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Safety and Certification for Electrified Propulsion

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Markets

- NASA is investing in research to enable Electrified Aircraft Propulsion (EAP).
 - NASA is working across a range of markets
 - The overarching strategy is to create enabling technology, demonstrate this technology in flight-test vehicles, and transfer the knowledge to industry for future products
 - Electrified aircraft propulsion has varying impact on air vehicle design depending on the key requirements of the market that the vehicle is intended to serve



Market: National/International

Impact: Fuel Burn/Emission
Reduction



Market: On demand mobility

Impact: New mobility capability



Market: Regional

Impact: Revitalization of smaller
routes

NASA Programs and Electrified Aircraft Content



Advanced Air Vehicles Program (AAVP)



Airspace Operations and Safety Program (AOSP)



Integrated Aviation Systems Program (IASP)



Transformative Aeronautics Concepts Program (TACP)

Vehicle Technology Maturation

Revolutionary Vertical Lift Technologies
<1MW

Advanced Air Transport Technologies
>1MW

Flight Demonstrations & Capabilities

Advanced Air Mobility
X-57
Electrified Powertrain Flight Demo

Transformative Tools & Technologies

Convergent Aeronautics Solutions
University-led Initiatives

R&D is managed by identifying and seeking to overcome Technical Challenges

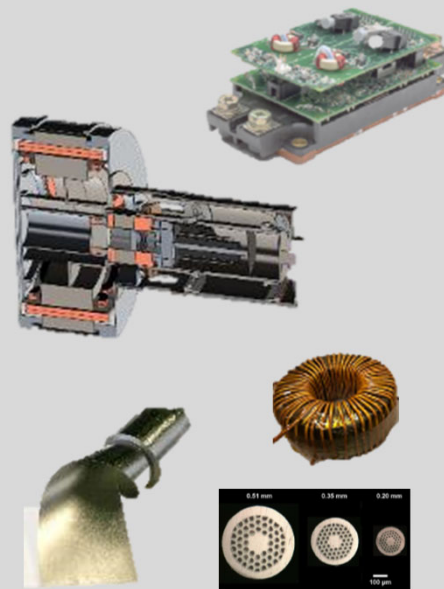
Safety Technology Maturation

Advancing Technical & Integration Readiness

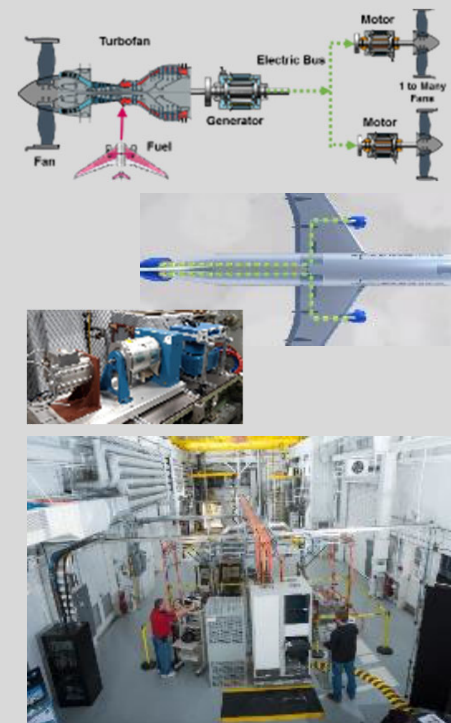
- 1**
- Concept Vehicles
 - Technology Gap Assessments
 - Key Performance Parameter Identification
 - Market Research
 - FMECA Studies



- 2**
- Subsystems
 - Components
 - Devices
 - Enabling Materials



- 3**
- Ground Testing
 - Integrated systems



- 4**
- Flight Experiments in relevant environment
 - UAM Grand Challenges

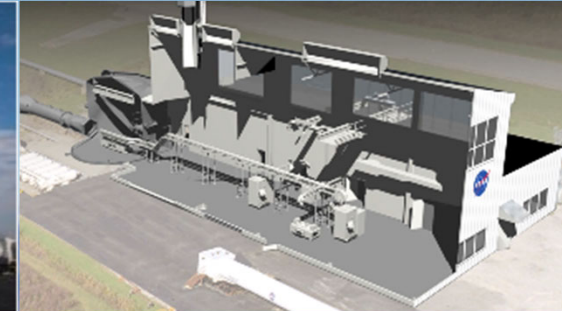


- Key data informing product decisions
- Knowledge to support certification
- Learning to inform further fundamental research

NEAT Powertrain Lessons

Reconfigurable Powertrain Testbed for Fault Testing

- Located at NASA Glenn Plum Brook Station in the recently refurbished Hypersonic Tunnel Facility (HTF)
- Supports full-scale megawatt powertrain testing under actual flight scenarios with cryogenic fuel, high voltage, large wingspan, electromagnetic interference, and high altitude



