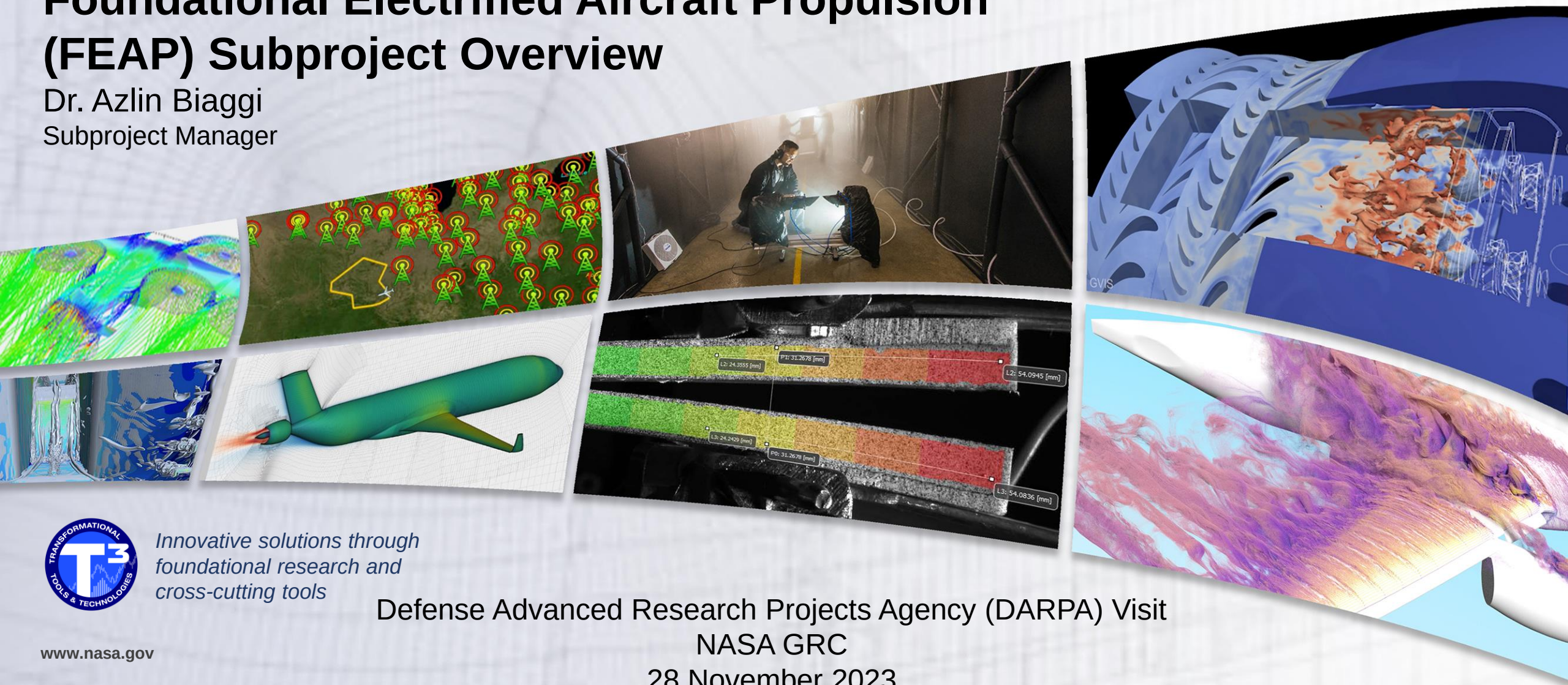


Foundational Electrified Aircraft Propulsion (FEAP) Subproject Overview

Dr. Azlin Biaggi
Subproject Manager



Foundational Electrified Aircraft Propulsion (FEAP) Sub-project



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

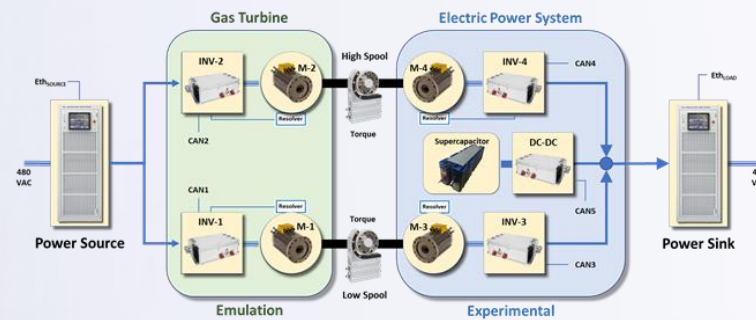
Objective 1: Enable high voltage and high-power distribution for EAP Systems (M&S)

