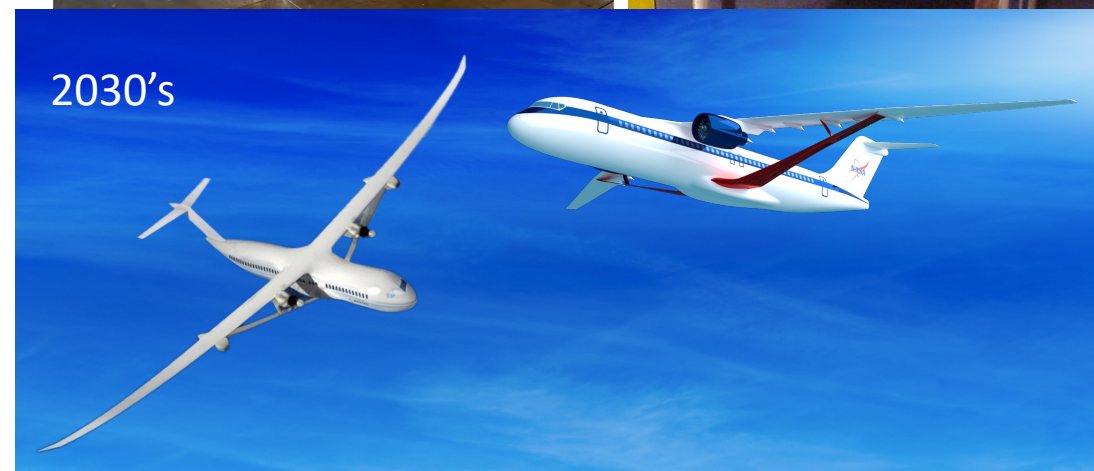
Assess, model, and predict the ability for next-generation propulsors to meet market-driven goals for noise (4dB reduction) and efficiency (3-5% fuel burn reduction) *with integration effects*, relative to 2021 best in class propulsors, and reduce risk to a new single-aisle aircraft in the 2030's.

Technical Areas and Motivation

- Unducted propulsors are a potential step-change improvement in fuel burn and emissions reduction
- Next-generation ducted propulsors with ultra-short nacelles offer evolutionary improvement in fuel burn and emissions at lower risk
- Next-generation ducted and unducted propulsors face challenges in [acoustics](#), [aeromechanics](#), [icing](#) and [airframe integration effects](#)
- NASA is uniquely positioned to address these challenges building on a long history of collaboration with FAA, engine and airframe OEMs

EQuiP TC addresses:

- NASA/Industry need for validated design tools suitable for a propulsor technology development with integration effects
- Risk mitigation for future flight tests and a 2030's product
- Limitations in NASA's propulsor prediction capabilities in support of MBS&E efforts and future vehicle studies



Addresses the Effect of Airframe on Propulsor – Propulsor Effect on Airframe TBD

Sustainable Aviation Fuels

Enable the use of 100% sustainable aviation fuels (SAF) and reduce climate impact

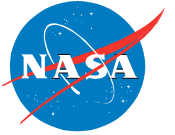


Photo Credit: Boeing / Paul Weatherman



Photo Credit: Boeing / Paul Weatherman

Scope

- Support adoption of high-blend ratio sustainable aviation jet fuels

Benefits

- Reduced aviation environmental impact
- Reduced uncertainty for climate impact of aviation-induced cloudiness
- Improved efficiency/emissions with drop-in synthetic and biofuels

Approach

- Characterize high-blend sustainable aviation jet fuel emissions on ground and in flight

In-Flight SAF Emissions and Contrail Measurements in October 2023



University Innovation Project



*University-led innovation addressing aviation challenges
Inspiring and supporting next generation of
researchers and entrepreneurs*

Continuing Portfolio Items in University Innovation



ULI Targets Faculty Proposals

- Propose to solve major, system-level technical challenges in aeronautics
- Receive \$1-2M/year for 3-4 years
- Two-step proposal submission and evaluation process
- 1 solicitation per year, typically solicitation opens in March
- Opportunities for undergraduate and graduate students to participate in aeronautics research
- Promote diversity in aeronautics with inclusion of minority-serving institutions and underrepresented university faculties

