To the Moon & Back

Using IMFD v4.2
By Andy McSorley

Using no more than IMFD and later, Orbit MFD, this tutorial will attempt to guide you on a two and a half day flight to the Moon and back. There's no fancy set-up to do, just a simple autoburn. On the way the only burn we make is a manual one to set our Periapsis at the Moon. A later retrograde burn using IMFD will place us into lunar orbit. Then it's about-turn and head for home, using Orbit MFD and IMFD together, to time the burn and set our return trajectory. This tutorial uses the scenario 'To the Moon and Back' supplied with the tutorial.

The method described in this tutorial is not a particularly fuel efficient one and is only suitable for a high powered spacecraft such as the Delta Glider, but it can be adapted to work with the TTM24 add-on. The main aim of the tutorial is to demonstrate the power and accuracy of IMFD, especially its Map Program. If you try an even faster outward trip to the Moon than the one described here; say half a day, the trajectory may send you on a collision course with the Earth. If it does, then a higher starting orbit maybe the solution. Experiment for yourselves.

For a more detailed tutorial on using IMFD take a look at my Europa to Callisto tutorial, available at http://www.aovi93.dsl.pipex.com/my_tutorials.htm and also at http://www.orbithangar.com/

Part 1 - Ejection from orbit around Earth

This scenario gives us over 2000 seconds to complete the course set-up and eject burn, which should be plenty of time. If not use pause to stop the scenario between set-up stages if necessary.

1. **Left MFD – Open Course Program (Off-Plane Intercept)**

    a) **Left Shift I** – Open Interplanetary MFD
    b) **MNU** – Open the top level menu
    c) **PG** – Switch IMFD to Shared mode
    d) **Course** – Select the Course program menu
    e) **Prv** – Select Off-Plane Intercept program
    f) **Set** – Open Off-Plane Intercept program
    g) **TGT** – Enter Moon

2. **Right MFD – View Orbit Eject Program – (Information Only - can be omitted)**

    a) **Right Shift I** – Open Interplanetary MFD
    b) **MNU** – Open the top level menu
    c) **Orbit Eject** – Select the Orbit Eject program
    d) Note **EIn** – 1.77 degrees. See Fig. 1. Leave it this way. We wont use the Orbit Eject program in this tutorial. I have found that the higher EIn is, the

longer the burn time is in the Course program. However the method still works the same way for higher values of EIn.

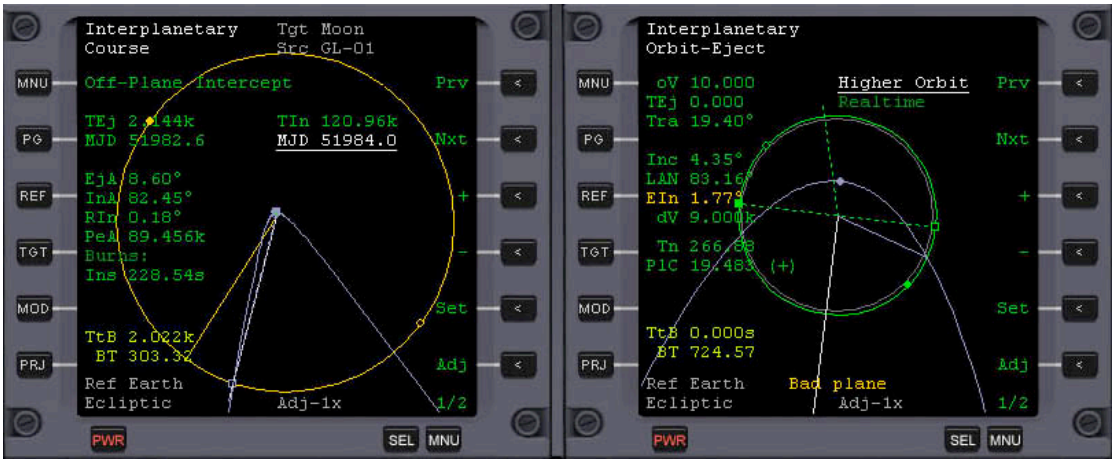

Fig. 1

3. <u>Left MFD</u> – Set Arrival MJD

a) **NXT** (x4) – Select MJD (RH)
b) **Set** – Enter 51984. This is the date of our arrival at the moon. Note the HTO (in blue) changes in IMFD.
c) **PG** – Toggle RH set of buttons
d) **AB** – Engage Autoburn. While waiting for the burn to take place, carry on with the stage below.

