The SOHO Mission Halo Orbit Recovery
From the Attitude Control Anomalies of 1998

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The joint ESA-NASA spacecraft called the Solar and Heliospheric Observatory (SOHO) is historically the second of five deep-space missions to be operated at one of the Sun-Earth collinear libration points by the NASA Goddard Space Flight Center (GSFC). SOHO, launched in December 1995 with a goal of revolutionizing solar science, has flown in a halo orbit around the Sun-ward $L_1$ point continuously since March 1996. This billion-dollar mission had an intended two-year minimum lifetime to be followed by an extended mission phase of at least four years.

However in 1998 SOHO’s life was nearly cut short twice by two separate, very different onboard anomalies of the severest natures. Both times SOHO was rescued, but only after immense and extraordinary struggles. The first mishap, which occurred in late June of 1998, saw SOHO lose 3-axis attitude control, with the resulting tumble severing communications with Earth. The loss of communications lasted until early August when radar signals re-discovered the de-powered, frozen spacecraft, slowly spinning about its major axis of inertia. By chance, SOHO’s geometrical circumstances were then becoming such that the solar panels would soon be receiving some sunlight despite its spinning, non-nominal attitude. This good fortune provided the opportunity for a rescue, and a strategy was developed for slowly and carefully re-powering and thawing the spacecraft. The rescue effort conducted over several weeks was successful, and by late September the spacecraft itself was functioning nearly normally (though not yet the science instruments).

Recovery operations including a series of delta-V maneuvers to restore the halo orbit continued during the autumn of 1998, and optimism was high until the last of the gyroscopes failed just before Christmas. This event did not lead to loss of the Sun-pointing attitude control, but did lead to an automatic fail-over of attitude control from the gyros and momentum wheels to the spacecraft’s thrusters. The problem was that, without the gyroscopes, there was no way to return attitude control to the reaction wheels and to cease the attitude thruster firing that was imparting a net delta-V in the Sun-ward direction. The continual thrusting posed a dual threat. Not only would SOHO eventually run out of fuel, but the cumulative delta-V imparted to the halo orbit as much as 0.4 m/sec per day threatened to push SOHO away from the $L_1$ region and into an independent and useless solar orbit. The mission appeared doomed, but after a months-long fight to rescue it a second time, SOHO was once again saved.

The aspects of the rescues that this communication will address concern the halo orbit. Halo orbits are not only extraordinarily sensitive to perturbations, but by their nature the delta-V costs to correct the orbit grow exponentially with the time elapsed.
from experiencing the perturbation. Due to the perturbations involved, both of the
SOHO accidents threatened escape from the $L_1$ region. Hence, the mission could still
have been lost despite all other efforts to re-establish control of the spacecraft’s attitude
and on-board functions, had personnel at GSFC’s Flight Dynamics Facility (FDF) not
found ways to restore the orbit while contending with numerous adverse circumstances
arising from the accidents. Among the problems was broken on-board, closed-loop
maneuver control, and orbit determination degraded to the point of uselessness. In re-
sponse, a number of critical improvisations were devised. The most important of these,
developed following the second mishap, was a technique for correcting orbital energy
via a time-staggered series of counter-active delta-V maneuvers while modeling the
propagation of the trajectory as a continuous low-thrust mission, which it essentially
was for a period of 40 straight days. This was a feat never before performed with a
halo orbit mission.