NASA
Space Environments and Effects (SEE) Project

Managed by: NASA's Marshall Space Flight Center

Technology Areas

Space Environments and Effects Project

- The Space Environments and Effects (SEE) Program develops engineering technology products in the following areas:
  - Electromagnetic Effects and Spacecraft Charging
  - Ionizing Radiation
  - Materials & Processes
  - Meteoroid and Orbital Debris
  - Neutral External Contamination
  - Ionosphere and Thermosphere (AD HOC)

Project Goals/Objectives
&
Success Criteria

Space Environments and Effects Project

Project Goals and Objectives

- ♦ **Sponsor research to develop, verify and transfer SEE-related technologies**
  - **To facilitate the design, manufacture, and operation of cost-effective spacecraft**
    - **By providing engineering tools early in the design and operations planning phases**
  - **To help maintain U.S. preeminence in space**
  - **To promote U.S. preeminence in space and economic competitiveness in the global market place**
- ♦ **Advocate technology development, flight experiments, and databases**
- ♦ **Maintain cutting-edge expertise in SEE-related technologies**
  - **Collaboration of NASA and Non-NASA technical experts/specialists**

Success Criteria

- ♦ **Target: Develop next generation space environment products (i.e., models, tools materials, knowledgebases) demonstrating within a system analysis to show a 15 percent reduction in spacecraft design uncertainties.**
- ♦ **Exit: Develop next generation space environment products (i.e., models, tools materials, knowledgebases) demonstrating within a system analysis to show a 10 percent reduction in spacecraft design uncertainties.**

SEE Program Organization

Space Environments and Effects Project

SEE PROGRAM MANAGEMENT

MSFC/ B. Kauffman (Mgr)
J. Minor
D. Hardage
K. McTaggart

*SC/ G. Brown
S. Yung

* ½ Time

Senior Advisor
Steve Pearson

SEE TECHNICAL WORKING GROUPS

ELECTROMAGNETIC EFFECTS & SPACECRAFT CHARGING
GRC/D. FERGUSON
MSFC/M. MCCOLLUM

MATERIALS & PROCESSES
LaRC/C. FAYE
MSFC/D. EDWARDS

IONIZING RADIATION
GSFC/J. BARTH
JPL/C. BARNES

METEOROID & ORBITAL DEBRIS
LaRC/W. KINARD
MSFC/R. SUGGS

NEUTRAL EXTERNAL CONTAMINATION
GSFC/P. CHEN
MSFC/D. BURNS

IONOSPHERE/ THERMOSPHERE

SEE Budget & Technical Approach

Space Environments and Effects Project

FY02	FY03	FY04	FY05	FY06
$1.5M	$1.55M	$1.5M	$1.5M	$1.5M

Technical Approach

The SEE Program is made up of technical disciplines with each area having membership of about 20 technical experts across the country from NASA, other government, industry and university. Through a workshop, the SEE Program provides these technical experts with NASA Enterprise technology needs/requirements for future missions. These experts then interpret these broad needs to individual technology development tasks and prioritizes them. The results of the prioritization then forms the technical basis of a solicitation. A broad steering group of NASA/AFRL Senior Technical and Program Personnel then determines which technical area should receive more resources based on their knowledge and programmatic constraints.

Specific Project Customers

Space Environments and Effects Project

Element	Principal NASA Customer	Targeted Areas
SEE	Code S	Environment modeling, effects tools and design guidelines for radiation, meteoroids, and spacecraft charging
	Code R	Environment modeling, effects tools for radiation, meteoroids, spacecraft charging (solar sail, electric thrusters)
	Code M	Environment modeling, effects tools, materials/coatings enhancement, knowledgebases for radiation, meteoroids, orbital debris, contamination
	Code Y	Environment modeling, effects tools, materials/coatings enhancement, knowledgebases for radiation, meteoroids, orbital debris, contamination

Research Portfolio

Space Environments and Effects Project

Title	PI	Company	Mechanism of Engagment	FY02 ($K)	FY03 ($K)	FY04 ($K)
State-of-the-Art Materials Knowledgebase (SAM-K)	Larry Bradford	CAT Flight Services	Direct Funded	50	50	50
Integrated Environments Tool	Many PI's Involved	MSFC/CSC/UWO/SAIC	Direct Funded	100	TBD<75	TBD<75
NASCAP 2K Documentation/Users Manual/OTK Enhancements	Myron Mandell/Victoria Davis	SAIC	Direct Funded	130	TBD	TBD
LEO Spacecraft Charging Guidelines	Dale Ferguson	GRC	Direct Funded	50		
Origin of Prjectile Residues/Largest LDEF Craters	Fred Horz	JSC	NRA8-31	54	53	
Determination of Meteoroid Masses	Rob Suggs	MSFC/Lincoln Labs	NRA8-31	147	149	
Nonionizing Energy Loss Tool	Mike Xapsos/Insoo Jun	GSFC/JPL	NRA8-31	43	57	165
Solar Particle Risk Assessment Tool	Mike Xapsos/John Wilson	GSFC/LaRC	NRA8-31	109	115	121
Outgassing Contamination Knowledgebase	Bob Wood	BWACS	NRA8-31	147	127	126
Thermal Control Coating Development	Mike Donley	AFRL/WPAFB	NRA8-31	150	150	150
In-Situ Materials Properties Sensor	Don Wilkes	AZ Technology	NRA8-31	150	150	
Electric Propulsion Interactions Code	Myron Mandell	SAIC	NRA8-31	150	150	
Measurement of Charge Storage Decay Time & Resistivity of Insulators	JR Dennison/ Robb Frederickson	Utah St/JPL	NRA8-31	150	150	

