

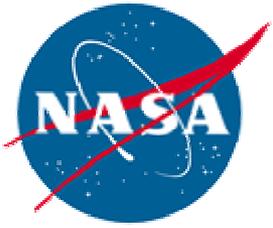
# ***Space Environment Testbed Project Overview***

**Janet Barth, NASA/GSFC**  
***LWS/SET Project Scientist***

***11 September 2003***

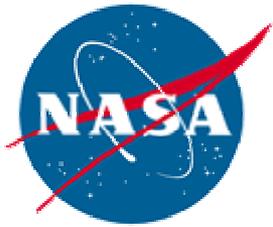
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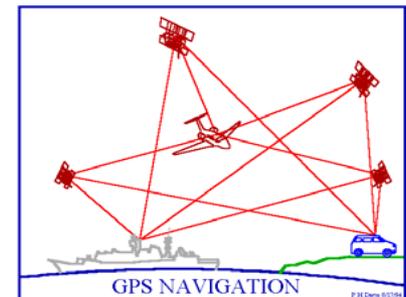
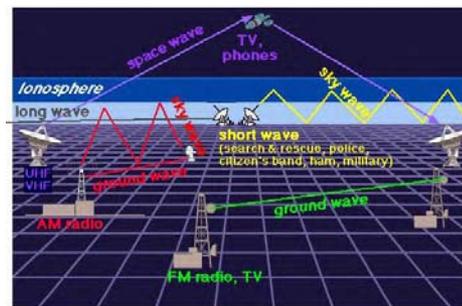
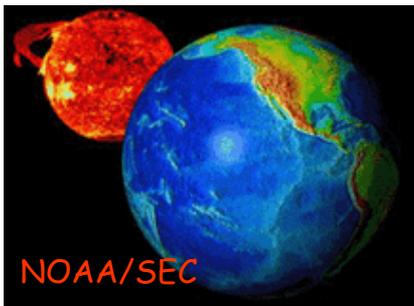
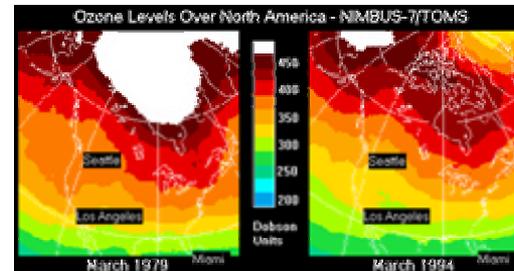
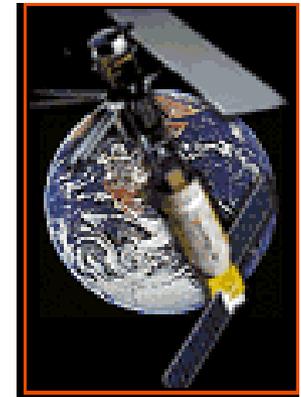
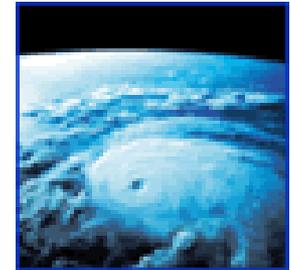
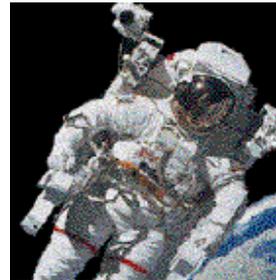
# Outline

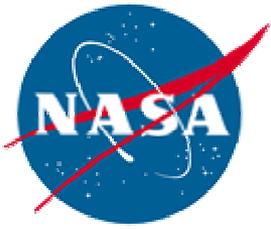
- **Part 1 – SET Project Overview**
  - Goal and Objectives
  - Project Concept
  - Status
- **Part 2 – NRA Process Overview**
  - Proposal content
  - Review process
  - Evaluation criteria
- **Part 3 – NRA Awards**
  - NRA #1 (FY01) - Model development and data mining
  - NRA #2 (FY03) - Flight investigations



# Increasing Importance of Support Functions Provided by Space Systems

- **Scientific Research**
  - Space science
  - Earth science
  - Human exploration of space
  - Aeronautics and space transportation
- **Navigation**
- **Telecommunications**
- **Defense**
- **Space Environment Monitoring**
- **Terrestrial Weather Monitoring**





# Space Systems Enabled through Transition of Technology to Space



## Living With a Star Program

- Understand environments external to the spacecraft
- Understand the induced environment in the presence of the spacecraft

