Aerospace Electrification- Development and Test For More Electrified Aircraft

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PM, Electrified Powertrain Flight Demonstration Project

NASA Integrated Aviation Systems Program

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Why Aerospace Electrification

1

Energy Efficiency

- Finding pathways to electrified flight could lead to significant energy and disruptive improvements in Cost per Average Seat Mile (CASM), and lower operational expenses

2

Mission Flexibility

- Potential for purpose-built, “mission-optimized” EAP to meet operational demands of specific routes, markets, and policy goals

3

Regional Market Sector Growth

- Significant market exists for EAP aircraft if the performance, operational and infrastructure requirements can be achieved
- Hybrid vehicle can cover 73% of the existing mid-sized cargo network within the range of 750 miles

Transformation to More Electrified Aircraft

with Advances in Energy Sources/Storage Systems

- Battery Pack specific energy
  - Have improved > 250% since the 90s
- Advanced chemistries needed to reach higher values
- Pack factors need reduction from 32% to 10-20%



25-50 miles

20 PAX commuter



100 miles

Current, 170-200 Wh/kg



100 miles

20 PAX commuter



200 -250 miles

300 – 350 Wh/kg

2026: In Development NOW

50 – 70 PAX



400 Wh/kg

Regional

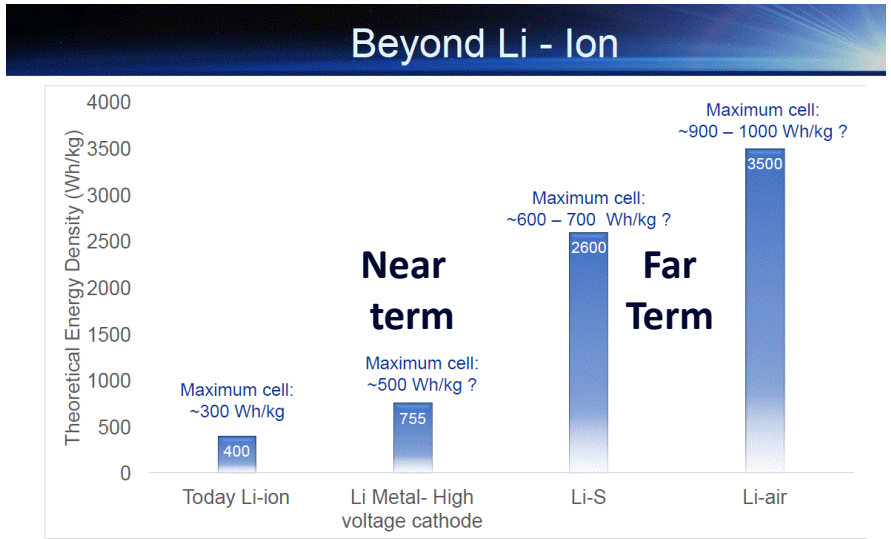


500 Wh/kg

Single-aisle, 737 class



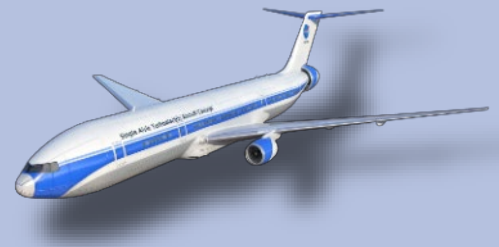
1000 Wh/kg



2030-2035 Entry-Into-Service Targets for EAP:
Thin haul, regional and next generation single aisle markets







Market	Regional Air Mobility	Regional Turboprops & Turbofans	Single Aisle
Passengers	*1-19*	*20-150*	*150-more*
Speed	*≈150-250 mph*	*≈300-400 mph*	*≈500-700 mph*
Range	*≈100-500 miles*	*500-1500 miles*	*1500-3500 miles*
Power	*≈1MW*	*1 to 5 MW*	*3 to 30MW*
Heat	***≈200 kW waste heat***	***200kw to 1MW waste heat***	***600kW to 6MW waste heat***