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

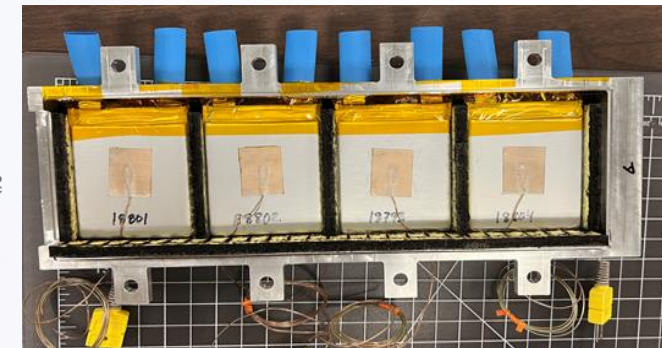
Objective 3: Develop safe battery technologies to improve performance metrics for EAP (M&S, MDAO)



Power Cable Model For Electric Materials



Hardware-in-the-loop Block Diagram



Preliminary Battery Design Pack Configuration

Evaluating Technology for Future Electric Engines



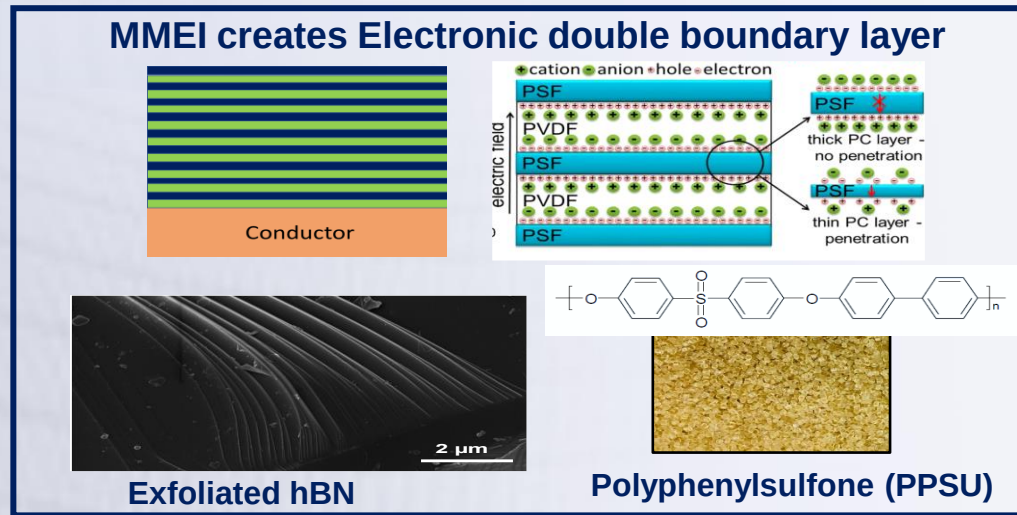
Exploring Beyond SFNP to Advance Sustainable Aviation

Established High Voltage materials modeling team (GRC & ARC)

- Modeling of modified Boron Nitride (BN) to be used as a composite filler for the development of new insulation materials

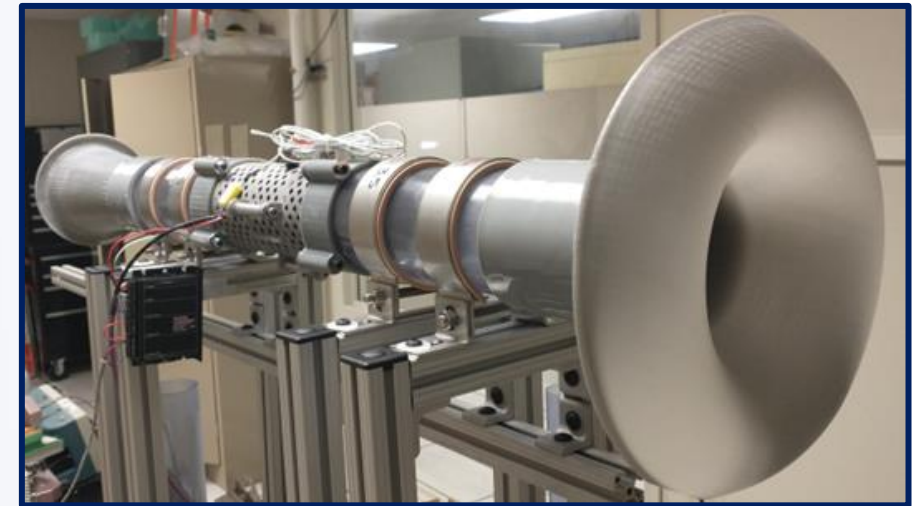
Next Generation of Micro Multilayered Electrical insulation (MMEI): Nano-MMEI

