The Exploration of Trans-Neptunian Objects via a Delta-VEGA Maneuver

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Abstract

Trans-Neptunian Objects (TNO) are objects beyond the orbital path of Neptune and have captivated the interest of scientists across the would since such distances were first reached by the Voyager 1 & 2 spacecraft. The distances of such objects have previously made such missions prohibitively expensive and technically strenuous, yet the data gathered from these objects provides invaluable insight into the origin of our solar system. Our senior design project proposes that an effective way to mitigate critical flight characteristics such as characteristic energy (C3), velocity (Δv) and transit time could be achieved by implementing a Delta-V Earth Gravity Assist (Delta-VEGA). As such, fifteen potential single and multi-target TNO missions were created using this technique with Spaceflight Solution's Mission Analysis Environment (MANE) tool. Additionally, analysis was conducted using modern launch vehicle capabilities, building upon previous studies by UTK design groups.

Rationale for the Capstone

- The only spacecraft to-date to visit a TNO is NASA's New Horizons spacecraft, which in 2019 passed by the target 2014 MU69 [2].
- The heaviest spacecraft to ever leave the Solar System was NASA's Voyager 2 spacecraft at 735 kg [3]. Proving that this weight limit could be increased would allow for more complex mission to one (or more) TNO's.
- Previous senior design groups at UTK sought to create similar trajectories without Delta-VEGA maneuvers for both spacecraft flyby and orbital missions to TNO's. The results have been deemed infeasible due to one of the following factors: prohibitively high characteristic energy (C3), prohibitively high velocity requirements (Δv), or prohibitively long transit time to TNO (on the order of 20+ years) [1]. All these factors have been minimized by including the Delta-VEGA maneuver.

First Three Steps

1) Establishing a Dedicated Team - Senior design teams are formed at the start of senior year for engineering students. I took it upon myself to carefully select who would work together, with the intent of creating an impactful final design proposal.

2) Cultivating a Shared Vision - Once formed, our team spent our first month together establishing what we could meaningfully contribute towards within the astronautics community. As a mediator in this conversation, we decided upon TNO trajectory planning.

3) Conducting Rigorous Background Research - Once a vision was established, research into novelties within TNO trajectory planning was conducted.

Project VVM

Challenge: Utilizing innovative spacecraft trajectory methods to enable robust exploration of the Kuiper Belt and associated Trans-Neptunian Objects.

Values: Curiosity, Dedication, Innovation and Integrity (both personal and intellectual)

Vision: To enable more capable, robust and insightful spacecraft missions to TNO's, in an effort to learn more about the origins of our solar system.

Mission: To implement optimized Delta-VEGA spacecraft trajectories to allow for greater payload masses to TNO's.

Other's Solutions

- Initially sought to create trajectories to the Neptunian moon Triton, but focus was shifted after discovering extensive papers on the topic.
- Numerous methods for trajectory improvement were considered, with a Delta-VEGA being used on selected TNO's due to novelty.
- Numerous trajectory optimization programs were considered (MANE, GMAT), with Spaceflight Solution's MANE software being used due to our research advisor knowing the developers.

Partnerships

Current

Source: spaceflightsolutions.com

Potential/Future

Source: jpl.nasa.gov

Project Status

Our senior design team is currently in the process of codifying our findings into a research paper, which will be submitted to the AAS/AIAA Astrodynamics Specialist Conference taking place in August 2021.

Source: space-flight.org

Source: aiaa.org

References

[1] Gleaves, Ashley M., "A Survey of Mission Opportunities to Trans-Neptunian Objects – Part II" (2012). Chancellor's Honors Program Projects.
[2] In depth. (2020, October 07). Retrieved March 25, 2021, from https://solarsystem.nasa.gov/missions/new-horizons/in-depth/
[3] In depth. (2021, February 04). Retrieved March 25, 2021, from https://solarsystem.nasa.gov/missions/voyager-2/in-depth/

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