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Destructive SEE pose serious challenges for the reliable use of COTS devices in space systems. We used system-level modeling to determine SEL rates that would likely compromise system reliability, resilience and capabilities. We then assembled a representative dataset of COTS CMOS parts and used nonparametric statistical techniques to assess the threat posed to redundant systems by destructive SEE.

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Authors	R. Ladbury <i>(Goddard Space Flight Center Greenbelt, Maryland, United States)</i> Michael Bay <i>(Bay Engineering Innovations, Inc.)</i> Jeff Zinchuk <i>(Bay Engineering Innovations, Inc.)</i>
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Threats to Resiliency of Redundant Systems Due to Destructive SEE
R. Ladbury, Member, IEEE, Michael Bay, Jeff Zinchuk

Abstract— Destructive SEE pose serious challenges for the reliable use of COTS devices in space systems. We used system-level modeling to determine SEL rates that would likely compromise system reliability, resilience and capabilities. We then assembled a representative dataset of COTS CMOS parts and used nonparametric statistical techniques to assess the threat posed to redundant systems by destructive SEE.

Index Terms— single-event effects, single-event latchup, reliability estimation, quality assurance; statistical techniques

I. INTRODUCTION
Single-event effects (SEE) pose challenges for the reliable use of Commercial Off The Shelf (COTS) parts in space systems. Not only are COTS devices used in space systems with little regard for the SEE susceptibility, the COTS vendors and parts make it unlikely that designers will find data on their part of choice in public archives—particularly given the short design cycles for COTS parts. Testing complex, commercial microcircuits is expensive and time consuming, often requiring sophisticated test equipment, and often, the results will cover only some of the part's operating state space. These challenges have strained conventional approaches to SEE analysis and mitigation. In designing reliable hardware despite incomplete understanding of SEE performance, system-level mitigation offers many advantages [1,2]. System-level techniques tend to

detailed understanding of the error/failure susceptibilities of parts in the system—e.g. transient duration to determine capacitive filtering or multi-bit upset susceptibility to determine the appropriate error correction codes (ECC). Moreover, miniaturization of microelectronics has decreased SWaP penalties for system redundancy, and system redundancy is effective against a broad range of error and failure modes. We examine how destructive SEE (DSEE) affect the resilience of a simple redundant model. Rather than examining realistic space systems, we seek to illustrate the sensitivities of this simple system to unit-level destructive and nondestructive SEE (NDSEE). We then summarize recent research and Single-Event Latchup (SEL) susceptibility in Metal Oxide Semiconductor (CMOS) devices. The implications of relying heavily on COTS parts in redundant systems. SEL susceptibility is widespread and widely variable, and it is difficult to predict how a given part is likely to perform in SEE testing. However, this lack of predictability at the part level is advantageous for modeling SEL at the system level, allowing application of nonparametric statistical techniques and SEL risk to be bounded with some confidence as a function of system complexity (# of susceptible parts, etc.).

II. SIMPLIFIED REDUNDANT SYSTEM WITH REPAIR
We study the simplest model that illustrates the threat DSEE

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