- NASA composite material significantly outperformed SOA insulation on corona resistance and surface erosion
- Impact:** Translate to much higher resistance to partial discharge, a leading cause of insulation degradation and breakdown



SmartFan: Small Scale Electric Engine with local power management and stability control

- Used to test and validate new energy management technology for stability detection and mitigation of stand-alone electric propulsors
- Potential benefits for decoupling propulsors from power source for improved power system stability while increasing the stable operating range for thrust production
- Benefits electric engines, e.g., SUSAN wing thruster or the STARC-ABL cone thruster



Collaboration with
Florida State University



SmartFan – free
hardware obtained from
ISS Program - ECLSS

Advanced Battery Technologies for the Aviation Environment



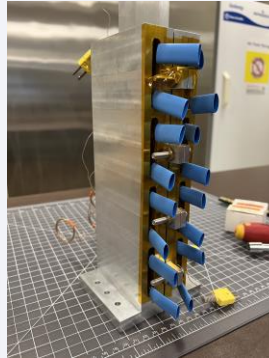
Safety-focused Design for Battery Systems in Flexible Aerospace Operating Environments

- Transitions from CAS SABERS and SPARRCI
- Develop relationships for thermal management weight as a function of battery architecture, size and composition
- Data from tests can be made publicly available and are critical for designing TMS systems that can handle runaway events

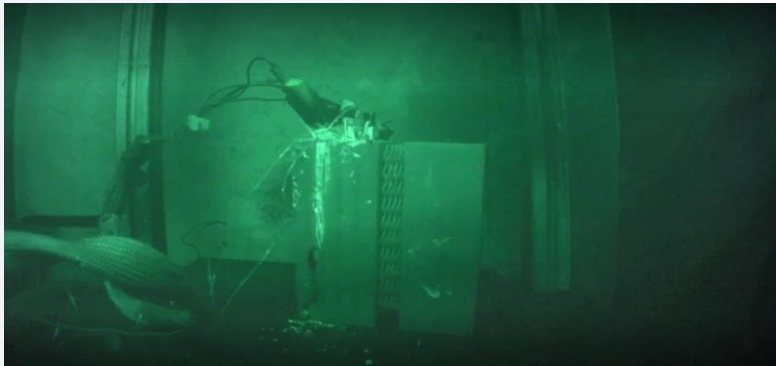
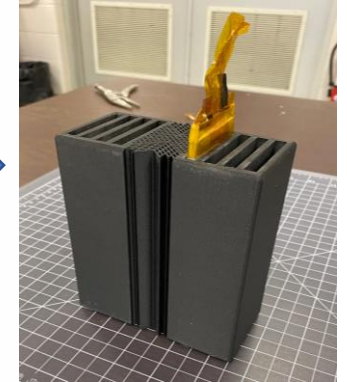
Prevention of Thermal Runaway (TR) Propagation

- 3 Li⁺ pouch cells (Amprius) inside Module 1 & 2
- TR triggered on the end cell to determine if it propagated to the other two cells
- TR event did not propagate to other cells
- **Cells 2 & 3 still intact and holding charge after TR event!!**

Battery Enclosures for Advanced Safety and Thermal (BEAST) Module 1

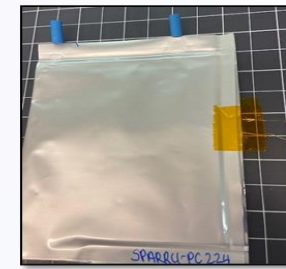
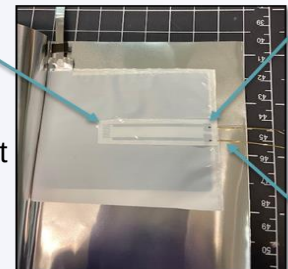


BEAST Module 2: PCM material around cell and aerogel on one side, with flex point.



