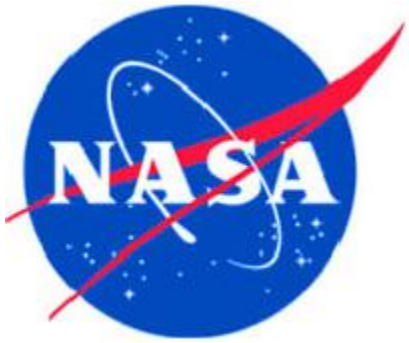

Goal Structuring Notation in a Radiation Hardening Assurance Case for COTS-Based Spacecraft

A. Witulski[1], R. Austin[1], J. Evans[2], N. Mahadevan[1], G. Karsai[1], B. Sierawski[1], K. LaBel[3], R. Reed[1]

[1]Vanderbilt University [2]NASA HQ [3]NASA GSFC

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Background: Mission Assurance

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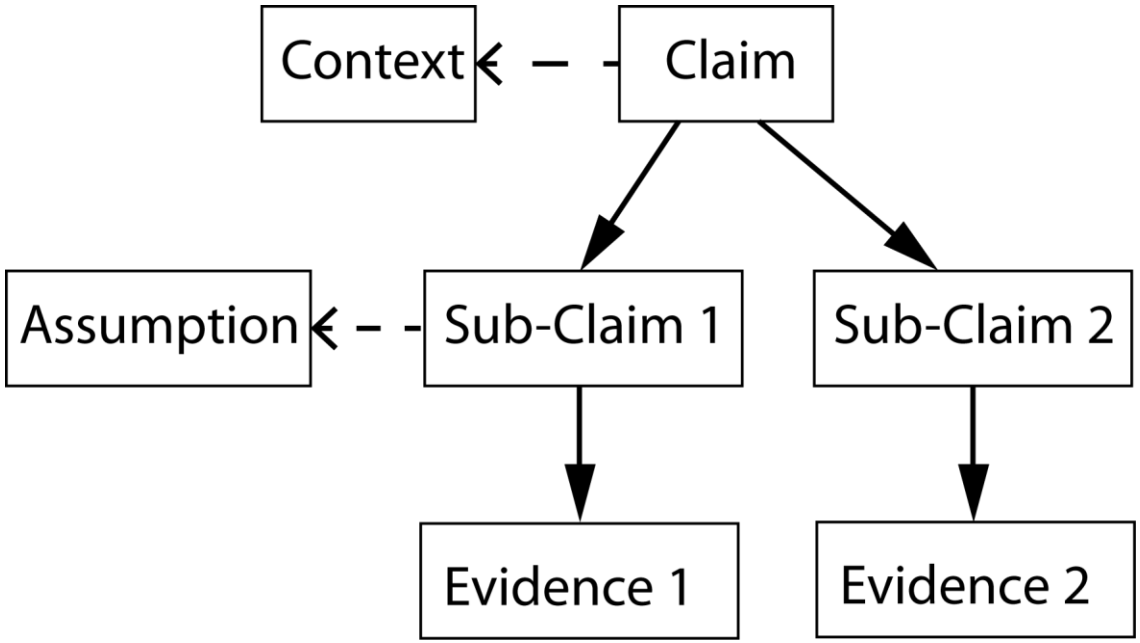
- **NASA classifies spacecraft missions by criteria: Cost, national significance, priority, lifetime, launch constraints**
  - Class A: High-budget, highly significant, e.g. space telescope
    - Low risk tolerance: Conventional radiation testing, hardened parts, etc.
  - (Sub) Class D: Low-budget, limited scope, short lifetime: Cube Sat
    - Relatively high risk tolerance
    - Conventional radiation hardness assurance too expensive
    - Majority use of commercial off the shelf (COTS) parts
    - Still need as much mission assurance as possible.
- **Model-Based representations of spacecraft systems can define sub-system functionality and interfacing, reliability parameters**
  - Quantitative evaluation of sub-system interactions
  - Entire team works from one virtual model set
  - Fault or failures can be propagated from one sub-system to another
- **New paradigm for assurance: model-centric, not document-centric**

