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Enabling Radiation Tolerant Systems for Space

Billy Kauffman
Donna Hardage

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Billy Kauffman, Donna Hardage
NASA Marshall Space Flight Center

ABSTRACT

A hazard to all spacecraft orbiting the Earth is the existence of a harsh environment with its subsequent effects. The effects can provide damaging or even disabling effects on spacecraft and its instruments. One of the most recognized and serious of the different space environments is ionizing radiation and its effects on spacecraft and spacecraft systems. This is increasingly becoming more of an issue for all missions due to the use of lighter composite materials, smaller satellites, and smaller electronics. NASA's Space Environments and Effects (SEE) Program was established to develop new plateaus of technical capability to reduce the cost of NASA's missions and provide leading-edge exploratory and focused technology to promote continued U.S. preeminence in space. The SEE Program has an "Implementation Plan" to develop roadmaps and fund technical tasks to enable radiation systems for space.

1. Need

The need for all missions is "Enabling Radiation Tolerant Systems for Space" but how to achieve it at a reasonable cost is hard to accomplish. Due to commercial demand, commercial use of space, end of the cold war, and shrinking budgets, the availability of radiation tolerant/hardness parts has diminished greatly.

The questions that seem hard to answer are:

Does NASA need radiation hardened parts?
&
What can be done by NASA if radiation hardened devices
and systems are available?

Figure I depicts a summary of the radiation device regimes for the natural space environment.

Radiation Device Regimes for the Natural Space Environment		
High	**Moderate**	**Low**
> 100 krads (Si)	10-100 krads (Si)	<10 krads (Si)
May have:	**May have:**	**May have:**
long mission duration	medium mission duration	short mission duration
intense single event environment	intense single event environment	moderate single event environment.
intense displacement damage environment	moderate displacement damage environment	low displacement damage environment.
Examples:	**Examples:**	**Examples:**
Europa, GTO, MEO	EOS, LEO, L1, L2, ISSA	HST, Shuttle, XTE
Type of device:	**Type of device:**	**Type of device:**
Rad hard (RH)	Rad tolerant (RT)	SOTA commercial with SEE Mitigation

Figure 1

If this figure was expanded to include all missions and detailed requirements, one would probably come to the conclusion that if Commercial-off-the-Shelf (COTS) parts came off the foundry lines around 100 krad hard, which would be sufficient for approximately 80% of all NASA's missions. The problem, however, is this is not happening in the commercial foundries. There is no incentive for them to incorporate rad hard/tolerant capabilities into their commercial foundry lines because NASA has not established a program to do the testing for the commercial foundries to provide them the appropriate information.

This critical situation requires "will, commitment, time, effort, and faith". The "satisfaction right now" mentality of today's world will not work. It will take years and the proper funding from a committed program to address this situation. There are areas where funding would provide immediate results but not solve the problem. Those results would quickly fade due to the extremely fast pace of the development of microelectronics technology. At this point, NASA must continue to keep the faith that the program is working and will succeed.

The next section provides a suggested approach for NASA to address the issues.

3. Approach

The genesis of this proposed effort started as a result of the "NASA/DoD Coordination Workshop for Radiation Tolerant Microelectronics and Systems for Space Applications" held at the Goddard Space Flight Center (GSFC) in October, 1998. This workshop took place as a result of an initiative by NASA's Chief Engineer, Dan Mullville. The Nuclear Regulatory Commission (NRC) and Defense Threat Reduction Agency (DTRA) were the co-chairs from the DoD.

The results of the workshop unveiled that NASA does not currently have a focused plan to address these issues. The SEE Program was then asked by NASA Headquarters to develop an "Implementation Plan" for NASA. The following is an overview of the status of that effort and how it is being approached.

First, the development of an "Implementation Plan" started by identifying the ultimate goal, which was determined to be "Enabling Radiation Tolerant Systems for Space". To achieve this goal, a NASA program would need adequate funding but would also need to be focusing on all opportunities that exist for leveraging from other agencies, industry and universities.