4 ULI awards / year



USRC Seeks Student Ideas

- Students propose their novel ideas for aviation
- Receive up to \$80K
- 3-page technical proposal
- 3 proposal cycles per/year, proposals due around February, June, November
- Gain technical and entrepreneurial skills
- Teams use crowdfunding (\$2K)
- Interface with NASA experts
- Open to all majors and interdisciplinary teams

10 USRC awards / year



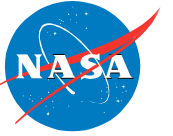
Student Group Competitions

- New competition topic each year
- As a team work on a future aviation concept
- Winning team receives NASA internships
- A 5-to-7-page paper/design study and an infographic
- Top 8 teams present to NASA
- Current competition was announced July 25, 2023, finishing end of May 2024
- Gain systems-level thinking
- Increase college students' interest in climate friendly aviation research
- Open to all majors and interdisciplinary teams

1 competition / year

*NASA seeks aviation-relevant creative ideas/concepts
from interdisciplinary university faculty and student teams*

Summary of Active ULIs Proposed and Awarded



From 30 states + DC

11 HBCUs (1 Lead) and
11 other Minority Institutions (5 Leads)

\$119M Awarded

19 Awards
with 59 Universities

29 Companies are
Team Members

Attracted 358
proposals

266 Named
Investigators

5 Women Principal
Investigators (PIs)

~300 Students Involved in Research

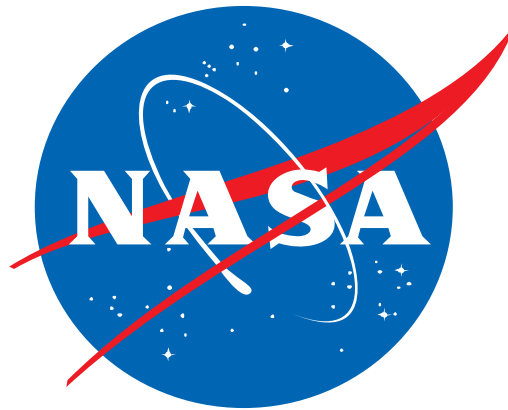
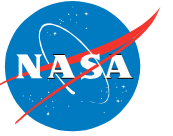
12 of 19 PIs are First Time
NASA Awardees



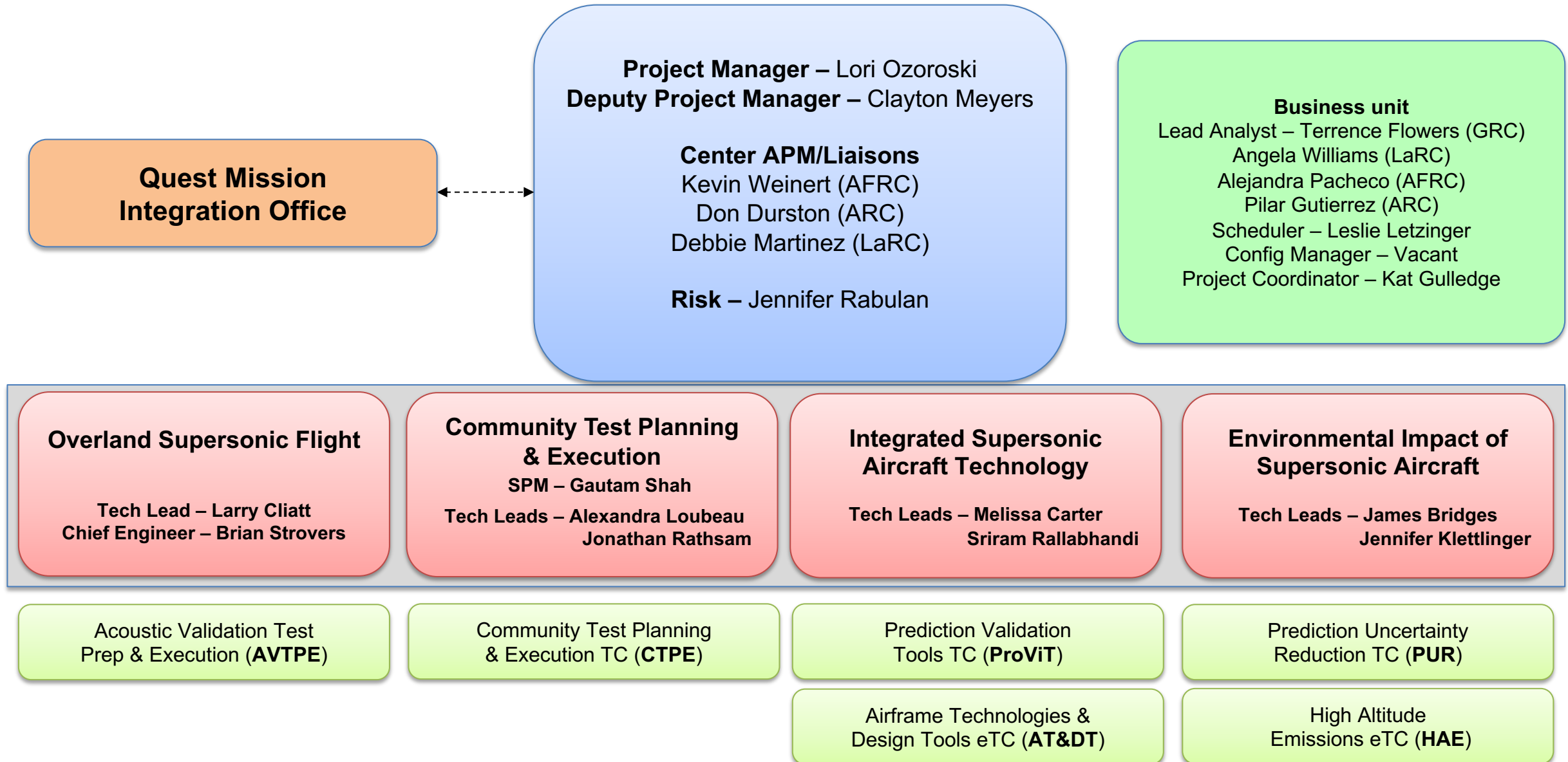
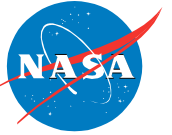


