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The Living with a Star Space Environment Testbed Program

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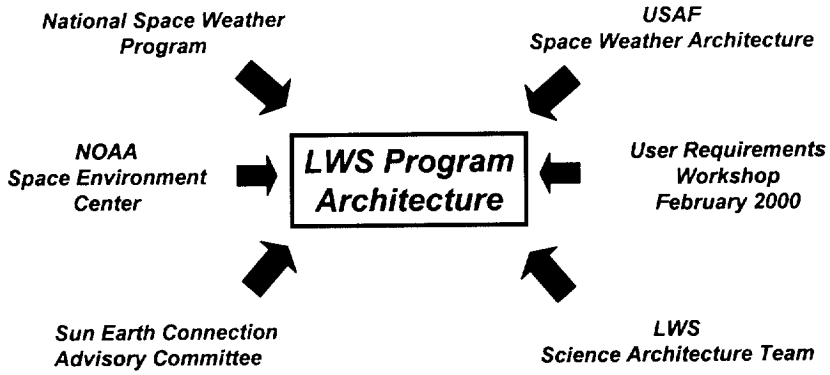
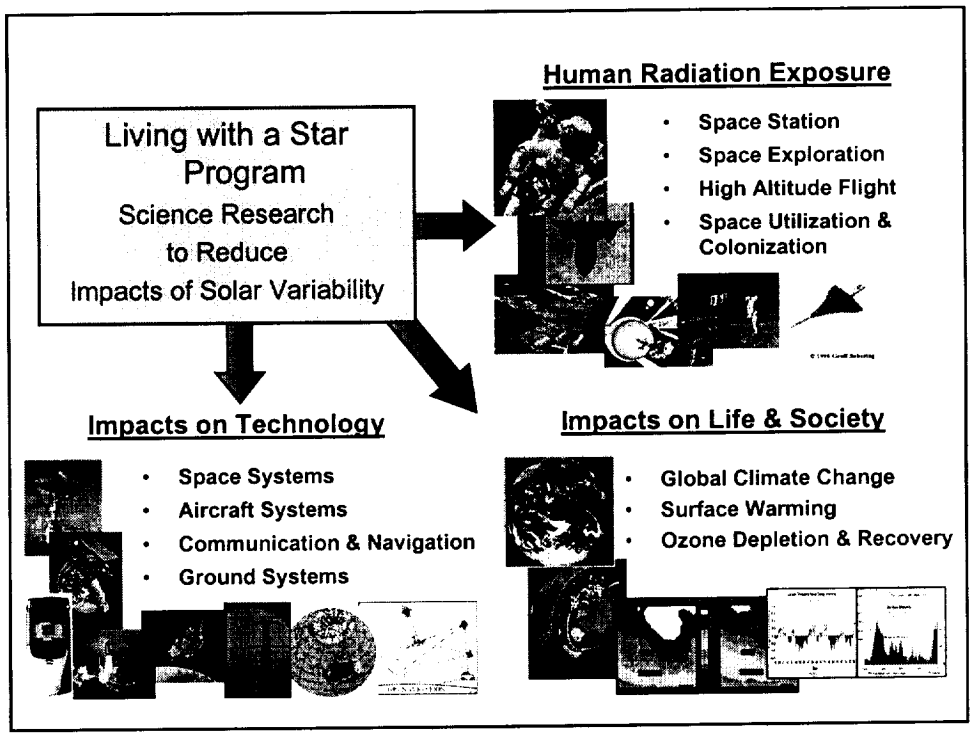
THE SUN EARTH CONNECTION

