Beacon Monitor Operations Experiment

EXTENDED ABSTRACT

The Beacon Monitor Operations Experiment was one of twelve new technologies that were flight validated on NASA's Deep Space One Mission. The technology enables a spacecraft to routinely indicate the urgency of ground contact using a tone signal rather than telemetry while also summarizing onboard data to be transmitted whenever telemetry contact is required. This technology can be used to lower operational cost, decrease mission risk, and decrease loading on the over-constrained Deep Space Network antennas. The technology is baselined on upcoming NASA missions to Europa, Pluto and the Sun. Successful flight validation has met a requirement to demonstrate the technology before routine use on the Europa mission.

The end-to-end beacon tone signaling system was developed to provide a low-cost and low-bandwidth method for determining when ground intervention is required. With beacon monitoring, the spacecraft sets the tone signal and it is transmitted either in a scheduled manner or continuously depending on spacecraft operability constraints. The tone signal is detected on the ground with smaller aperture antennas than would be required for telemetry on a given mission. Tone detection times are short—on the order of 15 minutes or less for most mission designs. The flight validation experiment checked out the functionality of the tone detection and message delivery system, characterized operational performance, obtained parameter limits, and tested selection of tone states by flight software based on the spacecraft's assessment of its own health. Baseline operation of this system was in X-band, but Ka-band tones were also tested as an upscope to the original experiment.

Engineering data summarization flight software creates event-driven summaries of spacecraft activities since the last contact. Episodes are created by identifying the culprit and causally-related sensors around the time of important events. This data is gathered at a high sample-rate, assigned a priority, and stored for downlink at the next telemetry pass. The gaps are filled in by "snapshots" of all sensor channels at a much lower sample-rate. The software can use either traditional (static) alarm thresholds or adaptive alarm limit functions that are determined by a neural network. The adaptive alarm limit technology, called ELMER (Envelope Learning and Monitoring using Error Relaxation) is one of two AI components in the current software design. The second AI-based method computes empirical transforms on individual data channels. These pseudo-sensors enhance the value of summaries and serve as an additional input in determining the adaptive limits. The software was originally developed to support beacon monitor operations, an approach that enables the spacecraft to determine when ground-contact is necessary. In this approach, summarization plays a key role in providing operators with the most important data since all of the stored data cannot be downlinked in a single telemetry pass. Efficient summaries also help facilitate quick troubleshooting and thus can reduce the risk of losing the mission. Summarization algorithms can also be applied to nonspace systems to decrease the time required for people to perform data analysis. The current version of the software runs on VxWorks and has been executed on the PowerPC and RAD6000 target processors.

The experiment also included operational testing of a ground system prototype, called BeaVis (Beacon Visualization), that was designed to facilitate quick interaction with BMOX data. The purpose of this system is to track beacon tone states throughout a mission and to display downlinked summary data. For beacon missions, the user must be able to quickly maneuver through summary data to arrive at an assessment of overall system state and to diagnose any problems that occur. The software enables the user to scroll through a graphical depiction of telemetry downlinks throughout the life of the mission to select the desired data. Summary data is represented graphically with a hypertext style link to the strip charts of the sensor channels contained in each of the four types of summary data packets. A web version of the tool was also implemented.