SLS and Orion
EM-1 Mission Notes

EM-1 Orion Mission Overview

Launch Orion on 10 day Lunar transfer.
Deploy Cubesats from ICPS stage, check ICPS disposal trajectory.
Orion course correction at T+24hrs for accurate Lunar flyby.
Lunar flyby - retrograde burn at 100km PeA, 180° Inclination for 70,000km Apolune.
3 day transfer to 70,000km Apolune.
At Apolune make burn to enter stable DRO.
Remain in DRO for 5 days until next Apolune.
At next Apolune, make burn to exit DRO and return to Moon for 100km PeA, 180° Inclination powered flyby (TEI).
2 day transfer to Moon flyby.
Make Trans Earth Injection burn at 100km PeA for Earth Reentry in 6 days.

Total Duration: 26 days
Total Orion dV: ~1035 m/s

Distant Retrograde Orbit (DRO)
A family of perturbed orbits around the Moon that are stable for long periods.
Resonant with Moon orbit. More stable than L1/L2 Halo orbits.
Can be identified in “Rotating Frame” orbit display - “kidney” shape orbit around Moon.

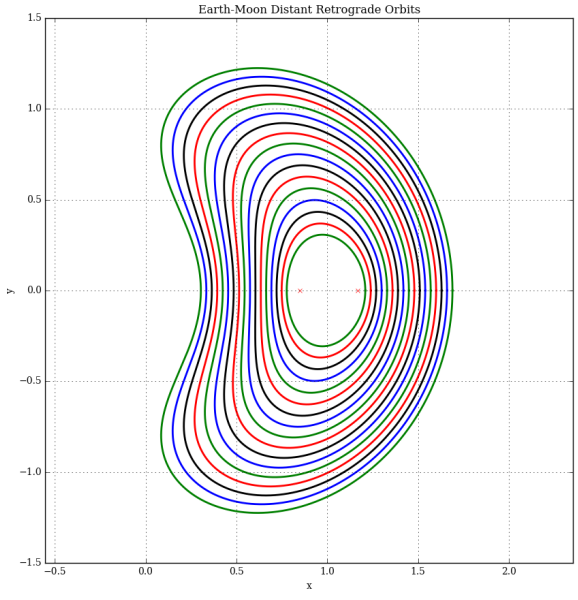
LagrangeMFD is the only Orbiter tool that can plan and execute the DRO Entry burn, and also display orbit in “Rotating Frame”.

More DRO info:
http://degenerateconic.com/distant-retrograde-orbits/
http://www.mdpi.com/2226-4310/3/4/37/pdf

Illustration of DRO family shown in “Rotating Frame” (Earth-Moon fixed)

Earth at origin (0,0)
Moon at (1,0)
L1 and L2 points shown as red x.

EM-1 mission uses orbit similar to smallest green plot shown.



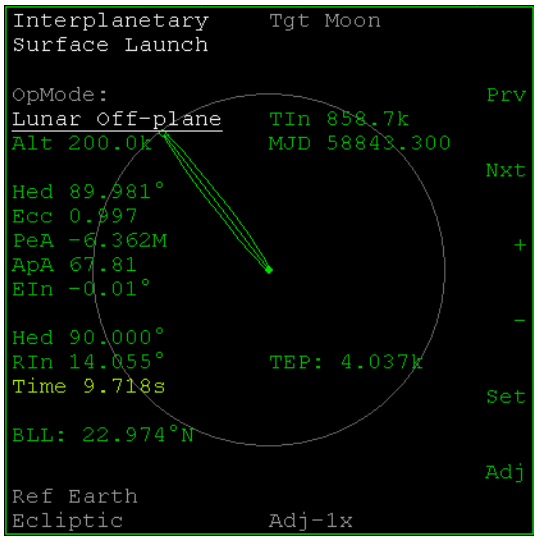
Launch
Using *IMFD Surface Launch – Lunar Off-plane* to find lift-off time.
Set Alt 200km and MJD for 10-day transfer.

Autopilot guidance file is set for launch to 90° azimuth, 2800km x 40km initial orbit.
Should put Perigee at correct place for efficient TLI.

