QUASI-PERIODIC ORBITS IN THE VICINITY OF THE SUN-EARTH SYSTEM L2 POINT AND THEIR IMPLEMENTATION IN "SPECTR-RG" AND "MILLIMETRON" MISSIONS

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ABSTRACT

This work considers construction of quasi-periodic orbits in the vicinity of the Sun-Earth system L_2 libration point that are suitable for the upcoming Roscosmos "Spectr-RG" and "Millimetron" missions. Both missions presuppose deployment of an astrophysical observatory in a quasi-periodic orbit around Sun-Earth system L_2 point. Since the scientific goals of these missions differ, different types of orbits have been proposed – "Spectr-RG" spacecraft should be placed in a halo orbit lying in a close vicinity of the L_2 point whereas "Millimetron" spacecraft should use a large radius halo orbit going 1 mln km away from the ecliptics plane.

To construct these halo orbits a new method and new mathematical algorithm providing ballistic design of the spacecraft transfer to the vicinity of the Sun-Earth system L_2 point and halo orbit motion in this area has been developed and implemented. The method is based on Dr. Lidov's idea of building isolines of function, connecting geocentric transfer trajectory parameters with the desired halo orbit parameters. This method provides one-impulse transfers to halo orbits with given geometrical dimensions in the ecliptics plane and in plane orthogonal to it.

For calculation of one impulse flights from Earth to the selected halo orbit (with the help of a Moon swing by maneuver or without it) the initial approximation construction algorithm has been implemented. These approximations are calculated by means of two variables' function isolines construction and analysis. The transfer trajectory pericentre height above the Earth surface is considered to be such a function. The arguments of this function are special parameters describing the halo orbit spatial geometry. Since the collinear equilibrium point L_2 and halo orbits around it have strong hyperbolic character it is possible to use the latter's stable manifold for the transfer from Earth. A local approximation (linearized equations of motion describing three body problem) of the stable manifold at a certain number of points of the nominal orbit is taken. The state vector at each point is propagated backwards in time until the trajectory comes close enough to Earth to intersect with the parking orbit. All dots of the phase space satisfying given conditions at both endings of the transfer trajectory (parking orbit height at the Earth ending and θ_A, θ_B parameters, describing halo orbit geometry) compose the set of isolines, serving as initial approximation for the exact numerical calculation of the transfer trajectory. Since the initial approximation for the transfer trajectory is selected on the stable manifold approaching towards a periodic halo orbit, no maneuver is needed to insert into the halo orbit.

As it was said the vicinity of the collinear libration points is a hyperbolically unstable

motion area, therefore some stationkeeping strategy is needed to keep the spacecraft in the desired halo orbit. An algorithm, calculating stationkeeping maneuver impulses and providing optimal stationkeeping strategy for the whole spacecraft lifetime has been developed, ΔV costs have been evaluated.

The halo orbits calculated with the help of the methods described above and presented in the study meet all ballistic requirements and restrictions of the "Spectr-RG" and "Millimetron" missions. Transfer trajectories and proposed quasi-periodic orbits have been selected as the nominal ones for both missions.

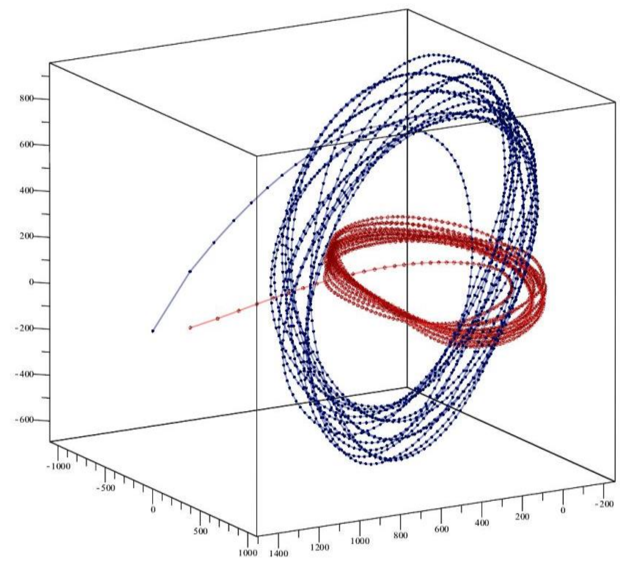

Fig. 1 3D view of the quasi-periodic orbits, proposed for "Spectr-RG" (red) and "Millimetron" (blue) spacecrafts in the rotating L_2 centered reference frame (X-axis points from the Sun) .

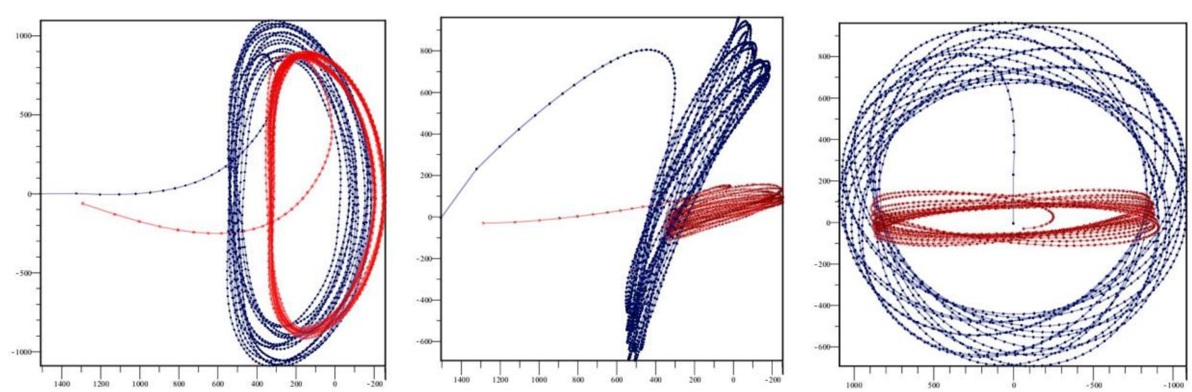

Fig. 2 2D view of the quasi-periodic orbits, proposed for "Spectr-RG" (red) and "Millimetron" (blue) spacecrafts in the rotating L_2 centered reference frame (X-axis points from the Sun).