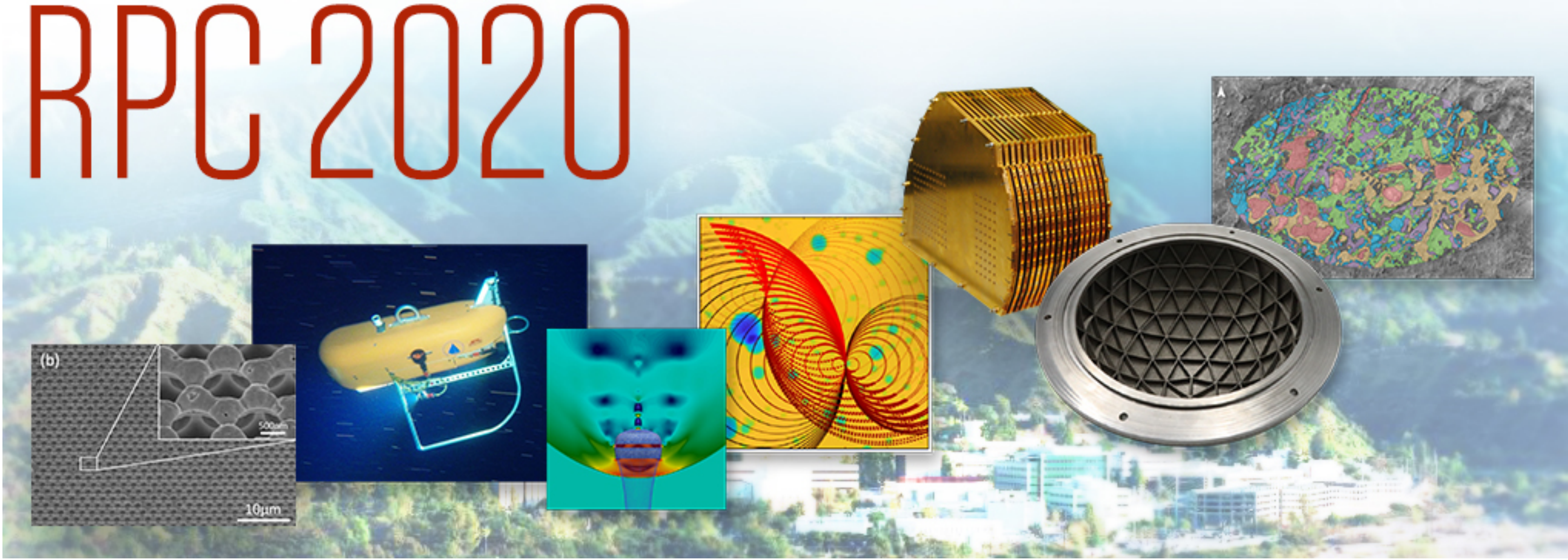

Virtual Research Presentation Conference

Concurrent Engineering

Principal Investigator: Melissa Meyers (513)
Co-Is: Clinton Mitchell (Bastion 513), Mitch Ingham (3100), Bill Whitaker (349), Andrew Daniel (514), Dr. Ali Mosleh (UCLA), Dr. Art Witulski (Vanderbilt)
Program: Strategic Initiative

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Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

- 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.
- There are four main objectives to accomplish this goal.
    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 qualification process by narrowing down and eliminating excessive margin through the use of validated modeling at critical steps in the assurance process.

Problem Description

As JPL and industry trends towards commercial and small electronics, we have less information about performance and reliability of parts in space. Full radiation testing is prohibitively expensive and impractical; And it's becoming increasingly difficult to find test facilities. Also, it is challenging to qualify components if design changes occur later in the development process.

Currently, JPL evaluates each reliability and radiation analysis independently and tracks the results for the design meeting the requirements for the analysis. At each step, margin is built into the analysis to ensure that we can safely meet the requirements. This tool and methodology advances the state of the art for mission assurance because there is currently no tool on the market that allows the complex combination of reliability data inputs at all levels of the spacecraft, in order to understand the overall risk drivers at the highest levels.

The impact for NASA and JPL for the successful implementation of this project is quite significant. We will be able to reduce the accumulated margin across all phases of our mission assurance process, once we have a validated library of component and assembly models and data. In addition to having more efficient design process, this tool also will decrease the amount of time that it takes to complete certain analyses during development. We will have a more thorough understanding of the overall reliability of the spacecraft, with efficient margin to meet requirements, for less cost on mission assurance.