SABERS Prototype Pouch Cell

Internal View of Sensor Placement



Fully assembled cell with sensor

SPARRCI Embedded Sensors



Expanding Capabilities Needed for Materials & Battery Testing



Established High Voltage (HV) Lab Capability

- Built and installed HV/High Frequency Environmental Chamber that delivers ambient pressure to high altitude conditions and partial discharge detector

Dedicated HV Lab helps mitigate safety concerns & meet safety requirements for HV testing

Acquired Automated Materials Laboratory

- Provides capability to demonstrate rapid materials development integrated with AI and ML
- Advances the time to discovery of materials with targeted properties for challenging applications

Invested in Environmental Chamber for Battery Pack Testing

- Thermotron Temperature and Altitude Chamber enables battery and cell (plus other components) level performance evaluation in conditions simulating those encountered during flight

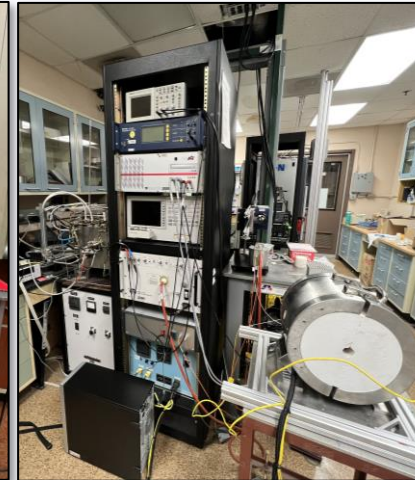
Chamber cost shared with EPFD



HV Lab



HV Chamber



HV Dielectric Spectroscopy



Pulse Electro-Acoustic Analyzer



Dielectric Rig



Altitude Chamber for Battery Pack Testing



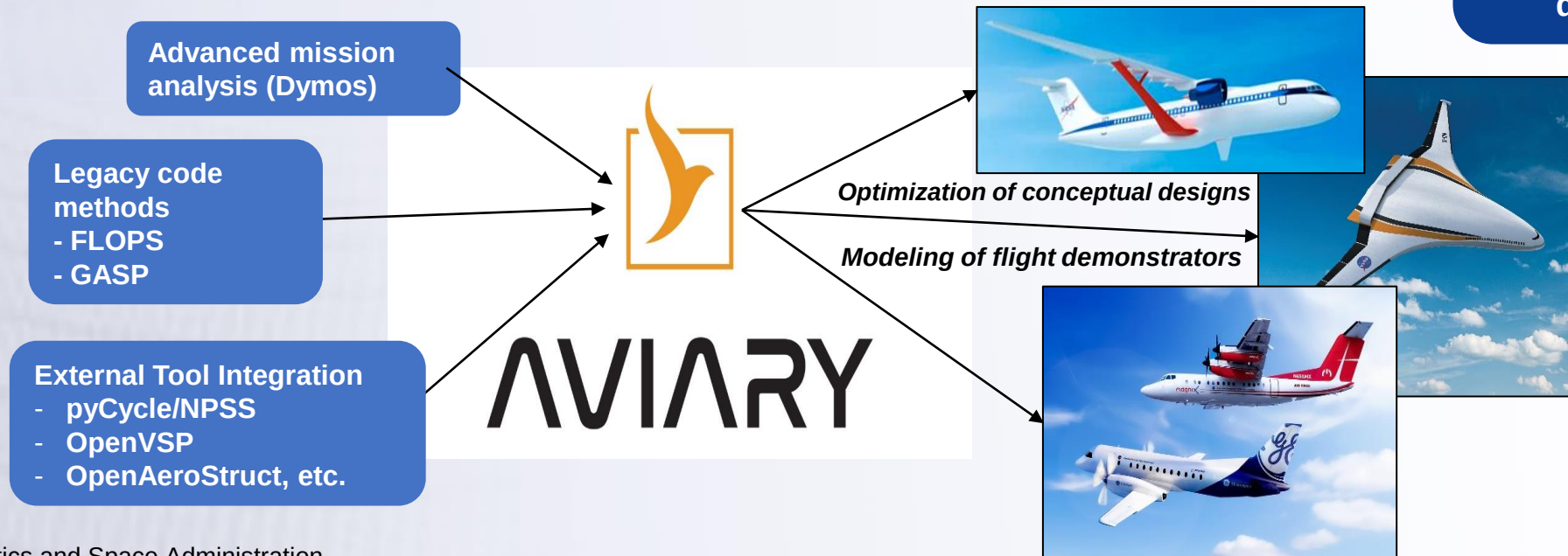
Automated Materials Laboratory (AML)

