Implementation Approach for an Electrified Aircraft Concept Vehicle in a Research Flight Simulator

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Objective

- To describe the development of a dynamic model of an electrified propulsion integrated aircraft concept vehicle appropriate for implementation in a research flight simulator
- To bring up questions related to flight decks for electrified propulsion integrated aircraft

→Ultimate implementation of the model should be based on the procedure outlined here and more fully described in the paper

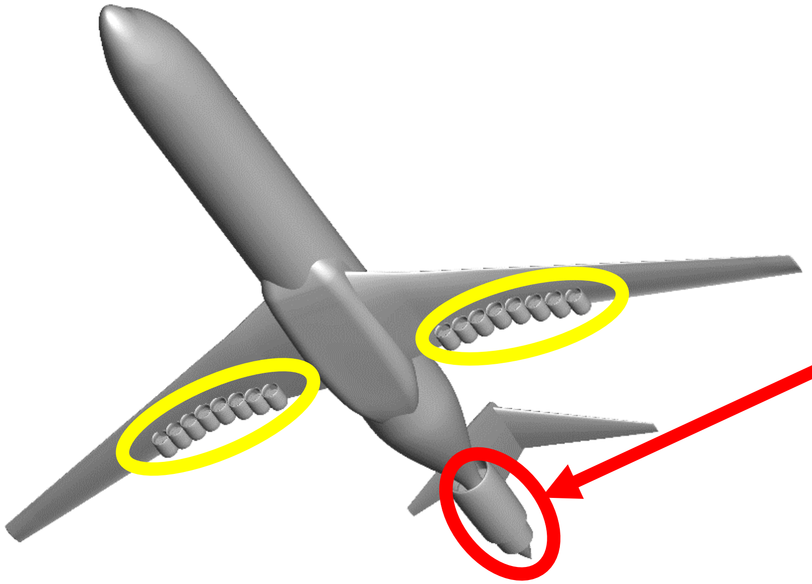
→The flight deck requirements for a 2040 entry-into-service type vehicle with electrified propulsion need to be defined and implemented to the extent possible within the existing cockpit

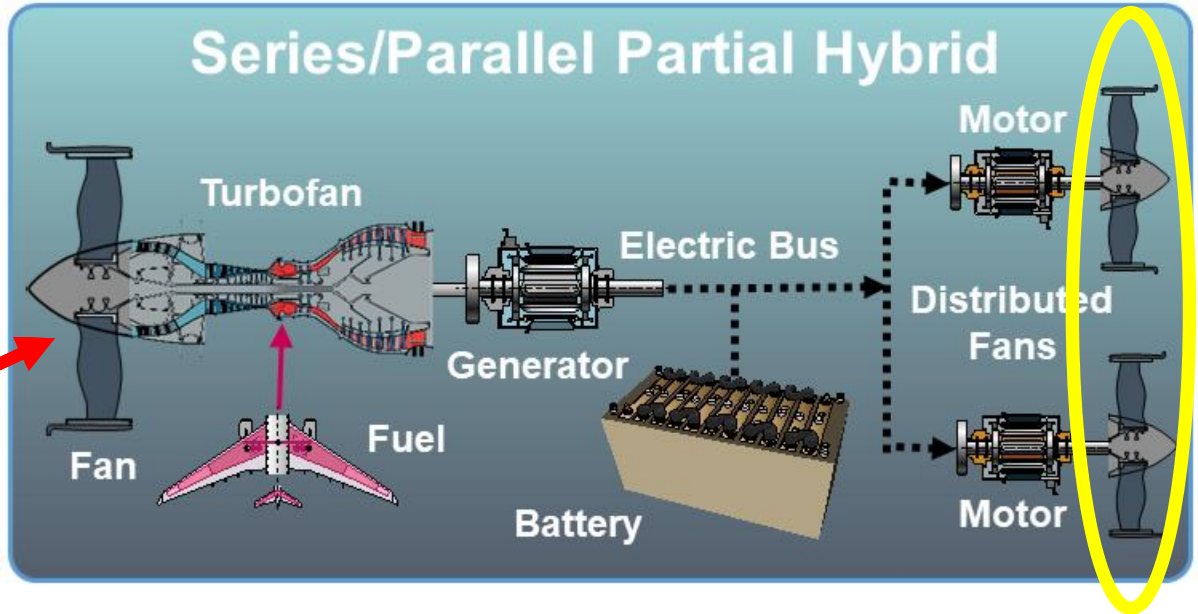
SUbsonic Single Aft eNgine (SUSAN) Electrofan

