System-Level Radiation Hardening

Although system-level radiation hardening can enable the use of high-performance components and enhance the capabilities of a spacecraft, hardening techniques can be costly and can compromise the very performance designers sought from the high-performance components. Moreover, such techniques often result in a complicated design, especially if several complex commercial microcircuits are used, each posing its own hardening challenges. The latter risk is particularly acute for Commercial-Off-The-Shelf (COTS) components since high-performance parts (e.g. double-data-rate synchronous dynamic random access memories—DDR SDRAMs) may require other high-performance commercial parts (e.g. processors) to support their operation. For these reasons, it is essential that system-level radiation hardening be a coordinated effort, from setting requirements through testing up to and including validation.

In this presentation, we examine the variety of radiation threats posed by the natural space radiation environment (see Figure 1).

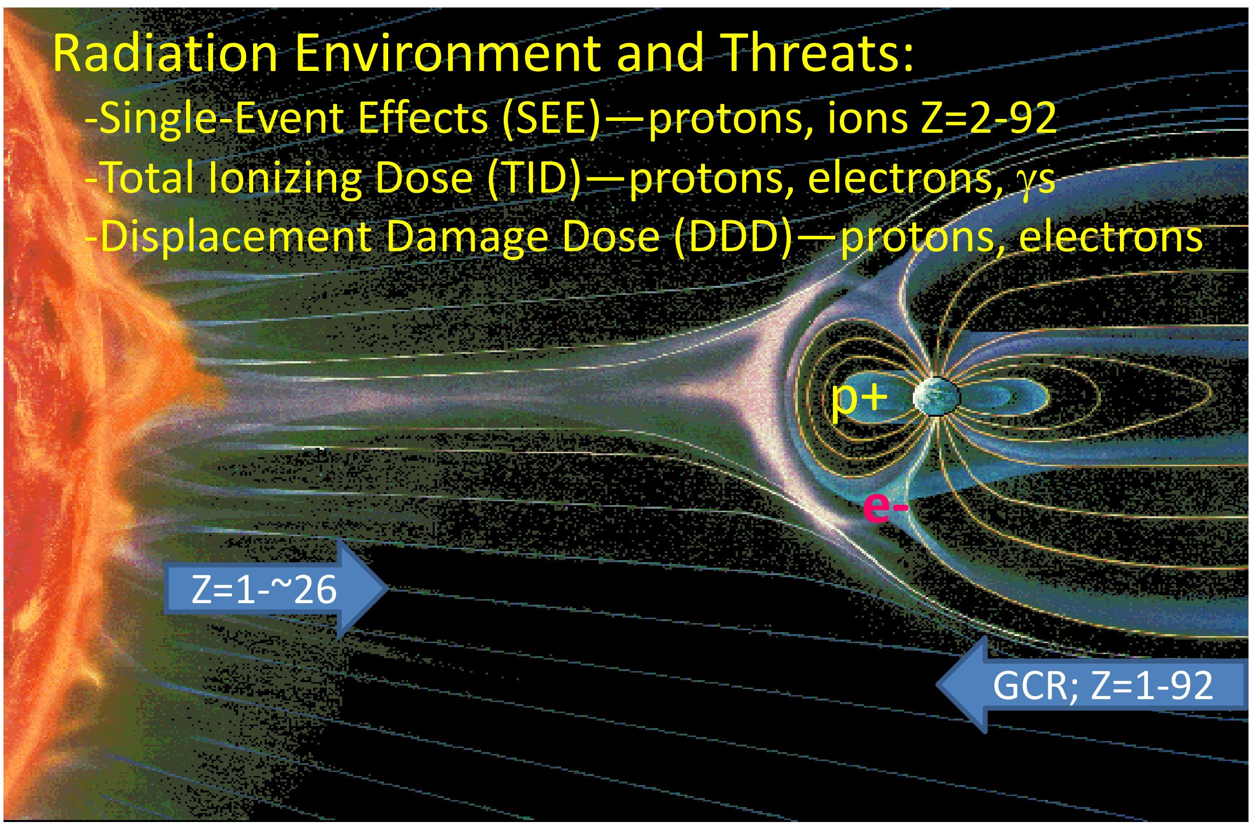

Figure 1 A schematic representation of the natural space radiation environment, its sources and the radiation threats it poses for spacecraft. (GCR – Galactic Cosmic Rays).

