Lightweight, Miniature Inertial Measurement System
Goddard Space Flight Center, Greenbelt, Maryland

A miniature, lighter-weight, and highly accurate inertial navigation system (INS) is coupled with GPS receivers to provide stable and highly accurate positioning, attitude, and inertial measurements while being subjected to highly dynamic maneuvers. In contrast to conventional methods that use expensive, ground-based, real-time tracking and control units that are expensive, large, and require excessive amounts of power to operate, this method focuses on the development of an estimator that makes use of a low-cost, miniature accelerometer array fused with traditional measurement systems and GPS. Through the use of a position tracking estimation algorithm, onboard accelerometers are numerically integrated and transformed using attitude information to obtain an estimate of position in the inertial frame. Position and velocity estimates are subject to drift due to accelerometer sensor bias and high vibration over time, and so require the integration with GPS information using a Kalman filter to provide highly accurate and reliable inertial tracking estimations.

The method implemented here uses the local gravitational field vector. Upon determining the location of the local gravitational field vector relative to two consecutive sensors, the orientation of the device may then be estimated, and the attitude determined. Improved attitude estimates further enhance the inertial position estimates. The device can be powered either by batteries, or by the power source onboard its target platforms. A DB9 port provides the I/O to external systems, and the device is designed to be mounted in a waterproof case for all-weather conditions.

This work was done by Liang Tang of Impact Technologies and Agamemnon Crassidis of the Rochester Institute of Technology for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16132-1

Optical Density Analysis of X-Rays Utilizing Calibration Tooling to Estimate Thickness of Parts
This method uses off-the-shelf data analysis software and a digitized x-ray for nondestructive testing.
John F. Kennedy Space Center, Florida

This process is designed to estimate the thickness change of a material through data analysis of a digitized version of an x-ray (or a digital x-ray) containing the material (with the thickness in question) and various tooling. Using this process, it is possible to estimate a material’s thickness change in a region of the material or part that is thinner than the rest of the reference thickness. However, that same principle process can be used to determine the thickness change of material using a thinner region to determine thickening, or it can be used to develop contour plots of an entire part.

Proper tooling must be used. An x-ray film with an S-shaped characteristic curve or a digital x-ray device with a product resulting in like characteristics is necessary. If a film exists with linear...
characteristics, this type of film would be ideal; however, at the time of this reporting, no such film has been known. Machined components (with known fractional thicknesses) of a like material (similar density) to that of the material to be measured are necessary.

The machined components should have machined through-holes. For ease of use and better accuracy, the through-holes should be a size larger than 0.125 in. (=3 mm). Standard components for this use are known as penetrators or image quality indicators. Also needed is standard x-ray equipment, if film is used in place of digital equipment, or x-ray digitization equipment with proven conversion properties. Typical x-ray digitization equipment is commonly used in the medical industry, and creates digital images of x-rays in DICOM format. It is recommended to scan the image in a 16-bit format. However, 12-bit and 8-bit resolutions are acceptable. Finally, x-ray analysis software that allows accurate digital image density calculations, such as ImageJ freeware, is needed.

The actual procedure requires the test article to be placed on the raw x-ray, ensuring the region of interest is aligned for perpendicular x-ray exposure capture. One or multiple machined components of like material/density with known thicknesses are placed atop the part (preferably in a region of nominal and non-varying thickness) such that exposure of the combined part and machined component lay-up is captured on the x-ray. Depending on the accuracy required, the machined component’s thickness must be carefully chosen. Similarly, depending on the accuracy required, the lay-up must be exposed such that the regions of the x-ray to be analyzed have a density range between 1 and 4.5. After the exposure, the image is digitized, and the digital image can then be analyzed using the image analysis software.

This work was done by David Grau of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13206

Fuel Cell/Electrochemical Cell Voltage Monitor
Lyndon B. Johnson Space Center, Houston, Texas

A concept has been developed for a new fuel cell individual-cell-voltage monitor that can be directly connected to a multi-cell fuel cell stack for direct sub-stack power provisioning. It can also provide voltage isolation for applications in high-voltage fuel cell stacks. The technology consists of basic modules, each with an 8- to 16-cell input electrical measurement connection port. For each basic module, a power input connection would be provided for direct connection to a sub-stack of fuel cells in series within the larger stack. This power connection would allow for module power to be available in the range of 9-15 volts DC. The relatively low voltage differences that the module would encounter from the input electrical measurement connection port, coupled with the fact that the module’s operating power is supplied by the same substack voltage input (and so will be at similar voltage), provides for elimination of high-common-mode voltage issues within each module. Within each module, there would be options for analog-to-digital conversion and data transfer schemes.

Each module would also include a data-output/communication port. Each of these ports would be required to be either non-electrical (e.g., optically isolated) or electrically isolated. This is necessary to account for the fact that the plurality of modules attached to the stack will normally be at a range of voltages approaching the full range of the fuel cell stack operating voltages. A communications/data bus could interface with the several basic modules. Options have been identified for command inputs from the spacecraft vehicle controller, and for output-status/data feeds to the vehicle.

This work was done by Arturo Vasquez of Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24592-1

Anomaly Detection Techniques With Real Test Data From a Spinning Turbine Engine-Like Rotor
These techniques are suitable for engine manufacturers and industries in aerospace and aviation.
John H. Glenn Research Center, Cleveland, Ohio

Online detection techniques to monitor the health of rotating engine components are becoming increasingly attractive to aircraft engine manufacturers in order to increase safety of operation and lower maintenance costs. Health monitoring remains a challenge to easily implement, especially in the presence of scattered loading conditions, crack size, component geometry, and materials properties. The current trend, however, is to utilize non-invasive types of health monitoring or nondestructive techniques to detect hidden flaws and mini-cracks before any catastrophic event occurs. These techniques go further to evaluate material discontinuities and other anomalies that have grown to the level of critical defects that can lead to failure. Generally, health monitoring is highly dependent on sensor systems capable of performing in various engine environmental conditions and able to transmit a signal upon a predetermined crack length, while acting in a neutral form upon the overall performance of the engine system.

Spin simulation tests were conducted on a turbine engine-like rotor with and