SPACE ENVIRONMENTS AND EFFECTS (SEE) PROGRAM: SPACECRAFT CHARGING TECHNOLOGY DEVELOPMENT ACTIVITIES

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Abstract

Reducing size and weight of spacecraft, along with demanding increased performance capabilities, introduces many uncertainties in the engineering design community on how materials and spacecraft systems will perform in space. The engineering design community is forever behind on obtaining and developing new tools and guidelines to mitigate the harmful effects of the space environment. Adding to this complexity is the continued push to use Commercial-off-the-Shelf (COTS) microelectronics, potential usage of unproven technologies such as large solar sail structures and nuclear electric propulsion. In order to drive down these uncertainties, various programs are working together to avoid duplication, save what resources are available in this technical area and possess a focused agenda to insert these new developments into future mission designs. This paper will introduce the SEE Program, briefly discuss past and currently sponsored spacecraft charging activities and possible future endeavors.

Introduction

The Space Environments and Effects (SEE) Program was formed by the National Aeronautics and Space Administration (NASA) in 1993 to support the growing need for the development and maintenance of a preeminent program in space environments and effects technology. This initiative is intended to provide a coordinated national focus for innovative technology development to support design, development, and operation of spacecraft systems that will accommodate or mitigate effects due to the presence of the space environment. The program is unique in that it was initiated as a customer-driven and product-oriented endeavor. Considerable effort was made to ensure that the potential industry, academia, and government agency users of the products were consulted and made an integral part of the program. Their assessment and prioritizing of future research needs for space environment definition and techniques for calculating the effects of the space environment on spacecraft systems forms the basis for the SEE Program's activities. This direct involvement of potential customers also ensures that the SEE Program sponsored research products are made available in a timely manner to those most concerned with the information, i.e. spacecraft designers and operators.

SEE Program Objectives and Goals

The objectives of the SEE Program are to collect, develop, and disseminate the SEE-related technologies required to design, manufacture, and operate more reliable, cost-effective spacecraft for the Government and commercial sectors. In order to satisfy these objectives, the SEE Program has developed the following goals:

Advocate technology development, flight experiments, and databases by creating and maintaining:

- Engineering environments definitions
- Up-to-date engineering focused models
- Environmental and materials databases
- Engineering design guidelines
- Flight/ground simulation/technical assessments
- Integrated assessment tools
- Simplified access to modeling and assessment tools

Maintain cutting edge expertise in SEE-related technologies by:

- Coordination with other agencies, industry, and academia
- The incorporation of technical experts and specialists
- Sustained awareness of state-of-the-art SEE technologies

Heighten the awareness of SEE significance and program capabilities through:

- Internet access
- Bulletin
- Displays
- Workshops
- Publications[1,2,3,4,5,6]

SEE Program Structure

While the SEE Program was established with NASA sponsorship, it was recognized from the start that the program's success would depend on its ability to interact with research activities of other agencies, industry, and academia. This interaction has now become one of the principal strengths of the SEE Program. The SEE Program focuses on bridging the gap between the science community and the engineering community by improving environment definitions and tools for spacecraft design and operations planning.[7]

