GUNNS

“Reach for the sky”

Intro Presentation
October 30, 2014

What is GUNNS?

- General-Use Nodal Network Solver
- GUNNS is a tool set to model flow systems in NASA's Trick simulation environment.
- 3 main tools:
  - GUNNS: run-time models (also called “core”)
  - GunnShow: network design GUI
  - GunnSite: run-time analysis GUI (prototype only)

What is GUNNS?

- Reusable common approach to 3 simulation domains (“aspects”):
  - Fluid (plumbing, life support systems, etc)
  - Electrical (generation, distribution, loads)
  - Thermal (structure temperatures, solar heating, etc)
- Reusable approach makes GUNNS compact and flexible
  - Lower dev & maintenance cost
- Dynamic interaction between all 3 flow aspects and external models

What is GUNNS?

- GUNNS uses Nodal Analysis to simulate flow systems
  - Models (batteries, pipes, valves, radiator panels, etc) are combined in a “network” to represent the physical system.
  - Network is propagated in time domain and model parameters updated.
- GunnShow used to draw up these networks, and run-time code & config files auto-generated from the drawings.
  - Deliverables are self-documenting

What is GUNNS?

- Many similar tools in the public domain
  - Matlab/Simulink/SimHydraulics
  - Thermal Desktop, SINDA/FLUINT
  - E-terra/Habitat
  - SPICE
- The same general algorithm is widely used in the energy sector & electronics:
  - Plant & pipeline modeling, petrochemical & nuclear industries
  - Electrical distribution & circuits

Value

- GUNNS value to NASA:
  - Optimized for Trick environment
  - Real-time or Monte-Carlo sims
  - Space vehicle applications
  - Highly reusable
  - No unneeded features and low 3rd-party licensing costs
- Customers get the biggest value when they need to simulate all 3 domains.
  - If just one domain, possibly not worth the overhead

Current Customers

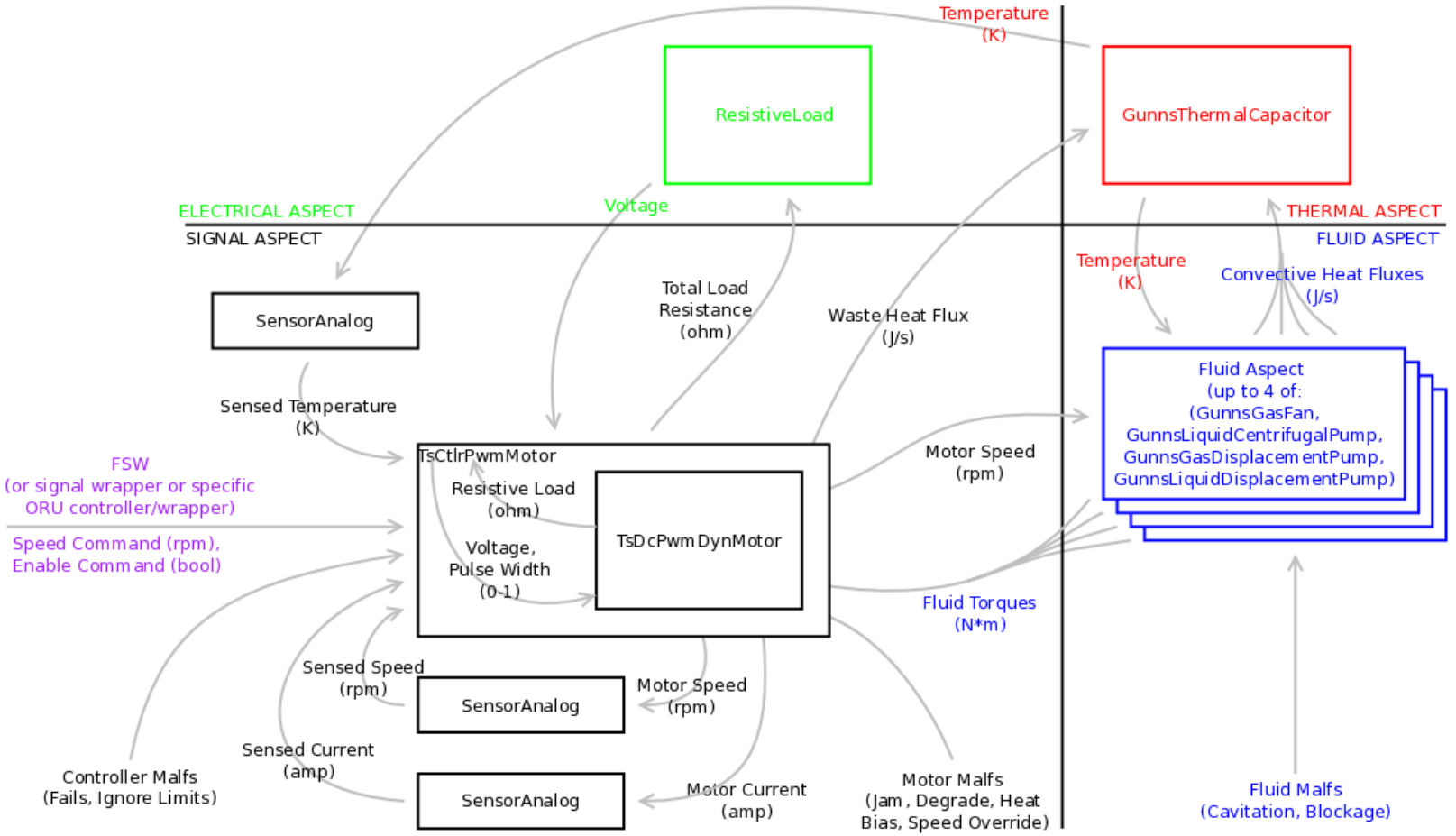
- Currently used in space vehicle simulations at JSC:
  - TS-21 ISS full-task trainer (SSTF)
  - TS-21 Generic Visiting Vehicle trainer
  - Multi-Mission Support/Exploration Vehicle (MMSEV) sims (Orion/MPCV, EAM)
  - Next-gen space suit studies
- Seeing growing use in Engineering Directorate