Research Portfolio

Space Environments and Effects Project

Title	Technical Goals/Results	TRL	Risk
State-of-the-Art Materials Knowledgebase (SAM-K)	Single location for state-of-the-art materials in support of solar sail missions thus reducing design costs for manpower searching for information; SEE Program maintians information and data comes from trusted sources throughout government, industry, acad	6	Low
Integrated Environments Tool	Development of universal model applicable to Earth-orbiting and interplanetary spacecraft for "sporadic" and stream meteoroid models; physics based so extrapolation can be utilized where no observations exist.	4-6	Medium
NASCAP 2K Documentation/Users Manual/OTK Enhancements	Replaces 20 year old codes; true NASA/Air Force cooperation; 100x faster than older code; leverages off Air Force DynaPAC code as well as NASA's old NASCAP codes.	4-6	Low
LEO Spacraft Charging Guidelines	Develop and publish a LEO Spacecraft Charging Guidelines Document utilizing ground test data. Submit guidelines for an AIAA Standard.	5-6	Low
Origin of Projectile Residues/Largest LDEF Craters	Will define the relative contributions of natural micrometeoroids and man-made debris; develop impact mitigation techniques for future spacecraft	6	Low
Determination of Meteoroid Masses	Replaces the 3 crude values used in todays models; permits hypervelocity tests to choose materials with similar bulk material; possible spacecraft weight savings due to reduced shielding.	4-6	Medium
Nonionizing Energy Loss Tool	Computations to heavy ions could reveal new phenomena; applications outside of space program such as solid state devices; calculation much simpler thus cutting design and analysis time.	5-6	Medium
Solar Particle Risk Assessment Tool	Enables managers to quantitatively assess risk-performance-cost trade-offs; leverages over 25 years of data collected.	5-6	Low
Satellite Contamination & Materials Outgassing Knowledgebase	Spacecraft designers will have at least 90% more materials data at their disposal; could reduce design time for contamination issues up to 50%; leverages thousands of dollars of testing.	5-6	Low
Thermal Control Coating Development	Will reduce thermal design uncertainties; lowers material UV absorptance and degradation.	4-6	Medium-High
In-Situ Materials Properties Sensor	Reduces design margins for optical & thermal control systems; provides a provision for health monitoring of a spacecraft; leverages existing technology for ground measurements.	4-6	Medium
Electric Propulsion Interactions Code	Enable effects issues for advanced propulsion for missions; payload protection from electric thruster mitigation techniques; leverages several other previous programs such as DS1 and NASCAP-2K.	5-6	Low
Measurement of Charge Storage Decay Time & Resistivity of Insulators	Resistivity & charge storage data will be available for specific NASA materials; results directly effect spacecraft charging codes; mainly applicapable to Code S and Code Y missions.	5-6	Low

Research Portfolio

Space Environments and Effects Project

Sunset/Risk Management/Future Study

- The SEE Program utilizes the NRA process to develop technologies and restricts efforts to no more than three years. If resources are available, a NRA will be utilized every 2-3 three years. The technical requirements are developed utilizing the process explained in the technical approach.
- Being an "engineering" technology product development program, our activities do not encompass a lot of risk. Risk management is performed by requiring kickoff meetings, quarterly reports and yearly reports in needed for multi-year efforts.
- Future studies will be determined by NASA Enterprises (future missions) technology requirements and available resources.

Accomplishments

- Collaboration with AFRL/Hanscom on the NASCAP-2K spacecraft modeling effort.
- Collaboration with AFRL and ESA in hosting the 8th Spacecraft Charging Technology Conference in October 2003 (back-up slide).
- Currently, the SEE Program has ~ 33 publications since its inception in 1994 and 8 new models/tools for distribution.

Community Connections

Space Environments and Effects Project

- There are approximately 100 people within the SEE Technical Working Groups with the following breakout:
  - Industry Participation: 50
  - Academia: 12
  - NASA: 32
  - Other Government: 6
- All of the SEE Program's "main" research is competed through a NRA utilizing a peer review process. Complete open competition between NASA, other government, industry and academia. All activities are in the form of firm fixed price contracts where applicable. All multi-year efforts are one year contracts with options.
- Membership and collaborative activities with other government experts allows for knowledge to be exchanged to avoid duplication.

Cost Sharing

- Cost sharing is implemented with AFRL/Hanscom in developing the NASCAP-2K code with a combined effort close to $1.5M.
- Cost sharing with the Code S Living With a Star: Space Environment Testbeds Code S on the Non-ionizing Energy Loss Tool where they provided ~90K out of $354K effort.
- Cost sharing with the Next Generation Space Telescope Program in validating the Meteoroid Integrated Environment Tool.

