



▶ 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.

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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