MARS SCIENCE LABORATORY NAVIGATION RESULTS

Tomas J. Martin-Mur[(1)], Gerhard L. Kruizinga[(2)], P. Daniel Burkhart[(2)], Mau C. Wong[(2)], Fernando Abilleira[(2)]

[(1)(2)] *Jet Propulsion Laboratory, California Institute of Technology,*
4800 Oak Grove Drive, Pasadena, CA 91109, USA,
[(1)]+1-818-393-6276, Tomas.J.Martinmur@jpl.nasa.gov

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ABSTRACT

The Mars Science Laboratory (MSL), also called Curiosity, is a NASA rover mission launched on November 26, 2011, that is expected to land at the Gale Crater in Mars on August 6, 2012. The MSL rover carries the biggest and most advanced suite of scientific instruments ever landed on the Martian surface, and the project is using an innovative system for entry, descent, and landing (EDL) to accurately and safely deliver the rover to a site of high scientific interest on the surface of Mars.

This paper will describe the interplanetary navigation for the MSL mission, from its launch from Cape Canaveral, to the landing at Gale. The main challenges for the interplanetary navigation of the mission are to deliver the spacecraft to the right interface point above the atmosphere of Mars, and to accurately tell the spacecraft where it is as it enters the atmosphere. MSL will use guidance during its descent to Mars, prior to the deployment of the parachute, in order to minimize landing dispersions and so be able to use a smaller landing zone that is close to terrain of high scientific interest. This requires a more accurate delivery of the spacecraft to the entry interface, and a late update of the spacecraft state at entry, which will be used to initialize the descent guidance system.

MSL was very accurately launched in an Atlas V 541, and had an uneventful initial acquisition by the Deep Space Network. The injection was so accurate that the execution of the first trajectory correction maneuver (TCM) could be postponed, and this allowed for the cruise team to concentrate in solving some unexpected issues with the spacecraft computer. Navigation worked with the Attitude Control team early in cruise to produce ground based attitude estimates, since the star scanner was not activated until after the computer issues were understood and corrected. The project decided to perform a lateral calibration maneuver before TCM-1 is order to assess the performance of the cruise reaction control system, and this was executed successfully on December 22, 2011. It was followed by TCM-1 on January 11, TCM-2, the first maneuver to target the entry point, on January 11, with TCM-3 currently planned for June 26. During early cruise an ACS/Navigation calibration activity was performed in order to assess the residual translation delta-V resulting from spacecraft turns, and the line-of-sight of subsequent turns was monitored to assess with what fidelity the delta-V could be predicted. Also during cruise the navigation team has provided targets to the Mars orbiter teams so they can maneuver their spacecraft in order to be able to support MSL communications during EDL.

Orbit determination during cruise has been very successful, being able to predict the line-of-sight position of the spacecraft after one week to within a few meters for most of the time. The usual interplanetary data types of range, Doppler and DDOR are used. Accurate processing of the data has required the estimation of the rotational state of the spacecraft, in order to remove the spin signature in the Doppler, and careful modeling of the solar radiation and thermal pressure acting on the spacecraft. In addition, the orbit determination team has estimated empirical charged particle delays in order to model the effects on the tracking of the increasing solar activity.

The atmospheric entry target for MSL is obtained using EDL simulations to target the required entry flight path angle, cross track bias, and landing point. The nominal landing point needs to be carefully selected in order to avoid ground hazards and so maximize the probability of landing success, while minimizing as much as possible the distance to the science target.

Over the next three months the navigation team will execute up to four more TCMs in order to compensate for trajectory prediction and maneuver execution errors, and in the last few days the team will generate several entry state parameter updated candidates for upload to the spacecraft, to accurately initialize the inertial EDL guidance system.

This paper will report on the actual operational experience of MSL Navigation, including those phases of the mission between now and landing.