

(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.

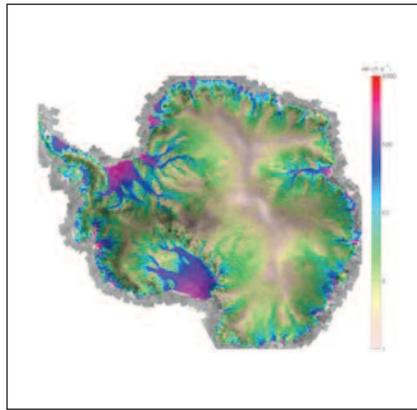
For each finite element referenced above, ISSM implements an adjoint. This adjoint can be used to carry out model inversions of unknown model parameters, typically ice rheology and basal drag at the ice/bedrock interface, using a metric such as the observed InSAR surface velocity. This data assimilation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

uted. It can run on the largest clusters, and is fully scalable. This allows ISSM to tackle models the size of continents.

ISSM is embedded into MATLAB and Python, both open scientific platforms. This improves its outreach within the science community. It is entirely written in C/C++, which gives it flexibility in its design, and the power/speed that C/C++ allows. ISSM is svn (subversion) hosted, on a JPL repository, to facilitate its development and maintenance.

ISSM can also model propagation of rifts using contact mechanics and mesh splitting, and can interface to the Dakota software. To carry out sensitivity analysis,



Modeled Antarctic Surface Velocity using ISSM.

mesh partitioning algorithms are available, based on the Scotch, Chaco, and Metis partitioners that ensure equal area mesh partitions can be done, which are then usable for sampling and local reliability methods.

*This work was done by Eric Larour and John E. Schiermeier of Caltech, and Helene Seroussi and Mathieu Morlinghem of Ecole Centrale Paris for NASA's Jet Propulsion Laboratory. For more information, see <http://issm.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-48164.*

## Automated Loads Analysis System (ATLAS)

Lyndon B. Johnson Space Center, Houston, Texas

ATLAS is a generalized solution that can be used for launch vehicles. ATLAS is used to produce modal transient analysis and quasi-static analysis results (i.e., accelerations, displacements, and forces) for the payload math models on a specific Shuttle Transport System (STS) flight

using the shuttle math model and associated forcing functions. This innovation solves the problem of coupling of payload math models into a shuttle math model. It performs a transient loads analysis simulating liftoff, landing, and all flight events between liftoff and landing.

ATLAS utilizes efficient and numerically stable algorithms available in MSC/NASTRAN.

*This work was done by Stephen Gardner, Scot Frere, and Patrick O'Reilly of The Boeing Company for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24987-1*

## Integrated Main Propulsion System Performance Reconstruction Process/Models

Lyndon B. Johnson Space Center, Houston, Texas

The Integrated Main Propulsion System (MPS) Performance Reconstruction process provides the MPS post-flight data files needed for post-flight reporting to the project integration management and key customers to verify flight performance. This process/model was used as the baseline for the currently ongoing Space Launch System (SLS) work.

The process utilizes several methodologies, including multiple software programs, to model integrated propulsion system performance through space shuttle ascent. It is used to evaluate integrated propulsion systems, including propellant tanks, feed systems, rocket engine, and pressurization systems performance throughout ascent based on flight pressure and temperature data. The latest re-

vision incorporates new methods based on main engine power balance model updates to model higher mixture ratio operation at lower engine power levels.

*This work was done by Eduardo Lopez, Katie Elliott, Steven Snell, and Michael Evans of The Boeing Company for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-25066-1*

## Phoenix Telemetry Processor

NASA's Jet Propulsion Laboratory, Pasadena, California

Phxtelemproc is a C/C++ based telemetry processing program that processes SFDU telemetry packets from the Telemetry Data System (TDS). It generates Experiment Data Records (EDRs) for several instruments includ-

ing surface stereo imager (SSI); robotic arm camera (RAC); robotic arm (RA); microscopy, electrochemistry, and conductivity analyzer (MECA); and the optical microscope (OM). It processes both uncompressed and compressed teleme-

try, and incorporates unique subroutines for the following compression algorithms: JPEG Arithmetic, JPEG Huffman, Rice, LUT3, RA, and SX4.

This program was in the critical path for the daily command cycle of the