Basic Concepts

- GUNNS is an 'orchestrator' in TS21 Aspect Architecture
- Aspect Architecture divides a model of a vehicle h/w object (such as a pump) into separate code objects, each implementing a specific aspect of the h/w (fluid, thermal, electrical, etc)
  - As opposed to traditionally: all aspects were combined in one code object or divided by other criteria
  - This allows networks of objects of like aspect to be solved as simultaneous systems
  - Improves fidelity, flexibility & stability

Basic Concepts

This “aspect diagram” illustrates the various aspects of a typical pump:



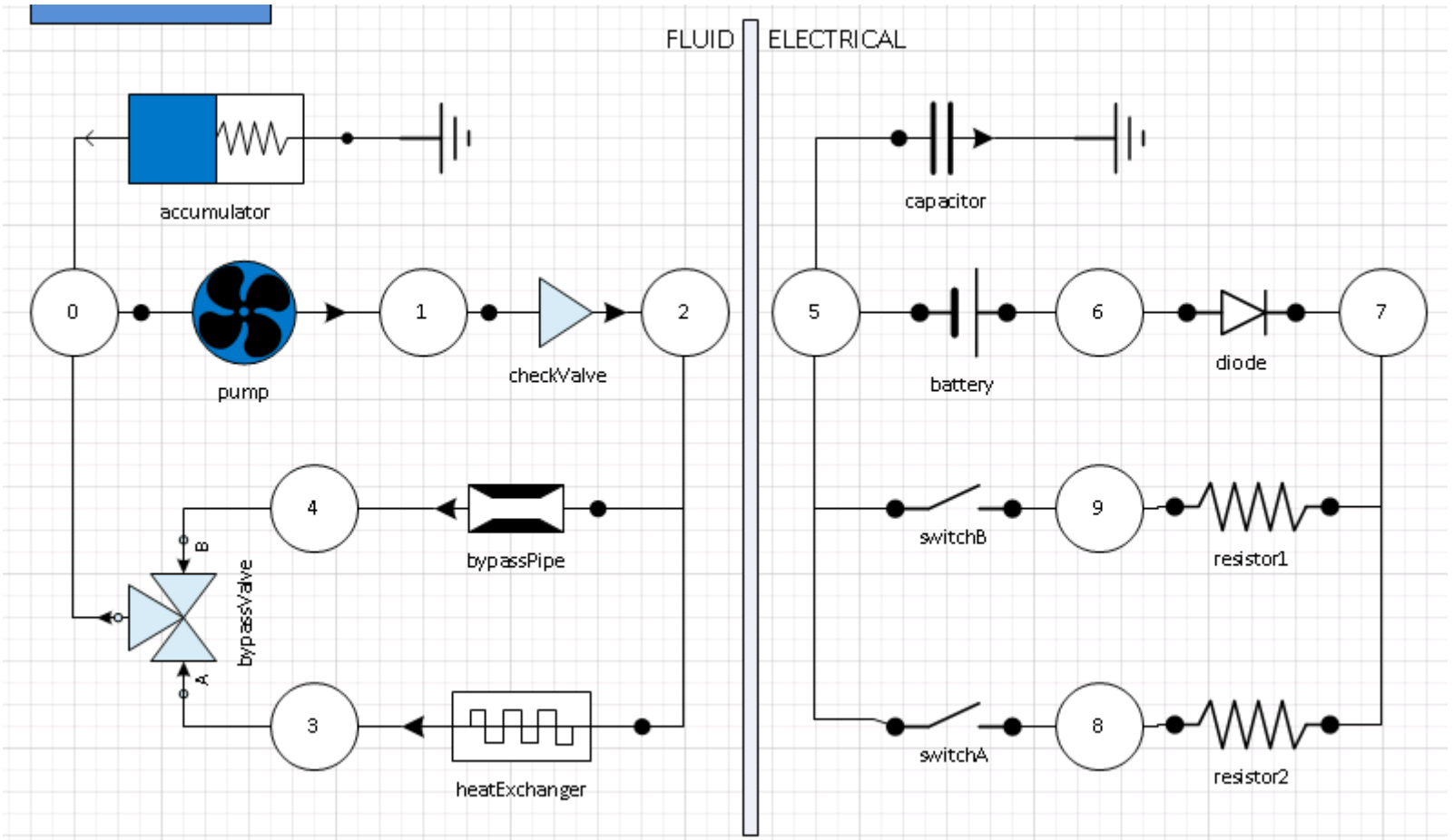
Basic Concepts

- GUNNS does Nodal Analysis -- solves a system of simultaneous equations of the form:
  - [A]{p} = {w}
- This form is good for simulating flow systems:
  - Fluid, Thermal, Electrical aspects
  - Medium-fidelity, medium-size systems
  - Perfect for real-time vehicle training simulations

Basic Concepts

- To simulate all 3 aspects, GUNNS uses the Hydraulic-Electric-Thermal Analogy
  - Potential: Pressure ≈ Voltage ≈ Temperature
  - Flux: Mass Flow ≈ Current ≈ Heat Flux
  - Capacitance: Volume ≈ Capacitance ≈ Mass * Cp
  - Conductance: Area ≈ 1/R ≈ Thermal Conductance
  - We get a lot of code & conceptual reuse from this
- Can also be used for other types of systems
  - Only requirement is [A] be symmetrical positive semi-definite

