Ram Logic | Metal Whisker Modeling

Project Report

SPONSORS
Missile Defense Agency
National Aeronautics and Space Administration
Naval Surface Warfare Center

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Table of Contents

I. PROJECT DESCRIPTION

I.1 Introduction

Metal whiskers are microscopic, hairlike protrusions that spontaneously grow from metal surfaces, particularly off materials like tin, zinc, cadmium, or other metals[1]. These whiskers spontaneously grow over time as a result of internal stress within the plating, thermal cycling, or mechanical strain [1].

Metal whiskers are cause for significant concern in electronic systems due to their potential to cause short circuits, arcing, and electrical malfunctions. These risks are especially critical in high-reliability environments such as aerospace and defense where failure leads to catastrophic outcomes.

Galaxy IV, a telecommunications satellite operated by PanAmSat, was lost on May 19, 1998 causing nearly 80% of pagers in the US to stop functioning [2]. The attitude control system of Galaxy IV relied on tin-plated printed circuit boards (PCBs), the attitude control system had redundant PCBs in place; however, the reliance on tin-plating resulted in failures of all PCBs in the attitude control system as tin whiskers shorted each one [2].

Pagers are reliability-critical components in hospital settings, and, granted the Galaxy IV loss occurred in 1998, these reliability-critical pagers extended across emergency services as well. While there are no statistics on indirect loss of life, there was a loss of life-dependent communications during this time.

The primary aim of this project is to statistically measure the impact of detached metal whiskers on PCBs. To this end the preceding team, the **Tin Whisker Investigative Team**, simulated forests of metal whiskers landing on simulated PCBs. The nucleation and growth of metal whiskers, however, are not within the scope of this project. This project is positioned in the domain of PCB reliability.

I.2 Background and Related Work

Previous work has been conducted by the Tin Whisker Investigative Team at WSU and will be continued by our team, Ram Logic. The project mentor, Jay Brusse, has mentioned this preceding metal whisker modeling project is state-of-the-art in this context.

The program generates metal whiskers of random dimensions according to the lognormal distribution [3]. The metal whiskers are then dropped on a PCB in a user-defined area [3]. The metal whiskers modeling framework then creates an Excel spreadsheet of bridged components [3].

Building on this lognormal metal whisker generator, the preceding team implemented Monte Carlo simulations for statistical analysis of whisker bridges.

I.3 Project Overview

The core PCB simulation framework is functional, users can import a PCB, configure conductive components, and run Monte Carlo simulations for metal whisker bridge statistical analysis. Key improvement areas include the following:

- UI fixes for enhanced workflow
- GPU acceleration for quicker Monte Carlo simulation
- Enhanced results visualization
- Automated conductive material detection
- Unit and system testing
- User guided tutorials and tooltips
- Optimizing user input parameter ranges

By addressing these enhancements, this project aims to increase usability, efficiency, and reliability of the metal whisker modeling system.

I.4 Client and Stakeholder Identification

The sponsors of this project are the Missile Defense Agency (MDA), the National Aeronautics and Space Administration (NASA), and the Naval Surface Warfare Center (NSWC) which all require highly reliable electronics for defense and aerospace.

Beyond the sponsoring organizations, this project has far-reaching application in electrical engineering and PCB reliability analysis. Reliability-critical components such as pacemakers, car accelerators, telecommunication satellites, etc. reveal key stakeholders of this project.