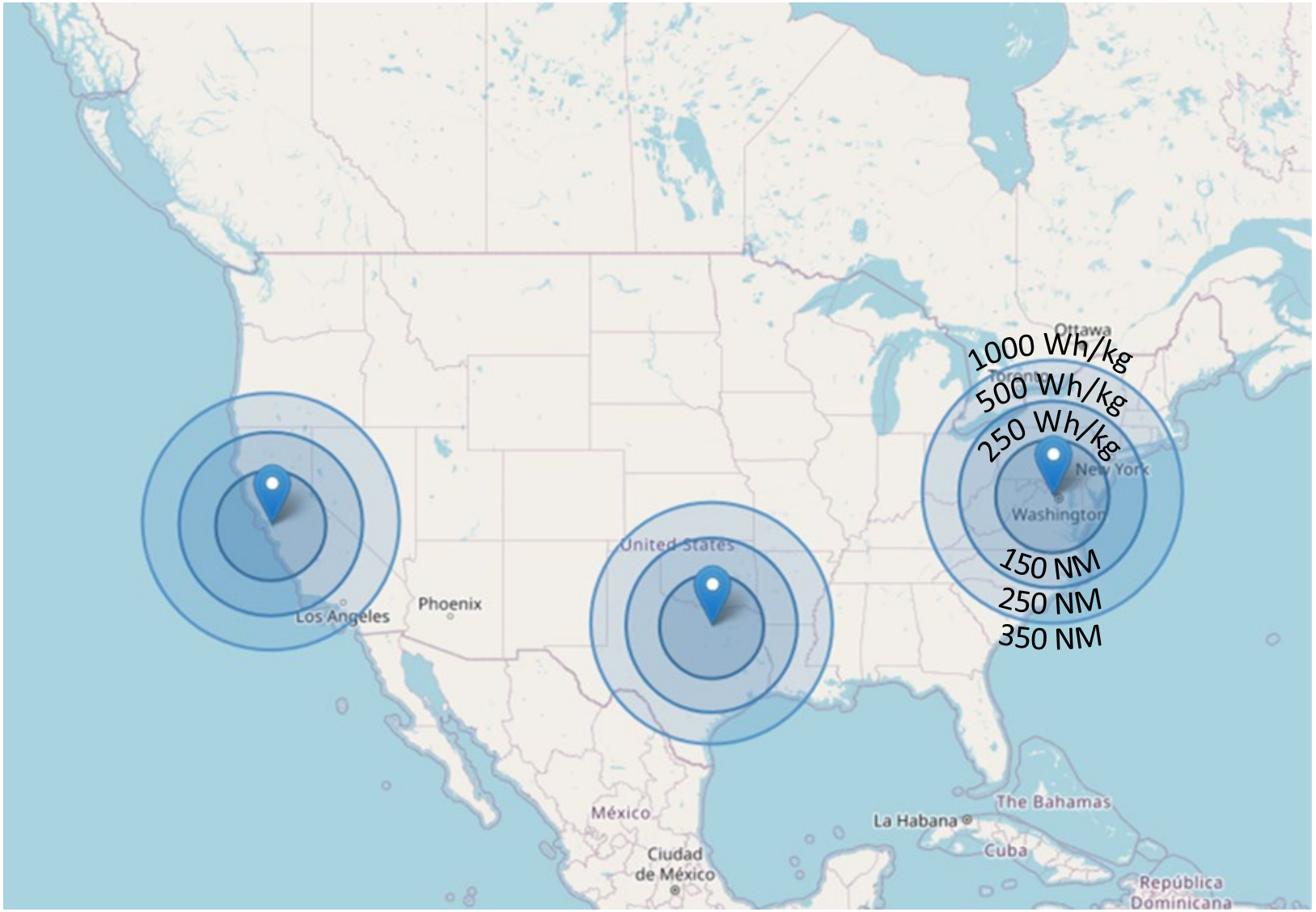
MW-Class EAP Barrier Risks to EIS in the 2030s

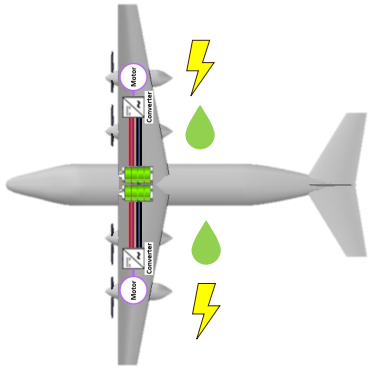
	Technical Barrier Risks	Integration Barrier Risks	
Essential For **Weight**	**High-Voltage Operation @ Altitude** Partial discharge and corona of high power/voltage transmission cables	**Powertrain System Integration** Stability, EMI compatibility, or performance requirements which will require redesign	Essential For **Weight**
Essential For **Weight**	**Battery System Performance Shortfall** Aviation grade, state of charge performance across mission, and recharging in flight	**Propulsion System Integration** Operational challenges integrating the turbomachinery with electric machines	Essential For **Lifetime**
Essential For **Lifetime**	**Thermal Management** Low grade waste heat requires a low parasitic power Thermal Management System	**Aircraft System Integration** Design challenges integrating EAP with existing aircraft systems	Essential For **Lifetime**

