Flight Experiments for Living With a Star Space Environment Testbed (LWS SET) – Relationship to Technology

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Outline

• Introduction
  – LWS SET overview
  – SET flight experiment goals
  – SET Experiment Services
• Flight Experiments
  – Experiment Selection Process
  – SET Pathfinder (SETPath) Experiments
  – NASA Research Announcement (NRA)
• Collateral programs
• Comments

Proton Fluxes – 99% Worst Case Event

GOES Space Environment Monitor
Living With a Star Program: a pure and applied science program with an engineering application

- **Program Goal** – *Perform investigations in space to understand solar variability & its effects leading to a reliable predictive capability of solar variability (i.e., space weather)*

- **LWS has three elements**
  - **Science Missions**: the what’s and why’s of the solar variant environment
    - Ex., Solar Dynamics Observer
  - **Theory and Modeling and Data Analysis**: the environment models and tools developed from solar-variant data
    - A sample product might be: Improved Trapped Particle Models
  - **Space Environment Testbeds (SETs)**: *Improve the engineering approach to accommodate and/or mitigate the effects of solar variability on spacecraft design & operations*
    - A sample of a predecessor: Microelectronics and Photonics Testbed (MPTB)

- **Continuous program started in FY01**
SET Technologies

- SET provides opportunities for flight validation experiments on technologies
  - Microelectronics
  - Photonics
  - Materials
  - Sensors
    - Environment, imaging, etc.

- These investigations focus on
  - Demonstration of environment tolerance
    - Radiation hardening approaches
  - Validation of technology ground test methods and performance prediction techniques
    - Ex., correlate space dose rates to ELDRS sensitive device performance

- Investigations must require exposure to solar-variant environment
Solar Variant Example:
**SOHO/LASCO C3 Coronograph**

*July 14, 2000*

Solar storm induces transients in a Charge-Coupled Device (CCD)


Sample LWS SET Goals:
Understand enough about the technology and the environment to minimize science data outages. Validate cosmic ray rejection methods...
Sample Solar Variant Technology Effects: Radiation Effects on Spacecraft

- Long-term effects: failure/degradation increases with mission lifetime
  - Total ionizing dose (TID)
  - Displacement damage

- Transient or single particle effects (Single event effects or SEE): random strikes by a particle
  - Soft or hard errors

- Four quadrants, each representing a different design
- Particle hits spread among multiple pixels
- Ion strikes are minimized by utilization of a non N-well, n+ recessed implant photodetector design

Active Pixel Sensor courtesy of Photobit Technologies via NASA SBIR and DTRA Sensors Hardening Program


Destructive SEE in a commercial-off-the-shelf (COTS) 120V device, after Howard, 2002

LaBel LWS SET Experiments Overview – Mar 13, 2003 - Presented by Kenneth A. LaBel at HEART meeting, Albuquerque, NM
Other Technology Effects of Interest to LWS SET - Examples

- **Spacecraft charging**
  - May be the single largest cause of space environment induced anomalies
    - Can damage solar arrays, electronics, etc

- **Material degradation**
  - Brittleness, optical property degradation, thermal effectiveness,…

CEASE II instrument,
www.amptek.com
SET Services Provided to Experiments

**Host S/C**

- 28V
- RS-422 or other

**SET Payload**

- Power Conversion & Distribution
- Analog Interface
- Correlative Environment Monitor(s)
- Data, Command, Power
- DOSE, TEMP

- Exp 1
- Exp 2
- Exp N-1
- Exp N

**Carrier Electronics**

(mechanical, thermal, etc. not shown)

**Experiments may alternately fly without carrier if host S/C agreement is included**

+ NASA and DTRA are collaboratively investigating infrastructure requirements for imaging sensors
Flight Experiment Selection Process: 

*Two methods*

- **NRA:** a competitive action for investigations
  - Proposal process
  - Must demonstrate need to fly in solar-variant environment
  - Must have collateral ground test and/or model development program
  - No technology development efforts funded by this NRA
  - Data is non-proprietary (may be ITAR)
  - No funds exchanged with international entities

- **Partnering**
  - Partner may provide investigation(s) outside of the NRA process in exchange for support of the LWS SET Program
    - Funding
    - Launch opportunity
    - Infrastructure, etc…
  - Data can be proprietary or secure
SETPath Experiments Overview

• SETPath experiments are based on flight investigations originally designed for Space Technology Research Vehicle – 1d (STRV-1d) mission
  – No data returned due to spacecraft communications system failure
  – Originally selected by a peer team for STRV-1d inclusion
  – Some updates provided to original experiment to increase investigation utility

• Five experiment cards
  – COTS-1a: Linear Single Event Transients (LSETs)
  – COTS-1b: Enhanced Low Dose Rate Sensitivity (ELDRS)
  – COTS-2a: Digital Commercial-off-the-Shelf (COTS) Electronics
  – COTS-2b: Field Programmable Devices
  – COTS-3: Optocouplers
COTS-1a: Linear Single Event Transients (LSET)

**Purpose**
- Collect data in space to validate single event transient (SET) performance models & test protocols for linear bipolar devices

**NASA Benefit**
- Provide more consistent performance & lifetime; lower likelihood of LSET anomalies as observed in Cassini, MAP, & TDRSS

**NASA Application**
- Linear bipolar devices are common in comparators and operational amplifiers -- basic building blocks in all NASA spacecraft & instruments

**History**
- Designed for STRV 1-d; will be built by Aerospace Corp
- A sample LSET, after Poivey, 2002

**Partners**
- Aerospace Corp., NASA’GSFC, NAVSEA-Crane, Vanderbilt University, JPL, DoD, Industry, RLP

**Leveraging**
- The NASA Electronics Parts & Packaging (NEPP) and DTRA supports development of ground radiation tests, protocols, & prediction models
  - Ground test protocol will be issued in FY 2003 (Poivey/GSFC)
  - Supports Vanderbilt model development
- Devices provided by industry (NSC, et al?)

