**Potential Orbital Capture Missions to Trans-Neptunian Objects.** Gautamraj Baskaran, Anurag Bonthalapati, James Evans Lyne, Jusin D. Lewis, Kyle J. Malone, and Harsh Ved[1], [1]12409 West Kings Gate Road Knoxville, TN 37934; hved@utk.edu

**Introduction:** Several previous missions including Voyager I and II, Pioneer 10 and 11 and New Horizons have explored the trans-Neptunian region of the Solar System, but to date, only New Horizons has been designed to target a specific Trans-Neptunian Object (TNO) [1-2]. Our group has previously analyzed high thrust missions using a single Jovian Gravity Assist (JGA) to several TNOs including Makemake, Eris, Huya, Varuna, Ixion, Sedna, Quaoar and Huamea.

In the current study, we extend our previous work by examining high thrust missions using Jupiter-Saturn Gravity Assist (JSGA) trajectories to a range of TNOs. With this new profile, the objective is to compare critical mission parameters (departure C3, transit time, Jovian radiation environment, arrival hyperbolic excess speed, etc.) to those of the previously generated missions using a single JGA. The current study also includes orbital capture mass potential and retrograde burn oppoutrunites are to be analyzed upon arrival of each TNO.

**Methdology and Assumptions:** Trajectory analysis is being done using the software package Mission Analysis Environment (MAnE) [3]. High thrust trajectories for the JSGA are being the constructed by finding the conjunction (near-side alignment) dates of Jupiter and Saturn. The Cassini mission had a transfer time from Jupiter to Saturn of approximately 3.5 years [5]. Using this data, the location of Jupiter's position a year before the conjunction date is recorded and the location Saturn's position 2.5 years after the conjunction date is recorded. Though utilizing a JSGA can be advantageous, many problems arise because the synodic period of Jupiter and Saturn is roughly 20 years; hence, mission opportunities are limited. After the initial trajectory is built, the resultant heliocentric trajectory can be utilized to find any TNOs that have close encounters with this trajectory.

Because a Jovian Gravity Assist will most likely be used for all our missions to TNOs, it is quintessential that there be an adequate assessment of the threat posed to electronic systems of the spacecraft caused by the intense Jovian radiation environment. In order to determine the radiation dose the Keplerian elements is input into the Program to Optimize Simulated Trajectories (POST) [6]. POST is able to provide the 3D position of the spacecraft as a function of time as it performs the flyby. The data from POST is then input into the Space Environment Information System (SPENVIS) which uses the Galileo Interim Electron Environment (GIRE) model to determine the number of trapped particles [7]. SPENVIS can then calculate the radiation dose in silicon for certain shielding thicknesses.

Orbital capture and retrograde burn opportunities are executed by assuming an impulsive burn. Both methods will use a two-stage solid and liquid booster rocket since it promotes reliability for long missions. The solid rocket booster utilized for analysis is manufactured by ATK which have ISP's of ~286s [8]. The second stage would be liquid-fuelled and modeled on the Cassini insertion engine [9], using mono-methyl hydrazine (MMH) and nitrogen tetroxide as fuel ($N_2O_4$). It would make use of a HiPAT, an upgraded version of the Cassini engine, providing an ISP of 323s.

Capture opportunities for TNOs are difficult because each body possess a relatively low mass. In most cases the decrease in speed required for capture is identical to the arrival speed. Hence, longer missions with lower arrival speeds are favorable for orbital capture.

Retrograde burns are being analyzed to increase the observation time of the target body for a fly-by. The propellant mass would be much lower for a retrograde than orbital capture burns. Shorter mission will be paired with retrograde burns because of high arrival speeds. Orbital capture for shorter missions would require much higher propellant mass, some cases may exceed the departure mass at Earth. Though retrograde burns provide additional observation time, instrumentation mass may be limited if the burn is more significant.

**References:** [1] 1Guo, Y., and Farquhar, R. W., "New Horizons Mission Design," *Space Science Reviews*, Vol. 140, No. 1-4, 2008, pp. 49-74. [2] NASA, *New Horizons, The First Mission to Pluto and the Kuiper Belt: Exploring Frontier Worlds*, Launch Press Kit, 15 December 2005. [3] MAnE, Mission Analysis Environment, Software Package, Ver. 3.5g, Space Flight Solutions, Hendersonville, NC, 2013. [6] Brauer, G. L., Cornick D. E., and Stevenson R., "Capabilities and Applications of the Program to Optimize Simulated Trajectories (POST)", NASA CR-2770, Feb. 1977. [7] Kruglanski, M., "The Space Environment Information System", https://www.spenvis.oma.be/intro.php. Accessed January 4, 2014.