Onboard Data Summarization and Long-term Onboard Archives for Long-Duration Missions

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An ongoing research effort at JPL is evolving an operational concept and associated technology components required to implement highly adaptive, spacecraft-initiated operations. Current work in this area has culminated in the successful deployment of the Beacon Monitor Operations Experiment on the Deep Space One (DS1) Mission. This experiment, which is currently active, implements a capability that enables the spacecraft to determine when tracking is required, transmits that information to the ground using an sub-carrier beacon signal, and then transmits intelligent data summaries after the beacon tone has resulted in a telemetry track. This technology is relevant to many types of missions, but especially deep space missions since these tend to be more bandwidth limited. The beacon operational concept is baselined for Pluto and Europa missions and is also planned for inclusion in the DS1 extended mission.

The software flown on DS1 creates event-driven summaries of spacecraft events 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.

This paper describes the DS1 summarization system for context but also looks beyond the scope of what has currently been developed to address broader knowledge management issues over the life of the mission. Planned missions to Europa and Pluto will only downlink approximately 5% of all engineering data gathered onboard. It becomes imperative, therefore, to develop software that not only summarizes what information should be sent back to Earth, but also summarizes for the purpose of creating a long-term archive that will be maintained onboard throughout the mission. Given that onboard data storage hardware is sized for the large amount of science data that will be acquired at the target body, for most of the mission this storage space would go unused anyway. There is in fact much more available storage than bandwidth at each downlink opportunity. What this means is that maintaining an archive onboard can enable storage of higher-resolution and/or more complete data sets than would be sent to Earth. This can benefit the mission in many ways, from both cost and risk standpoints. The ability to have more comprehensive fault protection systems that refer to historical data onboard the spacecraft can enable long-term, automated, space-based trend analysis to occur. During anomalies, onboard access to historical data can reduce the risk incurred from the time delays associated with deep space communication. Onboard archives also have the advantage of being able to reduce the risk and cost associated with maintaining personnel skills and contending with turnover common in multi-year flight project operations. Summarization strategies will likely evolve over the life of the mission. This paper will explore these strategies along with planned new directions in onboard data summarization technology.