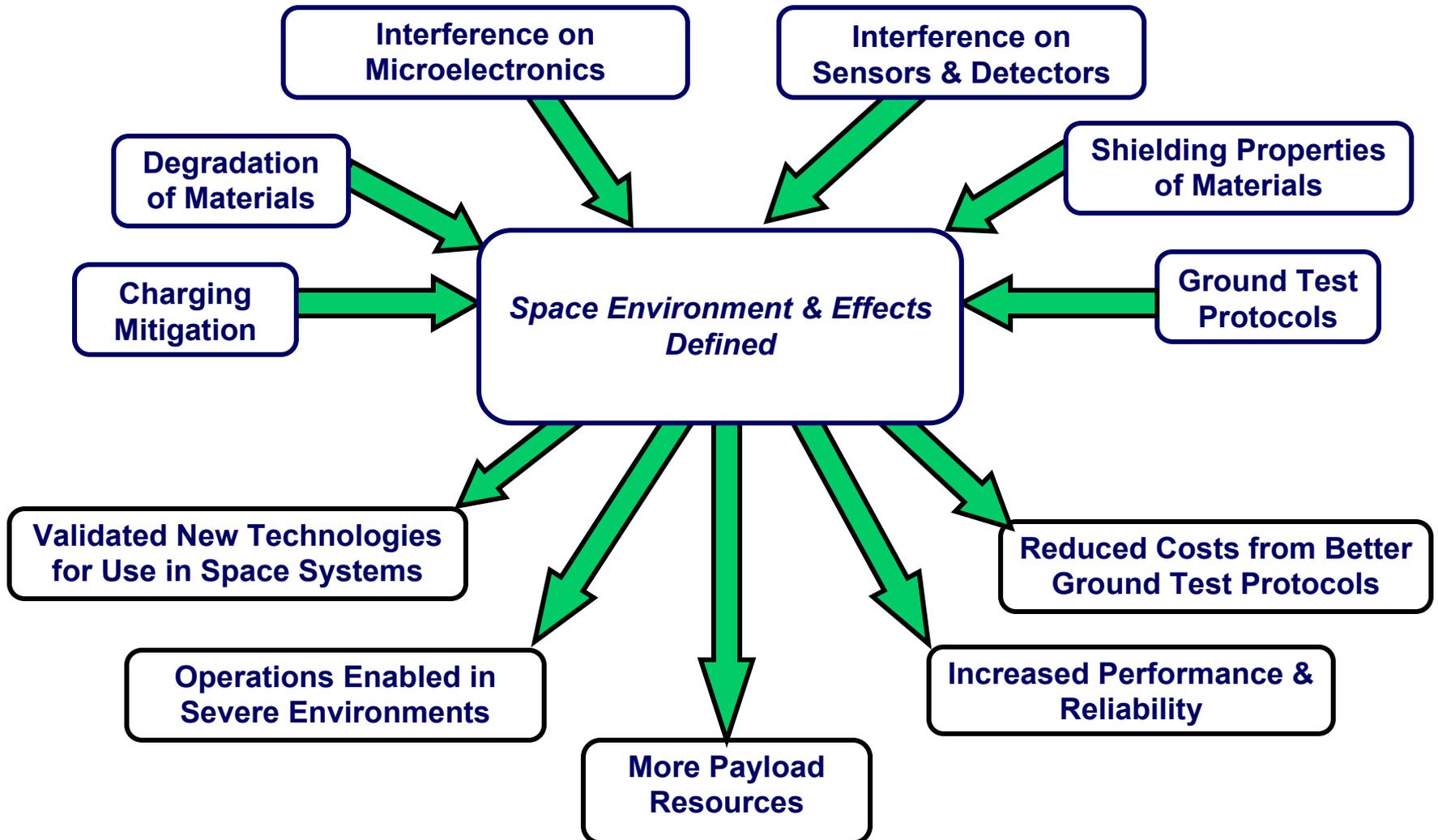
*Solar varying environments*

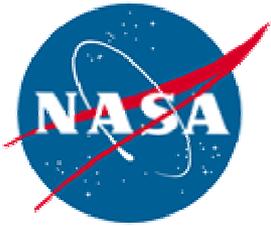


*Technology use in space systems*



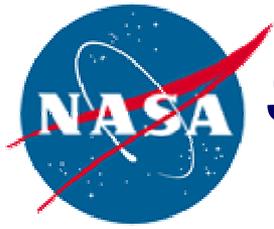
# Large Uncertainties in Space Environment & Effects Preclude Cost Effective Use of the Space Environment





# *Estimates of Uncertainties*

- **Well understood technologies**
  - 10-15% of technologies
  - x2 design margin applied
  - Example – CMOS, down to .25 micron
- **Poorly understood technologies**
  - 85-90% of technologies
  - Technologies currently in use
    - x5 – x10 design margins applied
    - Example – linear bipolar devices
  - Emerging technologies
    - > x10 design margins applied
    - Examples - Exotic materials, SiGe



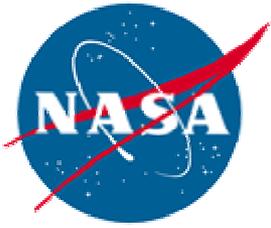
# Space Environment Testbeds (SET) Project

## Goal

*Improve the capability to accommodate or mitigate the effects of solar variability on spacecraft and instrument design and operations*

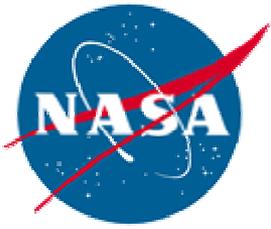
**Need to replace empirical models of space environment effects with physics-based models**





# ***SET Objectives***

- **Define the mechanisms for space environment and effects**
- **Reduce uncertainties in the definitions of the induced environment and effects on spacecraft and their payloads**
- **Improve design and operations guidelines and test protocols**
  - **Reduce spacecraft anomalies and failures due to environment effects during operations**



# *SET Project Concept*

*Funded investigators develop products that meet the Goal and Objectives of the LWS SET Project.*

**Fund investigators through NASA  
Research Announcements (NRAs)**

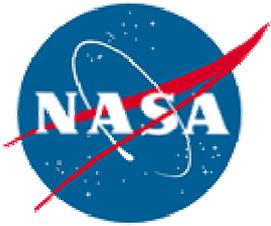
**This  
NRA**

**SET Data Analysis Component:**

- Models, tools, or databases that describe performance variations in space in the presence of a spacecraft that change due to solar variability

**SET Space Flight Component:**

- Investigations that include data collection from an experiment in space whose data are used to improve the physics-based understanding of response of systems to the solar varying space environments