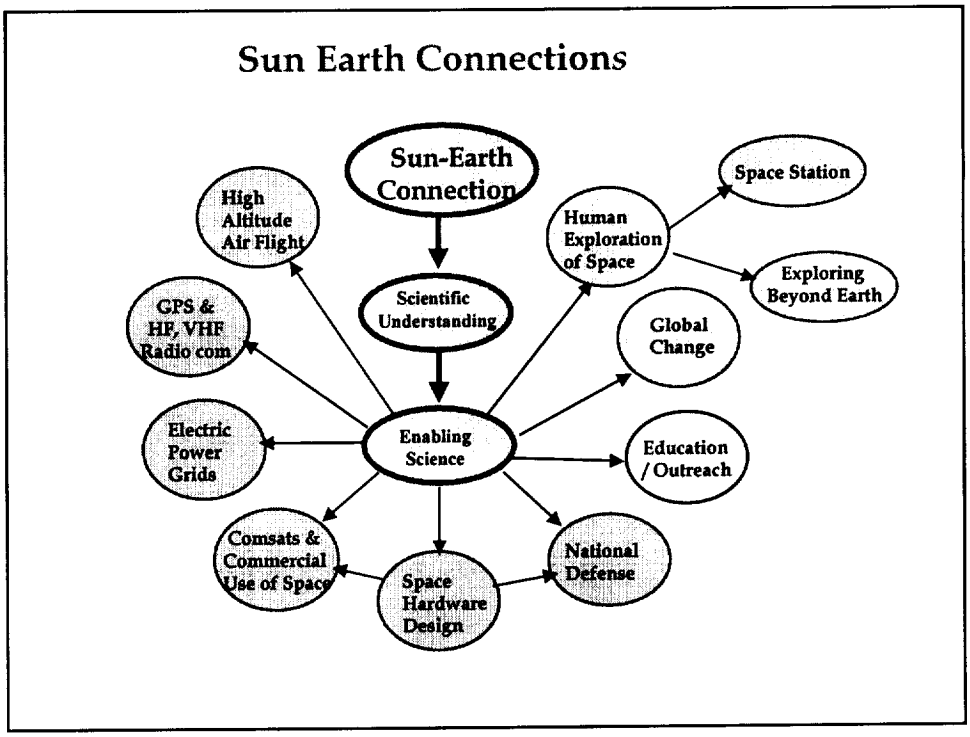
Outline

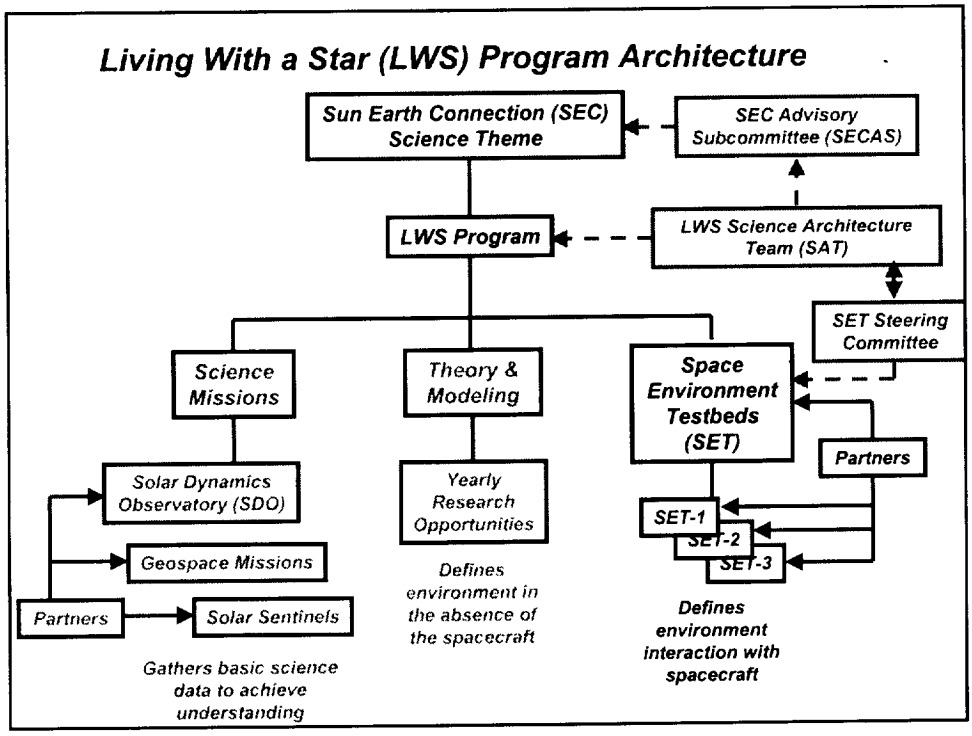
- ***LWS Program Formulation***
- ***LWS Goals***
- ***LWS/Space Environment Testbed Concept***
- ***Program Status***