Press P at T-10s for ascent autopilot.
Launch at 08:38:58 UTC, 16 Dec 2019

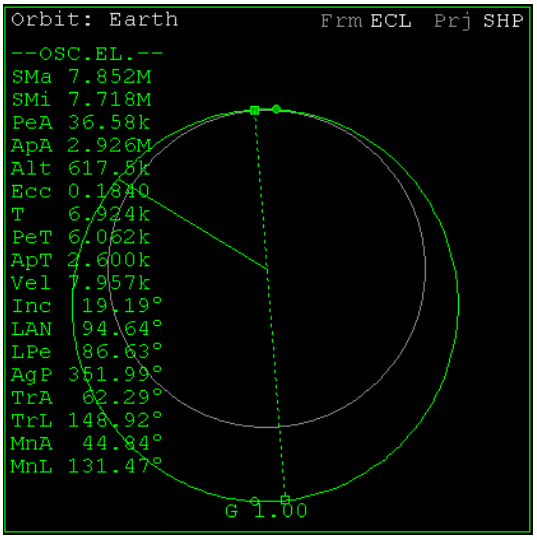
Jettison 1st Stage after MECO

As initial orbit is elliptical, Perigee must be at the correct place to perform efficient TLI burn.



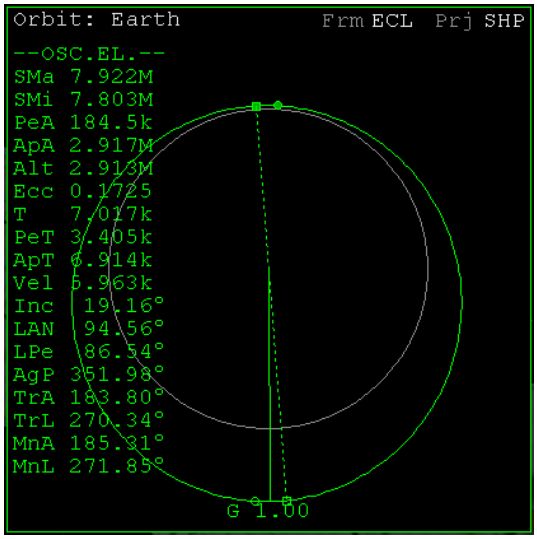
2nd Stage Initial Orbit
Turn Prograde and make Periapsis Raise Manoeuvre (PRM) at Apogee.

Raise PeA to 185km.

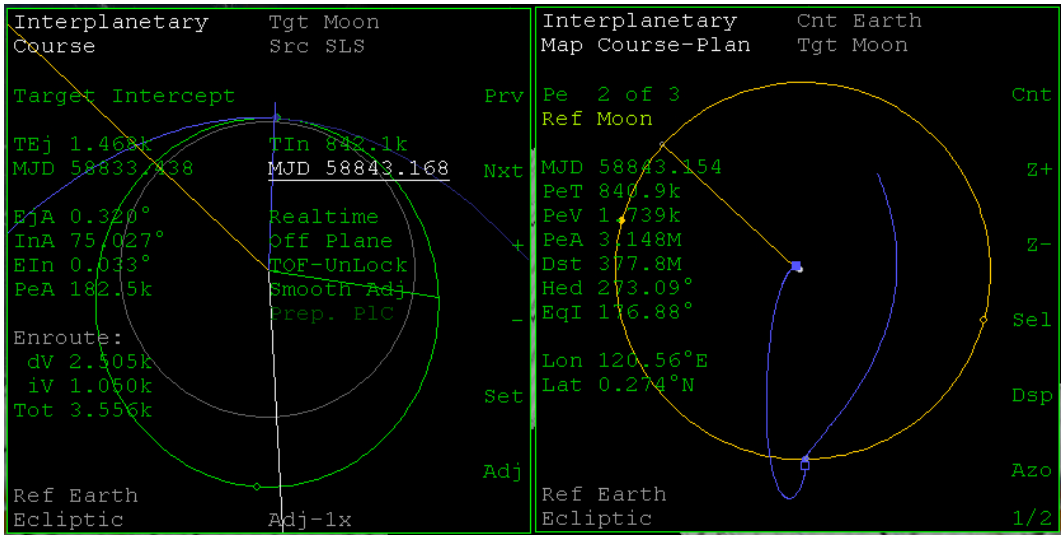


Post PRM orbit
PeA is raised to 185km.

Start to plan Trans Lunar Injection (TLI)



TLI Set-up



Using *IMFD Course – Target Intercept* and *IMFD Map – Plan View*.
Optimize dV by adjusting TEj and TIn.
Check result on IMFD Map – Plan View.

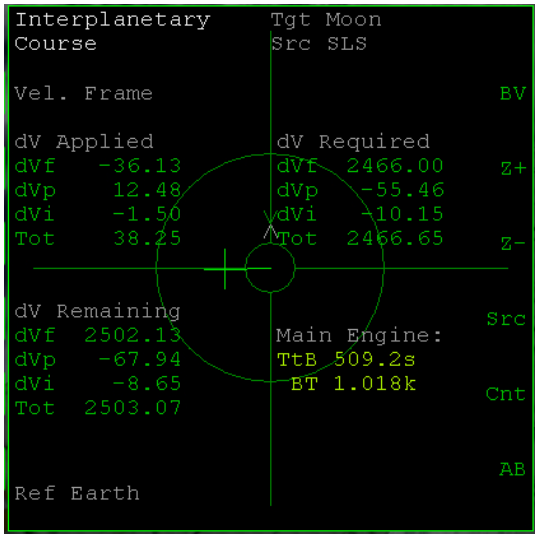
Performing TLI burn

Switch to BV view, but go to Prograde attitude.
Do NOT engage IMFD AutoBurn [AB]

TLI burn must be reasonably efficient, the first part is performed in Prograde attitude.