4. <u>Right MFD</u> – Open Map Program

a) **MNU** – Return to top level menu
b) **Map** – Open Map program
c) **PRJ** – Change to Self
d) **DSP** – Show Orbits
e) **Z-** (x6) – To zoom out
f) **PG** – Toggle RH set of buttons
g) **Soi** – Show Sphere of Influence boundary
h) **MOD** (x3) – To clear display of text. Fig. 2.

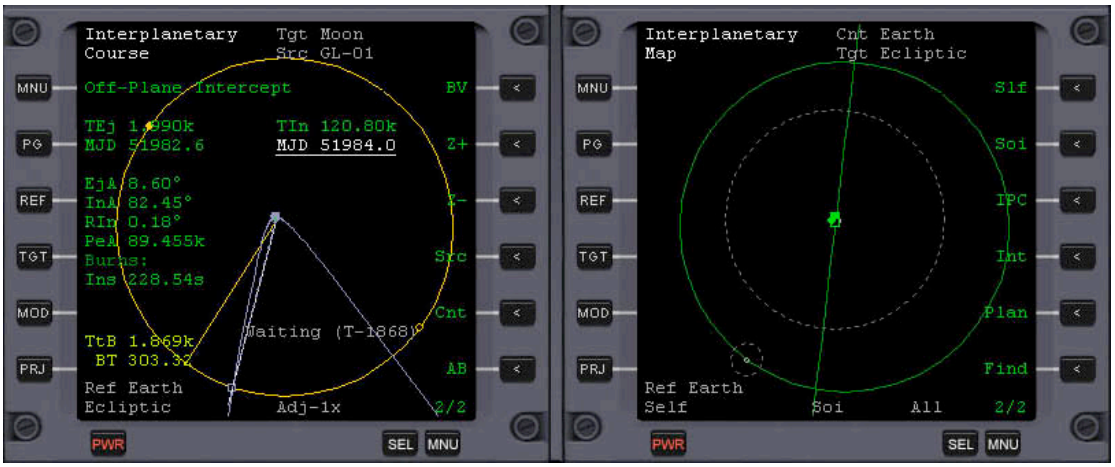

Fig. 2

To get to the time to burn (TTB) quicker, fast forward time 100x.

After the burn Map will show where you will intercept the Moons orbit, see Fig. 3.

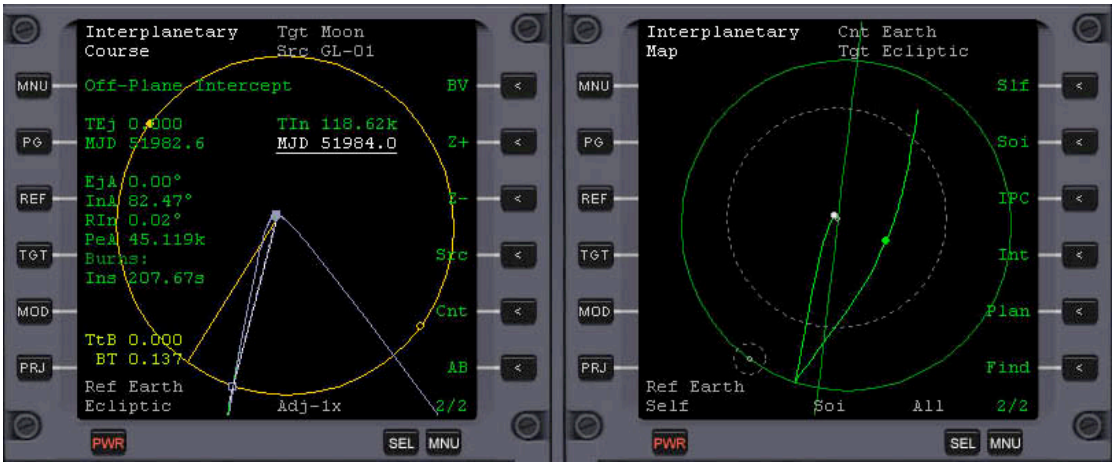

Fig. 3

Ignore the orbit tail on the right. You can see that we are headed for a point in the Moons orbit, where we hope it will be in about a day and a half. But how can we be sure? Take a look.

i) **REF** – Moon
j) **PG** – Toggle RH set of buttons
k) **Z-** (x 8) – Should be spot-on. See Fig. 4.

