SUSAN Power/Propulsion System Emulation Test Predictions

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SAE Energy & Mobility Conference

Cleveland, OH. September 12th –14th, 2023

Presentation Outline

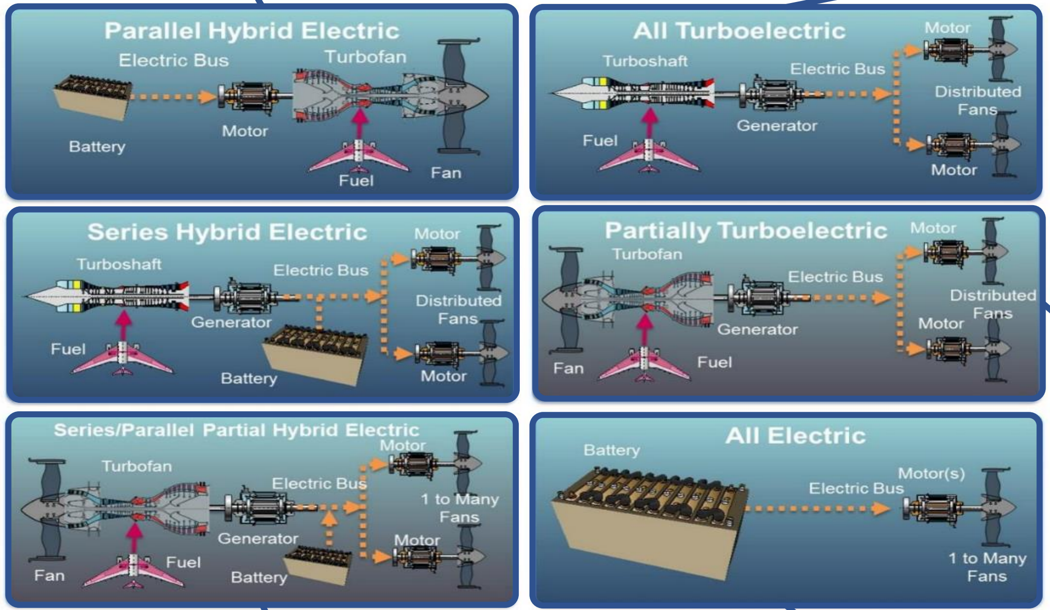
- NASA EAP Background
- SUSAN Concept and Control Design
- HyPER Lab
- Hardware-in-the-Loop Integration
- Hardware-in-the-Loop Model Predictions

NASA EAP Background

- Electrified Aircraft Propulsion (EAP) technology has been identified by the Sustainable Flight National Partnership (SNFP) as an important step towards achieving Net Zero carbon emissions from the commercial aviation sector by 2050
- EAP enables fuel burn benefits through concepts such as propulsion-airframe integration (PAI) and optimal power/energy management
- NASA has developed six reference EAP architectures, shown to right

