# Software

## Automated Performance Characterization of DSN System Frequency Stability Using Spacecraft Tracking Data

This software provides an automated capability to measure and qualify the frequency stability performance of the Deep Space Network (DSN) ground system, using daily spacecraft tracking data. The results help to verify if the DSN performance is meeting its specification, therefore ensuring commitments to flight missions; in particular, the radio science investigations. The rich set of data also helps the DSN Operations and Maintenance team to identify the trends and patterns, allowing them to identify the antennas of lower performance and implement corrective action in a timely manner.

Unlike the traditional approach where the performance can only be obtained from special calibration sessions that are both time-consuming and require manual setup, the new method taps into the daily spacecraft tracking data. This new approach significantly increases the amount of data available for analysis, roughly by two orders of magnitude, making it possible to conduct trend analysis with good confidence.

The software is built with automation in mind for end-to-end processing. From the inputs gathering to computation analysis and later data visualization of the results, all steps are done automatically, making the data production at near zero cost. This allows the limited engineering resource to focus on high-level assessment and to follow up with the exceptions/deviations.

To make it possible to process the continual stream of daily incoming data without much effort, and to understand the results quickly, the processing needs to be automated and the data summarized at a high level. Special attention needs to be given to data gathering, input validation, handling anomalous conditions, computation, and presenting the results in a visual form that makes it easy to spot items of exception/deviation so that further analysis can be directed and corrective actions followed.

*This work was done by Timothy T. Pham, Richard J. Machuzak, Alina Bedrossian, Richard M. Kelly, and Jason C. Liao of Caltech for NASA's Jet Propulsion Laboratory.*

## Histogrammatic Method for Determining Relative Abundance of Input Gas Pulse

To satisfy the Major Constituents Analysis (MCA) requirements for the Vehicle Cabin Atmosphere Monitor (VCAM), this software analyzes the relative abundance ratios for $N_2$, $O_2$, Ar, and $CO_2$ as a function of time and constructs their best-estimate mean. A histogram is first built of all abundance ratios for each of the species vs time. The abundance peaks corresponding to the intended measurement and any obfuscating background are then separated via standard peak-finding techniques in histogram space. A voting scheme is then used to include/exclude this particular time sample in the final average based on its membership to the intended measurement or the background population. This results in a robust and reasonable estimate of the abundance of trace components such as $CO_2$ and Ar even in the presence of obfuscating backgrounds internal to the VCAM device.

VCAM can provide a means for monitoring the air within the enclosed environments, such as the ISS (International Space Station), Crew Exploration Vehicle (CEV), a Lunar Habitat, or another vehicle traveling to Mars. Its miniature pre-concentrator, gas chromatograph (GC), and mass spectrometer can provide unbiased detection of a large number of organic species as well as MCA analysis. VCAM's software can identify the concentration of trace chemicals and whether the chemicals are on a targeted list of hazardous compounds. This innovation's performance and reliability on orbit, along with the ground team's assessment of its raw data and analysis results, will validate its technology for future use and development.

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## Predictive Sea State Estimation for Automated Ride Control and Handling — PSSEARCH

PSSEARCH provides predictive sea state estimation, coupled with closed-loop feedback control for automated ride control. It enables a manned or unmanned watercraft to determine the 3D map and sea state conditions in its vicinity in real time. Adaptive path-planning/replanning software and a control surface management system will then use this information to choose the best settings and heading relative to the seas for the watercraft.

PSSEARCH looks ahead and anticipates potential impact of waves on the boat and is used in a tight control loop to adjust trim tabs, course, and throttle settings. The software uses sensory inputs including IMU (Inertial Measurement Unit), stereo, radar, etc. to determine the sea state and wave conditions (wave height, frequency, wave direction) in the vicinity of a rapidly moving boat. This information can then be used to plot a "safe" path through the oncoming waves.

The main issues in determining a safe path for sea surface navigation are: (1) deriving a 3D map of the surrounding environment, (2) extracting hazards and sea state surface state from the imaging sensors/map, and (3) planning a path and control surface settings that avoid the hazards, accomplish the mission navigation goals, and mitigate crew injuries from excessive heave, pitch, and roll accelerations while taking into account the dynamics of the sea surface state. The first part is solved using a wide baseline stereo system, where 3D structure is determined from two calibrated pairs of visual imagers.

Once the 3D map is derived, anything above the sea surface is classified as a potential hazard and a surface analysis gives a static snapshot of the waves. Dynamics of the wave features are obtained from a frequency analysis of motion vectors derived from the orientation of the waves during a sequence of inputs. Fusion of the dynamic wave patterns with the 3D maps and the IMU outputs is used for efficient safe path planning.