Second, the broad issues required to meet this goal should be identified. It was determined that these issues should feed information (Figure 2) to the personnel that would be actually working on achieving the goal. They are as follows:

- Determine the mission needs and requirements for each of NASA's four strategic enterprises.

  The program would need to identify what types of microelectronics and the levels of radiation tolerance required for future missions to make NASA's vision happen.

- Determine where NASA can leverage DoD, DOE, commercial, and university efforts.

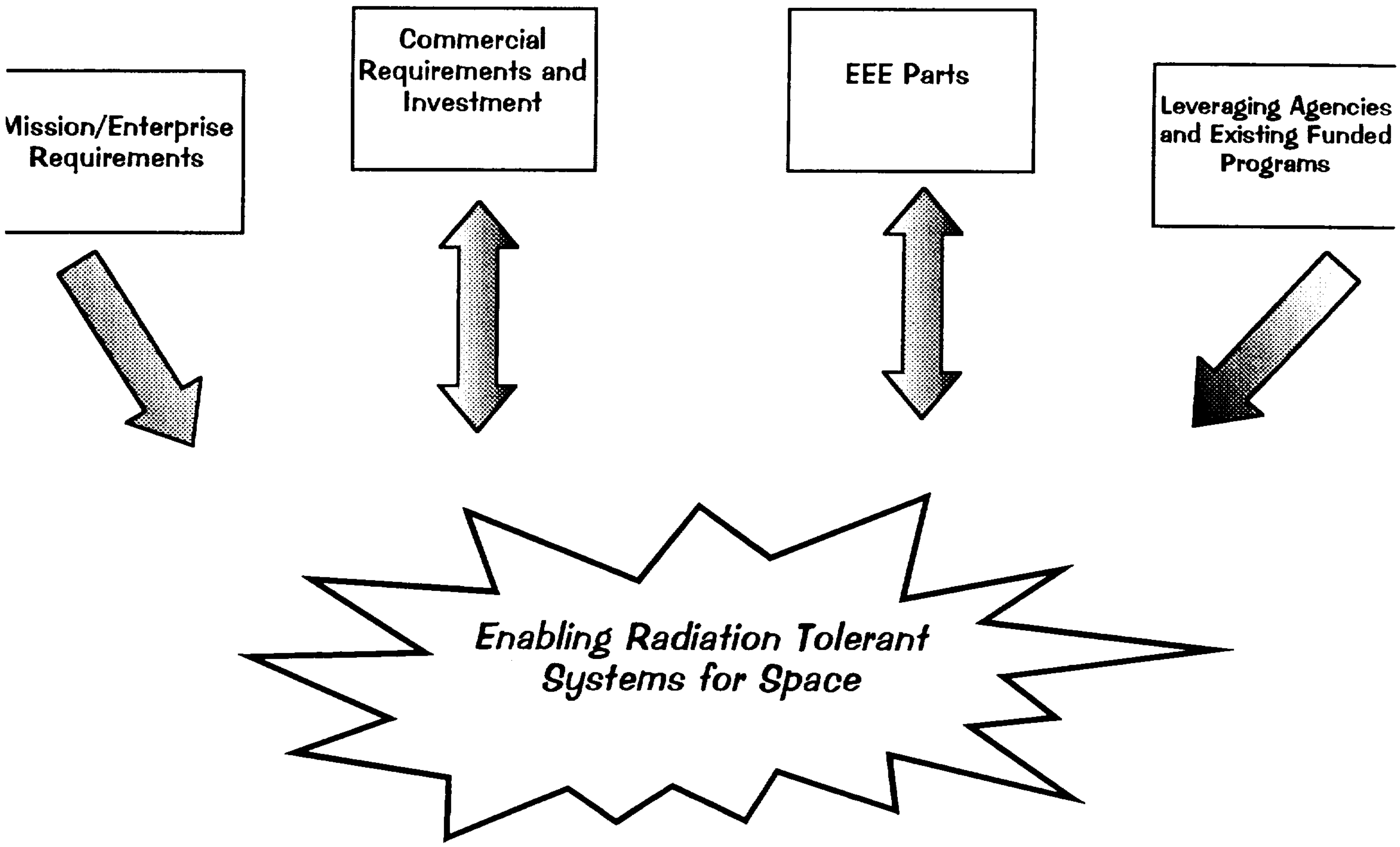
  The program **MUST** identify existing and future planned programs by other government agencies, industry, and universities. Neither agency can afford to fund a program by itself and be fully successful.

