National Aeronautics and Space Administration

Design-Concurrent Radiation and Reliability Qualification of Space Flight Hardware

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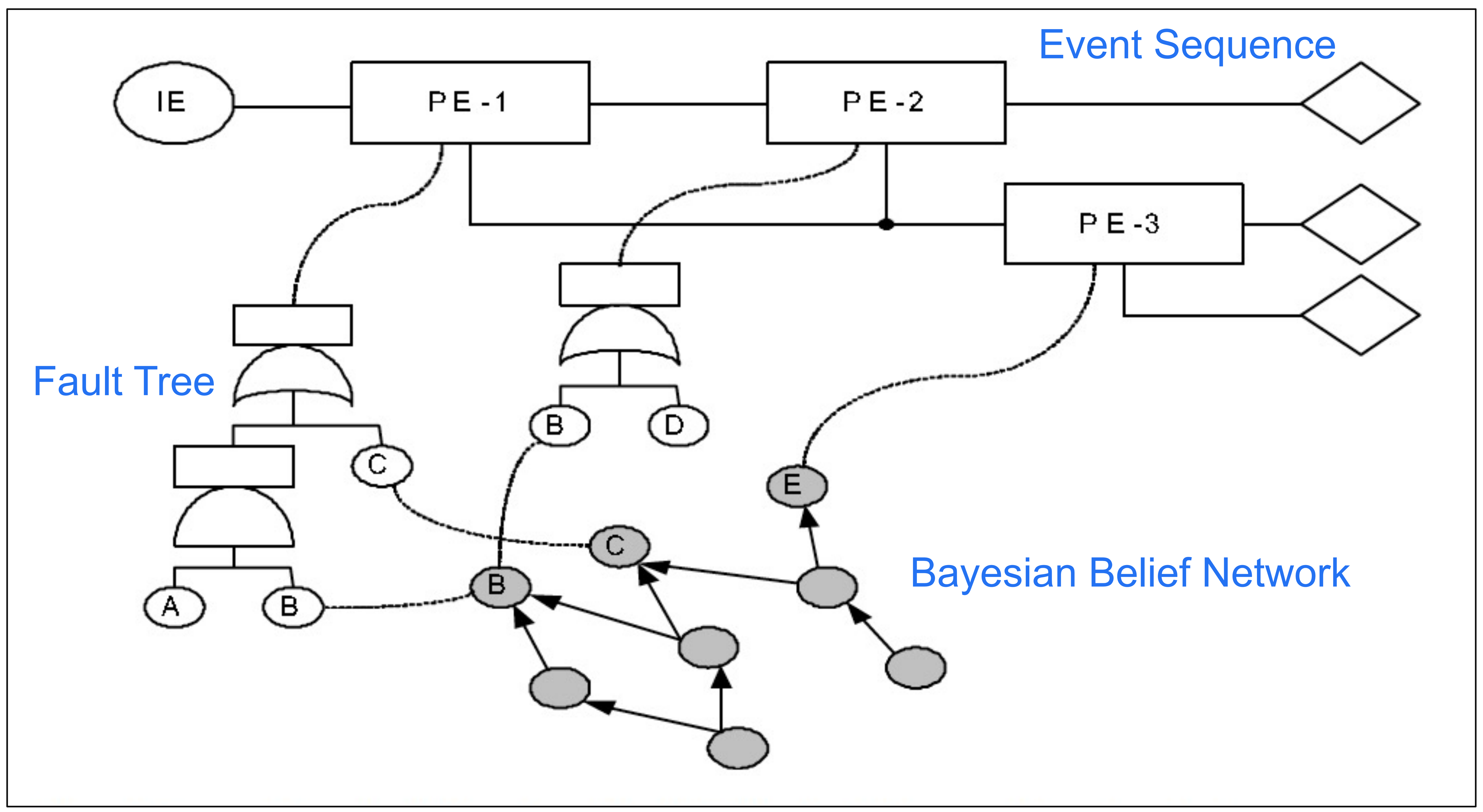
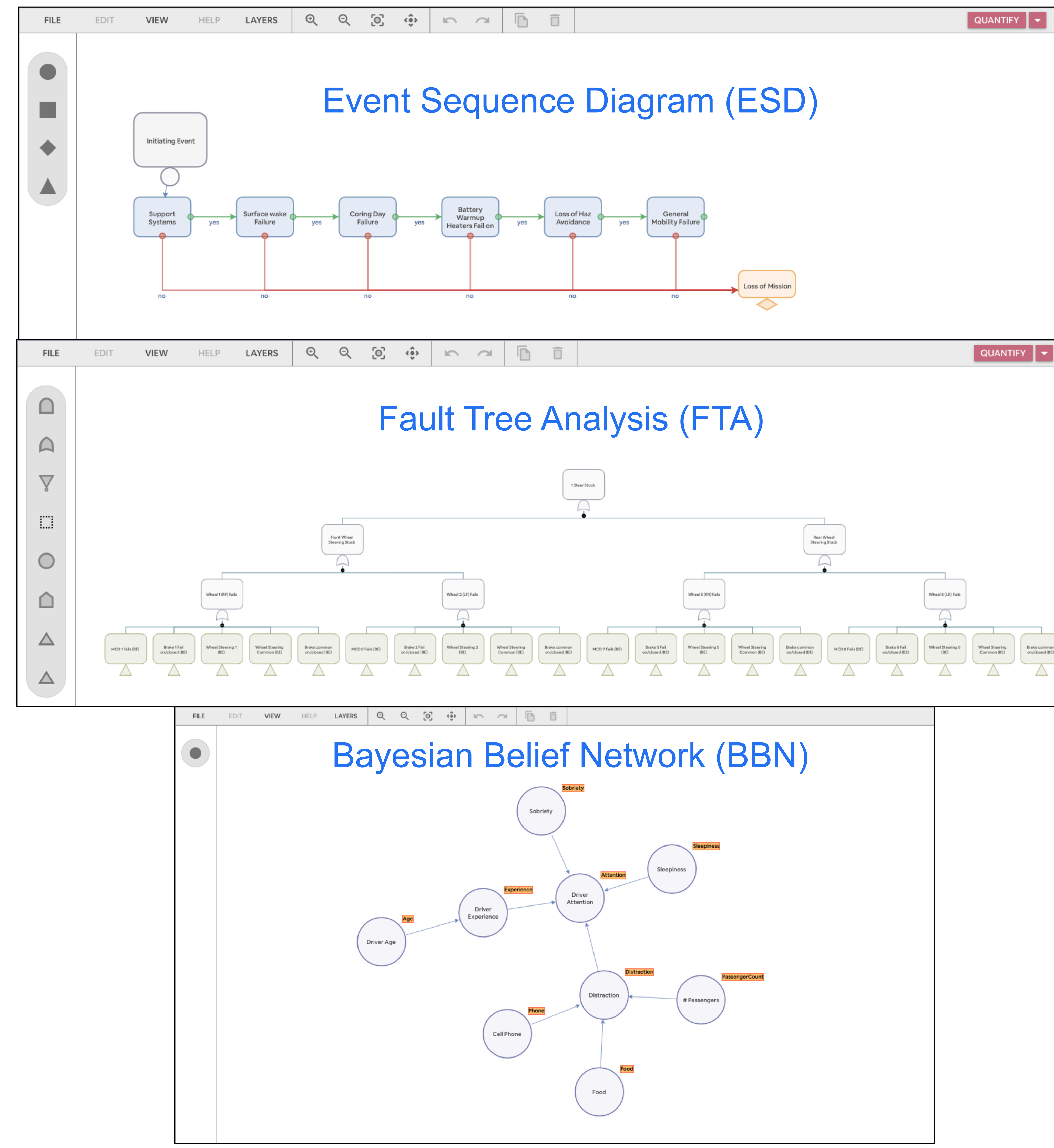


