



(Unclassified)

The Role of Space Experiments in the Radiation Qualification of Electronic and Photonic Devices and Systems

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"The Role of Space Experiments in the Radiation Qualification of Electronic and Photonic Devices and Systems"
Presentation by Stephen Buchner at Hardened Electronics and Radiation Technology (HEART), Tampa, FL, March 24, 2005

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Outline

- Introduction
- Rational for doing a space experiment
- Limitations of space experiments
- Limitations of ground experiments
- Elements of a space experiment
- Results of previous space experiments

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Introduction

- Space experiments are occasionally launched to study the effects of radiation on electronic and photonic devices. This begs the following questions:
 - Are space experiments necessary?
 - Do the costs justify the benefits?
 - How does one judge success of space experiment?
 - What have we learned from past space experiments?
 - How does one design a space experiment?

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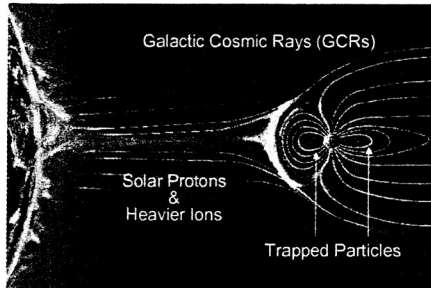
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Space Radiation Environment

- Solar Particles
- Cosmic Rays
- Trapped Particles

Electrons
Protons
Heavy ions



Nikkei Science, Inc. of Japan, by K. Endo

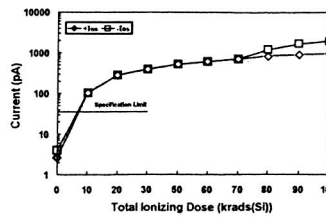
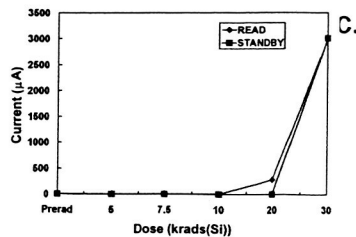
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Radiation Damage

- Total Ionizing Dose:
 - **Parametric degradation** – increased leakage currents, decreased speed, gain degradation.
 - **Functional failure** – CMOS transistor's threshold voltage changes so the part cannot switch, too much supply current.
- TID Occurs in most devices – CMOS, bipolar, MEMS,



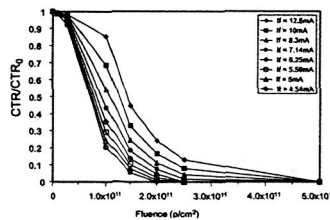
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Radiation Damage

- Displacement Damage:
 - Parametric degradation – solar cell efficiency, bipolar gain, LED light emitting efficiency
 - Functional failure – solar cell efficiency drops below that needed for intended application, optocouplers fail to transmit data



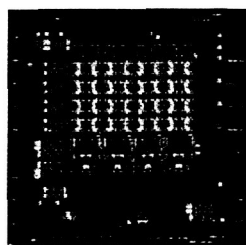
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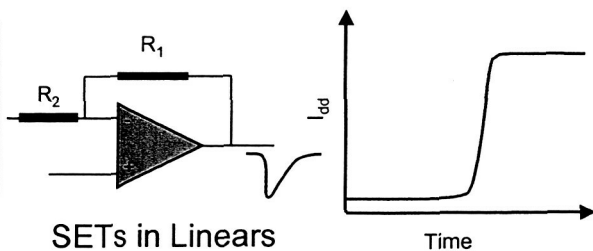
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Radiation Damage

- Single Event Effects:
 - Non-destructive (SEU, SET)
 - Destructive (SEL, SEB, SEGR)



SEUs in SRAM



SETs in Linears

Latchup Current

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Radiation Damage Accounts for Some Anomalies/Failures