Priority EAP A/C Technologies

Electric Engines		ASTM F39.05 SAE E-40 IEC 60439-4	• PMM Tests supporting HV cable loads • Continued development of ASTM F3338 Standard Specification for Design of Electric Engines
Energy Storage Systems		ASTM F39.05 SAE AE-10 RTCA DO-311	• Development of AS7499, Power Quality for HV systems (SAE AE-10) • New Guide for Design and Production of Energy Storage Systems to Power Aircraft Propulsion (ASTM F39)
Wiring & Connectors	 	SAE AE-10 SAE AE-7	• Cable tests to support HV standards for AE-10 High Voltage Committee and AE-7 Aerospace Electrical Power and Equipment Committee (SAE) • Arc fault detection requirements and technology (SAE)
Airplane Integration		SAE E-40 ASTM F44 RTCA DO-160	• ARP8677, Safety Considerations for Electrified Propulsion Aircraft (SAE) • Powerplant working groups on the installation of propellers for electric engines, ASTM • Powerplant Displays for electric engines

50 PAX Near-Term Regional Turboprop Operations Tradespace

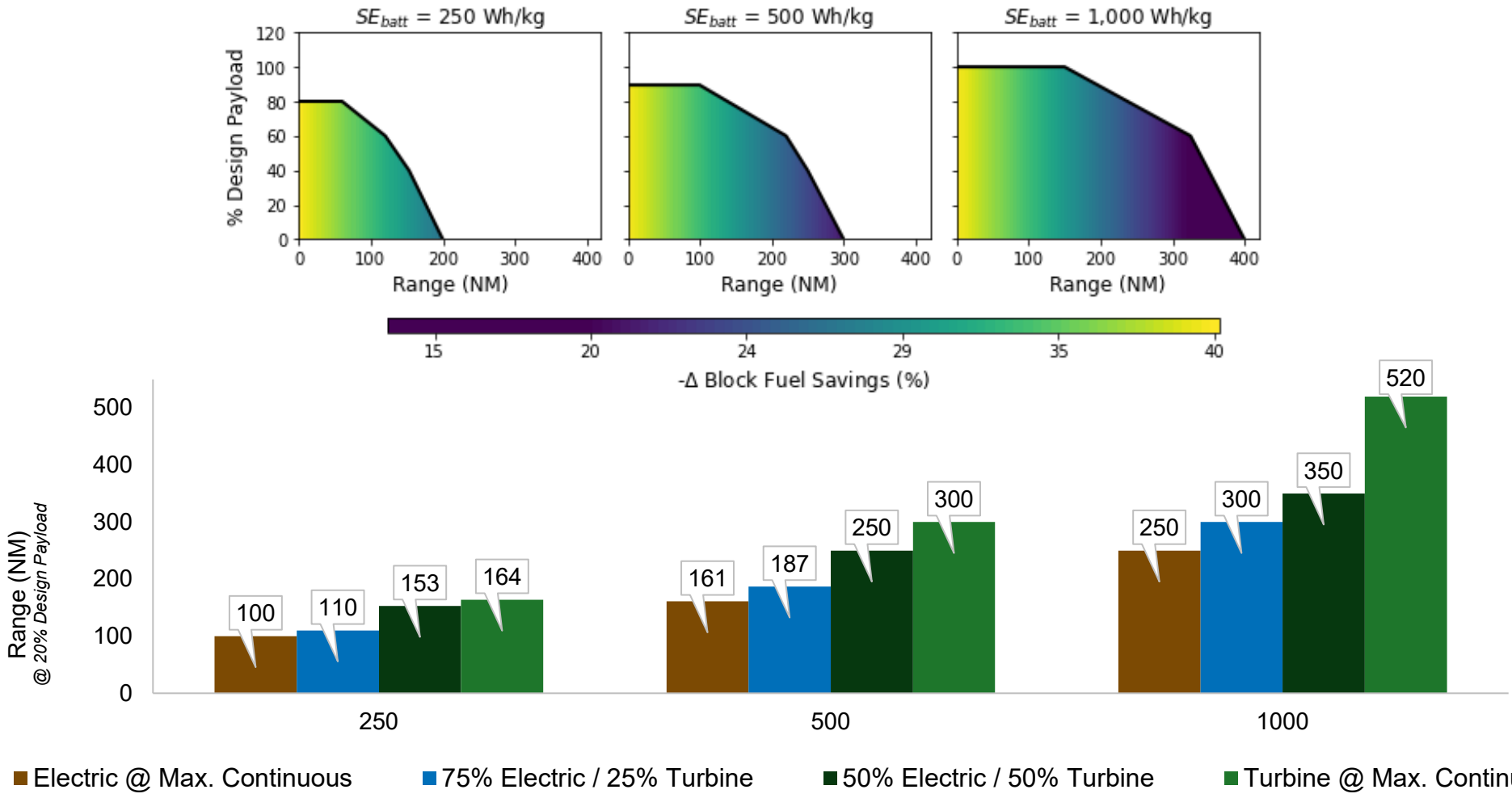




50/50 Cruise Power Split
At 20% of Design Payload

For the same aircraft, improvements in Battery Specific Energy expand maximum range performance, allowing for improved market coverage

