

N91-17734

# The Environment Power System Analysis Tool Development Program

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## Introduction

The Environment Power System Analysis Tool (EPSAT) is being developed to provide space power system design engineers with an analysis tool for determining system performance of power systems in both naturally occurring and self-induced environments. The program, which is funded by SDI/SLKT and directed by NASA/LeRC, is producing an easy to use CAE tool general enough to provide a vehicle for technology transfer from space scientists and engineers to power system design engineers. This paper presents the results of the project after two years of a three year development program.

The Strategic Defense Initiative (SDI) systems require the generation of very large power levels in space for defense applications. These power levels must be available, on demand, anytime in the 10 year mission life of the system requiring the power system to survive prolonged exposure to the space environment and then be fully functional. The space environment interacts with power systems in many ways including: ionization and bulk breakdown, plasma-induced surface flashover, oxygen erosion, meteor and debris damage, and radiation effects. Previously, engineers needing to assess the system impact of these interactions were forced to perform separate calculations and analysis for each interaction and then attempt to piece the intermediate results together. This made system analysis time consuming and unreliable and made extensive system tradeoff studies nearly impossible.

EPSAT is being developed to provide engineers of space power systems with system analysis capabilities. The program consists of four major areas. These are:

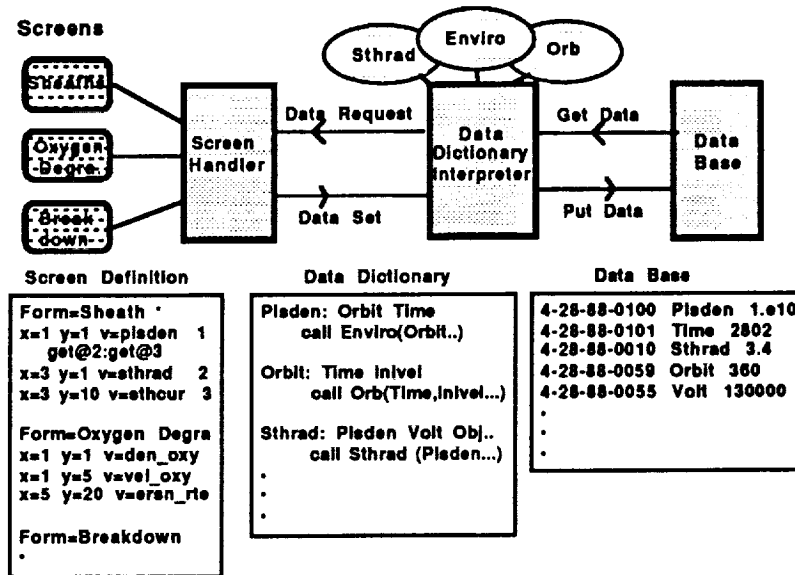
- (1) Identify the relevant power systems envisioned for SDI applications and determine which environment-power system interactions are most likely to be important in the operation of the space systems.

- (2) Develop a modern robust CAE tool to provide a natural framework to integrate newly developed or existing modeling software into a comprehensive analysis tool with a modern user interface.
- (3) Identify existing modeling codes and start development on new codes needed for modeling environment power system interactions. A separate detailed analysis phase will follow to determine the accuracy of the analysis codes and relevance of the interactions to the design of high power systems for the space environment.
- (4) Determine deficiencies in modeling capabilities, material properties, etc. relevant to environment-power system interactions and recommend corrective steps.

## **EPSAT**

A useful CAE tool provides engineers with the necessary design information for the systems under consideration. While this seems obvious, it places severe requirements on software design. SDI configurations are still in the conceptual design phase, hence power system designs, requirements, and planned applications evolve with time. A power system environment interactions CAE tool must be capable of absorbing changes and extensions quickly and reliably. To meet this need, EPSAT has been designed for change. The interface is user friendly and easily modified. The code is highly structured with calculational modules which can be altered or replaced. New modules can be added to give new results or build on results from other modules. All facets of the CAE tool, from the way information is presented to the user to the physical models used in the calculations, are easily changed. A unique architecture has been used to provide this capability and is shown in Figure 1.