Graphical Argument

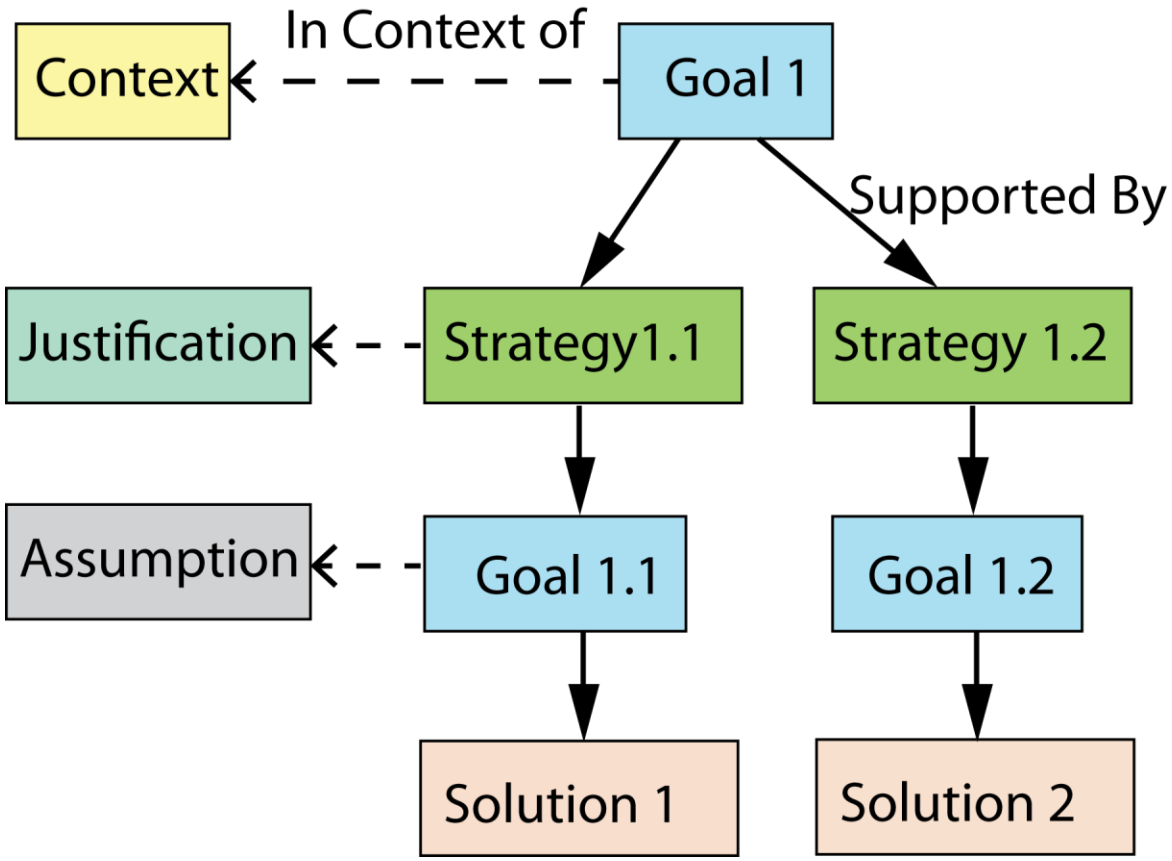


Argument: "A connected series of claims intended to support an overall claim." [1]

Assurance Case: "A reasoned and compelling argument, supported by a body of evidence, that a system, service or organisation will operate as intended for a defined application in a defined environment." [1]

[1] GSN Community Standard Version 1 2011

Goal Structuring Notation (GSN)



GSN is a visual representation of a hierarchy of claims [1]

University of York U.K.