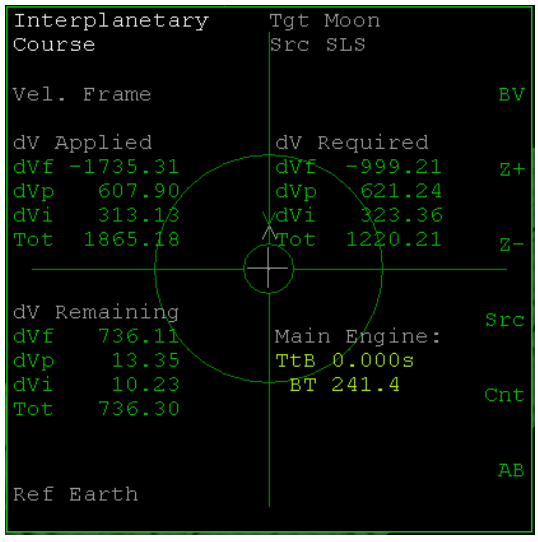
Begin burn *manually* when TtB (Time to Burn) is equal to ½ BT (Burn Time).

Maintain Prograde attitude until BV cursor is centered in cross-hairs.



When BV cursor is central in cross-hairs, cut engines and engage IMFD AutoBurn [AB] for remainder of burn.

Check engine is OFF at end of burn.



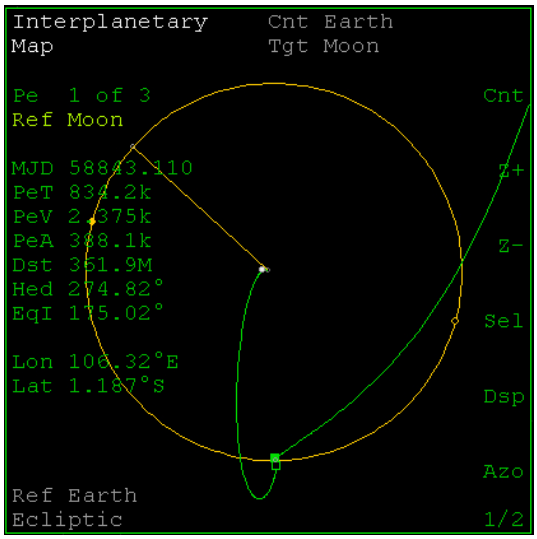
NOTE: Using *IMFD Course – Delta Velocity* is even more efficient, but more hassle!

Post TLI

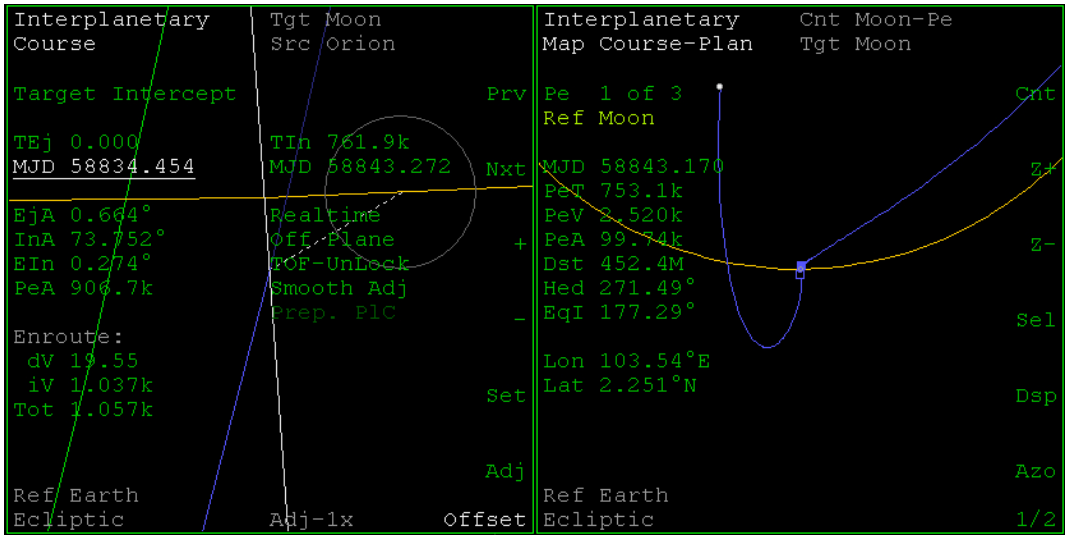
Lunar transfer trajectory.

