Information Technology

Automated 3D Damaged Cavity Model Builder for Lower Surface Acreage Tile on Orbiter

The principles may be applicable to commercial space vehicles.

Lyndon B. Johnson Space Center, Houston, Texas

The 3D Automated Thermal Tool for Damaged Acreage Tile Math Model builder was developed to perform quickly and accurately 3D thermal analyses on damaged lower surface acreage tiles and structures beneath the damaged locations on a Space Shuttle Orbiter. The 3D model builder created both TRASYS geometric math models (GMMs) and SINDA thermal math models (TMMs) to simulate an idealized damaged cavity in the damaged tile(s). The GMMs are processed in TRASYS to generate radiation conductors between the surfaces in the cavity. The radiation conductors are inserted into the TMMs, which are processed in SINDA to generate temperature histories for all of the nodes on each layer of the TMM.

The invention allows a thermal analyst to create quickly and accurately a 3D model of a damaged lower surface tile on the orbiter. The 3D model builder can generate a GMM and the corresponding TMM in one or two minutes, with the damaged cavity included in the tile material. A separate program creates a configuration file, which would take a couple of minutes to edit. This configuration file is read by the model builder program to determine the location of the damage, the correct tile type, tile thickness, structure thickness, and SIP thickness of the damage, so that the model builder program can build an accurate model at the specified location. Once the models are built, they are processed by the TRASYS and SINDA.

Before the existence of this automated process, a thermal analyst would manually build a 2D or 3D damaged tile model or modify an existing model by hand. However, existing models that are available only cover a portion of the lower surface of the orbiter, and the 2D models cannot be used to calculate realistic thermal gradients in the structure layer. If an existing model for the damaged location is available, the thermal analyst would make manual edits to the model, removing or modifying the nodes in the model to simulate the damaged cavity. The model may require additional modifications if the simulated location was built with the incorrect tile thickness, tile type, or structure thickness. In addition, if the cavity in the model required heating augmentation factors, the factors would have to be manually added to the model. These manual processes can be very time consuming and prone to editing errors.

The automation of the damaged cavity model, GMM, and TMM allows the thermal analyst to build thousands of models with varying cavity dimensions at various locations on the bottom of the orbiter. The results from all the model runs were merged into a set of damage tolerance maps that allows trained personnel to quickly screen a damaged cavity found in the on-orbit photos to see if the damage site required additional analysis. Although the system is specific to the Space Shuttle Orbiter in its current configuration, it is able to be re-programmed to support any commercial space vehicle that uses tiles as part of its external surface.

This work was done by Shannon Belknap and Michael Zhang of The Boeing Company for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-25177-1

Mixed Linear/Square-Root Encoded Single-Slope Ramp Provides Low-Noise ADC With High Linearity for Focal Plane Arrays

This technique is applicable to all scientific imagers and could be used by commercial camera vendors.

NASA's Jet Propulsion Laboratory, Pasadena, California

Single-slope analog-to-digital converters (ADCs) are particularly useful for on-chip digitization in focal plane arrays (FPAs) because of their inherent monotonicity, relative simplicity, and efficiency for column-parallel applications, but they are comparatively slow. Square-root encoding can allow the number of code values to be reduced without loss of signal-to-noise ratio (SNR) by keeping the quantization noise just below the signal shot noise. This encoding can be implemented directly by using a quadratic ramp. The reduction in the number of code values can substantially increase the quantization speed. However, in an FPA, the fixed pattern noise (FPN) limits the use of small quantization steps at low signal levels. If the zero-point is adjusted so that the lowest column is on-scale, the other columns, including those at the center of the distribution, will be pushed up the ramp where the quantization noise is higher.

Additionally, the finite frequency response of the ramp buffer amplifier and the comparator distort the shape of the ramp, so that the effective ramp value at the time the comparator trips differs from the intended value, resulting in errors. Allowing increased settling time decreases the quantization speed, while increasing the bandwidth increases the noise.