Boeing SUGAR Volt

NASA N3-X



NASA STARC-ABL

NASA SUSAN

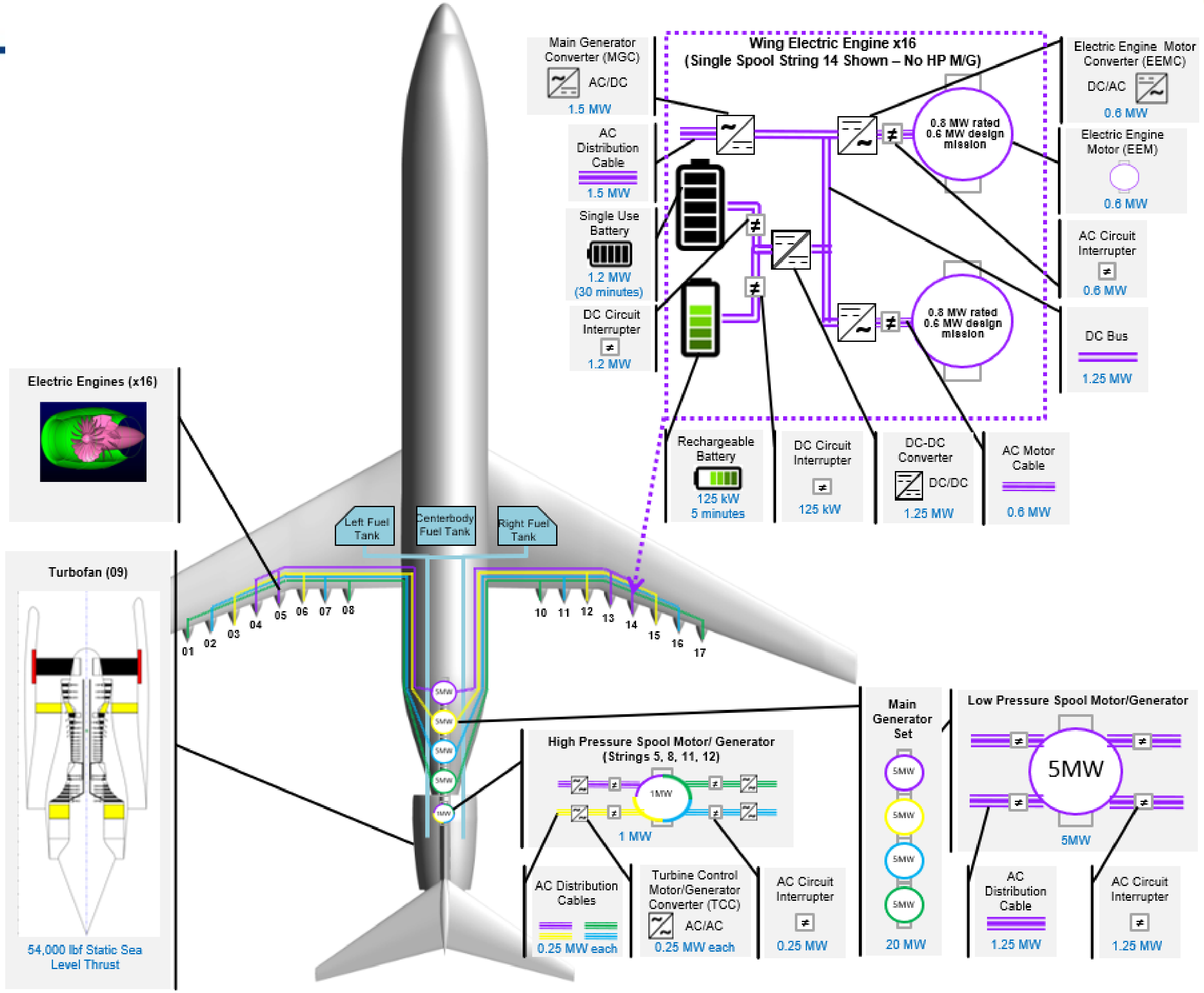
NASA RVLT Lift+Cruise

SUSAN Concept

- Hybrid-electric single-aisle concept developed by NASA Convergent Aeronautics Solutions Project (CAS)
- Single boundary-layer ingesting (BLI) tail-mounted turbofan with power offtake for 16 underwing distributed electric propulsors (DEP)
- Leverages BLI, EAP, DEP, and PAI technologies to achieve a net fuel-burn benefit
- System model developed in MATLAB/Simulink with NASA developed toolboxes
  - EMTAT and T-MATS

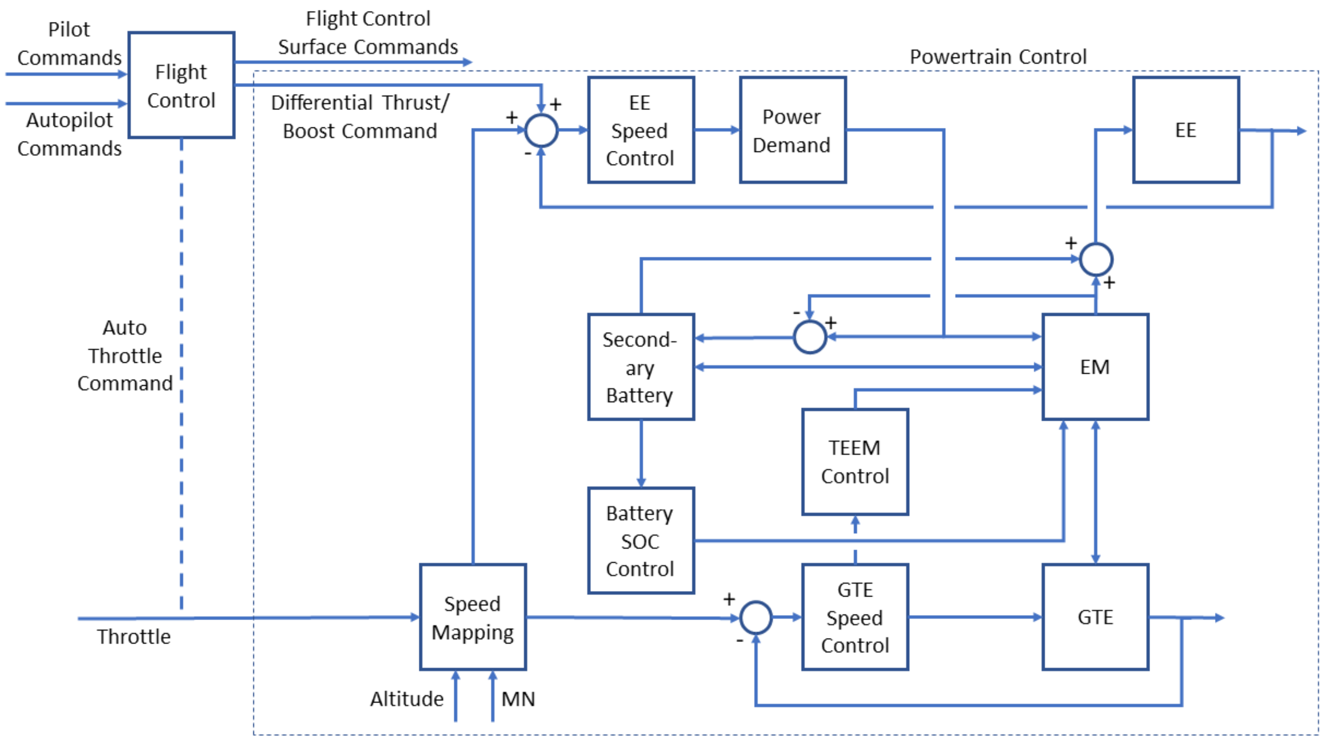
J. Chapman, T. Lavelle, R. May, J. Litt and T.-H. Guo, "Toolbox for the Modeling and Analysis of Thermodynamic Systems (T-MATS) User's Guide," NASA/TM-2014-216638, January 2014.