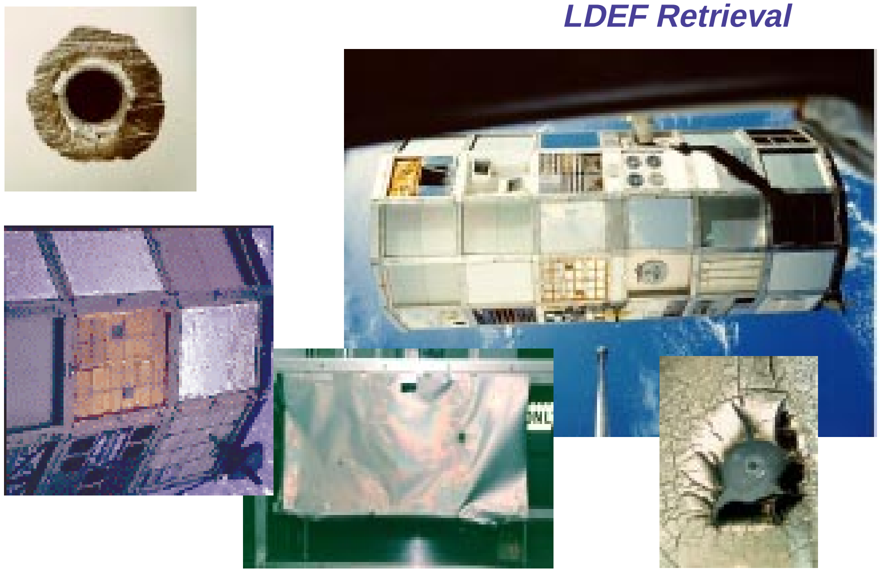
Backup

NRA8-31 Activities

FY02-FY04

Origin of the Projectiles Residues in the Largest LDEF Craters

LDEF Retrieval



Description:

- Analyze the composition of impactor residue in the 100 largest craters of LDEF experiment S0001 and classify whether man-made or natural;
- Develop and establish craters as a function of particle size the directionality dependency of meteoroids and man-made debris and the relative impact flux of these particles;
- Develop a database utilizing the latest data analysis.

Benefits to NASA:

- Will define the relative contributions of natural micrometeoroids and man-made debris particles to the overall collisional hazard in low-Earth orbit (LEO);
- 0.1 to 10 mm sized particles cannot be studied by ground-based sensors – Shuttle surfaces are routinely studied post-flight;
- S0001 crater population is much more systematic and statistically superior to determine the relative frequency of diverse projectile types and their sources;
- Will help develop impact mitigation techniques for future spacecraft.

Schedule & Cost:

	FY02	FY03	FY04
• Harvesting plan	▬		
• Harvest impact data	▬		
• Sample analysis	▬	▬	
• Summary and synthesis		▬	
• Catalog data		X	
• Transfer data to SEE Program database		X	
	$54K	$53K	

Meteoroid Masses, Densities and Ballistic Coefficients

Meteor Showers

Description:

- Directly estimating the densities of ablating meteoroids from measurements of the decelerations;
- Orbit will be determined for these meteoroids, which, when combined with the density information, will shed further light on the solar system's origin and evolution;
- Utilize and leverage three existing unique datasets from ALTAIR radar (Kwajalein Atoll);
- Develop database that will serve as a baseline to begin a future meteoroid knowledgebase; results to be utilized by future models.

Benefits to NASA:

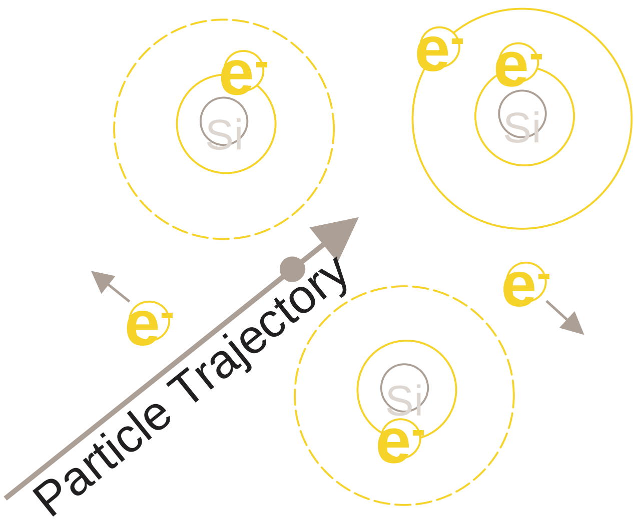
- Major impact upon spacecraft meteoroid analyses due to density distributions employed instead of 3 crude values that exist today;
- Permit hypervelocity experimenters to choose materials with similar bulk properties for gun tests;
- Orbital information will give insight on meteoroid density variation with increasing distance from the Sun, possibly resulting in weight savings (less shielding, more instrumentation) for interplanetary vehicles.

Schedule & Cost:

	FY02	FY03	FY04
• Automation of analysis procedure			
• Sidelobe analysis			
• Development of database			
• Automated analysis of all data sets			
• Mass determinations			
• Delivery of final product			X
	$147K	$149K	

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

Nonionizing Energy Loss – Displaced Target Atoms



Description:

- Provide a user friendly computer program for calculating NIEL in elemental and compound semiconductors for electrons, protons and heavy ions having energies relevant for space applications;
- Calculate NIEL spectra equivalent to LET spectra for space environments of concern e.g. galactic cosmic rays and solar particle events.

