Dependable Multiprocessor (DM) Implementation for Nano-satellite and CubeSat Applications

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Abstract

Funded by the NASA New Millennium Program (NMP) Space Technology 8 (ST8) project since 2004, the Dependable Multiprocessor (DM) project is a major step toward NASA's and DoD long-held desire to take advantage of high-performance, Commercial-Off-The-Shelf (COTS) technology in onboard processing solutions for space applications. DM is a cluster of high performance COTS processors connected with a high speed interconnect and operating under the control of a reliable system controller and platform- and technology-independent fault tolerant middleware (see Figure 1). The development of DM technology represents a significant paradigm shift. For applications that only need to be radiation tolerant, DM technology allows the user to fly ten to one hundred times the processing capability of current radiation hardened space systems. As a software-based and platform and technology-independent technology, DM enables space missions to employ current COTS devices as opposed to technologies 2 or 3 generations behind the state-of-the-art in terrestrial computing capability. Since most COTS technologies today offer reasonable Total Ionizing Dose performance, Single Event Upset (SEUs) remain the dominate radiation effect to be mitigated. DM software technology focused on the mitigation of transient radiation effects, SEUs, SEFIs (Single Event Functional Interrupts), and non-catastrophic SELs (Single Event Latch-ups).

The DM project conducted its TRL6 Technology Validation in 2008 and 2009. The DM TRL6 technology validation demonstration included component-level radiation beam tests which characterized component SEU, SEL, and SEFI rates of the COTS Data Processing boards, comprehensive software-based fault injection testing which profiled the fault/error syndrome mapping and validated DMM response to faults, and system-level radiation beam testing in which one (1) COTS DP board was exposed to a proton beam while executing the TRL6 application suite and operating in the context of a DM flight system including all DMM, experiment interface, and experiment data collection software. The system-level radiation testing validated DM design and operation in a radiation environment. In addition to being a significant advancement in the state-of-the-art, the DM project refined the well-established process for flying COTS technology in space (see Figure 2).

As a software-based and platform- and technology-independent technology, there are several options for flying DM technology in space: 1) fly the original ST8 DM flight unit design, a hybrid 6U/3U size system implementation, 2) fly a smaller, all 3U size, system implementation, 3) insert DM hardware and software into a user's 6U or 3U size chassis, or 4) port the DM software to other hardware platforms.

There is currently a great deal of interest in flying constellations of small satellites. As a result, the DM project has been investigating the use of DM technology in nano-satellite and CubeSat applications. Space applications are almost always severely constrained by mission size, weight and power limits. Meeting the size, weight, and power constraints of a nano-satellite can be tough enough but, because of the small size and, correspondingly, limited surface area, CubeSats present even more challenging packaging problems, which require some "out-of-the-box" thinking. Nano-satelllite and CubeSat applications also require consideration of small, light-weight, and low power Gumstix and Computer-On-Module (COM) technology.

The portability of DM software has been demonstrated across a range of PPC-based platform, X86-based platforms, and state-of-the-art multi-core processors. Currently, the use of DM technology with many-core processors including the Tilera 64 and MAESTRO, the radiation hardened version of the Tilera device, is also being investigated. Based on past porting experience, porting DM software to Gumstix and other COM technologies should be very quick and straightforward. DM software is portable to any processor with a Linux kernel a and a reasonable chain of software tools for application development. Gumstix and COM technologies have been flown in space, but only as uni-processors on short duration missions and in very benign radiation environments. Flying a cluster of Gumstix or COM modules with DM software is unique.

The paper will discuss the results of Honeywell's investigations of nano-satellite and CubeSat implementations of DM.

References

[1] Samson, Jr., John R., et. al, "NMP ST8 Dependable Multiprocessor: Technology and Technology Validation Overview," Proceedings of the 48th AIAA Aerospace Sciences Meeting Conference, Orlando FL, January 4-8, 2010.

[2] Samson, Jr. John R., "NMP ST8 High Performance Dependable Multiprocessor," 13th High Performance Embedded Computing Workshop, M.I.T. Lincoln Laboratory, September 21, 2009.