M. E. Bell and J. S. Litt, "Electrical Modeling and Thermal Analysis Toolbox (EMTAT) User's Guide," NASA/TM 20205008125, October 2020.



SUSAN Control Structure

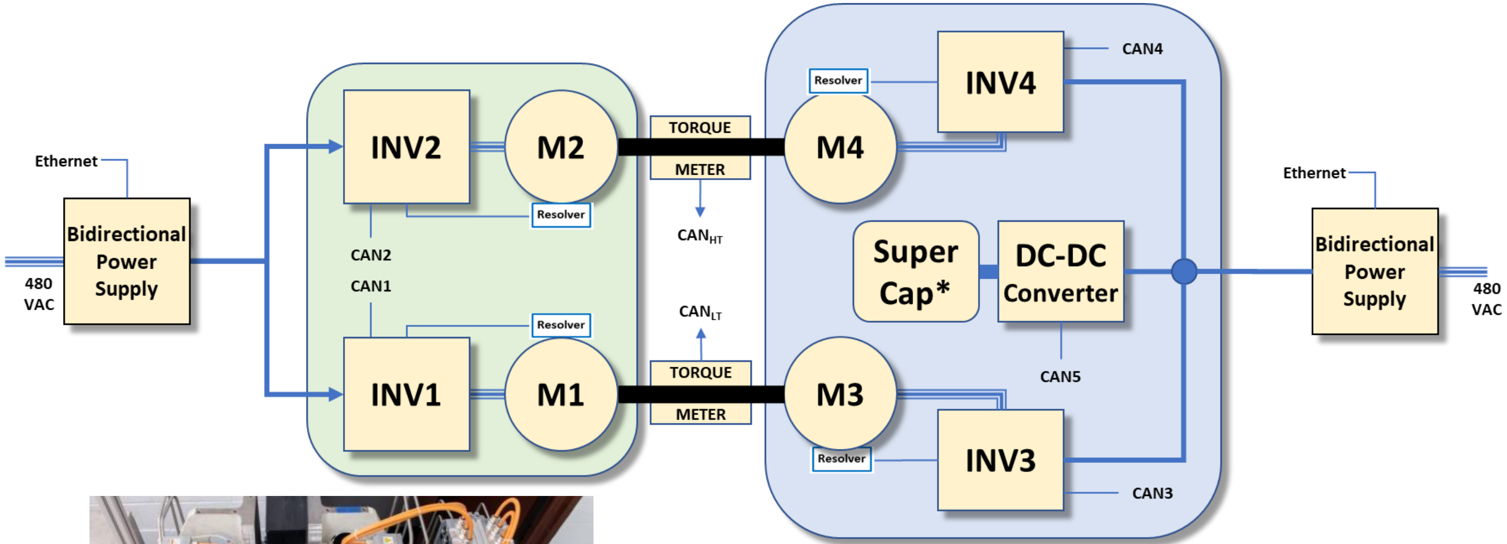
- Complex control interactions
- Multiple copies of components such as electric engines (EEs) and Batteries

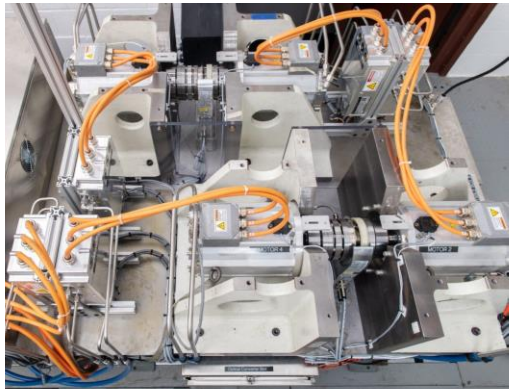


J. S. Litt, J. L. Kratz, J. S. Bianco, J. J. Sachs-Wetstone, P. T. Dever, H. E. Buescher and a. et, "Control Architecture for a Concept Aircraft With a Series/Parallel Partial Hybrid Powertrain and Distributed Electric Propulsion," in AIAA SciTech Forum, National Harbor, MD, 2023.

