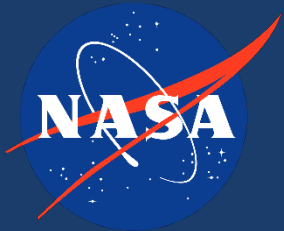


An Electrical Modeling and Thermal Analysis Toolbox for Electrified Aircraft Propulsion Simulation



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HX5, LLC / NASA GRC

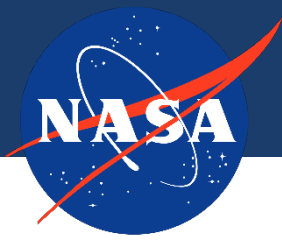
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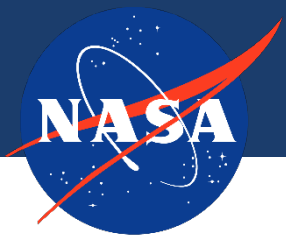


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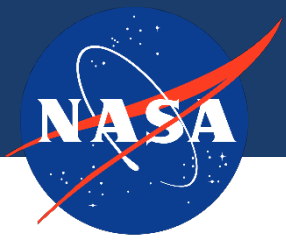


Problem Statement



- NASA is funding research to improve aeropropulsion system performance through the addition and integration of electric machines with turbomachinery.
- Electrified Aircraft Propulsion (EAP) is becoming a topic of great interest to the aviation community, and it requires the capability of dynamic simulations of power and propulsion systems.



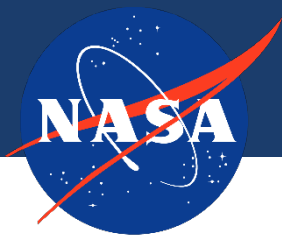


EMTAT Definition



- The Electrical Modeling and Thermal Analysis Toolbox (EMTAT) provides the capability to simulate the electrical components of EAP systems at a timescale appropriate to capture the interaction with turbomachinery.
- EMTAT is compatible with the NASA-developed Toolbox for the Modeling and Analysis of Thermodynamic Systems (T-MATS) software package, which is used for simulating turbomachinery.



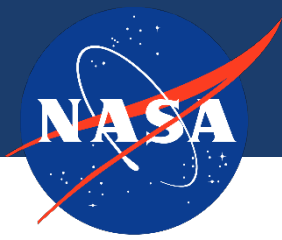


Steady State Simulation



- Due to the relatively slow time step of most T-MATS turbomachinery simulations, EMTAT assumes electronic devices in those simulations to be operating at steady state.
- Steady state simulation of electrical devices allows the electrical performance calculations to be simplified, with high speed transient losses captured as a general efficiency loss.

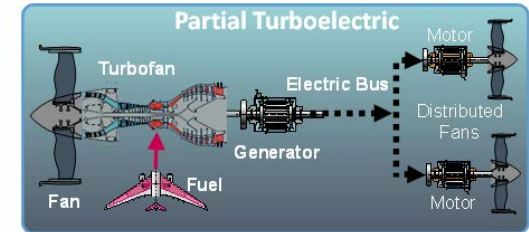
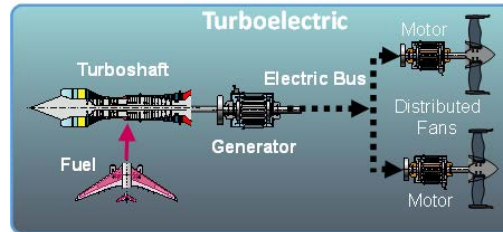
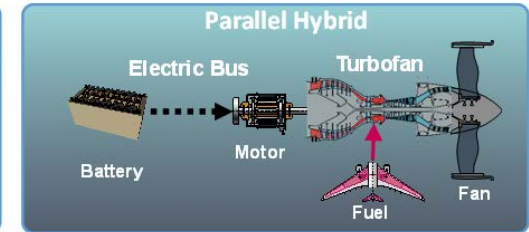
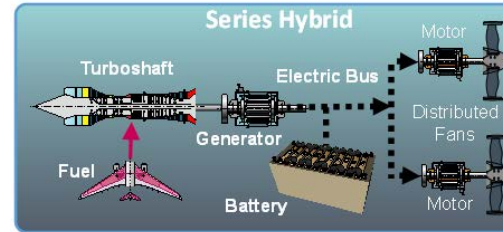
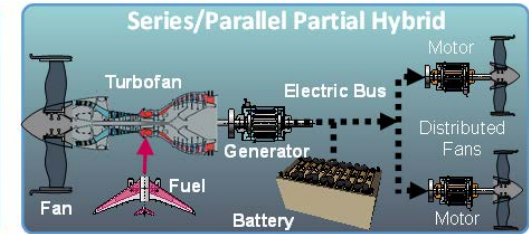
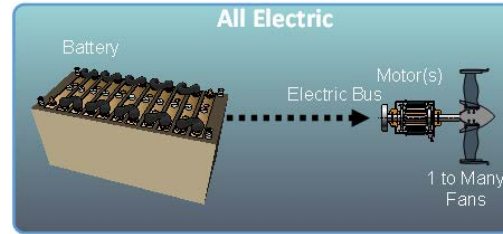


