The approach to this homework assignment was to first set up the loop conditions and data structures that would record the values. The main iterables were Time Delay (TD) and Time of Flight (TOF) with values for position, velocity, semimajor axis, parameter, velocity change, and true anomaly being recorded in the loops.

With these set up, I did an initial analysis of the ISS where I found the ISS’s mean motion, eccentric anomaly with newton’s method, and time since the ISS’s time of periapsis. This later part was important since we cannot directly find the time of periapsis, however we can find the time since time of periapsis which still allows the use of Kepler’s Equation.

From this, we can tell that the Moon is ~13 hours behind the ISS. Synchronizing the Moon and the ISS at this point made the analysis at the initial conditions more understandable. This was done by finding the Moon’s mean motion, the Moons initial time, the Moons Mean Anomaly w.r.t the ISS, and then re-finding the Moon’s initial time w.r.t the ISS.[[1]](#footnote-1)

With these found, a for loop could be made that would iterate on TD and TOF to find the ideal transfer between the ISS and the Moon. This was done in two steps. The first step was iterating across TD to find the initial position and velocity vectors of both the ISS and the Moon. The next step was iterating across TOF in a nested for loop placed at the end of the TD for loop to find the final position and velocity vectors for both the ISS and the Moon.

|  |  |  |
| --- | --- | --- |
|  | Initial | Final |
| ISS | TD | TD & TOF |
| Moon | TD | TD & TOF |

Both steps followed the same general formula of first finding the new mean anomaly, using newton’s method to find the eccentric anomaly, then finding the radius magnitude, true anomaly, and finally doing through the DCM to find position and velocity vectors. Once the values are found, values for true anomaly, position, and velocity are moved out of the loop.

This was the general pattern used for the initial and final positions of the ISS and Moon.

1-4 are put through a quad check program to find the correct value. With found, , , , , , , and can be converted from classical to cartesian coordinates which will output and .

The last part of the loop was putting the and through Lambert’s Black Box. Outputting , , , .

Changes in velocity were also found before the loop ended.

The final output were several 3D and 4D arrays. With these three contour plots were made that plotted TD on the x-axis, TOF on the y-axis, and on the z-axis. See the figures below.

A different colored shapes on a blue background

Description automatically generated with medium confidence

The graph on the right is the TLI, middle the V infinity, and left the total delta V.

|  |  |  |  |
| --- | --- | --- | --- |
|  | TLI | Vinf | Total VDel |
| Velocity (km/s) | 3.1108 | 0.8664 | 4.3384 |
| TD (hours) | 2.4417 | 0.1667 | 2.4417 |
| TOF (days) | 15.7292 | 4.6875 | 15.7292 |

Going forward, the values gotten from the total delta V were used as it represents the lowest value overall for the transfer.

The first step to analyzing the transfer trajectory selecting the correct values from

1. The Moon is referred to as Lun in equations and variables. It’s also referred to as Luna in code. [↑](#footnote-ref-1)