

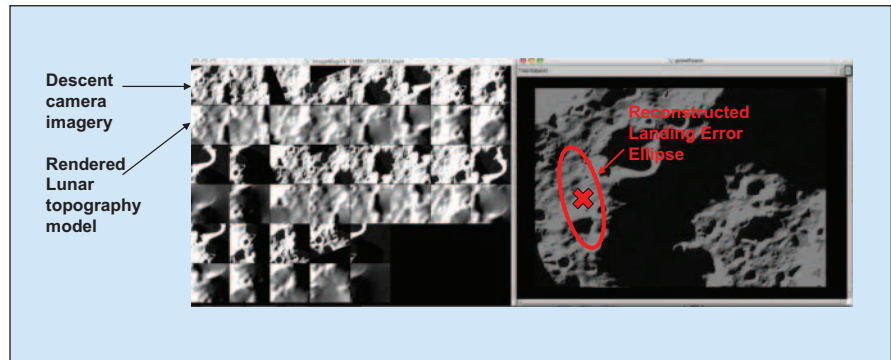


## Covariance Analysis Tool (G-CAT) for Computing Ascent, Descent, and Landing Errors

NASA's Jet Propulsion Laboratory, Pasadena, California

G-CAT is a covariance analysis tool that enables fast and accurate computation of error ellipses for descent, landing, ascent, and rendezvous scenarios, and quantifies knowledge error contributions needed for error budgeting purposes. Because G-CAT supports hardware/system trade studies in spacecraft and mission design, it is useful in both early and late mission/proposal phases where Monte Carlo simulation capability is not mature, Monte Carlo simulation takes too long to run, and/or there is a need to perform multiple parametric system design trades that would require an unwieldy number of Monte Carlo runs.

G-CAT is formulated as a variable-order square-root linearized Kalman filter (LKF), typically using over 120 filter states. An important property of G-CAT is that it is based on a 6-DOF (degrees of freedom) formulation that completely captures the combined effects of both attitude and translation errors on the propagated trajectories. This ensures its accuracy for guidance, navigation, and control (GN&C) analysis. G-CAT provides the desired fast turnaround analysis needed for error budgeting in support of mission concept formulations, design trade studies, and proposal development efforts.



Landing Site Reconstruction based on descent camera imagery. Copyright 2010 California Institute of Technology. Government sponsorship acknowledged.

The main usefulness of a covariance analysis tool such as G-CAT is its ability to calculate the performance envelope directly from a single run. This is in sharp contrast to running thousands of simulations to obtain similar information using Monte Carlo methods. It does this by propagating the "statistics" of the overall design, rather than simulating individual trajectories.

G-CAT supports applications to lunar, planetary, and small body missions. It characterizes onboard knowledge propagation errors associated with inertial measurement unit (IMU) errors (gyro

and accelerometer), gravity errors/dispersions (spherical harmonics, mass-cons), and radar errors (multiple altimeter beams, multiple Doppler velocimeter beams). G-CAT is a standalone MATLAB-based tool intended to run on any engineer's desktop computer.

*This work was done by Dhemetrios Bousalis and David S. Bayard of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47854.*

## Enigma Version 12

Lyndon B. Johnson Space Center, Houston, Texas

Enigma Version 12 software combines model building, animation, and engineering visualization into one concise software package. Enigma employs a versatile user interface to allow average users access to even the most complex pieces of the application. Using Enigma eliminates the need to buy and learn several software packages to create an engineering visualization. Models can be created and/or modified within Enigma down to the polygon level. Textures and materials can be applied for additional

realism. Within Enigma, these models can be combined to create systems of models that have a hierarchical relationship to one another, such as a robotic arm. Then these systems can be animated within the program or controlled by an external application programming interface (API). In addition, Enigma provides the ability to use plug-ins. Plug-ins allow the user to create custom code for a specific application and access the Enigma model and system data, but still use the Enigma drawing functionality.

CAD files can be imported into Enigma and combined to create systems of computer graphics models that can be manipulated with constraints. An API is available so that an engineer can write a simulation and drive the computer graphics models with no knowledge of computer graphics. An animation editor allows an engineer to set up sequences of animations generated by simulations or by conceptual trajectories in order to record these to high-quality media for presentation.

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