

Mars Global Surveyor: Aerobraking with a Broken Wing

by

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The Mars Global Surveyor spacecraft was launched successfully on November 7, 1996 on a Delta II 7925. During the initial spacecraft deployment following launch, one of the two solar wings failed to deploy fully. The solar array has two wings, one on each side of the spacecraft. Each wing has two solar panels and a kapton flap for added drag during the aerobraking phase. The +Y wing deployed fully and the panels latched into place. The hinge between the outer and inner panels on the -Y wing also latched into place, but the hinge between the inner panel and the yoke assembly did not latch into place. Telemetry from the spacecraft indicates that the inner panel is 20.5° away from full deployment. Tests show that the hinge is not latched. The failure scenario that explains both the body rates during deployment and which is consistent with a 20.5° offset is that the deployment damper shaft sheared off during deployment and the lever that turned the shaft became wedged between the inner panel and the yoke where the damper is located,

The deployment springs, which are currently supplying a moment of about 60 in-lb, are enough to hold the panel in position during most of the mission. The planned propulsive maneuvers would have applied a moment of about 300 in-lb about the hinge, so the spacecraft team had to reconfigure the spacecraft for propulsive maneuvers so that the propulsive acceleration would generate a moment orthogonal to the hinge rather than around the hinge as originally planned. The first Trajectory Correction Maneuver demonstrated that the new configuration works for propulsive maneuvers. The aerobraking phase will begin four orbits after a propulsive insertion into a highly elliptical orbit around Mars on September 12, 1997,

Mars Global Surveyor will use an aerobraking phase much like that used to circularize the **Magellan** orbit. The solar wings supply most of the surface area that provides the drag that will result in a total ΔV of more than 1200 m/s during the four month aerobraking phase. The orbit period will shrink from 48 hours to less than 2 hours. Aerobraking moments might be as large as 500 in-lb at the unlatched hinge in the worst case situation. Since the 60 in-lb spring force is clearly not large enough to hold the panel in position for the planned aerobraking configuration, a new configuration had to be developed for the aerobraking phase. The configuration developed for propulsive maneuvers would put the solar wings edge-on to the flow, which would not have supplied

enough drag to circularize the orbit in time to achieve the local solar time required for mapping. The solution was to flip the unlatched panel by 180° using the inner gimbal, and hold the panel in position using the outer gimbal. In the original configuration, the outer gimbal was against a hard-stop so the gimbal motor could be unpowered. The new configuration requires that the gimbal is powered to hold the panel in position during the drag pass. Since the gimbal will overheat if powered hold mode is on for too long, the sequencing software must be modified to turn the powered hold mode on and off each orbit. Another consequence of the new configuration is that the cell-side of the unlatched wing will be exposed to the flow so the solar cells on both panels of that wing will be significantly hotter than those on the other wing, which is oriented such that the back sides of the panels are exposed to the flow. The qualification panel is currently undergoing a requalification to demonstrate that the cell-side will have adequate thermal margin to survive the expected heating environment during **aerobraking**.

The paper will describe the new aerobraking configuration, and cover the tests and simulations that were used to demonstrate that sufficient margins are available to achieve the required 2 pm mapping orbit. The baseline trajectory will be used to show various aspects of aerobraking at Mars including the walkin phase used to overcome the lack of data about the Martian atmosphere, the thermal and power limitations near the end of the aerobraking phase that are created by the shorter orbit periods and the rapid precession of the node and argument of **periapsis**. The paper will show that aerobraking will be a very exciting time for the team of people that must fly the spacecraft through the critical aerobraking phase in order to achieve the mapping orbit required to satisfy the mission objectives.