Hybrid-Electric 50 PAX Regional Turboprop Payload-Range

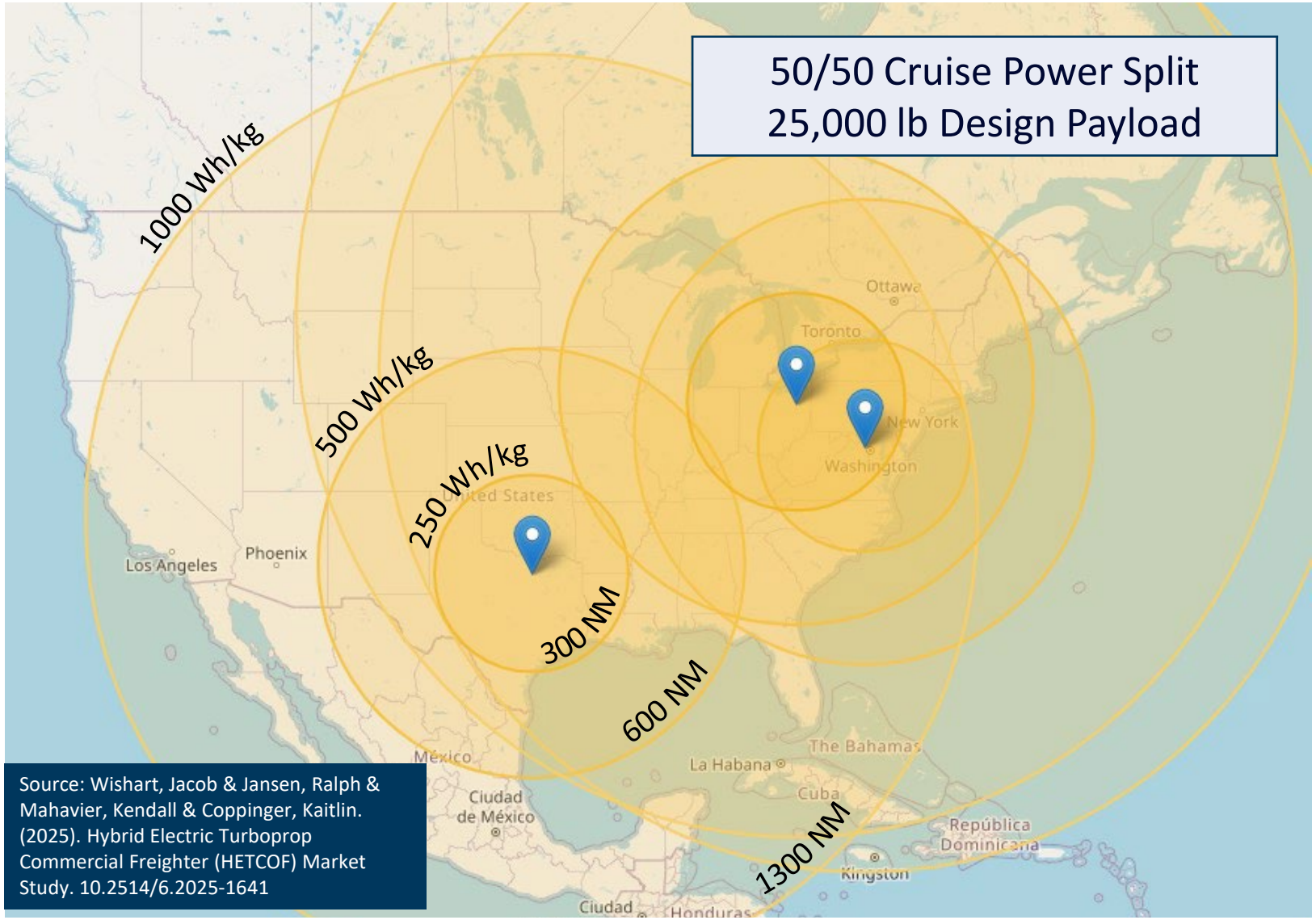


Payload capacity and range performance expands with improvements to battery technologies

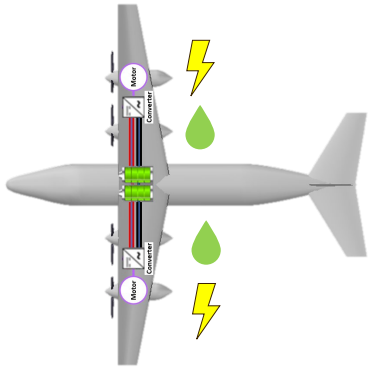
Parallel-hybrid architecture enables flexibility in efficient power-split throughout flight to achieve target ranges at optimal fuel savings

