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THE ENVIRONMENT WORKBENCH
A DESIGN TOOL FOR SPACE STATION FREEDOM

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INTRODUCTION

The Environment WorkBench (EWB) is being developed for NASA by S-CUBED to provide a standard tool that can be used by the Space Station Freedom (SSF) design and user community for requirements verification. The desktop tool will predict and analyze the interactions of SSF with its natural and self-generated environments. The project is funded by Space Station (SSE) and managed by NASA/Lewis Research Center. In this paper, we briefly review the EWB's design and capabilities. We then show calculations using a prototype EWB of the on-orbit floating potentials and contaminant environment of SSF. We examine both the positive and negative grounding configurations for the solar arrays to demonstrate the capability of the EWB to provide quick estimates of environments, interactions, and system effects.

THE ENVIRONMENT WORKBENCH

The design of the EWB is based on the Environment Power System Analysis Tool (EPSAT) developed by S-CUBED for NASA and SDIO. EPSAT integrates into one modern screen-oriented desktop tool the environment and analysis modules needed to design and perform system studies on power systems. For the EWB, the environment and interaction modules are being replaced with modules containing Space-Station-approved models. The architecture of the EWB is shown below in Figure 1. The user interface is isolated from the calculation modules, allowing sophisticated display capabilities to be standardized. The calculational portion of the tool is designed to allow modules containing physics models to be "plugged" into software expansion slots similar to a bus on a PC. The process controller then coordinates all input/output (I/O) from the individual modules and data bases. This structure provides flexibility and expandability. When new modeling capabilities are needed, the necessary modules are "plugged" and automatically work with all the other physics modules and the display module.

The environment and interaction modules to be incorporated into the EWB are called out in SSF 30425 and are listed in Figure 2. The SSF document also details the specifics of the

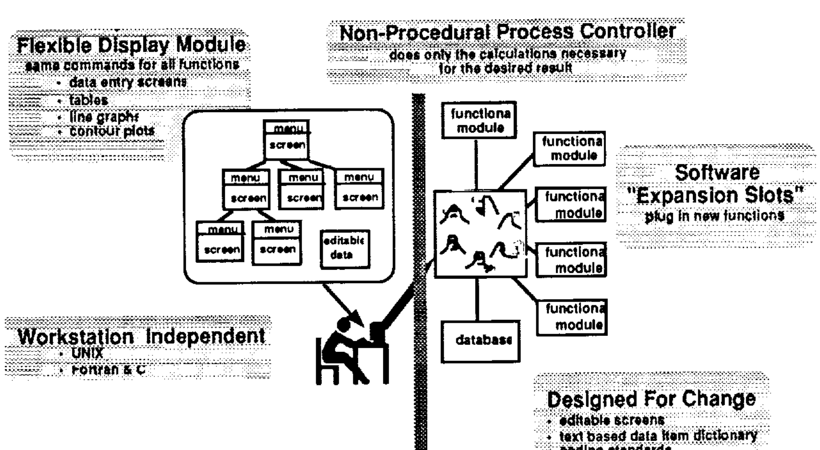

Figure 1. The architecture of the EWB. The display module presents information to the user on screens or in tables and graphs. The software bus integrates the calculational modules and handles all data storage and I/O from the modules.

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Neutral Atmosphere

Plasma
- **Ionospheric plasma**
- **Auroral Plasma**
- **Geosynchronous Plasma**

Penetrating Charged Particles
- **Magnetospheric**
- **Trapped Radiation**
- **Cosmic Rays**

Electromagnetic Radiation
- **Galactic Radiation Noise**
- **Solar EM Noise**
- **Natural Environment EMR**
- **Man-made Noise**

Meteor and Debris
- **Meteoroids**
- **Debris**

Earth's Magnetic Field

Gravitational Field

Induced Environmental Effects
- **Plasma Wake**
- **Neutral Wake**
- **Glow**
- **Charging**
- **Contamination**
- **EMR from Power**
- **Induced Perturbations**
- **V x B**
- **Plasma Currents**
- **Drag**
- **Torques**
- **Radiation Dose**
- **Meteor and Debris Impacts**
- **Surface Degradation**

Figure 2. Environment and interaction models to be incorporated into the EWB.

models as currently conceived. However, as discussed above, the modular design of the EWB will facilitate modifications, extensions, and replacements as needed.

SPACE STATION FREEDOM CALCULATIONS

In this section, we present prototype EWB calculations of the $\mathbf{v} \times \mathbf{B}$-induced potentials, floating potentials, and contaminant environment about SSF. The prototype EWB is an extension of EPSAT and forms the basis of the EWB. These calculations show that, for the negative ground configuration of the solar arrays, the truss structure will float more than 100 volts negative. During these conditions, thruster firings can ground the structure significantly, increasing the current through the structure.

