RE-ENTRY DISPOSAL ANALYSIS FOR LIBRATION POINT ORBITS MISSIONS

Elisa Maria Alessi[(1)] **, Camilla Colombo**[(2)] **, Markus Landgraf**[(3)]

[(1)] *IFAC–CNR, Via Madonna del Piano 10, 50019 Sesto Fiorentino (FI), Italy,*
+39 055 5226315, `em.alessi@ifac.cnr.it`
[(2)] *Politecnico di Milano, Aerospace Science and Technology Dept., Via La Masa 34, 20156 Milano, Italy,*
+39 02 23998370, `camilla.colombo@polimi.it`
[(3)] *European Space Agency – ESOC, Robert-Bosch-Str. 5, 64293 Darmstadt, Germany,*
+49 6151 903627, `Markus.Landgraf@esa.int`

ABSTRACT

The neighborhood of the Lagrangian collinear libration points L_1 and L_2 of the Sun–Earth system has been recognized as a vantage location to place astrophysics and solar missions since the end of the 70's, with the NASA ISEE-3 mission. As a matter of fact, L_1 and L_2 Libration Point Orbits (LPO) are relatively easy and inexpensive to be reached and they offer a simple communication design system. The region around L_1 represents a good observation site of the Sun, while L_2 is the most suitable place to put highly precise telescopes requiring great thermal stability.

In this work, we are interested in providing a thorough analysis of one of the disposal strategies, namely the Earth re-entry, which can be adopted at the end-of-life of such missions. Indeed, nowadays the mission design also comprises the implementation of disposal solutions to preserve the space environment. These solutions must be conceived as feasible, sustainable and not demanding from the point of view of the operations. The re-entry turns out to accomplish all these features and represents one of the best concepts envisaged within an ESA study carried out recently.

The missions selected for this work are Herschel (quasi-halo orbit around L_2), SOHO (halo orbit around L_1) and GAIA (Lissajous orbit around L_2). Herschel is proposed as a reference mission, since it just ended and thus it gives the opportunity to compare our disposal strategy with the solution selected by ESA. GAIA is a near future mission, as it is planned to be launched at the end 2013 and therefore can pave the way for new mission concepts by using a pre-planned disposal strategy. Finally, SOHO is selected since it is currently orbiting around L_1 and its expected end is in 2016. We also notice that at the end of their life both SOHO and Herschel have about an expected available Δv of about 150 $\mathrm{m/s}$, while GAIA just 10 $\mathrm{m/s}$.

To design the re-entry, we first exploit the natural dynamics corresponding to the unstable invariant manifold associated with the nominal LPO within the Circular Restricted Three–Body Problem (CR3BP) framework and then we develop, within a full dynamical model, a differential correction procedure aimed at computing the precise maneuver which allows to reach the Earth. In particular, the CR3BP analysis reveals that the hyperbolic invariant manifolds provide zero-cost solutions for Herschel and SOHO, but not for GAIA. In the latter case, the minimum distance to

the Earth without performing any maneuver is about 50000 km and this is particularity of the small Lissajous orbits and thus applies to other missions like Planck.

In a second step of the analysis, by considering the full dynamical model, we are able to compute almost zero-cost re-entry trajectories for Herschel, SOHO and GAIA. It turns out that GAIA can arrive to the Earth at no expense by traveling through either a heteroclinic or homoclinic connection to a very high amplitude LPO (see Fig. 1). The equations of motion adopted account for Sun, Earth, Moon and all the planets from Mercury to Pluto, solar radiation pressure, atmospheric drag (exponential model) below an altitude of 2000 km and 20×20 geopotential. Both for the solar radiation pressure and the atmospheric drag, a detailed study on the area-to-mass ratio of the three spacecraft is performed. The initial conditions for Herschel are taken from the JPL HORIZONS system, the ones for SOHO are foreseen on the basis of the actual ephemerides provided by the same system, while for GAIA they are computed by means of a Fourier series expansion.

We pay attention not only on the maneuver cost, but also to the re-entry angle and to the collision risk with the GEO-LEO protected regions, which can be considered negligible. Moreover, the total time of flight is alway less than 1 year and the regions on the surface of the Earth affected by the re-entry are identified. Concerning the re-entry angle, all possible values can take place, depending on the initial phase on the LPO, but values greater than -20° are advisable. A simplified model is applied to estimate the mechanical and thermal loads during the final leg of the re-entry and the resulting possible fragmentation.

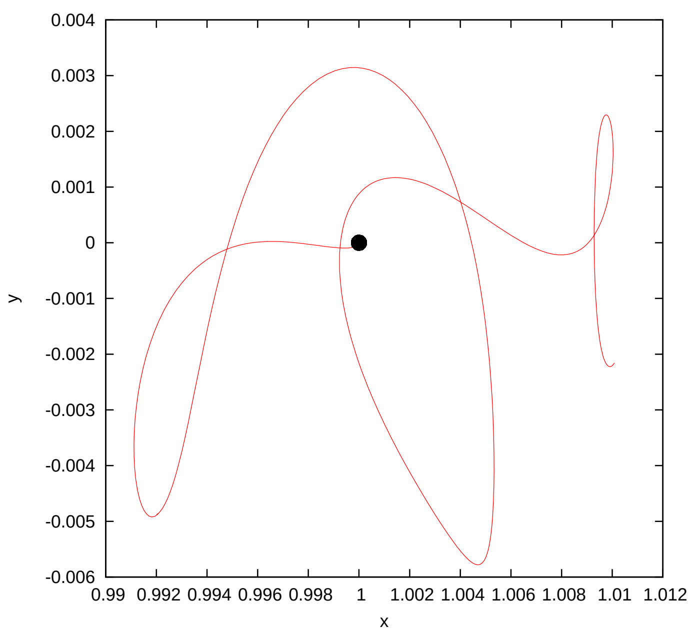

Figure 1: Example of heteroclinic connection, computed within the full dynamical model, which allows GAIA to re-entry at almost Δv zero-cost. Synodical reference system, non dimensional units.