2001 Mars Odyssey Aerobraking

John C. Smith, Julia L. Bell

Jet Propulsion Laboratory,
California Institute of Technology

Extended Abstract

The successful completion of aerobraking in January 2002 by the Mars 2001 Odyssey orbiter represented the start of new opportunities for Mars science and the return to the proven aerobraking techniques used by the Mars Global Surveyor (MGS) spacecraft in 1997. Odyssey's use of aerobraking to reduce the orbital period significantly reduced the launch mass required to achieve the desired mapping orbit and, therefore, enabled the use of the Boeing Delta 7925 launch vehicle.

This paper details the strategy, implementation, and results of the aerobraking phase of the Odyssey mission. Aerobraking sub-phases, constraints, modeling, maneuver logic, trajectory characteristics, and key decisions are described. Differences between Odyssey and the MGS aerobraking strategies and implementation are included.

The variability of the Martian atmosphere, and the intricate slate of spacecraft activities that must be performed during each aerobraking orbit, made aerobraking the most demanding part of the Odyssey mission. Aerobraking implementation required 24 hour a day, 7 day a week operations at both the Jet Propulsion Laboratory in Pasadena and Lockheed Martin Astronautics Operations in Denver. Additional teams throughout the United States supported the daily operations including staff of the NASA Langley Research Center, Mars atmospheric scientists, and members of the MGS spacecraft and science teams who provided atmospheric monitoring.

During an aerobraking pass, atmospheric friction leads to heating of the spacecraft; therefore, the primary limitation to the possible period reduction per drag pass is the thermal limit of the spacecraft. Periapsis altitude and thus free-stream heat rate is maintained by apoapsis maneuvers. The timing and magnitude of these maneuvers were determined by a daily process involving the Navigation team, atmospheric scientists, and the spacecraft team.

Figure 1 depicts the heat rate (qdot) time history for the Odyssey aerobraking phase. The generalized strategy was to maintain heat rate between the lower and upper heat rate limits with nearly 100% margin with respect to the flight allowable temperature to account for the unpredictability of the Martian atmosphere. Odyssey completed 330 drag passes reducing the orbital period from 18.6 hours to under 2 hours in 75 days from October 28, 2001 to January 11, 2002. A total of 33 aerobraking maneuvers, using 46.6 m/s of propellant, were utilized to govern the trajectory through this phase. Aerobraking provided the equivalent of a 1.08 km/s maneuver.

The aerobraking process is subject to a number of constraints adopted to ensure the safety of the spacecraft. The overriding constraint was to protect the spacecraft from damage due to high temperatures resulting from atmospheric friction during an aerobraking pass. The Odyssey solar panel was utilized as the primary aerobraking drag surface and was the most thermally sensitive spacecraft component. A maximum allowable thermal constraint of 175°C for the solar array, and a safety and planetary protection requirement for 80-100% margin against this limit, provided the primary structure to the aerobraking mission design. Other constraints on the design included power considerations, science mapping orbit requirements, operational complexity, safe-mode events, and the possibility of a global dust storm developing during the aerobraking phase.

The MGS experience provided a substantial foundation from which Odyssey derived both atmospheric models and operational procedures. However, the Odyssey aerobraking differed from that of MGS in many key areas. Odyssey aerobraking was conducted at latitudes and Mars seasons not experienced by MGS. Odyssey aerobraking also was conducted at about twice the heat rate of MGS and was therefore completed in about one third of the MGS aerobraking duration. The spacecraft constraints and the requirements related to the science mapping orbit to be achieved were also different for the two missions.

In addition, although several short-term atmospheric "wave models" were developed during Odyssey operations to help model the variability that was observed, those models changed much more rapidly in both form and content than during the MGS experience. Even with the increased atmospheric variability, Odyssey completed aerobraking ahead of schedule with favorable science conditions. Following a brief transition phase, the mission is now ready to begin the bulk of the scientific investigations that are planned for Odyssey's contribution to the exploration of Mars.

The Mars Odyssey mission is managed at JPL under the auspices of the Mars Exploration Directorate. The spacecraft flight elements are built and managed by Lockheed-Martin Astronautics in Denver, Colorado.