LWS Program Formulation

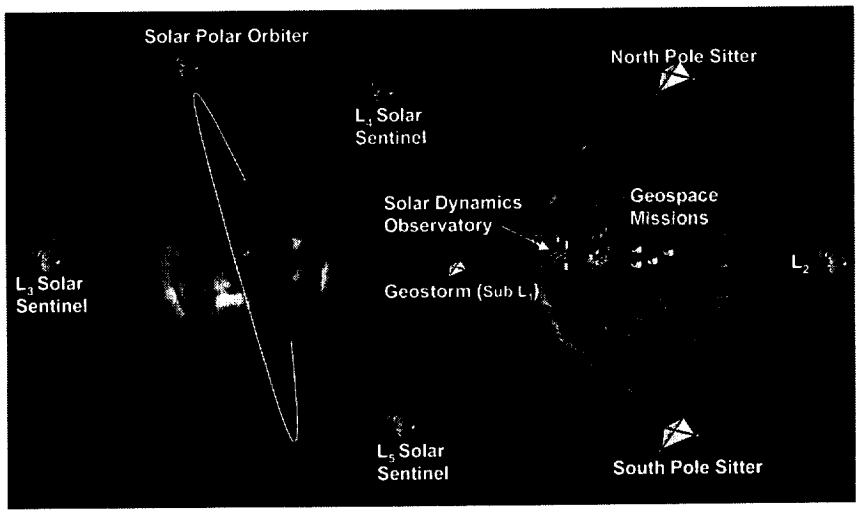





Sun Earth Connections
Sun-Earth Connection
High Altitude Air Flight
Scientific Understanding
Human Exploration of Space
Space Station
Exploring Beyond Earth
GPS & HF, VHF Radio com
Global Change
Electric Power Grids
Enabling Science
Education / Outreach
Comsats & Commercial Use of Space
Space Hardware Design
National Defense


Living With a Star (LWS) Program Architecture
Sun Earth Connection (SEC) Science Theme
SEC Advisory Subcommittee (SECAS)
LWS Program
LWS Science Architecture Team (SAT)
SET Steering Committee
Science Missions
Theory & Modeling
Space Environment Testbeds (SET)
Partners
Solar Dynamics Observatory (SDO)
Yearly Research Opportunities
SET-1
SET-2
SET-3
Geospace Missions
Partners
Solar Sentinels
Defines environment in the absence of the spacecraft
Defines environment interaction with spacecraft
Gathers basic science data to achieve understanding

Living With a Star (LWS) Science Missions: A Network to Quantify the Sun-Earth Connected System



Living With a Star Theory & Modeling

Objective

Perform research to refine the understanding of space weather & the role of solar variability in terrestrial climate change

Approach

- ***Improve understanding of space weather & solar variability***
- ***Improve understanding of solar variability & its effect on long term climate change***
- ***Perform research & development to enable improved environment specification models & predictive capability***

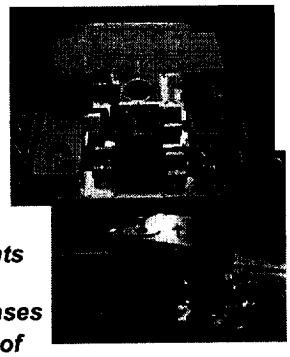
Scope

Solar atmosphere to Earth's ionosphere

Living With a Star Space Environment Testbeds

Objective

Improve the engineering approach to accommodate and/or mitigate the effects of solar variability on spacecraft design & operations



