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BENCHMARKING SPACE-GRADE AND COTS HIGH-PERFORMING, LOW-MASS, AND LOW-COST COMPUTING PRODUCED AT SCALE FOR DEEP SPACE TUMBLEWEED SCIENCE MISSIONS

Abstract

Advancing planetary science is crucial to understanding deep space environments. It requires robust computing architectures for rovers and orbiters to manage substantial scientific data. The onboard computing performance for space applications lags significantly behind its commercial equivalent, despite exponential progress in computing power. This disparity is due in part to the harmful impact of radiation in deep space environments, whose negative impact worsens with the transistor density per unit area.

Space-grade computing systems utilize radiation hardening techniques to adapt commercial components for space but are failing to enable high-performance, low-mass, and particularly low-cost computing at scale. However, such computing abilities are required for deep space missions like the Tumbleweed Science Mission - a low-cost Mars surface mission generating novel datasets by using a swarm of wind-driven mobile impactors deploying a network of measurement stations. Consequently, the missing economies of scale lead to a significant increase in the cost beyond commercial processing units.

Although increasingly more research on using COTS in near-earth space environments is being done, there is a need for a benchmark survey, based on the selection criteria for perpetual and reliable use of COTS versus space-grade computing systems in deep space at scale, as the Tumbleweed Science Mission requires for its mission profile. The objective of this paper is to identify and benchmark the features of commercial computing components and architectures, which can support high data processing at a low design cost while maintaining the processing powers and clock rates found in modern SoCs against space-grade computers.

We identify the benchmark criteria and provide a systematic analysis of radiation hardening by design (RHBD) approaches for space-grade commercial processing components. These are benchmarked against the state-of-the-art commercial processors for their processing power (FLOPS), clock rates, efficiency, and processor operations for space applications.

The results show a quantitative comparison of space-grade processors with their commercial counterparts, based on the relevant identified key drivers. These results are considered for scaled long-duration deep space missions, as well as the Tumbleweed Science Mission in particular. This benchmark survey

helps unlock the democratization of deep space and makes computing systems for many types of deep space missions more accessible.