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

**S. Buchner, QSS Group Inc.,  
K. LaBel and J. Barth, NASA/GSFC,  
A. Campbell, NRL**

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## Outline

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1. Introduction
2. Lessons Learned from Space Experiments
3. Design of a space experiment
4. Summary and Conclusions

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## 1. Introduction

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## Introduction

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During 2003 alone, the following spacecraft exhibited anomalies whose origins were attributed to particle radiation :

- Aqua
- TERRA
- TRMM
- GALEX
- CHIPSat
- GOES-12
- Landsat
- TOMS
- NOAA-17
- ACE
- GOES-8
- GOES-10

**All of these spacecraft are essentially space radiation experiments, but with no control and no dosimetry.**

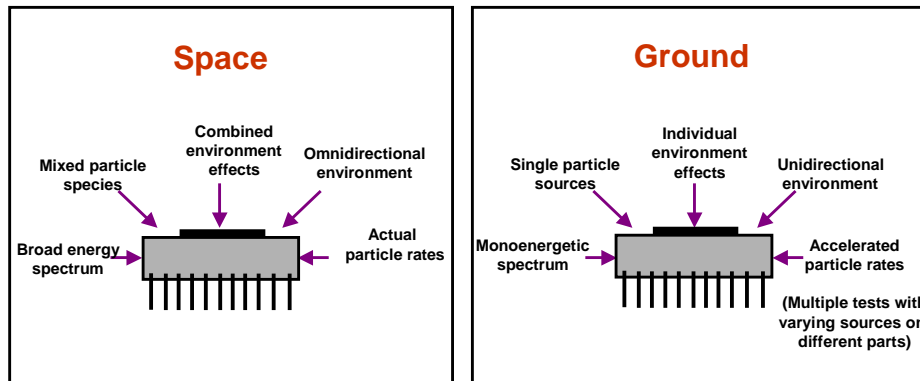
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## Introduction



Track size, shielding, margins

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## 2. Lessons Learned from Space Experiments

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## Some Lessons Learned

- Test it as you fly it – not always!
- How much ground testing is needed?
- Role of dosimetry.
- Need sponsors for data gathering and analysis.

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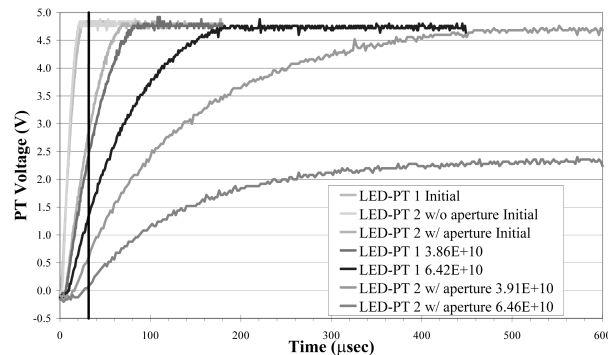
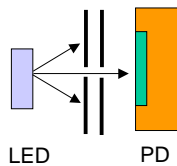
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## Hubble – Optical Encoder Pair

### Test it as you fly it – System Configuration



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## MPTB - DRAM

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### Test it as you fly it – not always!

- 16 Mbit DRAMs on MPTB.
- The following problems arose during ground testing:
  - Reading data was not compatible with ground testing.
  - Ground test involved telemetry, panel and board that was not user unfriendly.
  - Could not count number of upsets after each run without processing data, which required reboot of entire system that took about 12 minutes.

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## MPTB - ADC

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### How much Ground Testing is Needed?

- Three 8-bit Flash ADCs from Analog Devices (AD9058)
- Apply a fixed DC input and read the output. Check only for values outside a window to avoid too much data.
- Vary DC input every few months.

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## MPTB - ADC

### How Much Ground Testing is Needed?

- Because of limited accelerator time, tested part with just one DC input to calculate error rate.
- For one value of input, the data from space showed that the SEU rate dropped by an order of magnitude while environment monitors showed little decrease.
- Used the pulsed laser to investigate the reason.
- Found that, by chance, for the one DC value none of the comparators in the flash ADC was SEU sensitive, just the output register was sensitive.

