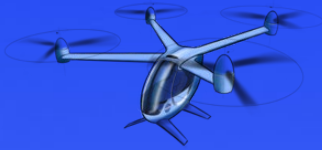


RVLT



RVLT Tool Chain Workshop, Day 2: July 16, 2021
Topic: Electrical Power System–Sizing and Analysis Tool (EPS-SAT)
and Numerical Propulsion System Simulation (NPSS)
Presenter: George Thomas and Patrick Hanlon (GRC-LEM)



- Introduction
- Electrical Power System–Sizing and Analysis Tool (EPS-SAT)
 - Background
 - Main purpose of the code in our tool chain
 - Main tasks
 - Input/Output
- Numerical Propulsion System Simulation (NPSS)
 - Background
 - Main purpose of the code in our tool chain
 - Main tasks
 - Input/Output



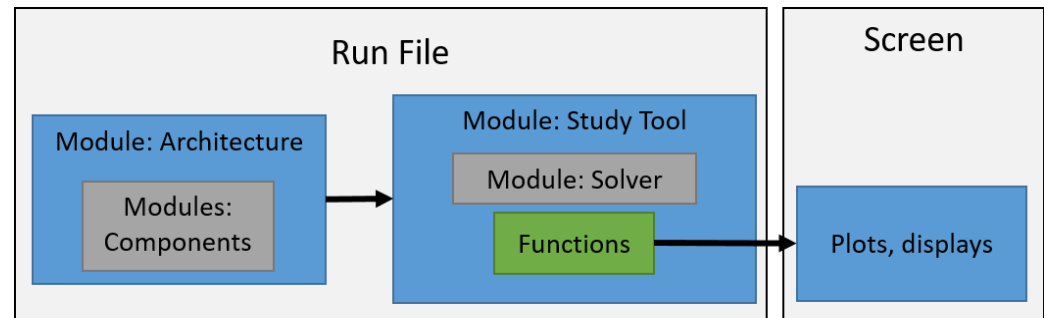
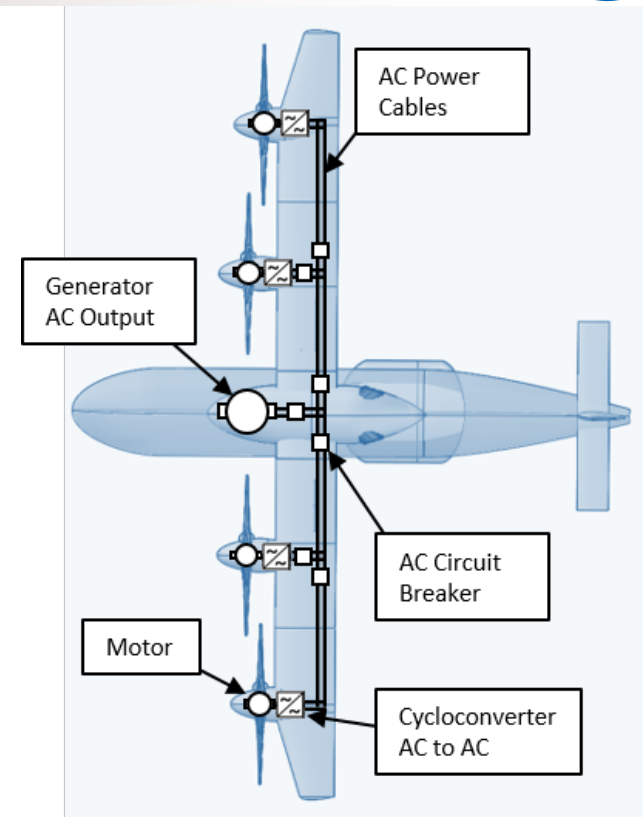
Introduction — Motivation

