NASA Phase 2 Project Summary

CFDRC Project # 8851

Firm: CFD Research Corporation
Contract Number: NNM08AA07C
Project Title: Improved Models and Tools for Prediction of Radiation Effects on Space Electronics in Wide Temperature Range

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)
All NASA exploration systems operate in the extreme environments of space and require reliable electronics capable of handling a wide temperature range (-180ºC to +130ºC) and high radiation levels. To design low-temperature radiation-hardened (rad-hard) electronics and predict circuit and system characteristics, such as error rates, modeling tools are required at multiple levels. To determine the electrical responses of transistors and circuits to radiation events, physics-based Technology Computer Aided Design (TCAD) and mixed-level tools are required. This project provides models and tools that will improve capabilities for prediction of technology-dependent responses to radiation in wide temperature range, which will lead to better design of rad-hard electronics, better anticipation of design margins, and reduction of testing cost and time.

Innovations of this project: Detailed high-energy-physics-based simulations of radiation events efficiently coupled in a user-friendly, automated manner with advanced device response computations by a three-dimensional (3D) device simulator with robust and validated models over a wide temperature range (-230ºC to +130ºC). This enables a large number of runs on a massively parallel supercomputing cluster, and provides results and data for the development and verification of higher-level, fast engineering models for single event error rate prediction and radiation-hardening of nano-scale electronic devices, circuits, and systems.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)
The overall, far-reaching objective of this effort is a better prediction of space electronics response to high radiation levels in a wide range of temperatures, plus estimating and increasing radiation-hardness. The major technical goals were:

1) establish a set of models which would be useful in efficient characterization of the single event response and error rates for the chosen technology;
2) develop and demonstrate a general methodology that can be applied to other technologies;
3) enhance the capability to analyze and predict the response of semiconductor devices and circuits to microscopic radiation events in wide temperatures, by automation of this process and utilization of parallel cluster, to enable the statistics of large numbers of such responses;
4) provide tools for producing results and data for the development and verification of fast engineering models used in analysis, design, and radiation-hardening of nano-scale electronic devices, circuits, and systems.

The Work Plan included:

- Enhancing the CFDRC's 3D device simulator (NanoTCAD) to enable efficient, low-temperature modeling of selected SiGe HBT technologies.
- An automated interface between CFDRC NanoTCAD and Vanderbilt MRED/Geant4.
- Development of methods to use TCAD simulations to develop appropriate higher-level, fast models for use in efficient single event analyses, and behavioral models suitable for Spice-level simulations for error rate calculations in systems.
- Use experimental data from Georgia Tech and Vanderbilt for model development and validation.
- Benchmark testing and verification of updated CFDRC's models, solvers, and tools, for 3D TCAD and mixed-mode simulations of radiation effects at wide/low temperatures.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)
All the technical objectives of the project have been accomplished. The major achievements and accomplishments of this SBIR team are:

1. Developed new methods to use TCAD simulations to generate higher-level, fast models suitable for efficient single event analyses in integrated circuits and systems. Circuit simulations using the new model showed excellent agreement with measured data, as well as data simulated in TCAD. The infrastructure established can leverage cluster computing to facilitate simulation of a large matrix of parametric variation for time efficient technology calibration, and result in models that can be used by circuit designers in an efficient manner.
2. Enhanced the NanoTCAD 3D modeling capabilities, by including new, advanced physical models for semiconductor device behavior at extreme temperatures, plus fully coupled electro-thermal solver. The new models have been validated with experimental data.
3. Developed an integrated, automated coupling of Vanderbilt MRED/Geant4 nuclear radiation events models with CFDRC's NanoTCAD 3D device simulator, for more accurate and more efficient simulation and prediction of radiation effects in nano-scale electronics.
4. Developed and demonstrated an automated, user-friendly integration of the two simulation capabilities (Vanderbilt and CFDRC) running on the parallel supercomputing cluster.
5. Extended and demonstrated CFDRC's Mixed-Mode simulation tools for radiation effects analyses at very low temperatures and validated on SiGe test circuits relevant to NASA.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)
Prediction of electrical performance and radiation hardness of electronic components in extreme environments (wide temperatures, high radiation) are crucial to design reliable electronics for all NASA Exploration Missions (Moon, Mars, etc.), for both crewed and robotic systems. Since electronic parts are getting smaller, the radiation and temperature effects are more severe – the life time and reliability become essential – the capability to predict them increases confidence and reduces risk. The new tools are immediately applicable to the NASA Radiation Hardened Electronics for Space Exploration (RHESE) Program, and other mission programs. The new models and design tools will help NASA to: 1) assess and select new electronics technologies, materials, and devices for very low temperature operation in radiation environments; 2) investigate, generate, test, and validate new fast/compact engineering models used in designing larger circuits and systems; 3) design low-temperature rad-hard electronics with better understanding and control of design margins; 4) predict circuit and system level characteristics, such as error rates; 5) reduce the amount of testing cost and time.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)
Potential other users include all space electronics suppliers, in particular for DoD space communication, surveillance, and imaging systems, as well as commercial satellites. Since modern electronic technologies and parts are continually getting smaller, the radiation and extreme temperature effects become more severe, the life time and reliability become essential, and the capability to predict them increases confidence and reduces risk. The new computer aided design (CAD) tools can also be applied for cryogenic electronics for high-sensitivity, low-noise analog and mixed-signal applications, such as metrology, infrared (IR) imagers, sensors (radiation, optical, X-ray), radiometrology, precision instruments, radio and optical astronomy, infrared and photon detectors, and other sensitive equipment. For all such devices and systems, predictive and accurate modeling and design tools reduce the amount of required radiation/temperature testing, thus decreasing their cost, and time to market or field application.

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