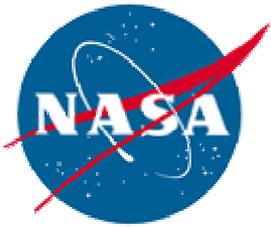
# ***Description of SET Products***

- **Product categories**
  - **Characterization of the space environment in the presence of a spacecraft**
  - **Definition of the mechanisms for materials' degradation and the performance characterization of materials designed for shielding from ionizing radiation**
  - **Accommodation and/or mitigation of space environment effects for detectors and sensors**
  - **Performance improvement methodology for microelectronics used in space**
  - **Accommodation and/or mitigation of charging/discharging effects on spacecraft and spacecraft components**
- **Product examples**
  - **Validated ground test protocol**
  - **Definition of a damage mechanism**
  - **Development of an accommodation or mitigation technique**
  - **Better definition of the induced environment**



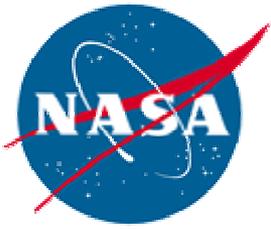
# ***Data Acquisition for Product Development***

- **Existing data – “data mining”**
  - Ground test data
  - Data from non-SET flight investigations
- **SET Missions – SET-1, SET-2, ....**
  - Series of small missions that provide opportunities to collect data in support of investigations
  - Each mission comprised of individual experiments to support science investigations and product delivery
    - Interfaces to permanently attach the experiments to a host spacecraft (i.e., piggyback)
    - Attachment may be either through an experimenter-provided interface or an SET-provided experiment carrier
  - Mission every two years
    - Manifest investigations into most appropriate environment
    - Cover the 11-year solar cycle
    - Respond to new technology needs



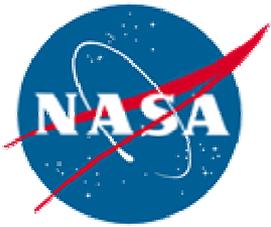
# ***SET Status***

- **FY01 (Data Mining) - NRA released for model development and data mining**
  - 9 awards totaling \$800K
  - Final reports and products available for 7 of 9
- **FY02 (SET Pathfinder) – Funding approved for existing peer-reviewed investigations from STRV-1d**
- **FY03 (SET-1) - NRA released for flight investigations**
  - 7 awards
  - Kick-off on June 5, 2003
  - In Phase A of development
- **On-going SET carrier development**
  - SET implementation responsibility assigned to GSFC Sub-Orbital and Special Orbital Projects Directorate
  - SET-1 carrier ride identified
    - Agreement in negotiation
    - Accommodation studies in progress
  - Pursuing ride opportunity for SET-2



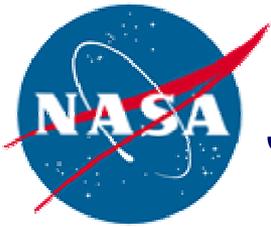
# ***NASA Research Announcements (NRAs)***

## **Part 2 – The NRA Process**



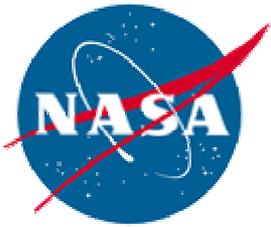
# Constituent Parts of an NRA Proposal

Section	# of pages
• Proposal Cover Page	
• Budget Summary (contiguous with Cover Page)	
• Table of Contents	1
• Summary of Personnel and Work Efforts	1
• <b>Scientific/Technical/Management Section</b>	<b>15*</b>
• References and Citations	As needed
• Facilities and Equipment (if applicable to proposal)	2
• Curriculum Vitae for the Principal Investigator	3
• Curriculum Vitae for each Co-Investigator	1
• Current and Pending Support	As needed
• Co-I and/or Collaborator Commitments	As needed
• Budget Details (incl. Proposing Institution Budget)	As needed
• Special Notifications and/or Certifications	As needed
• Reprint(s)/Preprint(s) (optional)	Not applicable



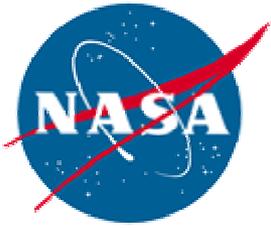
## ***Scientific/Technical/Management Section***

- **What will you accomplish?**
  - Objectives and expected significance of the proposed research, especially as related to the objectives given in the NRA
  - Technical approach and methodology to be employed in conducting the proposed research
  - Perceived impact of the proposed work to the state of knowledge in the field
  - Relevance of the proposed work to the specific objectives given in the NRA
- **How are you going to accomplish it? - A general plan of work**
  - Anticipated key milestones for accomplishments
  - Management structure and cost for the proposal personnel
  - Substantial collaboration(s) and/or use of consultant(s) that is(are) proposed to complete the investigation
  - Description of the expected contribution to the proposed effort by the PI and each person regardless of whether or not they derive support from the proposed budget



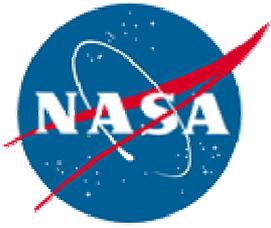
# ***Evaluation Criterion #1***

- **Intrinsic merit**
  - **Proposal's technical merits**
  - **Degree to which the investigation meets the requirements solicited**
  - **Overall feasibility of the end-to-end investigation including the approach and plan for meeting schedule requirements**
  - **Degree to which the proposer has the requisite experience and organizational capability to complete the investigation**
  - **Commitment of the organization's management to the proposed technology development**



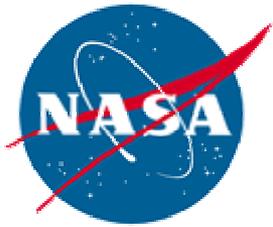
## ***Evaluation Criterion #2***

- **Relevance to NASA's objectives (which include objectives of space system users and providers)**
  - Degree to which the proposed investigation meets the solicited requirements
  - Credibility of the basis for substantiating the projected margin, risk reduction, performance enhancements, or cost reductions
  - Need for space flight data