- eVTOL is an emerging research area
 - Limited powertrain system tools with integrated power, propulsion, and thermal models
 - Limited deep dive systems tools focused on power systems and power management and distribution (PMAD)
- RVL T UAM Propulsion team's modeling and tool development efforts addresses these weaknesses
 - Electrical Power System—Sizing and Analysis Tool (EPS-SAT)
 - Enables fast sizing and analysis of power system architectures
 - Numerical Propulsion System Simulation (NPSS) Power Library
 - Enables building and sizing power systems in NPSS, with integration into propulsion and thermal management models

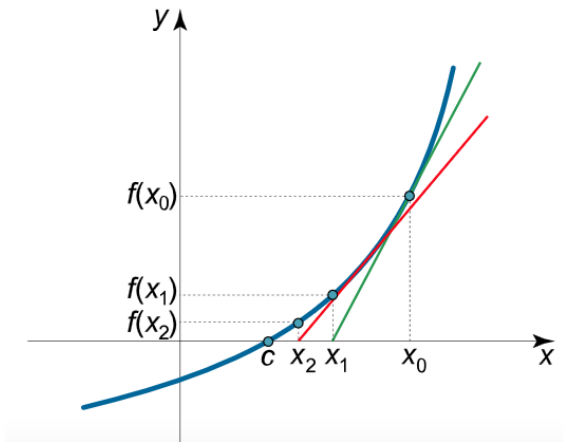
EPS-SAT – Introduction



- EPS-SAT enables high level modeling of aerospace power system concepts
 - Addresses the need for a tool to study the electrical power system
 - Supports DC, single, and polyphase AC systems
- Included in library
 - Component models
 - Loads, sources, PMAD
 - Cable design
 - System/architecture models
 - Solver and other core tools

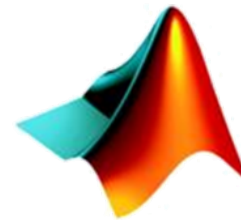


EPS-SAT – Introduction



- Capabilities
 - Newton Raphson solver
 - Performance maps
 - Parameter sweeping
 - Running simulation test profiles
 - Visualization tools
 - and more!

- Requirements for use
 - Have a MATLAB license
 - Have one or more possible architectures specified for your problem
 - Know or can estimate needed model input parameters such as
 - Transmission line lengths and constraints (e.g. voltage drop tolerance)
 - Component nominal efficiencies and specific powers (kw/kg)