ICPS on course for disposal to heliocentric orbit.

Deploy Cubesats.

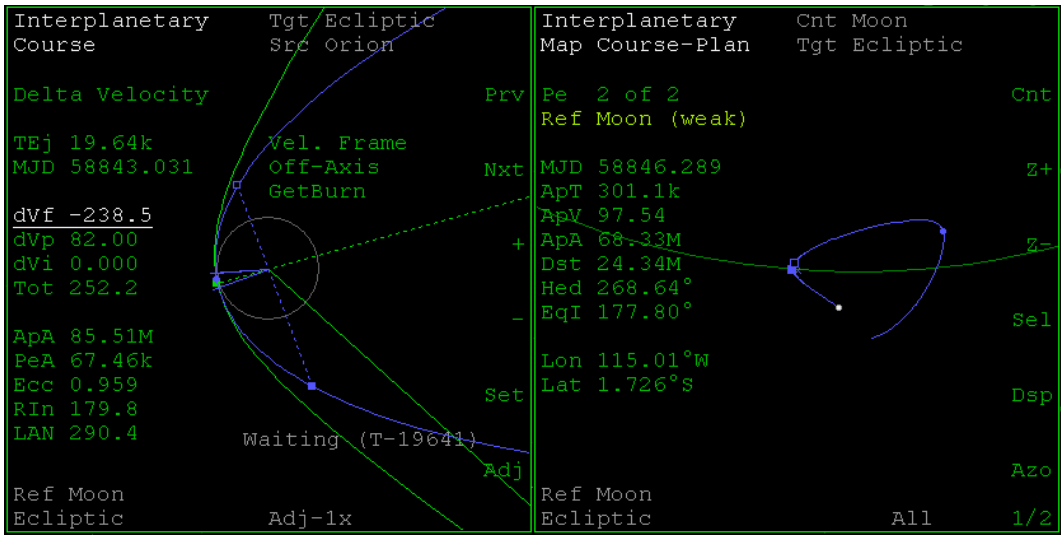


Orion MCC1 at T+24hrs



Using *IMFD Course – Target Intercept* and *IMFD Map – Plan View*
Target Intercept “Offset Mode” is used to plan burn for correct trajectory to Lunar flyby.
Target is 100km PeA, Inclination as close as possible to 180°.

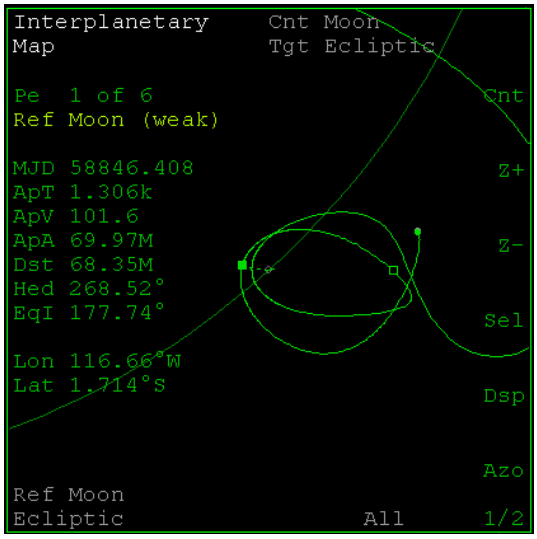
Arrival at Moon – Powered flyby (retrograde burn)



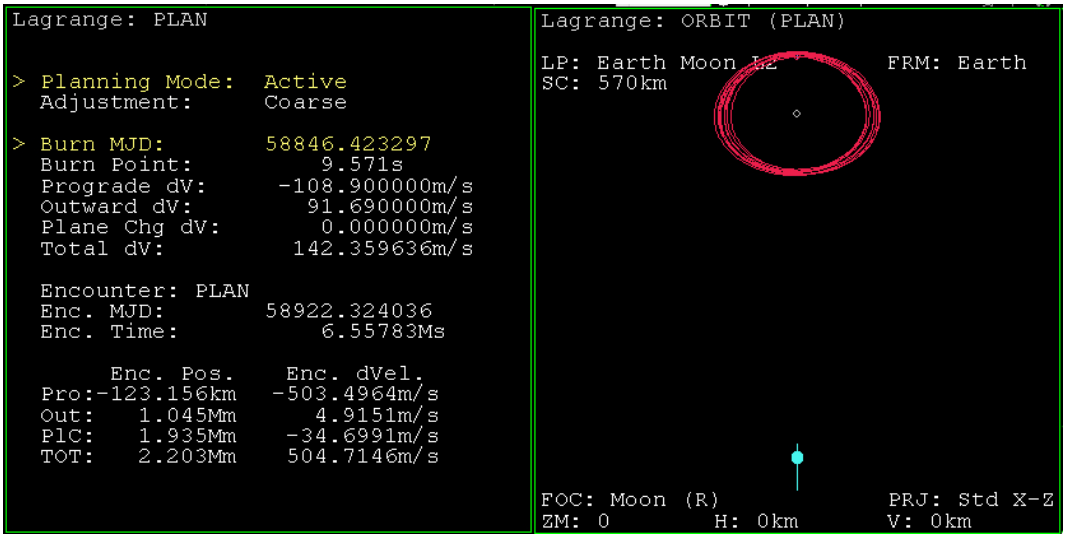
Using *IMFD Course – Delta Velocity* and *IMFD Map – Plan View*
Target 70,000km ApA, as close as possible to 180° Inclination.