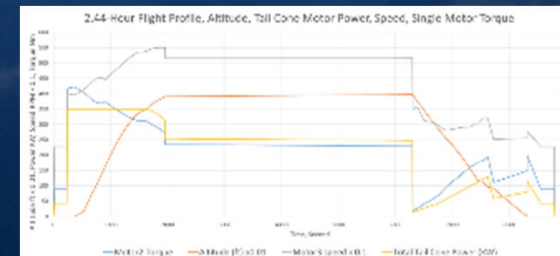
TRL maturation:

- | | |
|--|--|
| <ul style="list-style-type: none"> • High voltage bus architecture –
Insulation, geometry, 600V up to 4500V • High power MW Inverters, Rectifiers-
Commercial, In-House, NRAs • High power MW Motors, Generators-
Commercial, In-house, NRAs • System Communication –
Aircraft CAN, Ethernet, Fiber-optics | <ul style="list-style-type: none"> • System EMI Mitigation and Standards –
Shielding, DO-160G, MIL-STD-461 • System Fault Protection –
Fuse, Circuit Breaker, Current Limiter • System Thermal Management –
Active/Passive, Ambient/Cryo • Altitude Integration-
Cosmic, creepage, partial discharge |
|--|--|



Powertrain Lessons Learned:

- | | |
|--|---|
| <ul style="list-style-type: none"> • EMI shielding is critical for safe and proper operation of the powertrain even with DO-160G compatible equipment. • Federated fault response with localized feedback/controls are important for orderly shutdown sequencing. • System interactions between components must be tested to account for common modes, grounding loops, and resonant conditions | <ul style="list-style-type: none"> • Optical fiber and digital instrumentation are required for robust communication and sensors • Higher voltage and current present new issues such as insulation resistance breakdown and power quality challenges when operating near rated equipment limits • Shielding throughout the powertrain limits the ability to acquire data from transducers forcing calculated software measurements. |
|--|---|



Flight Demonstrator Projects

X-57 All-Electric

Goal – Help develop certification standards for emerging electric aircraft market

- High aspect ratio wing enabled by high lift system, wingtip propellers
- Better cruise efficiency, zero in-flight carbon emissions, quieter flight

Mod II



Mod III



Mod IV



ELECTRIFIED POWERTRAIN FLIGHT DEMONSTRATION

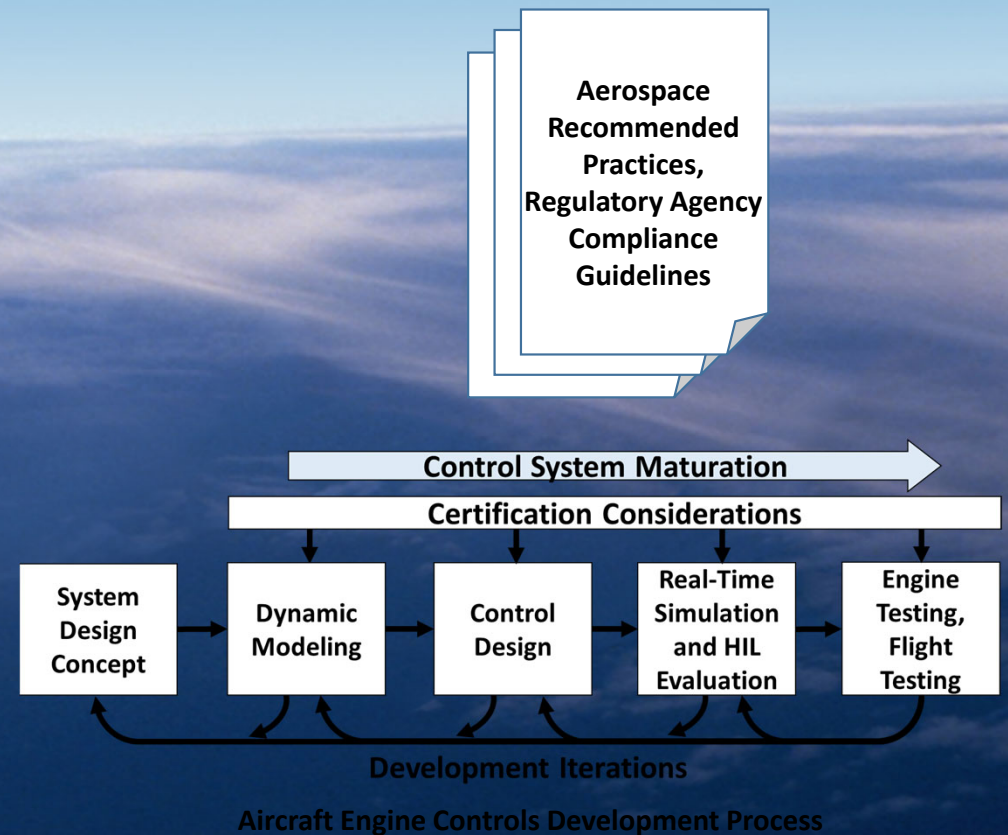
Certification Goal: plan ground and flight test campaigns to provide appropriate data to establish standards to address gaps in certification requirements