- Representative of a vehicle with an entry-into-service date of 2040
- Concept electrified propulsion integrated aircraft
- Single Boundary-Layer-Ingesting (BLI) turbofan engine at the back
- Multiple wing-mounted BLI electric engines

SUbsonic Single Aft eNgine (SUSAN) Electrofan

- The architecture of the powertrain is Series/Parallel Partial Hybrid
- The BLI turbofan engine in the tail provides thrust as well as power for the wing mounted BLI electric engines

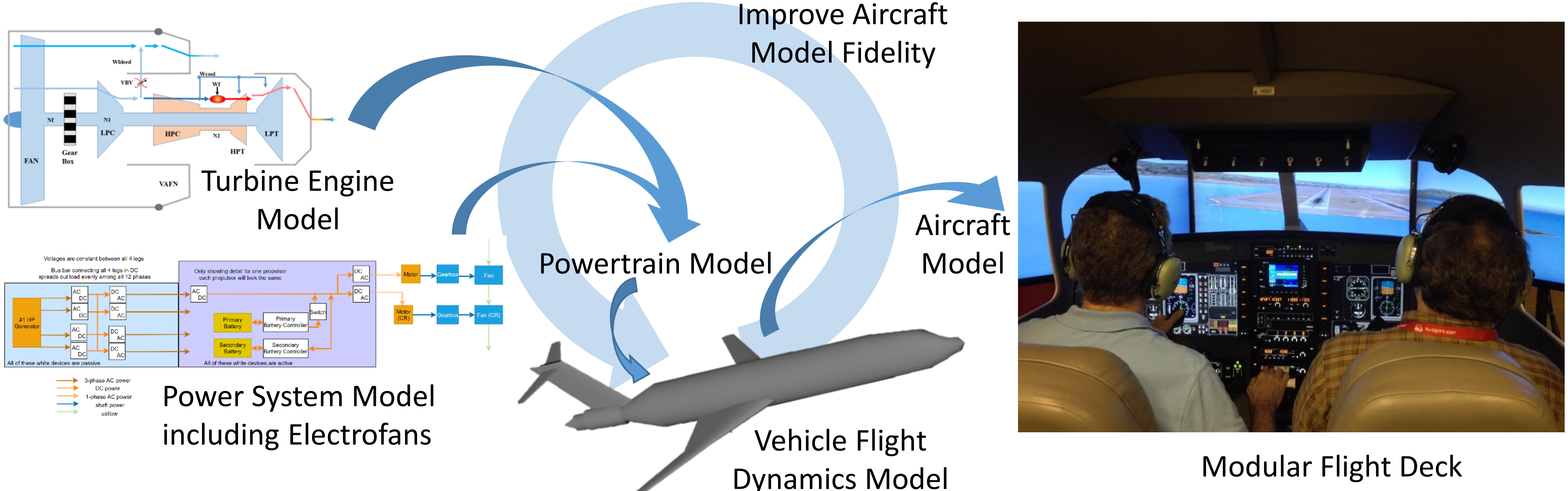




Software Tools

- Toolbox for the Modeling and Analysis of Thermodynamic Systems (T-MATS)
  - NASA-developed Simulink®-based modular thermodynamic modeling framework for building dynamic simulations that run much faster than real time
  - Designed for easy creation of custom Component Level Models (CLM) of jet engines
  - Open Source library available at https://github.com/nasa/T-MATS
- Electrical Modeling and Thermal Analysis Toolbox (EMTAT)
  - NASA-developed Simulink® library that simulates a variety of power electronic devices, using both physics-based and power flow calculations
  - Component models operate at on the timescale of the shaft dynamics. This allows the calculations to be simplified, with high-speed transient losses captured as a general efficiency loss
  - Designed to interface with T-MATS
  - Open Source libraries available at https://github.com/nasa/EMTAT
- X-Plane®
  - Commercial software
  - Enables access to modular flight deck interfaces to take advantage of existing infrastructure
  - Used for communication between the aircraft simulation and cockpit, both visuals and pilot controls