In the calculations below, a 28° inclination 300 kilometer orbit is used. Figure 3 shows a plot of the north, east, and down components of the Earth's magnetic field as a function of mission time for this orbit. The plot extends for approximately one orbit. The magnetic field module contains the IGRF-87 model of the earth's magnetic field. The orientation of SSF on its orbit has the cabin facilities in the gravity gradient direction and the truss structure normal to the orbit plane. In this orientation, the down component of the magnetic field induces the potential gradient along the 130 meter truss structure. As seen in Figure 3, the down component changes sign between the northern and southern magnetic hemisphere and ranges to almost 0.3 Gauss.

The induced $\mathbf{v} \times \mathbf{B}$ potential across the entire truss structure is shown below in Figure 4. The potential is given as a function of mission time for an entire day (86,400 seconds). The potential is not periodic with orbit due to the rotation of the earth. The sign of the potential changes with that of the down component of the magnetic field (see figure 3). The maximum potentials of +33 volts and -32 volts occur when SSF is nearest to the magnetic poles.

Floating potential calculations were performed for the two grounding schemes of the solar arrays. The results are shown in Figures 5 and 6. For both cases, the 130m × 5m × 5m truss structure was assumed to be solid and conductive. The solar arrays were assumed to generate 150 volts continuously. (Shadowing by the earth was ignored.) Solar array plasma current collection is taken as the sum of the collection by the individual solar cells. Each solar cell is assigned a voltage depending on its position in the array and the array ground potential. The plasma current collection by an individual cell is dependent on the array and cell design and must be parametrically defined. We use the form shown in Figure 7,

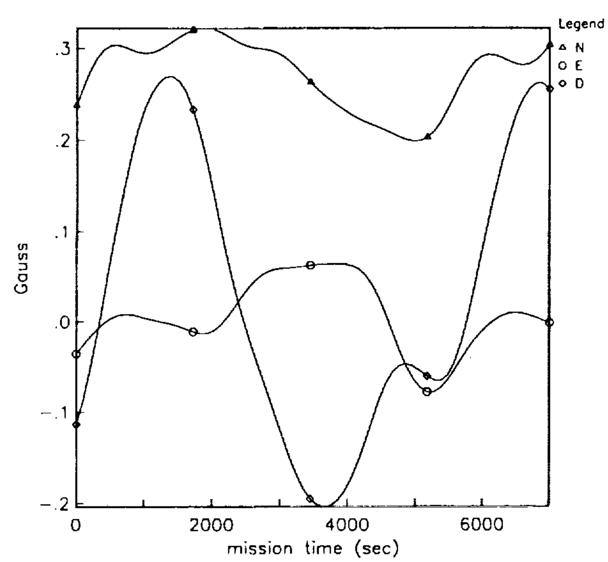


Figure 3. The north (N), east (E), and down (D) components of the Earth's magnetic field for one orbit. The magnetic field values are not periodic with each orbit due to the revolution of the Earth.

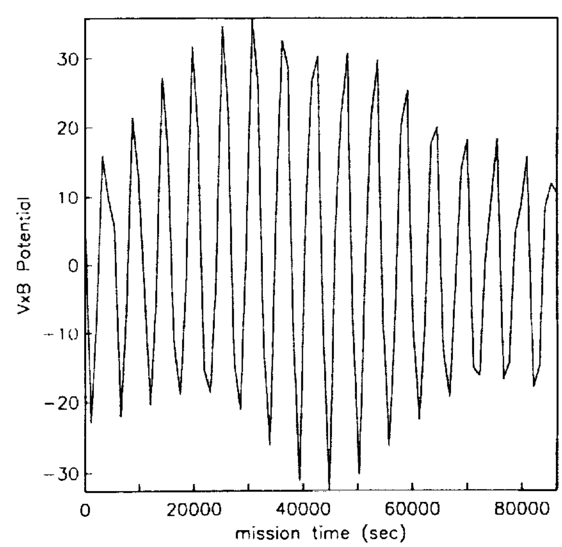


Figure 4. The potential induced across the truss of SSF by its motion through the Earth's magnetic field. The cyclic motion is due to the orbit around the earth, and the envelope is due to the earth's rotation.

