

Commercially, because it is so generic, Enigma can be used for almost any project that requires engineering visualization, model building, or animation. Models in Enigma can be exported to many other formats for use in other applications as well. Educationally, Enigma

is being used to allow university students to visualize robotic algorithms in a simulation mode before using them with actual hardware.

*This work was done by David Shores and Sharon P. Goza of Johnson Space Center; Cheyenne McKeegan, Rick Easley, Janet Way,*

*and Shonn Everett of MEI Technologies; Mark Manning of PTI; and Mark Guerra, Ray Kraesig, and William Leu of Tietronix Software, Inc. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24211-1*

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## Micrometeoroid and Orbital Debris (MMOD) Shield Ballistic Limit Analysis Program

*Lyndon B. Johnson Space Center, Houston, Texas*

This software implements penetration limit equations for common micrometeoroid and orbital debris (MMOD) shield configurations, windows, and thermal protection systems. Allowable MMOD risk is formulated in terms of the probability of penetration (PNP) of the spacecraft pressure hull.

For calculating the risk, spacecraft geometry models, mission profiles, debris environment models, and penetration limit equations for installed shielding configurations are required. Risk assess-

ment software such as NASA's BUMPER-II is used to calculate mission PNP; however, they are unsuitable for use in shield design and preliminary analysis studies.

The software defines a single equation for the design and performance evaluation of common MMOD shielding configurations, windows, and thermal protection systems, along with a description of their validity range and guidelines for their application. Recommendations are based on preliminary reviews of fundamental assumptions, and accuracy in pre-

dicting experimental impact test results.

The software is programmed in Visual Basic for Applications for installation as a simple add-in for Microsoft Excel. The user is directed to a graphical user interface (GUI) that requires user inputs and provides solutions directly in Microsoft Excel workbooks.

*This work was done by Shannon Ryan of the USRA Lunar and Planetary Institute for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24582-1*

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## Spitzer Telemetry Processing System

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The Spitzer Telemetry Processing System (SirtfTlmProc) was designed to address objectives of JPL's Multi-mission Image Processing Lab (MIPL) in processing spacecraft telemetry and distributing the resulting data to the science community. To minimize costs and maximize operability, the software design focused on automated error recovery, performance, and information management.

The system processes telemetry from the Spitzer spacecraft and delivers Level 0 products to the Spitzer Science Center. SirtfTlmProc is a unique system with automated error notification and recovery, with a real-time continuous service that can go quiescent after periods of inactivity.

The software can process 2 GB of telemetry and deliver Level 0 science products to the end user in four hours. It provides analysis tools so the operator can

manage the system and troubleshoot problems. It automates telemetry processing in order to reduce staffing costs.

*This work was done by Alice Stanboli, Elmain M. Martinez, and James M. McAuley of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.*

*This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47803.*

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## Planetary Protection Bioburden Analysis Program

*NASA's Jet Propulsion Laboratory, Pasadena, California*

This program is a Microsoft Access program that performed statistical analysis of the colony counts from assays performed on the Mars Science Laboratory (MSL) spacecraft to determine the bioburden density, 3-sigma biodensity, and the total bioburdens required for the MSL prelaunch reports. It also contains numer-

ous tools that report the data in various ways to simplify the reports required. The program performs all the calculations directly in the MS Access program. Prior to this development, the data was exported to large Excel files that had to be cut and pasted to provide the desired results. The program contains a main menu and a

number of submenus. Analyses can be performed by using either all the assays, or only the accountable assays that will be used in the final analysis.

There are three options on the first menu: either calculate using (1) the old MER (Mars Exploration Rover) statistics, (2) the MSL statistics for all the assays, or

(3) the MSL statistics for only the accountable assays. Other options on the main menu include a data editing form and utility programs that produce various reports requested by the microbiologists and the project, and tools to generate the groupings for the final analyses.

