Trajectory Design for the Mars Reconnaissance Orbiter Mission

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Extended Abstract

In 2005 NASA will launch the Mars Reconnaissance Orbiter (MRO) towards the planet Mars. The orbiter will perform multiple remote sensing science observations with unprecedented resolution, conduct site characterization for future landers, and provide telecom and navigation relay capabilities for follow-on missions. The spacecraft will be launched from an intermediate-class expendable launch vehicle (Atlas IIIB-DEC or Atlas V-401) from the Cape Canaveral Air Force Station at the USAF Eastern Space and Missile Range. A propulsive maneuver will establish the MRO spacecraft in orbit at Mars after seven months of interplanetary cruise. Approximately six months of aerobraking will be used to reduce the orbit period, following which the orbiter will be delivered into the Primary Science Orbit (PSO) and will begin the collection of science data for the next two years. The PSO is a frozen orbit with a periapsis altitude near 250 km (lower than any previous Mars mission) and a constant local mean solar time (LMST) of 3:00 pm at the daylight ascending node. The spacecraft will remain in this orbit for two more years in its relay capacity, and continue to operate at Mars until the end of 2015.

The 2005 Earth – Mars launch space is a stressful one, characterized by high injection energies (> 20 km^2/sec^2) and launch declinations (> 40 degrees). A launch targeting strategy was developed to balance these requirements over a 22-day launch period while maximizing the orbiter dry mass and maintaining the capability to aerobrake to the 3:00 pm constraint. The launch period is 10 August through 31 August 2005, with arrival dates from 10 March to 16 March 2006. The targeted launch energy and declination and right ascension of the launch asymptote are shown in Figure 1. A constant 8:30 pm LMST at arrival is close to optimal for this mission.

Mars Orbit Insertion will target a 35-hour capture orbit with a 300 km periapsis altitude. This requires up to 1000 m/s of velocity change. The MRO all-monopropellant propulsion system is unusual for a planetary mission, with six 170N engines firing together for MOI. Thrust vector control will be achieved using six 22N engines in off-pulsed mode. The aerobraking phase will begin once the orbiter is delivered to orbit in a stable configuration.

Aerobraking will reduce the apoapsis altitude to 450 km over a period of 160 to 171 days (470 to 550 orbits). The orbiter has been designed with a high cross-sectional area and is capable of up to 180 days of aerobraking operations. The high cross-sectional area allows aerobraking at lower atmospheric densities than either Mars Odyssey or Mars Global Surveyor. The rate of aerobraking will also be determined by the orbit LMST since time must be spent in the aerobraking orbit to allow the node to move from 8:30 pm LMST to 3:00 pm LMST. Aerobraking too quickly would result in an orbit with a later LMST, violating the science constraints on the Primary Science Orbit (PSO). The optimal LMST profile is shown in Figure 2. Once the 450 km apoapsis altitude has been reached, a transition phase will establish the PSO with propulsive maneuvers.

The PSO is designed to provide a sun-synchronous low-altitude orbit with a desirable groundtrack repeat pattern while minimizing atmospheric drag effects. This was achieved with a frozen orbit with periapsis altitude near 250 km and apoapsis altitude near 320 km. The orbit has a near-polar inclination of 92.7 degrees and argument of periapsis at the south pole. This also allows a short-term groundtrack repeat cycle of five to six days with a 300 km separation at the equator. A groundtrack separation of about 100 km is reached after 17 days, allowing repeated targeted science over a short period of time. The final separation between adjacent groundtracks after the full 349 Martian day (sol) repeat cycle is less than 5 km.

This paper addresses the analysis and characteristics of the MRO trajectory from launch through end-of-mission. The details of the launch/arrival strategy and trade-offs will be presented. In addition the effects of the atmosphere on the orbit will be described for both the aerobraking and primary science phases.