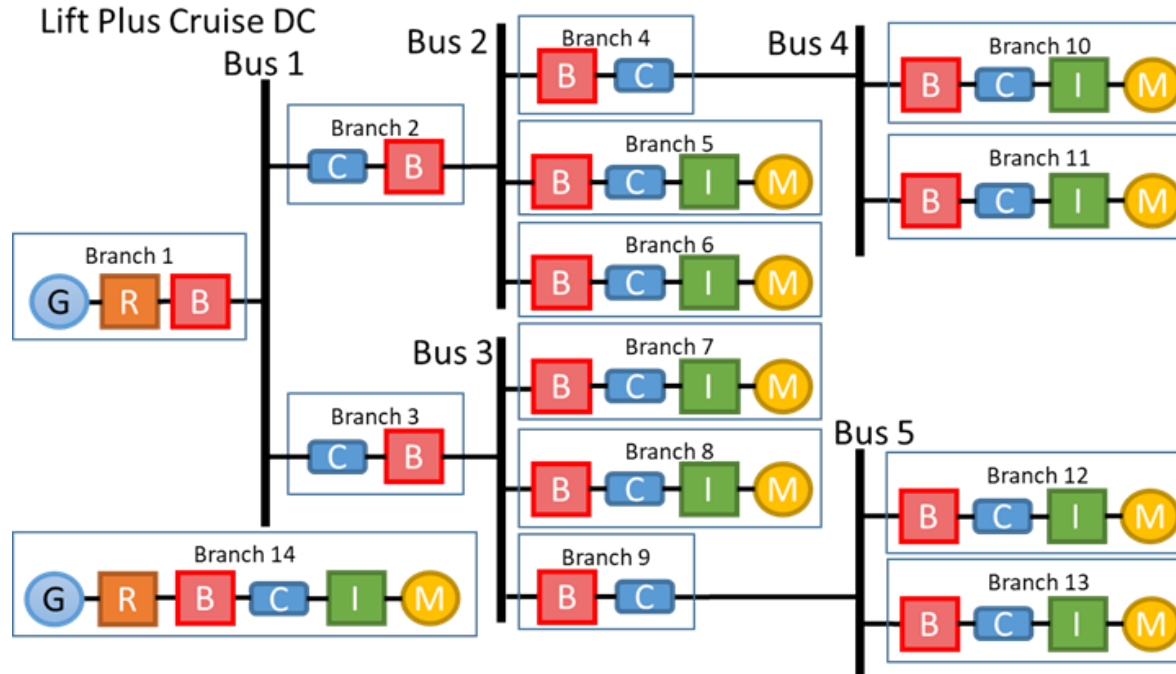


MATLAB

EPS-SAT – Main Purpose in RVLT Tool Chain



- EPS-SAT enables quick and easy power system studies/trades
 - Better direct investment dollars
 - Evaluate the strengths and weaknesses of various designs/architectures
 - Newton Raphson solver tuned specifically for power system models
 - Large networks can be constructed (see L+C below)
 - Sweep parameters, trade architectures (AC vs DC)