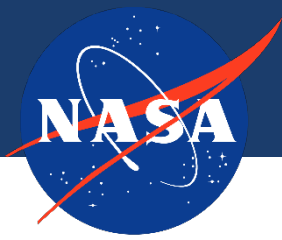


EAP Architectures



- Together, EMTAT and T-MATS can be used to simulate a variety of different EAP architectures.
- EMTAT can simulate a range of stand alone electric power systems.

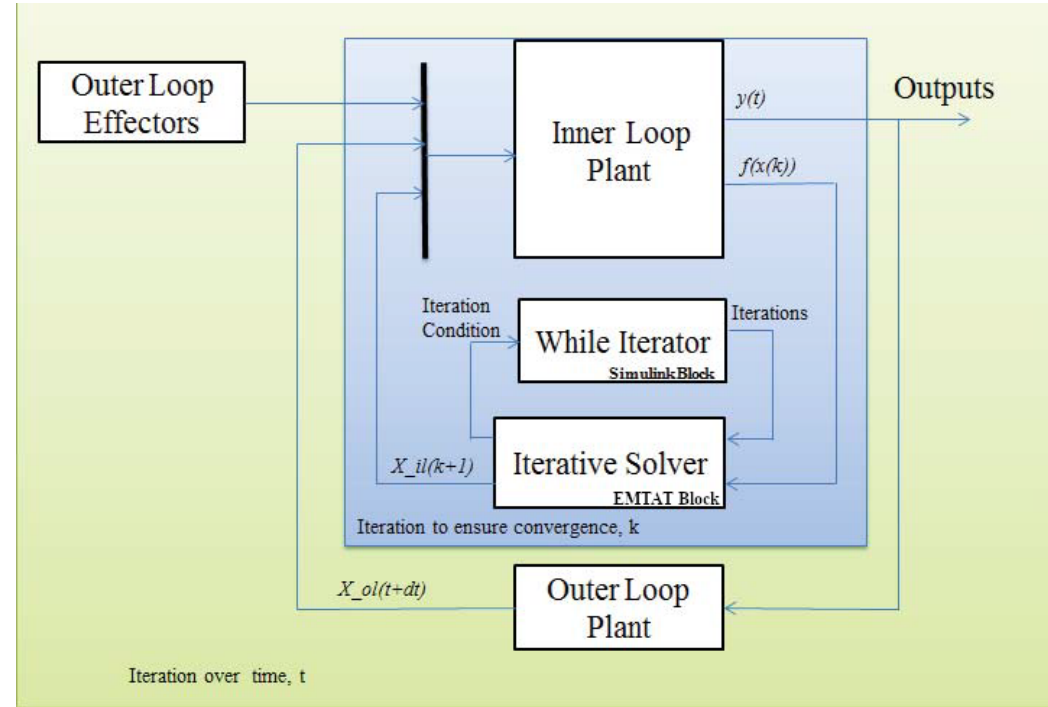


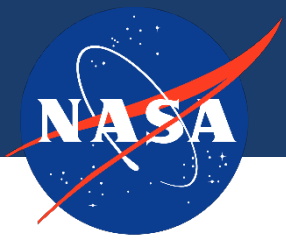


Simulation Architecture



- Like T-MATS, EMTAT uses a generic multi-loop architecture.
- The inner loop plant is where most EMTAT models reside, with controllers outside