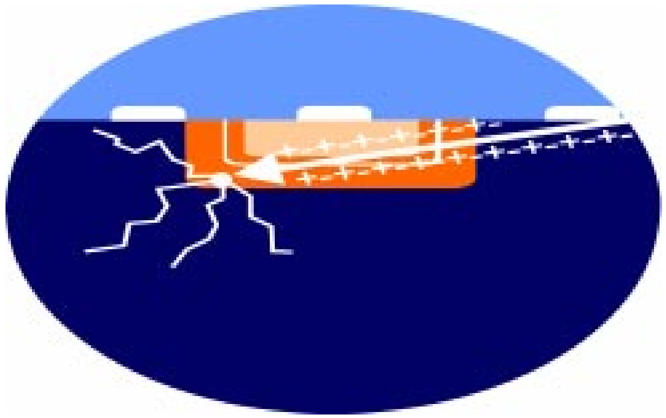
Benefits to NASA:

- Remove a significant obstacle in applying concept to future missions involving space radiation environments;
- Extension of the computations to heavy ions could reveal new phenomena unanticipated at present;
- Potentially has wide applications outside the space program; useful for processing new solid state devices;
- Make displacement damage calculations due to complex spectra much simpler thus cutting design and analysis time.

Schedule & Cost:

	FY02	FY03	FY04
• Establish method for calculating NIEL			
• Comparison of proton results			
• Include NIEL for high-energy heavy ions			
• Comparison of ion results			
• Calculation of NIEL spectra			
• Heavy ion NIEL at end of range			
	$132K	$138K	$84K

Solar Particle Risk Assessment Tool (SPRAT)



Simulated Particle Impact on Microelectronics

Description:

- An accurate risk assessment tool, which provides confidence-level parameterizations of enhanced Single Event Effects (SEE) rates and doses for:
  - Arbitrary orbits;
  - Mission durations and timeframes;
  - Shielding distributions;
- The tool would cover both protons and heavy ions for the entire range of relevant energies.

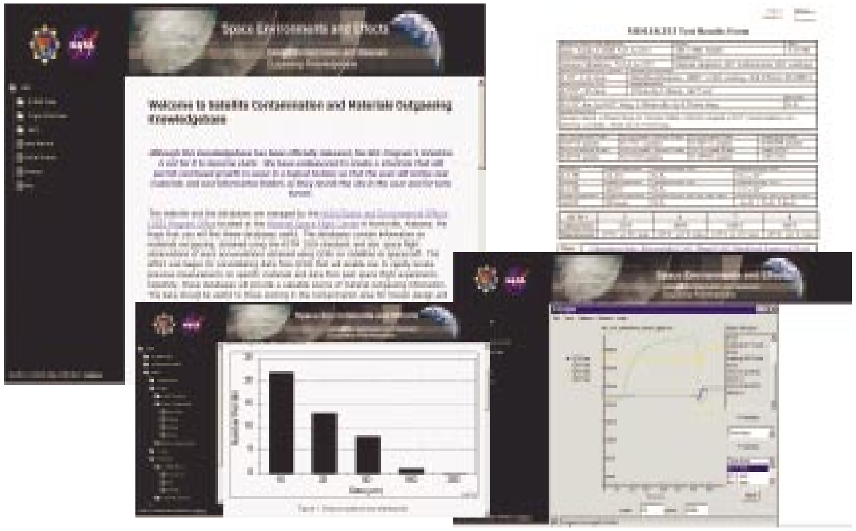
Benefits to NASA:

- Would enable managers to quantitatively assess risk-performance-cost tradeoffs during space system design;
- Leverages existing databases on solar particle events collected over the past 25 years;
- Establishes confidence and robustness in NASA satellite designs.

Schedule & Cost:

	FY02	FY03	FY04
• Modify existing model	▬▬		
• SPE Shielding calculations performed	▬▬		
• Heavy ions added		▬▬	
• Extend model to LEO and MEO		▬▬	
• Add Interplanetary capability			▬▬
• Add Solar Cycle 23 data			▬▬
• Add additional shielding calculations			▬▬
	$109K	$115K	$121K

Satellite Contamination & Materials Outgassing Knowledgebase



Satellite Contamination and Materials Outgassing Knowledgebase

Description:

- Expand and improve the only comprehensive contamination knowledgebase to include materials tested after 1997;
- Development of a spectral library of the optical characteristics, absorption, and emission for a wide variety of contaminants that does not exist in the knowledgebase;
- Space environmental effects on surfaces of materials;
- Provide a comparison of data taken at different facilities by performing a round-robin series of test.

Benefits to NASA:

- At completion, spacecraft designers have at least 90% more materials outgassing data (ASTM E1559) at their disposal;
- Having this data available easy could reduce “design time for contamination sensitive components by at least 50%”;
- Each material tested can easily cost $5K/test for each QCM operating temperature. The Knowledgebase will contain ~500 materials (donated by various organizations).

Schedule & Cost:

	FY02	FY03	FY04
• Identify new material datasets			
• Implement first set of 100 materials			
• Implement second set of 100 materials			
• Implement third set of 50 materials			
• Optical effects data literature search			
• Organize/format optical properties data			X
	$147K	$127K	

Improved Thermal Control Coating

Thermal Control Coatings

Description:

- Improve Z-93P thermal control coatings that have better initial performance and significantly better EOL performance over desired lifetime;
- Develop new polymeric binder materials to improve physical properties such as flexibility and adhesion, maintain UV transparency, and lower solar absorptance and UV degradation;
- Develop electronic database and and integrate with other databases as appropriate to form a knowledgebase.