Methodology

The approach for this year at a high level was to develop an integrated platform for system reliability modeling analyses that allowed the user to incorporate a variety of risk and reliability information into candidate flight architecture models and then quantify those models to give predicted system performance and ranked risk drivers for the mission.

A critical piece of this task was the integration of work from UCLA, who developed the primary modeling tool capability, and Vanderbilt University, who provided their expertise in experimental radiation effects and modeling.

Together, these universities came together to create a new connection across traditional reliability and radiation analysis, and demonstrate the framework for a completely new way to do mission assurance. Radiation degradation analysis has never been included in traditional reliability analyses; it is usually considered separately and independently.

By continuing to build on this capability and including validated reliability and radiation inputs into spacecraft models at any level of hardware development, we can quickly determine risk drivers earlier in the development process where it is much more cost effective to address.

Results

The following goals were stated in our proposal and successfully delivered by the team this year:

1. Assess contribution of Uncertainty though the system.
2. Establish simulation path from component to circuit to board; demonstrate how quantitative inputs interact with qualitative modeling at higher levels
3. Define the appropriate use of qualitative and quantitative data in a mixed, multi-level model
4. Establish rules for the most useful inclusion of probability distributions
5. Translate project requirements into analytic functions and create hardware model
6. Build out functional libraries in HCLA from the board level to the system level
7. Create and implement functionality to attach documentation to each model block at any level to be used in report generation
8. Demonstrate a quick architecture trade study on a small-scale class B hardware assembly (Sabertooth board) within less than one month

This year, we achieved all of our primary goals for development and delivery of our integrated modeling tool. We demonstrated the capability for our core modeling tool, HCLA, to accept reliability and radiation inputs from various sources in ways that no commercial tool has been able to do before

UCLA Modeling

HCLA Capabilities

- Reliability Growth Tracking
- Architectural Modeling
- MBSE Model Capture
- Simulation Models

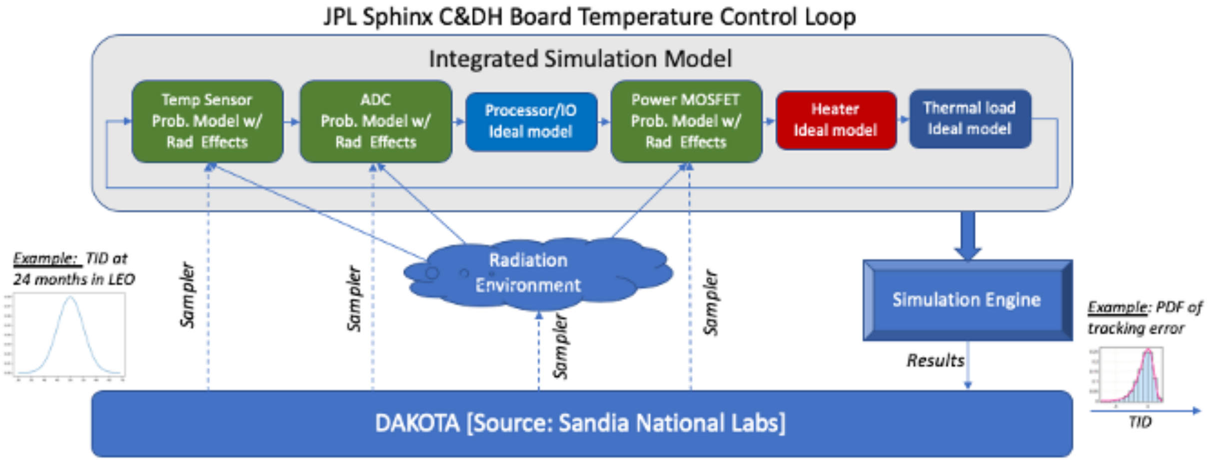
- Risk Mitigation and Trade Studies
- Electronic Device Modeling
- Software Failure Logic Modeling
- Human / Process Failure Modeling
- Probabilistic Physics of Failure Modeling
- Part Libraries

- Importance Measures
- Markov Modeling
- Common Cause Failure Modeling
- Bayesian Net Soft Causal Models
- Parametric and Non-Parametric Reliability Models
- Rel Standards Data and Models

- Uncertainty Propagation
- Binary Logic Solution Algorithms (BDD)
- Hybrid Causal Logic Algorithms (HCL)
- System Fault Tree Modeling
- System Reliability Black Diagram Modeling
- Advanced Bayesian Estimation Methods