- What investment in the commercial consortia should be made.

  The commercial industry has a better defined insight to where commercial technologies are headed. The program should invest in a partnership for them to develop roadmaps of the commercial technologies and provide this information for input to the overall NASA roadmap.

- Ensure that the EEE Parts program at NASA is involved to the greatest extent in order to leverage efforts and avoid duplication.

  NASA's EEE Parts Program provides a different, but closely related, service to the proposed program by the SEE Program. The EEE Parts Program provides a "quick evaluation" of existing electronic parts whereas the proposed program focuses on the "evaluation and input of the development of future microelectronics". It is vital that these programs work closely to ensure they compliment each other and avoid any duplication of efforts.



Mission/Enterprise Requirements
Commercial Requirements and Investment
EEE Parts
Leveraging Agencies and Existing Funded Programs
Enabling Radiation Tolerant Systems for Space

Figure 2

Third, the SEE Program has determined the technical areas (Figure 3) that must be addressed to develop "Enabling Radiation Tolerant Systems for Space" for NASA.

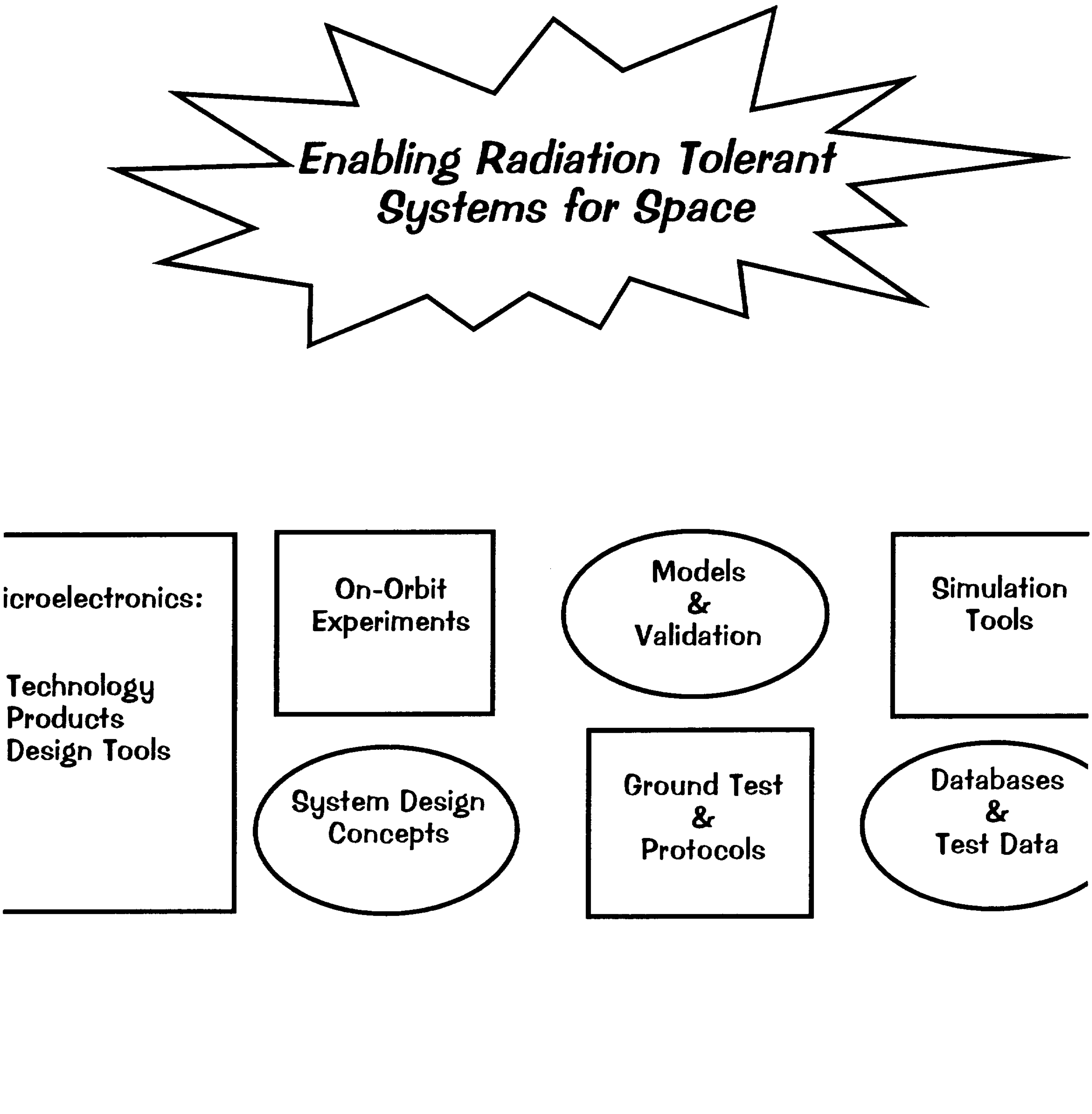


Figure 3

Different agencies have their own ideas/definitions for the technical topics presented in Figure 3. The following is a listing of the technical titles and a defined explanation as seen by the SEE Program:

Microelectronics:

> **Technology:** Investment in the acceleration of microelectronics processes to meet the performance and radiation needs by investing in foundry capabilities
>
> **Products:** Development of actual devices and components
>
> **Design Tools:** Automated design tools aimed at allowing a designer to sit at their workstation and design a rad tolerant chip using computer tools

On-Orbit Experiments: Opportunities to flight validate new and existing technology. Radiation test facilities and methods inherently have errors in simulating the actual space environment and its effects on microelectronics. Currently, the electronics used on spacecraft still have a large safety margin but with enough flight data, this margin can be reduced.

System Design Concepts: Research how to design a rad tolerant system and appropriate radiation risk analysis