Chronology of satellite failures

Date	Satellite	Problem(s)
September 1997	PAS-6	Circuit failures in solar arrays
mid-May 1998	EchoStar IV	One of two solar panels did not deploy
19 May 1998	Galaxy IV	Failure of primary and spare satellite control processor; total loss
13 June 1998	Galaxy VII	Temporary shutdown of some C-band capacity, failure of primary satellite control processor
24 June 1998	SOHO	Contact lost following a combination of ground control errors
June 1998 (?)	PAS-5	Partial loss of ability to recharge batteries
June 1998 (?)	EchoStar III	Overheated electric power converters; several transponders lost
4 July 1998	DBS-1	Failure of primary satellite control processor
7 July 1998	GOES 9	Overheated momentum wheel; satellite replaced by GOES-10
mid-July 1998	EchoStar IV	Loss of two transponders confirmed
Autumn 1998	Galaxy VIII	Partial loss of ability to recharge batteries
Autumn 1998	PAS-4	SCP failure
27 October 1998	GOES 8	Temporary loss of attitude control owing to Earth sensor anomaly
24 November 1998	Palapa C1	Partial loss of ability to recharge batteries
6 December 1999	(Compton) GRQ	Gyroscope failure; spacecraft later de-orbited for safety reasons
December 1998	TOMS	Single Event Upset disrupts spacecraft's computer operations, putting it into safehold mode
December 1998	PAS-8	Two of three Ku-band antennas not aligned properly
21 December 1998	SOHO	Safe mode, probably owing to loss of gyro

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Ground Testing Used to Qualify Parts for Space

- TID testing
 - Total Ionizing Dose:
 - Gamma rays (Co⁶⁰), X-rays
 - Co60 emits 1.17 and 1.33 MeV gamma ray. Rates on the order of 10 krad(Si) per hour.

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Ground Testing Used to Qualify Parts for Space

- DD testing
 - Proton (accelerator), neutron (accelerator or reactor)

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Ground Testing Used to Qualify Parts for Space

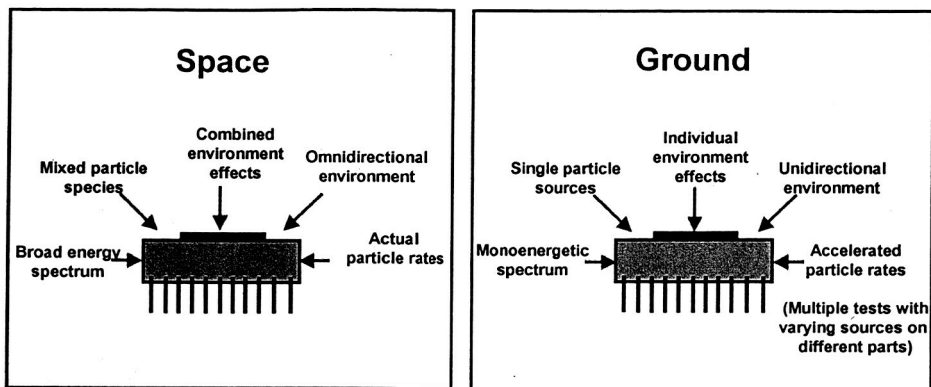
- Single Event Effects Testing
 - Accelerator, Cf 252, pulsed laser

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Testing Issues



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Modeling

- Models
 - Total Ionizing Dose & Displacement Damage Dose - SOLPRO, JPL, Xapsos/NASA
 - Single Event Effects - CREME96 (Protons & Heavier Ions), SPENVIS, GEANT
- Accuracy of models

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Previous Successes

- What are the metrics of success?
 - Number of papers published
 - Parts used in later missions

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Previous Successes

- MPTB
 - 56 papers published
 - Parts used in later missions
- CRRES
 - Papers published
 - Other information

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Lessons Learned from Previous Space Experiments

- For best results assumed that testing needed to be done under identical conditions. This was found to be a problem with MPTB:
 - Identical boards, panel, software, telemetry. However, software was set for reading DRAMs in a way that was incompatible with ground testing due to higher rate on ground.
 - Starting telemetry took a long time. If a single error in typing occurred, had to reboot which took 11 minutes.
 - Data files gigantic as they contained telemetry information that was of no interest. Had to strip files.
 - Could not count the number of upsets unless check the data and that involved reboot of system.
 - Engineers unwilling to change software as no longer had funding.
- Need to find sponsors for data gathering and analysis.

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The Essentials for a Space Experiment

- Spacecraft needed
 - Proper orbit for what you want to study, don't start too early (5 yrs for parts),
- Environment monitors
 - P-FETs dosimeters
 - Particle telescopes CREDO
 - Bernie Blake's monitor
- Measure as much as possible
 - SEUs
 - Supply currents, leakage currents
 - Temperature
- Funding for data analysis and storage

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