Goal=Claim
Strategy=Inference
Solution=Evidence
Context=Background
Justification=Rationale
Assumption=Unsub-stantiated Claim

Colors/Shapes Denote Function

[1] GSN Community Standard Version 1 2011

Benefits of GSN

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- Graphical argument form clarifies relationships between claims and makes assumptions explicit
- Facilitates connecting mission assurance claims to model-based representations of the system
  - Document-centric/model-centric mission assurance (MA)
  - Eventual goal: connect MA and quantitative models
- Graphical assurance case can be constructed concurrently with design-MA influences design
- Radiation Context:
  - References rad test data, hardened part specs
  - Relates mitigation strategy to total Assurance Case

Vanderbilt Custom GSN Modeling Language

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- **Vanderbilt Institute for Software Integrated Systems**
- **WebGME: Web-based Generic Modeling Environment**
- ***WebGME used to develop Modeling Framework for Goal Structured Notation (GSN)***
- **Support for customizable Domain Specific Modeling Languages (DSML)**
  - Specify modeling rules (meta-models)
- **Allow for customizable visualization**
- **Support for model interpretation**
  - Software that traverses models to generate artifacts – documents/ texts, code, inputs for integrating with other software/ utilities/ analysis engines
  - Provides framework for linking to model-based descriptions of sub-systems

WebGME GSN Screenshot

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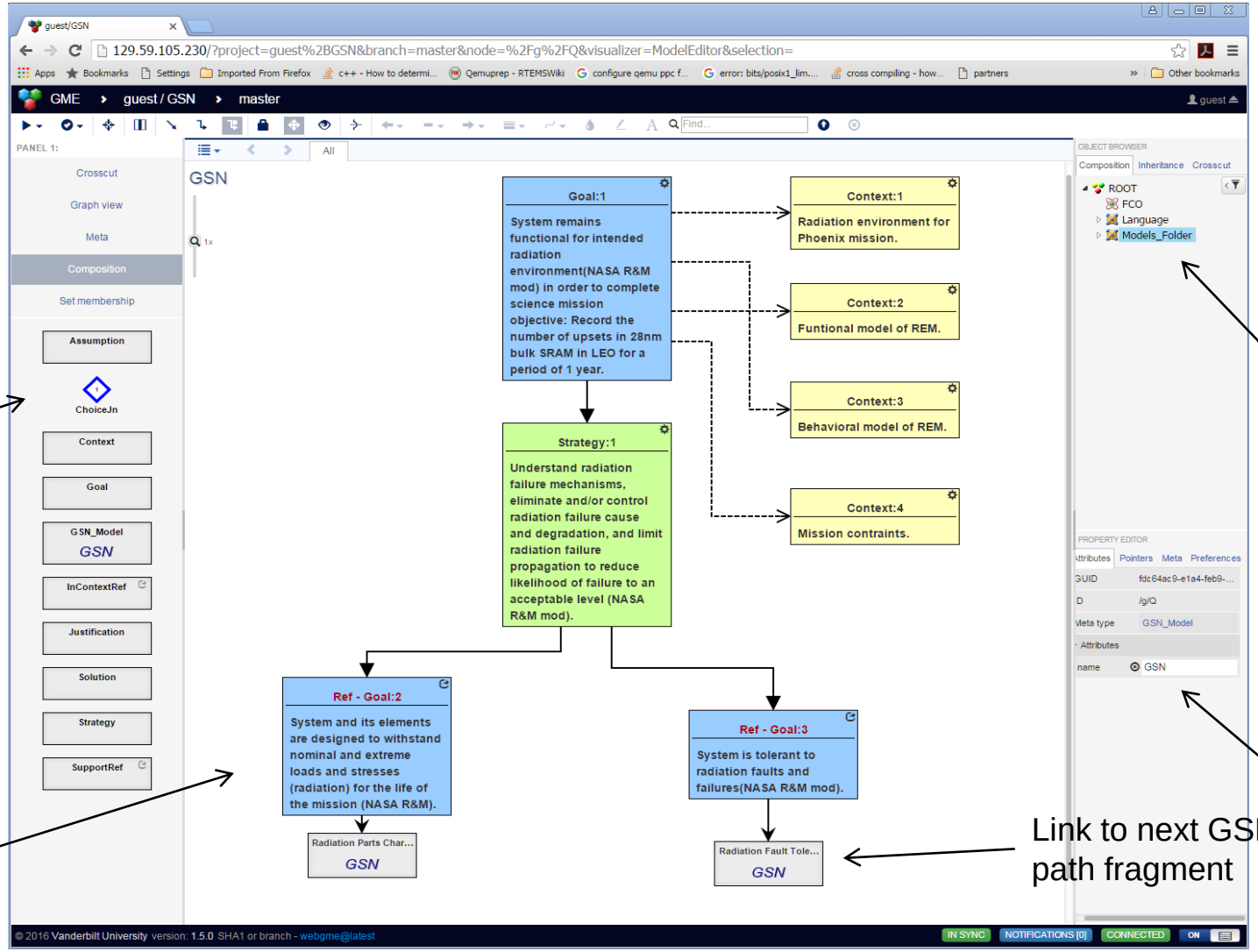