The FPN problem is solved by breaking the ramp into two portions, with some fraction of the available code values allocated to a linear ramp and the remainder to a quadratic ramp. To avoid large transients, both the value and the slope of the linear and quadratic portions should be equal where they join. The span of the linear portion must cover the minimum offset, but not necessarily the maximum, since the fraction of the pixels above the upper limit will still be correctly quantized, albeit with increased quantization noise. The required linear span, maximum signal and ratio of quantization noise to shot noise at high signal, along with the continuity requirement, determines the number of code values that must be allocated to each portion.

The distortion problem is solved by using a lookup table to convert captured code values back to signal levels. The values in this table will be similar to the intended ramp value, but with a correction for the finite bandwidth effects.

Continuous-time comparators are used, and their bandwidth is set below the step rate, which smoothes the ramp and reduces the noise. No settling time is needed, as would be the case for clocked comparators, but the low bandwidth enhances the distortion of the non-linear portion. This is corrected by use of a return lookup table, which differs from the one used to generate the ramp. The return lookup table is obtained by calibrating against a stepped precision DC reference. This results in a residual non-linearity well below the quantization noise. This method can also compensate for differential non-linearity (DNL) in the DAC used to generate the ramp.

The use of a ramp with a combination of linear and quadratic portions for a single-slope ADC is novel. The number of steps is minimized by keeping the step size just below the photon shot noise. This in turn maximizes the speed of the conversion. High resolution is maintained by keeping small quantization steps at low signals, and noise is minimized by allowing the lowest analog bandwidth, all without increasing the quantization noise. A calibrated return lookup table allows the system to maintain excellent linearity.

This work was done by Chris J. Wrigley, Bruce R. Hancock, Kenneth W. Newton, and Thomas J. Cunningham of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-47836, volume and number of this NASA Tech Briefs *issue, and the page number.*

RUSHMAPS: Real-time Uploadable Spherical Harmonic Moment Analysis for Particle Spectrometers

High-performing hybrid systems embed unprecedented amounts of onboard processing power.

Goddard Space Flight Center, Greenbelt, Maryland

RUSHMAPS is a new onboard data reduction scheme that gives real-time access to key science parameters (e.g. moments) of a class of heliophysics science and/or solar system exploration investigation that includes plasma particle spectrometers (PPS), but requires moments reporting (density, bulk-velocity, temperature, pressure, etc.) of higher-level quality, and tolerates a low-pass (variable quality) spectral representation of the corresponding particle velocity distributions, such that telemetry use is minimized. The proposed methodology trades access to the full-resolution velocity distribution data, saving on telemetry, for real-time access to both the moments and an adjustable-quality (increasing quality increases volume) spectral representation of distribution functions.

Traditional onboard data storage and downlink bandwidth constraints severely limit PPS system functionality and drive cost, which, as a consequence, drives a limited data collection and lower angular energy and time resolution. This prototypical system exploit, using high-performance processing technology at GSFC (Goddard Space Flight Center), uses a SpaceCube and/or Maestro-type platform for processing. These processing platforms are currently being used on the International Space Station as a technology demonstration, and work is currently ongoing in a new onboard computation system for the Earth Science missions, but they have never been implemented in heliospheric science or solar system exploration missions.

Preliminary analysis confirms that the targeted processor platforms possess the processing resources required for real-time application of these algorithms to the spectrometer data. SpaceCube platforms demonstrate that the target architecture possesses the sort of compact, low-mass/power, radiation-tolerant characteristics needed for flight. These high-performing hybrid systems embed unprecedented amounts of onboard processing power in the CPU (central processing unit), FPGAs (field programmable gate arrays), and DSP (digital signal processing) elements. The fundamental computational algorithm deconstructs 3D velocity distributions in terms of spherical harmonic spectral coefficients (which are analogous to a Fourier sine-cosine decomposition), but uses instead spherical harmonics Legendre polynomial orthogonal functions as a basis for the expansion, portraying each 2D angular distribution at every energy or, geometrically, spherical speed-shell swept by the particle spectrometer. Optionally, these spherical harmonic spectral coefficients may be telemetered to the ground. These will provide a smoothed description of the velocity distribution function whose quality will depend on the number of coefficients determined.

Successfully implemented on the GSFC-developed processor, the capabil-