The analyses can be carried out in three ways: Each assay can be treated separately, the assays can be collectively treated for the whole zone as a group, or the assays can be collected in groups designated by the JPL Planetary Protection Manager. The latter approach was used to generate the final report because assays on the same equipment or similar

equipment can be assumed to have been exposed to the same environment and cleaning. Thus, the statistics are improved by having a larger population, thereby reducing the standard deviation by the square root of  $N$ .

For each method mentioned above, three reports are available. The first is a detailed report including all the data. This version was very useful in verifying the calculations. The second is a brief report that is similar to the full detailed report, but does not print out the data. The third is a grand total and summary report in which each assay requires only one line. For the first and second reports, most of

the calculations are performed in the report section itself. For the third, all the calculations are performed directly in the query bound to the report. All the numerical results were verified by comparing them with Excel templates, then exporting the data from the Planetary Protection Analysis program to Excel.

*This work was done by Robert A. Beaudet of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov).*

*This software is available for commercial licensing. Please contact Dan Broderick at [Daniel.F.Broderick@jpl.nasa.gov](mailto:Daniel.F.Broderick@jpl.nasa.gov). Refer to NPO-47863.*

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## Wing Leading Edge RCC Rapid Response Damage Prediction Tool (IMPACT2)

*Lyndon B. Johnson Space Center, Houston, Texas*

This rapid response computer program predicts Orbiter Wing Leading Edge (WLE) damage caused by ice or foam impact during a Space Shuttle launch (Program "IMPACT2"). The program was developed after the Columbia accident in order to assess quickly WLE damage due to ice, foam, or metal impact (if any) during a Shuttle launch. IMPACT2 simulates an impact event in a few minutes for foam impactors, and in seconds for ice and metal impactors.

The damage criterion is derived from results obtained from one sophisticated commercial program, which requires hours to carry out simulations of the

same impact events. The program was designed to run much faster than the commercial program with prediction of projectile threshold velocities within 10 to 15% of commercial-program values. The mathematical model involves coupling of Orbiter wing normal modes of vibration to nonlinear or linear spring-mass models.

IMPACT2 solves nonlinear or linear impact problems using classical normal modes of vibration of a target, and nonlinear/linear time-domain equations for the projectile. Impact loads and stresses developed in the target are computed as functions of time.

This model is novel because of its speed of execution. A typical model of foam, or other projectile characterized by material nonlinearities, impacting an RCC panel is executed in minutes instead of hours needed by the commercial programs. Target damage due to impact can be assessed quickly, provided that target vibration modes and allowable stress are known.

*This work was done by Robert Clark, Jr., Paul Cotter, and Constantine Michalopoulos of The Boeing Company for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24988-1*

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## ISSM: Ice Sheet System Model

*NASA's Jet Propulsion Laboratory, Pasadena, California*

In order to have the capability to use satellite data from its own missions to inform future sea-level rise projections, JPL needed a full-fledged ice-sheet/ice-shelf flow model, capable of modeling the mass balance of Antarctica and Greenland into the near future. ISSM was developed with such a goal in mind, as a massively parallelized, multi-purpose finite-element framework dedicated to ice-sheet modeling.

ISSM features unstructured meshes (Tria in 2D, and Penta in 3D) along with corresponding finite elements for both

types of meshes. Each finite element can carry out diagnostic, prognostic, transient, thermal 3D, surface, and bed slope simulations. Anisotropic meshing enables adaptation of meshes to a certain metric, and the 2D Shelfy-Stream, 3D Blatter/Pattyn, and 3D Full-Stokes formulations capture the bulk of the ice-flow physics. These elements can be coupled together, based on the Arlequin method, so that on a large scale model such as Antarctica, each type of finite element is used in the most efficient manner.

For each finite element referenced above, ISSM implements an adjoint. This adjoint can be used to carry out model inversions of unknown model parameters, typically ice rheology and basal drag at the ice/bedrock interface, using a metric such as the observed InSAR surface velocity. This data assimilation capability is crucial to allow spinning up of ice flow models using available satellite data.

ISSM relies on the PETSc library for its vectors, matrices, and solvers. This allows ISSM to run efficiently on any parallel platform, whether shared or distrib-