Solar Array Verification Analysis Tool (SAVANT) Developed

Modeling solar cell performance for a specific radiation environment to obtain the end-of-life photovoltaic array performance has become both increasingly important and, with the rapid advent of new types of cell technology, more difficult. For large constellations of satellites, a few percent difference in the lifetime prediction can have an enormous economic impact. The tool described here automates the assessment of solar array on-orbit end-of-life erformance and assists in the development and design of ground test protocols for different solar cell designs. Once established, these protocols can be used to calculate on-orbit end-of-life performance from ground test results.

The Solar Array Verification Analysis Tool (SAVANT) utilizes the radiation environment from the Environment Work Bench (EWB) model developed by the NASA Lewis Research Center's Photovoltaic and Space Environmental Effects Branch in conjunction with Maxwell Technologies. It then modifies and combines this information with the displacement damage model proposed by Summers et al. (ref. 1) of the Naval Research Laboratory to determine solar cell performance during the course of a given mission. The resulting predictions can then be compared with flight data.

The Environment WorkBench (ref. 2) uses the NASA AE8 (electron) and AP8 (proton) models of the radiation belts to calculate the trapped radiation flux. These fluxes are integrated over the defined spacecraft orbit for the duration of the mission to obtain the total omnidirectional fluence spectra.

Components such as the solar cell coverglass, adhesive, and antireflective coatings can slow and attenuate the particle fluence reaching the solar cell. In SAVANT, a continuous slowing down approximation is used to model this effect.

The displacement damage model is based on a damage correlation using the "displacement damage dose" derived from the product of the calculated nonionizing energy loss and the fluence. It can very accurately predict the expected degradation of solar cell performance in a complex space radiation environment based on Earth-made measurements with only one proton energy and two electron energies, or proton and electron energy, and Co^{60} gammas.

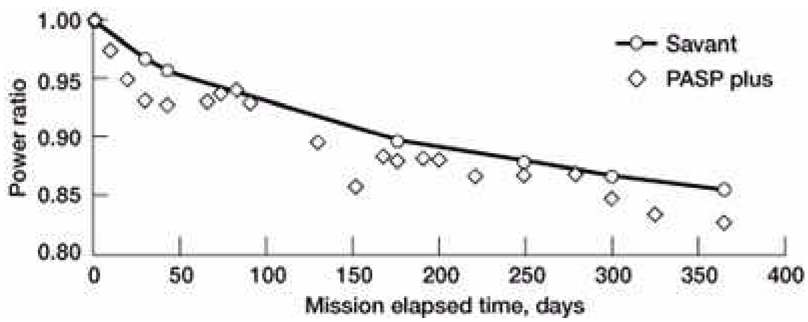
The displacement damage dose is the nonionizing equivalent of the ionizing dose, and the nonionizing energy loss coefficients are the nonionizing counterpart to the collision stopping power. The displacement damage dose is calculated by integrating the product of the differential fluence and the nonionizing energy loss values over energy. This displacement damage dose is calculated for both electrons and protons, and the total dose is found by summing the two after the electron dose has been converted to an effective dose by dividing it by a dose ratio experimentally determined for the particular solar cell type. The displacement damage dose can then be related to solar cell power loss.

$$P_{max}/P_0 = 1 - C \ln[1 + (D_T/D_x)]$$

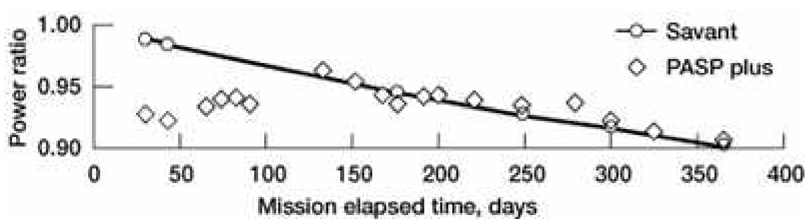
where P_{max} is the maximum power output of the cell, P_0 is the original power output, C and D_x depend on the specific solar cell, and D_T is the total displacement damage dose.

A comparison of the SAVANT prediction with the albedo-free data from the Photovoltaic Array Space Power Plus

Diagnostics (PASP Plus) flight experiment for the silicon and gallium arsenide modules follows.

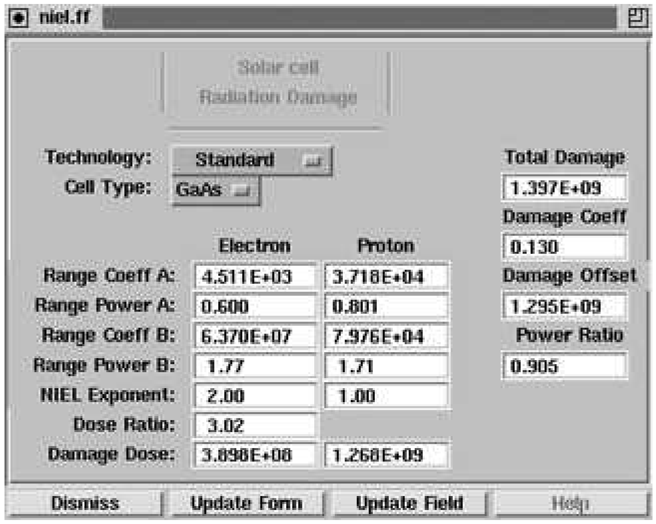


Normalized power ratio for the silicon module.



Normalized power ratio for the gallium arsenide module.

The SAVANT tool fully integrates the required models end to end, including the trapped particle environment, cell shielding, geometry and type, slowing of the incident fluence by shielding, resultant displacement damage dose, and effect on cell power output. Parameter trade studies are extremely easy to perform with SAVANT. The effect of shielding material or thickness, orbit parameters, mission length, or cell type can be examined. The SAVANT tool provides a time-effective way to compare a variety of array parameters.



SAVANT screen capture showing solar cell radiation damage.

References

1. Summers, G.P.; Burke, E.A.; and Zapsos, M.A.: Displacement Damage Analogs to Ionizing Radiation Effects. Radiation Measurements, vol. 24, no. 1, 1995, pp. 1-8.

2. EWB: The Environment WorkBench. Online information: http://satori2.grc.nasa.gov/DOC/EWB/ewbhome.html

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