Approach

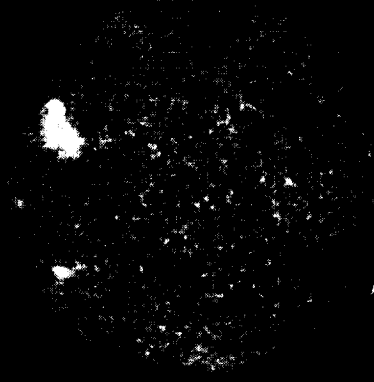
- ***Collect data in space to validate new & existing ground test protocols for the effects of solar variability on emerging technologies & components***
- ***Develop & validate engineering environment prediction & specification models, tools, & databases***
- ***Collect data in space to validate the performance of instruments for LWS science missions & new space technology***

Scope

Spacecraft hardware & design /operations tools whose performance changes with solar variability

NASA Space Environment Testbed (SET) Program

OBJECTIVE: Infuse New Technologies into Space Programs



Collect Data in Space to Validate Model/Tool

Collect Data in Space to Validate Ground Test Protocol

Flight Validation of Technology

Technology Application Model/Engineering Tool Development

Ground Test Protocol Development

Technology Development

RESULT: Improvement in the Engineering Approach to Accommodate and/or Mitigate the Effects of Solar Variability on Spacecraft Design & Operations.

Development of Space Systems

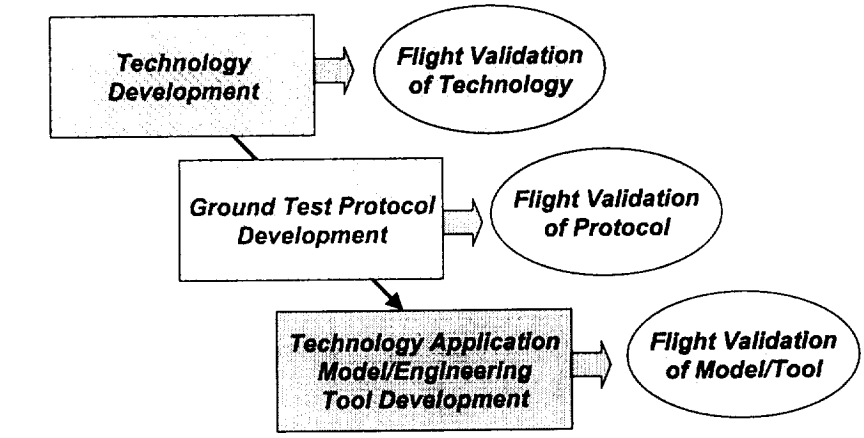
- Systems must perform in complex Sun-Earth environments
- Environments vary with solar activity
  - Long term solar cycle
  - Events on the Sun
- Variable environments pose challenge for system developers
  - Design phase
  - Operational phase
- Models are used to predict performance of systems
  - Inputs
    - Estimates of environment levels
    - Results of ground test protocols
  - Design margins are used to account for inaccuracy in prediction methods
- Large uncertainties in models preclude use of environmentally sensitive technologies
- Model development & validation efforts have not kept pace with technology changes

Changes in System Design Environment

- Demise of environment hardened market
- Commercial demand for electronics
- Short mission development times
- Smaller, lighter spacecraft
- More demanding mission requirements
- Desire to operate in more severe environments

- Consequences
  - Use of commercial off the shelf (COTS) components
  - Use of emerging technologies
  - Higher environment specifications
- Result
  - Risk avoidance → Risk management
  - Accommodations in Design Phase → Accommodations in Flight
  - Capability is eroded with environment accommodation overhead