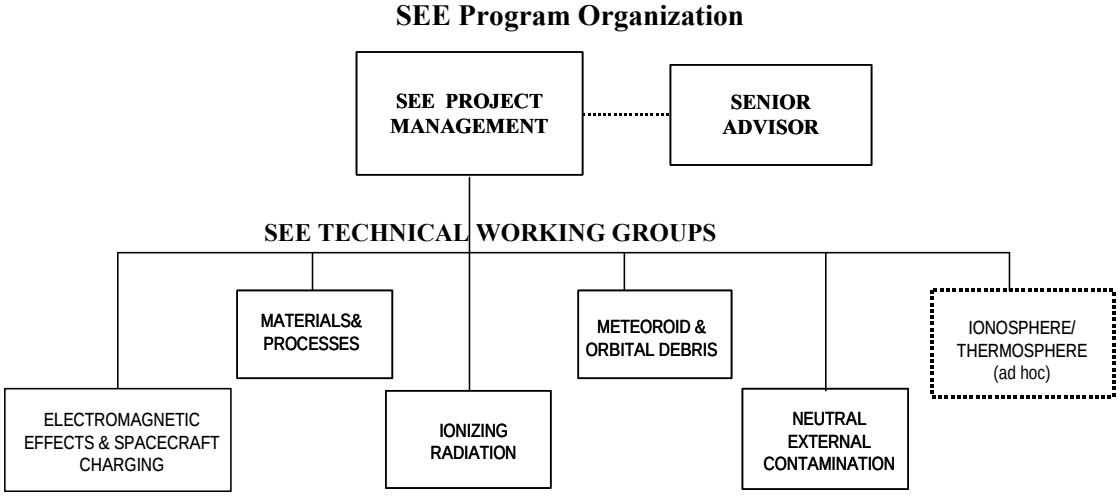

Figure 1. Space Environments and Effects Program Organization

The Space Environments and Effects Program is organized (Figure 1) to facilitate the implementation of the Program's mission, which is directed toward research, development, verification, and transferring SEE-related technologies to the aerospace customers.[8] While the program functions under the direction and oversight of the NASA Office of Aerospace & Technology Enterprise; Enabling Concepts and Technology Program at NASA Headquarters, the key to its ability to accomplish its mission is the Technical Working Groups (TWGs). These groups encompass the disciplines of electromagnetic effects & spacecraft charging, materials and processes, meteoroid and orbital debris, ionizing radiation, neutral contamination, and ionosphere and thermosphere (ad hoc). Their activities and responsibilities include: (1) ensuring communication with working group members, (2) coordinating development, evaluation, and maintenance of working group technical content and research areas, (3) coordinating research and development of new technologies and design issues that impact their respective space environmental areas, (4) coordinating development and use of engineering tools, models, and databases, and (5) coordinating development of spacecraft design and test techniques and methodologies for accommodating or mitigating space environment effects.

The membership in the SEE Technical Working Groups is drawn from NASA, Department of Defense (DoD), National Oceanic and Atmospheric Administration (NOAA), industry, and academia.

The six TWGs, as shown in Figure 1, are the Electromagnetic Effects & Spacecraft Charging, Ionizing Radiation, Materials & Processes, Meteoroid & Orbital Debris, Neutral External Contamination, Ionosphere and Thermosphere (ad hoc) Working Groups. Members of these groups direct and, in some cases, conduct studies and tests that meet a recognized need of the customer. The data from these studies are incorporated into databases, design guidelines, and/or models and provided to the customers.

Technology Development Activities

Since its inception in 1993, the SEE Program has released three separate NASA Research Announcements (NRAs) for technology development. To date, approximately fifty contracts have been awarded (not including direct funded contracts), using peer review, with the technical disciplines represented including all those encompassed by the SEE Technical Working Groups. Organizations receiving the contracts included industry, academia, and government agencies. The products of these contracted efforts from the 1994 and 1997 NRAs are now being realized and as the reports are received and processed, they are being distributed to the aerospace community through the SEE Program.[10] Results from two-year efforts from the 2001 NRA will become available in the spring of 2004.

Past SEE Program Funded Spacecraft Charging Activities

The following is a listing of activities pertaining to spacecraft charging that have been funded by the SEE Program. The list is intended to introduce and make one aware that a product exists. More information about each may be obtained by visiting the SEE Program website (given in the Conclusion section of this paper) or contacting someone in the SEE Program Office.

Title: Electronic Properties of Materials Applicable to Spacecraft Charging*
Organization: Utah State University
Principal Investigator: J.R. Dennison
Objective: Determine the electrical properties for a wide array of spacecraft materials and integrate this new information into relevant NASA databases and models. Specifically, measure secondary and backscattered electron total yields from electron-induced, ion-induced and photon-induced energies.

Title: Interactive Spacecraft Charging Handbook 3.01
Organization: SAIC (Formerly Maxwell Technologies)
Principal Investigator: Ira Katz
Objective: A browser-based, preliminary design spacecraft charging analysis tool with updated spacecraft charging models, updated design guidelines and analysis tools, including algorithms on deep dielectric charging, auroral charging and a 3-D modeling tool.

Title: Low-Earth Orbit (LEO) Spacecraft Charging Guidelines
Organization: NASA Glenn Research Center (GRC)
Principal Investigator: Dale Ferguson
Objective: Develop and publish a LEO spacecraft charging guideline and incorporate new test data as necessary.

* The SEE Program has been continuing this task and is currently testing new materials

Present SEE Program Funded Spacecraft Charging Activities

The following is a list of activities pertaining to spacecraft charging that are ongoing and being funded by the SEE Program. The list is intended to introduce and make one aware that an effort is underway and a product should be available in the future. More information about each may be obtained by visiting the SEE Program website (given in the Conclusion section of this paper) or contacting someone in the SEE Program Office.

Title: Electric Propulsion Interactions Code (EPIC): Integrated Guidelines and Tools for the Assessment of Electric Propulsion Impact on Spacecraft
Organization: Science Applications International Corporation (SAIC)
Principal Investigator: Myron Mandell
Objective: To enhance and combine existing plasma simulations codes into an integrated package, EPIC, to provide system designers with a tool for assessing electric propulsion spacecraft interactions.

Title: Measurement of Charge Storage Decay Time and Resistivity of Spacecraft Insulators
Organization: Utah State University
Principal Investigator: J.R. Dennison
Objective: Investigate the methods for measurement of charge storage and the magnitude of the effect in typical space applications through a combination of straightforward measurements and reference to existing theory on conduction in insulators. Specifically: (i) perfect methods and test protocols to study and quantify the effect, (ii) perform ground-based measurements of the effect in a limited number of controlled studies on near-term, ground-based measurement of the effect in a limited number of controlled studies on near-term missions and (iii) extend existing preliminary work to develop improved techniques so that a wider array of materials and their parameters can be efficiently tested in multiple-sample testing procedures.