II. REQUIREMENTS AND SPECIFICATIONS

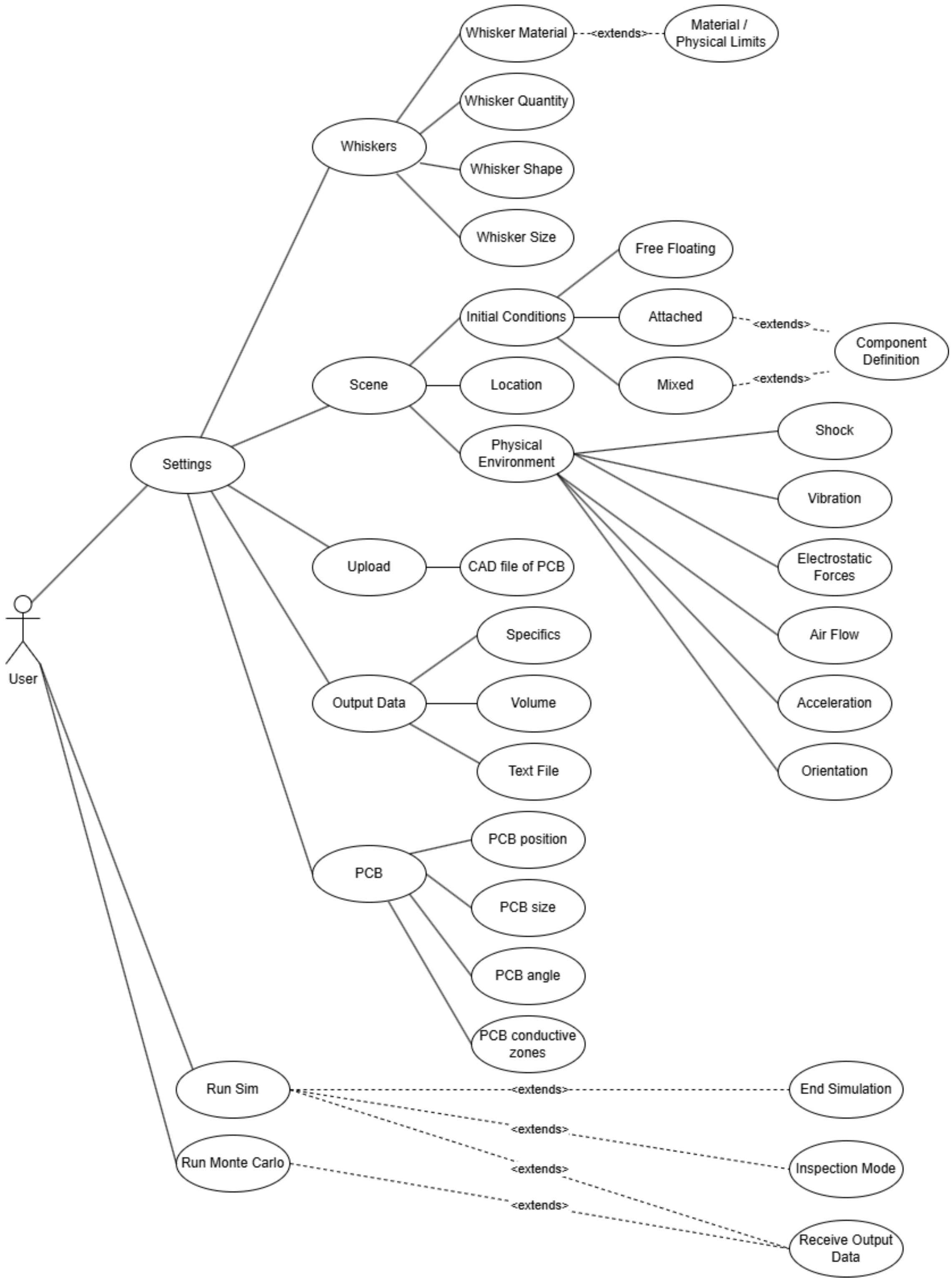
II.1 Introduction

The Tin Whiskers Unity 3D App is a software tool designed to simulate the impact of metal whiskers on printed circuit boards (PCBs). Metal whiskers are electrically conductive hair-like structures that can cause short circuits and system failures in electronic components. The project aims to develop a simulation that captures a 3D model of a PCB, identifies exposed conductors, and simulates detached metal whiskers landing on the board.

Any organization that relies on circuitry can utilize the program to gain another perspective on metal whisker risks and mitigate failures. This project is beneficial to any company which wants to simulate metal whisker failures and serve as potential clients.