Analogous Fluid/Electric Components

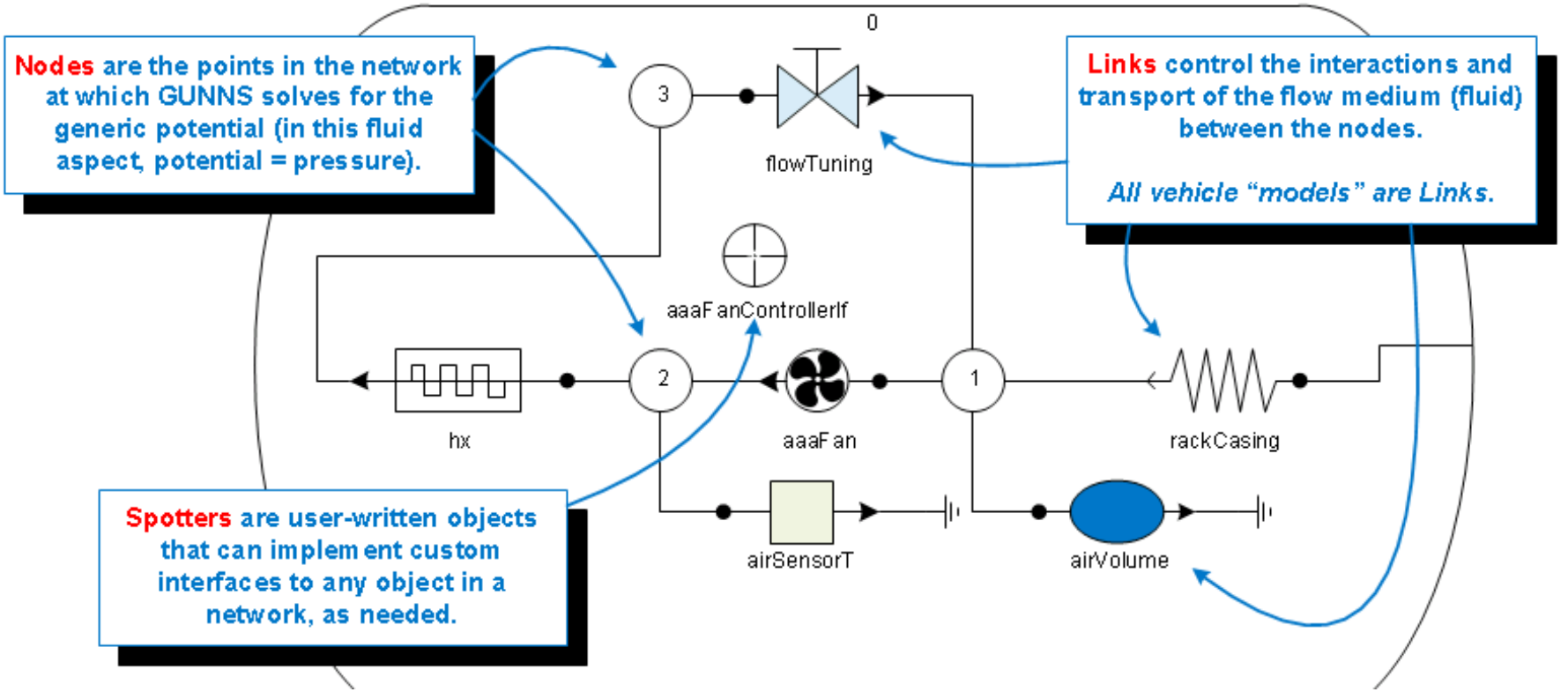


Building Blocks

- Vehicle systems are divided up into GUNNS Networks
  - Networks are systems that are more-or-less self-contained, with clear interfaces to other systems
    - For instance, the brake system in your car is separate from the fuel system - they would be separate networks
- Networks contain:
  - Nodes & Links which model the vehicle and implement the system of equations
  - A solver which solves & propagates the system
  - Spotters, which are highly flexible objects that embed custom interfaces and capabilities.

Building Blocks

This GunnShow example illustrates some of the basic building blocks of a GUNNS network:



Scalability

- Large networks have high CPU demand:
  - CPU demand scales as cube of # network nodes
  - To mitigate, we divide vehicle systems into separate networks as needed
  - Networks of similar aspect can interface & flow between them (fluid-fluid, thermal-thermal, etc)
    - Trick multi-thread simbus & aspect architecture makes this easy
- In full-task ISS sim (SSTF), all GUNNS networks run on 3 Xeon cores leaving >50% overhead.
  - Largest network (primary EPS) is ~430 nodes