Benefits to NASA:

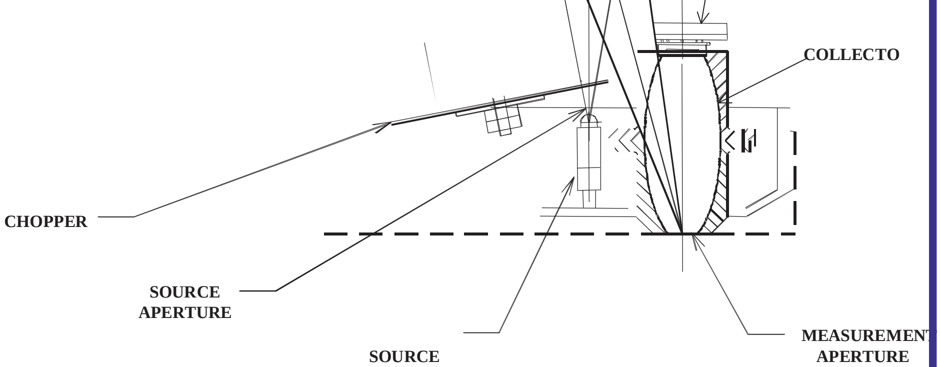
- Reduced thermal design margins for spacecraft;
- Improved coatings for increased spacecraft operational lifetimes;
- Spacecraft weight reductions from films ½ as thick as existing materials;
- Optimizes zinc-oxide (ZnO) efficiency by obtaining maximum scattering with the lowest pigment volume concentration;
- Lowers material UV absorptance and degradation.

Schedule & Cost:

	FY02	FY03	FY04
• Optimization of pigment particle size	▬		
• SCEPTRE evaluation	▬		
• Evaluation of new pigments		▬	
• SCEPTRE evaluation		▬	
• Investigation of new binder materials			▬
• Scale-up of fully formulated coatings			▬
• SCEPTRE evaluation			▬
• Deliver coatings technology to SEE Program			X
	$150K	$150K	$150K

In-situ Materials Properties Sensor

IMPS Optical Path Configuration for Measuring Solar Absorptance



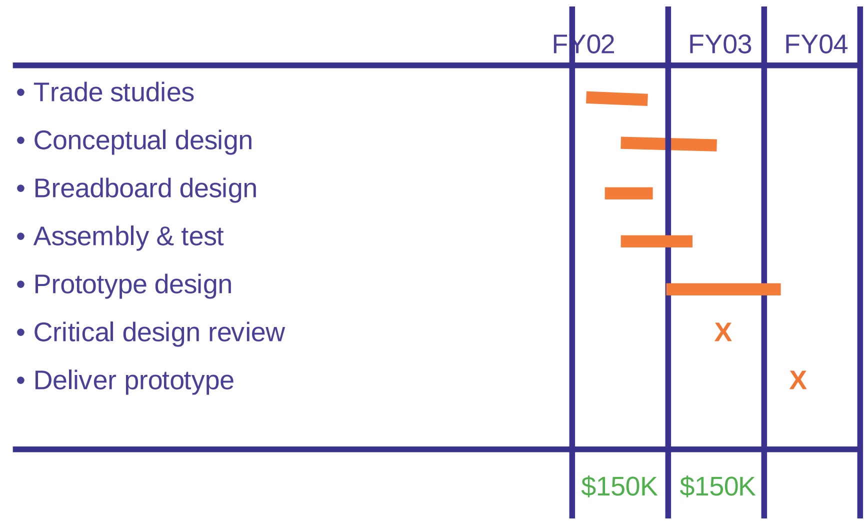
Description:

- Development of a small, compact optical properties measurement sensor system that can be configured for a wide range of uses for space experiments and ground tests;
- Capability to measuring one or a combination of solar absorptance, thermal emittance, and optical scatter;
- Sensor system will include a sample positioning system that can accommodate from one to many test samples for exposure to the space environment and for measurement by the optical measurement system.

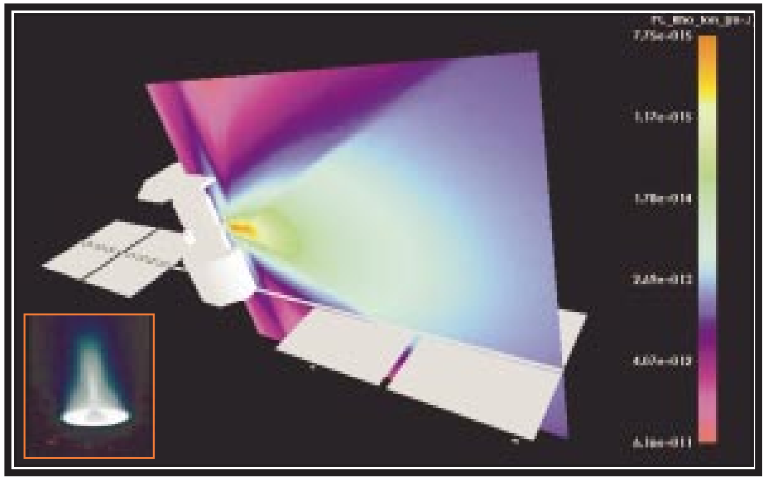
Benefits to NASA:

- Provision for health monitoring of a space component;
- Improvement upon the Space Portable Spectroreflectometer (SPSR) flown by NASA aboard the MIR space station;
- Reduces design margins for optical and thermal control systems aboard spacecraft;
- Provides on-orbit flight data for comparison with ground-test simulations;
- Leverages a technology (optical ellipsoidal collector) that is used at KSC for inspection of ISS components and assemblies.