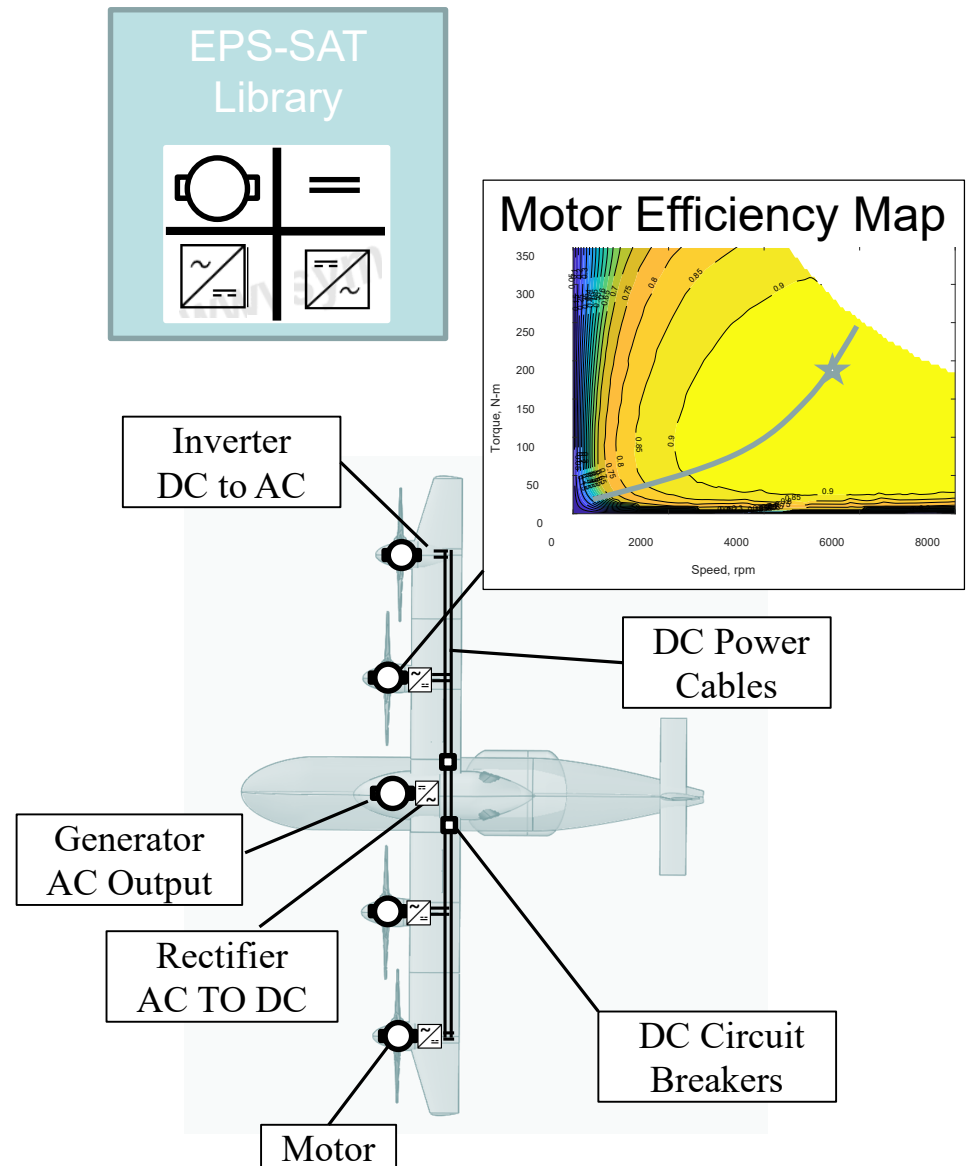


EPS-SAT – Main Tasks



List of common tasks in EPS-SAT workflow:

1. Define system architecture
2. Determine study to be conducted
 - Sweep a design parameter
 - Run a flight profile
 - Etc
3. Select components
4. Provide system parameters
 - e.g. efficiency, specific power
5. Run on-design
 - Means: Size the system at design conditions
 - Outputs system weight, loss, etc.
6. Run off-design
 - Evaluate established system at conditions other than design
 - E.g., mission, flight envelope, etc.
 - Note: not shown in graphic
7. Interpret results



EPS-SAT – Input/Output



- Input

- Model file

- Define architecture
 - Select components
 - Input design assumptions
 - E.g. Machine specific power = 16 kW/kg

```
classdef configuration_example < generic_configuration
    methods
        %% Set up the architecture
        function obj = setup_architecture(obj)

        % -- Initialize the branches --
        obj.components.gen1      = generator_class(400,13,0.96);
        obj.components.gen1.map  = power_efficiency_map_class();
        obj.components.cpl1_1    = circuit_protector_class(350,0.995);
    end
end
```

- Run file

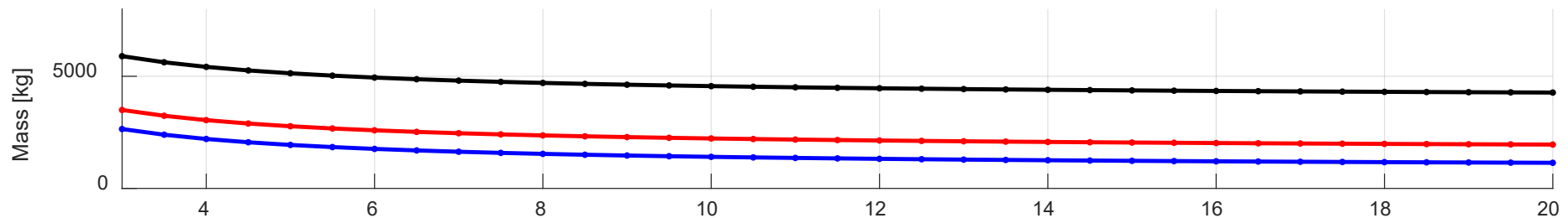
- Define input parameters
 - Define solver variables and ICs

This is a sweep of electric machine specific power (kW/kg)