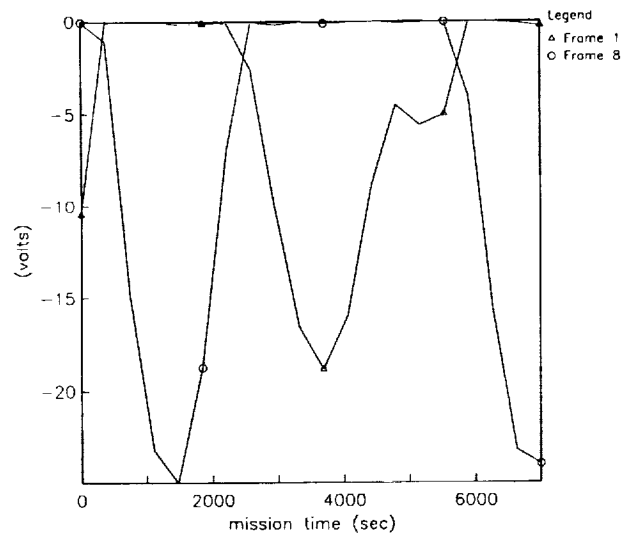


Figure 5. Floating potential of the truss for the positive ground configuration. The two curves show the potentials with respect to plasma ground of the two ends of the truss.

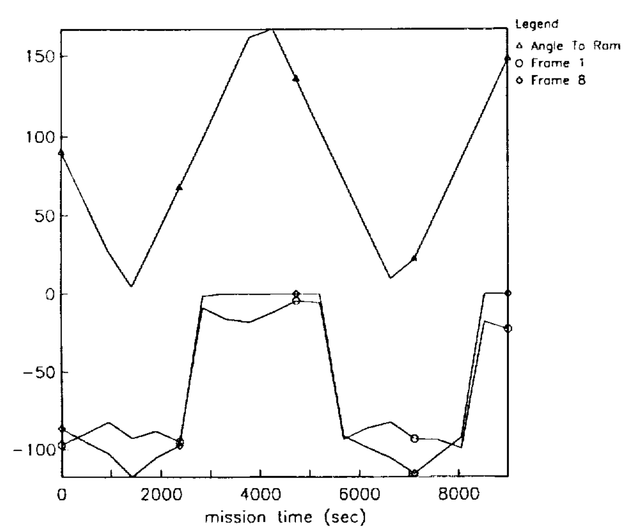


Figure 6. Floating potential of the truss for the negative ground configuration. The two lower curves show the potentials with respect to plasma ground of the two ends of the truss. The top curve shows the orientation of the solar arrays with respect to the ram.

which allows for different ion and electron collection efficiencies and secondary electron and snapover effects. The specific values used in these calculations were chosen to reproduce the collection efficiencies of NASCAP/LEO simulations of the SSF solar cells.

The SSF floating potential as a function of mission time is shown in Figure 5 for the solar array positive ground

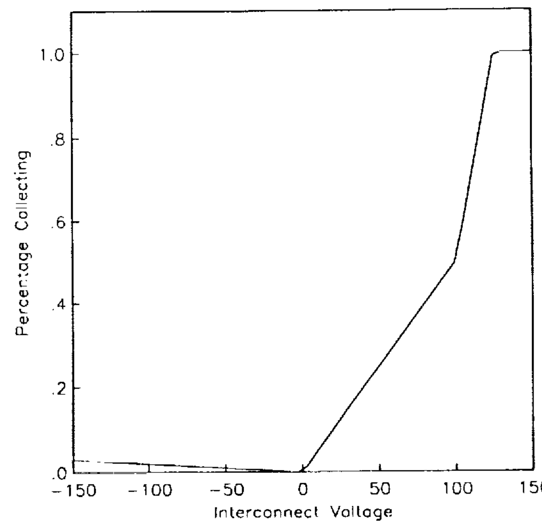
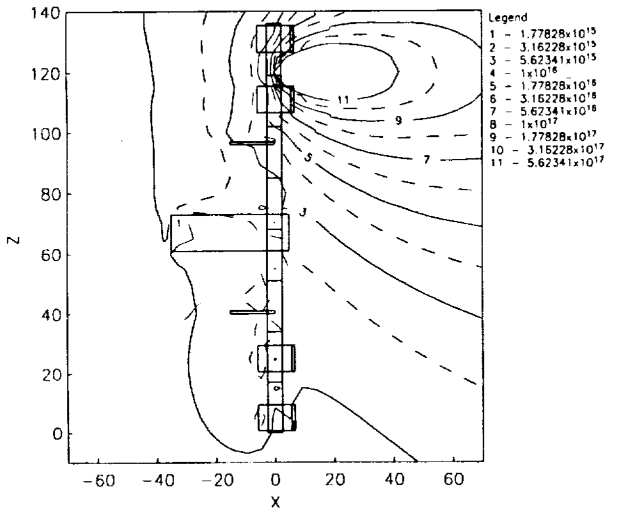


Figure 7. Parametrized collection efficiency of a single solar cell used in the floating potential calculations. The plasma current collected is the incident plasma current onto the cell surface multiplied by the collection efficiency.