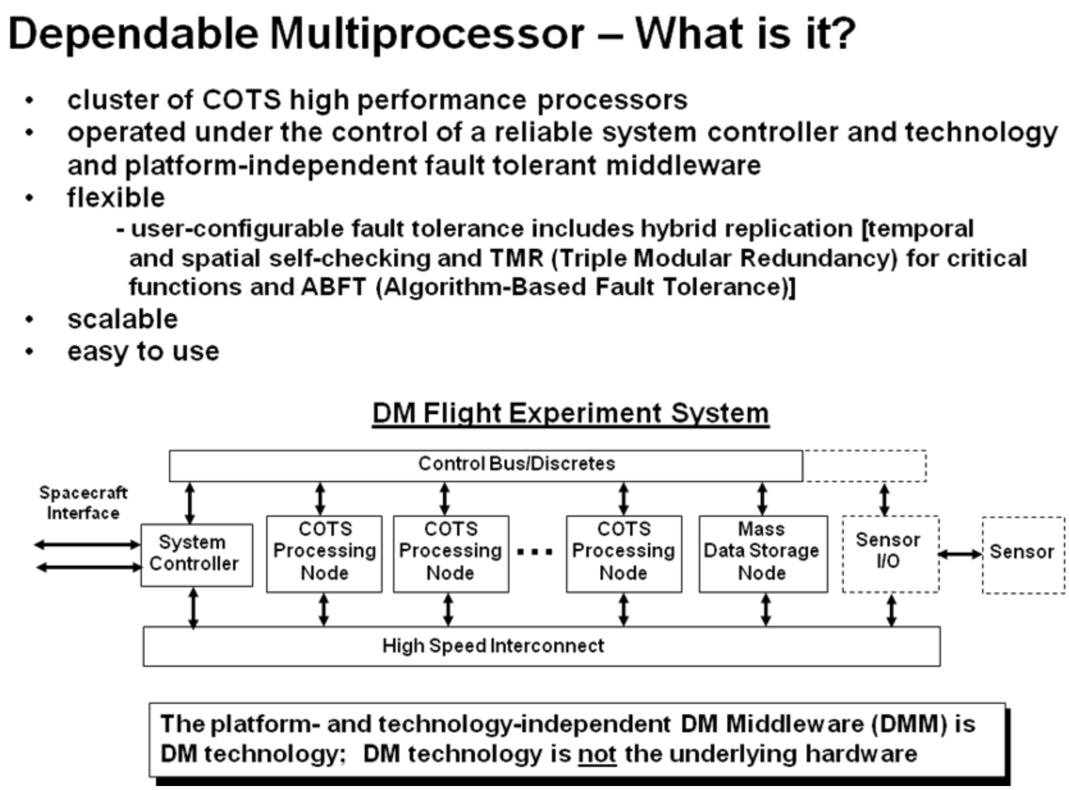

Figure 1 – Dependable Multiprocessor

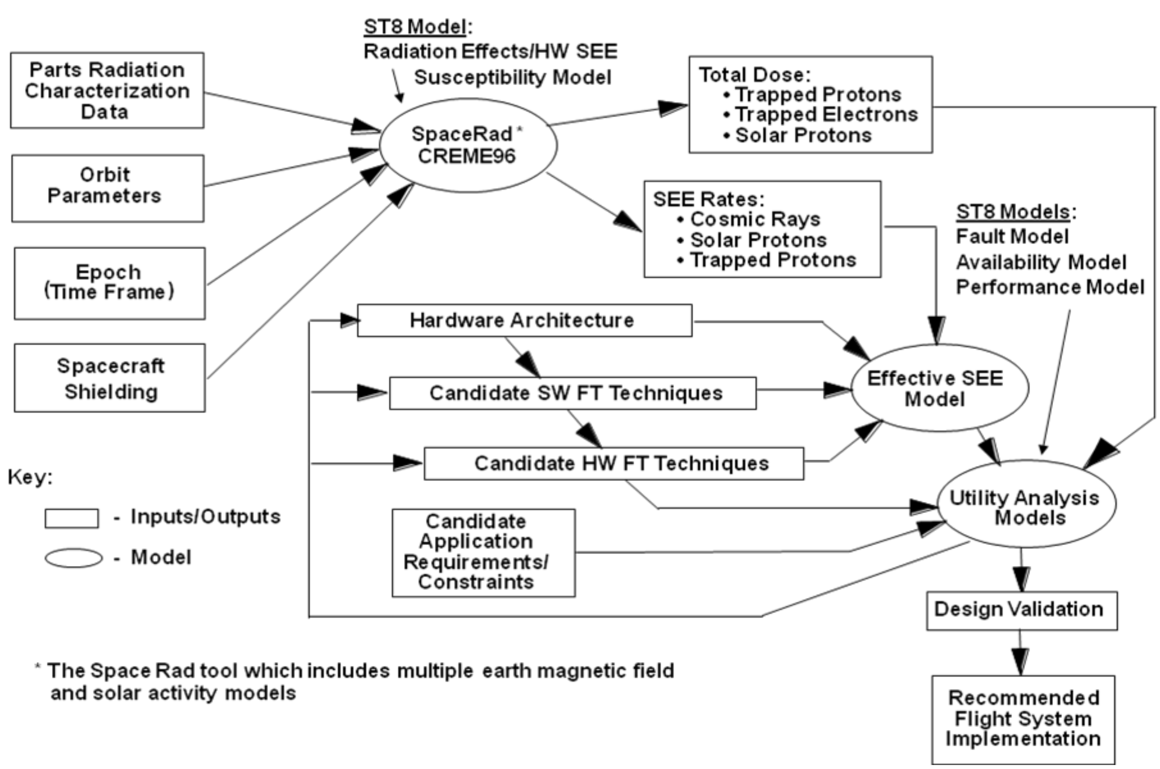

Figure 2 – Methodology for Migrating COTS to Space