Model Parts Panel

Model Tree Browser

Attributes Panel

Model Editor Canvas

Link to next GSN path fragment

NASA Reliability & Maintainability Template

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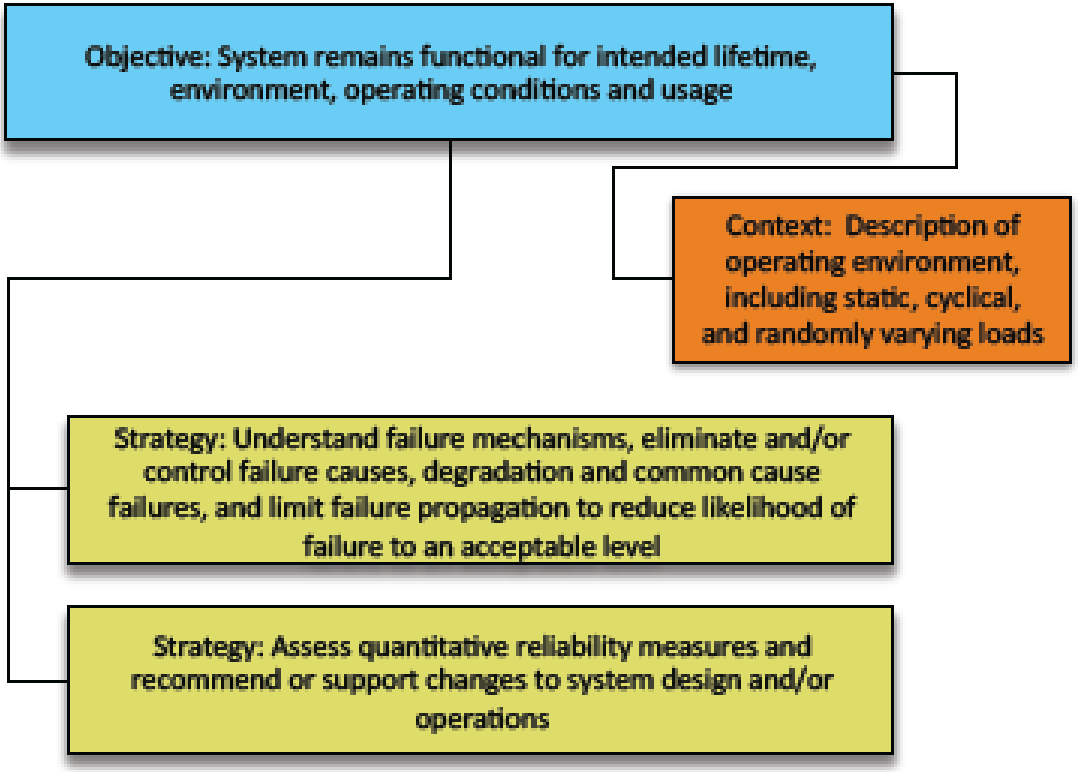