Conceptual Overview of Hybrid Causal Logic (HCL) Model Interactions



Implementation of Causal Logic Models within HCLA Tool

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Objectives

The overall objective for this effort is to develop a tool and methodology to radically revolutionize the accuracy and efficiency of the JPL reliability and radiation assurance process throughout the development lifecycle.

The four specific objectives to accomplish this are as follows:

1) Eliminate the inherent conservative approach to radiation assurance by modeling system level performance and integrate radiation effects into our predictions.

2) Find an alternative to costly radiation testing through building a robust assurance model library that has been rigorously tested and validated.

3) Track potential problems through the design cycle by creating useful models where designers can quickly compare and contrast potential design changes and immediately see the performance impacts of those changes.

4) Reduce cost and schedule of our hardware qualification process by narrowing down and eliminating excessive margin through the use of validated modeling at critical steps in the assurance process.

Background

This task meets the OSMS strategic plan of new technology infusion and innovative assurance approaches and is envisioned as one of the early programs within the newly formed Radiation Center for Excellence with OSMS.

Particularly in light of the industry trend towards using more COTS electronics and smaller spacecraft with ever more restrictive cost caps, **a more agile assurance approach is needed to supplement routine hardware testing with predictive model-based assurance.**

Miniaturization is JPL's emerging, game changing technology that only achieves its highest potential for SWaP reduction if it is able to incorporate commercial electronic components and subsystems. Our 20-year long experience of radiation testing of commercial electronics showed that without this new assurance approach, the scale of miniaturized envisioned at JPL is not cost effective and will continue to leave performance on the table.

Approach and Results

As a consequence of both COVID-19 complications and a processing error that resulted in a lapse in expected funding, the approach was tailored around the allocated bridge funding. Due to constraints related to COVID-19, the previously expected radiation effort was unable to be validated as the Vanderbilt University team was not allowed access to their lab. Since this aspect of the effort was unable to completed last fiscal year, the choice was made to use this year's limited bridge funding to review and analyze the effectiveness of the existing capabilities of the HCLA platform in order to assess prioritization for future investment.

The approach of this assessment had **four primary goals**:

1) Understand and review the objectives, goals, and motivations of the HCLA effort
2) Identify the strengths and weaknesses of the HCLA toolset as currently implemented
3) Compare the HCLA toolset against other industry standard PRA tools (SAPHIRE)
   The intent here is to both assess the effectiveness of HCLA's novel capabilities and to identify potential deficiencies towards broader adoption
4) Document the findings and feed results into future investment prioritization

The assessment identified the following **key findings**:

1) In order to assess the effects of radiation on reliability and at a system level, both the modeling and validation efforts previously lead by Vanderbilt must be completed and integrated into the HCLA platform.
2) Both tools are capable of solving logic models and have the ability to incorporate manual user expressions. Currently, HCLA is only capable of solving via a Binary Decision Diagram (BDD) routine, and would benefit from also incorporating a Minimal Cut Set (MCS) solution.
3) The development of the HCLA tool platform has predominately been focused and viewed through the lens of Probabilistic Risk Assessment (PRA), however, it's web-based accessibility, simple navigability, and data storage functionality also lends itself to be more broadly adopted as a fault tree tool.
4) HCLA's in-house storage of Projects, Subsystems, Components, and Parts Library is a promising area of re-use functionality. Future efforts should expand beyond the storage of logic models.
5) In HCLA, it is possible to directly incorporate BBNs into the broader systems analysis. In SAPHIRE, one would solve a BBN externally and incorporate the solution via a basic event. The primary use case of incorporating BBNs appears to relate to human, organizational, and software (e.g., fault detection) factors.

