# Software

## Galactic Cosmic Ray Event-Based Risk Model (GERM) Code

This software describes the transport and energy deposition of the passage of galactic cosmic rays in astronaut tissues during space travel, or heavy ion beams in patients in cancer therapy. Space radiation risk is a probability distribution, and time-dependent biological events must be accounted for physical description of space radiation transport in tissues and cells. A stochastic model can calculate the probability density directly without unverified assumptions about shape of probability density function.

The prior art of transport codes calculates the average flux and dose of particles behind spacecraft and tissue shielding. Because of the signaling times for activation and relaxation in the cell and tissue, transport code must describe temporal and microspatial density of functions to correlate DNA and oxidative damage with non-targeted effects of signals, bystander, etc. These are absolutely ignored or impossible in the prior art.

The GERM code provides scientists data interpretation of experiments; modeling of beam line, shielding of target samples, and sample holders; and estimation of basic physical and biological outputs of their experiments. For mono-energetic ion beams, basic physical and biological properties are calculated for a selected ion type, such as kinetic energy, mass, charge number, absorbed dose, or fluence. Evaluated quantities are linear energy transfer (LET), range (R), absorption and fragmentation cross-sections, and the probability of nuclear interactions after 1 or 5 cm of water equivalent material. In addition, a set of biophysical properties is evaluated, such as the Poisson distribution for a specified cellular area, cell survival curves, and DNA damage yields per cell.

Also, the GERM code calculates the radiation transport of the beam line for either a fixed number of user-specified depths or at multiple positions along the Bragg curve of the particle in a selected material.

The GERM code makes the numerical estimates of basic physical and biophysical quantities of high-energy protons and heavy ions that have been studied at the NASA Space Radiation Laboratory (NSRL) for the purpose of simulating space radiation biological effects. In the first option, properties of mono-energetic beams are treated. In the second option, the transport of beams in different materials is treated. Similar biophysical properties as in the first option are evaluated for the primary ion and its secondary particles. Additional properties related to the nuclear fragmentation of the beam are evaluated. The GERM code is a computationally efficient Monte-Carlo heavy-ion-beam model. It includes accurate models of LET, range, residual energy, and straggling, and the quantum multiple scattering fragmentation (QMSGRG) nuclear database.

*This work was done by Francis A. Cucinotta of Johnson Space Center and Ianik Plante, Artem L. Ponomarev, and Myung-Hee Y. Kim of the Universities Space Research Association. Further information is contained in a TSP (see page 1). MSC-24760-1*

## Sasquatch Footprint Tool

The Crew Exploration Vehicle Parachute Assembly System (CPAS) is the parachute system for NASA's Orion spacecraft. The test program consists of numerous drop tests, wherein a test article rigged with parachutes is extracted or released from an aircraft. During such tests, range safety is paramount, as is the recoverability of the parachutes and test article. It is crucial to establish an aircraft release point that will ensure that the article and all items released from it will land in safe locations. A new footprint predictor tool, called Sasquatch, was created in MATLAB. This tool takes in a simulated trajectory for the test article, information about all released objects, and atmospheric wind data (simulated or actual) to calculate the trajectories of the released objects. Dispersions are applied to the landing locations of those objects, taking into account the variability of winds, aircraft release point, and object descent rate.

Sasquatch establishes a payload release point (e.g., where the payload will be extracted from the carrier aircraft) that will ensure that the payload and all objects released from it will land in a specified cleared area. The landing locations (the final points in the trajectories) are plotted on a map of the test range.

Sasquatch was originally designed for CPAS drop tests and includes extensive information about both the CPAS hardware and the primary test range used for CPAS testing. However, it can easily be adapted for more complex CPAS drop tests, other NASA projects, and commercial partners.

CPAS has developed the Sasquatch footprint tool to ensure range safety during parachute drop tests. Sasquatch is well correlated to test data and continues to ensure the safety of test personnel as well as the safe recovery of all equipment. The tool will continue to be modified based on new test data, improving predictions and providing added capability to meet the requirements of more complex testing.

*This work was done by Kristin Bledsoe of Jacobs Engineering for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-25117-1*

## Multi-User Space Link Extension (SLE) System

The Multi-User Space (MUS) Link Extension system, a software and data system, provides Space Link Extension (SLE) users with three space data transfer services in timely, complete, and offline modes as applicable according to standards defined by the Consultative Committee for Space Data Systems (CCSDS). MUS radically reduces the schedule, cost, and risk of implementing a new SLE user system, minimizes operating costs with a "lights-out" approach to SLE, and is designed to require no sustaining engineering expense during its lifetime unless changes in the CCSDS SLE standards, combined with new provider implementations, force changes.

No software modification to MUS needs to be made to support a new mission. Any systems engineer with Linux experience can begin testing SLE user service instances with MUS starting from a personal computer (PC) within five days. For flight operators, MUS provides a familiar-looking Web page for entering SLE configuration data received from SLE. Operators can also use the Web page to back up a space mission's entire set of up to approximately 500 SLE service instances in less than five seconds, or to restore or transfer from another system the same amount of data from a MUS backup file in about the same amount of time. Missions operate each MUS SLE service instance independently by sending it MUS "directives," which are legible, plain ASCII strings. MUS directives are usually (but not necessarily) sent through a TCP–IP (Transmission Control Protocol–Internet Protocol) socket from a MOC (Mission Operations Center) or POCC (Payload Operations Control Center) system, under scripted control, during "lights-out" spacecraft operation. MUS permits the flight operations team to configure independently each of its data interfaces; not only commands and telemetry, but also MUS status messages to the MOC.

Interfaces can use single- or multiple-client TCP/IP server sockets, TCP/IP client sockets, temporary disk files, the system log, or standard in, standard out, or standard error as applicable. By defining MUS templates in ASCII, the flight operations team can include any MUS system variable in telemetry or command headers or footers, and/or in status messages. Data fields can be arranged within messages in different sequences, according to the mission's needs. The only constraints imposed are on the format of MUS directive strings, and some bare-minimum logical requirements that must be met in order for MUS to read the mission control center's spacecraft command inputs. The MUS system imposes no limits or constraints on the numbers and combinations of missions and SLE service instances that it will support simultaneously. At any time, flight operators may add, change, delete, bind, connect, or disconnect.

*This work was done by Toby Perkins of Honeywell Technology Solutions Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1).* ***.*** *GSC-16091-1*