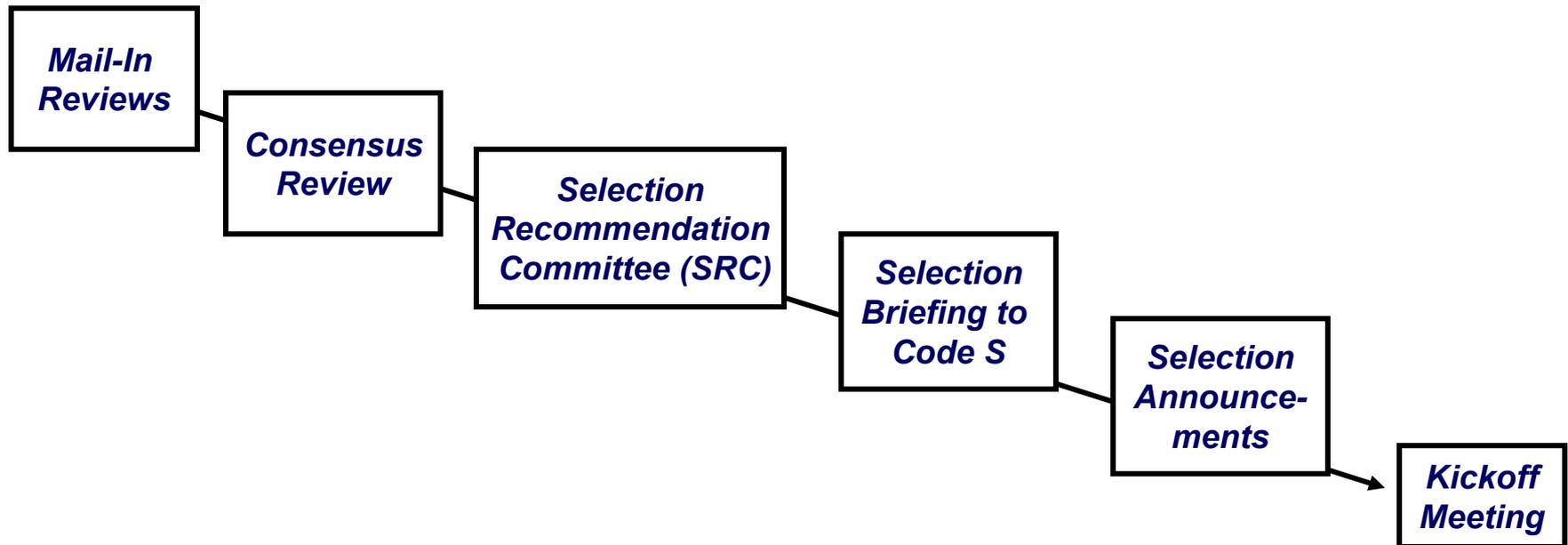
## ***Evaluation Criterion #3***

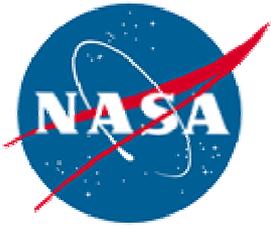
- **Cost**
  - **Credibility of the entire budget for the investigation including the funding requested from NASA**
    - **Value of all resources contributed by the proposer in lieu of funding**
    - **Funding contributed by the proposer (if applicable)**
    - **Products and services requested from NASA in addition to funding**
  - **Realism and reasonableness of the proposed cost, management structure, and schedule for the investigation approach to assure delivery at the end of the investigation**



# *Proposal Solicitation/Peer Review Process*

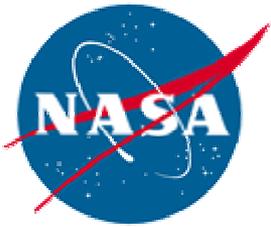
- **Technology solicitation**
  - Open competition: industry, academia, government labs
  - Issued by HQ
  - No exchange of funds with international organizations
- **Peer Review led by HQ using NASA Peer Review Services (NPRS)**





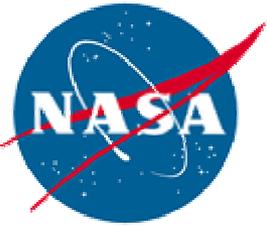
# ***NASA Research Announcements (NRAs)***