Significance/Benefits to JPL and NASA

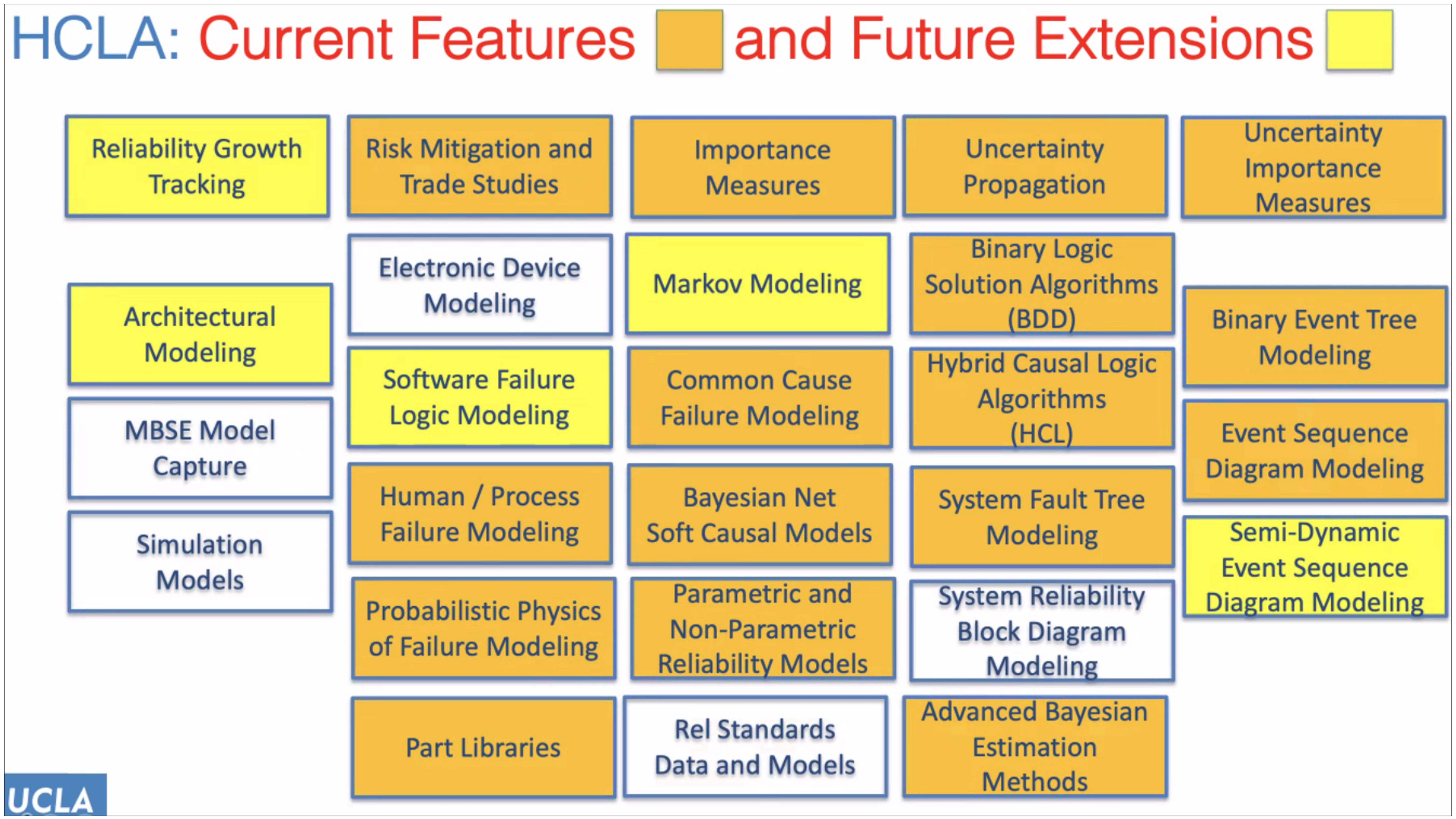
This year, the reduced scope bridge funding allowed the team to assess the effectiveness of the existing HCLA functionality and to focus future investments.

We identified the need to *prioritize the radiation model validation effort and its consequent incorporation into the HCLA platform*.

Additionally, a variety of high-level PRA functionalities were identified to both prioritize and descope in order to expedite broader JPL adoption. This year's effort ultimately refocused and oriented the strategic initiative to be on a more effective path to success if continued in the future.