Technology Flowdown



☐ Not SET Funded

LWS/SET Implementation Plan

SET Implementation

- *Establish Steering Committee*
- *Design modular carrier concepts to capitalize on launch opportunities*
- *Fly orbiting testbed every 2 years*
  - *Missions of opportunity in FY04*
  - *Full carrier in FY05*
- *Hold bi-yearly workshops*
- *Leverage off other programs*
- *Fund NASA Research Announcements*

Space Environment Testbeds (SET Advisory Structure

SET Steering Committee

Chair: Janet Barth, GSFC
Co-Chair: Kenneth LaBel, GSFC
NASA Centers
LWS/SET Partners

Steering Committee Functions:

- *Represent organization's integrated set of technology needs*
- *Prioritize technical importance of tasks across all areas in response to (customer) needs*
- *Coordinate with technology developers & other technology customers*

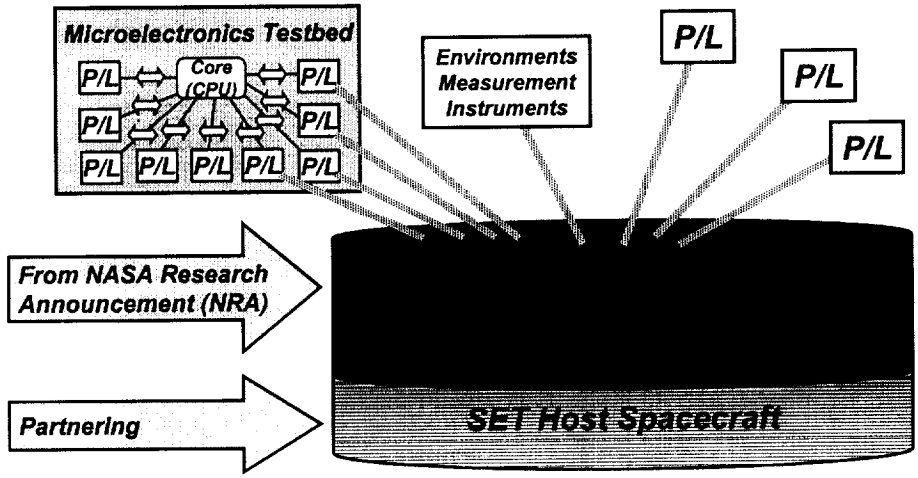
SET Working Groups

Materials
Microelectronics
Detectors/Sensors
Spacecraft Charging/Discharging
Environment Monitiroing

Technology Working Group Functions:

- *Provide expertise as technology providers*
- *Develop candidate tasks for the LWS SET & prioritize them*
- *Review & coordinate technical products& issues with other technical providers*

Space Environments Testbed (SET) Interface Requirements Concept



LWS/Space Environment Testbed

- Common support hardware and software to validate several sub-systems or components on orbit
  - Each mission will include a suite of appropriate environment sensors (space radiation, plasma, etc.) based on the technology experiment needs and launch constraints.
- NASA provides launch, on-orbit operation, and data return.
- Standard agreement with payload partners requires partners to provide ground test data, on-orbit data after reduction, and funding for integration.
- Partnering agreement is negotiable based on NASA interest and partner contribution to launch.

Appropriate Candidates for the LWS/SET Program

SET Space Flight Candidates:

- *Technology that requires space flight for performance characterization or validation*
- *Technology candidates applicable to more than one mission or to a LWS mission*
- *Technology whose performance changes due to the effects of solar variability*
  - *Performance changes cannot be minimized by changing the spacecraft design*

SET Data Analysis Candidates:

- *Data that describe performance variations in space in the presence of a spacecraft that changes due to solar variability*

