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Creation and Utilization of a World Wide Web Based Space Radiation Effects Code: SIREST

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Abstract

In order for humans and electronics to fully and safely operate in the space environment, codes like HZETRN (High Charge and Energy Transport) must be included in any designer's toolbox for design evaluation with respect to radiation damage. Currently, spacecraft designers do not have easy access to accurate radiation codes like HZETRN to evaluate their design for radiation effects on humans and electronics. Today, the World Wide Web is sophisticated enough to support the entire HZETRN code and all of the associated pre and post processing tools. This package is called SIREST (Space Ionizing Radiation Effects and Shielding Tools). There are many advantages to SIREST. The most important advantage is the instant update capability of the web. Another major advantage is the modularity that the web imposes on the code. Right now, the major disadvantage of SIREST will be its modularity inside the designer's system. This mostly comes from the fact that a consistent interface between the designer and the computer system to evaluate the design is incomplete. This, however, is to be solved in the Intelligent Synthesis Environment (ISE) program currently being funded by NASA.

KEYWORDS: Space radiation, collaborative design, design optimization, space radiation transport.

1. Introduction

The space radiation environment and its effects on astronauts and electronics have been studied for many decades [1]. This has entailed the study of the space environment from low earth orbit to deep space, atomic and nuclear interactions, particle production, charged and neutral particle transport in various media types, distribution of energy production in tissue and electronics, and damage estimates from the particle's energy distribution.

The analysis codes to date have been written with the radiation researcher in mind [2, 3, 4 as examples]. Much information and many theories have been analyzed and accepted or rejected. However, this does not help a mission manager design or operate a spacecraft. The next step is to transfer the information gathered over these many decades and produce an environment that a designer and manager can use to make decisions optimized on variable and numerous risks and constraints without detailed knowledge of the physics or numerics of the underlying models.

NASA has chosen to call this type of environment the Intelligent Synthesis Environment (ISE) [5,6]. Many computational tools will need to be gathered and made to work together. One of these tools must determine radiation risk. Therefore, the Langley Research Center developed code, HZETRN [2], will be converted and improved to work in the ISE. Initially, the model will be based on an existing World Wide Web interface called the Framework for Analysis and Collaborative Engineering (FACE) [7].

While this paper will not give details of the physical models used to generate the HZETRN code or its pre and post processors, it will describe the flow necessary to exist in the FACE environment. This new flow will be called the Space Ionizing Radiation Effects and Shielding Tools or SIREST.

2. SIREST System Inputs

There are many user inputs needed to design and optimize a spacecraft. Those user inputs that are specific to radiation risk assessment are few however. The major category input types are listed in Table I. These input categories hide a complexity that is inherent in this process.

As an example, the item labeled Geometry Definition is not as simple as it appears. Many different tools besides radiation risk need a geometrical description of the vehicle or habitat. Structural analysis codes need only a surface rendering of the shape or can use solid (brick) elements. Thermal analysis codes could use a thickness distribution, but can also use a surface rendering. Rack layout designers need only

Table I – SIREST User Input Categories.

User Input	Usage
Environment Definition	Mission Trajectory
	Mission Segment Departure and Arrival Times
	Estimated Level of SPE Events and Severity
Geometry Definition	Major Mass Component Placement and Thickness
	Interior Rack Layouts
	Duty Station Layouts
	Storage Layouts
	External Component Placement
Materials Definition	Elemental Material Composition
	Overall Material Density
	Cross Section Determination
Vehicle Layout	Material Thickness along Geometry
	Material Composition along Geometry
Output Definition	Regulatory Quantities Mapped to Vehicle
	Particle Flux Values Mapped to Vehicle
	Tissue Damage Estimates Mapped to Vehicle
	Electronic Damage Estimate Mapped to Vehicle

the internal volume description. Manufacturers however need a component-by-component engineering drawing. Radiation physics does not need the detail of an engineering drawing, but a simple surface model is not sufficient.

Other tools within the ISE will have the same problem or problems related to the level-of-detail complexity. Two tools need the same type of data. The first tool needs a gross level of detail and the second a fine level. Either two models will need to be developed, or a tool to reduce level-of-detail from fine to gross will need to be developed with a fine detail model needed before the gross level of detail tool can be used.