HyPER Lab

- Hybrid Propulsion Emulation Rig (HyPER) Lab
- Controls testbed that allows for rapid reconfiguration and iteration of EAP control concepts with emulated turbomachinery

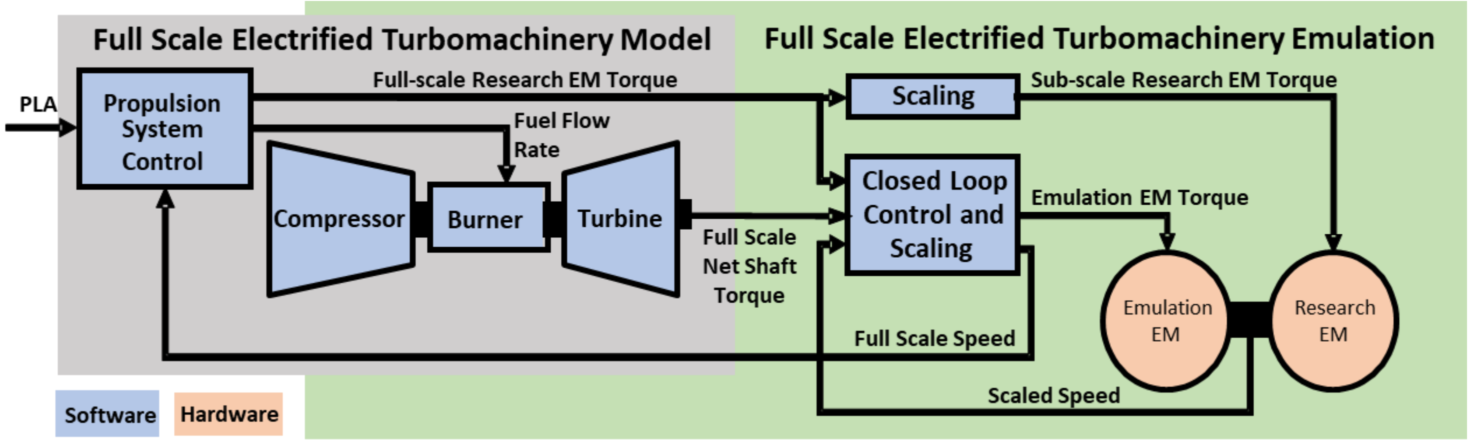




H. E. Buescher, D. E. Culley, S. J. Bianco, J. W. Connolly, A. E. Dimston, J. R. Saus, C. J. Theman, A. M. Horning and N. C. Purpera, "Hybrid-Electric Aero-Propulsion Controls Laboratory: Overview and Capability," in AIAA SciTech Forum, National Harbor, MD, 2023.

Hardware-in-the-Loop Integration

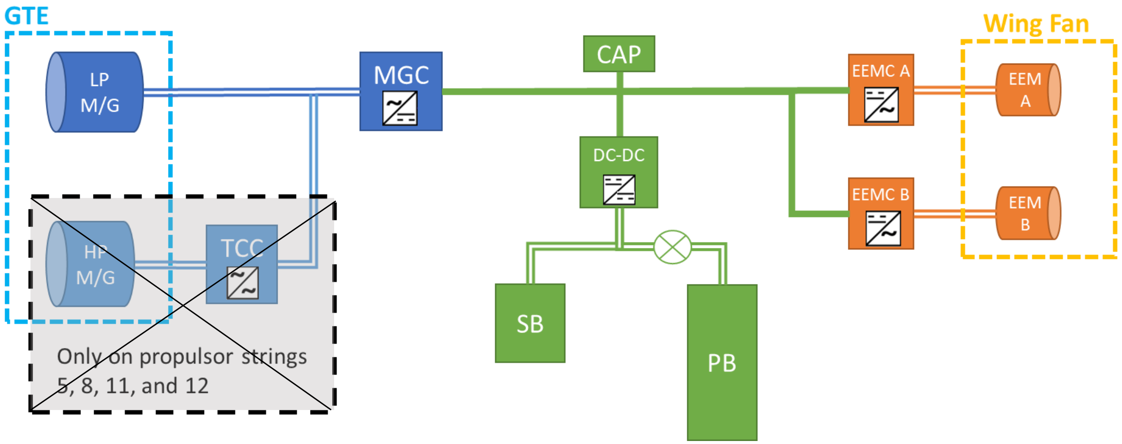
- Implement Sliding Mode Impedance Controller with Scaling (SMICS)
- Used to dynamically emulate the scaled torque response of the turbomachinery/rotor shafts in response to the applied motor torques

