MISSION DESIGN FOR THE EXPLORATION OF NEPTUNE AND TRITON

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ABSTRACT

Neptune and its largest moon Triton are essential pieces of the Solar System puzzle. A mission dedicated to their exploration is challenging in terms of communication, power, and mission design; however, it would yield paradigm-changing advances in multiple fields of planetary science.

This work is part of a white paper [Masters et al., 2013] supporting the exploration of Neptune and Triton, in response to the recent call from ESA to define science themes for the two L-class missions (The original work was extended to include a broad search if interplanetary transfers). The required enabling technologies for an orbiter mission are found to be (1) extended deep-space network capability, (2) European Radioisotope Thermoelectric Generators, and (3) Solar Electric Propulsion module. This paper describes mostly the mission design, focusing on the interplanetary transfer and on the Neptune orbiter tour.

Interplanetary transfer to Neptune. Issues such as RTG lifetime (20 years, including pre-launch ground phase) make the duration of an interplanetary transfer to Neptune an essential aspect of any discussion of Neptune orbiter mission concepts. We investigated trajectory options involving a launch from Kourou centred on the 2028-2034 timeframe. Rather than project future Ariane launcher performance, we assume an Ariane 5 ECA launcher for this preliminary analysis. Interplanetary transfer to Neptune requires a Gravity Assist (GA) by either Jupiter or Saturn a few years after launch because of RTG lifetime and to mitigate propellant requirements. However, a Jupiter GA is more effective than a Saturn GA for a Neptune orbiter mission [Landau et al., 2009].

Favourable opportunities for a Jupiter GA will exist in 2033 and in 2046 (separated by a Jupiter-Neptune synodic period of ~13 years). We thus studied interplanetary transfers that take advantage of each of these opportunities. One or more Earth GAs and orbital manoeuvres are required prior to the Jupiter GA in both cases, with mission-enabling SEP employed in this phase since chemical propulsion would require large amounts of fuel (>4 tons, neglecting use of low-TRL aerocapture for Neptune orbit insertion). Figure 1 shows an example interplanetary transfer for each Jupiter GA opportunity. Launch is in 2028 and Neptune arrival is in 2043 in the first example, and launch is in 2041 and Neptune arrival is in 2056 in the second example. The transfer duration is ~15 years in both examples. These transfer options deliver ~1,800 kg dry mass into Neptune orbit, in line with estimates provided by the past Neptune orbiter study by NASA [Marley et al., 2010], and similar to the JUICE dry mass of 1,800 kg (including radiation shielding not required at Neptune).

Neptune orbital tour Another essential aspect of a Neptune orbiter mission concepts discussion is the question of whether a spacecraft tour would allow the necessary observation

opportunities. The frequency and geometry of Triton flybys is crucial. The key point we would like to highlight is that Triton is an effective “tour engine”, allowing a wide range of orbit trajectories and observation opportunities. We present one example Neptune tour here, which is essentially a proof of concept. Although not optimised, this tour would address all scientific questions. Our example tour is 2 years in duration, starting with interplanetary transfer arrival conditions given by the first stage of this preliminary analysis. At the beginning of the tour the spacecraft flies between the inner rings and executes NOI at 3,000 km altitude, following previous NASA mission concepts [Marley et al., 2010]. The tour is shown in Figure 2A. In two years there are 55 Triton flybys, with groundtracks shown in Figure 2B. Total chemical Delta-V for the whole mission is ~3 km/s, similar to *JUICE* (~2.6 km/s).

During the three phases of this example tour there are inclined Neptune orbits and orbits in Triton’s orbital plane. Triton flybys occur over the full range of Triton orbital locations, and at altitudes between ~150 and ~1,000 km. There is significant flexibility in, for example, Triton flyby altitudes, which can be raised or lowered as necessary. Our preliminary analysis suggests that a Triton orbit phase could be included at a Delta-V cost of ~300 m/s, using a transfer similar to that planned for *JUICE* [Campagnola et al., 2012].

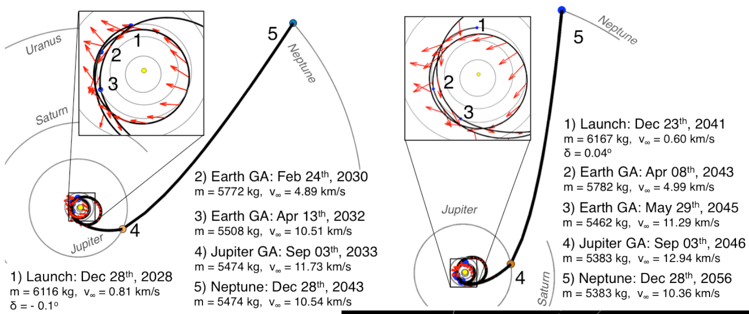

Figure 1. Example interplanetary transfer with launch in 2028 (left) and 2041 (right). Trajectory arcs where SEP is employed are modelled by small impulsive Delta-V (represented by red arrows).

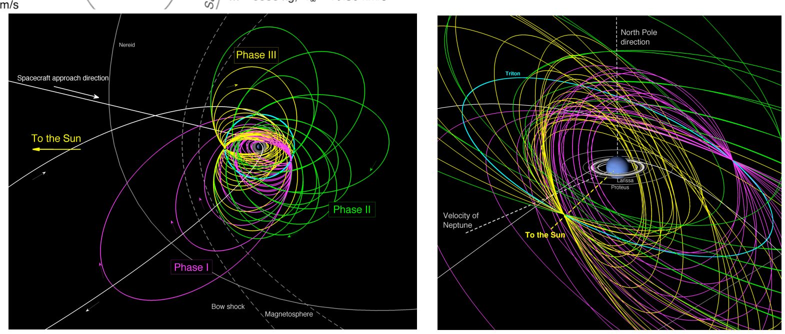

Figure 2. Example Neptune orbital tour. Left: Viewed from Neptune’s north pole. Right: Close-up of the tour.

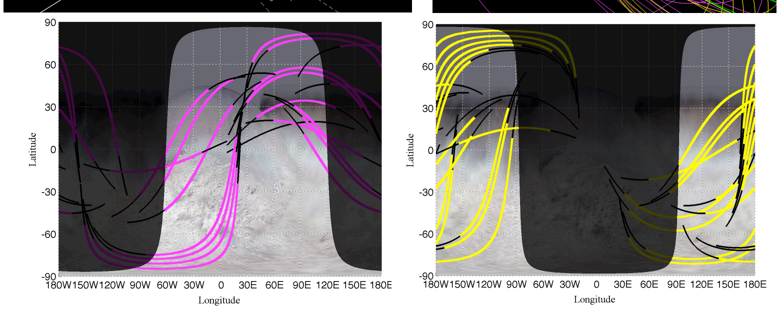

Figure 3. Groundtracks of Triton flybys during Phase I (left) and Phase III (right). Below 5000 km (black), below 1000 km (coloured).

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