At Apolune 70,000km

IMFD Map display of trajectory immediately before insertion to DRO.



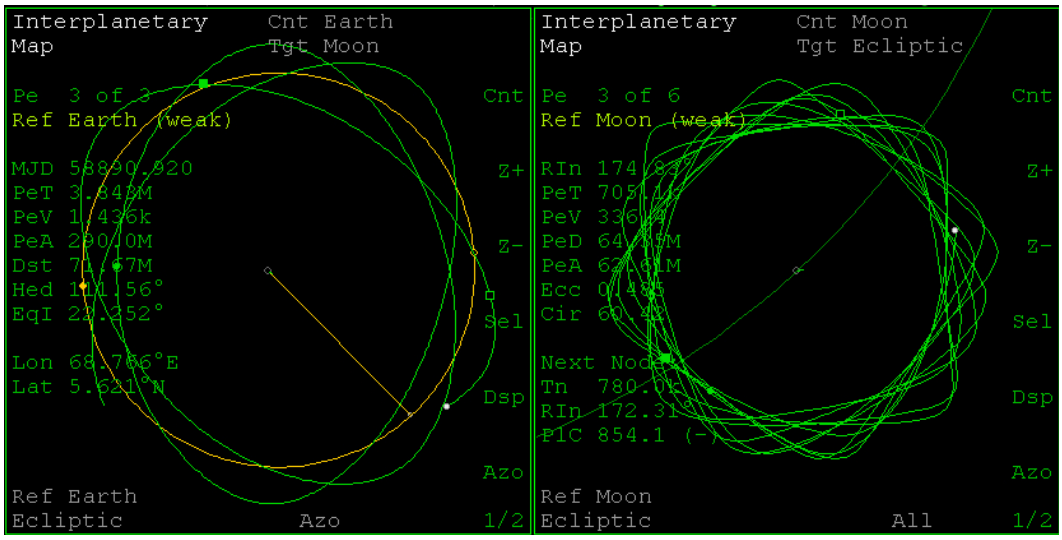
DRO Insertion Burn



Using *LagrangeMFD* to plan the burn.
At 70,000km Apolune, make burn to insert Orion into DRO.
You will need to adjust Prograde and Outward dV values until the resulting orbit becomes stable, as seen in the “Rotating Frame” view on right (Earth-Moon line fixed)
You can see the oblate “kidney” shape.

LagrangeMFD Autoburn function can be used to perform burn.

Post DRO Insertion

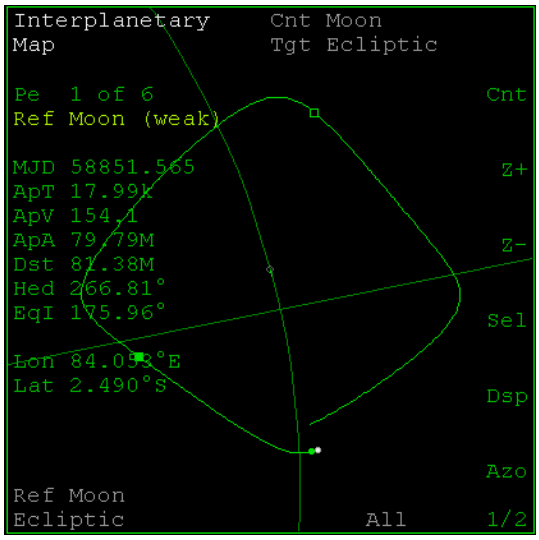


DRO trajectory displayed by *IMFD Map.*
Earth centered inertial frame on left, Moon centered inertial frame on right.
Not as easy to interpret as the LagrangeMFD “Rotating Farme” display.
Shows the resonance nicely though!