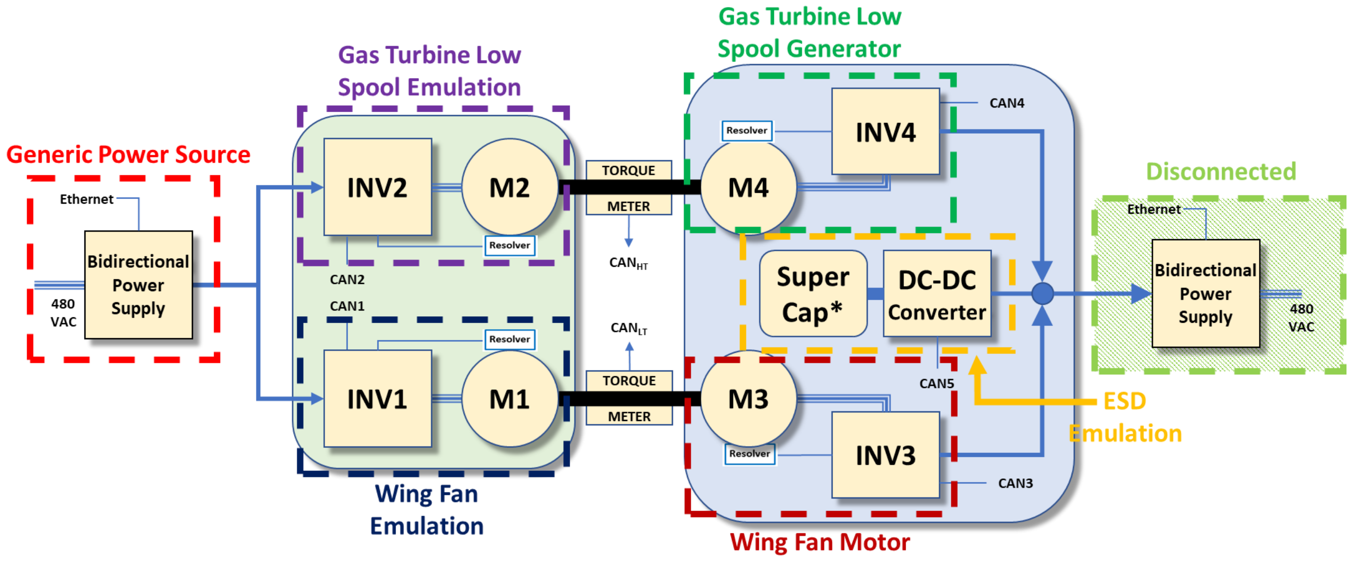


S. J. Bianco and D. L. Simon, "Sliding mode transient scaling controller for gas turbine engine emulation on an electric machine," in *AIAA Propulsion and Energy Forum*, Virtual Event, 2020

Model Implementation – Single Spool String

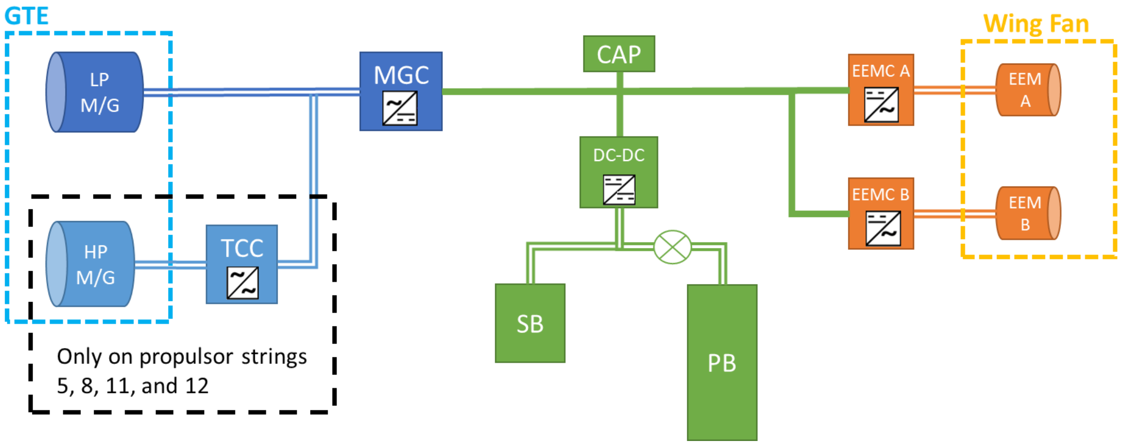
- Representing a complete, single-spool propulsor string on a component-by-component basis
- Focus on energy storage device state-of-charge (SoC) controller and response
- Bidirectional power supply is disconnected, the system manages its own energy
- Model two wingfan motors as one for the purpose of HIL integration