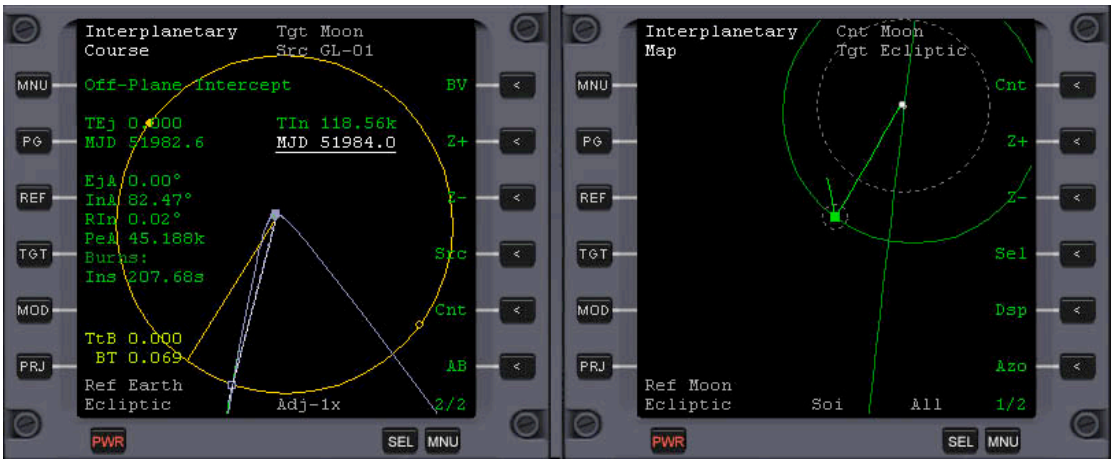

Fig. 4

Carrying on …

l) **Cnt –** Enter x to see white dot leave earth, i.e. YOU!
m) **Z+** (x3) – To zoom in
n) Advance Time (max 10, 000x) until you've left Earths SOI
o) **Cnt –** Enter Moon
p) **Z+** (x5) – To zoom in
q) **PRJ** (x2) – Change to Periapsis
r) **MOD** (x1) – To display values

Orientate the spacecraft prograde and thrust at about 5-20 % to set PeA to 60k or thereabouts (use translation for fine adjustments). See Fig. 5.

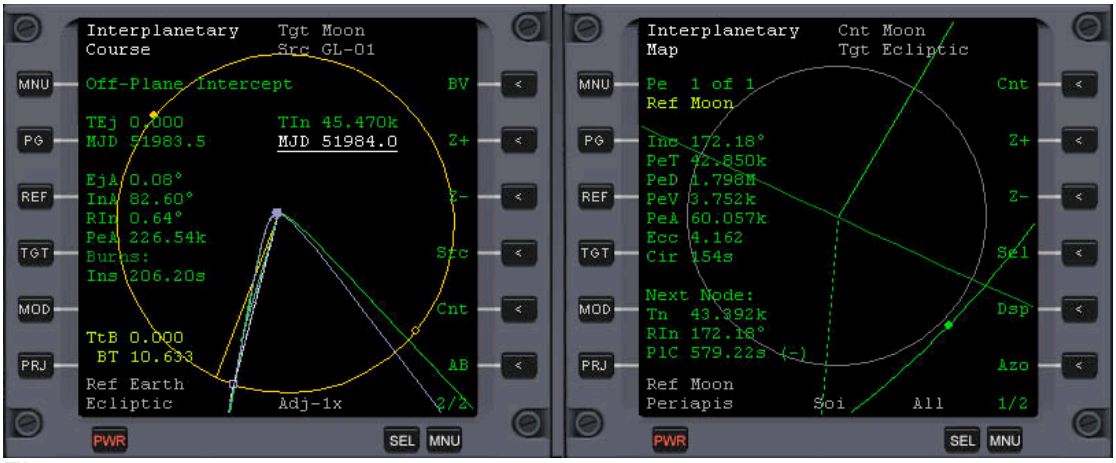

Fig. 5

Before doing this, we could have used the LH MFD to make another autoburn to remove any inaccuracies that may have crept in since leaving Earth, but for the purposes of this tutorial I didn't think it necessary.

s) Disengage Prograde
t) **Z**- (x6) – to zoom out
u) Advance time (max 1000x) and zoom in two times **Z+** (x2) as we go in until we are inside the Moons SOI. Then bring up the HUD in orbit mode and wait until it changes to 'ORBIT [Moon]' in the top LHS of the screen. Your MFDs will now look something like those in Fig. 6.