Title: NASCAP-2K*
Organization: SAIC
Principal Investigator: Myron Mandell
Objective: A five year, collaborative effort with U.S. Air Force to develop a comprehensive revision to NASA's spacecraft charging analysis code. The code possesses new algorithms for LEO, GEO, polar orbits, deep-dielectric charging, radiation belts and interplanetary space. It also possesses a new interactive, object-oriented spacecraft design tool called Object Toolkit (OTk).

Title: L2 Charged Particle Environment Model and Extreme Event Case Studies
Organization: Jacobs Sverdrup
Principal Investigator: Joe Minow; Bill Blackwell
Objective: Develop a semi-empirical engineering model of electrons and ions (from a few 100's eV to approximately 1MeV) that include the thermal plasma distributions as well as bulk flow effects in the distant magnetotail.

* Co-funded with Hanscom AFRL

Title: Variability in LEO Plasma Environment
Organization: Jacobs Sverdrup
Principal Investigator: Joe Minow
Objective: Develop a model using a plasma variability database to specify statistical variations of plasma parameters (Ne, Te, Ni, Ti) in LEO environments (approximately 200 km to 2000 km).

Title: The "Charge Collector" – A Collection of Spacecraft Charging-Related Products
Organization: SEE Program
Principle Investigator: Multiple
Objective: A compilation of spacecraft charging-related products offered by NASA's SEE Program. The information contained was developed by various organizations of government, industry and academia, all under contract to the SEE Program. The type of information contained the Charge Collector includes databases, reports, tabulated data and design guidelines.

Past Living With a Star Program: Space Environment Testbeds Program Spacecraft Charging Funded Activities

The following is a listing of activities pertaining to spacecraft charging that were sponsored by NASA's Office of Space Science Living With a Star (LWS): Space Environment Testbeds (SET) Program. These activities were funded through the 2001 SEE Program NRA and were managed by the SEE Program. The list is intended to introduce and make one aware that an effort is close to completion or has been completed. More information about each may be obtained by visiting the SEE Program or SET Program websites.

Title: Characterization of Magnetospheric Spacecraft Charging Environments Using the LANL Magnetospheric Plasma Analyzer Data Set
Organization: Science Applications International Corporation (SAIC)
Principal Investigator: Victoria Davis
Objective: Spacecraft charging due to diurnal variations in the plasma environment produces spacecraft anomalies and failures. The current models of the plasma environment are not correlated to spacecraft charging events. This effort will identify those parameters that are important to spacecraft charging and allow for accurate predictive charging capabilities.

Title: Electrostatic Return of Contaminants
Organization: ROR Enterprises
Principal Investigator: Ray Rantanen
Objective: Develop a model capable of calculating the electrostatic return of spacecraft emitted molecules that are ionized and attracted back to the spacecraft by the spacecraft electric potential on its surfaces.

Title: Mining CRRES IDM Pulse and Environment Data
Organization: NASA Jet Propulsion Laboratory (JPL)
Principal Investigator: Robb Frederickson
Objective: Investigate IESD pulsing by insulators flown on the CRRES Spacecraft in relation to radiation-belt particle spectra.

Possible Future SEE Program Activities

The SEE Program is currently partnering with a new NASA Program, Jupiter Icy Moon Orbiter (JIMO), to develop 3D electric propulsion plume and integrated models. JIMO will possess unique, high energy, and multiple thruster plumes that introduce uncertainties and modeling requirements never experienced before. Currently, an effort is scheduled to begin in FY04 for multiple years and will leverage previous efforts (NASCAP-2K and EPIC).

The SEE Program is currently working with NASA HQs to determine if resources will be available for another SEE Program NRA to be released in FY04. If approved, several spacecraft charging topics will be solicited in this opportunity. Due to the sensitive nature, the areas of interest cannot be made available at this time. If FY04 resources cannot be secured, the SEE Program will delay the NRA and plan to release it in the 3rd quarter of FY04 using FY05 & FY06 resources.

Conclusion

Since 1993, NASA's Space Environments and Effects (SEE) Program has made significant progress towards updating and developing new products to mitigate spacecraft charging issues. As this paper illustrates, the SEE Program reflects an interagency and broad industry scope. The program also plays an important role as an advocate for space environments and effects related flight experiments. The program's success, however, depends upon the feedback from aerospace industry and government programs on their anticipated needs and the value of the program's products in their spacecraft systems development activities.

Those having interest in the SEE Program activities*, whether from opportunities for participation, information on products, or to contribute inputs on future spacecraft needs relative to space environment definition or effects of the space environment on spacecraft systems, are invited to visit the website homepage at *http://see.msfc.nasa.gov*.

Acknowledgements

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* All non-U.S. citizens and foreign nationals living in the U.S. must obtain an International Agreement from NASA Headquarters to receive any products that have export control restrictions.

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