Potential for purpose-built, "mission-optimized" EAP to meet specific routes, markets, & policy goals

Mid-Term (2035) EAP Turboprop Freighter Operations Tradespace



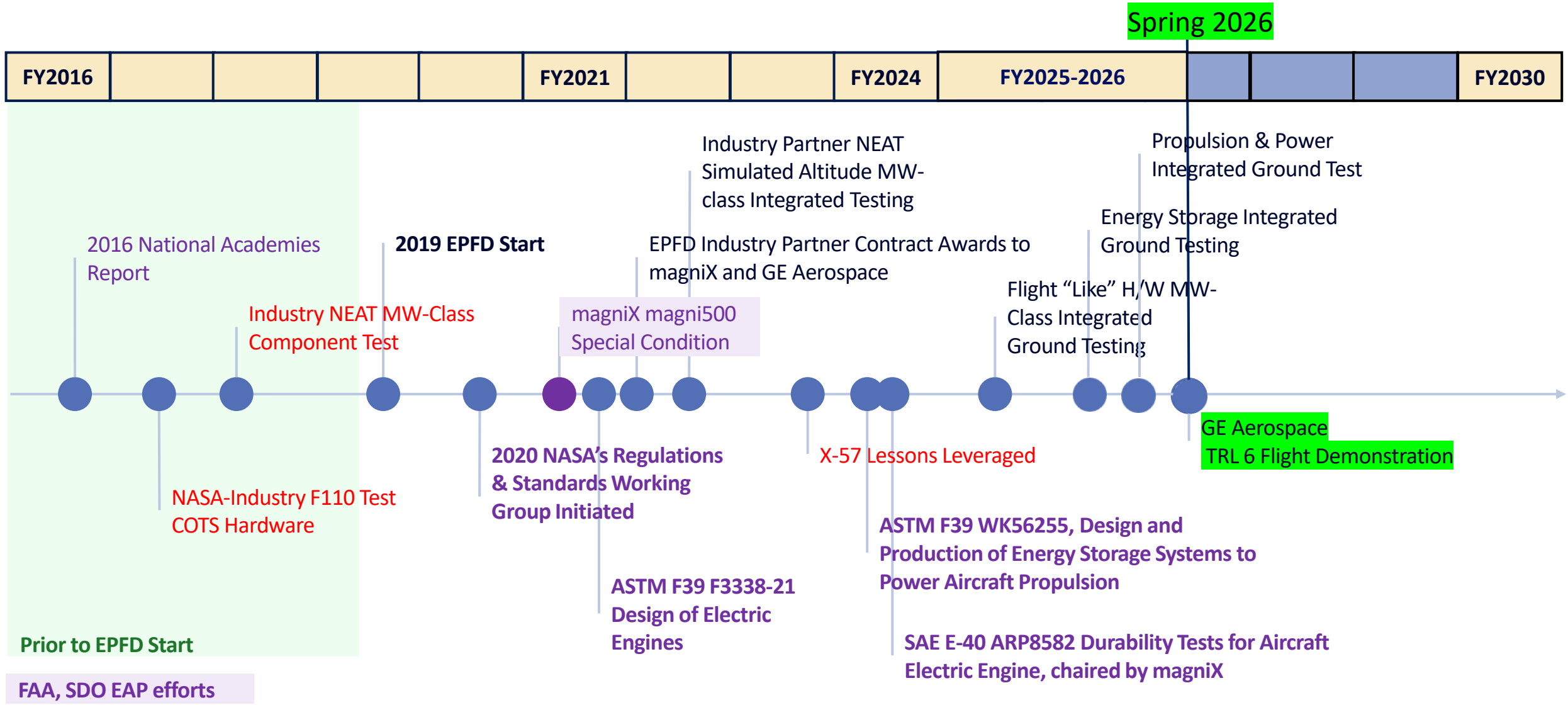
Source: Wishart, Jacob & Jansen, Ralph & Mahavier, Kendall & Coppinger, Kaitlin. (2025). Hybrid Electric Turboprop Commercial Freighter (HETCOF) Market Study. 10.2514/6.2025-1641