II.2 System Requirements Specification

II.2.1 Use Cases



Upload File:

Pre-condition	Application running and on the main menu.
Post-condition	PCB loaded and configured
Basic Path	1. Click on the Load button. 2. Select file.
Related Requirements	File must be .obj or .mtl

View Monte Carlo Simulation Results:

Pre-condition	On the main menu.
Post-condition	Display results of the simulation.
Basic Path	1. User has configured preferred settings. 2. Navigated back to the main menu. 3. Run Monte Carlo Simulation and input the preferred number of simulations. 4. Click on Sim Results. 5. Select View Monte Carlo Simulation Results
Related Requirements	A Monte Carlo simulation was run.

Edit box parameters:

Pre-condition	Application running and on the main menu.
Post-condition	Box settings updated.
Basic Path	1. Locate Sim Settings 2. User enters in parameters of the box (xyz position and xyz size)

Edit Whiskers Parameters:

Pre-condition	Application running and on the main menu.

Post-condition	User will have selected preferred type of whisker (size, shape, material, amount)
Basic Path	1. Locate Sim Settings. 2. User selects the preferred material type. 3. User enters in parameters of the whisker itself (i.e., # of detached whiskers, whisker length, and whisker thickness distribution parameters).

Edit Board Parameters:

Pre-condition	Application running and on the main menu.
Post-condition	User will have selected preferred board settings (size, position, and angle)
Basic Path	1. Locate Board Settings. 2. User enters in parameters of the whisker itself (i.e., size in xyz, position in xyz, select conductive materials, tilt on x and z axis).
Related Requirements	Board has been uploaded.

Run Simulation:

Pre-condition	Application running and on the main menu.
Post-condition	Receive Data Output.
Basic Path	1. User has configured preferred settings. 2. Navigated back to the main menu. 3. Run Simulation. 4. Collect Output .
Related Requirements	User has loaded and configured preferred settings.

Run Monte Carlo Simulation:

Pre-condition	Application running and on the main menu.

Post-condition	Receive monte carlo data output.
Basic Path	1. User has configured preferred settings. 2. Navigated back to the main menu. 3. Run Monte Carlo Simulation and input the preferred number of simulation.. 4. Collect Output.
Related Requirements	User has loaded and configured preferred settings.

Inspect Simulation:

Pre-condition	A simulation is running.
Post-condition	The simulation is paused to be inspected.
Basic Path	1. User has configured preferred settings. 2. Navigated back to the main menu. 3. Run Simulation. 4. Click on the Inspection Mode button.
Related Requirements	Simulation must be running and the user must configure preferred settings.

End Simulation:

Pre-condition	Application running and in the middle of simulation.
Post-condition	Simulation stops and results are saved.
Basic Path	1. User has configured preferred settings. 2. Navigated back to the main menu. 3. Run simulation and end the simulation. 4. Collect Output.
Related Requirements	Simulation must be running and the user must configure preferred settings.

II.2.2 Functional Requirements

II.2.2.1 Software Assurance and Testing

Software Assurance Check:

Description	Identify and fix anomalies, defects and issues in existing software as well as the new software being developed at each stage.
Source	Mandatory request from Dr. Havrisik.
Priority	0

Unit and System Testing:

Description	Ensure the functionality of individual functions by including unit testing and to verify overall reliability of the system by including system testing.
Source	Suggested by the previous team and required from Dr. Havrisik.
Priority	0

II.2.2.2 Performance and Simulation

GPU Acceleration for Monte Carlo Simulation:

Description	The program currently has no GPU acceleration as Unity's physics engine implementation is CPU-bound. The metal whisker simulation must include GPU acceleration for reasonable simulation time.
Source	Future work left by the preceding metal whisker modeling team confirmed by Dr. Havrisik in an email on 2/4/2025.
Priority	0

Optimization of User Parameters Ranges:

Description	The program can break as a result of user input. Parameters for different inputs in the program should be restricted to an acceptable range.
Source	Mentioned in future work left by the preceding team and confirmed by

	Dr. Havrisik.
Priority	1

II.2.2.3 User Interface and Visualization

Enhanced Results Visualization:

Description	The application should include simulation results visualization. In the current implementation, users must navigate to a results directory and open CSV files using a spreadsheet application. The application should be unified to fulfill user needs.
Source	Mentioned by preceding confirmed by Dr. Havrisik in an email on 2/4/2025.
Priority	0

