# NASA CubeSat/SmallSat Reference Model

Authors: Nancy J. Lindsey (NASA GSFC), Lionel-Nobel Sindjui (NASA GSFC), Mahdi Alimardani (NASA GSFC)

**For more information or the Model leave email or contact :**
nancy.j.lindsey@nasa.gov

## Objectives

- Enabling Mission Success and effective design improvements
- Identify Risk (safety, performance, availability, failure) for mitigation
- Ensuring safety through hazard identification and control verification
- Preventing investments from becoming debris
- Optimizing monitoring for preventative action and fault prevention

## Benefits of Model-based Approach

- Automated analyses and reporting
- Analyst agnostic analyses
- Fault simulation and impact visualization
- Efficiency**, consistency, and accuracy**
- Knowledge digitization (enables re-use)
- Traceability of analyses and model changes

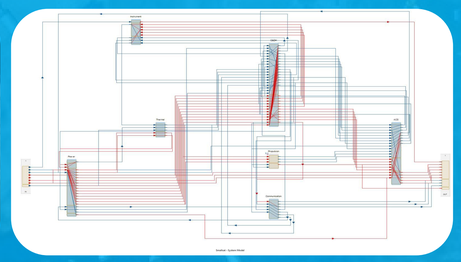
## CubeSat/SmallSat Model Configuration

The CubeSat/SmallSat Reference model configuration is shown here – it is derived from an actual NASA small satellite mission model.

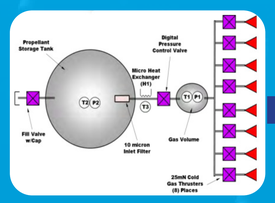
Red lines represent energy flow (hydraulic pressure, electric voltage etc).

Blue lines represent data flow (discrete amplitude, continuous data etc).

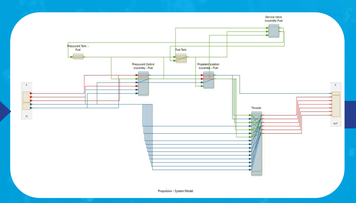
Green lines represent material flows (fuel)



## Reference Model Creation




System Schematic

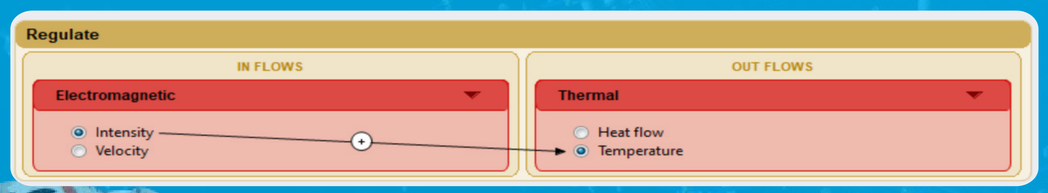


MADe Model

Physical System

The Reference Model was developed using representative smallsat design information to create blocks, functions and flows to create a digital twin that was then generalized represent a generic space-mission within PHM's Maintenance Aware Design environment (MADe). As such it includes a mission profile and all the standard active subsystems configuration items (not the passive - structural subsystem). Each block has functions and flows defined from a fixed taxonomy and are hierarchical to fully capture the behavior if the systems.

## Functions and Flows




Functions and flows are used to describe the inputs and outputs of a block in the system. defined from a fixed taxonomy and are hierarchical. A causal relationship is represented via the connecting arrow between the inputs and outputs which drives the propagation of potential failures in the system given a component failure.

By identifying potential propagation of failures within the system, it allows for planning of mitigating risk and ensures successful operation of the CubeSat/SmallSat.

## Mission Assurance

**Reliability** in the Reference Model can be assessed in multiple ways (prediction, fault trees, failure mode analysis, maintainability and availability). If component reliability is known, it can be entered as an MTTF or Part Failure Rate for Exponential Distribution type Reliability or Slope and Characteristic Life for Weibull Distribution type Reliability. In the case where system components are not yet selected from a vendor (i.e., design phase), it is possible to set target reliability values in MADe to determine the required reliability for each component. The values are used in Reliability Block Diagrams to support design trade studies and assess system reliability, and used in fault trees to assess scenario risks. In failure mode analysis, reliability is used to find the likelihood of critical failure points. They are also used in availability and maintainability analyses to develop sufficient operational and support plans.

**Safety** in the Reference Model can be assessed by modeling the hazards and inhibits. The fault-injection simulation capability can then be used to assess the robustness and independence of safety features. Enhanced Reference model available in late 2022.

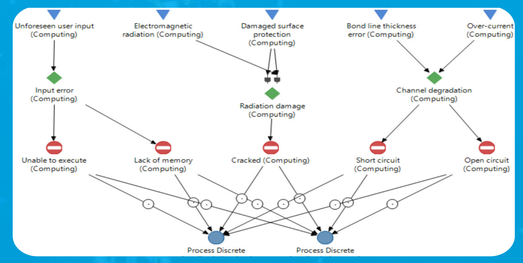
**Quality Assurance** can be assisted with the system models for insights and dependencies. The fault-injection simulation capability can then be utilized to see the impact of non-compliant or suspect implementations. Further with the integration of requirements quality verifications can be tracked and kept current for all disciplines.

**Software Assurance** can be supported in the same way as hardware assurance.

## Functional Failures For Reliability

A failure diagram is a tree-like structure which describes the cause, mechanism and fault which leads to a functional failure.

Causes are represented by:
Mechanisms are represented by:
Faults are represented by:




Failure diagrams can be populated by using library or custom taxonomy to capture knowledge of previous lessons learned.
With functional failures defined a Fault Tree Analysis, Availability, Reliability, and a Failure Modes, Effects, and Criticality Analysis (FMECA) reports can be automatically generated based on the modeled connections and failure diagrams. These reports should be reviewed to verify the system meets desired fault tolerance, longevity, or performance needs.

In addition, simulations can be used to perform “what-if” scenarios and determine how the system would respond and perform given a particular component failure.

Safety and Risk reporting and analyses use these diagrams for consistent and repeatable results as well.

## WHAT IS MADe?

The Maintenance Aware Design environment is a model-based engineering tool that provides a suite of software applications that can be used to design, assess, and optimize availability, sustainablity, and Prognostics and Health Management systems for use in a wide variety of high-risk industries where safety and reliability are critical. MADe analyses also enable trade studies on the safety systems.