Program Status

LWS Program Status

- *NASA/HQ NRA in FY00 for Theory and Modeling*
- *LWS Funded for FY01*
- *Science Architecture Team (SAT) appointed by NASA/HQ*
  - *First meeting was in November 2000*
  - *SAT Workshop and Meeting in January & May 2001*
- *Solar Dynamics Observer*
  - *Science Definition Team Formed*
  - *Launch Date – FY06*
- *Geospace Missions*
  - *Study team formed*
  - *Goal is to characterize & understand "geoeffectiveness" of solar variability*
  - *Magnetosphere & Ionosphere*
  - *Includes Space Environment Testbeds*
  - *Seek "Mission of Opportunity" for FY05*

Space Environment Testbed Status

- *Technology Provider Workshop in August 2000*
- *Pre-NASA Research Announcement Workshop on January 25-26 2001*
- *NRA focus areas*
  - *Instrument investigations – LWS Geospace AO*
  - *Flight experiment development – November 2001*
  - *Engineering tool and model development – July 2001*
- *Concept studies*
  - *Environment modeling requirements for SET*
  - *Methods for flight validation of sensor technologies*
  - *SET Carrier requirements*
- *SET Missions*
  - *FY04 – Missions of Opportunity*
  - *FY05 – Microelectronics carrier with LWS Geospace Missions*

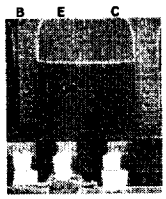
Summary

- *LWS is research science focused to facilitate enabling science*
- *LWS architecture is formulated under the NSF/AF Space Weather Architecture*
- *LWS aids technology infusion into space through the SET Program*
- *Partnering is required to achieve LWS goals*

SET Technologies - Backup

Example: SiGe Technology Flowdown for SET - Technology Development

Technology Development



DARPA and DoD have invested >$100M in the development of SiGe Technology at IBM and elsewhere

- **High-speed (approaching 100 Ghz)**
- **Low noise**
- **Low power consumption**
- **Mixed signal capabilities**
- **Standard Si compatible**

NASA has keen interests

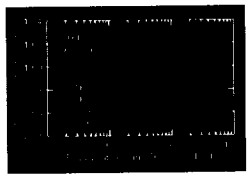
- **RF/Microwave/Communications**
- **Mixed signal/System-on-a-chip**
- **Ultra-high speed data transfer**
- **Low-noise instrumentation**
- **Potential extreme temperature applications**

Example: SiGe Technology Flowdown for SET - Ground Test

Technology Development

Ground Test Protocol Development

Proton irradiation test fixture



SiGe Damage Data

The NASA Electronic Parts and Packaging (NEPP) Program along with DoD is in process of developing technology radiation sensitivity models

- **Dose and damage tests have been performed with encouraging results**
- **Preliminary single event data indicates a single event sensitivity*. FY01/02 plans focus on single event testing, modeling, and hardening**
- **Test protocols available NLT FY03**
- **NEPP also supporting reliability modeling of SiGe**
- **Total investment >>$1M**

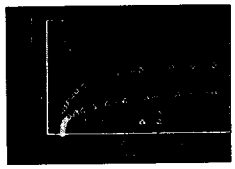
* Single event environment is solar-modulated

Example: SiGe Technology Flowdown for SET - Tools

Technology Development

Ground Test Protocol Development

Technology Application Model/Engineering Tool Development



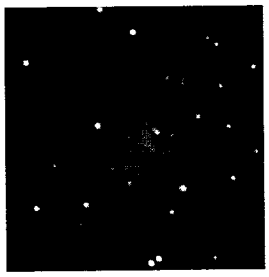
SiGe Charge Collection Modeling

Upon completion of ground test protocol development, predictive performance tools are greatly desired

- Modules for single event upset (SEU) for industry standard software (CREME 96)
- SEU-hardened cell library

Example: Detector Technology Flowdown for SET - Technology Development

Technology Development



CCD Messier image

Detector technologies have been critical to increased science knowledge for NASA

- Examples include Hubble Space Telescope's charge coupled device (CCD) based instruments. Newer Si-based CCDs have scaled geometries allowing better image resolution.
- Wavelengths of interest include visible, x-ray, ultraviolet, and infrared
- Engineering applications include star trackers and star cameras