- Output

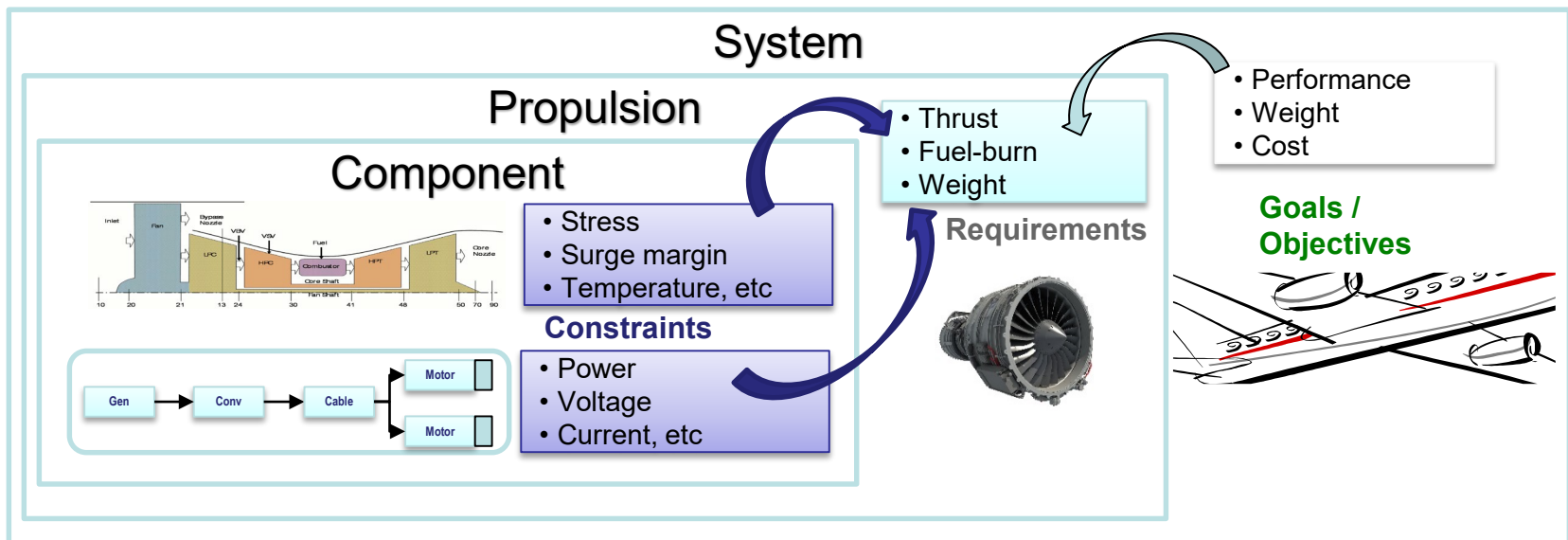
System Mass vs. Machine Specific Power



NPSS – Introduction



- Engines are designed using systems analysis
 - Steady-state system-level simulations (e.g. cycle decks)
 - Engine companies often use NPSS for early, conceptual level design
- Propulsion systems designed given objectives and constraints
 - Objectives: fuel burn, emissions, noise, cost, performance
 - Constraints: component min/max operating conditions (e.g. temperatures)
- Electrified propulsion presents need for tools to model power and propulsion
 - Difficult to produce good designs without tools that simultaneously model both
- NPSS Power System Library and Electric Port represents these tools

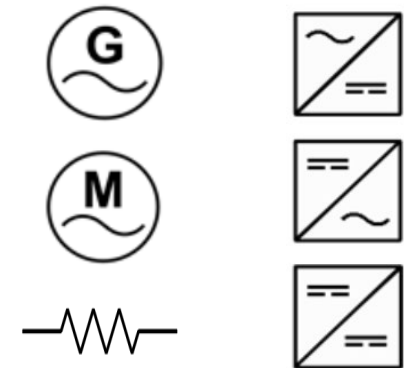


NPSS – Introduction

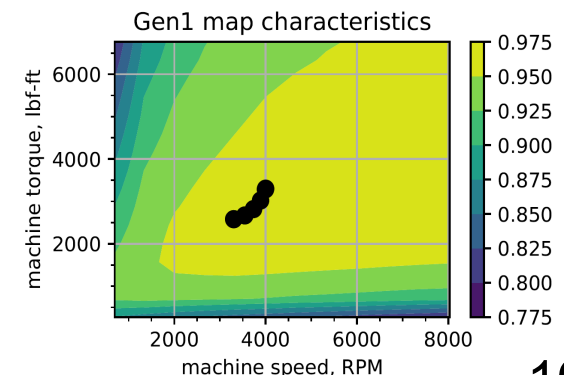


- NPSS Consortium to add electrical port into next official release
- NASA developing open source library of power components for port
 - <https://github.com/nasa/NPSS-Power-System-Library>
- Applying to RVLT project studies now