Schedule & Cost:



Electric Propulsion Interactions Code (EPIC): Integrated Guidelines and Tools for the Assessment of Electric Propulsion Impact on Spacecraft



Electric Propulsion – Spacecraft Interactions Studies

Description:

- High specific impulse electric thrusters are enabling technologies for NASA;
- Electric thrusters generate plasma that interact with spacecraft systems and scientific payloads;
- EPIC will allow assessments/comparisons with existing data from Deep Space 1 (DS1), laboratory measurements, and other sources;
- Development of integrated computer tools for assessment of interactions between electric propulsion generated plasma and S/C systems, including surface sputtering, charging, heating and torques.

Benefits to NASA:

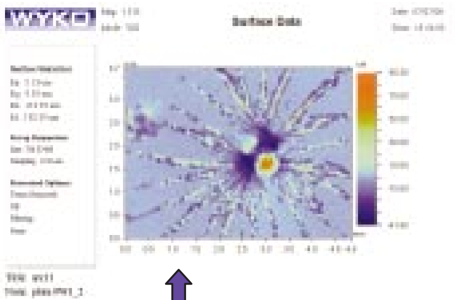
- Enables new technologies to be used with NASA missions such as advanced propulsion for science missions;
- Provides greater understanding of electric thruster/environment/spacecraft interaction;
- Allows payload protection from electric thruster mitigation techniques and design practices;
- Leverages effort from previous NASA programs such as DS1 and NASCAP-2K.

Schedule & Cost:

	FY02	FY03	FY04
• Software specifications design document	X		
• 1st customer review	X		
• Beta Code delivery		X	
• Beta code test feedback		X	
• 2nd customer review			X
• EPIC release version due			X
	$150K	$150K	

Space Environments and Effects (SEE) Program

Charge Storage Decay Time and Resistivity of Insulators



Arc Site Profile Analysis

Plasma Interaction with High Voltage Systems Can Degrade Materials

Arc Site Damage

Description:

- A materials testing and model development program to determine how long spacecraft insulators store charge (resistivity) and their associated decay rates;
- Preliminary resistivity tests of polyimides have shown that their experimental resistivities were at least three orders of magnitude above that predicted in various handbooks and data currently used in spacecraft charging guidelines;
- This new information will be compiled into a database for common spacecraft materials for use by NASA and the aerospace community.

Benefits to NASA:

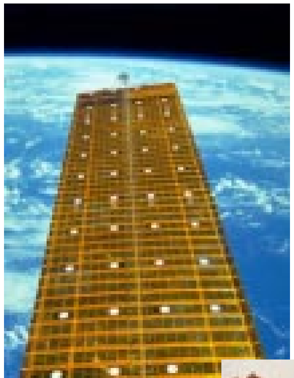
- Resistivity and charge storage data will now be available for the specific materials NASA uses;
- Modeling efforts will much more accurately determine charging susceptibility;
- More robust satellite designs mean longer mission lifetimes and reduced overall costs;
- Applicable to Code S; Code Y, Europa mission, solar and interplanetary missions.

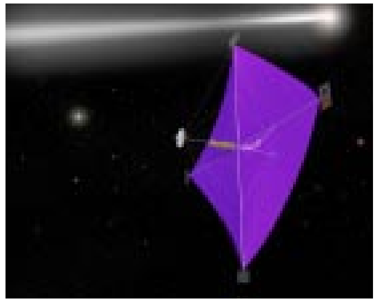
Schedule & Cost:

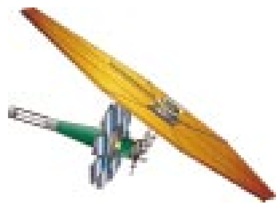
	FY02	FY03	FY04
• Database experimental measurements			
• Development of model			
• Application of data to model			
• Modified engineering design guidelines			
• Modify engineering database			
• Final Report due			X
	$150K	$150K	

Direct Funded Activities

State-of-the-Art Materials Knowledgebase (SAM-K)







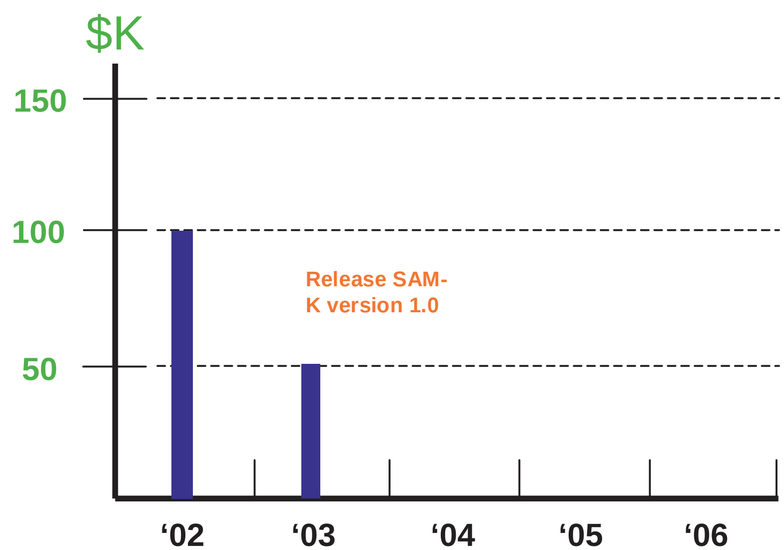
Description:

- Development of a comprehensive Gossamer materials knowledgebase to support NASA's Gossamer scientific and technological communities.
- Single location for data on existing, in-development and research materials and adhesives;
- Materials data, manufacturing methods, materials processing and joining technologies included;
- Knowledgebase will be upgradable to include additional materials.