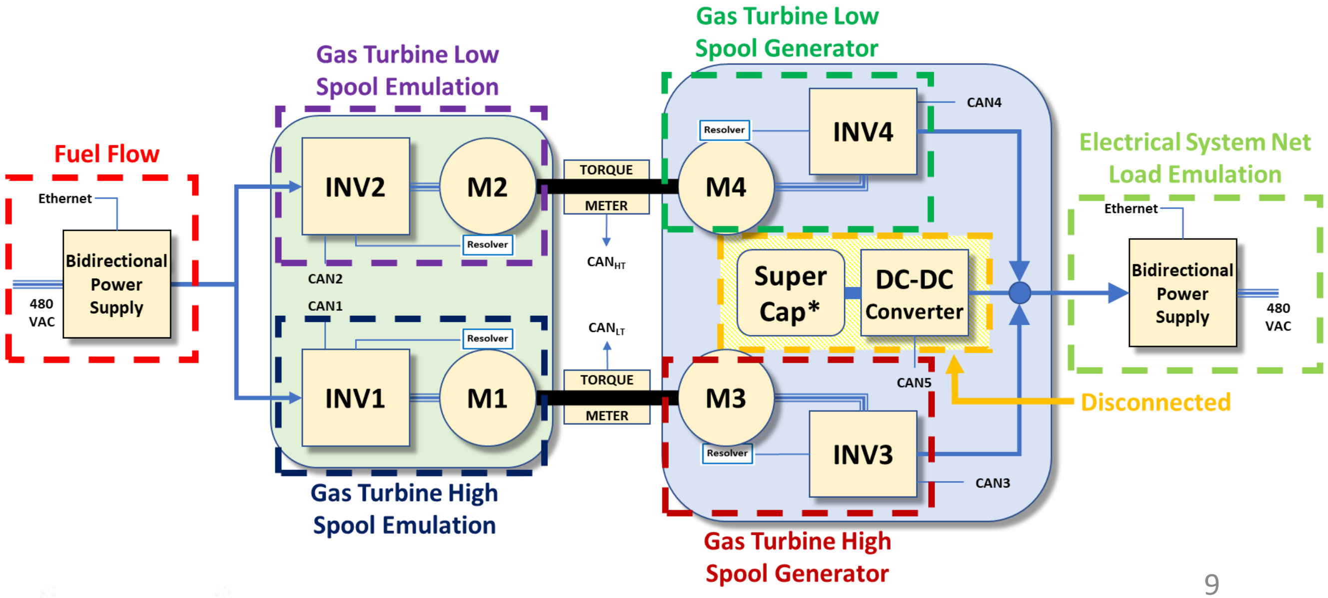




Model Implementation – Power Extraction

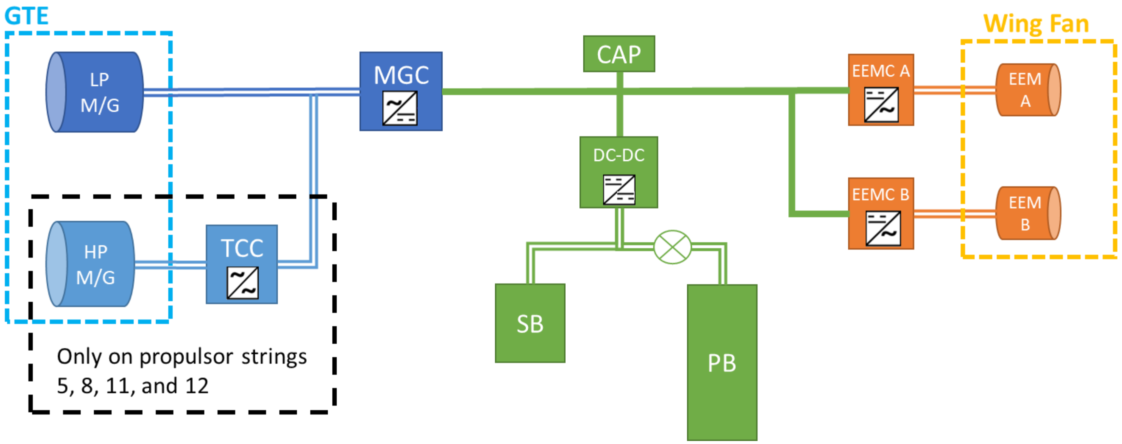
- Representing the combined generator loads on the engine
- Focus on engine emulation and response to power extraction inputs
- Energy storage device not used, use bidirectional power supply to emulate net load from power supplies

