Mars 2005 Reconnaissance Orbiter
Aerobraking Reference Trajectory

by

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Abstract:

The Mars Reconnaissance Orbiter (MRO) will be launched in August of 2005 and will arrive at Mars in March of 2006. The primary purpose of the MRO mission is to obtain very high resolution images of the surface of Mars. The high resolution requires a relatively low altitude mapping orbit. MRO will be propulsively captured into a 35 hour, 300 km periapsis altitude orbit inclined 93° to the equator. A few days later, a six month aerobraking phase will be started to provide the 1200 m/s needed to shrink the orbit apoapsis from 44,000 km to 400 km. The relatively long duration of the aerobraking phase is primarily a function of the time required for the Mean Local Solar time to reach the 3 pm target required for the mapping orbit. The long aerobraking phase means that relatively low aerodynamic heating is needed, so there will be considerable margin available to accommodate aerodynamic variability. This paper will describe the MRO aerobraking reference trajectory.

Figure 1 shows various contours for the launch/arrival space for MRO. The lower part of the launch/arrival space is undesirable because the aerobraking orbit does not achieve the 3 pm requirement before solar conjunction unless the node is changed propulsively after Mars Orbit Insertion (MOI). There is also a tradeoff between the launch energy (C_3 = Red dashes) and the ΔV required for capture at arrival (Solid Blue). The upper part of the launch arrival space requires more than the 20 km^2/sec^2 design allocation. The unshaded area in the middle of the plot represents the design space, while the solid black line represents one option for optimizing the mass delivered to the final orbit [Ref. 1].

Figure 2 shows the Mean and True Local Solar Times at the node versus Days Since MOI for MRO during the aerobraking phase. Since there is very little nodal precession until the orbit is nearly circular, the slope of the curve is determined by the motion of Mars around the Sun. Thus the time available for aerobraking is determined by the mean local solar time at arrival and the target value required for the mapping orbit (3 pm). For this mission opportunity, the aerobraking duration turns out to be about 6 months.
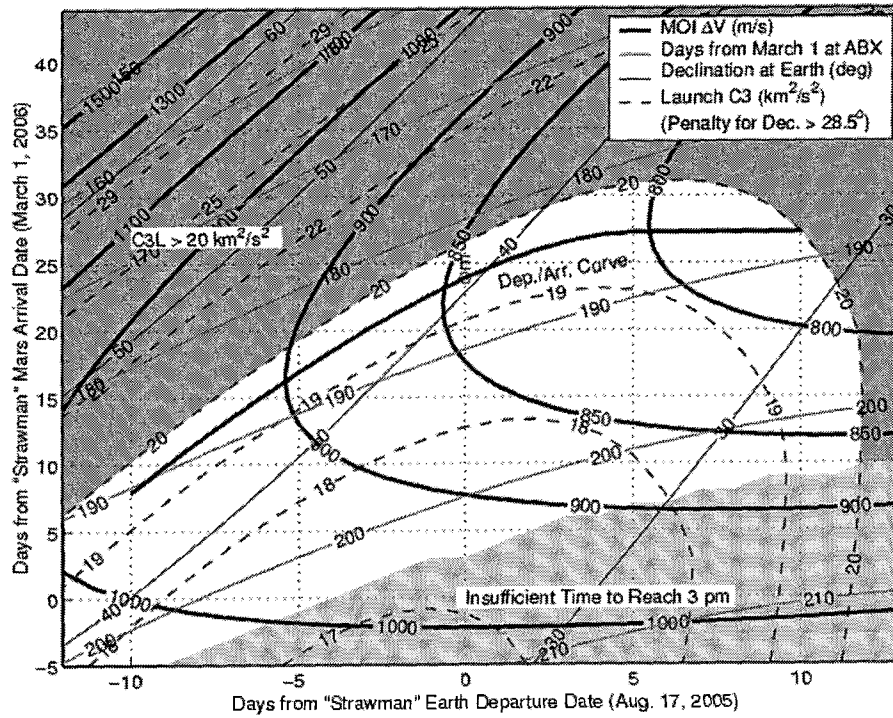
Figure 1   MOI ΔV, Days at ABX, Declination at Earth, and Launch C3
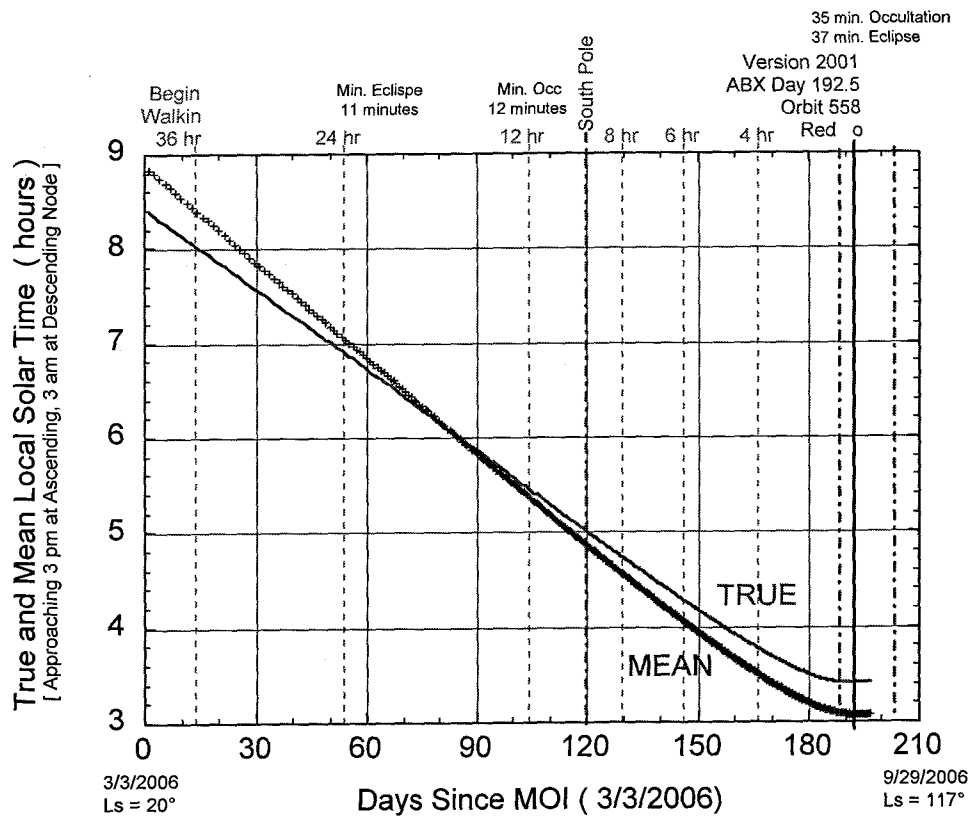