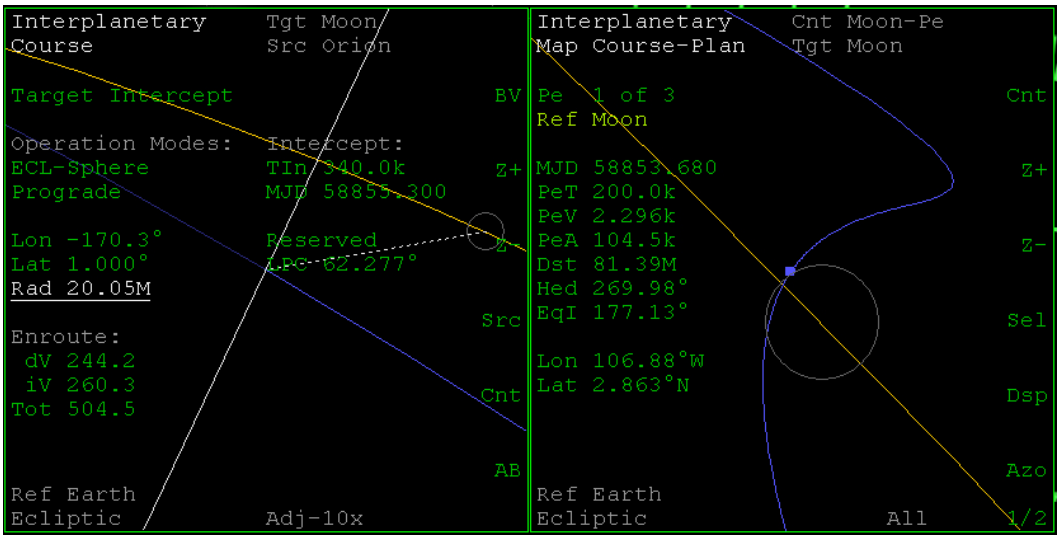
At 2nd Apolune – immediately before DRO exit burn

IMFD Map showing arrival at 2nd Apolune after ~5 days.

Make burn to transfer to Moon for powered flyby (Trans Earth Injection).

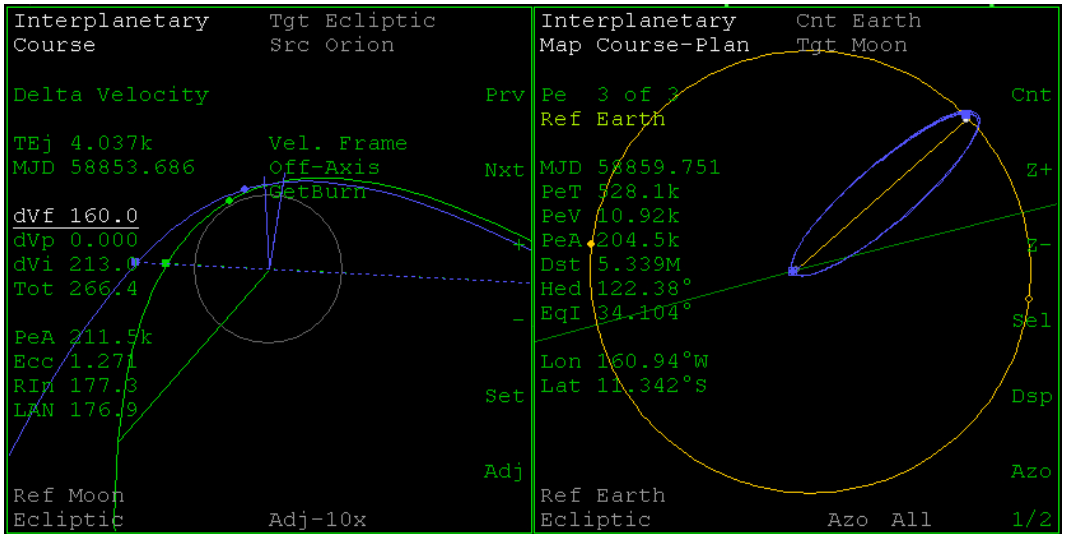


DRO Exit Burn



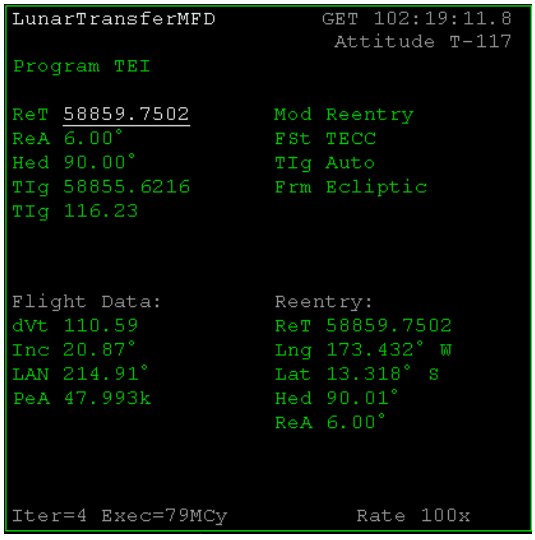
Using *IMFD Course – Target Intercept (Offset Mode)* and *IMFD Map – Plan View.*
Target Moon flyby at 100km PeA, close to 180° Inclination, transfer time ~2 days.

