USE OF LIBRATION-POINT ORBITS FOR SPACE OBSERVATORIES

ROBERT W. FARQUHAR
Goddard Space Flight Center, Greenbelt, Maryland 20770, U.S.A.
and
DAVID W. DUNHAM
Computer Sciences Corp., 10110 Aerospace Road, Lanham, Maryland 20706, U.S.A.

Abstract. The Sun-Earth libration points, L_1 and L_2, are located 1.5 million kilometers from the Earth towards and away from the Sun. Halo orbits about these points have significant advantages for space observatories in terms of viewing geometry, thermal and radiation environment, and delta-V expediture.

1. Introduction

The locations of the seven Lagrangian libration points near the Earth are shown in Figure 1. All five of the Earth-Moon libration points are included, as well as the L_1 and L_2 collinear points of the Sun-Earth system. The latter remain fixed on the Sun-Earth line, which is the horizontal axis of Figure 1. The configuration of the lunar libration points rotates around the Earth once each month.

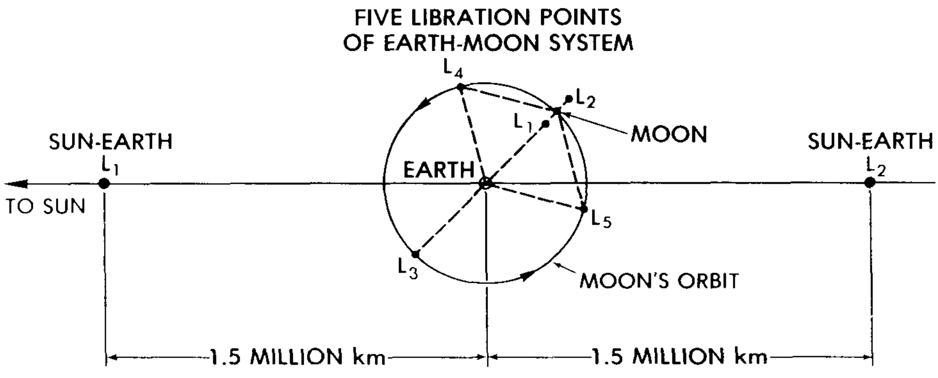

Fig. 1. Libration points in the vicinity of the Earth

The first comprehensive discussion of the use of libration-point orbits by artificial satellites was published by (Farquhar 1969). For space telescopes, the lunar libration points generally offer no special advantages over the Sun–Earth (SE) points. Even the triangular points do not have long-term stability due to strong solar perturbations.

Y. Kondo (ed.), Observatories in Earth Orbit and Beyond, 391–395.

2. Advantages of the Sun-Earth collinear points

The relatively fixed geometry of the Sun, the Earth, and the spacecraft in halo orbits about the L_1 and L_2 points of the SE system give them special advantages for siting space observatories. A halo orbit about the SE L_1 point was used by the third International Sun-Earth Explorer to monitor the solar wind (Farquhar *et al.* 1977; Farquhar *et al.* 1980). The European Space Agency's Solar and Heliospheric Observatory (SOHO) will use a similar halo orbit in 1995.

Orbits around the SE L_2 libration point are best for stellar observatories. The Sun, the Earth, and the Moon can be kept in back of the spacecraft for an unhindered view of over half of the sky at all times. The Soviet Union's Relict-2 spacecraft will use an L_2 orbit in 1993 (Eismont *et al.* 1990).

Spacecraft near either of the SE collinear points seldom need to change their orientation relative to the Earth or the Sun, simplifying thermal control and pointing of high-gain antennas. Large eclipses can be avoided, ensuring a continuous source of solar power.

Orbits around the SE L_1 and L_2 points are unstable, but stationkeeping costs are low, less than 5 m/sec per year. This could be achieved with low-thrust systems such as venting from a helium dewar or solar sails.

The delta-V costs to reach low orbits are shown in Figure 2. The total delta-V is the sum of two delta-V's needed to perform a Hohmann transfer from a low parking orbit (185 km altitude assumed) to a higher circular orbit whose radius is given in Earth radii (Re) of 6378 kilometers on the abscissa. DV1 is the delta-V needed to enter the transfer orbit. DV2 is a circularizing delta-V, performed at the apogee of the transfer orbit to achieve the final orbit. Vertical dashes mark the geosynchronous orbit and the 100,000-km orbit planned for the Space Infra-Red Telescope Facility (SIRTF).

Figure 3 is like Figure 2, but extended beyond the Moon's orbit. The Moon's gravity helps to "circularize" the trajectories of spacecraft sent to the lunar L_1 and L_2 points. These transfers utilize a powered close lunar swingby to decrease the libration-point insertion costs.