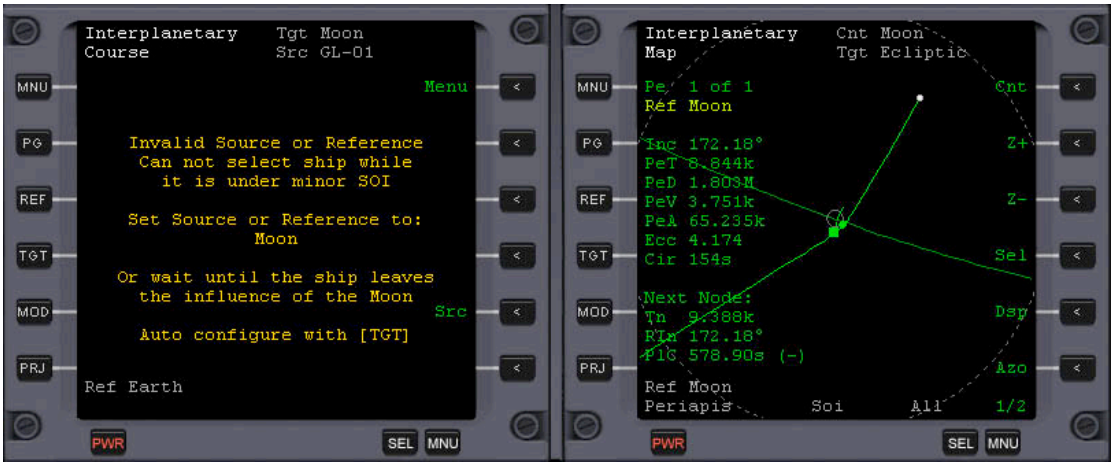

Fig 6

Return to normal time. Engage Prograde. Advance time (10x), and watch as the DG rolls over with reference to the Moon. This is because our eventual Lunar orbit will be retrograde and Orbiter shows us 'in orbit' the 'right-way-up' so to speak, orbiting in a Left to Right direction (normally East to West) thought in our case it will be West to East. Close the HUD.

5. **<u>Left MFD</u> – Set up Orbit Insert Burn**

a) **TGT** – Moon
b) **Nxt** (x1) – To underline Off-Plane Intercept
c) **+** - To select Course menu
d) **Nxt** (x3) - To underline Orbit Insert Program
e) **Set** – Display Orbit Insert Program. Fig. 7.

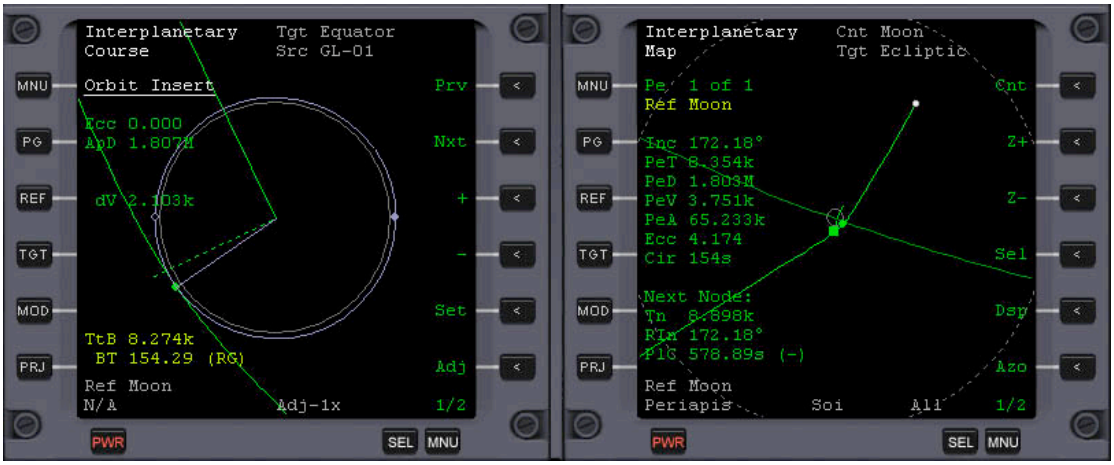

Fig 7

Note - in the RH MFD PeA has increased to 65.23k. Correct this if you like by using the method previously described at the bottom of page 3.