A dial for level-of-detail does not yet exist within ISE; therefore, the FACE interface will use parameters based on the level-of-detail models available at the time of the analysis. Once other models or support tools come on-line, the radiation tool will adapt and the uncertainty prediction of risk from radiation will decrease.

Special models of physical parameters, say Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE) environments, will always be improved once better data and validated models are available. The advantage of FACE rests in the instant update of these models to all users in a single-point manageable manner.

3. SIREST Flow

Figure 1 shows how all the parts of the radiation risk tool come together and flow to create SIREST. The geometry and materials can be optimized to create the minimum radiation risk and vehicle mass to support the defined mission. The geometry can be based on the number of crew or the amount of cargo needed. The material used can be based on what is available or what is needed to constrain the atmospheric pressure inside the craft. The design constraint is the lowest maximum radiation exposure that any one crewmember can accumulate on the mission, usually the youngest female or male.

This flow can also be used to map various quantities inside the vehicle. The quantities of interest usually are particle flux values, regulatory quantities (dose and dose equivalent), damage estimates based on various cell models, or damage estimates based on electronic component or detector response functions. This system is modular so that saved particle flux values can be converted to multiple output quantities at a later date.

The execution path through FACE is stateless, meaning that any module can be executed within FACE in any order. The data within an analysis is ordered however. One must determine the environment before a dose calculation can be performed. Therefore, the data itself must contain control parameters to guide the user through FACE. These control parameters are read when the user chooses a dataset. FACE then ghosts out the modules that cannot be logically run on the dataset. This means that the user has at least one if not more modules available for execution. If more than one exist, then the execution order is up to the user.

4. SIREST System Outputs

This is where an integrated version of SIREST can really shine. Once the data is calculated, the results