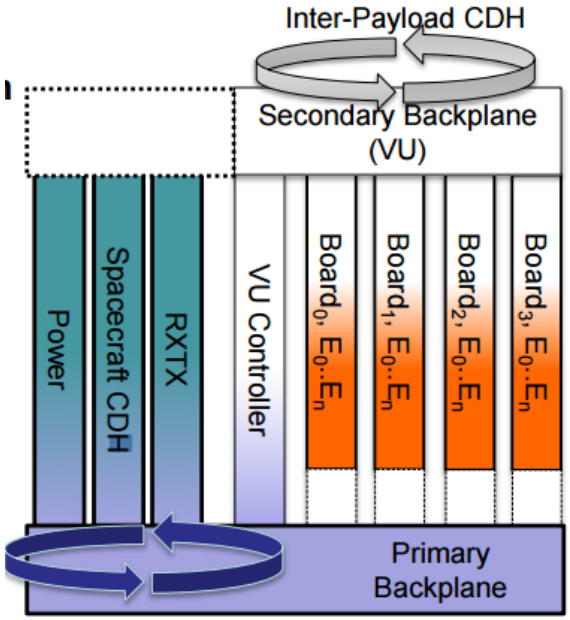
Objectives-based approach to Reliability and Maintainability

General Structure for top-level goals in GSN Assurance Case

[2] Groen, F.J.; Evans, J.W.; Hall, A.J., "A Vision for Spaceflight Reliability: NASA's Objectives Based Strategy," RAMS, 2015, 26-29 Jan. 2015

VU Cube Sat SRAM Experiment Test Bed

Vanderbilt Engineering



- VU Cube Sat Architecture
- Space environment radiation test bed for TID, SEE
- Successful 8 x 4Mb SRAM experiment, launched 2015, reports SEUs, resets, power

Primary CDH

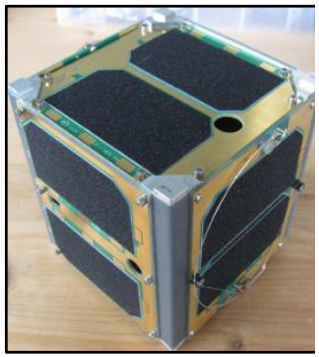
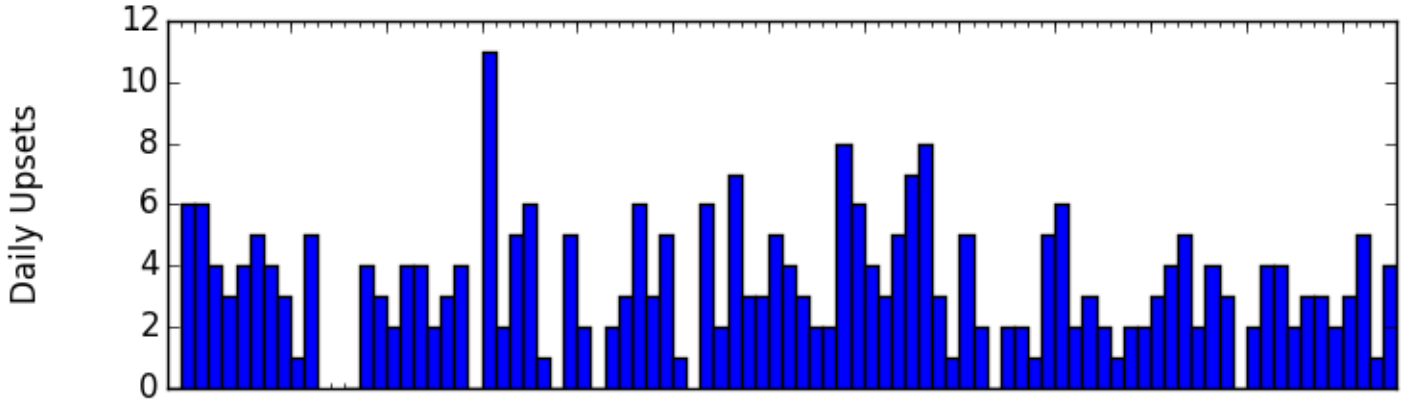