ELEMENT	MAP	MDP	DC	AC, 1-PHASE	AC, 3-PHASE
CABLE			X	X	X
MOTOR	X	X			X
GENERATOR	X				X
RECTIFIER	X		X		X
INVERTER	X		X		X
DC-DC CONVERTER	X		X		
BREAKER			X	X	X
LOAD			X	X	X
SOURCE		X	X	X	X
RESISTOR			X	X	
CAPACITOR			X	X	
INDUCTOR			X	X	



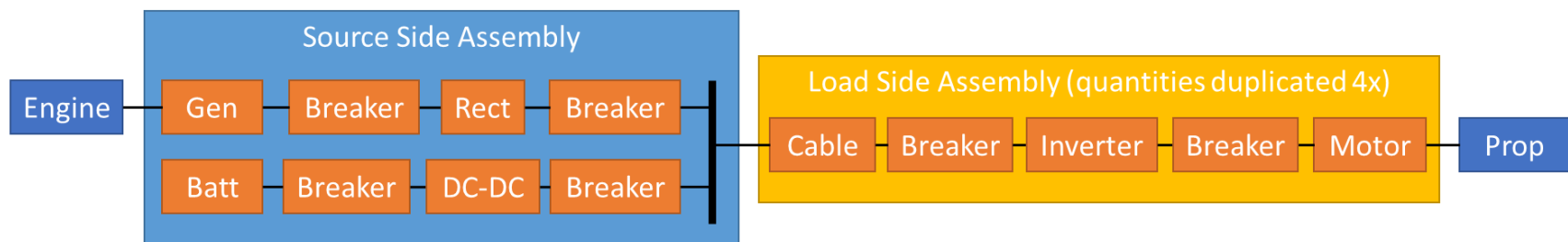
- Capabilities
 - Performance (efficiency) maps
 - Sizing logic (multi design-point (MDP), cable)
 - Integration with thermal/propulsion
 - Transients (thermal and shaft dynamics)



NPSS – Main Purpose in RVLT Tool Chain

- Enable multidisciplinary powertrain models and associated analysis
- Interfacing with wealth of previously existing NASA, industry models
- Conduct work in a proven environment
 - 20+ years of extensive use in US industry
 - Propulsion components validated over and over again
 - New power components validated against textbook problems, soon to be validated against testbed data
- NPSS already a part of RVLT toolchain
 - Now by adding power capabilities, can meet even more project needs

Series Hybrid Electric (w DC Bus)