The delta-V is largest to achieve an orbit of about 100,000-km. An even bigger saving for SE L_2 orbits is the elimination of DV2; the Sun's gravity can achieve the "circularization". The delta-V cost to reach a halo orbit about the SE L_2 point is a fifth less than that for a 100,000-km circular orbit, meaning that a correspondingly larger payload can be delivered to L_2 than to the currently planned SIRTF orbit using the same launch vehicle.

3. Examples of L_2 orbits

Fig. 4 shows a possible SIRTF trajectory. There are no planned delta-V's following injection on June 29, 1997. Starting a day after launch, trim maneuvers could be performed with helium normally vented from SIRTF's cryogenic cooling system. SIRTF could begin observations just after crossing the lunar orbit. The only eclipses are lunar transits covering less than 20

Relict-2 has plasma instruments to measure the geomagnetic tail. However, the

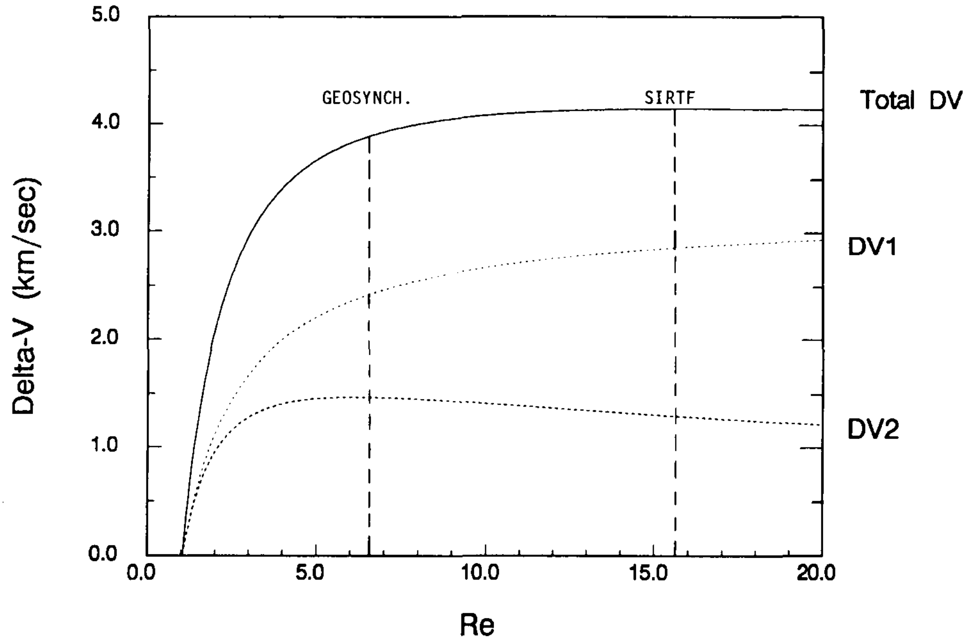

Fig. 2. Delta-V needed to attain circular orbits from 1 to 20 Earth radii

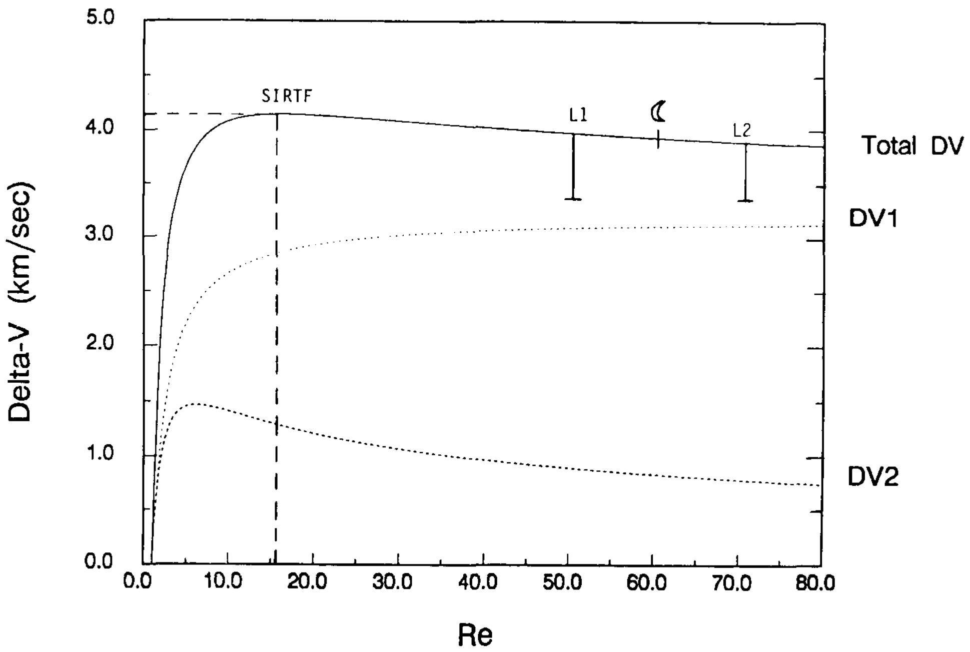

Fig. 3. Delta-V needed to attain circular orbits from 1 to 80 Earth radii