Image Credit: AMSAT



GSN Demo Case: 28nm Commercial SRAM SEU Test in LEO

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- Launch December 2016
- Radiation Effects Modeling (REM) Board
- Detect SEUs in the SRAM
  - Protect data from other SEEs on the board
  - Count upsets from SEUs in SRAM, not SELs
- Current monitoring for latch up detection
  - Monitor separate for SRAM and rest of the board
  - High-current on SRAM causes the experiment to reset and not count the upsets seen
  - High-current on the rest of the board causes the microcontroller to reset while the SRAM continues to be on and record upsets

Block Diagram SRAM SEU Experiment Board

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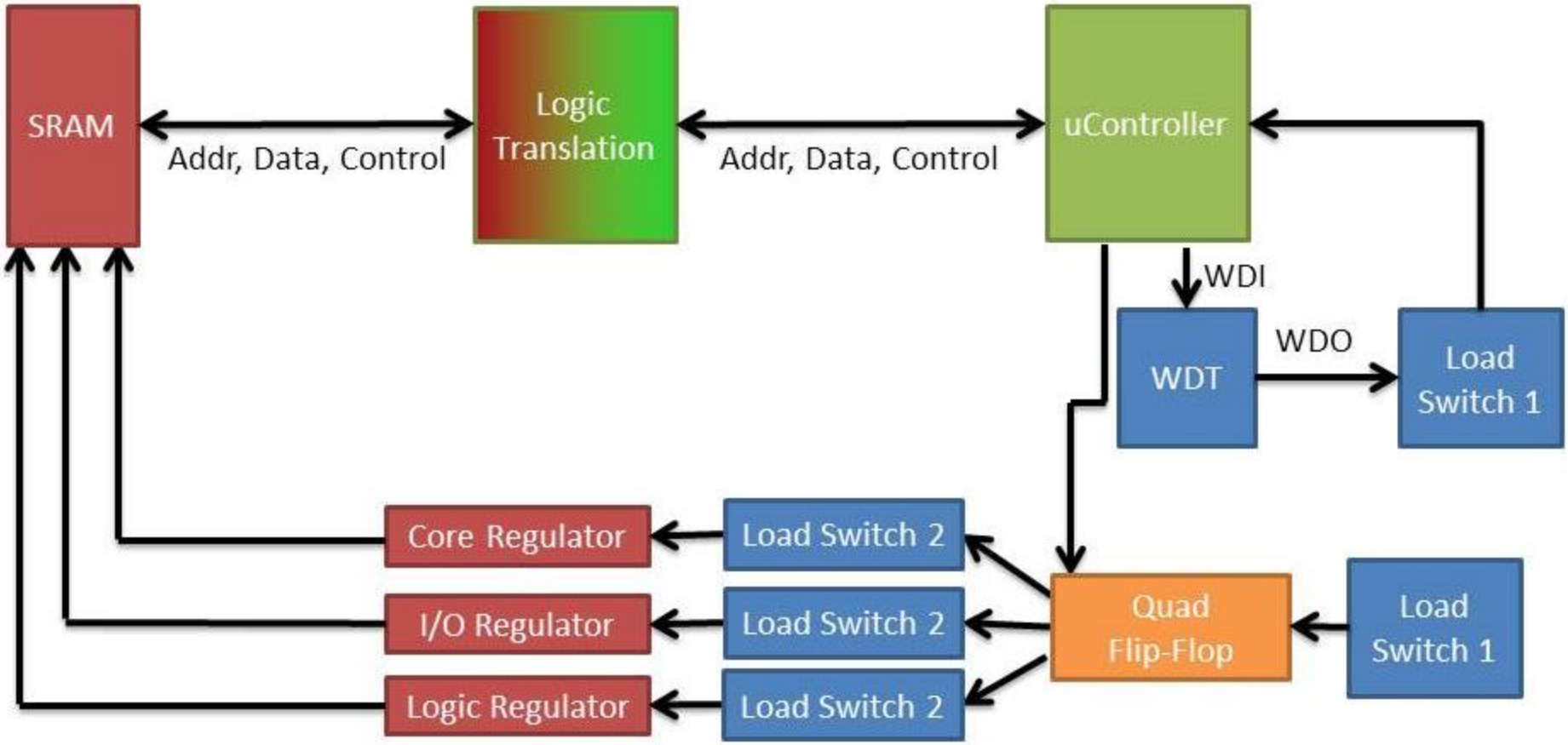
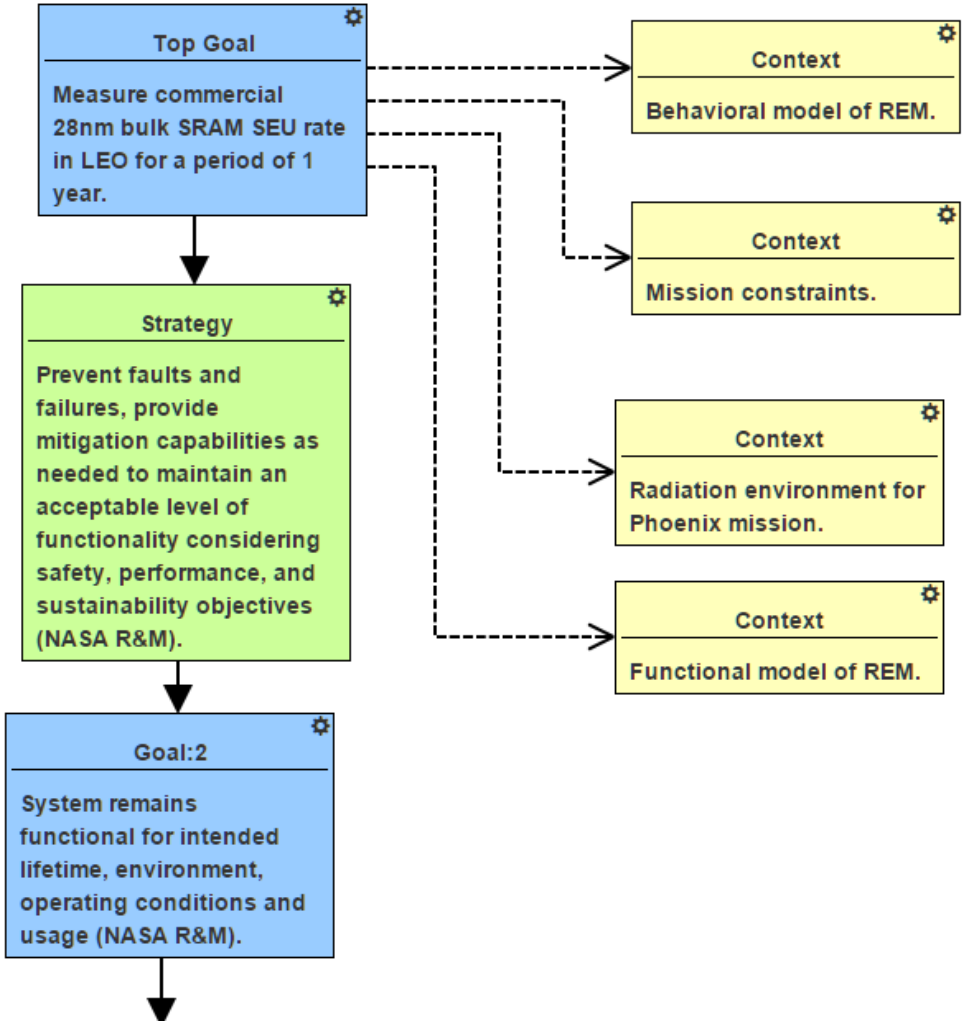


Mitigation techniques for latch-up in board components

GSN Assurance REM SEU Experiment Board



- Top Goal states overall objective
- Context statements give easy access to relevant mission docs
  - Artefacts
- Top level goals and strategies track NASA R & M template