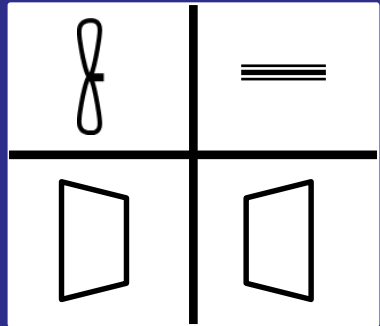


NPSS – Main Tasks

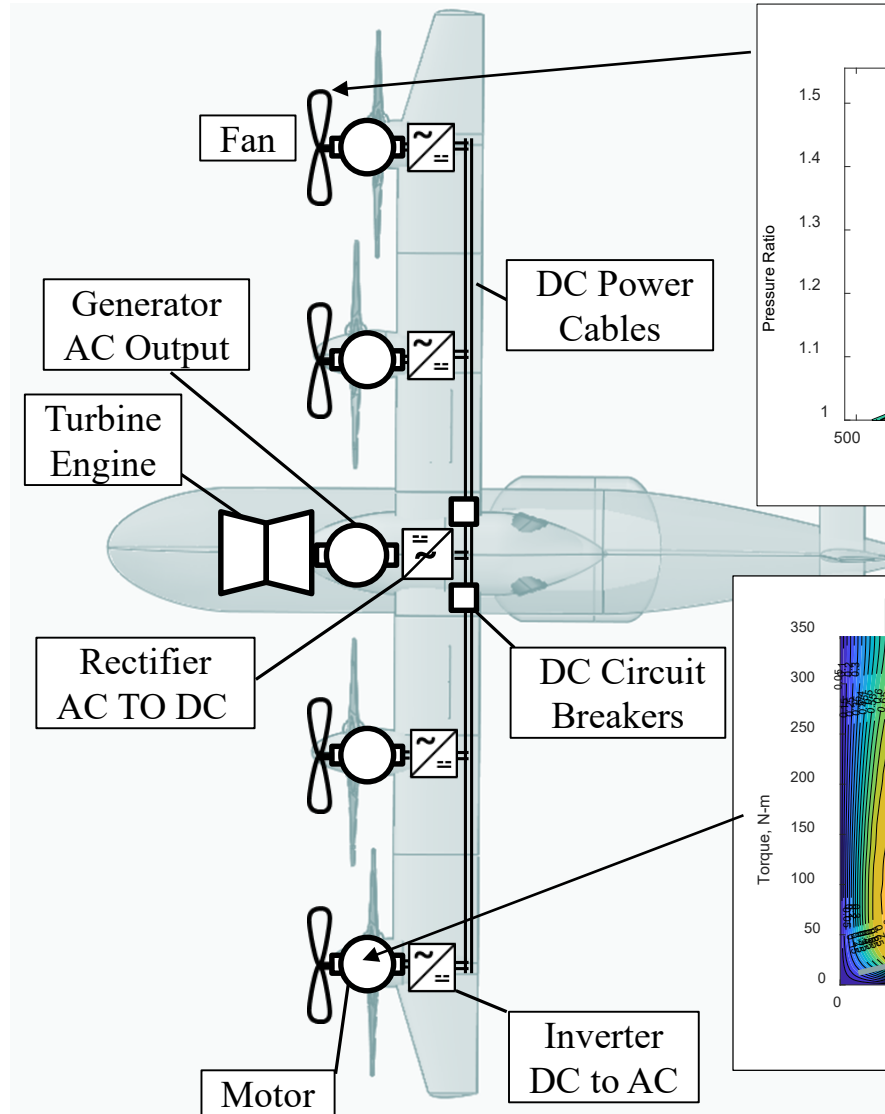
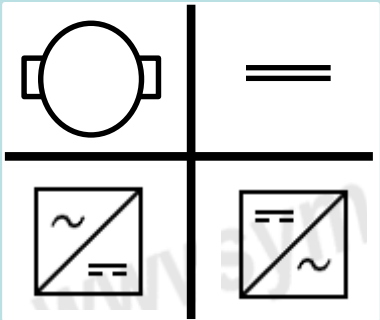


List of common tasks in NPSS workflow Model and size power and propulsion subsystems together