2nd Moon Flyby – Trans Earth Injection(TEI) Burn



Using *IMFD Course – Delta Velocity* and *IMFD Map – Plan View*
Adjust Tej and dVf, dVp, dVi to achieve Earth Return trajectory.

Earth Return Course Correction

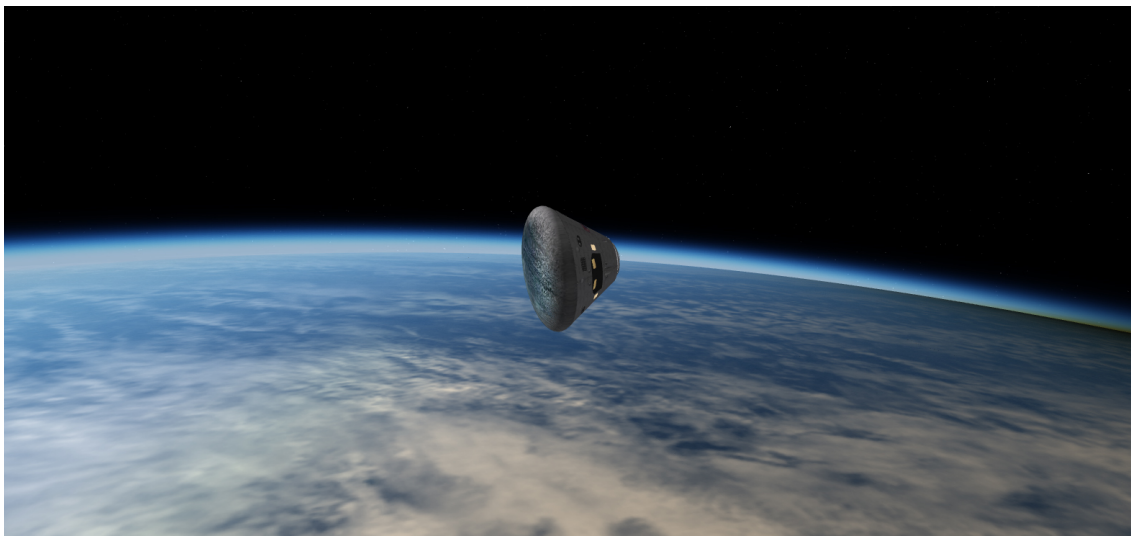


Using *LTMFD* (LunarTransferMFD)
Target 40km PeA at Earth for reentry over Pacific Ocean.