## **Part 3 – NRA Awards**



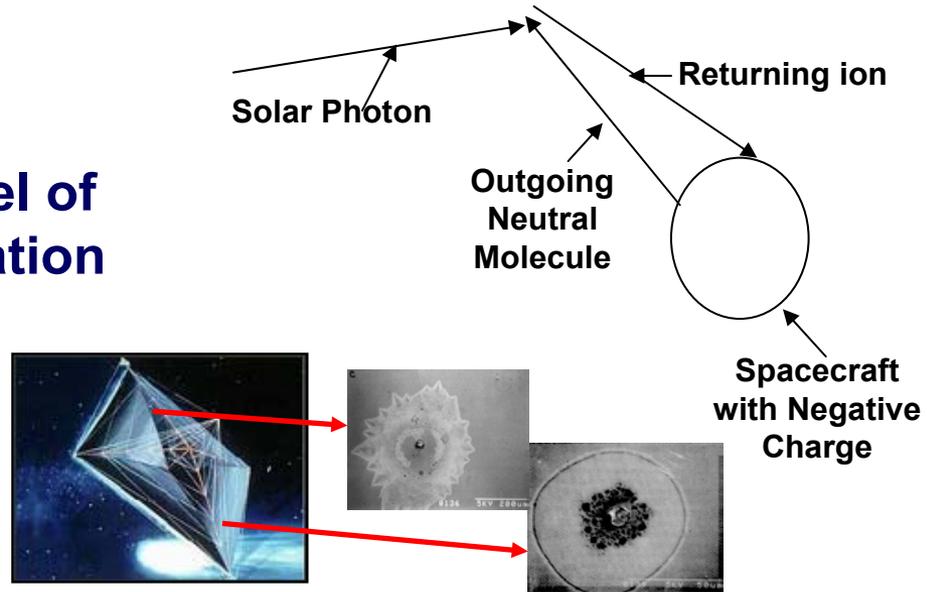
## ***Previous SET NRAs***

- **NRA #1 (FY01)**
  - Focus was on product development through mining of existing flight data.
    - 9 awards totaling \$800K
    - Final reports and products being released now
- **NRA #2 (FY03)**
  - Focus was on flight investigations that provide data for product development.
  - 7 awards
  - Investigators in Phase A of flight development



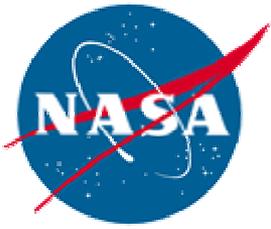
# Electrostatic Return of Contaminants (ESR)

- Model that predicts the level of spacecraft surface degradation from ESR
- Solar photons



PI: R. Rantanen

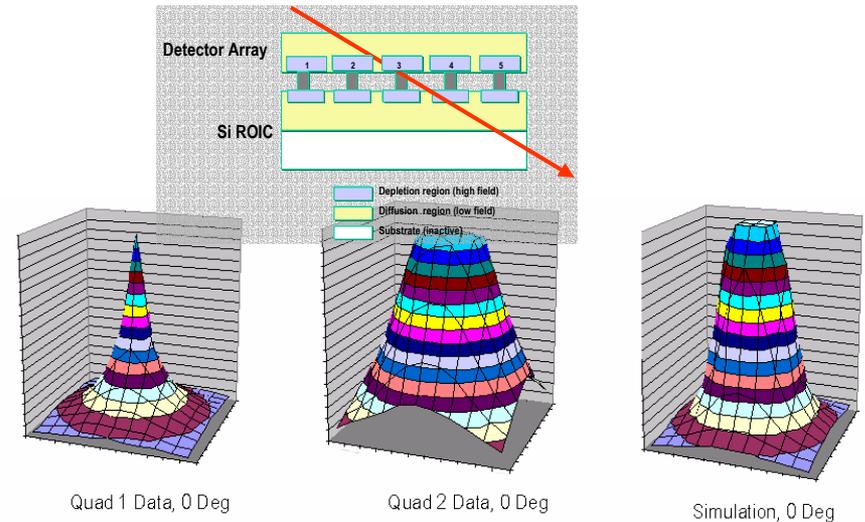
- Predicts the electrostatic return of spacecraft emitted molecules that are ionized and attracted back to the spacecraft by the spacecraft electric potential on its surfaces
- Provides levels of surface deposits and surface sputtering caused by the returning ions
- Accounts for different emitted molecular species and energy for a range of spacecraft environments (LEO, GEO, interplanetary)



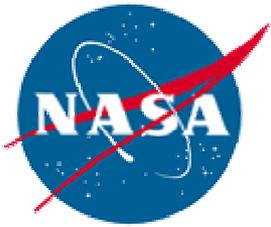
# Modeling Charge Collection in Detector Arrays

- A Monte Carlo/analytical model for focal plane array (FPA) applications
- High energy charged particles

PI: J. Pickel



- Addresses need for high fidelity simulation of particles interactions in complex FPA structures, including multiple layers, sub-regions with layers, variation of linear energy transfer (LET) with range, electron scattering, free-field diffusion, and field-assisted diffusion
- Can be applied to any semiconductor detector array
- Possible application to SOI and SiGe technologies
- Computer code, REACT, to predict charge collection in an array of elements



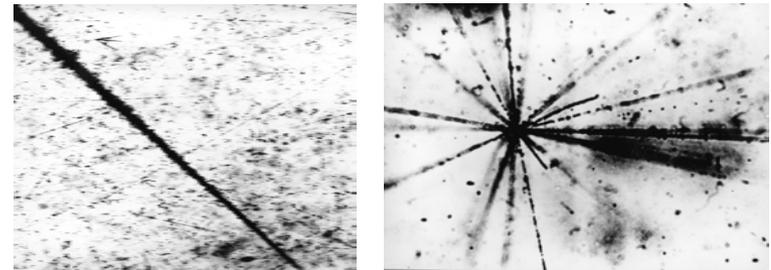
# Analysis of CRRES PHA Data for Low-LET Events

➤ **Charge collection models (COSMIC/CUPID) updated to include elastic interactions for application to modern devices where these interactions have been shown to dominate**

➤ **Protons and heavy ions**

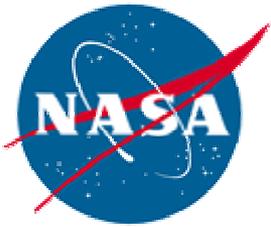
*PI: P. McNulty*

## IMPORTANT SOURCES OF SPACE RADIATION EFFECTS



Track of an iron nucleus that stops in lower right corner    A spallation reaction