Figures

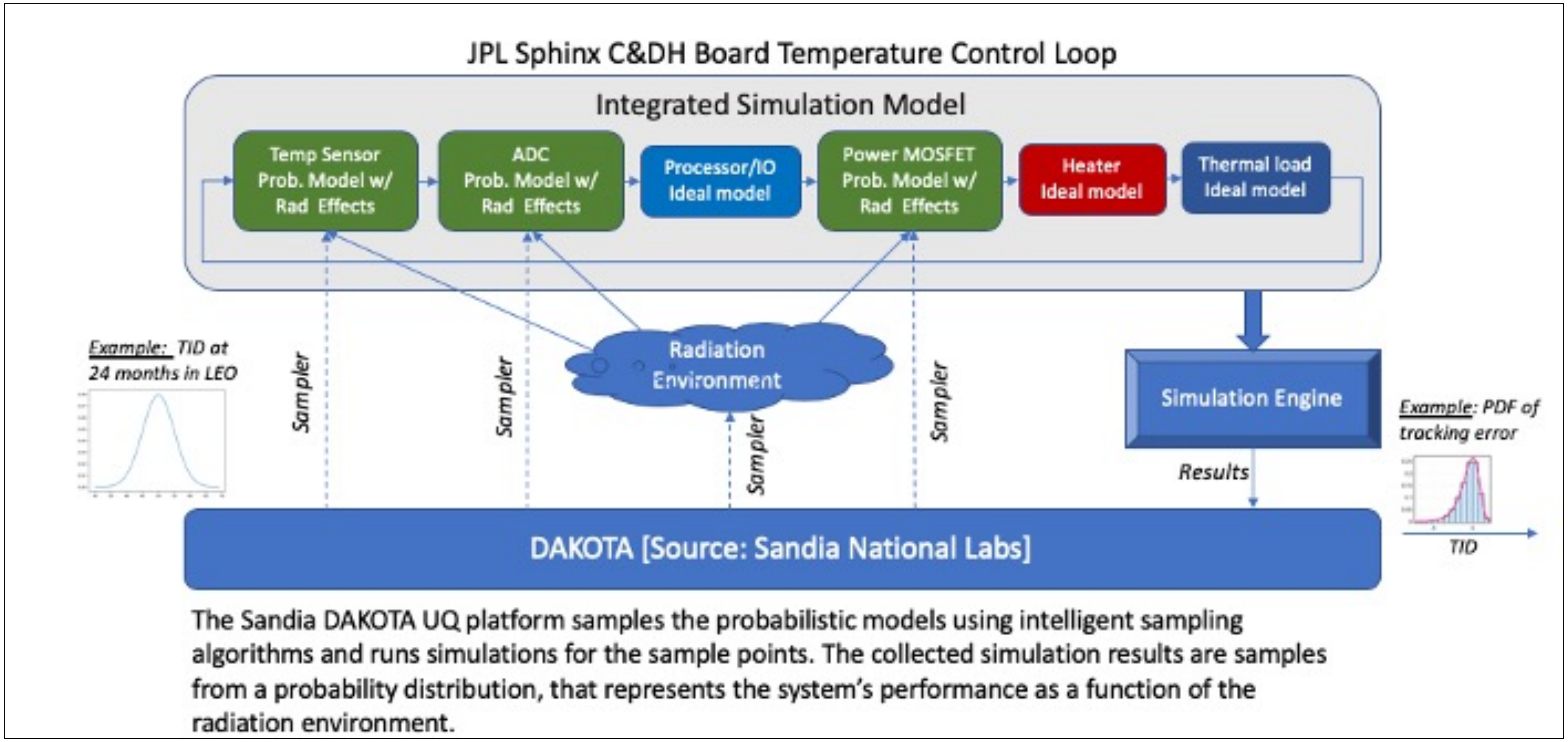
HCLA Functionality Overview



The HCLA tool developed by UCLA under this effort provides the above reliability related functionality, and intends to cover the full suite of features in the future. To date, no existing single PRA tool covers the full set.