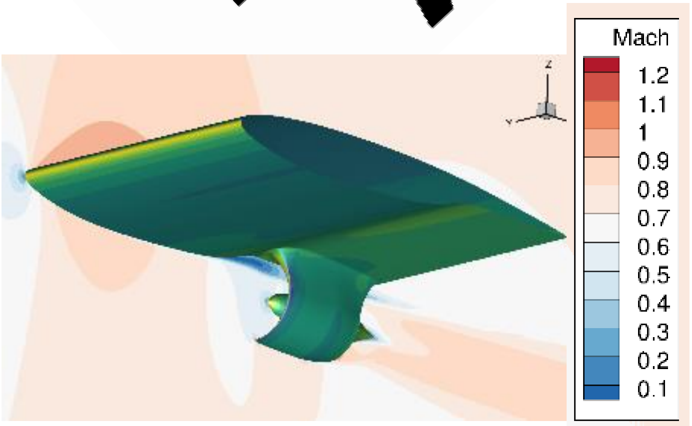
Research Flight Simulator Implementation



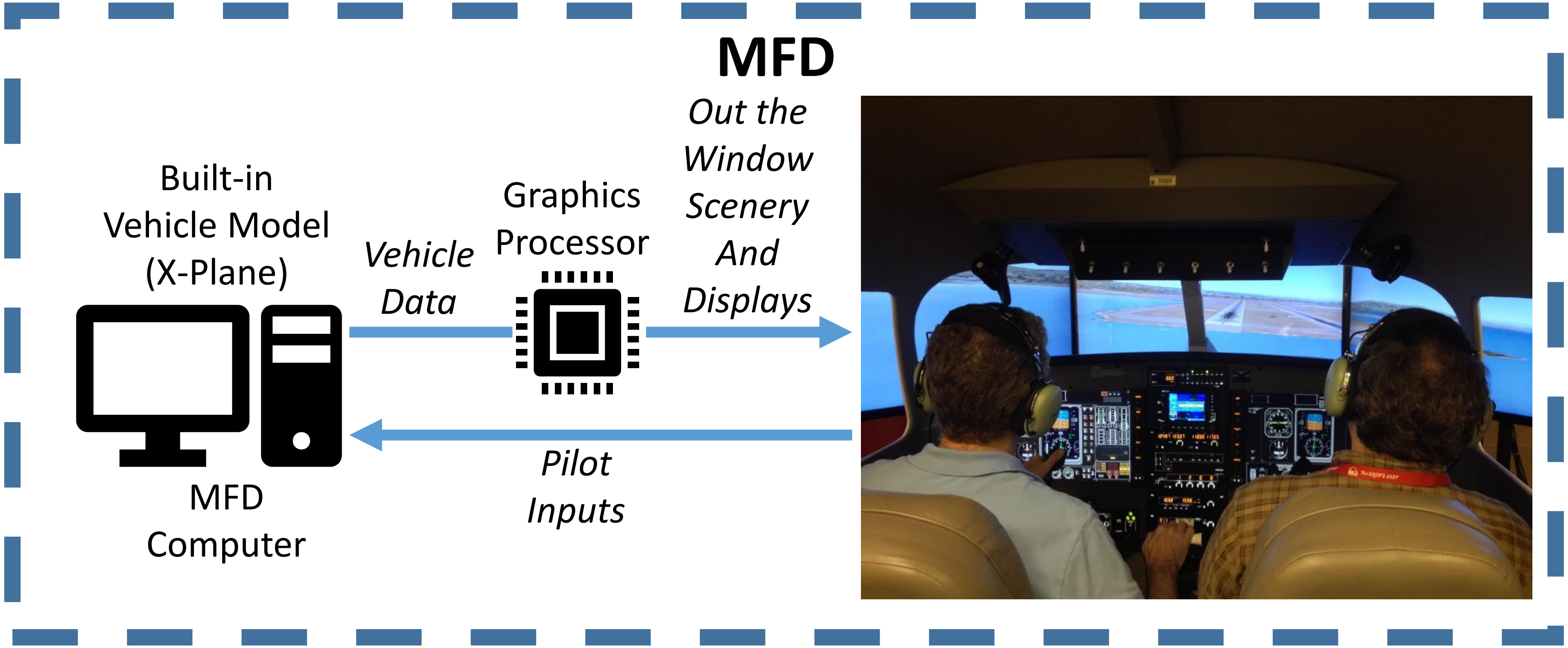
- Steps after the individual models are created
  - Integrate power system model and turbine engine model (powertrain model)
  - Integrate powertrain model with vehicle flight dynamics model (aircraft model)
  - Integrate aircraft model with modular flight deck (MFD)
  - Improve fidelity of aircraft model by incorporating BLI and other effects