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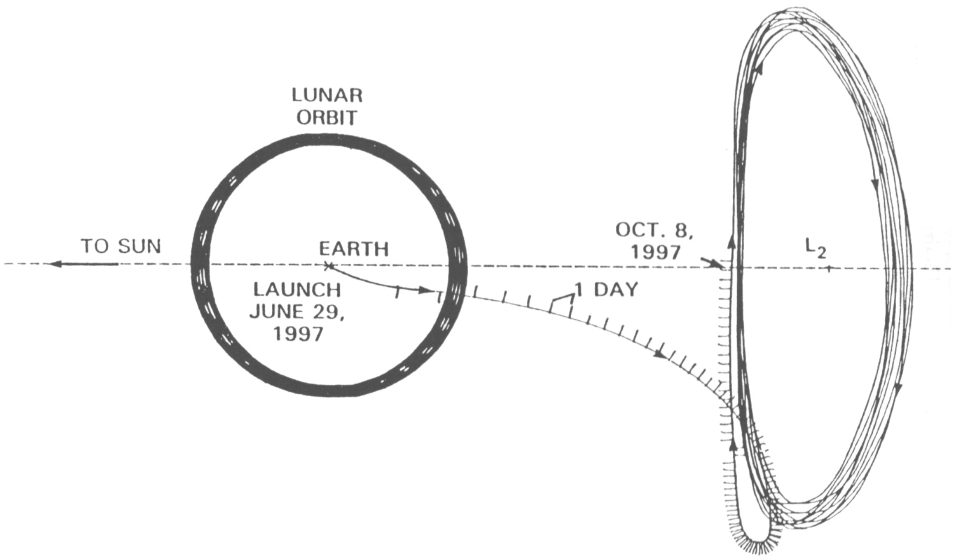

Fig. 4. SIRTF L_2 libration point trajectory

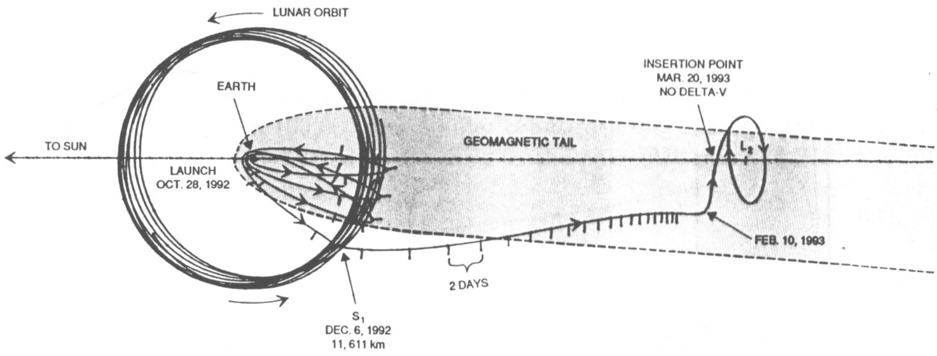

Fig. 5. Relict-2 trajectory using lunar swingby

orbit of Figure 4 quickly crosses this region. Geotail dwell time could be increased considerably with a smaller-amplitude orbit about L_2 achieved with a lunar swingby, as shown in Figure 5. Like the Figure 4 trajectory, there are no planned delta-V maneuvers after injection and no significant eclipses.

4. Conclusions

The advantages of halo-type orbits about the Sun-Earth L_2 libration point have been demonstrated. Future missions already plan to use Sun-Earth L_1 and L_2 orbits, including Relict-2, SOHO, the Advanced Composition Explorer, and one or two spacecraft of the Soviet Regatta series (Farquhar 1990). Until transportation to the lunar surface becomes almost routine, we believe that orbits near the Sun-Earth L_2 point may be the best places for space observatories.

Acknowledgements

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