LONG TERM MISSIONS AT the SUN-EARTH LIBRATION POINT L1: ACE, SOHO, and WIND

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Three heliophysics missions—the Advanced Composition Explorer (ACE), Solar Heliospheric Observatory (SOHO), and the Global Geoscience WIND—have been orbiting the Sun-Earth interior libration point L1 continuously since 1997, 1996, and 2004, respectively. ACE and WIND (both NASA missions) and SOHO (an ESA-NASA joint mission) are all operated from the NASA Goddard Space Flight Center (GSFC). While ACE and SOHO have been dedicated libration point orbiters since their launches, WIND has had also a remarkable 10-year career flying a deep-space, multiple lunar-flyby trajectory prior to 2004. That era featured 36 targeted lunar flybys with excursions to both L1 and L2 before its final insertion in L1 orbit.

Figure 1 depicts the orbits of the three spacecraft, showing projections of the orbits onto the orthographic planes of a solar rotating ecliptic frame of reference. The SOHO orbit is a quasi-periodic halo orbit, where the frequencies of the in-plane and out-of-plane motions are practically equal. Such an orbit is seen to repeat itself with a period of approximately 178 days. For ACE and WIND, the frequencies of the in-plane and out-of-plane motions are unequal, giving rise to the characteristic Lissajous motion. ACE's orbit is of moderately small amplitude, whereas WIND's orbit is a large-amplitude Lissajous of dimensions close to those of the SOHO halo orbit.

As motion about the collinear points is inherently unstable, stationkeeping maneuvers are necessary to prevent orbital decay and eventual escape from the L1 region. Though the three spacecraft are dissimilar (SOHO is a 3-axis stabilized Sun pointer, WIND is a spin-stabilized ecliptic pole pointer, and ACE is also spin-stabilized with its spin axis maintained between 4 and 20 degrees of the Sun), the stationkeeping technique for the three is fundamentally the same. The technique consists of correcting the energy of the orbit via a delta-V directed parallel or anti-parallel to the Spacecraft-to-Sun line. SOHO achieves this using thrusters oriented in line with the solar direction. WIND achieves the delta-V via pulsing radial thrusters when aligned with the Sun. ACE uses axial thrusters to apply delta-V with a component that is 94% or more aligned with the ACE-Sun line. Sunward thrust adds energy to the orbit preventing decay back toward Earth. Thrust directed anti-Sunward takes energy out of the L1 orbit, thereby preventing escape from the Earth-Moon system into independent heliocentric orbit.

Libration point orbit stationkeeping delta-V costs grow exponentially with time elapsed from the last maneuver performed. The doubling time constant is approximately 16 days. For the sake of fuel conservation, and for limiting the absolute magnitude of propulsion performance errors, stationkeeping maneuvers should be performed before the delta-V grows too large; for our purposes 'too large' is considered to be greater than 0.5 m/sec. In practice, the typical interval between burns for this trio is about three months, and the typical delta-V is much smaller than 0.5 m/sec. Typical annual stationkeeping costs have been around 1.0 m/sec for ACE and WIND, and much less than that for SOHO. All three spacecraft have ample fuel remaining; barring contingencies all three could, in principle, be maintained at L1 for decades to come.

This paper will review the L1 orbits and the mission history of ACE, WIND, and SOHO, and describe the stationkeeping techniques and orbit maneuver experience. The Lissajous phase control that was practiced for ACE during the period from 1999 to 2001 will also be briefly discussed. The final section will consider the future of these ongoing missions.

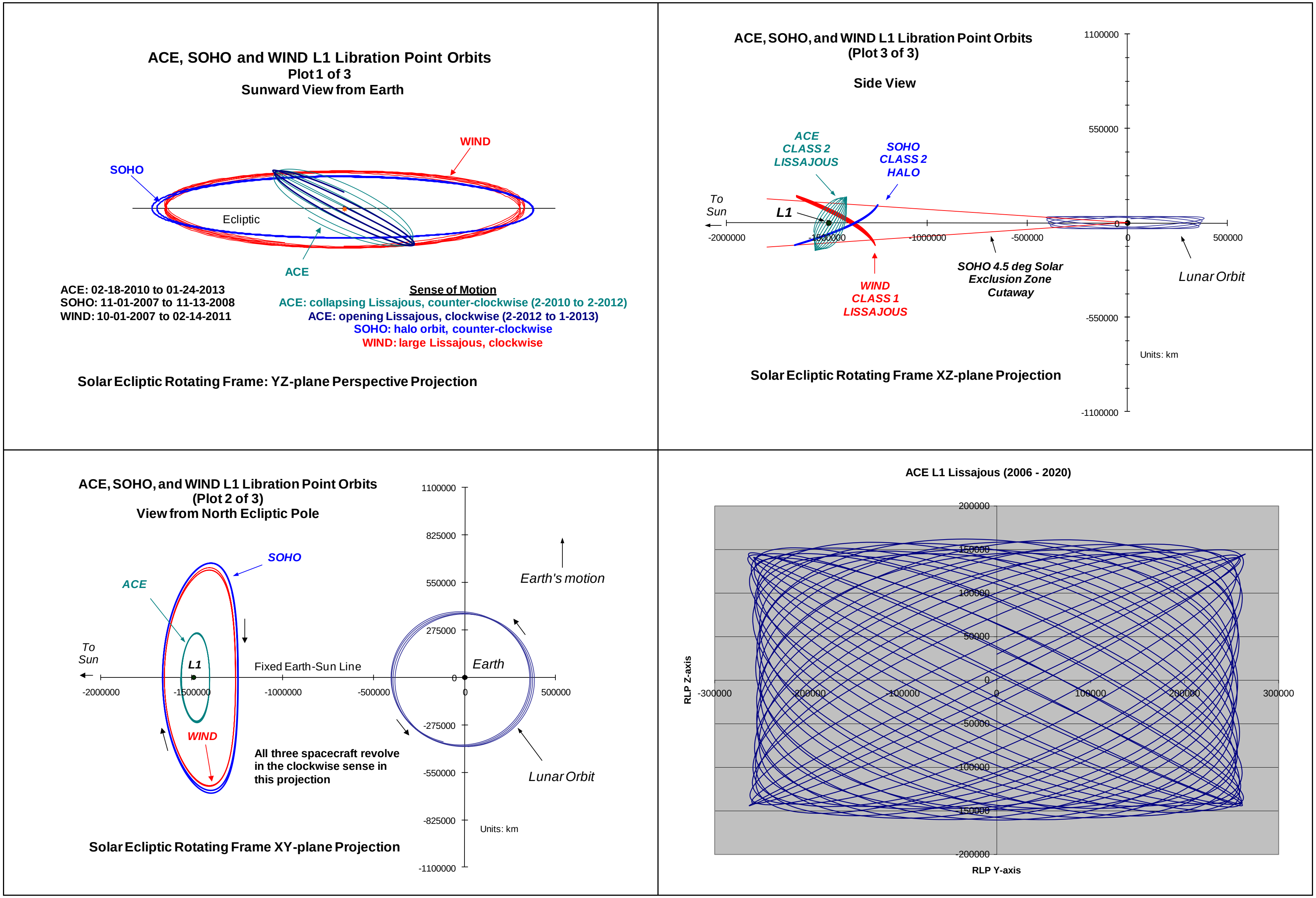

Figure 1. Solar Rotating Frame Plane Projection Views of the ACE, WIND, and SOHO L1 Libration Point Orbits

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