The EPSAT approach separates the CAE tool into three distinct functional units: a modern *user interface* to present information, a *data dictionary interpreter* to coordinate analysis; and a *data base* for storing system designs and results of analysis



**Figure 1.** The modern design of EPSAT allows for extension and change. The *user interface* presents data to the design engineer through menus, screens, and graphics. Screen definition files tell the screen handler which data items are to be displayed on the screens. The *data dictionary interpreter* receives data requests from the screen handler and uses a rule book, the *data dictionary*, to find recipes to construct the desired data

The *user interface* is externally programmable through ASCII data files, which contain the location and type of information to be displayed on the screen. The information being displayed to the user can be changed while EPSAT is running. Besides aiding in development, this approach provides great flexibility in tailoring the look and feel of the code to meet individual user's needs. The *user interface* has utilities for table generation, line plotting, contour plotting, and perspective plotting as shown below in Figure 2.

To use the CAE tool, the user makes menu selections to display screens of information. These contain information such as the ambient plasma density. Table generation facilities provide a means to vary one variable and examine its effect on other variables. For example the ambient plasma density as a function of altitude or mission time could be generated using this utility. Tables can be viewed directly, saved as an ASCII file, displayed as a plot, or saved as a *Postscript* plot file. A similar utility generates contour plots for slices of data. If the user modifies a value on a screen the change is recorded and the screen is updated to reflect this change and any other changes in displayed quantities

which are dependent on the modified variable. This is the typical mode of interaction between the user and EPSAT; change a parameter (or vary it over a range for a plot or table) and examine the effect on dependent quantities. This ability of being able to vary any quantity and watch its effect on any other quantity is the power of the *data dictionary* approach used in EPSAT.

