TO THE ADAPTIVE MULTIBODY GRAVITY ASSIST TOURS DESIGN IN JOVIAN SYSTEM FOR THE GANYMEDE LANDING

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Modern space missions inside Jovian system are not possible without multiple gravity assists (as well as in Saturnian system, etc.). The orbit design for real upcoming very complicated missions by NASA, ESA, RSA should be adaptive to mission parameters, such as: the time of Jovian system arrival, incomplete information about ephemeris of Galilean Moons and their gravitational fields, errors of flybys implementation, instrumentation deflections. Limited dynamic capabilities, taking place in case of maneuvering around Jupiter's moons, demand multiple encounters (about 15-30 times) for these purposes. Flexible algorithm of current mission scenarios synthesis (specially selected) and their operative transformation is required.

Mission design is complicated due to requirements of the Ganymede Orbit Insertion (GOI) ("JUICE" ESA) and also Ganymede Landing implementation ("Laplas-P" RSA [1]) comparing to the ordinary early "velocity gain" missions since "Pioneers" and "Voyagers". Thus such scenario splits in two parts.

Part 1(P1), as usually, would be used to reduce the spacecraft's orbital energy with respect to Jupiter and set up the conditions for more frequent flybys. Part 2(P2) would be used to lower the spacecraft's Ganymede relative velocity to set up the correct conditions for the GOI. The technique of P1 implementation is well known: it is the sequence of resonant same-body transfers "from Ganymede to Ganymede"(the solution based on the Lambert solution technique). But the P2 implementation couldn't be the same (in requirements of quasi ballistic gravity assist with low cost propellant consumption). The cause is the invariance of Tisserand's parameter in a circular restricted three-body system (CR3BP) [2]. Therefore it is impossible to change the magnitude of the V_∞ velocity vector of the spacecraft with respect to the Ganymede. Furthermore, the same-body flybys sequence on the Tisserand-Poincare (T-P) graph [2] falls according the V_∞-isoline to the "Extra Radiation" zone (XR-zone) with spacecraft's orbit pericenter height $r_p \le 10R_J$, R_J - Jupiter's radius (This height is critical for missions "JUICE" ESA and "Laplas-P" RSA. Approximately they shell have Total ionizing dose TID of 250-300 Krad behind a 10-ml Al spherical shell). So regular expensive corrections of pericenter's height increasing are demanding in this case.

But the other implementation of P2 can be used. They are- "crossed" gravity assists from one small body G("Ganymede") to the second small body $\bar{G}$ ("not Ganymede", generally for a not big TID it is Callisto) and then – in the opposite direction. We can "to outwit" the Tisserand's criterion like this. It allows us to build special effective "phase beam"(PB) methods of orbit design synthesis for "Laplas-P"-mission in classes of encounter sequences-disjunctions $G_1 \wedge \bar{G} \wedge G_2$ (or modified $G_1 \wedge \ldots \wedge G_k \wedge \bar{G}_m \wedge \ldots \wedge \bar{G}_{m+n} \wedge G_{k+1} \wedge \ldots$).

Tisserand-Poincare graph [2] allow to design mission dynamical maquette (but only in phase-free form). Algorithms with utilizing the real satellites configurations at the real time of close approach are required for upcoming missions implementation. NAIF JPL NASA Ephemeris have been employed in our simulations. Patched Conics can not be applied immediately in the trajectory design. The rigid fixation of scenario's conic points should be threat to the mission's implementation.

As the result, the idea of adaptive synthesis of mission design was constructed by authors. Then it was implemented by effective algorithm. The corresponding numerical scheme was developed with using Tisserand-Poincare graph and the simulation of hundreds of thousands of options formation of the calculation (Fig.1). The ΔV-low cost searching was utilized also for trajectory design with help of multiple rebounds of phase beams modeling. The techniques developed by the authors specifically to the needs of the mission "Laplas P" RSA. In the selection of hundreds of thousands of options for each date selected only those chains that form closed loops on Ganymede gravity assist after intermediate Callisto's flybys. The adaptive scheme, which retains the flexibility to clarify or an unforeseen change in external conditions, also in the case of errors during encounters implementations is presented, that provides the reliability of the mission and its multi-variant flexibility.

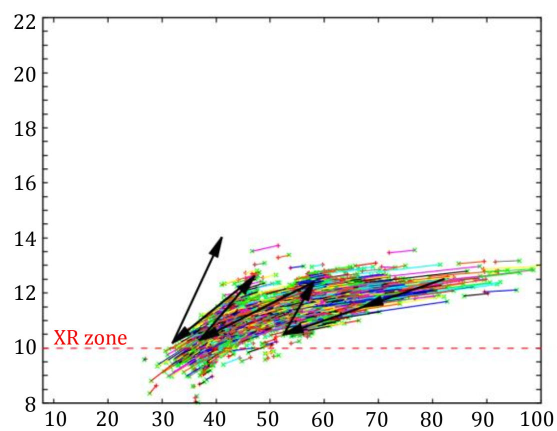

Fig. 1. T-P graph under a modified synthesis script with imposing requirements of multi rebounds. X-axis and Y-axis are spacecraft apocenter and pericenter height in R_J (Jupiter radii)

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