Automated Conductive Material Detection:

Description	The application should detect conductive surfaces on CAD modeled PCB files without user interaction.
Source	Mentioned by preceding team confirmed by Dr. Havrisik in an email on 2/4/2025
Priority	0

Guided Tutorials and Tooltips:

Description	The application should include a guided tutorial to briefly run through a set of simulations using different μ, σ, mechanical vibration, shock, and vibrate parameters.
Source	Left as future work from the preceding team confirmed by Dr. Havrisik in an email on 2/4/2025
Priority	1

User Interfaces Fixes:

Description	Resolve issues related to the design, layout, and functionality of the user interface. Fixes may include resolving visual inconsistencies, improving

	navigation, and enhancing responsiveness.
Source	Left as future work from the preceding team confirmed by Dr. Havrisik in an email on 2/4/2025
Priority	2

II.2.2 Non-Functional Requirements

Performance:

- The system should provide visualization results with minimal time delays.
- The system should process and simulate large scale PCBs without performance degradation.

Compatibility:

- The system should work in Windows, Linux and MacOS.
- PCB models files should be supported in formats OBJ and MTL.

Scalability:

- The system should support future refinements for physics models.
- There should be room to enhance GPU acceleration.

Maintainability:

- Documentation should be comprehensive and clear.
- Future updates and modifications should not affect main functionality.

Security:

- The system should follow software assurance best practices to ensure robustness and reliability.

II.3 System Evolution

This project is dependent on several key assumptions that influence design and implementation of the Unity Metal Whisker Modeling project. As the project evolves, we anticipate some assumptions may be revisited and revised due to changes in software and hardware constraints as well as user needs.

- GPU acceleration is feasible and necessary.
  - Simulating a high-density forest of metal whiskers falling on and interacting with a PCB board is computationally complex, our team assumes GPU acceleration will provide necessary performance gains.
  - We assume we can utilize unity shaders and/or third party plugins to access the GPU.
- Automated conductive material detection for CAD files is viable.
  - Our team assumes .OBJ CAD files can be reliably parsed and processed for conductive material extraction.
  - Our team assumes PCB CAD files will be created with this program in mind, wherein the user defines different components of the PCB using precise materials, and the CAD program makes .OBJ files.
  - Our team assumes inaccuracies in conductive area detection can be remedied with preprocessing techniques.
- User interface can be implemented without major overhaul.
  - Our team assumes a user will benefit from a structured onboarding process and the tooltips will be readable without information overload.
  - The project includes updates to the UI, including general tooltips, and adding a tutorial to the existing project. Our team assumes these additions can be implemented without significant structural changes.

Anticipated changes and risks:

- Hardware limitations and compatibility issues:
  - If our GPU acceleration methods do not work as expected for any of the following reasons: driver incompatibility, limited GPU support, performance bottlenecks, etc., then we may need to explore alternative methods.
- User experience challenges:
  - If users struggle with tutorial design, then additional design iterations of UI may be required.
  - If guided tutorials prove insufficient in the user structured onboarding process, then alternative methods must be explored such as an interactive walkthrough.

GLOSSARY

Metal Whiskers: Microscopic, hairlike protrusions that spontaneously grow from metal surfaces, particularly off materials like tin, zinc, cadmium, or other metals.

Printed Circuit Board (PCB): Flat, rigid board providing mechanical support and electrical connections for electronic components.

REFERENCES

[1] “NASA Goddard Tin Whisker Homepage,” nepp.nasa.gov. https://nepp.nasa.gov/whisker/ (accessed Jan. 29, 2025).

[2] “Galaxy IV,” wikipedia.org. https://en.wikipedia.org/wiki/Galaxy_IV (accessed Jan. 29, 2025).

[3] “Tin Whiskers: Unity 3D App,” github.com. https://github.com/WSUCptSCapstone-S24-F24/-mda-unity3dapp-/blob/main/Project%20Report%20Final.pdf (accessed Jan. 29, 2025)