Research Flight Simulator Implementation

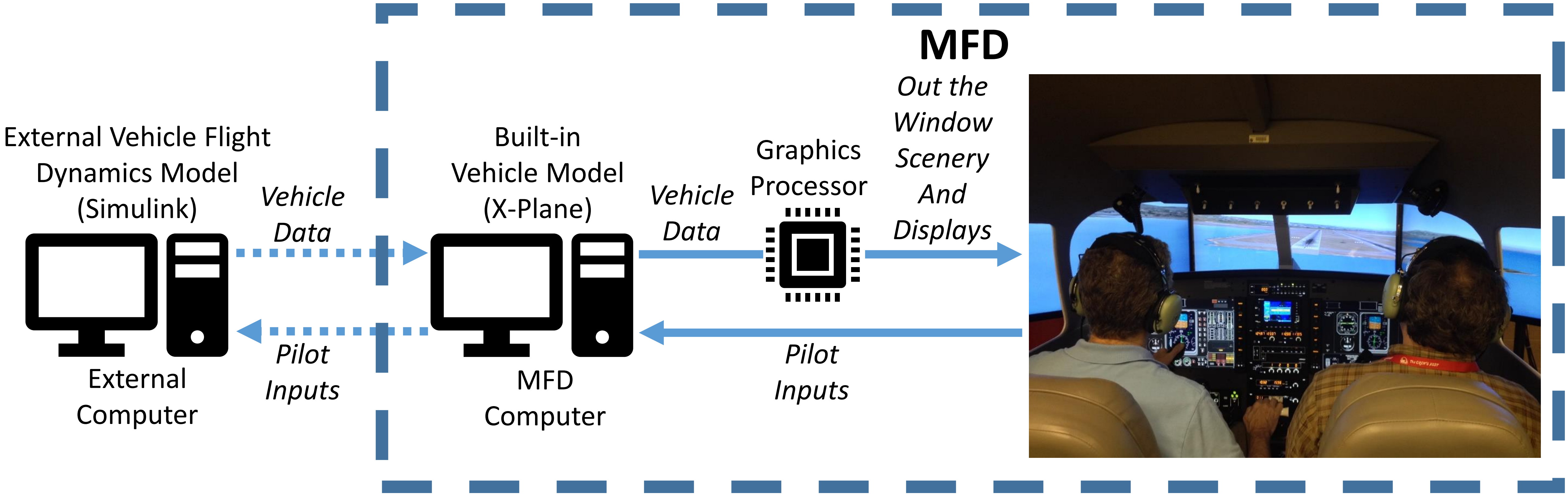
- Powertrain Model and Vehicle Flight Dynamics Model Integration
  - Simplified implementation assumes independence, i.e., powertrain-produced thrust is applied to vehicle at appropriate locations
  - Fidelity improvements in later iterations include adding aeropropulsive effects, which potentially requires modification of the interface between the models to include additional variables impacting engine performance and thrust production



