Deep Space 1 telecom link analysis: enabler of spacecraft mission recovery and ground station performance maintenance

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The Deep Space 1 (DS1) telecommunication system was designed to provide standard X-band uplink and downlink capability with the stations of the Deep Space Network (DSN). From the beginning of flight operations, the telecom analysis job included prediction for planning data rates, comparison of the actual spacecraft and station signal levels with predictions, analysis and resolution of discrepancies, and updating of prediction models when needed. In several instances, telecom analysis went beyond this routine to become an integral part of identifying spacecraft and station problems that would have endangered the return of unique science data. In one situation, to be described in detail, telecom analysis became part of a ground-in-the-loop process for continuing the DS1 mission in 3-axis stabilized mode after the failure of the on-board star tracker.

Accurate modeling of received signal levels in software allowed the telecom analyst to make new predictions in minutes. This ability was key to rapidly identifying significant spacecraft problems such as entry into safemode. Rapid resolution of one safemode event led to the resumption of the asteroid flyby science sequence in July 1999 with minutes to spare. Modeling of the varying signal levels resulting from a special spacecraft "coning" attitude enabled development in early 2000 of a sequence to return to 3-axis control with the high gain antenna pointed near enough to Earth. The sequence required both the rapid acquisition of downlink carrier at the station and a subsequent precisely timed acquisition of uplink carrier and commanding of the spacecraft, accounting for the round trip light time on the day of the activity. Subsequent control of the antenna pointing toward Earth during the pass required continued accurate monitoring and comparison against predictions of station signal levels. This ground-in-the-loop analysis included recommendations for the magnitude and timing of corrective turn commands to maintain antenna attitude in the absence of the star tracker.

The DS1 spacecraft, including its secondary Ka-band downlink, also became a signal source for maintenance of existing station performance and implementation of new station capability. Prediction and signal level comparison against prediction over a series of passes at one station or one type of station could be used to identify and (in some cases) correct for unexpected station performance. The range of problems encountered during the DS1 mission include systematic station antenna pointing errors at low elevation angles, receiving system noise temperature discrepancies at different times within a pass, and aberration of the uplink beam direction relative to the downlink beam for a spacecraft with proper motion. DS1 telecom analysis verified the performance of new implementations such as X-band uplink at the 70-m stations, the arraying of 34-m stations at X-band, and the Ka-band monopulse pointing system.

DS1 telecom prediction and analysis showed how the careful performance assessment at both ends of a deep space communication link can benefit both the flight project and the ground network. DS1 lost little science data due to link problems despite planning data rates with less than 1 dB of margin above mean predicted signal level. (500 words)