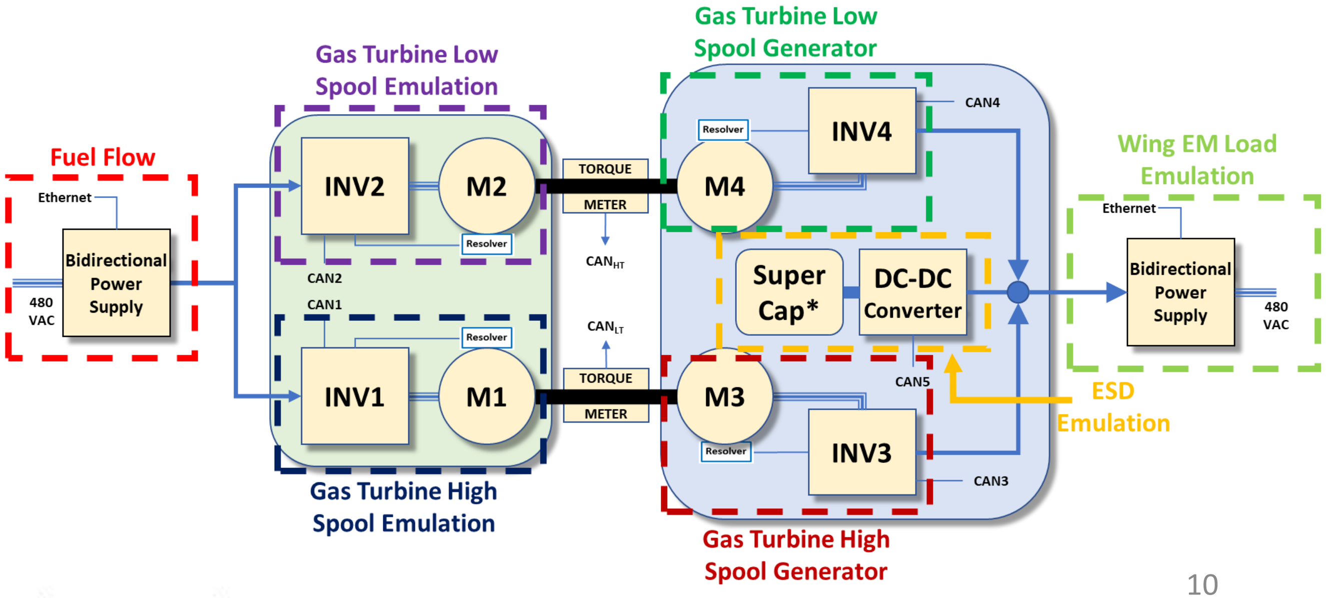




Model Implementation – Dual Spool String

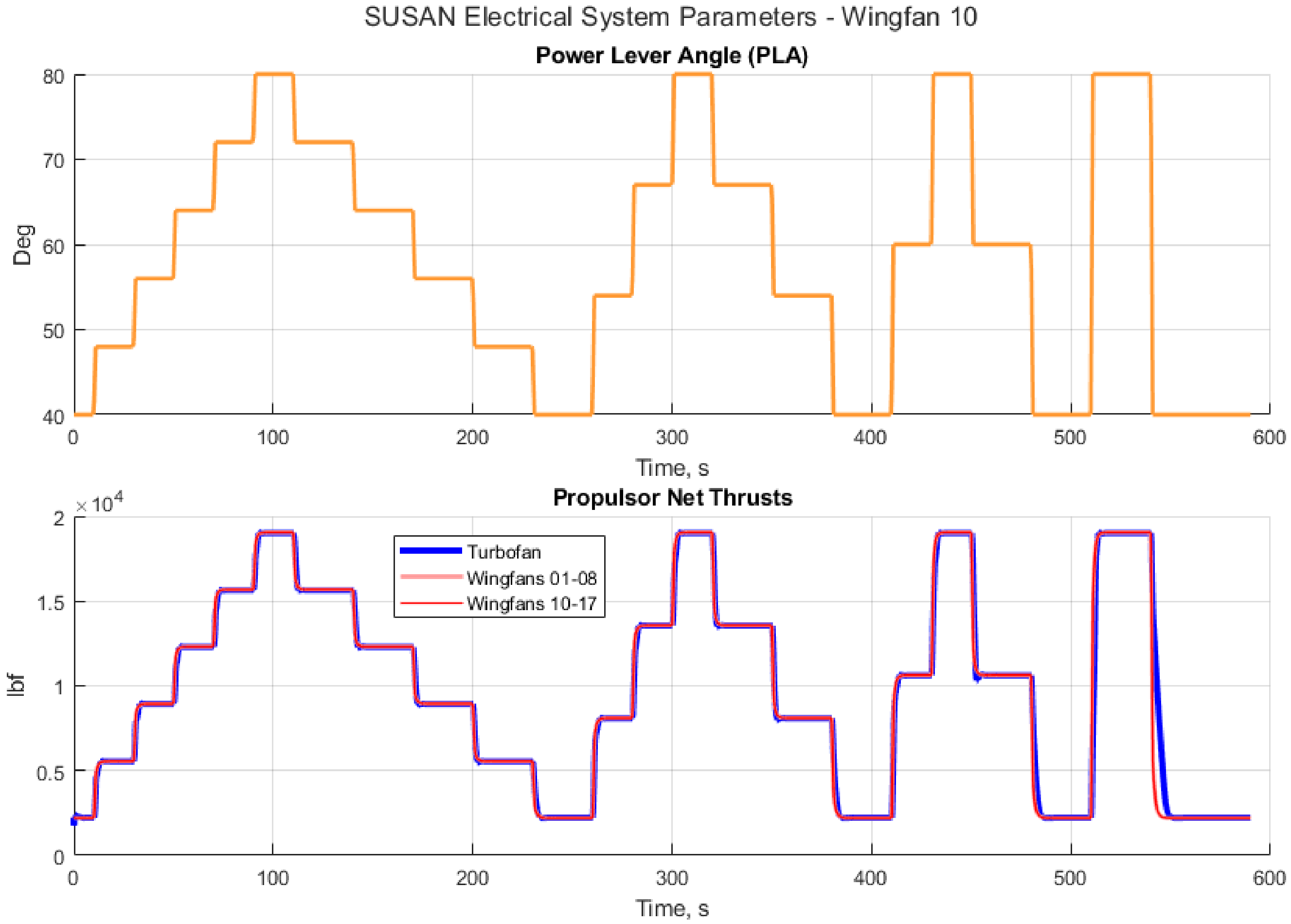
- Represent a dual-spool propulsor string
  - Component analogues are not perfectly on-to-one
- Similar focus on power extraction and state-of-charge controller
- Bidirectional power supply used to emulate load from electric propulsors