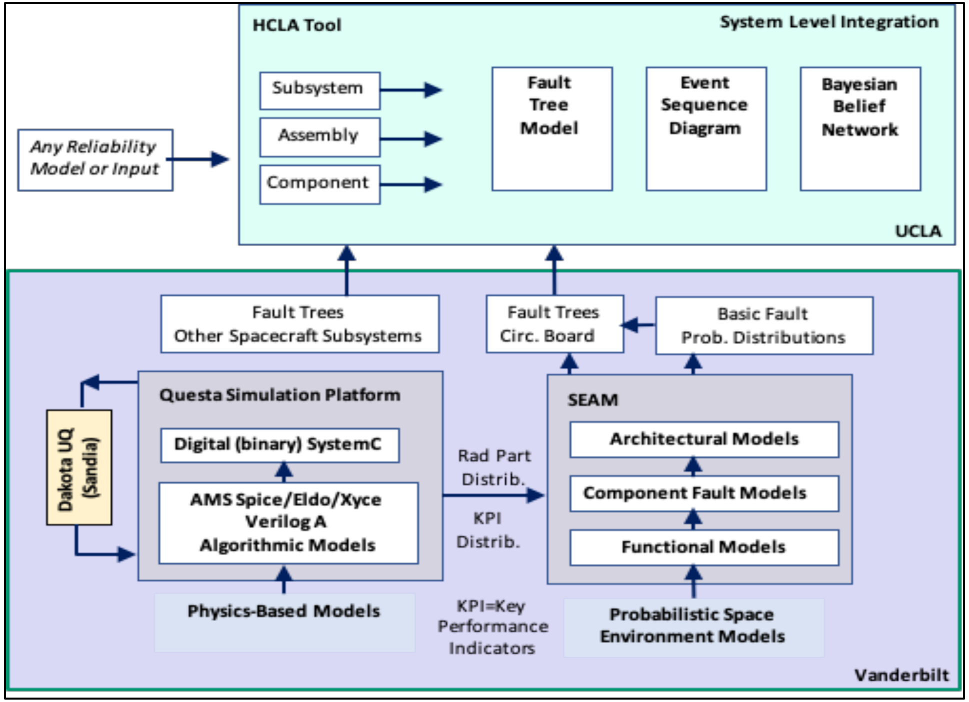
- Uncertainty Importance Measures
- Binary Event Tree Modeling
- Event Sequence Diagram Modeling
- Semi-Dynamic Event Sequence Diagram Modeling

Vanderbilt Modeling



The Sandia DAKOTA UQ platform samples the probabilistic models using intelligent sampling algorithms and runs simulations for the sample points. The collected simulation results are samples from a probability distribution, that represents the system's performance as a function of the radiation environment.

Combined Reliability and Radiation Modeling



Results

Each of the accomplishments this year leads us to the next step in our three-year plan to completely redesign and improve the JPL mission assurance process. We have laid the foundation to continue on this year's success, fine tune the integration process, and roll out this tool and methodology for wide use across the lab.

The next steps in the continuation of this task include but is not limited to the following:

- Addressing the importance of Uncertainty Quantification in hardware models
- Leveraging the JPL IMCE effort by creating a connection to the CAESAR framework for use by model-based JPL projects
- Develop the methodology for time sequenced events and implement the developed methodology in the HCLA platform
- Demonstrate end-to-end predictive reliability and radiation effects modeling capability on a small-scale class B project such as the Sphinx or Sabertooth board
- Develop the ability to model software based radiation mitigation techniques and their interactions between hardware and software degradation

Publications and References

1. M. W. Rony, En Xia Zhang, Mahmud Reaz, Kan Li, Robert A. Reed, Jeffrey Kauppila, Arthur Witulski, Andrew Daniel, Bernard Rax, Philippe Adell, Ronald D. Schrimpf, “An Ionizing-Dose-Aware Behavioral Model of a Successive-Approximation Analog to Digital Converter,” *NSREC*, 2020. To be presented virtually (November 29 - December 30).

2. M. W. Rony,A. Witulski, K. Ryder, M. Reaz, G. Karsai, N. Mahadevan, R. Reed, B. Sierawski, R. Schrimpf, “Architectural Models of Analog-to-Digital Converters for TID Radiation System Modeling,” *NEPPETW*, 2020.