Figures

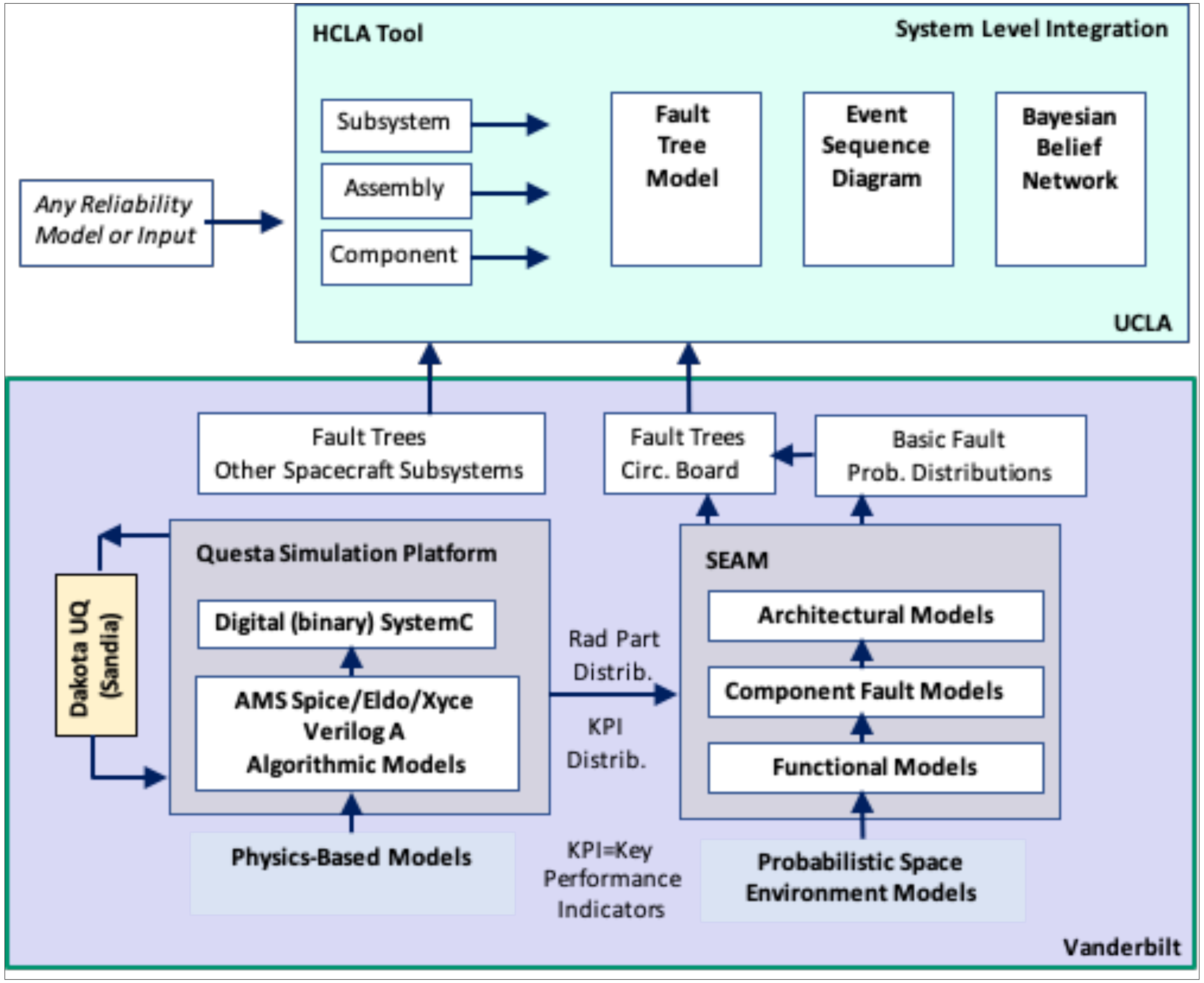
Vanderbilt University Modeling Process



Overview of the Vanderbilt University radiation modeling process developed for this task. Multiple tools are combined to sample radiation effects and simulated to assess system performance and the impact of radiation on reliability. Future work aims to incorporate these models directly into the HCLA platform.

Figures

Overview of Tool Platform Integration



UCLA's HCLA tool will accept inputs from the Vanderbilt models made in QUESTA and SEAM, as well as arbitrary external reliability model inputs. These efforts combined will provide a comprehensive platform to assess reliability with the added ability to incorporate physics of failure models to more accurately incorporate and quantify the effects of radiation throughout the system.

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