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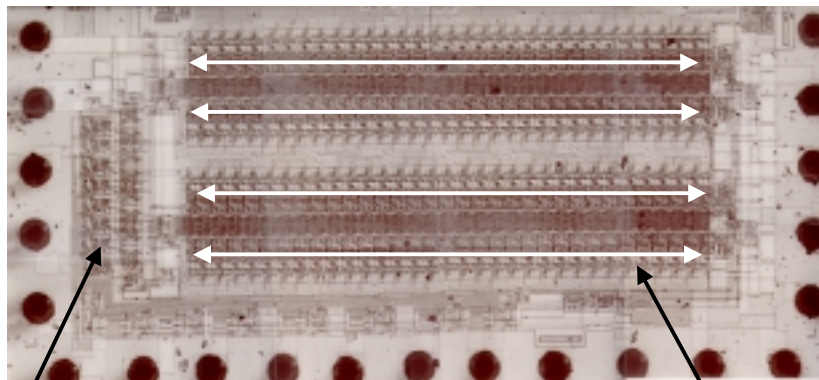
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## MPTB - ADC

### How Much Ground Testing is Needed



Output registers

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Comparators

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## MPTB – Dosimetry/Particle Detector

- Environmental monitors are essential – dosimeter (RADFET, UVPROM) and particle detectors (energy and LET spectrometers)
- Even remote dosimetry can sometime be used such as the processor resets on MAP correlated to solar event detected by GOES satellites.
- MPTB had:
  - RADFETs for dose
  - CREDO particle detector (able to measure LET)
  - Aerospace dosimetry unit (DSU)

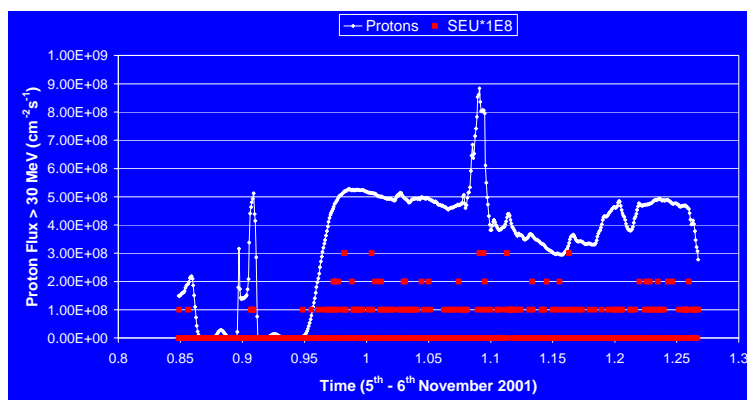
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## MPTB – CREDO (Particle Detector)



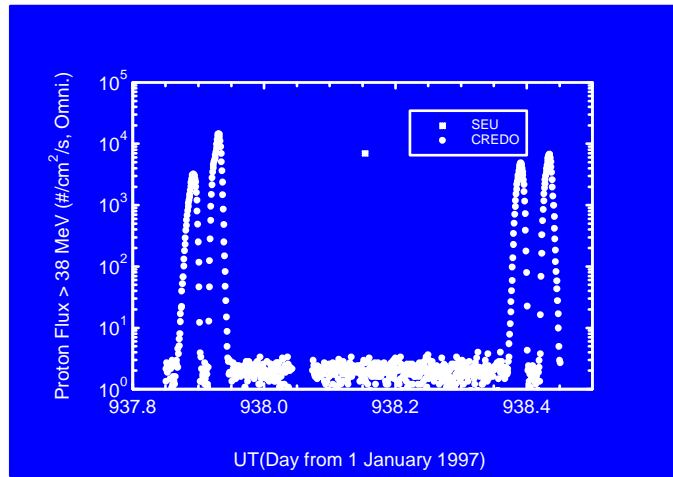
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## MPTB – CREDO (Particle Detector)



