the plasmon resonances of the SERS. Conversely, the plasmon of the SERS substrate could be tailored so that its resonance would lie in the charge-transfer energy band of the R-T complex. In addition to the aforesaid factor-of-10^8 SERS enhancement, there would be an additional enhancement, by a factor of the order of 10^3 to 10^6, contributed by the vibronic energy levels associated with the charge transfer.

With this further enhancement, the detection principle is a form of surface enhanced resonance Raman scattering (SERRS) spectroscopy. The resulting Raman spectrum would consist of a mixture of SERS vibrational peaks from R and T as well more intense SERRS peaks associated with R and T modes that participate in the charge transfer. These strong charge-transfer peaks would enable discrimination of important target molecules from interferants that may also be SERS-active. The sensor/molecule system as described thus far would potentially be reversible in the sense that the R-T interactions could be turned off by applying a bias voltage to electrochemically reduce T to T-. Because T- would no longer have an affinity for R, T could be easily washed away.

This work was done by Eric Wong of Caltech, Amar Flood of the Indiana University Bloomington, and Alfredo Morales of Sandia National Laboratories for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
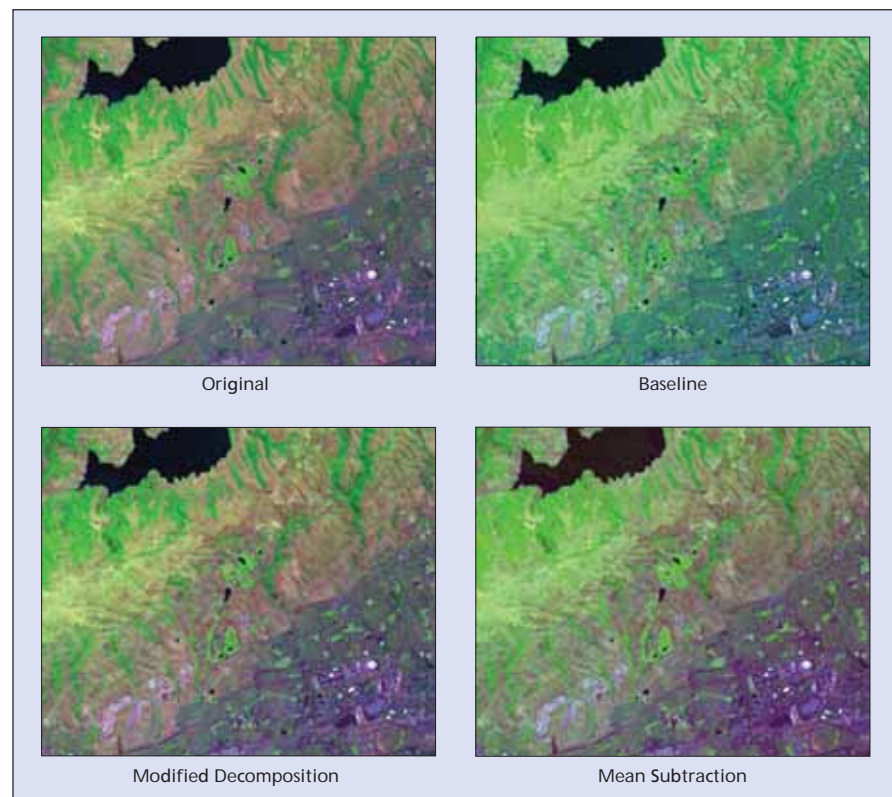
Improving 3D Wavelet-Based Compression of Hyperspectral Images
Detrimental effects of spectral ringing are reduced or eliminated.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two methods of increasing the effectiveness of three-dimensional (3D) wavelet-based compression of hyperspectral images have been developed. (As used here, "images" signifies both images and digital data representing images.) The methods are oriented toward reducing or eliminating detrimental effects of a phenomenon, referred to as spectral ringing, that is described below.

In 3D wavelet-based compression, an image is represented by a multiresolution wavelet decomposition consisting of several subbands obtained by applying wavelet transforms in the two spatial dimensions corresponding to the two spatial coordinate axes of the image plane, and by applying wavelet transforms in the spectral dimension. Spectral ringing is named after the more familiar spatial ringing (spurious spatial oscillations) that can be seen parallel to and near edges in ordinary images reconstructed from compressed data. These ringing phenomena are attributable to effects of quantization. In hyperspectral data, the individual spectral bands play the role of edges, causing spurious oscillations to occur in the spectral dimension. In the absence of such corrective measures as the present two methods, spectral ringing can manifest itself as systematic biases in some reconstructed spectral bands and can reduce the effectiveness of compression of spatially-low-pass subbands.

One of the two methods is denoted mean subtraction. The basic idea of this method is to subtract mean values from spatial planes of spatially low-pass subbands prior to encoding, because (a) such spatial planes often have mean values that are far from zero and (b) zero-mean data are better suited for compression by methods that are effective for subbands of two-dimensional (2D) images. In this method, after the 3D wavelet decomposition is performed, mean values are computed for and subtracted from each spatial plane of each

These false-color **Images of Terrain** at Moffett Field, California include an original image formed from three spectral bands and three different similarly-formed versions as reconstructed after 3D wavelet-based compression of the original image to 0.1 bits/sample.

spatially-low-pass subband. The resulting data are converted to sign-magnitude form and compressed in a manner similar to that of a baseline hyperspectral-image-compression method. The mean values are encoded in the compressed bit stream and added back to the data at the appropriate decompression step. The overhead incurred by encoding the mean values — only a few bits per spectral band — is negligible with respect to the huge size of a typical hyperspectral data set.

