

input(s) to a system and the resultant output(s) in real time or a posteriori, or from software-generated data sets, were presented to the system, which generated outputs. Once a system is learned, the coefficients and constants can be

frozen and the algorithm embedded in an application.

*This work was done by Michael J. Krasowski and Norman F. Prokop of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18887-1.*

## ➤ Kalman Filter Input Processor for Boresight Calibration

**The new software brings this technology to the industrial level.**

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

Ka-band ranging provides the phase center (PC) to phase center range, which needs to be converted to the center of mass (CM) to center of mass range. Nominally, both PC and CM lie on the line connecting the spacecraft GRAIL A and GRAIL B. In this case, the conversion should be done simply by adding the CM-to-PC distance  $L$  to the measured range for both spacecraft. However, due to various technical reasons, such as displacement of the true CM from its nominal position in the SRF, or spacecraft attitude fluctuations, the PC and CM define a unit vector that may be different from the nominal line of sight. The objectives of the software are to determine the actual line of sight direction for each spacecraft and correct the previously recorded range data, and to provide instructions for how to ma-

neuver each spacecraft to make necessary attitude corrections.

While elements of this approach have been used for the boresight calibration in the GRACE project, the new software brings this technology to the industrial level. It is now fully documented and can be used by people other than its developers. This innovation provides graphic outputs and log files that are critical for quick analysis and troubleshooting. In addition to the line of sight direction, the software allows one to evaluate the CM-PC base length, which is important when the PM location is subject to variations (e.g., due to fuel depletion).

This software is implemented in Python and offers excellent cross-platform porting possibilities. It is very versatile, and may be applied under various circumstances and for other related pur-

poses. This innovation is capable of combining the input data from several calibration maneuvers, evaluating individual range biases, and compressing the time stamps. It uses Lagrange interpolation for the orbit data, and a unique quaternion-interpolating algorithm for interpolating the attitude data. As a result, data files with different data rates and independent time stamps can be handled together.

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*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-48479.*

## ➤ Organizing Compression of Hyperspectral Imagery to Allow Efficient Parallel Decompression

**Higher compression factors can be attained.**

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

A family of schemes has been devised for organizing the output of an algorithm for predictive data compression of hyperspectral imagery so as to allow efficient parallelization in both the compressor and decompressor. In these schemes, the compressor performs a number of iterations, during each of which a portion of the data is compressed via parallel threads operating on independent portions of the data. The general idea is that for each iteration it is predetermined how much compressed data will be produced from each thread.

A simple version of this technique is applicable when the image is divided into "pieces" that are compressed inde-

pendently. As an example, for a compressor that does not make use of inter-band correlation, a piece could be defined to be an individual spectral band, or a fixed number of bands. In the technique, the compressed output for a piece is comprised of multiple "chunks." The concatenated chunks for a given piece form the compressed output for the piece. Most of the compressed image is produced in multiple iterations, where during a given iteration, one chunk is produced for each piece. Prior to the start of an iteration, chunk sizes are calculated for each piece. The chunks can be produced or decompressed in parallel. It is noted that it is not specified how

much of the image data will go into a chunk, and in fact a chunk may contain incomplete portions of encoded samples (at the chunk's start or end). The compressor iterates the process of deciding on chunk sizes and producing chunks for each piece of the requested size, until compression of each piece is almost finished. At that point, the remainder of the pieces is compressed serially without a target chunk size.

Typically, the chunk size calculation should seek to balance the progress through each piece, i.e., to leave equal numbers of samples remaining in each piece; a suggested procedure has this aim. A key requirement on the chunk

size calculation is that reasonable chunk sizes must be decided on based only on information from the compressed data available at a given point in the process. Similarly, from previous data, it must be possible to evaluate when to switch from the parallel chunk compression to the

serial process that completes compression of each piece.

A more general technique accommodates pieces that are not compressed independently, allowing compressors such as the Fast Lossless (FL) to more fully exploit dependencies between spectral

bands, which generally allows a higher compression factor to be achieved.

*This work was done by Matthew A. Klimesh and Aaron B. Kiely of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48521*

## Temperature Dependences of Mechanisms Responsible for the Water-Vapor Continuum Absorption

Results can be used to develop better empirical models.

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The water-vapor continuum absorption plays an important role in the radiative balance in the Earth's atmosphere. It has been experimentally shown that for ambient atmospheric conditions, the continuum absorption scales quadratically with the H<sub>2</sub>O number density and has a strong, negative temperature dependence (T dependence). Over the years, there have been three different theoretical mechanisms postulated: far-wings of allowed transition lines, water dimers, and collision-induced absorption. The first mechanism proposed was the accumulation of absorptions from the far-wings of the strong allowed transition lines. Later, absorption by water dimers was proposed, and this mechanism provides a qualitative explanation for the continuum characters mentioned above. Despite the improvements in experimental data, at present there is no consensus on which mechanism is primarily responsible for the continuum absorption.

Because all three mechanisms scale as the square of the H<sub>2</sub>O monomer number density, one way to discriminate between the mechanisms is by their T dependences. This work involved a

detailed study of the T dependence of the continuum absorption based on the far-wing theory. Because the calculated absorption coefficients, especially their T dependences, match the new NIST measurements very well, one can conclude that in the 800 to 1,150 cm<sup>-1</sup> region, contributions from far-wings of allowed H<sub>2</sub>O lines are the dominant source responsible for the continuum.

Although all three mechanisms have a negative T dependence, their T dependences would be characterized by individual features. To analyze the characteristics of the latter will enable one to assess their roles with more certainty. The dimer spectra exhibit a very strong negative T dependence, the far-wing theory exhibits a moderately strong negative one, and the collision-induced absorption has a weak and mainly negative T dependence. In addition, these three have quite different T dependence patterns, i.e., the strength of its T dependence varies differently as the frequency of interest varies.

The far-wing theory exhibits the most complex T dependence pattern and it could vary significantly as the frequency

of interest varies. On the other hand, the collision-induced absorption spectra exhibit a systematic T dependence with frequency. Finally, the pattern of the T dependence of the dimer absorption is rather simpler. By comparing theoretical calculations from the far-wing theory with the most recent and accurate experimental data at different temperatures ranging from 310.8 to 363.6 K in the infrared windows, it was found that theoretical results agree very well with measurements in the 800 to 1,200 cm<sup>-1</sup> region. Meanwhile, the new measurements show that at room temperature, the continuum data are in reasonable agreement with the widely used semi-empirical MT\_CKD continuum model, but at higher temperatures, the MT\_CKD model provides very low values, up to 50% less than those experimentally measured. This indicates that the T dependence exhibited in the current MT\_CKD model is not correct, and this model has to be modified.

*This work was done by Qiancheng Ma of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16075-1*