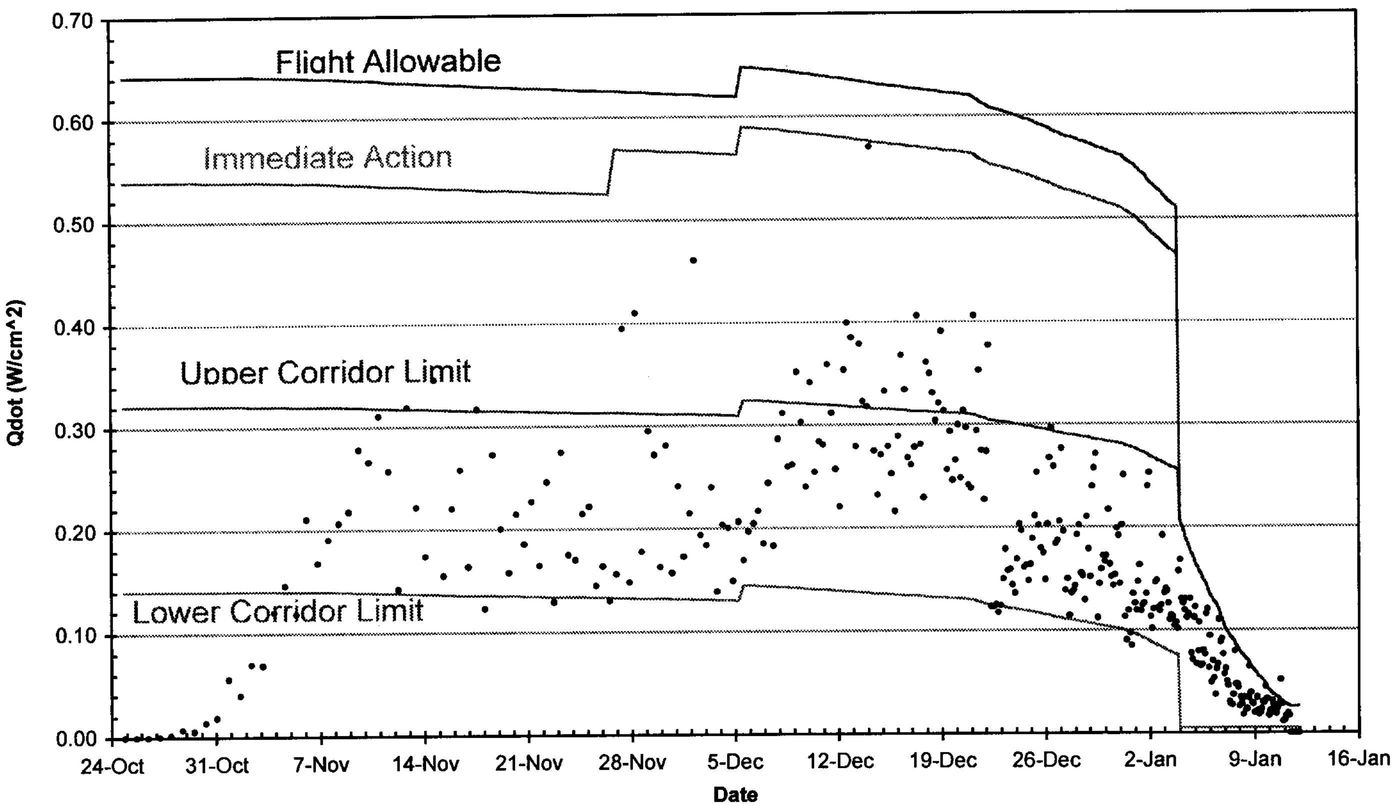

Figure 1 Odyssey Aerobraking Heat Rate Time History

100 Word Short Summary

2001 Mars Odyssey Aerobraking

The Mars Odyssey spacecraft was inserted into a highly elliptical, 18.6 hour period capture orbit about Mars on October 24, 2001. The science instrumentation was designed to operate in a low altitude, near circular science mapping orbit with a period of just under 2 hours. The necessary orbital period reduction was achieved by 330 successive drag passes over a 75 day time period. This paper details the strategy, implementation, and results of the aerobraking phase of the mission. Aerobraking sub-phases, constraints, modeling, maneuver logic, trajectory characteristics, and key decisions are described. Differences between Odyssey and the MGS aerobraking experiences are included.