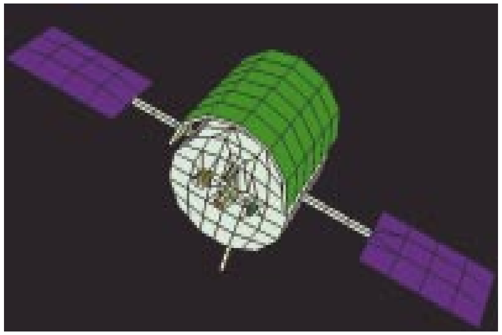
Benefits to NASA:

- Single location for state-of-the-art materials information;
- Reduction in design costs by not having to spend $ and man-hours searching for information;
- Ddata available to support Gossamer and ASTP technology needs;
- Materials data comes from trusted sources from US government, industry, academia and international space agencies;
- Information available to support other NASA needs;
- Knowledgebase maintained and updated by NASA's SEE Program.

Schedule & Cost:

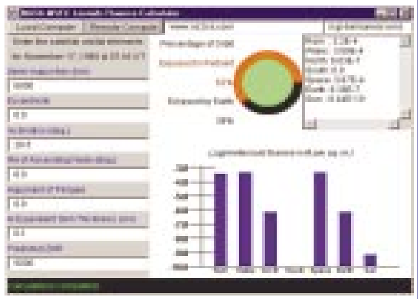


Meteoroid Environment Integrated Tool



Object Definition Toolkit

Meteor Shower



Leonid Storm Calculator

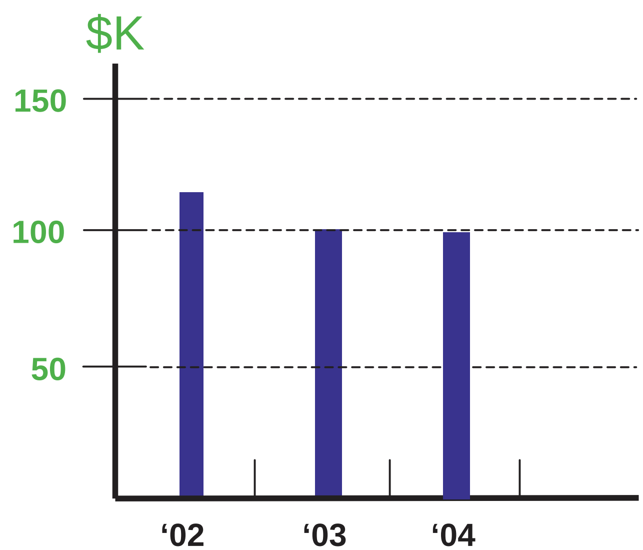
Description:

- Develop a universal model applicable to Earth-orbiting and interplanetary spacecraft for "sporadic" (or "background") and stream meteoroids;
- Model is "physics-based" so Earth observations are only used for validations. Model also allows for extrapolation to other locations that is not possible with existing empirical models;
- Existing models yield only decent results for spacecraft in LEO. Not valid at all for fixed orientation spacecraft like NGST, MAP, etc.

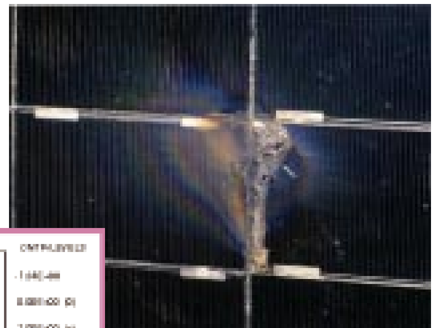
Benefits to NASA:

- The only models available today are empirical fits to observations. Applicability beyond earth orbit is highly questionable;
- Lighter, larger vehicles with less design tolerance; better environment definition required;
- Model will allow for extrapolation with confidence to Moon, Mars, Venus and Mercury;
- Leverages a $600K investment by USAF for purchase of three frequency meteor radar;

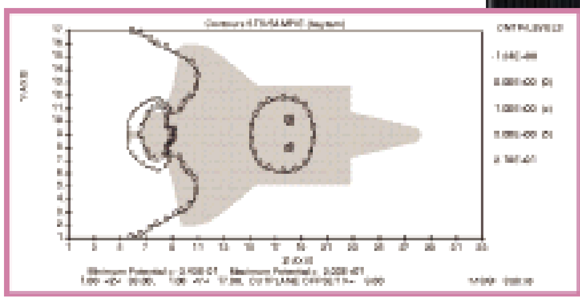
Schedule & Cost:



NASCAP-2K



Solar Array Arcing



NASCAP Analysis of Shuttle

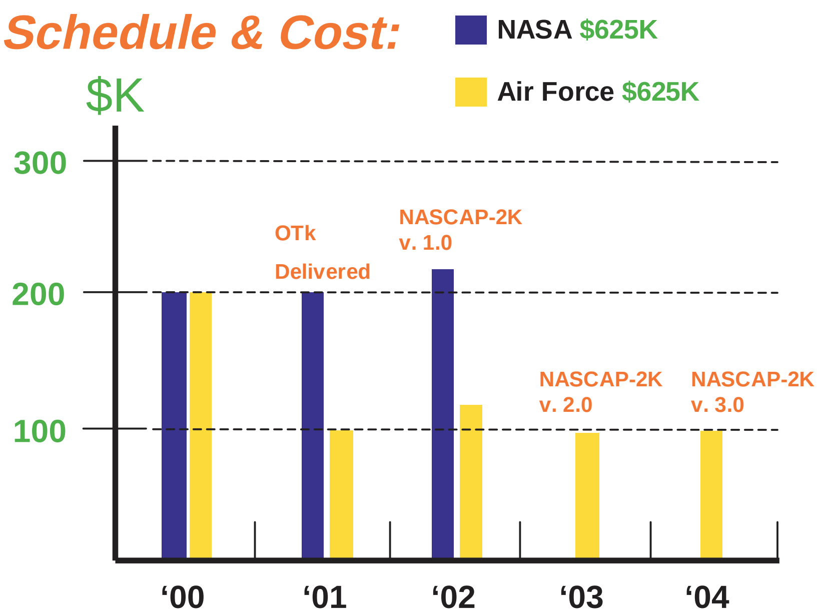
Description:

- NASA/Air Force Spacecraft Charging Analyzer Program: A five-year, collaborative effort with the US Air Force to develop a comprehensive revision to NASA's spacecraft charging analysis codes;
- Air Force to develop algorithms for low-Earth orbit (LEO), geosynchronous (GEO), and polar orbits, deep-dielectric charging, radiation belts and interplanetary space;
- NASA to develop Object Toolkit (OTk), Interactive Graphical User Interface, Chemistry, Boundary Conditions and Disjoint Grids.

Benefits to NASA:

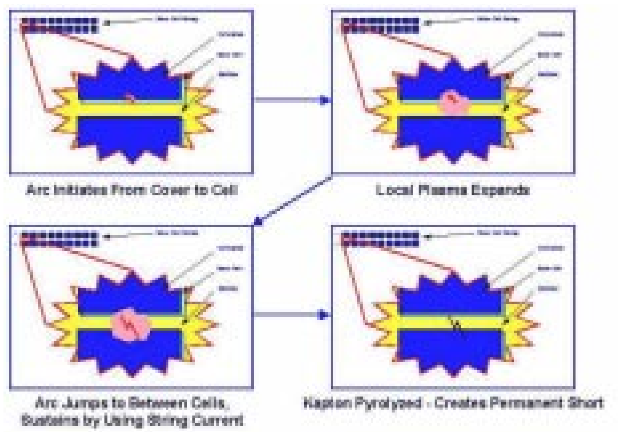
- Replaces 20 year old codes;
- Uses Air Force's DynaPAC algorithms - the best charging algorithms written to date;
- New Object Toolkit (OTk) uses generalized shapes to define spacecraft geometry, no size limitations, 3-D interactive design;
- 100 X Faster than older NASCAP code;
- Leverages NASA/Air Force Partnership Council;
- FEB '01: On schedule and within budget.

Schedule & Cost:



Low-Earth Orbit (LEO) Spacecraft Charging Guidelines

Spacecraft Surfaces and Solar Arrays Can Arc into the LEO Plasma:



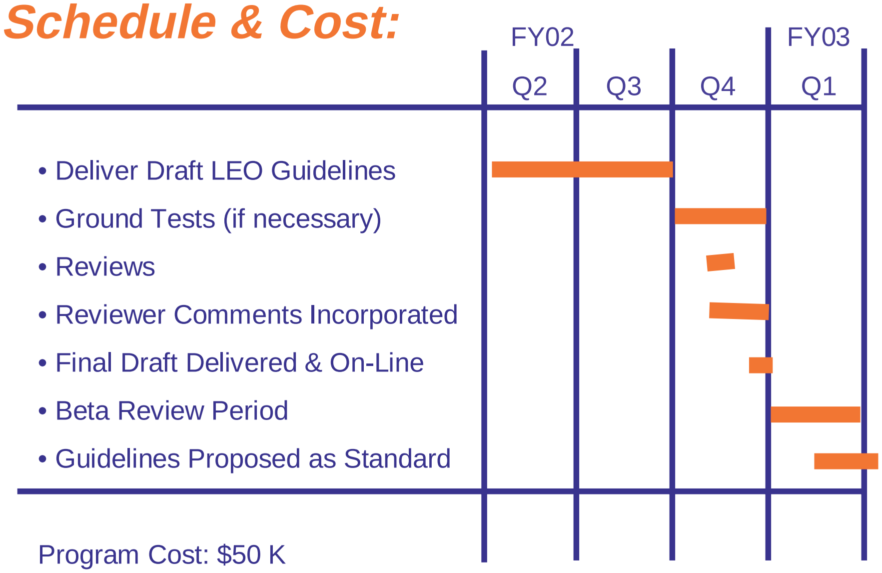
Description:

- Develop and publish a LEO Spacecraft Charging Guidelines Document;
- Perform ground tests as necessary to support Guidelines;
- Submit reviewed guidelines as a NASA and AIAA Standard;
- Deliverables: Draft LEO Guidelines, NASA and AIAA standards.

Benefits to NASA:

- Guidelines for Spacecraft Design that will Mitigate LEO Charging;
- Prevention of TSS-1R type failures;
- Elimination of costly add-on fixes (a la Deep-Space 1, EOS-AM1);
- Enhanced reliability through NASA and AIAA Spacecraft Charging Standards.

Schedule & Cost:



October 20 – 24 2003
Huntsville Marriott

Topics Include:

Models and Computer Simulations
Ground Testing Investigation & Techniques
On-Orbit Missions & Investigations
Environment Specifications
Plasma Propulsion
Materials Development