**Development Path**
- Modification of existing design (Koga & Crain/Aerospace Corp)

**Delivery Date:** Jan 2004

**Risk of Schedule Slip**
- Low; based on existing design
COTS-1b: Linear Enhanced Low Dose Rate Sensitivity (ELDRS)

**Purpose**
- Collect data in space to validate ground test protocols for linear bipolar devices that exhibit ELDRS
  - ELDRS is failure at a lower cumulative total ionizing dose in space compared to traditional accelerated ground test dose rates

**NASA Benefit**
- Provide more consistent performance & lifetime

**NASA Application**
- Linear bipolar devices are common in comparators and operational amplifiers -- basic building blocks in all NASA spacecraft & instruments

**History**
- Early experiment concept successfully flown on MPTB by NAVSEA-Crane (COTS-1b experiment developer)

**Partners**
- NAVSEA-Crane, Vanderbilt University, NASA/GSFC, JPL, DoD, Industry, RLP

**Leveraging**
- The NASA Electronic Parts & Packaging Program (NEPP) delivers a ground test & technology guideline in FY 2003 (Johnston/JPL)
  - Devices provided by industry (NSC, et al)
  - Mil 1019.6

**Development Path**
- Modification of existing design by NAVSEA-Crane (Turflinger, et al)

**Delivery Date:** Jan 2004

**Risk of Schedule Slip**
- Low; based on flight-heritage design
COTS-2a: Digital COTS

Purpose
• Collect data in space to validate single event effect (SEE) & total ionizing dose (TID) performance models for:
  – Commercial fuzzy logic processors;
  – Static random access memories (SRAM); &
  – Field programmable gate array (FPGA) logic devices

NASA Benefit
• Reduce design margins & provide more consistent performance in space

NASA Application
• Fuzzy logic: Robotics, docking, & constellation management applications
• SRAMS: Solid state recorders
• FPGAs: Replace custom solutions

Partners
• NASA/GSFC, CNES, ONERA, TIMA

Development Path
• Modification to existing STRV 1-d flight card for LWS SET carrier interface (NASA/GSFC)

Delivery Date: November 2003

Risk of Schedule Slip
• Low; existing hardware

Ground data availability
• Heavy ion & proton data in hand from Orsay, France

History:
• Built for STRV 1-d but not flown
COTS-2b: FPGA Technology Concept Validation

Purpose
• Collect data in space to validate single event effect (SEE) and total ionizing dose (TID) performance models & test protocols for COTS and environment-hardened FPGAs

NASA Benefit
• Provide more consistent performance in spacecraft electronics systems.

NASA Application
• Replace custom solutions in electronics system design at a fraction of the cost in virtually all NASA spacecraft; save power, weight, volume, & schedule

History
• Designed for STRV 1-d by NASA/GSFC; devices will be updated to state of the art

Partners
• NASA/GSFC, DoD, Industry, (is TIMA interested?)

Leveraging
• The NASA Electronics Parts & Packaging Program supports development of ground test protocols, guidelines, & technology development
• Devices provided by DoD & industry

Development Path
• Existing design (Katz - NASA/GSFC) with mission-specific modifications

Delivery Date
• Jan 2004

Risk of Schedule Slip
• Low – existing design with experienced flight designer
COTS-3: Optocouplers

Purpose
- Collect data in space to validate single event effect (SEE), total ionizing dose (TID), and device displacement damage (DDD) performance models & test protocols for optocouplers
  - Portions of the models may also be applicable to high-speed fiber optic links

NASA Benefit
- Reduce design margins & increase reliability
  - Anomalies on HST, TERRA, & TOPEX/Poseidon)

NASA Application
- Used to isolate electrical signals between spacecraft sub-systems & instruments; ex., power converters

History
- Designed for STRV-1d by NASA/GSFC; new optocouplers will be utilized for SETPath

Partners
- NASA GSFC, JPL, DoD, Industry

Leveraging
- The NASA Electronic Parts & Packaging Program (NEPP) and DTRA deliver a ground test & technology guideline in FY 2003 (Reed/GSFC)
- Devices provided by industry

Development Path
- Existing design; mission-specific interface modifications & newer devices (Buchner – GSFC)

Delivery Date: Jan 2004

Risk of Schedule Slip: Low; based on an existing design

Ground data availability
- Heavy ion & proton data in hand; all new ground data to be funded by NEPP

A sample SET, after Reed, 1998
Collateral Programs

- Ground-test programs are developing protocols or that require validation. Examples include:
  - Electronics
    - NASA Electronic Parts and Packaging (NEPP) Program
    - Defense Threat Reduction Agency’s (DTRA’s) Radiation Hardened Microelectronics (RHM) Program
    - Air Force Space and Missile Command
    - ESA
    - CNES
  - Materials
    - Air Force Wright Patterson
- Environment-tolerant approaches require validation
  - Air Force Research Laboratories
  - DTRA
  - Industry
Final Comments

- Ground test methods require validation with in-flight data
  - Must have correlative environment monitors (CEMs) or we can’t adequately reduce design margins
- No one likes to be the first to fly a new solution
  - LWS SET can provide that opportunity for new technologies that require solar-variant environment validation
- NRA results due out in near-term
  - Future NRA planning has begun
- Collaboration with others is critical
- Contact for more info
  - kenneth.a.label@nasa.gov
  - http://nepp.nasa.gov

Europa: future challenges for radiation, temperature, and lifetime