



Technology Focus: Test & Measurement

▶ **Measurements of Ultra-Stable Oscillator (USO) Allan Deviations in Space**

NASA's Jet Propulsion Laboratory, Pasadena, California

Researchers have used data from the GRAIL mission to the Moon to make the first in-flight verification of ultra-stable oscillators (USOs) with Allan deviation below 10^{-13} for 1-to-100-second averaging times. USOs are flown in space to provide stable timing and/or navigation signals for a variety of different science and programmatic missions.

The Gravity Recovery and Interior Laboratory (GRAIL) mission is flying twin spacecraft, each with its own USO and with a Ka-band crosslink used to

measure range fluctuations. Data from this crosslink can be combined in such a way as to give the relative time offsets of the two spacecrafts' USOs and to calculate the Allan deviation to describe the USOs' combined performance while orbiting the Moon. Researchers find the first direct in-space Allan deviations below 10^{-13} for 1-to-100-second averaging times comparable to pre-launch data, and better than measurements from ground tracking of an X-band carrier coherent with the USO. Fluctuations in

Earth's atmosphere limit measurement performance in direct-to-Earth links. In-flight USO performance verification was also performed for GRAIL's parent mission, the Gravity Recovery and Climate Experiment (GRACE), using both K-band and Ka-band crosslinks.

This work was done by Daphna G. Enzer, William M. Klipstein, Rabi T. Wang, and Charles E. Dunn of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48705

▶ **Gaseous Nitrogen Orifice Mass Flow Calculator**

Lyndon B. Johnson Space Center, Houston, Texas

The Gaseous Nitrogen (GN2) Orifice Mass Flow Calculator was used to determine Space Shuttle Orbiter Water Spray Boiler (WSB) GN2 high-pressure tank source depletion rates for various leak scenarios, and the ability of the GN2 consumables to support cooling of Auxiliary Power Unit (APU) lubrication during entry. The data was used to support flight rationale concerning loss of an orbiter APU/hydraulic system and mission work-arounds.

The GN2 mass flow-rate calculator standardizes a method for rapid assessment of GN2 mass flow through various orifice sizes for various discharge coefficients, delta pressures, and temperatures. The calculator utilizes a 0.9-lb (0.4 kg) GN2 source regulated to 40 psia (≈ 276 kPa). These parameters correspond to the Space Shuttle WSB GN2 Source and Water Tank Bellows, but can be changed in the spreadsheet to accommodate any system parameters. The cal-

culator can be used to analyze a leak source, leak rate, gas consumables depletion time, and puncture diameter that simulates the measured GN2 system pressure drop.

The software is programmed into a Microsoft Excel Solver spreadsheet.

This work was done by Charles Rittrivi of The Boeing Company for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24873-1

▶ **Validation of Proposed Metrics for Two-Body Abrasion Scratch Test Analysis Standards**

In principle, any scratch can be analyzed by this method.

John H. Glenn Research Center, Cleveland, Ohio

Abrasion of mechanical components and fabrics by soil on Earth is typically minimized by the effects of atmosphere and water. Potentially abrasive particles lose sharp and pointed geometrical features through erosion. In environments where such erosion does not exist, such as the vacuum of the Moon, particles retain sharp geometries associated with fracturing of their parent particles by

micrometeorite impacts. The relationship between hardness of the abrasive and that of the material being abraded is well understood, such that the abrasive ability of a material can be estimated as a function of the ratio of the hardness of the two interacting materials. Knowing the abrasive nature of an environment (abrasive)/construction material is crucial to designing durable equipment for

use in such surroundings.