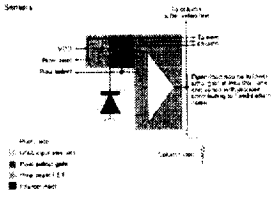
Technology limitation: performance in the space radiation environment

- DoD and NASA have invested in hardened sensor technologies for space utilization (p-channel CCDs and monolithic advanced pixel sensors (APS))

Example: Detector Technology Flowdown for SET - Ground Test

Technology Development

Ground Test Protocol Development



Schematic representation of an advanced pixel sensor

While many detectors and detector-based instruments have been tested and calibrated prior to flight, there is no community-wide test standard

- NASA (NEPP) and DoD have begun collaborations which will lead to a "lessons learned" overview of ground testing.
- In some areas, test data is limited or old. A relevant example is ground test data for determining cosmic ray rejection in images.

Ground tests of newer technologies may or may not be able to leverage on older data

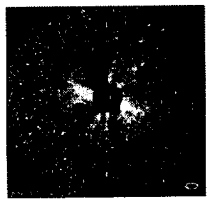
- Flight performance has rarely matched predicted models (AXAF, HST, SOHO, et al)
- Shortcomings may be due to technology or shielding models or mapping of the flight environment to the ground test environment

Example: Detector Technology Flowdown for SET - Tools

Technology Development

Ground Test Protocol Development

Technology Application Model/Engineering Tool Development



SOHO/LASCO coronograph spotted with solar particles during July 14, 2000 event

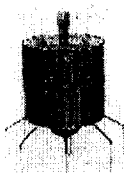
Advanced column sensor array

Upon completion of ground test protocol development, predictive performance tools are greatly desired

- Modules for image degradation due to radiation damage
- Methods for cosmic ray rejection
- Methods for damage hardening

Example: Spacecraft Charging Technology Flowdown for SET - Technology Development

Technology Development ⇨



GOES 8

MUNIN 7 - 6 kg

Spacecraft flying in high electron populations can no longer afford to be protected by Faraday cages

Spacecraft charging may be the dominant cause of anomalies in the natural space environment

- Deep dielectric charging
- Surface charging

Symptoms include

- Distortion in science measurements
- Arcing
- Increased contamination risk
- Reduced spacecraft power
- Anomalies in electronics similar to single particle induced effects

Technologies of interest

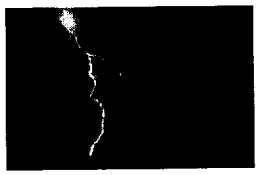
- Materials interaction with plasma/ electrons
- NASA, DoD and commercial aerospace all have programs in this arena

Example: Spacecraft Charging Technology Flowdown for SET - Ground Test

Technology Development

↘

Ground Test Protocol Development ⇨



Terrestrial lightning strike reminiscent of a solar array arc

Ground tests on materials are typically performed with monoenergetic electrons per ASTM standards

- Correlation of flight to ground has very limited statistics
- Correlation of plasma environment with in-situ measurements is limited
- For example: knowledge of solar array area affected by arcing in flight is limited

Complex spacecraft geometries and dynamic solar-modulated environment complicate accuracy of ground testing and effectiveness of charging mitigation

Example: Spacecraft Charging Technology Flowdown for SET - Tools

Technology Development

Ground Test Protocol Development

Technology Application Model/Engineering Tool Development

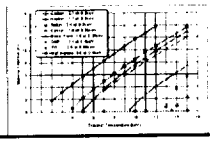
AFRL's CEASE Instrument

Current tools for design are limited

- **NASCAP 2K and spacecraft charging handbook are not fully validated or complete tools**

New validated tools are highly desired

- **Dynamic tools**
- **Novel charge mitigation techniques**



Material potential versus electron temperature