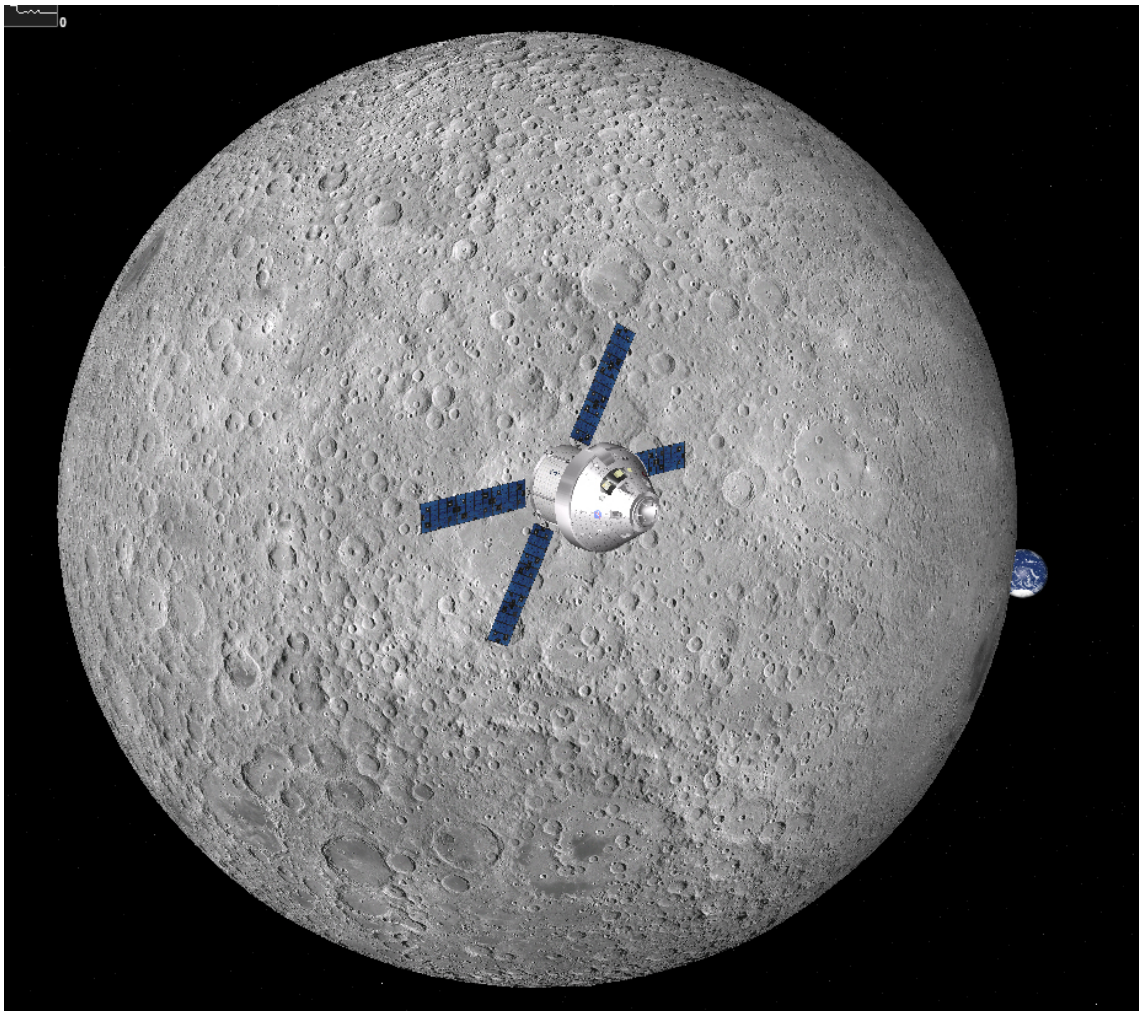
Or you can use IMFD Base Approach, etc. to set your reentry conditions.

Orion is stable at ~30° AoA
Heads-down attitude for maximum lift!

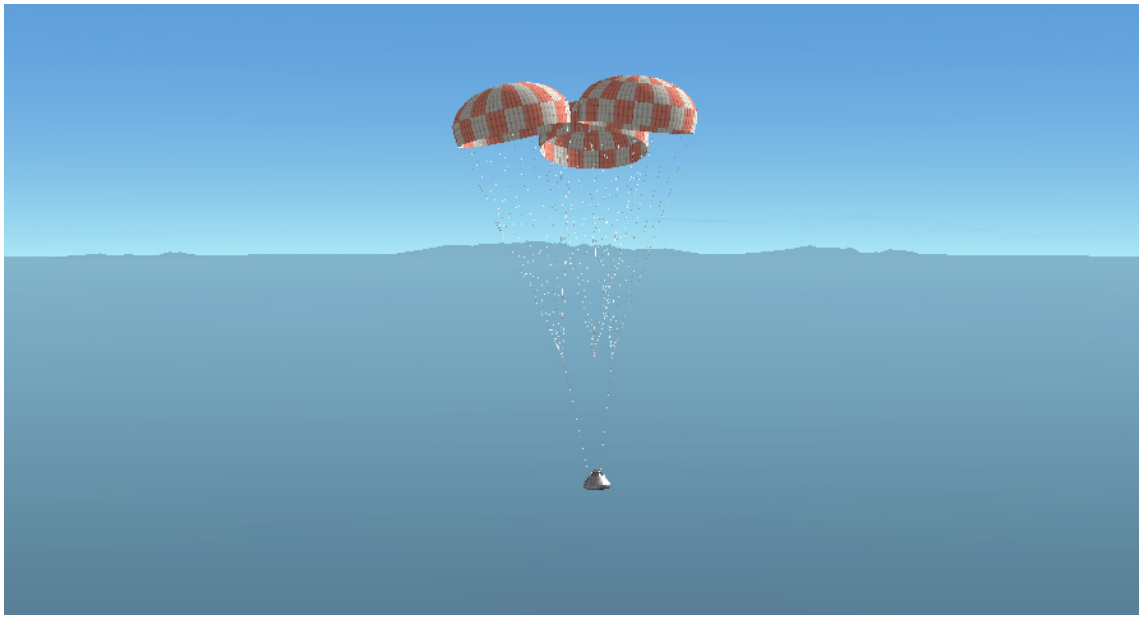
Control range/cross-range by bank angle, same as shuttle.



Approaching 1st Lunar Flyby



Splashdown near Tahiti



Have fun & happy orbits :-)
BrianJ
March 2018