The other method is denoted modified decomposition. This method is so named because it involves a modified version of a commonly used multiresolution wavelet decomposition, known in the art as the 3D Mallat decomposition, in which (a) the first of multiple stages of a 3D wavelet transform is applied to the entire dataset and (b) subsequent stages are applied only to the horizontally-, vertically-, and spectrally-low-pass subband from the preceding stage. In the modified decomposition, in stages after the first, not only is the spatially-low-pass, spectrally-low-pass subband further decomposed, but also spatially-low-pass, spectrally-high-pass subbands are further decomposed spatially.

Either method can be used alone to improve the quality of a reconstructed image (see figure). Alternatively, the two methods can be combined by first performing modified decomposition, then subtracting the mean values from spatial planes of spatially-low-pass subbands.

Improved Signal Chains for Readout of CMOS Imagers

Two major imitations of prior readout signal chains are overcome.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved generic design has been devised for implementing signal chains involved in readout from complementary metal oxide/semiconductor (CMOS) image sensors and for other readout integrated circuits (ICs) that perform equivalent functions. The design applies to any such IC in which output signal charges from the pixels in a given row are transferred simultaneously into sampling capacitors at the bottoms of the columns, then voltages representing individual pixel charges are read out in sequence by sequentially turning on column-selecting field-effect transistors (FETs) in synchronism with source-follower- or operational-amplifier-based amplifier circuits.
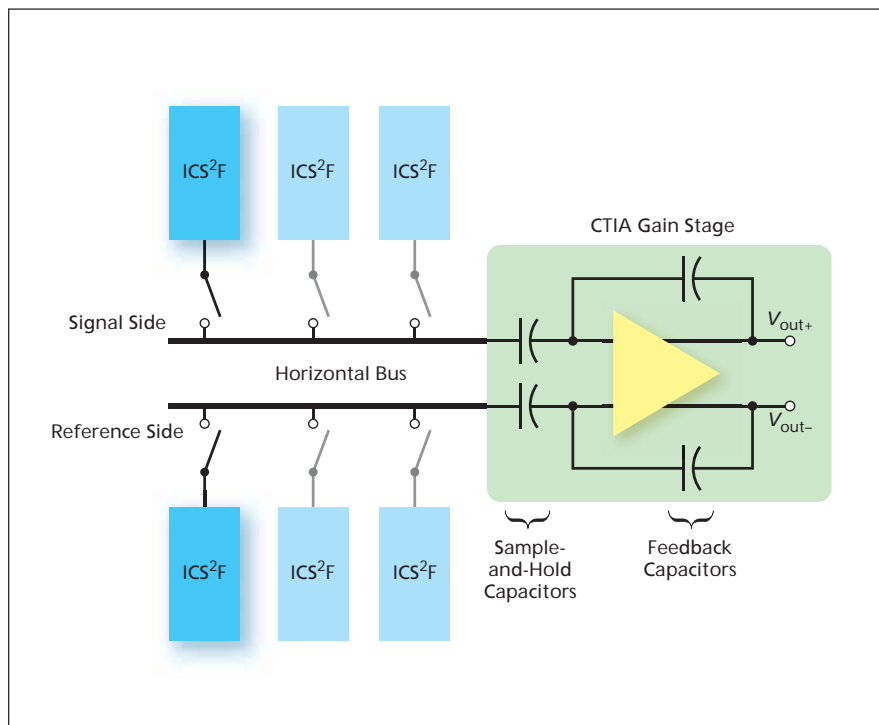
The improved design affords the best features of prior source-follower-and operational-amplifier-based designs while overcoming the major limitations of those designs. The limitations can be summarized as follows:

• For a source-follower-based signal chain, the ohmic voltage drop associated with DC bias current flowing through the column-selection FET causes unacceptable voltage offset, nonlinearity, and reduced small-signal gain.

• For an operational-amplifier-based signal chain, the required bias current and the output noise increase superlinearly with size of the pixel array because of a corresponding increase in the effective capacitance of the row bus used to couple the sampled column charges to the operational amplifier. The effect of the bus capacitance is to simultaneously slow down the readout circuit and increase noise through the Miller effect.

The improved design (see figure) provides a switched source follower in each column, one each for the signal and reference samples [denoted an in-column switched source follower (ICS²F)], followed by a single capacitive transimpedance amplifier (CTIA) gain stage. The ICS²F consists of a different configuration of the column-selecting FET such that no DC bias current flows through it, and hence, without the associated ohmic voltage drop. Unlike in a prior operational-amplifier-based design involving direct connection of the sample and hold capacitors to the row-bus, the input terminals of the amplifier present CTIA gain stage are not in direct contact with the bus and, therefore, this stage produces voltage gain without the bandwidth reduction and noise multiplication that is caused by the Miller effect. Secondly, as a result of using ICS²Fs, the bus carries a predominantly voltage signal, (as opposed to a predominantly

The **Improved Design** affords the best features of prior source-follower and operational-amplifier designs.