NEPTUNE ATMOSPHERIC RETROGRADE ORBITER – A MISSION TO NEPTUNE AND ITS MOONS.

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Introduction: The 2023–2032 Planetary Science Decadal Survey published in 2022 identified the outer planets, especially the ice giants Uranus and Neptune, to be of particular interest for upcoming planetary science missions. Therefore, an MSc student project as part of the course in spacecraft design and system engineering at Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland proposes a multi-decade large-scale mission to study Neptune and its system of rings and moons, with a particular focus on Triton. The primary mission goals of this concept are threefold:

(i) Studying the nature of Neptune's atmosphere and magnetosphere at the outer fringes of the solar system.
(ii) Examining the composition and geophysics of Triton, a potentially captured Kuiper Belt Object (KBO), including its hypothetical sub-surface ocean.
(iii) Performing technology demonstration for the outer solar system, namely aerocapture, optical telecommunication, next-generation RTGs, and a deployable high-gain antenna.

Concept of Operations: The developed mission concept proposes a transfer to Neptune with (powered) fly-bys of Mars and Jupiter for a preliminary launch target fixed on February 7, 2031 [1], using Vulcan-Centaur as a launch vehicle. Arrival at Neptune is foreseen for October 2044 after a 13-year-long cruise phase. Orbital insertion into a highly elliptical retrograde orbit is achieved through an aerocapture maneuver, demonstrating the viability of this concept for the outer solar system and allowing for in-situ measurements of Neptune's atmosphere. Following a periapsis raising maneuver after emerging from the atmosphere, an orbit with a periapsis of 4,000 km and an apoapsis of 430,000 km (both values measured above Neptune's 1 bar atmospheric layer) with a period of 80 days is targeted. This orbit is optimized to minimize the impact of the radiation environment around Neptune while simultaneously maximizing the science potential [1]. The orbit is of retrograde orientation with an inclination of 157.345°, co-planar to the orbit of Triton, allowing for in-depth study of the moon. The primary science phase is performed from this orbit.

For a primary mission of five years, several fly-bys of Triton and Neptune's smaller moons are to be performed. The primary mission may be extended if the health and status of the spacecraft allow for this at the end of the primary mission. The mission is concluded by a Cassini-like "Grand Finale", consisting of multiple shallow passes above Neptune, leading to a last series of atmospheric measurements until the spacecraft is completely deorbited.

Scientific Payload: An extensive suite of scientific payload based on instruments with flight heritage from NASA New Horizons, NASA Juno, as well as other prior and proposed interplanetary NASA and ESA missions is proposed (reference designs listed in parentheses):

(i) Ultraviolet-visible spectrophotometer (Alice – NASA New Horizons)
(ii) Visible-infrared spectrophotometer (Ralph – NASA New Horizons)
(iii) Optical telescope (LORRI – NASA New Horizons)
(iv) Mass spectrometer (MASPEX – NASA Europa Clipper)
(v) Microwave radiometer (MWR – NASA Juno)
(vi) Radio and plasma wave sensor (Waves – NASA Juno)
(vii) Magnetometer (MAG – NASA Juno)
(viii) Laser altimeter (BELA – ESA Bepi-Colombo)
(ix) Ice-penetrating radar (RIME – ESA JUICE)
(x) Optical transceiver (DSOC – NASA Psyche)

The scientific areas of interest to be investigated by these instruments include Neptune itself, its associated atmospheric and magnetic environment, and its plasmasphere. In relation to Triton, its topology and composition, as well as the properties of its hypothetical sub-glacial ocean are investigated. Furthermore, the other Neptunian moons will be explored via fly-bys and telescopic observations similar to how NASA Cassini investigated Saturn's minor moons. The ring system of Neptune is observed as well, especially towards the end of the mission, with the spacecraft passing between it and the Neptunian cloud tops.

Spacecraft Architecture:

The main spacecraft bus is encapsulated within an aeroshell to withstand the constraints of the aerocapture maneuver [2]. In addition to classical downlink using RF technology in Ka-band, a demonstrator for optical telecommunication based on the DSOC payload flying on NASA Psyche is added to the spacecraft. All relevant subsystems of the spacecraft (telecommunication, electrical power system, structure, command & data-handling, attitude determination & control system, propulsion, and thermal regulation system) were studied individually, and appropriate architectures and hardware implementation were suggested.

Specifically, the spacecraft will be powered by modular next-generation RTG technology to meet its electrical power and heating needs. It will implement the SpaceWire protocol to manage its internal data flow.

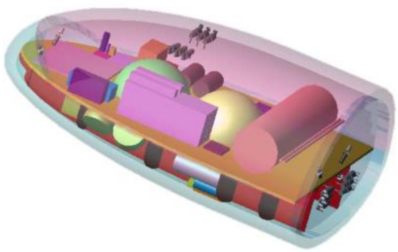

Figure 1: Reference orbiter concept packaging [2]

Systems Engineering: Engineering budgets for the spacecraft were established based on the analyses of the subsystems. For a scientific payload mass of 150 kg, a total spacecraft wet mass of 1600 kg is obtained. The maximum power consumption of the spacecraft is estimated at 580 W, with all systems being powered on, which can be reduced as a function of the mission phase.

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References: [1] K. M. Hughes et al. (2012) *AAS 13-805*. [2] M. K. Lockwood (2004) *AIAA Atmospheric Flight Mechanics Conference and Exhibit 23681-2199*.