MARS SCIENCE LABORATORY ORBIT DETERMINATION RESULTS

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ABSTRACT

The Mars Science Laboratory (MSL) is the latest NASA rover mission, which was launched on 26 November 2011 and is scheduled for a precision landing inside Gale Crater on 6 August 2012. This paper describes the details and results of the orbit determination process for launch, cruise and the unique orbit determination challenges during the final approach to reach the Martian atmospheric target interface with the accuracy required for a precision landing at Gale Crater.

The main objective of the MSL orbit determination team is to determine the spacecraft state, predict its future trajectory and characterize the uncertainty associated with the predicted trajectory. For this objective, high fidelity force modeling and associated uncertainties are needed to meet required trajectory accuracies and in particular during approach, where the estimated atmospheric entry state will be used to initialize the MSL Entry Descend and Landing (EDL) system.

The requirements for the atmospheric entry state uncertainty (3σ) are 0.2^{o} for entry flight path angle, 2.8 km for entry position knowledge and 2.0 m/sec for entry velocity knowledge. In order to meet these requirements an interplanetary tracking schedule was developed for range, Doppler and DDOR measurements. Based on covariance analysis, five Trajectory Correction Maneuvers (TCM) were positioned in cruise, such that the atmospheric entry target state could be reached with the minimum propellant usage while still meeting the atmospheric entry state uncertainty requirements.

An overview will be given of processing of the interplanetary data tracking types of range, Doppler, DDOR, and also DDOR measurements between MSL and the Mars orbiters. Furthermore the correction of range and Doppler tracking for the spacecraft spin state will be discussed. This is correction is required in order to meet range and Doppler data tracking quality requirements. As of this writing the MSL orbit determination team found it necessary to include an estimate of the the charged particle delay between the spacecraft and Earth due to increased solar activity.

A complete description of the force modeling will be given, along with discussion of activities to improve the force modeling and their associated uncertainties in flight. The calibration activities include the determination of outgassing forces after launch, residual ΔV during spacecraft turns,

Solar Radiation Pressure model, TCM reconstruction and thermal radiation pressure introduced by the Radio isotope Thermoelectric Generator (RTG). Most of these calibration activities require many months of tracking data to either improve observability or to characterize the time-dependent nature of certain force model calibrations.

The orbit determination process uses the Mission analysis and Operational Navigation Toolkit Environment (MONTE) filter developed at the Jet Propulsion Laboratory (JPL). An overview will be given of the filter assumptions and parameterization used during launch, cruise and approach. Additionally filter setup variations used during cruise and approach will be discussed as a tool to assess the performance of the orbit determination process and to assist in the maneuver execution decisions and EDL trajectory updates during approach.

Finally the orbit determination results, force model calibrations will be presented including a analysis of the post flight reconstruction trajectory versus the predicted trajectories in flight.