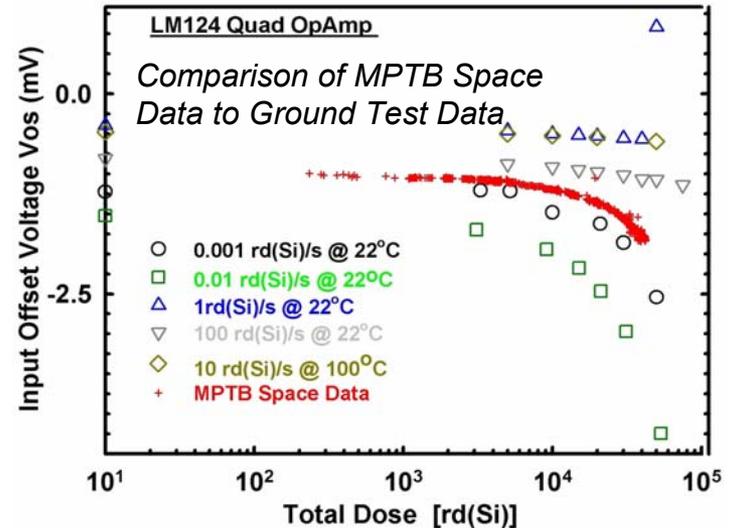
- **Simulations from updated code agree well with the CRRES data**
- **Evidence for significant contributions to the spectrum from both elastic scattering at low energy depositions and pion production at high energy depositions**
- **Small number of large pulses in the data from direct traversals of the detector by heavy cosmic-ray ions**



# Mining Enhanced Low-Dose Rate Sensitivity (ELDRS) Data from MPTB

- Guidelines for accommodating the ELDRS effect on linear bipolar devices
- Charged particles

PI: T. Turflinger

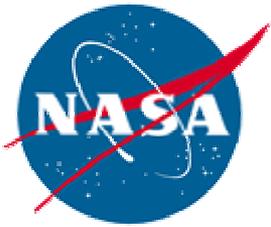


## • Implications for ground testing

- Microelectronics and Photonics Testbed (MPTB) observations agree well with ground test results, increasing confidence in the use of ground testing to predict ELDRS.
- Relatively constant rate of degradation was demonstrated over dose rate of 0.5 mrad(Si)/s to 8 mrad(Si)/s, increasing confidence that 10 mrad(Si)/s ground data are a good predictor of space degradation.

## • Implications for flight investigations

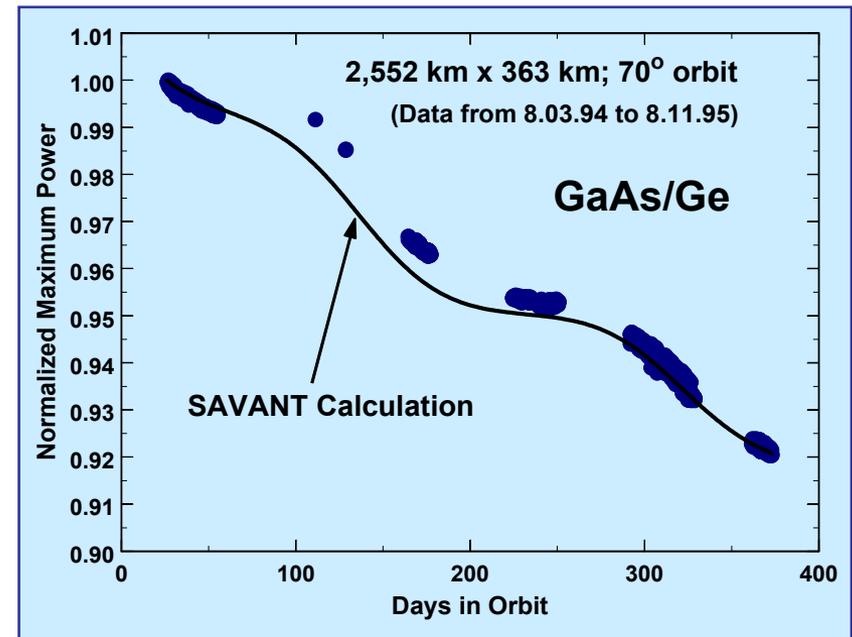
- GTO is not the ideal platform for studying the ELDRS effect



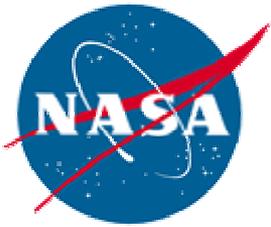
# Solar Array Analysis and Verification Tool (SAVANT)

- A tool to predict on-orbit solar array output as a function of time
- Charged particles

PI: R. Walters



- Windows™ based, user-friendly implementation of displacement damage (Dd) degradation method for solar arrays
  - Allows for predictions based on minimal amount of ground testing
  - Validated with Microelectronics and Photonics Testbed (MPTB) space flight data
  - Model can be extended to multijunction and thin film solar cells

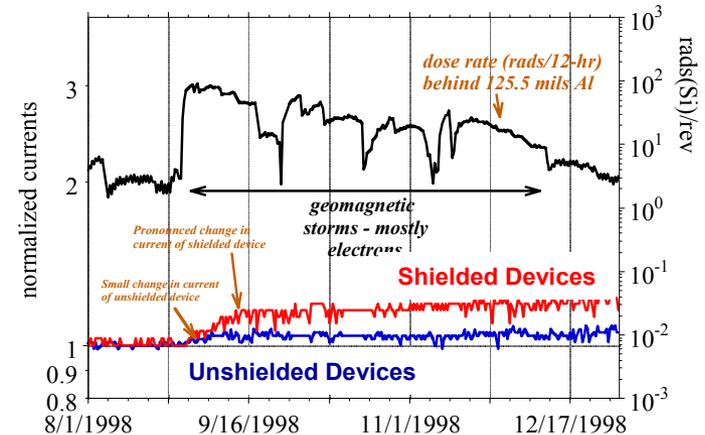


# TID Effects of High-Z Material Spot Shields on FPGA using MPTB Data

➤ Guidelines for using spot shielding (CuW) for reduction of dose in electron dominated environments