GSN Assurance REM SEU Experiment Board

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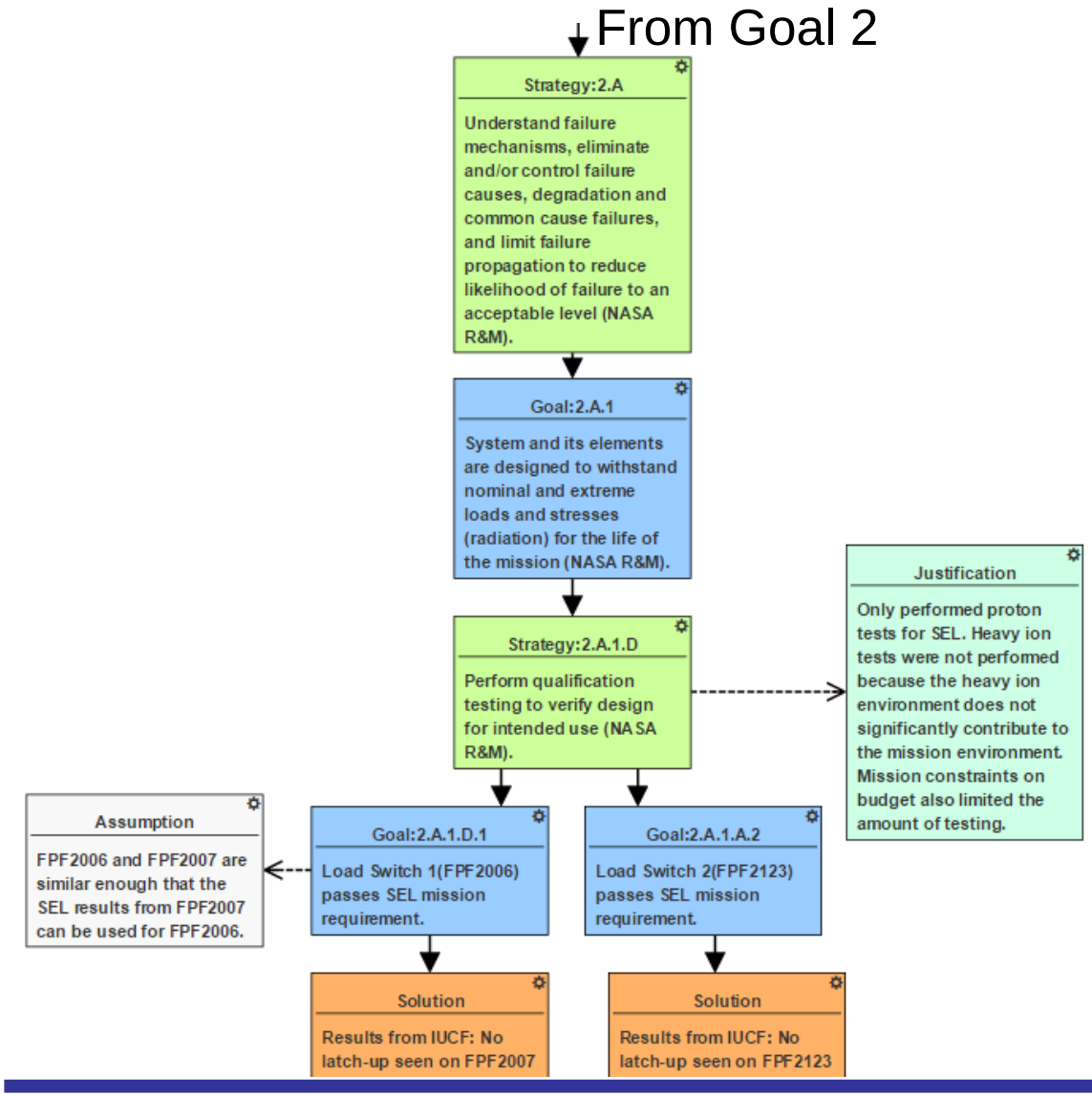

- Not all branches of GSN graph shown
- Assumptions are clearly identified
- Argument path terminates in Solution
- Validity of Assuance case determined by reading from Solutions to top level goals.

Summary