We next consider how system-level mitigations for radiation threats are dictated by the character of the radiation threat (e.g. Poisson vs. cumulative), its consequences and the exigencies peculiar to space hardware (see Figure 2). We offer a brief discussion of the mechanisms and consequences of destructive and nondestructive SEE and of degradation and failure due to the total ionizing dose (TID) and displacement damage dose (DDD). We then consider integration of multiple mitigation techniques and validation of mitigation.

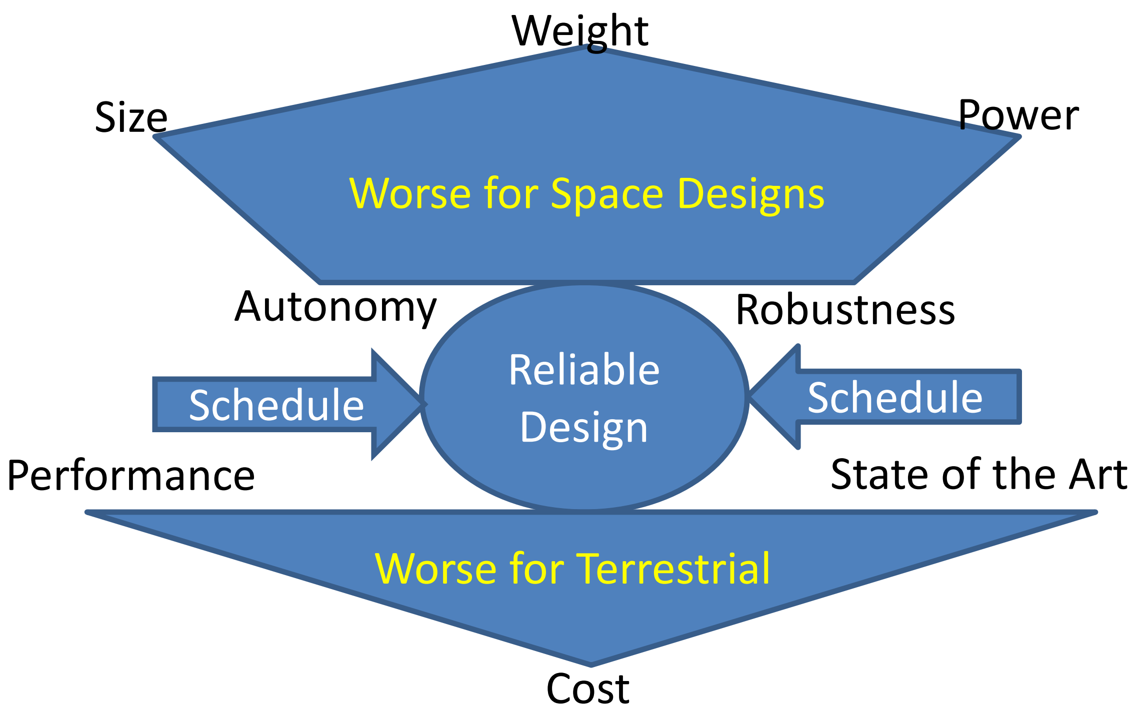

Figure 2 Although the mitigation techniques used for space systems are similar to those used to improve reliability in terrestrial systems, space systems face stringent limits on size, weight and power and must operate autonomously for extended periods of time and generally cannot be repaired after launch.

Next, we consider some of the things that can go wrong for system-level hardening. This includes violations of assumptions upon which radiation hardness assurance (RHA) has traditionally been predicated to limit costs of testing and analysis. Among the examples considered are the discovery of enhanced low-dose-rate sensitivity, which invalidated most of the accelerated test methods of the time for linear bipolar microcircuits. We then list some of the developments in our understandings of radiation effects and their implications for RHA and system-level mitigation. In particular, we examine some of the challenges posed by COTS technologies for system-level radiation hardening.

Finally, we briefly draw attention to some ongoing challenges, including the testability of complex devices, issues specific to COTS and the integration of COTS into radiation-hardened systems and the difficulties of engineering reliable systems in the face of uncertainties due to limited test data and imperfect models of radiation effects mechanisms, especially for rapidly evolving technologies.