Scalability

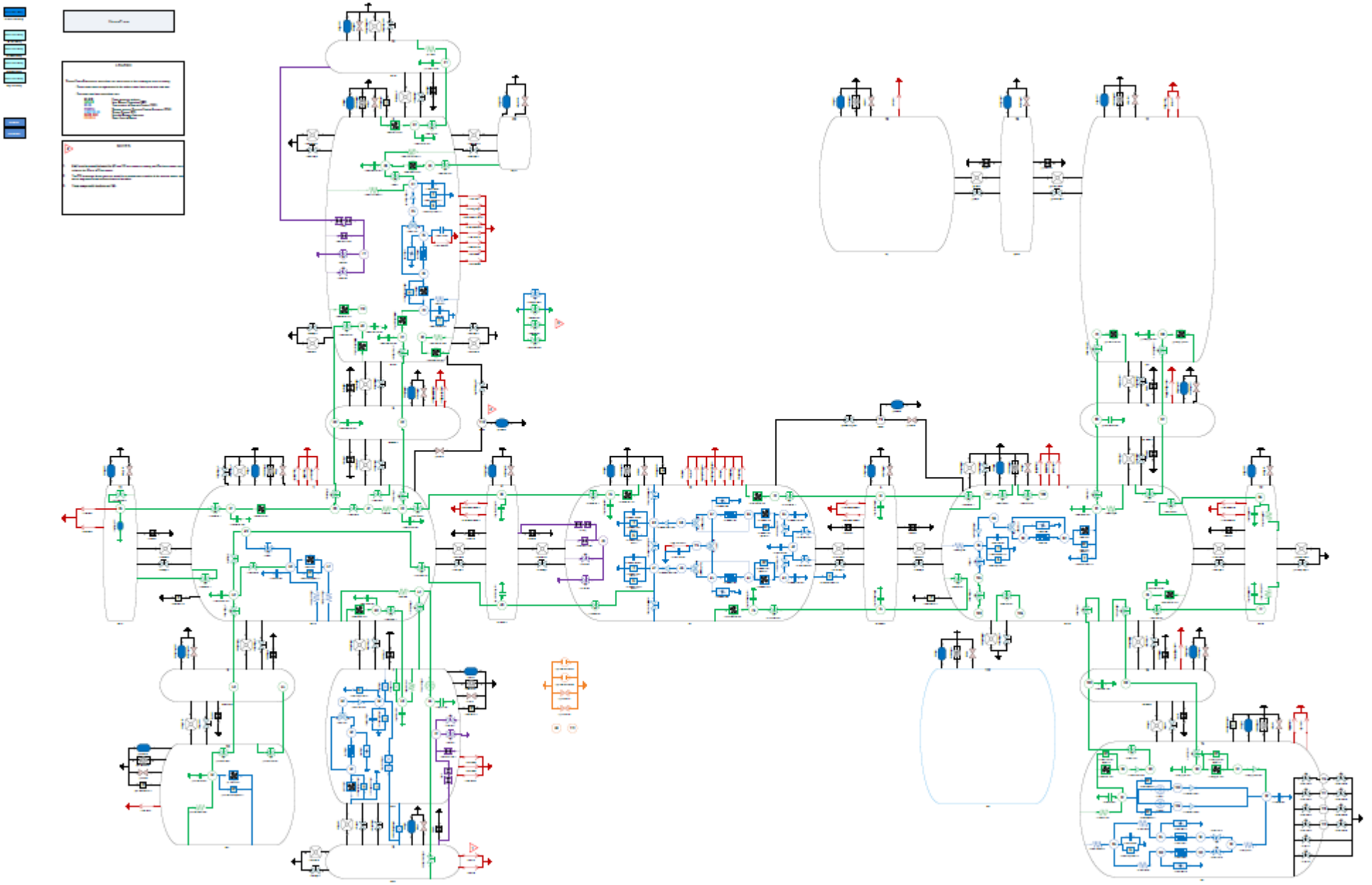
- Highly customizable:
  - Users can develop their own links & spotters from scratch or extend Core classes as needed
  - We welcome users contributing to an open-source library of reusable links & spotters
  - Network class itself can be extended as needed

GunnShow Visio

- GunnShow has a plug-in to MV Visio for a drag & drop GUI to build fluid & electrical networks
  - User drags links, nodes & spotters from a shape library and hooks them together
  - User enters config and initial condition data to objects (tank volumes, electrical resistances, initial fluid states, etc)
- Network C++ run-time class is auto-generated on export

GunnShow Visio Example

TS21 SSTF's cabin atmosphere fluid network, circa 2012:

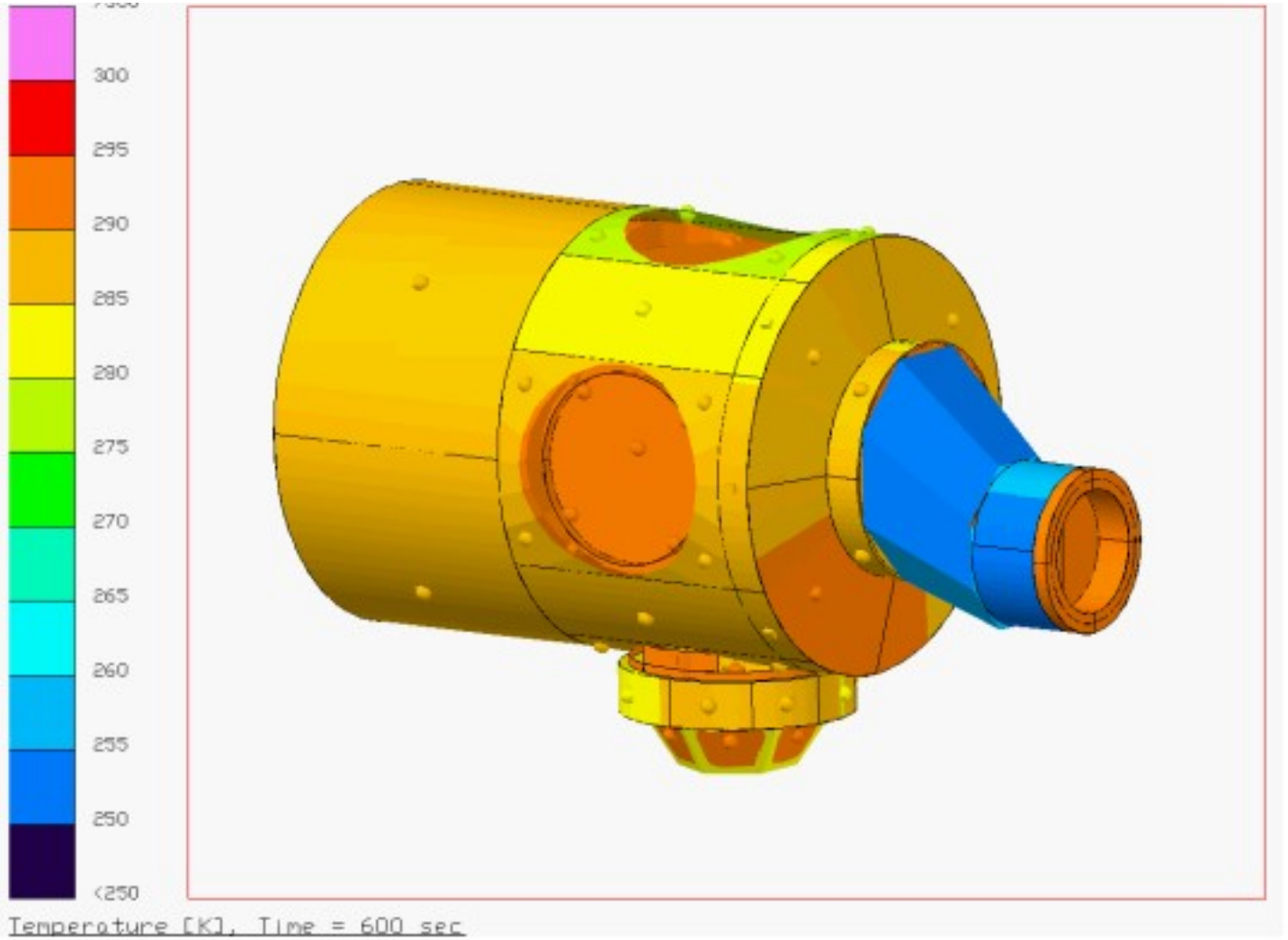


GunnShow Thermal Desktop

- GunnShow has a plug-in to Thermal Desktop as a 3D CAD GUI for building thermal networks
  - Drawing converted to XML files that configure & initialize network at run-time
  - Once set up, changes to network are entirely compile-free.