Figure 2: True and Mean Local Solar Time at the Node

Figure 3 shows the dynamic pressure at periapsis versus Days Since MOI for MRO. The most interesting thing about this plot is the very low value of the dynamic pressure that is required for this mission. The very low dynamic pressures are the result of the relatively long aerobraking duration and a very small ballistic coefficient. The ballistic coefficients for Magellan and MGS were both about 21 kg/m^2, while the ballistic coefficient for MRO is only about 13 kg/m^2. The original aerobraking duration for MGS was 4 months at a dynamic pressure of about 0.6 N/m^2. (The actual MGS aerobraking duration was quite a bit longer to accommodate a solar panel that was damaged during deployment. [Ref. 2])
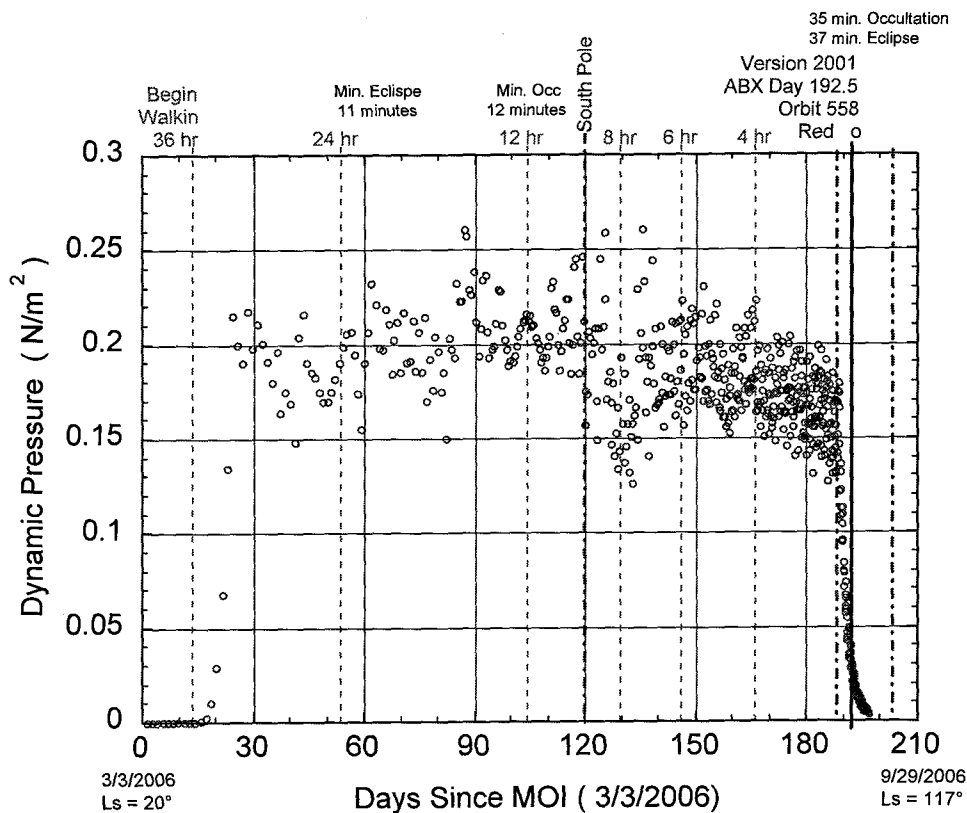