Models and Validation: Reduce design margins on the environment models by validating and incorporating new flight data.

Ground Test & Protocols: Research and develop better correlation between ground tests, predictions and in-flight performance

Simulation Tools: Development of products that come from continuous testing programs that enhance foundry processes. NASA could do testing and provide the results back to the foundries to have commercial parts come off the lines up to 100 krads. Software tools would be developed to model the techniques used to develop parts and reduce the vast amount of testing that is required today (avg. $5000/hr.).

Databases and Test Data: Increase capabilities, performance, ease of availability, and standardize the content of test and analyzed data

Rad Hard: Guaranteed radiation performance exceeding 100 krads(Si) total dose, no destructive SEE and reasonable SEU performance

Rad Tolerant: Any device that meets system requirements. Typically TID of 10-100 krads, no SEL, and reasonable SEU

Fourth, an effort to develop detailed roadmaps of each technical area (which has not been addressed at this time) is required. This would be accomplished by identifying specific technical task activities to meet the needs of each area. The key to the success of developing these roadmaps is that all appropriate personnel, having a responsibility for a technical area, must be involved and have inputs to the other technical areas. An example of this is as follows:

The individual responsible for the On-Orbit Experiments must receive the appropriate input from the Models & Validation and Microelectronics areas in order to develop and address their technical shortcomings aboard a flight demonstration.

If the roadmaps are prepared carefully and correctly, they should be able to generate one integrated NASA roadmap to develop "Enabling Radiation Tolerant Systems for Space".

4. Conclusion

Currently, there seems to be a genuine push from NASA to develop a focused program and address future mission requirements for NASA's four strategic enterprises. The SEE Program understands that NASA's and DoD's missions are different, but there are many existing and future opportunities to "officially" collaborate where appropriate. These opportunities need to be identified, documented and implemented by NASA. They are vital to offsetting shrinking budgets for both agencies.

ACKNOWLEGEMENTS

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