EMTAT Libraries

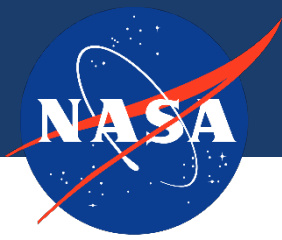


- EMTAT has both physics-based and power flow approaches available.
- Power flow models allow for more abstracted systems, while physics-based models provide more realism. Both model types may be used in a single simulation.



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Component	Power Flow Library Block	Physics-Based Library Block
Battery	Y	Y
DC Boost Converter	Y	Y
DC Buck Converter	Y	Y
Inverter / Rectifier	Y	Y
Electric Motor / Generator (PMSM)	Y	Y
Resistor	Y	Y
Transmission Line	Y	N
Super Capacitor	Y	Y
AC Transformer	Y	N
Temperature Block	N	Y

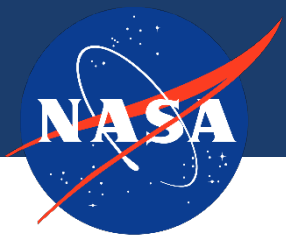


EMTAT Libraries



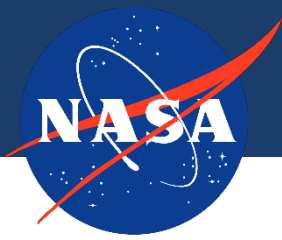
- Both physics-based and power flow models allow for heat power loss calculations, which can be used to calculate an overall efficiency for that component model.
- Physics-based models allow for realistic thermal rises to be calculated, along with associated component parameter performance impacts.





- Each physics-based EMTAT component model can be scaled to match user data or manufacturer specifications, using each model's iDesign tool.
- iDesign provides an automated approach for calculating electrical component internal parameters to allow individual electrical components to match system level performance parameters specified by the end user.

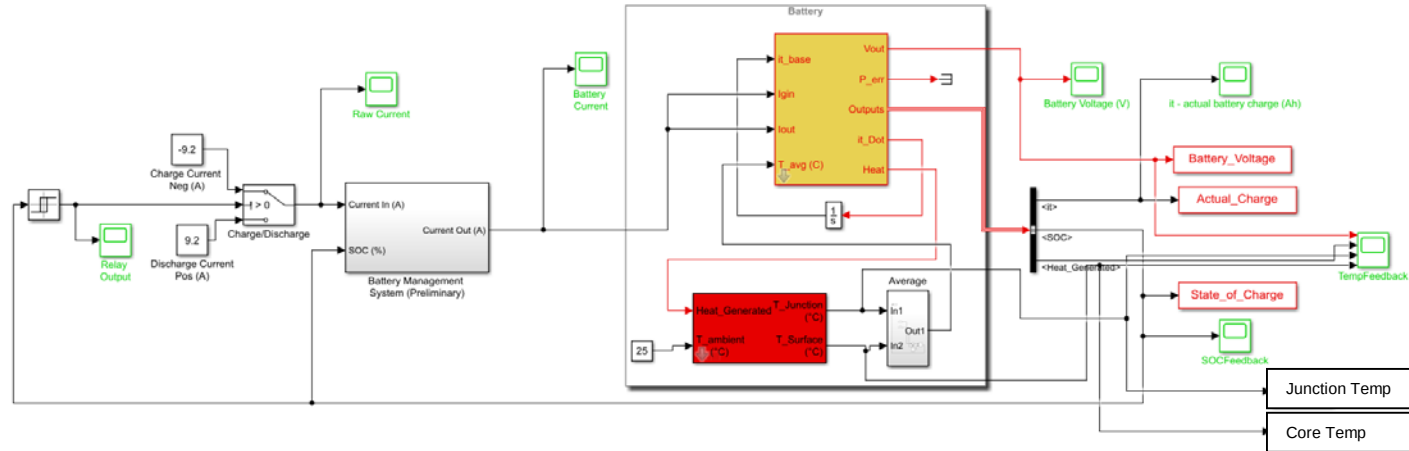




Temperature Feedback



- Temperature feedback allows users to see the performance changes associated with changing temperatures.
- Shown here is a battery charge/discharge simulation.