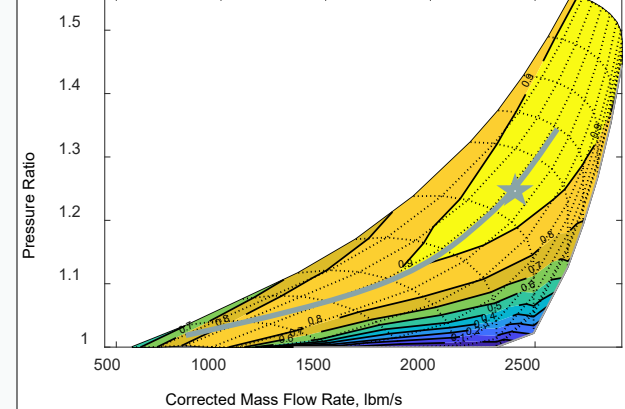
Gas Turbine Component Library



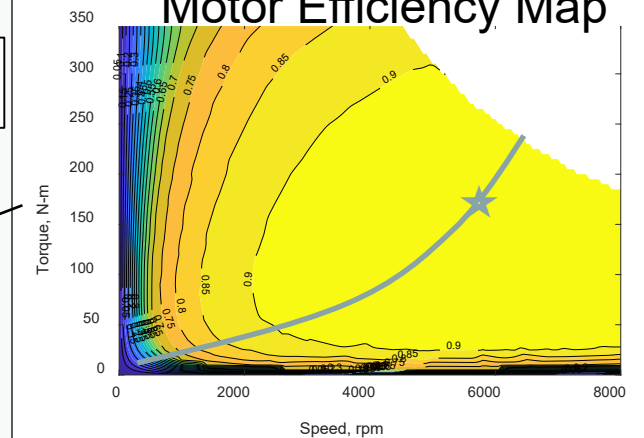
Power Systems Component Library



Fan Efficiency Map



Motor Efficiency Map



NPSS – Input/Output



Presenting I/O for team's RVLT Quad6 Model

- Inputs

- Modeling assumptions/constants file
- Model definition file(s)
 - Define architecture in terms of modular assemblies
- Run file
 - Instantiate a model
 - Define input parameters
 - Define solver variables and ICs

- Outputs

- Viewer Output files (NPSS Standard)
- CSV files (import to Excel)

```
▼ npss-rvlt-quad
  ▼ include
    ⚙ Acp_4001_NPSS.map
    ⚙ axi-3_2.map
    ⚙ hpt1269.map
    ⚙ lpt9013.map
    ⚙ techAssumptions.int
    > map_plotting
  ▼ model
    ▼ DC_Hyb_Model
      ⚙ DC_Hyb_Engine.mdl
      ⚙ DC_Hyb_LoadAssembly.mdl
      ⚙ DC_Hyb_Model.mdl
      ⚙ DC_Hyb_SourceAssembly.mdl
    ▼ TE_Model
      ⚙ TE_Engine.mdl
      ⚙ TE_LoadAssembly.mdl
      ⚙ TE_Model.mdl
      ⚙ TE_SourceAssembly.mdl
    ⚙ AC_Model.mdl
    ⚙ DC_Model.mdl
    ⚙ TS_1S.mdl
```

```
▼ run
  ⚙ AC_Model.run
  ⚙ DC_Hyb_Model.run
  ⚙ DC_Model.run
  ⚙ TE_Model.run
```

Future Work



- **Further Software Developments**

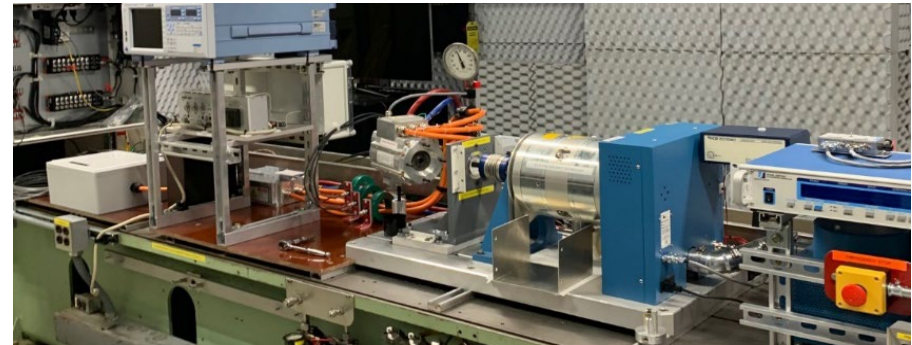
- Continue developing aero component models (EPS-SAT and NPSS)
- New STMD project work for EPS-SAT is funding development of space component and system models

- **NASA Project work:**

- NPSS → RVLT, AATT
- EPS-SAT → RVLT, STMD:GCD

- **Hardware:**

- Repurpose 2 existing test cells
- Produce data to validate, refine NPSS and EPS-SAT models
 - **Low power** (up to 9 kW) motor, controls tests
 - **Higher power** (up to 200 kW)/higher voltage (nominal 700 VDC, 1000 VDC peak)
Investigate efficiency, reliability, power quality, faults, thermal loads



Test setup in the SW13 Cell (Low Power Testbed)