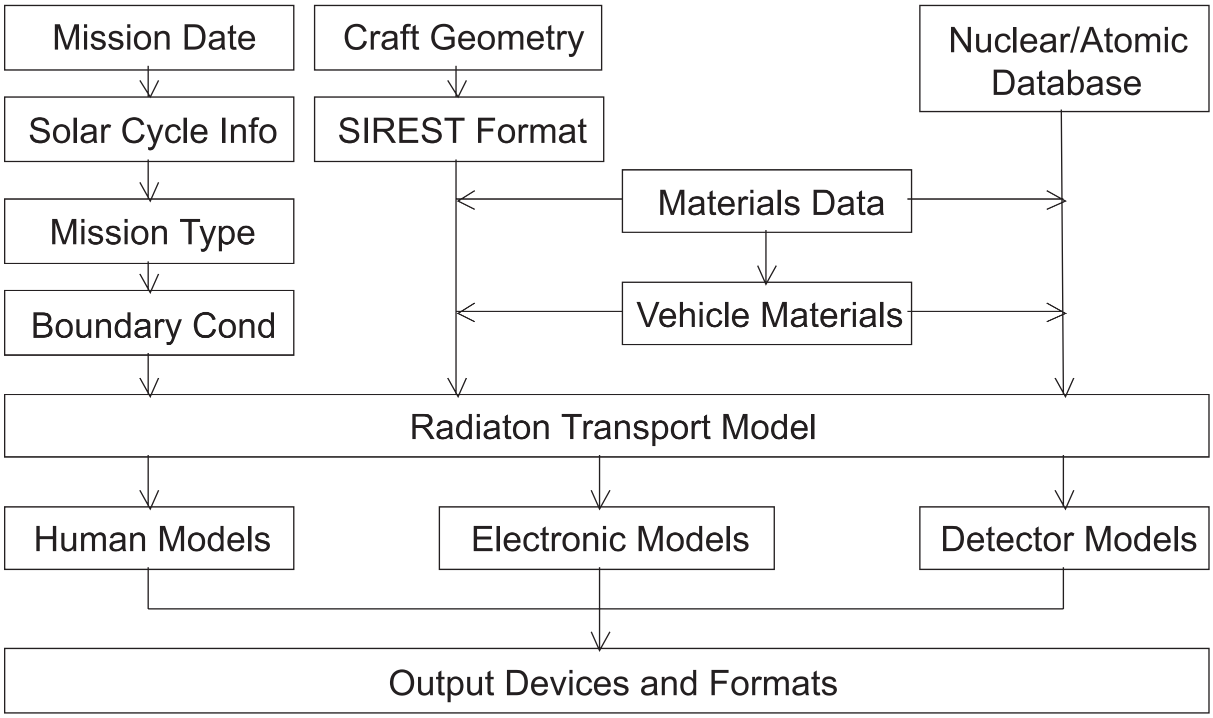

Fig. 1 – Preliminary Schematic for SIREST.

can be piped to existing tools to produce standard 2D plots or virtual reality CAVE™ models. All parties involved in a virtual meeting can explore the data in real-time. This is the ultimate outcome of the ISE project: collaborative design across thousands of miles by numerous teams and individuals. To design in this manner, variables must be optimized with constraints to achieve the mission at hand. All members of the team must be able to generate and explore the data in real-time. The ISE will allow this to happen. Our first step into ISE is the FACE interface to HZETRN.

5. Preliminary Design for a Special Tool to Perform Cost to Risk Optimization

A preliminary effort will be to create a FACE web site by the end of FY00 that will allow designers and managers to design and optimize a Mars Mission with simple trajectories. The user will input:

- Crew number,
- Crew age and sex,
- Crew performance level (low, medium, or high),
- Earth launch and Mars arrival dates,
- Mars Departure date,
- Earth arrival date, and
- Material of the reference mission vehicle.

The constraint will be the lowest maximum allowable exposure for the crew specified. The output will be the minimum mass to achieve the mission and the launch and reentry C_3 (related to initial energy) values in km^2/sec^2 that will realize the inputted dates. This output data can be used to determine launch costs at Earth and Mars and the type of reentry needed at Mars and Earth. If these parameters are unachievable with current spacecraft technology, then the dates, crew makeup, or vehicle materials can be changed and the optimization rerun.

This tool can be upgraded to include other planet or planetary body destinations and trajectory solvers. The radiation analysis can be changed to accommodate any vehicle or habitat configuration. New materials can be added for a broader trade study potential. This tool is very flexible and unique since it is based on actual HZETRN executions rather than table look up of equivalent aluminum radiation dose.

6. SIREST Design and Implementation Status

A computer with a bare version of FACE installed exists behind the LaRC firewall. This computer also holds a test web site for the HZETRN transport code conversion. These sites will be released to the radiation physics community when they are finished and have passed all the validation tests. Beta testers will be chosen to help evaluate the interface. The data for the cost to risk optimization tool is being gathered and compiled into a form that is compatible with FACE. The web site should be operational before the end of fiscal year 2000. The HZETRN conversion test site is being used to determine how to implement the code in a stateless web environment. The final version of the HZETRN conversion is not expected until the end of 2000.

REFERENCES

[1] Wilson JW. Overview of Radiation Environments and Human Exposure, National Council on Radiation Protection and Measurement (NCRP) (in publication).

[2] Wilson JW et al. HZETRN: Description of a Free-Space Ion and Nucleon Transport and Shielding Computer Program NASA TP 3495, May 1995.

[3] Wilson JW et al. BRYNTRN: A Baryon Transport Model NASA TP 2887, March 1989.

[4] Waters LS Editor. MCNPX User's Manual, TPO-E83-G-UG-X-00001, Rev 0. Los Alamos National Laboratory November 1999.

[5] Goldin DS, Venneri SL, Noor SL. Ready for the Future?. Mechanical Engineering 1999: 121(11); 60-66.

[6] Goldin SL, Venneri SL, Noor AK. A New Frontier in Engineering, Mechanical Engineering 1998: 120(2); 62-69.

[7] World wide web site http://vab02.larc.nasa.gov/IDS4/docs/ overview.html and http://george.arc.nasa.gov/~sta_ids/.http://george.arc.nasa.gov/~sta_ids/