

Turbine Tweaking on Virtual Aircraft

- Real-time simulation of a complex aircraft model
- HIL simulation with turbine emulator in the loop
- Optimization of turbine controller model

The Air Force Research Laboratory (AFRL) is taking advantage of hardware-in-the-loop (HIL) simulation with dSPACE Simulator to develop and optimize the propulsion systems for the next generation of aircraft. Real-time simulation of turbines and aircraft models performed together with real turbine hardware components opens new possibilities for turbine engine controls. The optimized algorithms allow aircraft to achieve higher altitudes, faster speeds, lower fuel consumption and lower heat rejection into recirculated fuel.

Aircraft power demands continue to grow with the increase in electrical subsystems. These subsystems directly affect the behavior of the power and propulsion systems and can no longer be neglected in system analyses. The performance of the whole aircraft must also be considered with the combined interactions between the power and propulsion systems. The larger loading demands placed on the power and propulsion subsystems result in thrust, speed, and altitude transients that affect the whole aircraft. This results in different operating parameters for the engine. The complex models designed to integrate new capabilities have a high computational cost.

HIL Opens up Integrated System Analyses

Using a hardware-in-the-loop (HIL) analysis with real time integration of the aircraft/propulsion system has

revealed tremendous potential. This method provides a significant reduction in computational runtime, and the airframe/turbine engine model has proved usable in an HIL environment. This also allows a more complete analysis of the interactions between engine loading and aircraft performance by including some real hardware components.

To determine the system-level consequences of these kinds of capabilities, the Air Force Research Laboratory (AFRL) is diving into integrated system analyses via advanced modeling and HIL simulation techniques.

“Propulsion, power and thermal subsystems on these types of aircraft need to be tested and analyzed to identify

interdependencies and any possible adverse interactions,” says AFRL senior electrical engineer and physicist Peter Lamm.

“Through advanced real-time simulation with turbine prototype hardware components, we can predict the interdependencies and address adverse interactions prior to costly hardware prototyping.”

Virtual Representation of Aircraft

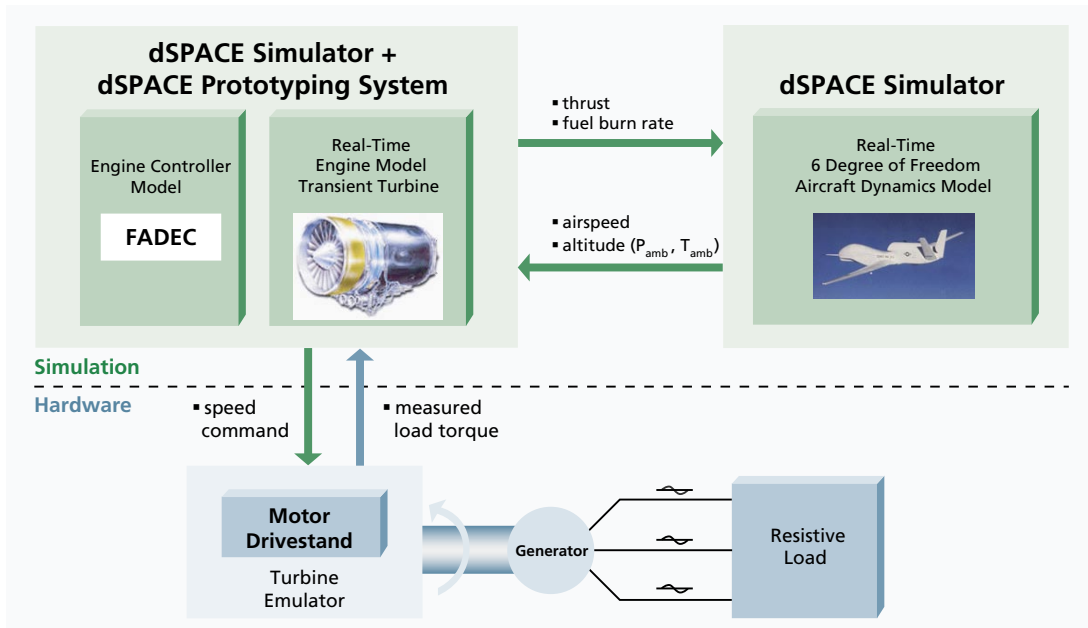
The AFRL has set up a real-time HIL simulation test facility – a virtual representation of an aircraft turbine engine and power system – to explore subsystem interactions between propulsion, power and thermal systems.

To take parameters such as ambient pressure, ambient temperature and airspeed into account, the simulation is

complemented by a real-time aircraft simulation.



▲ Next-generation aircraft will benefit from optimized turbine engine controls developed with the aid of dSPACE Simulator.



▲ Two dSPACE Simulators and a prototyping system are used to perform the controller model and the models of the aircraft systems in real time.

The test-bed includes four main components:

- Turbine engine dynamic and aircraft simulators, comprised of a dSPACE Prototyping System and a dSPACE Simulator (HIL)
- Generic turbine engine model, aircraft model and FADEC (Full Authority Digital Engine Control), developed in a MATLAB®/Simulink® environment
- Aircraft engine spool emulator, consisting of a motor drivestand, speed control and torque feedback
- Electric power system, containing an aircraft test generator and a load bank

Combination of Controller Model and Controlled System in Real Time

The dSPACE simulation environment comprises 3 systems: The generic turbine engine, aircraft, and FADEC models run as self-contained real-time models. The FADEC is performed on a dSPACE Prototyping System; the turbine model and the aircraft model (a full 6-degree-of-freedom aircraft dynamics model including rotation and translation in 3-D space) run on two dSPACE HIL simulators.

Variation Simulation Runs

Aircraft, propulsion, and power system modeling have been investigated with this system. Various experiments were performed using the low pressure (LP) generator as the

hardware component in the loop. Significant non-linear, transient variations occurred when the power loads were applied and removed. These simulations produced different results than those which assumed constant altitude

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Peter Lamm, Air Force Research Laboratory

and airspeed. These variations could cause the engine to surge, making it vital that transient events are modeled and analyzed with aircraft dynamics. Lamm comments, “These results validate the capability of HIL experimentation in avionics and provide the opportunity for significant propulsion configuration studies with minimal cost.”

HIL Investigations Deliver Better Performance Results

Lamm is convinced that the potential of HIL investigations opens new possibilities for turbine engine controls, and could provide a means of tweaking the performance of the turbine engine, allowing aircraft to achieve higher altitudes, faster speeds, lower fuel consumption and lower heat rejection into recirculated fuel.

Source:
Transient Analysis of an Aircraft/Propulsion System with Hardware-in-the-Loop Power Extraction, Kyle L. Miller, J. Mitch Wolff, Eric A. Walters, 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, 2007, OH, USA