Figure 3: Dynamic Pressure at Periapsis during Aerobraking

Figure 4 shows the time history of the apoapsis altitude during the aerobraking phase. The approximately constant dynamic pressure at periapsis results in a nearly linear decrease in apoapsis altitude versus time.
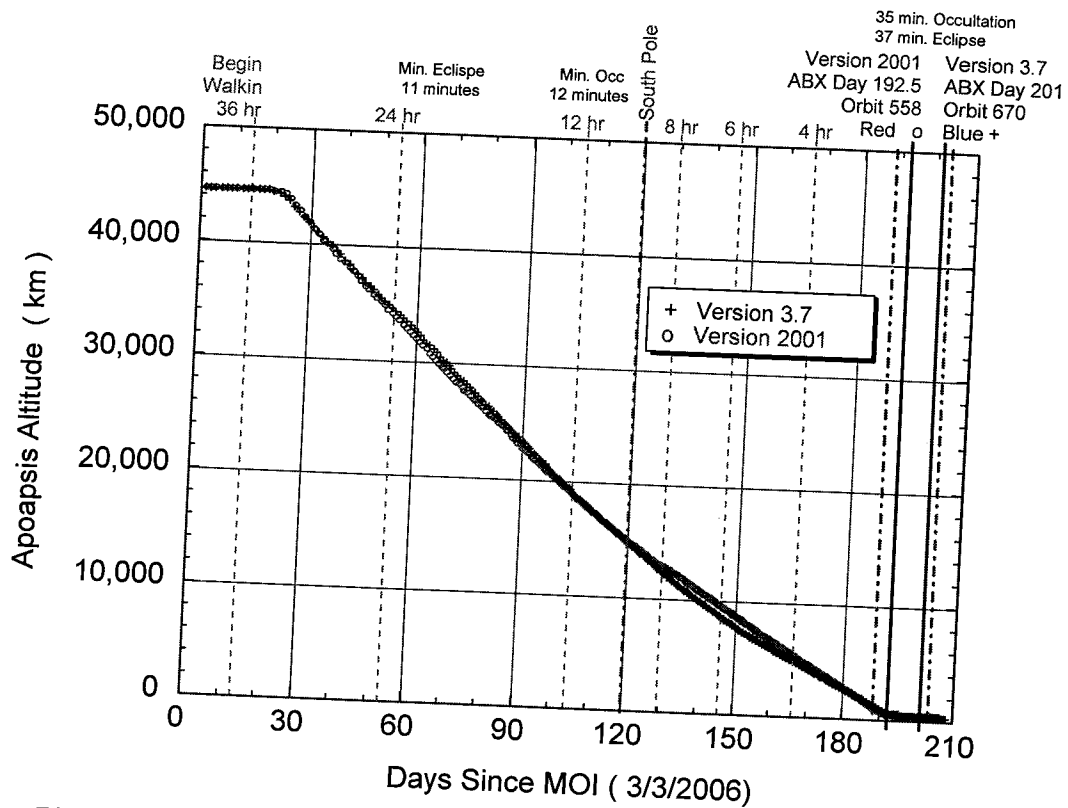
Figure 4: Apoapsis altitude versus Days Since MOI during Aerobraking

The MRO mission will return more science data than all other interplanetary missions combined. Aerobraking is essential for the success of this important scientific mission. The full paper will fully describe the reference aerobraking trajectory, and will highlight the new options that are associated with the MRO aerobraking phase, relative to previous aerobraking missions.

[1] Anderson, R.L.., Lyons, D.T., "Optimizing Mass Delivered to the Mars Mapping Orbit Using Aerobraking for the 2005 Launch Opportunity", AIAA/AAS Astrodynamics Specialist Conference, Quebec City, Quebec, Canada, July 30-August 2, 2001, AAS-01-390

[2] D.T. Lyons, "Mars Global Surveyor: Aerobraking with a Broken Wing", AIAA/AAS Astrodynamics Conference, Sun Valley Idaho, August 4-7, 1997. AAS-97-618.