Other Important Items

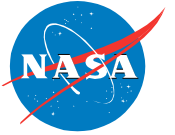
- NASA recognizes the challenge of achieving the aggressive 2050 climate goals - requires approaches that complement and go beyond current SFNP activities.
 - ❑ Collaboration with FAA for ground and in-flight emissions & contrail measurements behind Boeing ecoDemonstrator using 100% SAF and NASA DC-8 aircraft as chase plane; Oct. 2023.
 - ❑ Advanced Aircraft Concepts for Environmental Sustainability (AACES) 2050 study
 - Industry Day held on Sep. 7, 2023
 - ❑ Leveraging zero-emission aviation partnerships with universities to power toward net zero carbon and beyond.
- ARMD research efforts are well synchronized with FAA and are consistent with Administration's environmental sustainability priorities.
 - ❑ Recognized value in continuing to actively strengthen communication and coordination with other departments and agencies including DOE and FAA – and including the Inter-Agency Contrails Working Group.
- Overall support from key stakeholders continues to be strong – ARMD research efforts focused on both environmental impact and US economic growth.



CST Project Structure – Start of FY23



AATT Project Organization (October 2023)



Project Manager	<i>Dale Van Zante</i>
Deputy Project Manager	<i>Melinda Cagle</i>
Chief Technologists	<i>Scott Anders (Airframe)</i> <i>Ezra McNichols* (Propulsion)</i>
Flight Test Advisor	<i>Randy Thompson</i>
Business Manager	<i>Mark Monaco</i>
Center Integration Managers	
<i>Bruce Storms (ARC)</i>	<i>Sam Simpliciano (AFRC)</i>
<i>John Mudry (GRC)</i>	<i>Marisol Garcia** (LaRC)</i>
Center Resource Analysts	
<i>Eric Lee (ARC)</i>	<i>Alejandra Pacheco (AFRC)</i>
<i>Mark Monaco (GRC)</i>	<i>Marquetta Allen (LaRC)</i>
Project Coordinator	<i>Keshia Newsome</i>
Config. and Data Mgr.	<i>Michael J. Rogers</i>
Risk Facilitator	<i>Stephan Manchir</i>
Scheduler	<i>Leslie Letzinger</i>