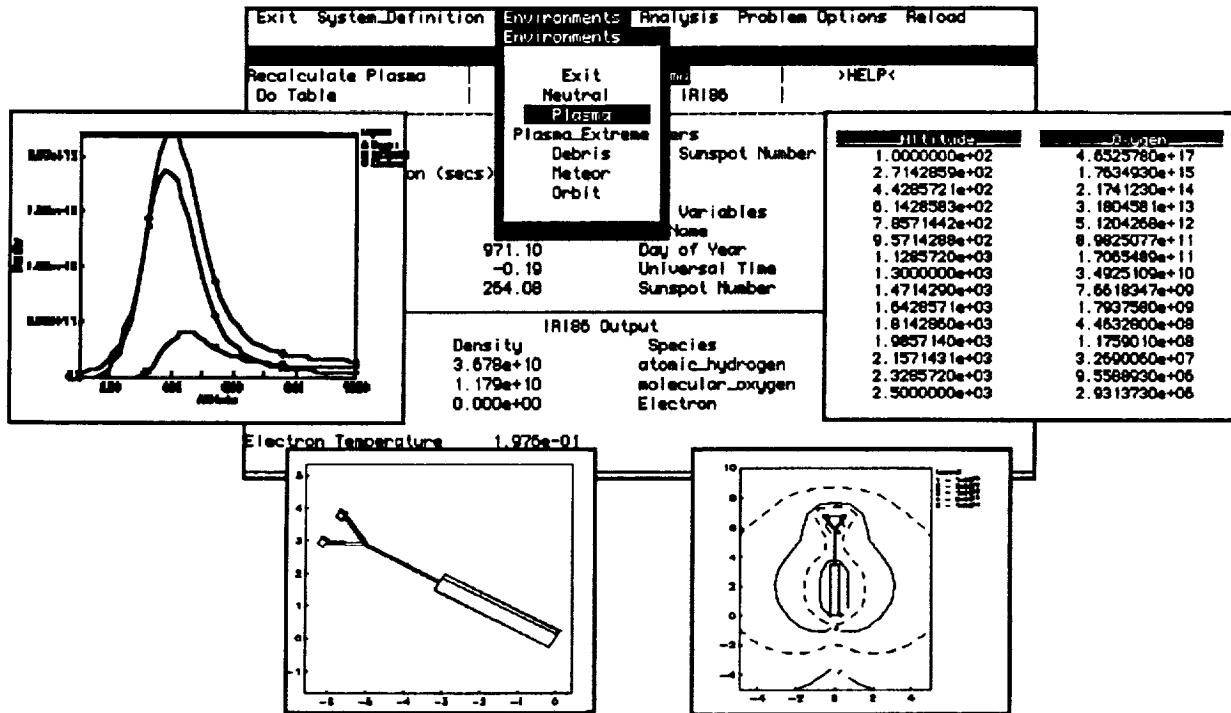


Figure 2. The EPSAT user interface presents information to the user through screens, line plots, perspective plots, contour plots and tables.

The *data dictionary interpreter* coordinates the analysis. It provides data requested by the user interface and insures that it is up to date with respect to all of the data on which it depends. This is accomplished by examining an ASCII file, the *data dictionary*, for recipes listing dependencies of data items and how to compute new values if required. If data needs to be computed then the appropriate analysis modules are called and their results stored in the *data base*. In this way complex multi-step calculations are reduced to a series of independent recipes each building on results determined by other recipes. Similarly, incorporation of new analysis modules is reduced to adding a recipe in the DDI containing the information on how the module is to be used. This increases both the speed of module incorporation and reliability.

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## Environment And Power System Interaction Models

Plasma	Polar & Auroral Charging Ram/Wake Effects Turbulence
High Energy Radiation	Radiation Damage Single Event Upsets
Meteoroid/Debris	Punctures & Surface damage Sensor Erosion
Neutrals	Atmospheric Drag Oxygen Erosion Vehicle Glow
Electromagnetic Solar Radiation	Forces, Torques, Stresses Solar Degradation Thermal Effects
Self-Generated	Nuclear Radiation Outgassing Contamination Effluents High Voltage Interactions High Current Interactions

Table 1. Environment categories and power system interactions.

Table 1 shows the categories of environments and their corresponding effects on power systems. The size of this list reflects the many interactions a power system will experience. For each environment and interaction an appropriate simulation model must be identified, coded (unless one already exists) and incorporated into EPSAT. Computational speed is an important factor in these modeling codes. EPSAT is intended for use in performing complex system tradeoff studies. Hence, large numbers of calculations consisting of parameter studies must be possible in a reasonable amount of time using a workstation. This restricts the models to engineering level approximations in which modeling fidelity is exchanged for the capability to model entire complex systems.

Table 2 shows the models currently in EPSAT along with additional models to be incorporated during the final year of the project.

## **Present Capabilities**

### **Simplified Object Generation**

#### **Environment Models**

**Neutral**

**Plasma**

**Earth's Magnetic Field**

**Meteor**

**Debris**

**Orbit Generator**

#### **Interaction Models**

**Meteor/Debris Damage**

**Space Charge Sheaths**

**Sheath Ionization**

**Floating Potentials**

**Oxygen Erosion**

**Outgassing**

**Nozzle Plume Expansion**

**Plume Shadowing**

**Column Densities**

**Scattering**

## **Under Development**

### **System Generation Module**

#### **Breakdown**

**Surface Flashover**

**Paschen**

**Plasma Induced**

#### **Neutral Interactions**

**Ionization**

#### **Radiation Environment**

#### **Surface Effects**

#### **Magnetic Field Interactions**

**Table 2** Power system-environment simulation models in EPSAT.

## **Summary**

The high power systems envisioned for SDI applications will interact with their ambient and self-generated environments more severely than the low power low voltage systems used to date. SDI power systems must be designed to survive many years in these environments and then operate in the environments on demand. The SDIO Space Power-Space Environment Effects Program is addressing this through the Environment Power System Analysis Tool, EPSAT, program. EPSAT will provide the design engineer with the capability to perform complex system tradeoff studies quickly and reliably. The unique design of EPSAT guarantees it will meet the evolving needs of space power system design engineers.