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Temperature Feedback

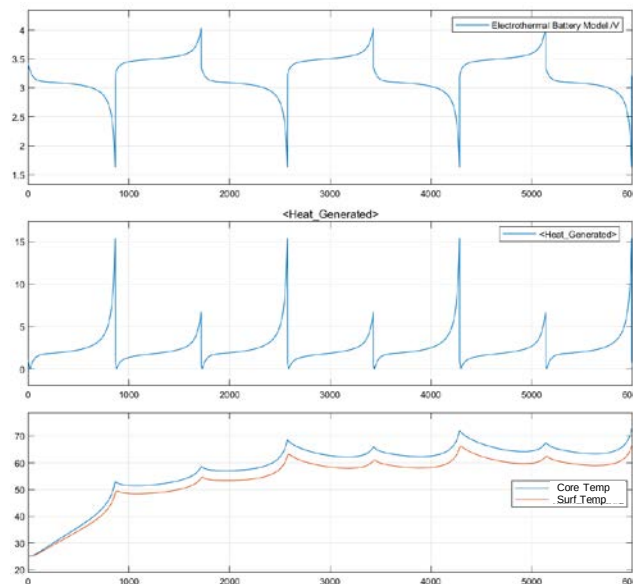


- As can be seen here, the increased internal temperatures leads to increased heat generation and faster discharge cycles.
- Internal temperatures affect physical component properties as specified by manufacturer data sheets.

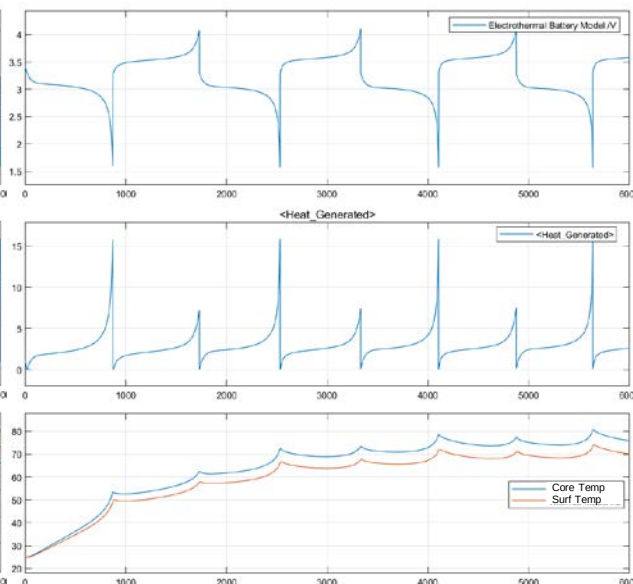


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No Temperature Feedback

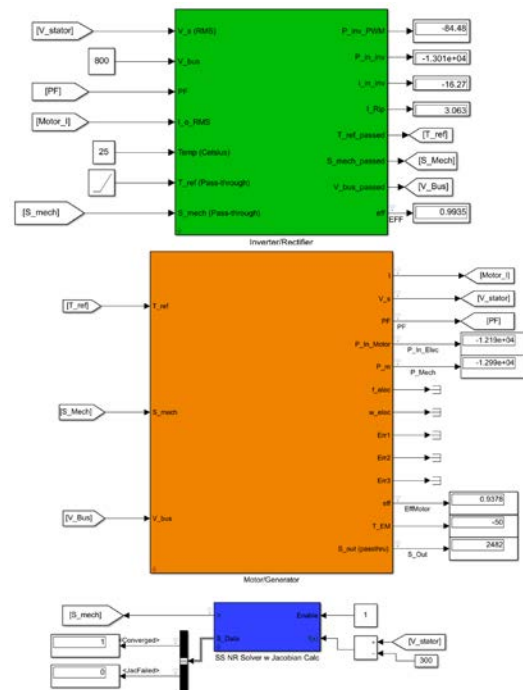


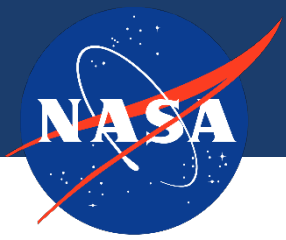
Temperature Feedback





- Bidirectional power flow capabilities allow these models to simulate the transition from power usage to power generation in AC motor/generator systems.
- Shown here is a system with the motor/generator and inverter/rectifier component models, and an iterative numeric solver. The torque is prescribed as a ramp from 50 to -50 N-m.