Research Flight Simulator Implementation

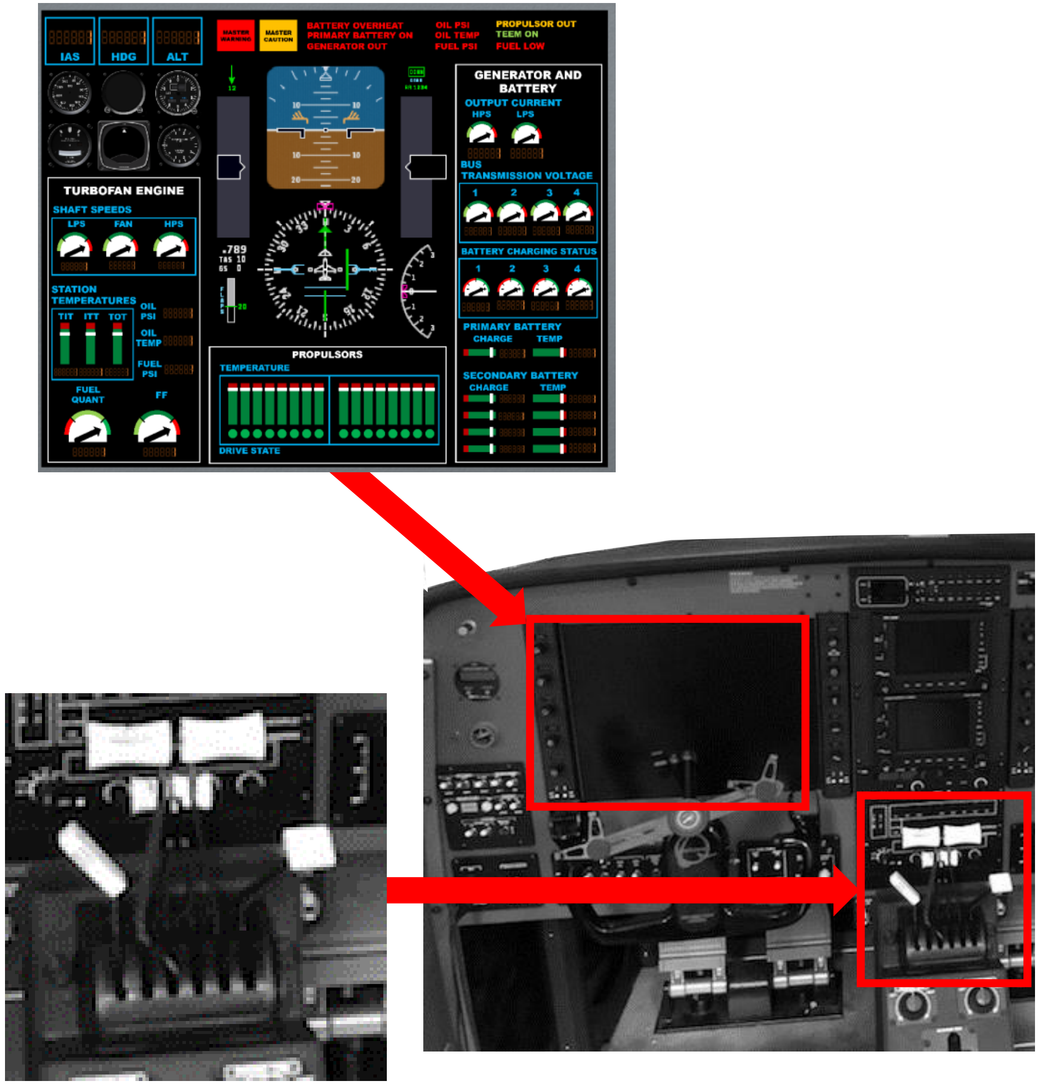


Research Flight Simulator Implementation



Flight Deck and Research Topics

- Pilot Displays
  - Electrified propulsion will require information beyond what is displayed in a traditional flight deck, e.g., battery and electric machine status
  - What information needs to be displayed?
  - What is the best way to display it?
- Pilot Controls
  - The current SUSAN design has 17 engines—one turbofan and 16 electric
  - How many pilot inceptors are required?
  - How are the pilot inceptors used?
  - Highly integrated and optimized aircraft will need to be highly automated to achieve maximum benefit, so how does the pilot interact with the aircraft?



Status and Future Plans

- Modeling for the flight simulator implementation is ongoing
  - Powertrain modeling continues (power and propulsion system)
  - Development of the vehicle flight dynamics model has begun
  - Initial interface defined between the powertrain model and the vehicle flight dynamics model
- Flight Deck
  - Initial pilot display defined for MFD
  - Plan to determine future (2040 timeframe) needs for pilot displays in electrified propulsion integrated aircraft; this will be modified to fit in MFD
  - Plan to determine number and use of pilot inceptors; this will be incorporated into MFD
  - The overall concept can provide direction for future flight deck design

Acknowledgments

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