Remain Prograde, advance time (max 100x). Using **Z+** in RH MFD to zoom as we go in. When TtB in the LH MFD reaches 750 (seconds), return to normal time.

f) **PG** – Toggle RH set of buttons
g) **AB** – Wait for burn. See Fig. 8. Advance time if you wish (max 100x).

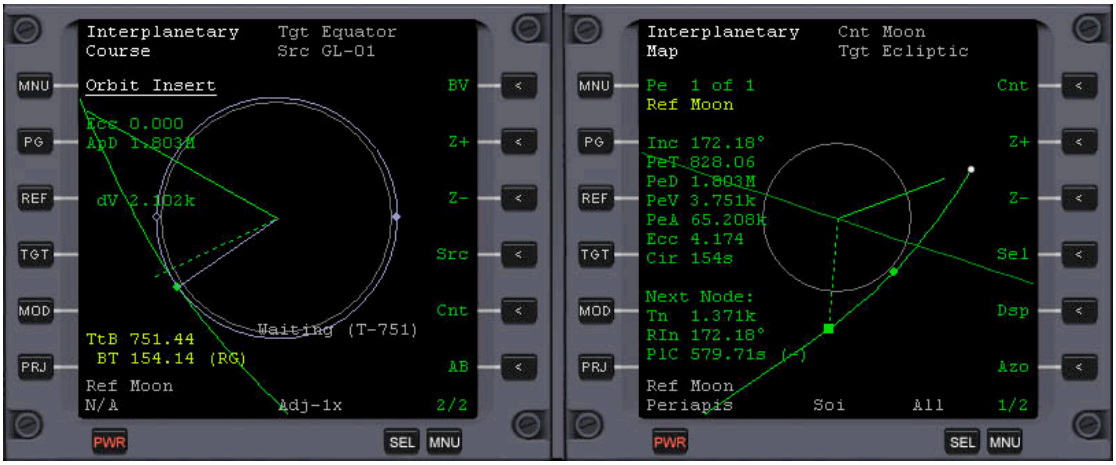

Fig 8

Once the burn is complete, you're in Lunar Orbit. See Fig. 9.

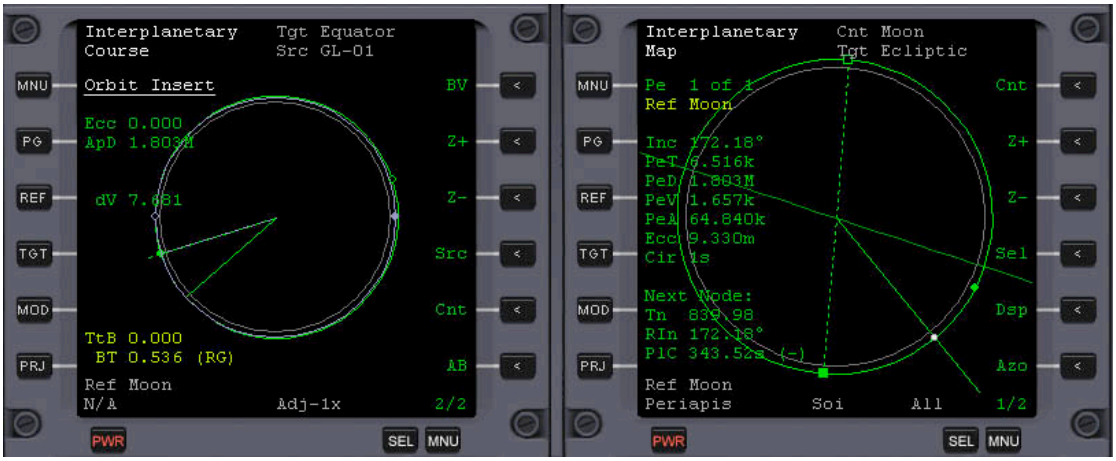

Fig 9

Part 2 – Heading for Home

Having quick saved your final state on arrival - you did, didn't you? Re-launch the saved scenario. I will dispense with the 'Recipe' format above for this part of the trip as if you have completed the outward part of this tutorial the next part is pretty straightforward. I will show a few screenshots of the various MFDs along the way to make my points clearer.