* Acting

** Phased Retirement

Systems Analysis & Integration

Eric Hendricks, SPM

- **MBSA&E**
- **AACES 2050**
- **Portfolio Analysis**

Aircraft Electrification

Amy Jankovsky, SPM

- **TC 10.1 EAP**
- **eTC 10.1 EAP Challenges for Single Aisle**

Airframe Technologies

Susan Wilz, SPM

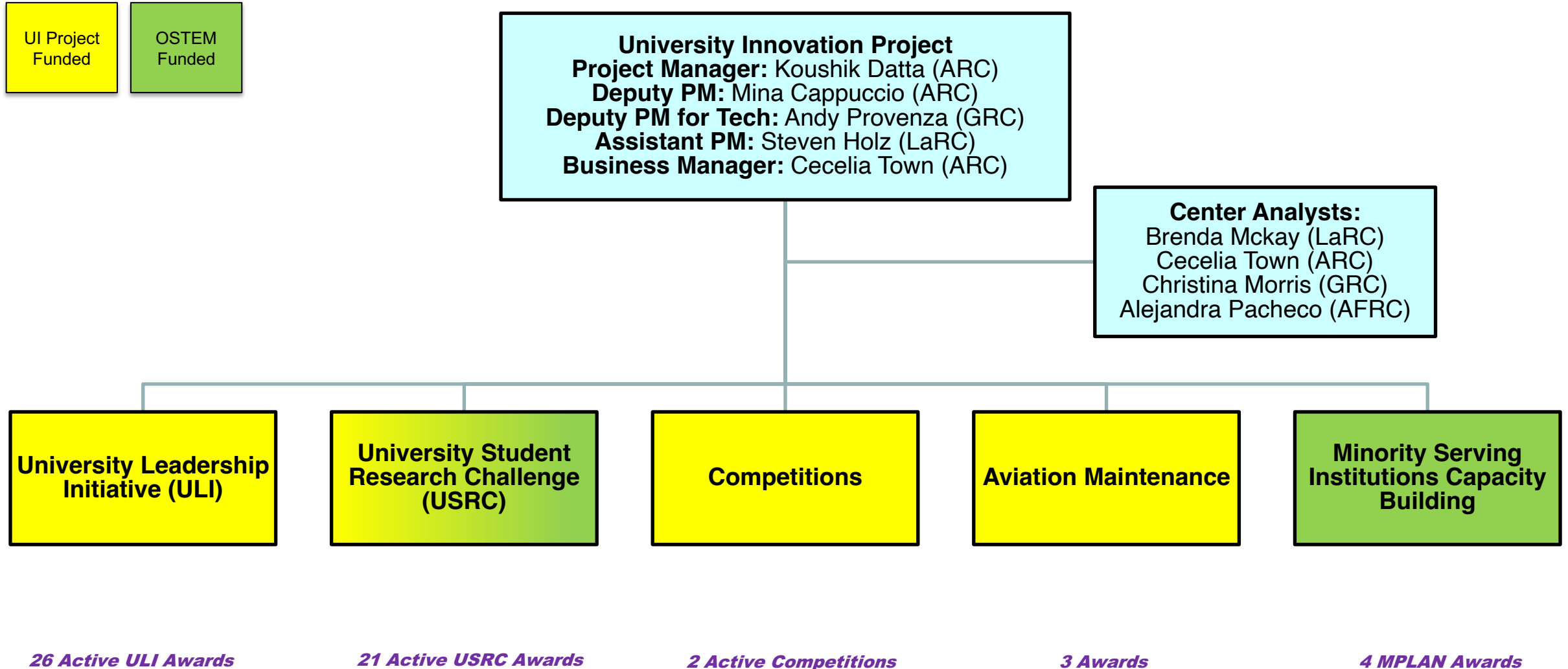
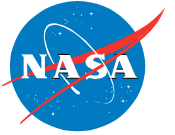
- **TC15.1 TTBW**
- **eTC 15.1 Aerosciences**
- **TC 2.1 Closeout IAWTM**

Propulsion Technologies

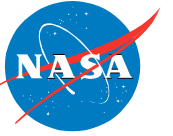
*Jess Reinert**

- **TC 19.1 EQulP**
- **eTC 19.1 Propulsion Technologies**
- **eTC 19.1 Small Core Advanced Technologies**
- **eTC 19.1 Combustion & Emissions**
- **eTC 19.1 Distortion Tolerant Propulsors**

ULI Project Management and Portfolio



Phase 1 X-59 Aircraft Development



**Major
assembly
complete**



**Engine
installation**

**Cockpit
systems
installation**