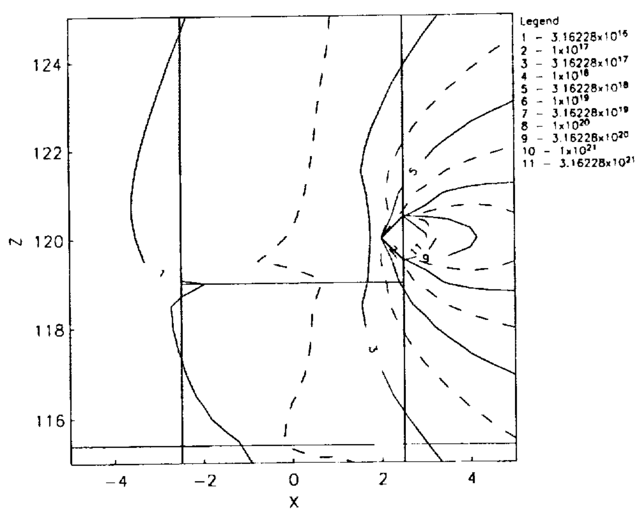
configuration. At each mission point, the EWB uses the IRI-86 plasma density module to compute the plasma density appropriate for the location and local time. The floating potential module then determines the potential that must be added to each component to produce zero net plasma current to the system. The two curves shown in Figure 5 are the potentials with respect to plasma ground of the two ends of the truss. As seen, the potential stays within $\mathbf{v} \times \mathbf{B} \bullet \mathbf{L}$ of plasma ground. The most positive part of the solar array is near plasma ground, and the most negative portions are 150 volts negative.

The negative ground configuration is shown below in Figure 6. The difference is dramatic. The truss floats between 100 and 130 volts negative depending on the $\mathbf{v} \times \mathbf{B} \bullet \mathbf{L}$ potential. When the truss is floating at 130 volts negative, over 1 ampere is flowing through the structure. Figure 6 also shows the angle of the solar arrays with respect to the ram. During part of the orbit, the solar arrays do not face into the ram plasma and cannot collect current. For these times, the floating potential falls to low values similar to the positive ground configuration.

The final EWB calculations show the effect of firing a 10 lb. thruster. As shown in Figures 8a and 8b, the density near the thruster is high enough to cause a Paschen breakdown (~ 0.2 Torr-cm). This is confirmed in Figure 9, which shows a plot of the pressure and the Paschen breakdown pressure threshold as a function of distance along the truss. Near the location of the thruster (120 m), the pressure threshold is exceeded. In this region, it is possible to have Paschen breakdown given high enough voltage. However, if breakdown does occur, it will tend to extinguish itself because the rest of the plasma circuit (truss, solar arrays, etc.) cannot collect enough current to sustain the arc. The system will be driven more positive, increasing the current to the arrays.



(a)



(b)

Figure 8. (a) Total neutral density near SSF during operation of a 10 lb. thruster located at 120 m up the truss. The calculation includes the ambient neutrals and accommodated thruster neutrals. (b) Blowup of the thruster region.

SUMMARY

The Environment WorkBench is being developed to provide Space Station designers and users with a tool to determine interactions of Space Station Freedom with its natural and self-generated environments. The EWB will integrate into one desktop tool the environment and interaction models needed to perform system analysis and requirements verification. As demonstrated by the prototype calculations presented here, having environment and interaction models integrated into one tool allows the user to analyze quickly and reliably system performance of configurations and to determine if requirements are being met.

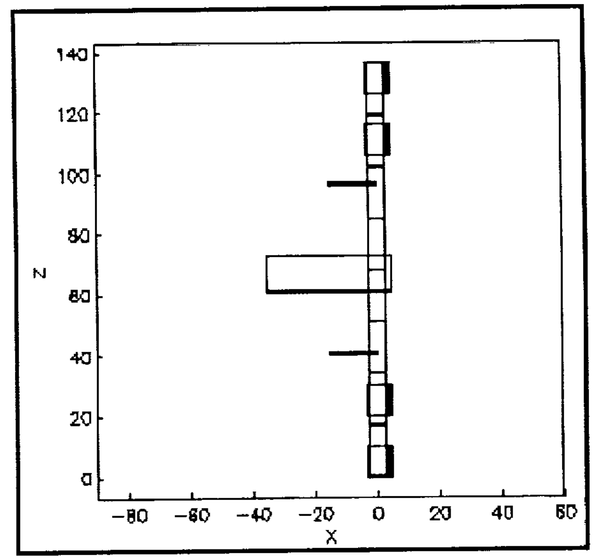


Figure 9. (a) Profile of the EWB space station model. The thruster is located at 120 m. (b) Neutral pressure and Paschen breakdown pressure threshold as a function of distance along truss. Near the thruster, the breakdown pressure is exceeded.

ACKNOWLEDGEMENT

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