At low SNR, the receiver symbol synchronization loop will be increasingly sensitive to transmitter timing jitter. Excessive timing jitter can cause bit slips in the receiver synchronization loop, which will in turn cause frame losses and potentially lead to receiver and/or decoder loss-of-lock. Therefore, it is necessary to investigate what symbol timing jitter requirements on the satellite transmitter are needed to support the next generation of NASA coded modulation techniques.

Measurements of ground segment receiver sensitivity to transmitter bit jitter were conducted using a satellite transponder and two different commercial staggered quadrature phase-shift keying (SQPSK) receivers. The symbol synchronization loop transfer functions were characterized for each receiver. Symbol timing jitter was introduced at the transmitter. Effects of sinusoidal (tone) jitter on symbol error rate (SER) degradation and symbol slip probability were measured. These measurements were used to define regions of sensitivity to phase, frequency, and cycle-to-cycle jitter characterizations. An assortment of other band-limited jitter waveforms was then applied within each region to identify peak or root-mean-square measures as a basis for comparability.

Receiver clock recovery loops that operate in low SNR ratio environments require that transmit clock jitter be constrained by several measures on different dimensions and operating regions. In this work, effects of transmit phase jitter (PhJ), frequency jitter (fJ), and cycle-to-cycle jitter (CCJ) were studied for sinusoidal and multi-tone jitter profiles on receiver performance. It was demonstrated that the receiver must have a loop bandwidth tight enough to avoid cycle slips, but loose enough to track some movement in the data signal. Movement that a tight loop cannot track is usually manifested first as intersymbol interference (ISI) (SER degradation) and then ultimately as cycle slipping in the receiver.

Results from the tests indicate that the receiver symbol synchronization loop is more sensitive to certain types of symbol jitter and jitter frequencies, depending on the selection of the loop filter and damping ratio. A framework is provided to properly compose a transmit jitter mask depending on receiver design parameters such as damping ratio in order to limit receiver performance degradation at low SNR regions.

This work was done by Chatwin Lansdowne and Adam Schlesinger of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24810-1

#### 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

**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 report-
ing, no such film has been known. Ma-
chined components (with known frac-
tional 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 penetrameters 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 con-
version properties. Typical x-ray digita-
tion equipment is commonly used in the
medical industry, and creates digital im-
ages of x-rays in DICOM format. It is rec-
nommended to scan the image in a 16-bit
format. However, 12-bit and 8-bit resolu-
tions are acceptable. Finally, x-ray analy-
sis software that allows accurate digital
image density calculations, such as Image-J 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 ex-
sure capture. One or multiple ma-
chined components of like material/
density with known thicknesses are
placed atop the part (preferably in a re-
gion of nominal and non-varying thick-
ness) such that exposure of the com-
combined part and machined component
lay-up is captured on the x-ray. Depen-
ding on the accuracy required, the ma-
chined 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 den-
sity 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 mon-
tor that can be directly connected to a
multi-cell fuel cell stack for direct sub-
stack power provisioning. It can also pro-
vide voltage isolation for applications in
high-voltage fuel cell stacks. The tech-
nology 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 con-
nection port, coupled with the fact that
the module’s operating power is sup-
plied by the same substack voltage input
(and so will be at similar voltage), pro-
vides for elimination of high-common-
mode voltage issues within each module.
Within each module, there would be op-
tions 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 iso-
lated) or electrically isolated. This is nec-
essary to account for the fact that the
plurality of modules attached to the
stack will normally be at a range of volt-
ages approaching the full range of the
fuel cell stack operating voltages. A com-
munications/data bus could interface
with the several basic modules. Options
have been identified for command in-
puts from the spacecraft vehicle con-
troller, and for output-status/data feeds
to the vehicle.

This work was done by Arturo Vasquez of
Johnson Space Center. For further informa-
tion, 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 mon-
tor the health of rotating engine com-
ponents are becoming increasingly at-
tractive to aircraft engine manufacturers in order to increase
safety of operation and lower mainte-
nance costs. Health monitoring remains
a challenge to easily implement, espe-
cially in the presence of scattered load-
ing 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 tech-
niques go further to evaluate material
 discontinuities and other anomalies
that have grown to the level of critical
defects that can lead to failure. Gener-
ally, health monitoring is highly de-
pendent on sensor systems capable of
performing in various engine environ-
mental conditions and able to transmit
a signal upon a predetermined crack
length, while acting in a neutral form
upon the overall performance of the en-
gine system.

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