First set prograde autopilot, then open Orbit MFD on the LHS. Set reference to Earth and Target Moon. We are going to use some numbers from this MFD to give us a 'guesstimate' on when to burn for home.

On the RHS set up the Map program (IMFD) to Ref Earth, Centre Moon and Zoom in (Z+) until your RH MFD looks like the one in Fig. 10. Also set PRJ to Ecliptic. You will see your current lunar Orbit as a long squiggly tail. That's OK.

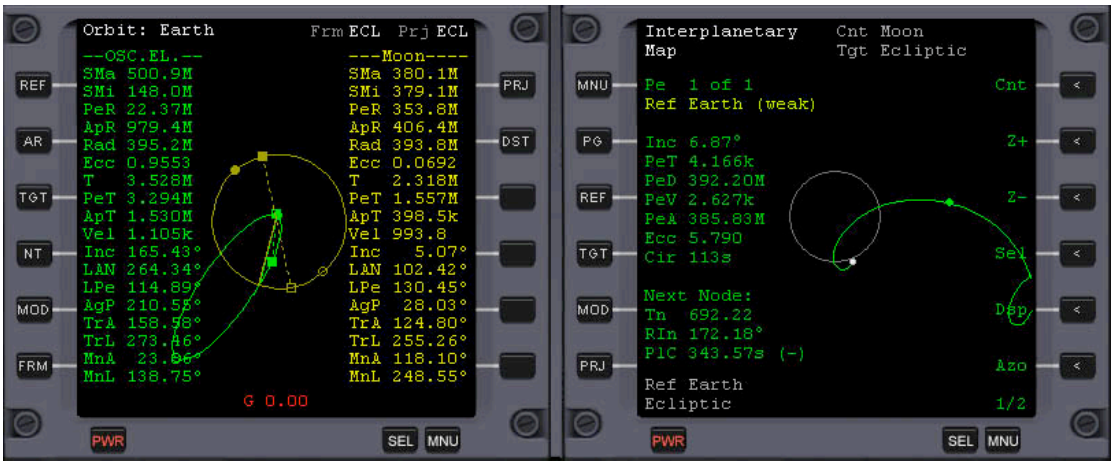

Fig. 10

Now advance time (up to 100x) observing your current position (white dot) around the Moon. Zoom in and out as necessary to see your situation in relation to Earth. Now look at your PeR reading in the LH (Orbit) MFD. As you emerge from behind the Moon you will note that this number begins rise (to about 104M) and then to decrease and your orbit will go through some very strange motions. But never mind that. What we want to know is when should we make the burn. We do this by

observing this number and when it reaches a minimum (around 1M) or just before or after – say 1M (Million Km) either side its OK to make the burn.

It works out that the earlier you make the burn the less time there is for increased velocity before PeR at Earth is reached and thus the slower your journey time will be. If you make the burn as the Earth rises over the Moons horizon at a PeR (Orbit MFD) of around 40M then you will arrive back at Earth in just over one day. So bearing this in mind, you choose when to burn.

Assuming you have started the burn, go to the RH MFD, (there should be plenty of time), and set Centre to Earth and PRJ to Periapsis. Zoom out a few times (Z-) until you can see the whole Earth Moon System. Then gradually zoom in as your orbit becomes hyperbolic. The squiggly tail gets longer and longer until it settles down, and swings in from the right towards Earth. Keep zooming in, and ease off the thrust as PeA approaches a distance of 250k (or whatever altitude you want to set). If you overshoot, it's sufficient just to use translational thrusters to correct the error. A little thrust at this distance from the target makes a big difference to the eventual PeA. See Fig. 11.

