Studies look at long-term aging of electronics in nuclear weapons

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Sandia National Laboratories researcher Rachelle Thompson inspects an electronic device that's part of a 30-year Sandia program to look at how environments, including radiation from a nuclear weapon itself, could affect the performance of electronics inside a W76-1 warhead. The study begun in 2006 will provide real-time data for the first time on how electronics age within a weapon. Credit: Randy Montoya

Sandia National Laboratories is studying how environments, including radiation that originates from a nuclear weapon itself, could affect the performance of electronics in the W76-1 warhead as they age.

Sandia, which is responsible for most non-nuclear components in U.S. nuclear weapons, is helping replace W76 warheads in the nation's stockpile with a refurbished version under the W76-1 Life Extension Program (LEP). The ballistic missile warhead is carried on the Trident II D5 missile aboard Ohio-class Navy submarines.

Researchers have studied radiation effects since the early days of nuclear weapons. But a 30-year program begun in 2006 will provide real-time data for the first time on how electronics age within the weapon. Studies in the past used techniques that artificially accelerated the aging process based on a range of assumptions resulting from experiments and previous research.

"There has always been the question with accelerated aging data, how reliable is it?" said principal investigator Rachelle Thompson.

The long-term project combines experiments, also known as physical simulation, with computational simulation and analysis. The approach developed as part of this project can be used in future LEPs, said Steve Wix, manager of Sandia's Component and Systems Analysis Department. Costs should be reduced for future stockpile surveillance and monitoring as well, since such lab-based studies cost less than accelerated aging techniques, which require using large environmental test facilities.

Study important in moving more toward predictive models

The project by Sandia's Electrical Sciences Group is important for science-based stockpile stewardship because new devices, or electronic parts, have been introduced into the W76-1 system since production began in 2008. These new parts must function with assured reliability and performance throughout the life of the system. The project also is moving such evaluations toward more predictive models of aging for stockpile stewardship, Wix said. Stockpile stewardship assures the safety, security and reliability of weapons in the absence of the underground nuclear tests the U.S. halted in 1992.

Most of the experiments and analysis are done in a small laboratory full of racks of test and computer equipment and in an adjacent room packed with small test chambers, square white boxes that resemble miniature refrigerators. Each test chamber contains parts in a unique environment that is continually monitored to control temperature, relative humidity and vibration frequency to ensure consistent levels of the multiple aging processes that will take decades. The experiments are overseen by test engineer Monica Espinosa.

Researchers develop and use advanced, physics-based computational simulations to predict how the electronics will perform as they age. They verify their predictions with experiments on the electronics to improve their understanding of the underlying physics engaged during the aging process. This research then guides further development of these critical simulation capabilities to resolve differences between the computer simulations and the aging experiments.

The researchers monitor thousands of devices that fall into six families of transistor and diode types. Hundreds are removed annually from the test chambers to determine their electrical performance under various operating conditions. The long-range test schedule was developed to assure that an adequate number of devices remain available for testing over the entire three decade-long study.

The parts under study were pristine when the project started eight years ago. Wix and Thompson said no significant aging changes were expected in these early years, and what they have seen matches those predictions. Currently, only simple electrical devices are being tested, but researchers hope to add more complex parts later in the project.

Project exposes aged devices to laser-based testing

Once devices have aged in the predetermined storage environments, the team uses a sophisticated laser-based technique to expose each one to more hostile short-duration operating environments, Thompson said.

Researchers take basic electrical measurements on the aged transistors and diodes, then repackage them in preparation for evaluation with a benchtop laser-based simulated radiation environment source. They expose the parts to two different types of lasers: a broad beam that sweeps the entire device and a focused laser beam to expose it in specific areas. This process evaluates the performance of aged devices in more harsh environments. It takes up to 15 to 20 minutes for each laser study of a part, and the project studies hundreds of parts per year, Thompson said. "There is a lot of handling of parts and data analysis involved," she said.

Unless the part is damaged or fails during testing, it goes back into the appropriate aging environment for future testing. A damaged or failed part is evaluated to better understand the underlying cause.

The techniques Sandia is developing will help officials make future stockpile decisions based on an improved understanding of the impact of aging on how parts perform in multiple environments, Wix said.

Provided by Sandia National Laboratories

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