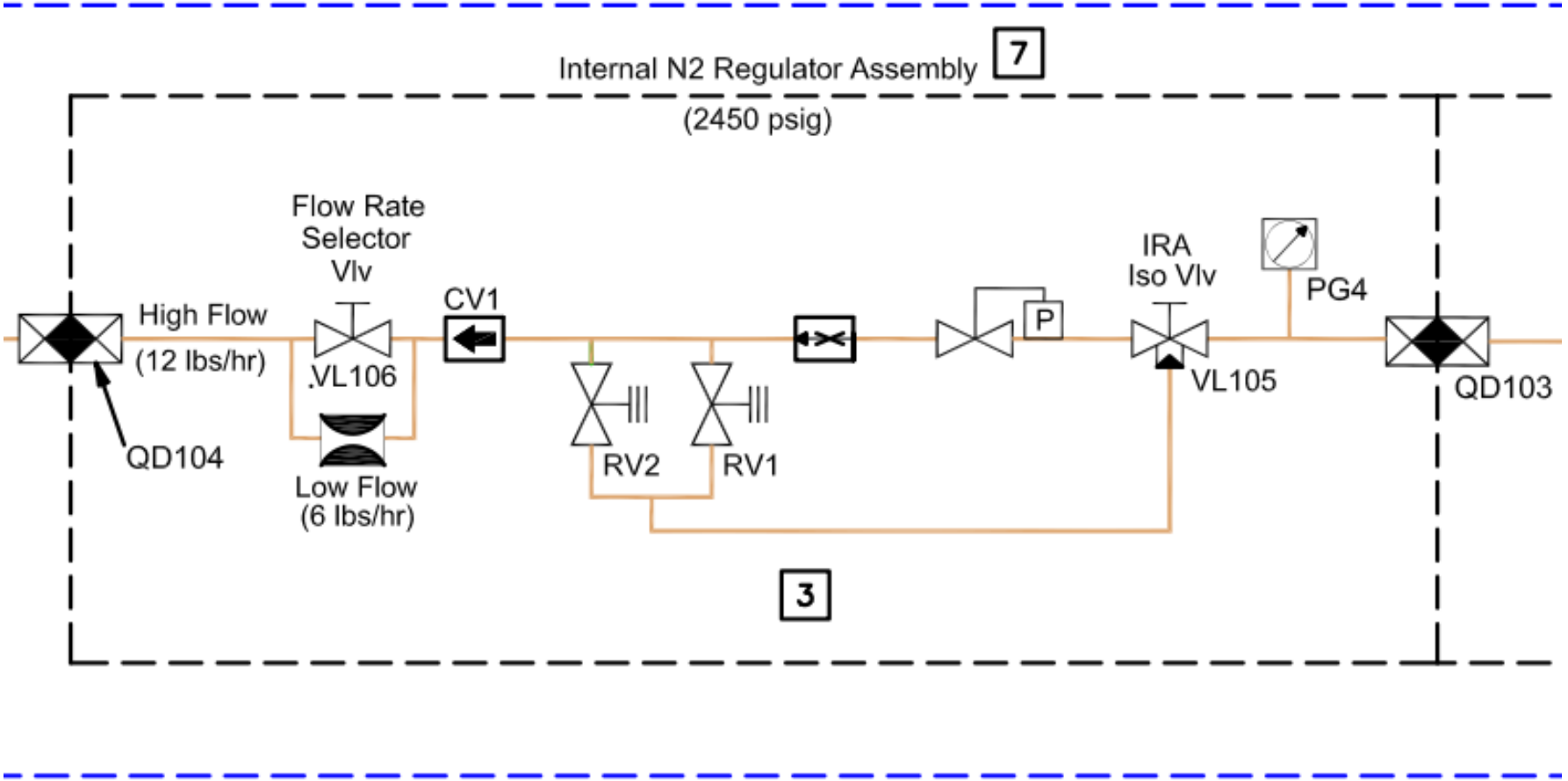
GunnShow Thermal Desktop Example

TS21 SSTF's Node 3 module with Cupola & PMA3:



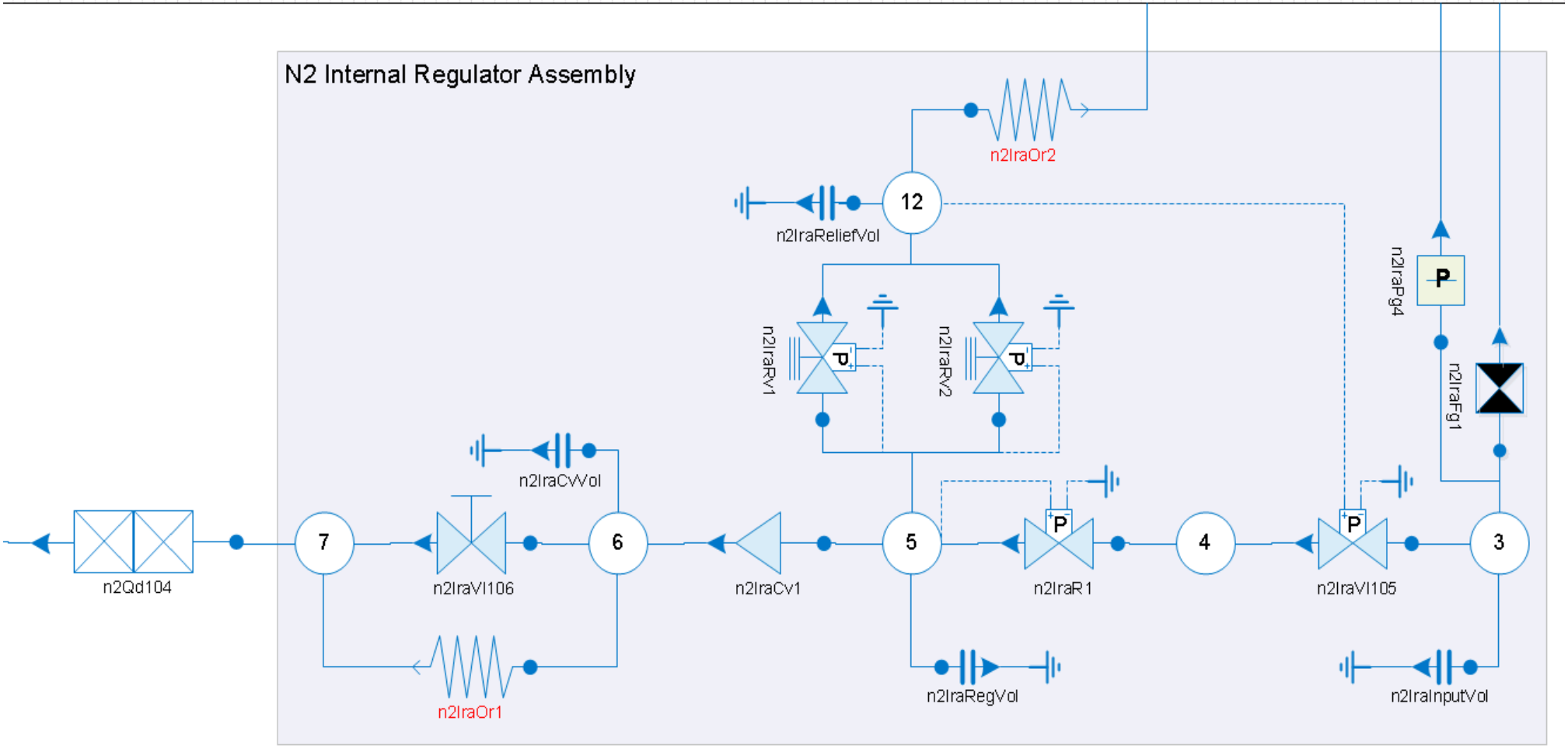
From Real-World to GUNNS

Vendor's Subsystem Drawing:



From Real-World to GUNNS

GunnShow Drawing Equivalent:



Limitations

- GUNNS is NOT a complete vehicle model
  - Only provides fluid, thermal, electrical aspects
  - Other aspects, such as sensors/effectors, motors, controllers (what we call “signal” & “mechanical” aspects, etc) must be provided by user and interface with GUNNS aspects as needed
    - TS21 has developed many such models in conjunction with GUNNS but these are not provided with our toolset
- Currently not well-documented

Dependencies

- Core is optimized for Trick sim environment
  - Can run outside of Trick, but user must provide own sim infrastructure (real-time sequencer, memory management, datastore, data transport, etc)
- GunnShow requires 3rd party s/w:
  - Fluid & electrical aspects use MS Visio Standard
  - Thermal aspect uses Thermal Desktop
  - However, GUNNS networks can be built & maintained by hand without using GunnShow