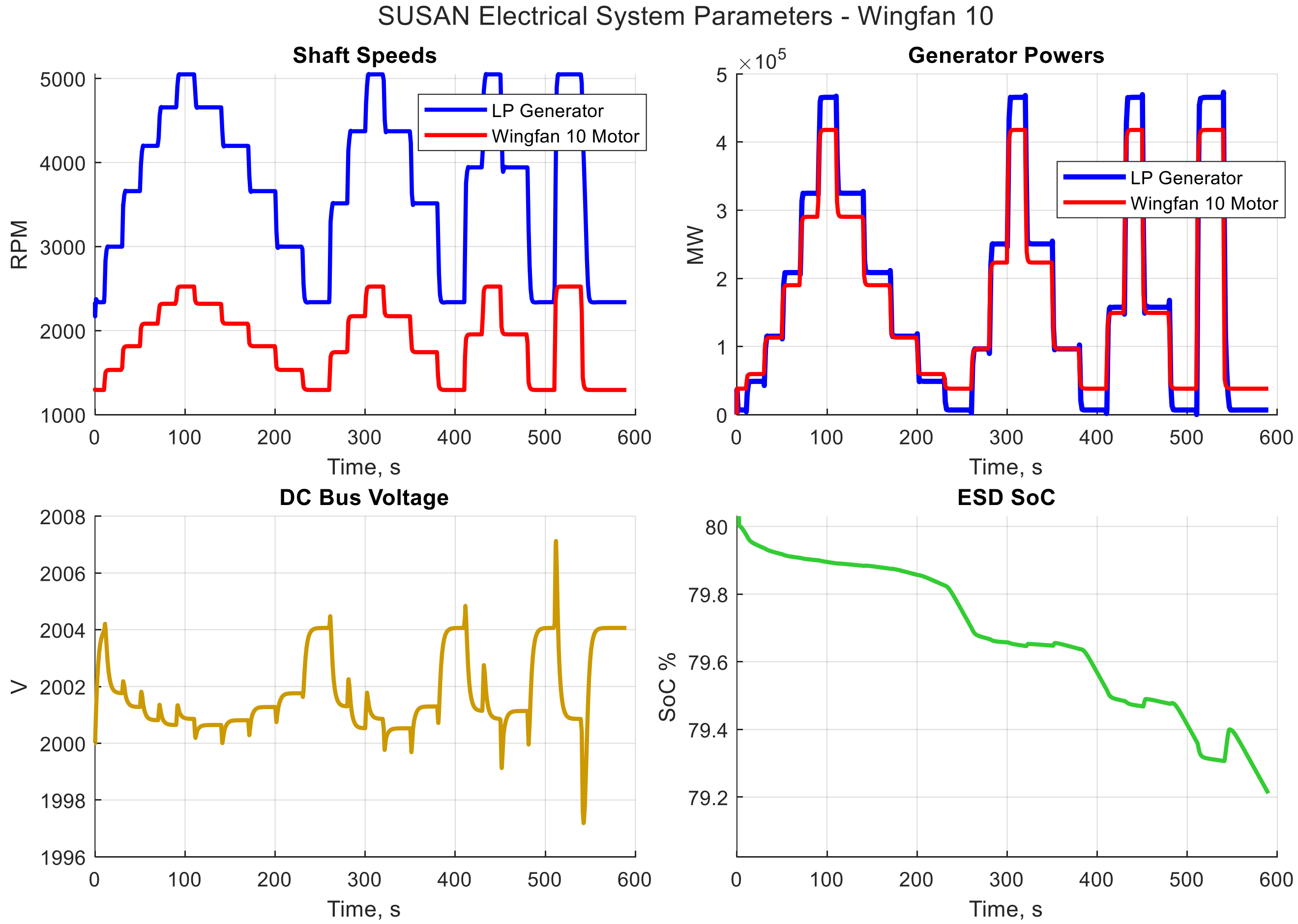
Model Predictions

- Model will be run at a variety of flight conditions (sea-level-static shown)
- Throttle steps will exercise operating range
- Expecting wing fan thrust response to be identical across simulated and hardware strings
  - System is sized for even thrust split between left wing fans, right wing fans, and turbofan



Model Predictions

- Monitor modeled and scaled shaft speed responses
- Monitor modeled and scaled DC Bus Voltages
- Monitor ESD state of charge (SoC) and ensure it remains within constraints



Concluding Remarks

- Preparation for potential HIL Test of SUSAN Power/Propulsion Model in HyPER Lab
- Intention is to demonstrate SUSAN control structure with elements of real hardware
    - Focus is on SoC Controller behavior

Acknowledgements

- NASA Transformational Tools and Technologies (TTT) Project
- NASA Convergent Aeronautics Solutions (CAS) Project

Thank You!

Questions?

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