Advanced Vehicle and Extreme Environment Electronics (CAVE^3)

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Tools to Ascertain Survivability and Prediction of Damage to Electronic Systems under High-G Shock at High Temperature

Electronics are transitioning to thinner form-factors. These are being used in extreme environments placing the components in ever increasing proximity to the external interfaces of the products and subjected to high temperature, mechanical shock and vibration. In many situations the loads may be significantly more severe than those encountered in consumer electronics.

Electronics in unmanned space missions can be subjected to the high-g stresses of launch, an issue addressed by this technology breakthrough. Credit: NASA/Bill Ingalls

In extreme applications electronics may be stored for a prolonged period of time prior to first use. The challenge of electronics survivability is even more daunting considering the fact that extreme environment applications such as automotive electronics or military electronics require high reliability for mission assuredness. High reliability is generally assured using accelerated tests, a process which is fairly time consuming and iterative. Part replacement in electronic systems is typically done on a timed basis to ensure safe reliable operation.

In order to address deficiencies in the state of art, the CAVE^3 research team developed advanced, multi-scale modeling methods and high-speed experimentation test protocols for analyzing system-level shock survivability of electronic products. Leading indicators of failure were developed for assessing accrued electronics damage during sustained high-g/high-temperature operation. The indicators allow for early assessment of system condition and for condition based maintenance of systems to ensure more reliable operation. The team's leading indicators for prognostics during high-g operation at high temperature have made possible assessment of damage states in operational systems. Contributions include resistance spectroscopy methods, feature extraction and classification methods for second-level interconnects, and methods for assessment of remaining useful life. The modeling methods and test protocols have made it possible to assess system-level shock loads and their impacts on interconnects at the package- and chip-levels.

The technical breakthrough of multi-scale methods for high-g shock assessment and leading indicator based prognostic health management allows for the following advantages: 1) Elimination of excessive accelerated testing for assessment of shock survivability of electronic systems; 2) Improved ability to design more reliable harsh environment electronic systems while using the latest consumer electronics components which may not have been originally designed for use in extreme applications; 3) Improved ability to determine damage states and remaining useful life in field deployed electronic systems without taking them out of operation, and; 4) Enhanced ability to perform repairs and replacements based on system condition thus allowing for meaningful intervention in the repair cycle prior to catastrophic failure.

The breakthrough has implications for a number of applications relevant to harsh environment electronics including: 1) Electronics in unmanned space missions which can be subjected to the high-g stresses of launch, atmospheric re-entry and landing often at high temperature or low temperature; 2) Electronics in missile fuzing applications may be subjected to 100,000g in hard target impact with a requirement to function throughout the event; 3) Automotive underhood electronics which are subjected to simultaneous temperature and vibration challenges with the expectation of reliable operation; 4) Defense electronics may be in storage for longer periods of time prior to deployment in high-g applications, and; 5) Electronics in downhole drilling applications may be subjected to high-g forces in addition to high temperatures.

> **Economic impact:** Health management system implementation in Automotive and Aerospace are currently limited to on-board diagnostics and reporting of diagnostic trouble codes. Economic impacts of this breakthrough work include: 1) Reductions in cycle-time for development of shock survivable electronic assemblies, reductions in product development cost, and in the number of iterations needed for design optimization; 2) Better foundations for development of new products for prognostic health management of electronic systems and assessment of remaining useful life; 3) Lowered risks associated with the deployment of new technologies through insight into accrued damage and system states; 4) More opportunities in workforce development for jobs in the assessment of the damage-state of electronic assemblies for intervention through repair and replacement.

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