Mars Science Laboratory Propulsive Maneuver Design and Execution

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Abstract

The NASA Mars Science Laboratory (MSL) rover, Curiosity, was launched on November 26, 2011 and is scheduled to land at the Gale Crater on Mars on August 6, 2012. The main scientific goal of this rover mission is to determine the habitability of the Martian environment. For that it carries an advanced suite of scientific instruments that includes cameras, spectrometers, radiation detectors, and environmental and atmospheric sensors. Further, Curiosity is equipped with the most sophisticated Entry, Descent, and Landing (EDL) system ever assembled for a planetary mission to allow targeting to a desired landing site with unprecedented accuracy. Before it enters the Martian atmosphere, however, Curiosity has to travel through 567 million kilometers of interplanetary distance from Earth to Mars. Since there are various constraints and requirements the spacecraft is subjected to during this 8-month journey, a comprehensive navigation system that includes orbit determination and maneuver design is needed. In this paper we will discuss the prelaunch maneuver analysis and the post-launch maneuver execution aspects of the navigation system.

Five nominal and two contingency Trajectory Correction Maneuvers (TCMs) have been scheduled for the MSL mission. These TCMs are strategically placed in order to satisfy various constraints and requirements, including planetary protection, propellant usage, telecommunication and thermal power, and delivery accuracy. The first three maneuvers (TCMs 1-3) were initially designated as deterministic, with their sizes computed using a multi-maneuver optimization scheme; that is, if there were no knowledge or delivery errors, these three maneuvers collectively would deliver the spacecraft to the desired aimpoint at the Martian atmosphere. The next two maneuvers (TCMs 4 and 5) were designated as statistical whose primary function was to correct for navigation errors. The last two maneuvers (TCMs 5X and 6) are for contingency; that is, they are needed only if TCM 5 cannot be executed or there are unexpected anomalies or both during the approach phase.

Before the Gale Crater was finally selected as the target landing site, a multitude of possible trajectory scenarios were studied during the mission design and analysis phase. The parameter space covered various landing sites, launch and arrival dates, and EDL relay opportunities. One the most critical factors in accessing the viability of the these trajectories was to determine whether the propulsive capability (with only about 70 kg of propellant allocated for both propulsive maneuvers and attitude control) could direct the

spacecraft to the desired aimpoint, given the planetary protection requirements and the estimated launch vehicle and navigation errors.

The launch on November 26, 2011 was very accurate, and the two maneuvers, TCMs 1-2 that have been performed to date (May 2012), were very successfully with small execution errors. Consequently, the propellant budget is no longer a concern in the maneuver design aspect of the approach phase. The maneuver design during this phase will focus on finding the optimal maneuver design among the three possible execution modes, namely, no-turn-vector, axial-only, and lateral-only. The selection will be based on a number of factors, including delivery accuracy, operational ease, EDL capability, and spacecraft health.

The design and execution of each of the TCMs will be discussed in the full paper to be presented at the meeting.