(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.

# 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.

# ISSM: Ice Sheet System Model

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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-