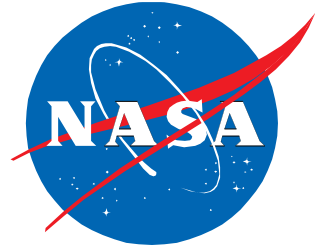
Aviary Software Tool Transition to SFNP

AVIARY Scheduled for Open-source Release by the End of 2024

- Aviary is the critical core component of the AATT MBSA&E framework
 - Framework will evaluate the transonic truss-based wing (TTBW) concept by connecting many standalone disciplinary tools
 - Aviary code must be ready to support that work
- Aviary team successfully created a TTBW model that incorporates multiple external tools into a system-level optimization
- Made significant upgrades to the Aviary source code as a part of this effort
 - Applied improvements to other tools including OpenMDAO
- Lessons learned will lead to more streamlined and user-friendly integration efforts in the future

Cross-Center teams led by early career researchers delivers on the foundation for NASA's unified aircraft design framework





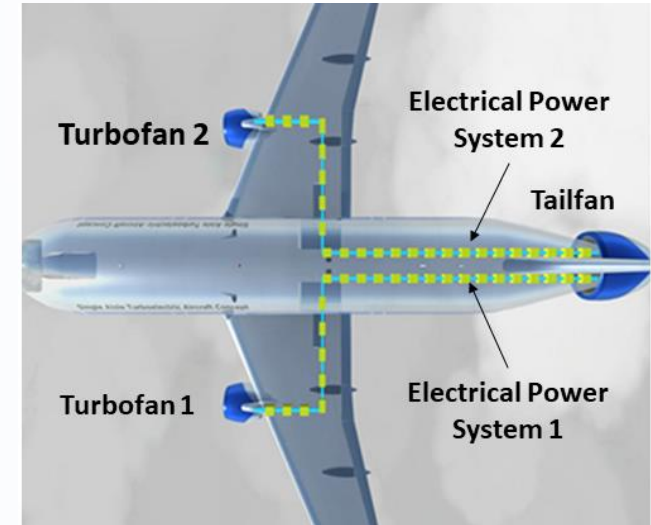
System-Level Modeling

TTT-developed tools used to demonstrate recovery from catastrophic faults in an electrified aircraft powertrain using a piloted flight simulator, with certification implications



Real-time electrified powertrain fault recovery demonstrated in piloted flight simulator

- **Details:** System-level modeling of the Single-aisle Turboelectric AiRCraft with Aft Boundary Layer Propulsor (STARC-ABL) powertrain using TTT-developed Toolbox for the Modeling and Analysis of Thermodynamic Systems (T-MATS) and the Electrical Modeling and Thermal Analysis Toolbox (EMTAT). Injected faults with realistic cascading catastrophic failures, on-line real-time fault detection, and robust reversionary control modes that recovered safe operation as well as certification implications.
- **Impact:** Demonstration of realistic fault injection and recovery assists the certification of electrified powertrains and provides a roadmap on how current regulatory standards can be applied to future aircraft designs.
- **Partners:** CAS SUSAN and AAAMP/AATT/Power and Propulsion Subproject, NASA Aero priorities F
- **Alignment:** Alternate demonstration of fault detection and recovery in the electrified powertrain of the Single-aisle Turboelectric AiRCraft with Aft Boundary Layer Propulsor (STARC-ABL) from an AATT L2 milestone.



STARC-ABL diagram showing powertrain components



Piloted flight simulator evaluation of powertrain fault modeling and recovery, and certification-type testing

Controls Testing Capabilities

Small, agile hardware-in-the-loop to explore controls and dynamics in real-time



- **Hybrid Propulsion Emulation Rig:** Reconfigurable subscale testing of full-scale Hybrid Propulsion architectures and dynamics in real-time
 - **Details:** Used to demonstrate TEEM control feasibility and validate modeling performance. Used extensively to test and validate engine controls including OEM models prior to engine testing.
 - **Impact:** Enables rapid prototyping of controls concepts in a low-cost testing environment for risk mitigation prior to large scale testing. Exceptional opportunity for work-force development.
 - **Partners:** HyPER is a joint effort between T3 and HyTEC
 - **Alignment:** SIP Thrust 3, HyTEC, AATT



Status Key	
●	Concluding
●	Ongoing
●	New
●	Pivot/Change