- Lower operating costs, lower mission fuel burn with reduced carbon and nitrogen oxide (NOX) footprints, and reduced community noise
- Demonstrate practical vehicle-level integration of MW-class Electrified Aircraft Propulsion (EAP) systems, leveraging advanced airframe systems

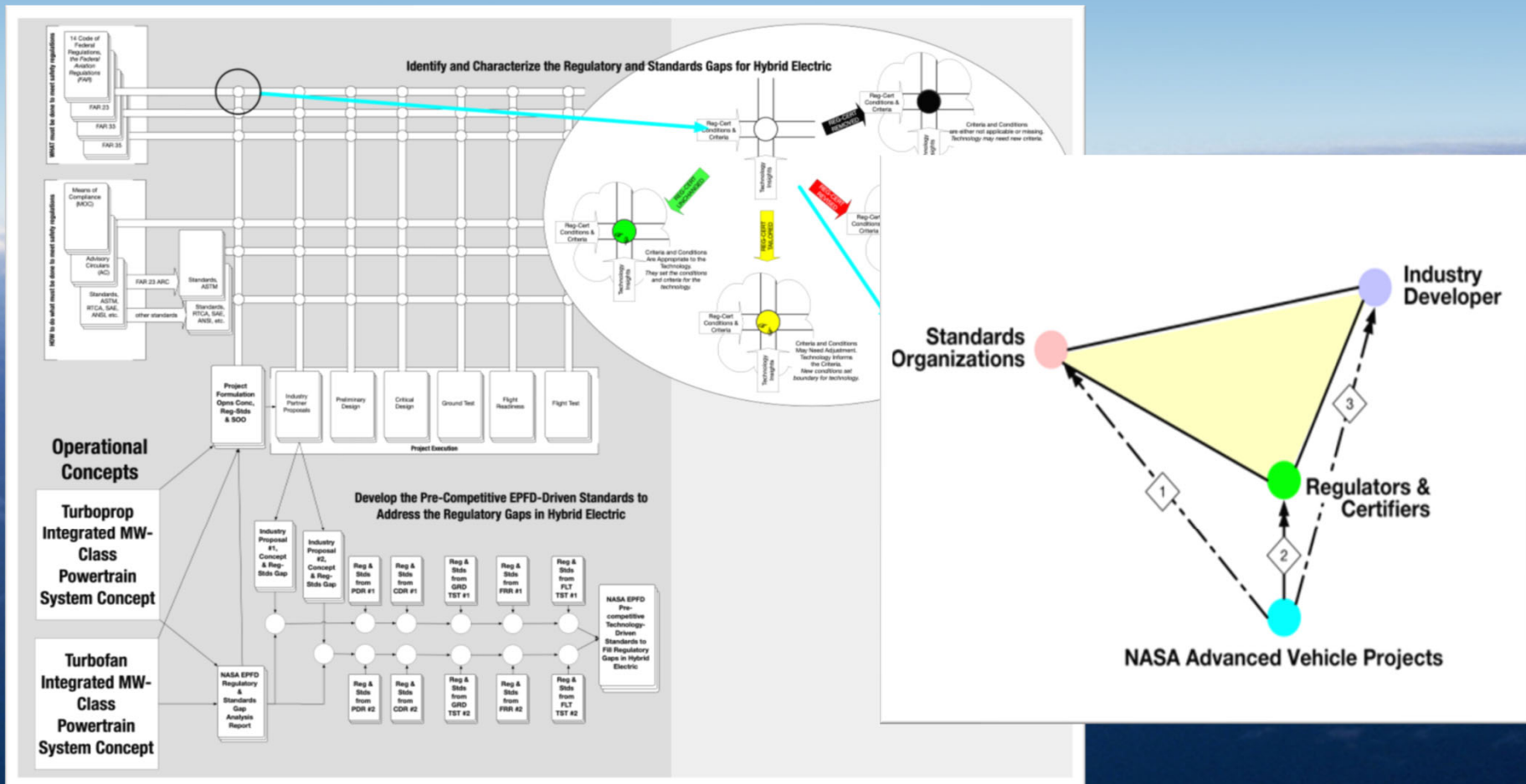


Certification Committee Status

- Established guidelines and safety assessments for EAP aircraft
- Control design has a significant role in assuring that EAP systems comply with the airworthiness standards
- The inherent coupling in EAP designs may necessitate certification of the full EAP system



Certification Roadmap



Summary and Vision

Feasible Vehicle Class Driven by Powertrain Specific Power and Efficiency
and Integrated Vehicle Design Optimization
Power, Propulsion, Thermal, and Airframe Safety Integration Key

- MW-class powertrain systems require new safety technologies due to high voltage, distributed low exergy, and multi-scale dynamics
- Electric Aero-Propulsion is enabled by new class of safety technologies:
 - Fault Management
 - Thermal Management
 - Distributed Controls
- Global EAP Market Acceptance Facilitated by International Standards Collaboration