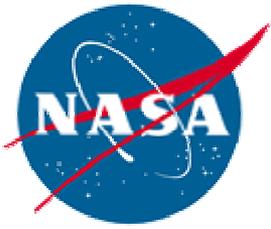
➤ Electrons

PI: S.Crain



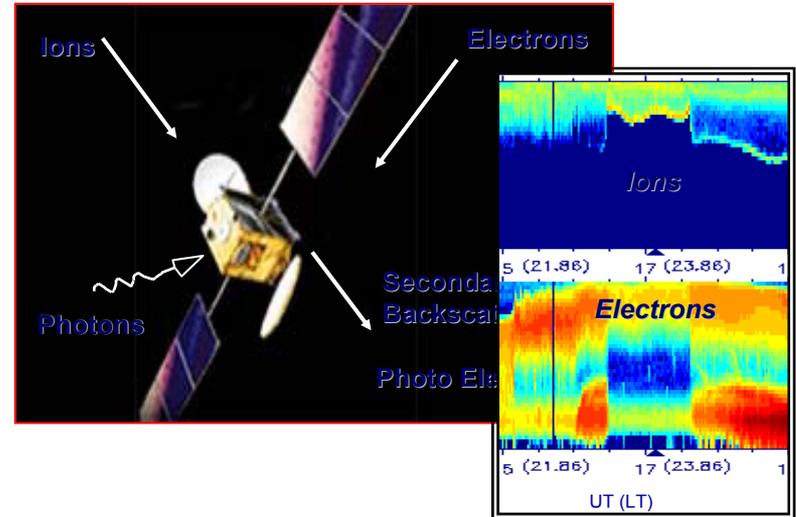
Example of anomalous response to electron storms of a shielded FPGA on MPTB

- Could not explain the unexpected behavior of the devices that were not shielded
  - Models may not be accurately predicting particle interactions in devices
    - Particle transport codes used are limited in how they handle photons with  $E < 1$  keV
    - Particle transport codes used are limited in how they handle the physics of dose enhancement at the die level
  - Measured energy spectra of electrons was much harder during the geomagnetic storms of 1998 than those predicted by the models that average over several solar cycles.



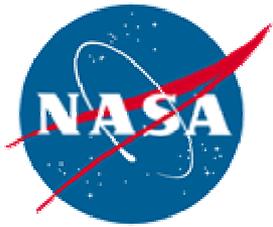
# Characterization of Magnetospheric Spacecraft Charging Environments using LANL Data

- Guidelines for charging environments fitting functions for NASCAP2
- Low energy electrons



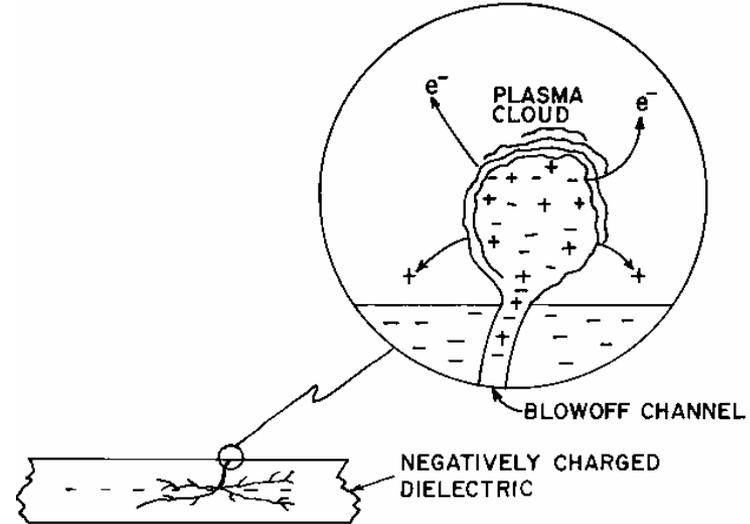
PI: V. Davis

- Solar Minimum vs. Solar Maximum charging environments
  - Fluxes and resulting charging during charging periods are the same at solar minimum as at solar maximum. **HOWEVER**, during solar maximum, the frequency of high charging environments increases.
- Recommendations for environment fitting functions for NASCAP2K
  - Kappa fit for electrons and Maxwellian fit for ions give “post-dictions” with accuracy similar to those using the LANL measured spectra



# Mining CRRES IDM Pulse and Environment Data

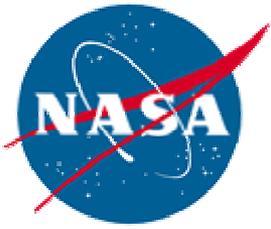
- Improvements in ground test fidelity to minimize internal electrostatic discharge
- Mid-energy electrons



Charged electrical insulators break down producing large electric pulses

PI: R. Frederickson

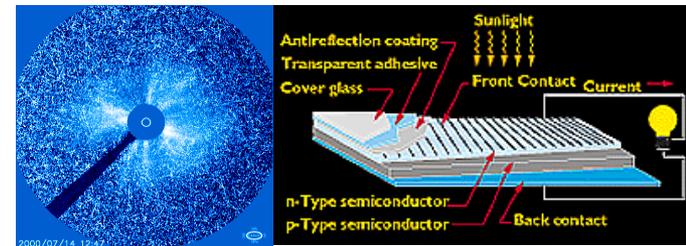
- Investigate IESD pulsing by insulators flown on the CRRES spacecraft in relation to radiation-belt particle spectra
- Ground tests indicate that IESD pulse rate and pulse amplitude are proportional to electric field in the insulator. Estimate the electric fields that occurred in the insulators on CRRES as the particle spectra varied, and correlate this to measured pulse rates and amplitudes.