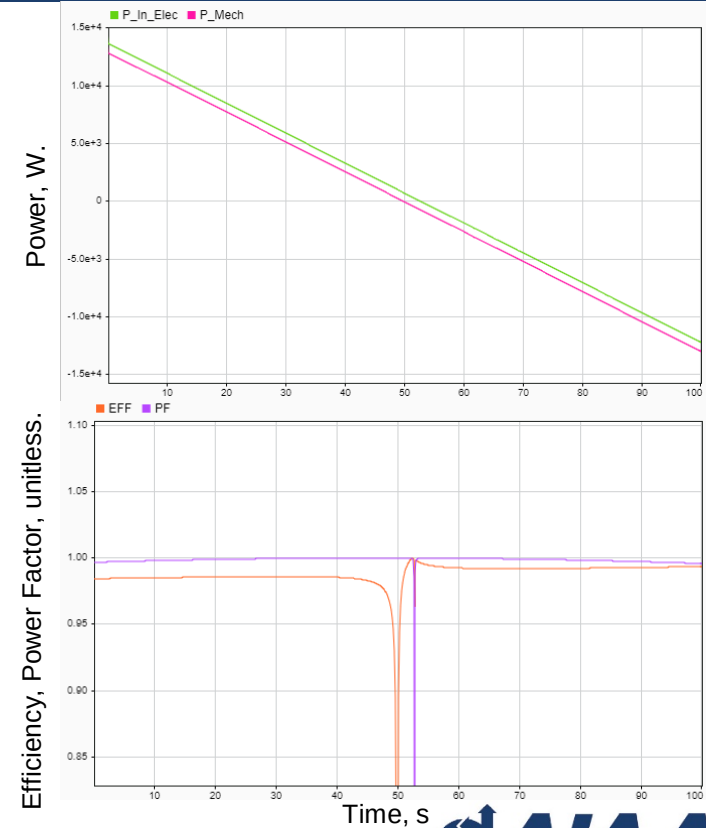
Bidirectional Power Flow

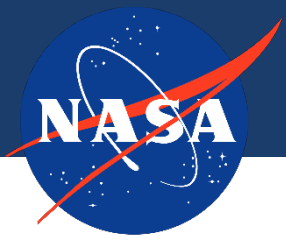


- The system models can seamlessly transition from power usage to power generation.
- Efficiencies are calculated based on model performance, rather than the other way around, so discontinuities do not propagate into the simulation.



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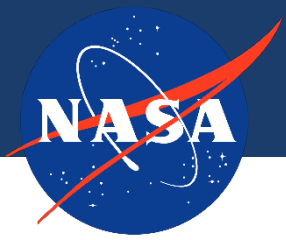


Summary



- EMTAT is an open-source MATLAB/Simulink toolbox that provides simple to use modeling and simulation tools to facilitate control design, analysis, evaluation, and virtual testing of EAP concepts.
- This toolbox can be adapted to a wide variety of electrical system modeling problems where high-frequency dynamics of the electrical components are not required.



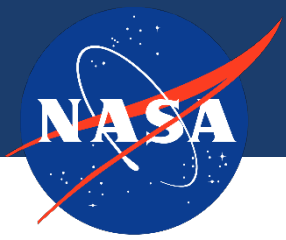


Contact



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 - Mark E. Bell, HX5
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- Expected software release in September, 2020
 - <https://github.com/nasa/EMTAT>



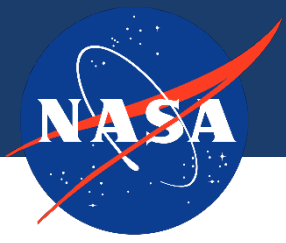


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Questions