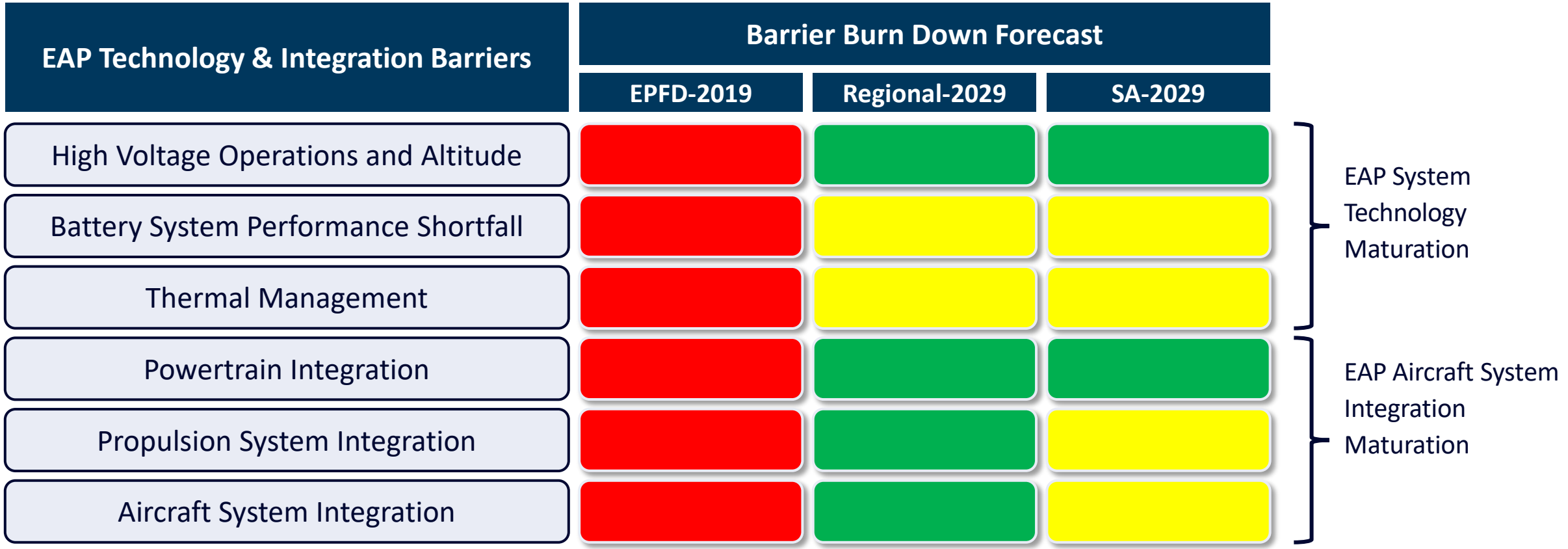
Fuel savings of 24% to 52% across 250-1,500 NM missions translate directly to reductions in CO_2 emissions compared to conventional cargo aircraft