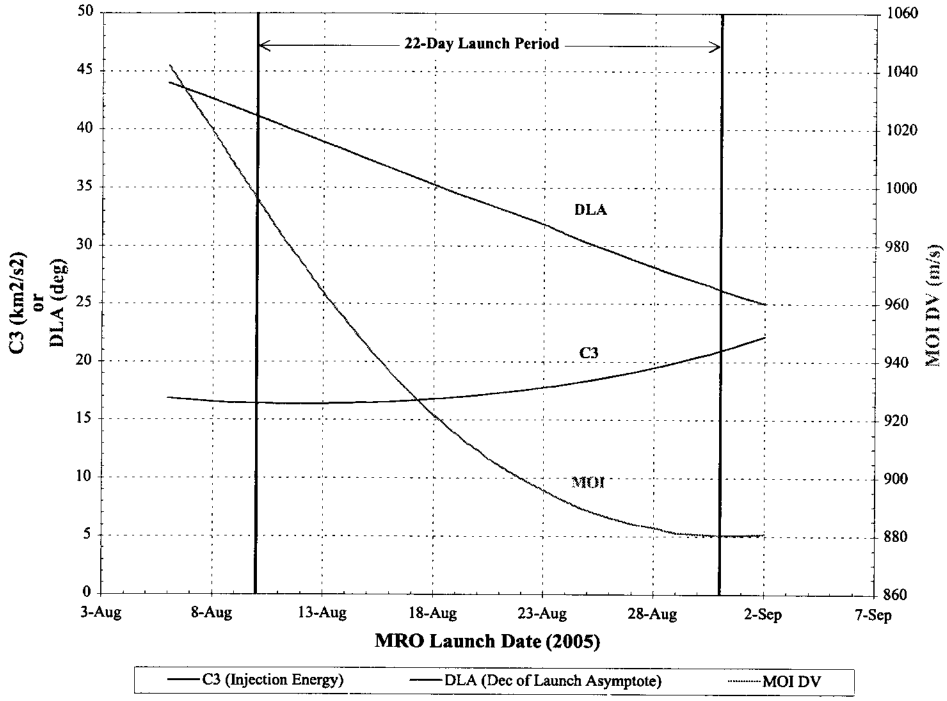

Figure 1: MRO Launch / Arrival Space

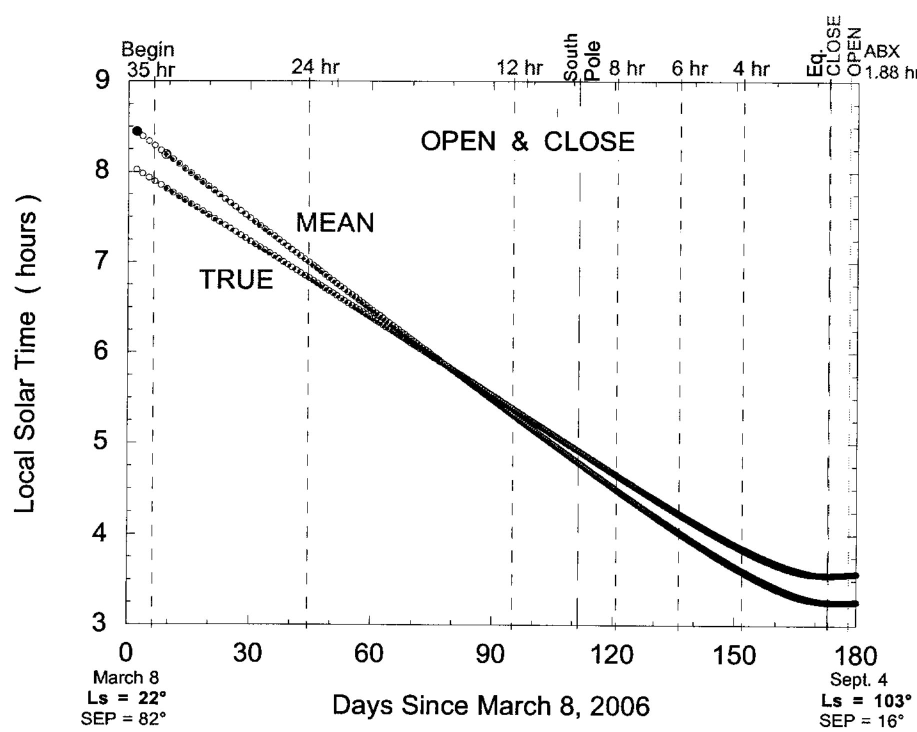

Figure 2: MRO Aerobraking Profile

Condensed Abstract

This paper describes the analysis and design evolution of the Mars Reconnaissance Orbiter trajectory from launch to end-of-mission. The mission uses a combination of propulsive maneuvers and aerobraking techniques to deliver the orbiter to a low-altitude frozen orbit at Mars. The launch/arrival space for the 2005 Earth-Mars opportunity will be described as well as the particular launch strategy chosen for this mission. Details of the aerobraking profile will be provided. Finally, the Primary Science Orbit will be examined, and the trade-offs between science objectives and orbiter capability will be presented.