The objective of this work was to evaluate a set of standardized metrics proposed for characterizing a surface that has been scratched from a two-body abrasion test. This is achieved by defining a new abrasion region termed "Zone of Interaction" (ZOI). The ZOI describes the full surface profile of all peaks and valleys, rather than just measuring a scratch width. The ZOI

has been found to be at least twice the size of a standard width measurement; in some cases, considerably greater, indicating that at least half of the disturbed surface area would be neglected without this insight. The ZOI is used to calculate a more robust data set of volume measurements that can be used to computationally reconstruct a resultant profile for detailed analysis. Documenting additional changes to various surface roughness parameters also allows key material attributes of importance to ultimate design applications to be quantified, such as depth of penetration and final abraded surface roughness. Furthermore, by investigating the use of custom scratch tips for specific needs, the usefulness of having an abrasion metric that can measure the displaced volume in this stan-

dardized manner, and not just by scratch width alone, is reinforced. This benefit is made apparent when a tip creates an intricate contour having multiple peaks and valleys within a single scratch.

The current innovation consists of a software-driven method of quantitatively evaluating a scratch profile. The profile consists of measuring the topographical features of a scratch along the length of the scratch instead of the width at one location. The digitized profile data is then fed into software code, which evaluates enough metrics of the scratch to reproduce the scratch from the evaluated metrics.

There are three key differences between the current art and this innovation. First, scratch width does not quantify how far from the center of the scratch damage oc-

curs (ZOI). Second, scratch width does not discern between material displacement and material removal from the scratch. Finally, several scratches may have the same width but different zones of interactions, different displacements, and different material removals. The current innovation allows quantitative assessment of all three.

This work was done by Kenneth W. Street, Jr. of Glenn Research Center; Ryan L. Kobrick of MIT, and David M. Klaus of the University of Colorado at Boulder. 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-18780-1.

Rover Low Gain Antenna Qualification for Deep Space Thermal Environments

NASA's Jet Propulsion Laboratory, Pasadena, California

A method to qualify the Rover Low Gain Antenna (RLGA) for use during the Mars Science Laboratory (MSL) mission has been devised. The RLGA antenna must survive all ground operations, plus the nominal 670 Martian sol mission that includes the summer and winter seasons of the Mars thermal environment. This qualification effort was performed to verify that the RLGA design, its bonding, and packaging processes are adequate.

The qualification test was designed to demonstrate a survival life of three times more than all expected ground testing, plus a nominal 670 Martian sol missions. Baseline RF tests and a visual inspection

were performed on the RLGA hardware before the start of the qualification test. Functional intermittent RF tests were performed during thermal chamber breaks over the course of the complete qualification test. For the return loss measurements, the RLGA antenna was moved to a test area. A vector network analyzer was calibrated over the operational frequency range of the antenna. For the RLGA, a simple return loss measurement was performed.

A total of 2,010 (3×670 or 3 times mission thermal cycles) thermal cycles was performed. Visual inspection of the RLGA hardware did not show any anomalies due to the thermal cycling.

The return loss measurement results of the RLGA antenna after the PQV (Package Qualification and Verification) test did not show any anomalies. The antenna pattern data taken before and after the PQV test at the uplink and downlink frequencies were unchanged. Therefore, the developed design of RLGA is qualified for a long-duration MSL mission.

This work was done by Rajeshuni Ramesham, Luis R. Amaro, Paula R. Brown, and Robert Usiskin of Caltech; and Jack L. Prater of Polytechnic High School for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48500

Automated, Ultra-Sterile Solid Sample Handling and Analysis on a Chip

This technique could be used in the pharmaceutical industry for the automated manipulation of small amounts of powdered drugs.

NASA's Jet Propulsion Laboratory, Pasadena, California

There are no existing ultra-sterile lab-on-a-chip systems that can accept solid samples and perform complete chemical analyses without human intervention. The proposed solution is to demonstrate completely automated lab-on-a-chip manipulation of powdered

solid samples, followed by on-chip liquid extraction and chemical analysis.

This technology utilizes a newly invented glass micro-device for solid manipulation, which mates with existing lab-on-a-chip instrumentation. Devices are fabricated in a Class 10 cleanroom at the

JPL MicroDevices Lab, and are plasma-cleaned before and after assembly. Solid samples enter the device through a drilled hole in the top. Existing micro-pumping technology is used to transfer milligrams of powdered sample into an extraction chamber where it is mixed with liquids to