# Non-Ionizing Energy Loss (NIEL) Tool for Space Applications\*

- A tool to calculate non-ionizing energy (NIEL) loss is the dominating damage mechanism in some optical technologies, e.g. CCDs, optocouplers, solar cells
- Charged particles

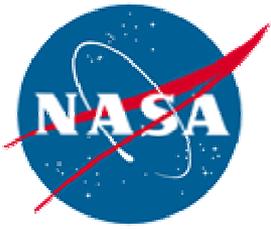
Non-ionizing energy loss is the dominating damage mechanism in some optical technologies, e.g. CCDs, optocouplers, solar cells.



\*Co-funded with Code R, Space Environments & Effects Program

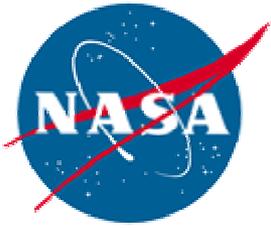
PI: M. Xapsos

- Computer program for calculating
  - NIEL in elemental compounds and semiconductors for electrons, protons, and heavy ions
  - NIEL spectra equivalent to linear energy transfer spectra for space environment



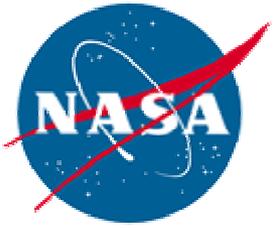
## ***NRA #2 - Space Investigations***

- **Space Flight Evaluation of the Radiation Performance of PolyRAD**
- **Energetic Particle Spectrometer for Characterizing the Environment Around the LWS-SET Spacecraft. Also referred to as a Light Particle Detector (LPD)**
- **Definition of the Mechanisms for On-Orbit Degradation of Variable Emissivity, Variable Absorptivity and Variable Reflectivity Materials Degradation**
- **Dosimetry Intercomparison and Miniaturization**
- **Development of Space-Based Test Platform for the Characterization of Proton Effects and Enhanced Low Dose Rate Sensitivity (ELDRS) in Bipolar Junction Transistors**
- **Cosmic Radiation Environment Dosimetry and Charging Experiment (CREDANCE)**
- **Total Dose and SEU Radiation Hardness Degradation Due to the Addition of Built-In Self Test (BIST) to Mixed Signal Electronic Circuits**

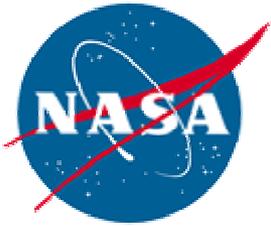


## ***Where to Access NRA Information***

- **Open NRA Announcements**
  - [http://research.hq.nasa.gov/code\\_s/open.cfm](http://research.hq.nasa.gov/code_s/open.cfm)
- **NRA Awards**
  - [http://research.hq.nasa.gov/code\\_s/code\\_s.cfm](http://research.hq.nasa.gov/code_s/code_s.cfm)
- **NRA Results**
  - <http://lws-set.gsfc.nasa.gov/Opportunities.htm>

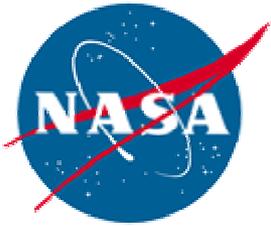


# *Backups*



# ***NRA FY01 – Data Mining***

- **Displacement Damage Effects in Solar Cells - Mining Damage Data From the Microelectronics and Photonics Testbed (MPTB) Space Experiment, PI: R. Walters/NRL**
- **Non-Ionizing Energy Loss (NIEL) Tool for Space Applications, PI: M. Xapsos/NASA/GSFC**
- **Modeling Charge Collection in Detector Arrays, PI: J. Pickel/PR&T**
- **Study of the Total Ionizing Dose Effects of High-Z Material Spot Shields on Field Programmable Gate Arrays (FPGA) Using the Flight Data From the Experiment Board on the Microelectronics and Photonics Testbed, PI: Susan Crain/The Aerospace Corporation**
- **Analysis of CRRES Pulse Height Analyzer (PHA) Data for Low-Linear Energy Transfer (LET) Events, PI: P. McNulty/Clemson University**
- **Solar Variability, the Near-Earth Radiation Environment, and Transient Effects on Microelectronics - Mining Enhanced Low-Dose Rate Sensitivity (ELDERS) Data from the Microelectronics and Photonics Testbed (MPTB) Space Experiment, PI: T. Turflinger/NAVSEA Crane**
- **Mining CRRES IDM Pulse Data and CRRES Environment Data to Improve Spacecraft Charging/Discharging Models and Guidelines, PI: Robb Frederickson/JPL**
- **Characterization of Magnetospheric Spacecraft Charging Environments Using the LANL Magnetospheric Plasma Analyzer Data Set, PI: V. Davis/SAIC**
- **Electrostatic Return of Contaminants, PI: Dr. R. O. Rantanen/ROR Enterprises**



# *Peer Review Rules*

- **The NASA Office personnel will be separated ("firewalled") from the remainder of NASA personnel and the outside world for the duration of this technology selection process.**
- **Participants in the review process for a given area cannot have participated in the development or review of proposals in response to that area in the NRA.**
- **Peer reviewers from industry cannot review proposals from industry.**
- **A mail-in peer reviewer will review proposals from different organizations instead of reviewing multiple proposals from a single organization.**
- **A mail-in peer reviewer will not review a proposal from his or her parent organization.**
- **Names of participants in the review process are not to be disclosed to proposers or other personnel without a need for this information.**
- **All participants in the review process have agreed that they have no conflict of interest with the proposing institutions and will not disclose information in the proposals except as part of the review process.**
- **Conflict-of-interest issues should be directed to the SET Program Executive for resolution.**