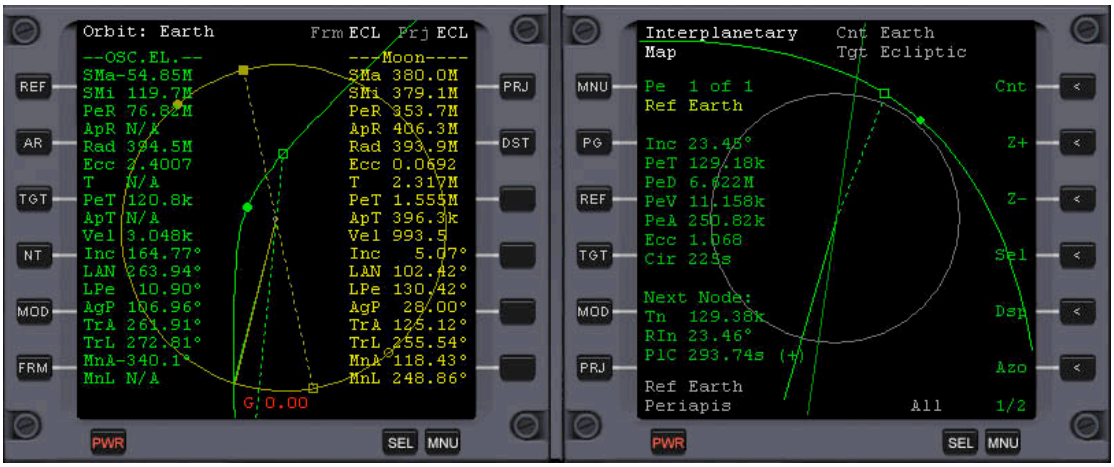

Fig. 11

That's it really. Compare the PeR/PeD values on the two MFDs. Quite a difference. The value given by IMFD is the most accurate by far.

Now advance time, remembering to disengage the prograde autopilot if more than 100x. Sit back and watch your approach to Earth. Make sure you are showing the SOI boundary in the RH MFD and when you are within the Earths, slow time to normal and engage the prograde autopilot. Observe the ship rotating 'right-way-up' for a 'prograde' orbital approach to Earth. Disengage the prograde autopilot and advance time once again, using zoom as necessary to view your approach in the RH MFD.

Well before we reach Earth we need to bring up IMFD in the LH MFD and open the Orbit Insert program. *Note - if you haven't quit the scenario from the beginning of this tutorial, the Orbit Insert program will still be set to 'Moon'. Use PG and '+' to return to the menu and click 'Set', this will make the program reference the Earth.* When TtB is about 2.500k engage autoburn. See Fig 12

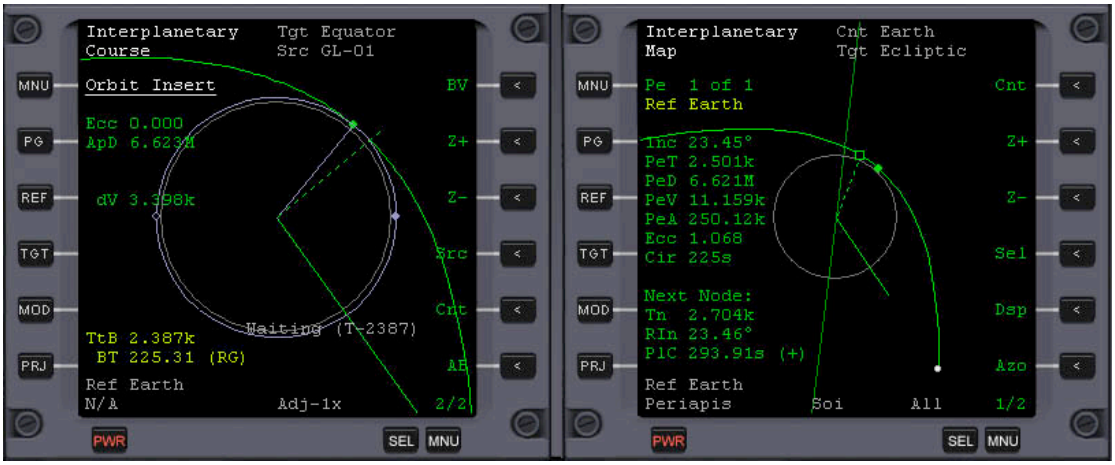

Fig. 12

When the burn is complete, you're all done!

Fig. 13

Well, I hope you found this tutorial useful. Feel free to Email me any comments or suggestions you may have, to: webmaster@virtualspaceflight.com.

Many thanks to Jarmo Nikkanen for creating IMFD. Interplanetary MFD is available at: http://koti.mbnet.fi/jarmonik/Orbiter.html

Thanks also to Bruce Irving for the comments and suggestions that I have tried to incorporate into this tutorial. Any mistakes or omissions of course, remain mine.