Ranges up to 1,300 NM capture 95% of total annual U.S. narrowbody cargo operations

NASA's EAP Maturation and SDO EIS Risk Burndown



EAP EIS Barrier Risks Burndown Forecast



By the end of this decade, significant burndown of EAP technology and aircraft-level integration barriers will have occurred, accelerating EAP adoption and EIS in the early-mid 2030s

Reflections…

- Global investment in Electrified Aircraft Propulsion (EAP) is happening, driven by socio-economic drivers
- Cost share partnerships have created a viable path to product introduction for Aircraft and Rotorcraft (Part 23, 25 and 27) and Aircraft Engines (Part 33) in the 2030s
- Flight research is critical to demonstrating practical vehicle level integration of EAP systems solutions AND informing regulatory and certification processes
- EAP requires a new generation of system of systems expertise requiring the integration across traditional aerospace, electrical power systems and commercial passenger/cargo aircraft flight and ground operations sectors

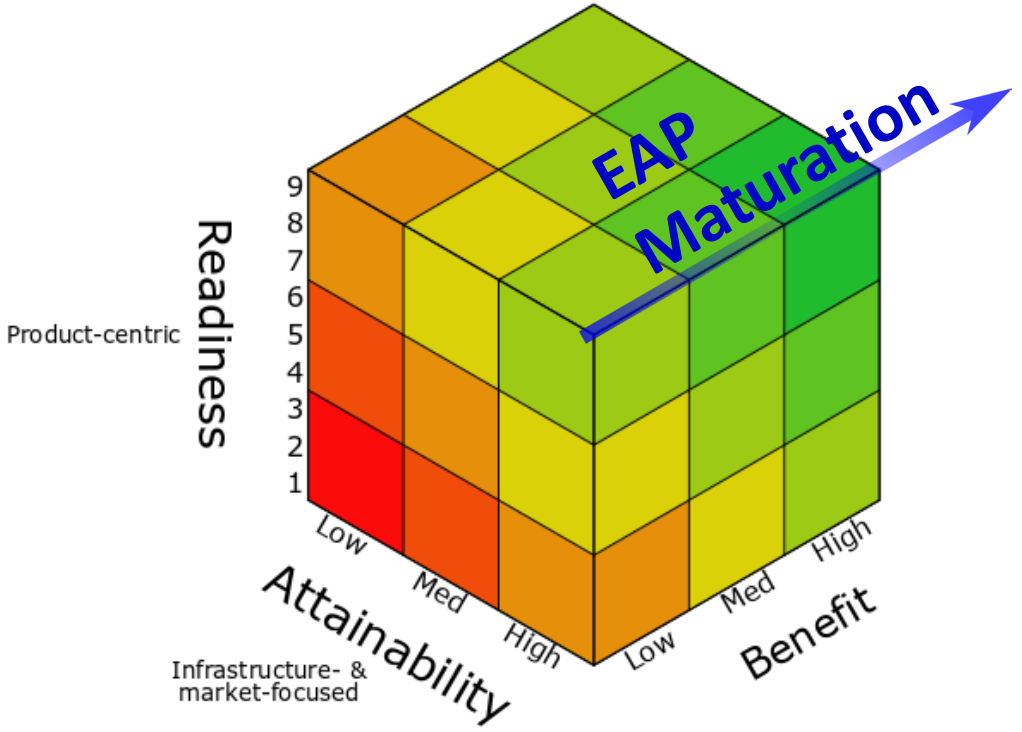
Data-driven performance validation, acquired from integrated ground test and flight demonstrations will enable significant burndown of EAP technology and aircraft-level integration barriers enabling acceleration of EAP adoption and EIS

Transition to Panelists

Panel Q&A

EAP Readiness Q&A

- Has the **technology** improved enough?
  - Battery technology, thermal management, etc.
- How much **storage** is needed for reserves?
- How would the **diversion** due to bad weather be handled?
- How can an electric aircraft be **certified**?
  - Safety (fire)
- Would **NAS operations** be affected by electric aircraft?
  - Takeoff, climb, cruise performance
  - Turnaround time
- How much **infrastructure** change would be required?



Source: ICAO LTAG Tech SG/ 2023