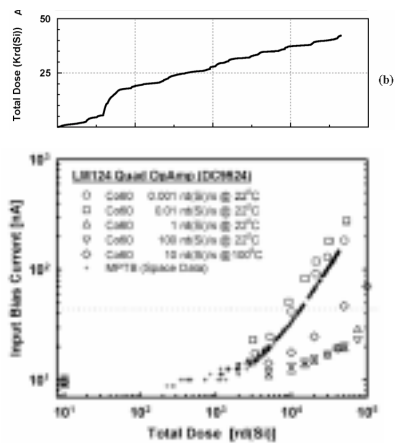
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## MPTB – pFET Dosimeter for ELDRS



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### 3. Space Experiment (LWS-SET)

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### Future Space Experiment

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- Living With a Star – Space Electronics Testbed (LWS-SET)
- Experiment proposed to measure damage and transients in a variety of optocouplers.

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## Displacement Damage in Optocouplers

- First Observed in Topex Poseidon
  - High-Inclination Earth Orbit (1300 km, 98 degrees) that skirts the edge of proton radiation belts)
- Optocouplers failed 2.7 years after launch, much earlier than predicted based on TID testing.
- Circuit failure due to 4X reduction in current transfer ratio (CTR) as a result of displacement damage.
- Implications:
  - Parts must be tested for displacement damage.
  - Cold “spares” are of no use due to displacement damage

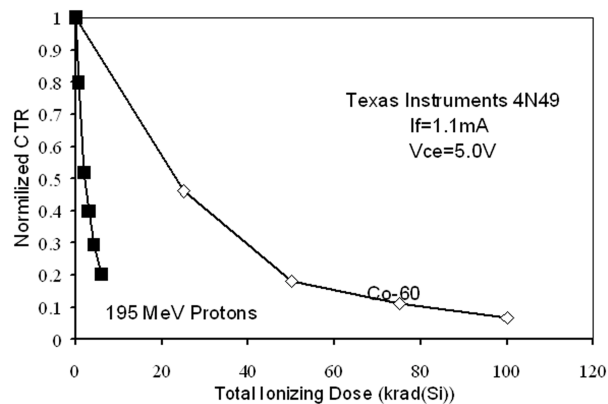
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## Displacement Damage in Optocouplers



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## LWST-SET Optocouplers

- System shutdown occurred in power converter on Hubble Space Telescope whenever HST passed through SAA.
- Power converter contains an optocoupler.
- Tests at proton and heavy-ion accelerators showed that the shutdown was caused by transients in the optocoupler.
- In particular, protons incident at large angles could produce transients via direct ionization in the detector, which leads to high upset rates.

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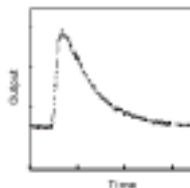
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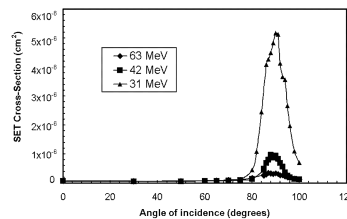
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## LWST-SET Optocouplers

Proton Induced Transient



Angular Dependence of Cross-Section



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## LWST-SET Optocouplers

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- Candidate Parts:
  - HCPL-5630
  - Micropac 4N49
  - Micropac 66013
  - Micropac 66099
  - Isolink OLH249
  - Isolink 4N49
- Will be measuring CTR periodically and monitoring for transients all the time.
- Ground testing will be done to compare with the space data.
- Goal is to validate models for both CTR degradation and proton-induced transients.

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## 4. Summary & Conclusions

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## Summary & Conclusions

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- Space experiments are an essential part of any radiation effects qualification program.
- All spacecraft are potential space experiments, but the most useful are those designed specifically for collecting data on radiation-induced effects – TID, DDD, SEE.
- Test the way you fly it – but be smart.

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