Double Jupiter Gravity Assist for Achieving High Heliocentric Asymptotic Escape Speeds and Missions to Interstellar Objects. A. Hibberd1, T. M. Eubanks2, 1Initiative for Interstellar Studies (27 South Lambeth Road, London, SW8 1SZ, United Kingdom), 2Space Initiatives Inc. (Newport, VA 24128 USA).

Introduction: The discovery in the last two years of the passage through our solar system of two interstellar objects – firstly 1I/‘Oumuamua (1I) in 2017 and secondly 2I/Borisov (2I) in 2019 – has stimulated proposals of missions to intercept these bodies [1], [2] & [3]. There has also been a campaign gaining momentum for the development of a probe to travel to and study the interstellar medium [4].

Here a way of achieving these mission goals is explored, by accelerating a spacecraft (s/c) to high heliocentric asymptotic escape velocities, \(V_\infty\), using a double Jupiter Gravitational Assist (GA). The OITS (Optimum Interplanetary Trajectory Software) preliminary mission design tool, developed by Adam Hibberd is employed.

The method involves firstly an Earth Launch to Jupiter, followed by an unpowered GA taking the spacecraft on a 6 year journey out of the ecliptic plane before returning to Jupiter which in the meantime has traversed half a Jupiter cycle. A Deep Space Maneuver (DSM) is inserted between the two Jupiter encounters at a solar distance of 5.2AU. A Jupiter Oberth maneuver then takes place to accelerate the spacecraft to achieve a high value of \(V_\infty\). (Note that a dual Jupiter assist has been proposed in the past but with a Solar Oberth between the two Jupiter encounters [5].)

An example 3D plot of such a trajectory is shown in Figure 1.

Although the results reveal this method is less effective than the Solar Oberth maneuver in terms of the magnitude of \(V_\infty\) achieved for a given \(\Delta V\) as it takes the spacecraft against the sun therefore necessitating a heat shield on the spacecraft, in turn imposing extra mass requirements and complicating the s/c design. The method elucidated here requires no heat shield.

Comparison with Solar Oberth: The Solar Oberth maneuver [6] involves a close approach of the s/c to the sun and a burn is applied by the s/c at the perihelion distance where the benefit of \(\Delta V\) application is maximized. The perihelion distance is often measured in Solar Radii (SR) and the resulting asymptotic escape velocity in AU/year. Figure 2 shows the comparison of the effectiveness of the double Jupiter GA against that of a Solar Oberth at 3SR and 10SR from the sun’s centre. In fact the double Jupiter Oberth appears to be equivalent to a Solar Oberth at around 38SR.

Missions to 1I & 2I: Various methods of intercepting 1I and 2I have been investigated, [1], [2] & [3]. To maximize the return of scientific knowledge the former, ‘Oumuamua, is considered here as it has various unusual characteristics, including its elongated shape as is indicated by its unusual light curve.

A mission to 1I has been found to be feasible using a Solar Oberth at 6SR [2]. A 3 year \(V_\infty\) leveraging maneuver [7] is utilised to reduce the \(\Delta V\) required at Earth to get to Jupiter. The scenario is similar to that propounded in the KISS study [6]. An image of the mission trajectory is provided in Figure 3, which shows

Figure 1: An example double Jupiter Gravitational Assist for achieving high heliocentric velocities. The mission shown has the goal of achieving 1000AU, 200000 days after the 2\(^{nd}\) Jupiter encounter, at a speed (approx. \(V_\infty\)) of 1.76AU/yr. (The heliocentric longitude and latitude at this distance are optimized by OITS.)

Figure 2: \(\Delta V\) Required for the J-DSM-J of an E-J-DSM-J-1000AU Trajectory Compared to Theoretical \(\Delta V\)’s for Solar Oberth at 10 SR and 3 SR
a view from above the solar system, i.e. the ecliptic co-ordinates x & y.

Launch is in 2030 and the total ΔV is 15.3km/s with arrival at 1I in 2052, after 22 years overall mission duration.

Can a double Jupiter GA provide a means of intercepting 1I with a comparable TOA? Figure 4 shows such a mission where the 3 year \( V_\infty \) leveraging maneuver is replaced by one lasting approx. 1 year. The mission has a larger ΔV of

![Figure 3: E-DSM-E-J-6SR-II Launch 2030 Total ΔV=15.3km/s](image)

16.4km/s and furthermore a longer overall mission duration of around 28 years but does not incur the dangers of a close approach to the sun.

![Figure 4: E-E-J-DSM-J-II Launch 2023 Total ΔV=16.4km/s](image)

**Sedna & Eris:** Missions to these Trans-Neptunian Objects (TNO’s) have been proposed [8], lasting around 24 years. As both these missions involve an unpowered Jupiter GA, there is consequently no improvement observed from a double Jupiter GA. Furthermore, there is also no benefit from reducing the overall mission duration, as significant sun-radial velocities are then required at the 2nd Jupiter encounter which render the double Jupiter GA less effective.

**References:**