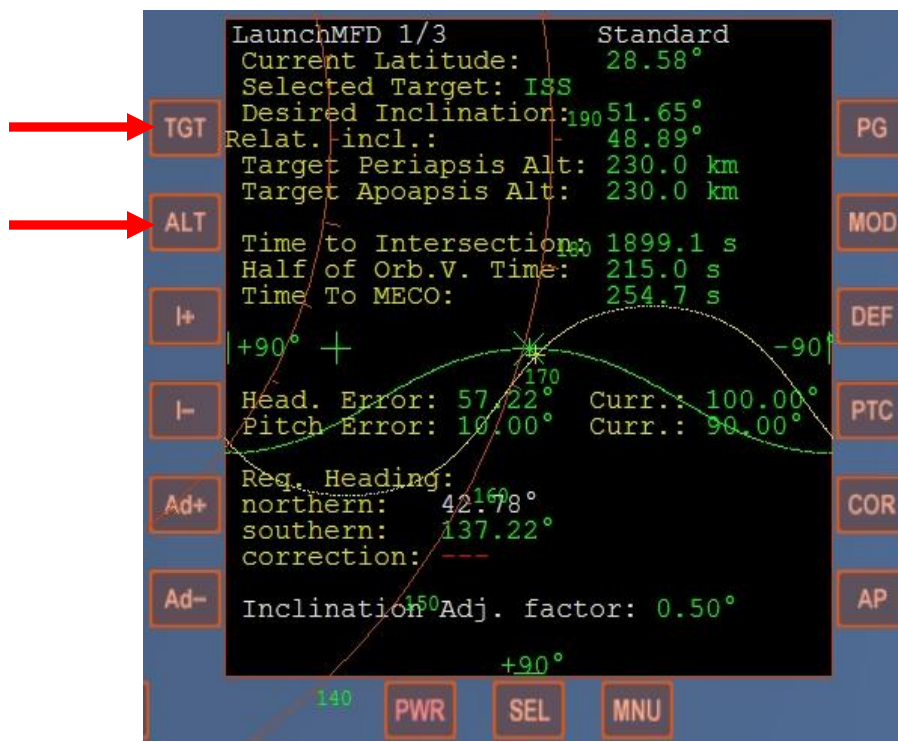# OA-4 Off-Plane Launch Tutorial

The OA-4 mission to the ISS was designed to have an unprecedented 30 minute long launch window. This is a **very** long window for a LEO rendezvous mission. More information can be found here:
http://spaceflightnow.com/2015/11/18/atlas-5-flights-to-station-enjoy-longer-launch-windows/

This additional flexibility was achieved by the using excess energy available on the Atlas V/Centaur vehicle to perform an off-plane maneuver during launch. Fortunately, this can be emulated in Orbiter 2010 with enjo's Launch MFD:
http://www.orbithangar.com/searchid.php?ID=2802

Pre-Launch Preparation
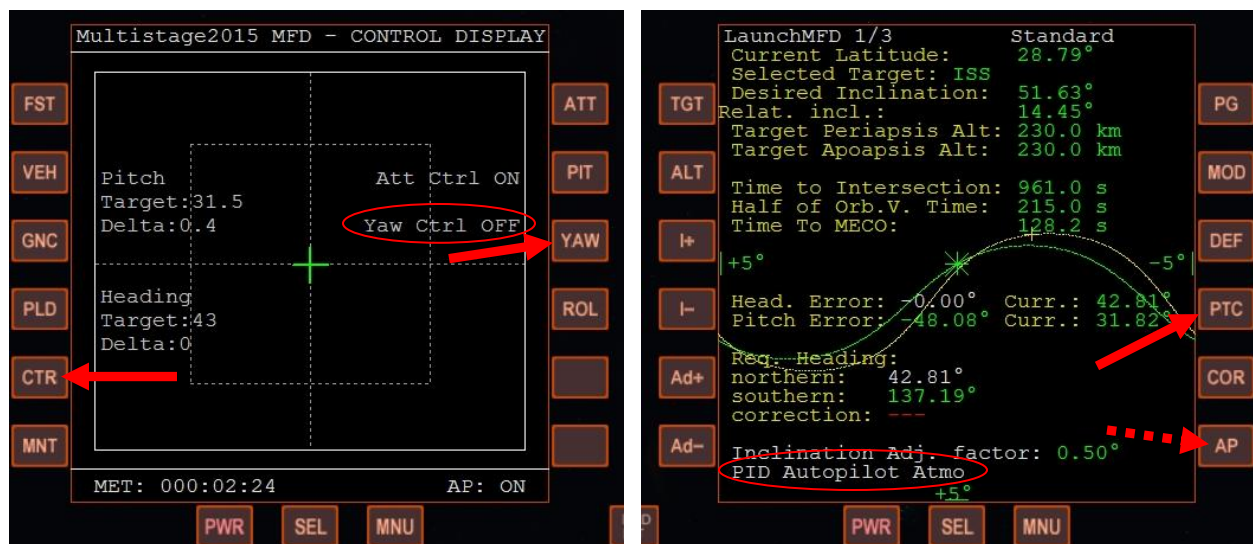

1)   Open Launch MFD. Set the target to **ISS** and the altitude to **230** km.

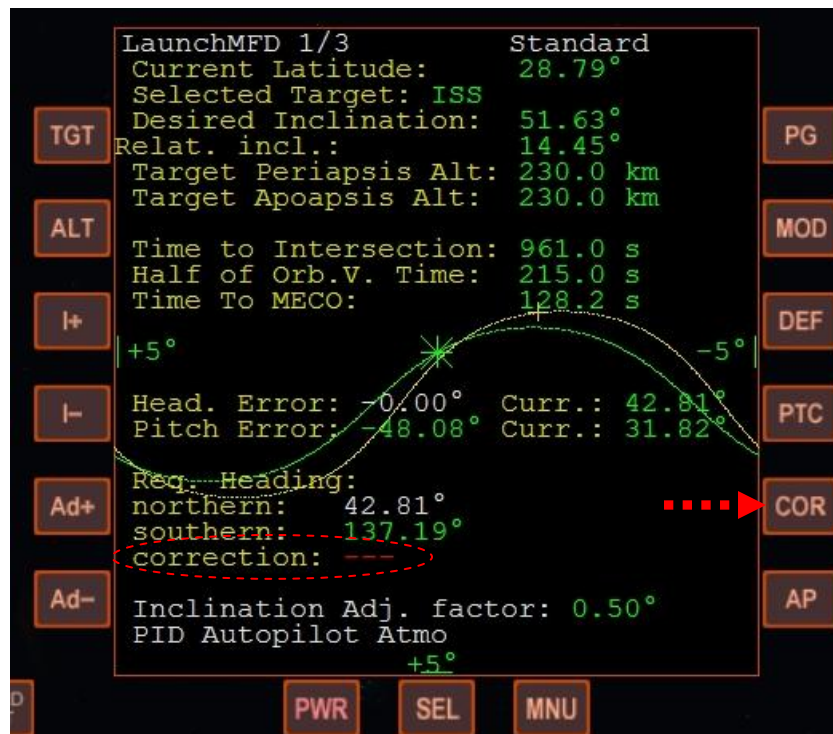2)   Press 'P' at T-10s to launch anytime during the 30 minute window starting at 21:44:56 UTC.

1st Stage Flight

The general idea is to let the Multistage2015 autopilot control pitch and Launch MFD control yaw.

3)   Let the Multistage2015 autopilot guide until you reach a safe altitude of about 35 km.

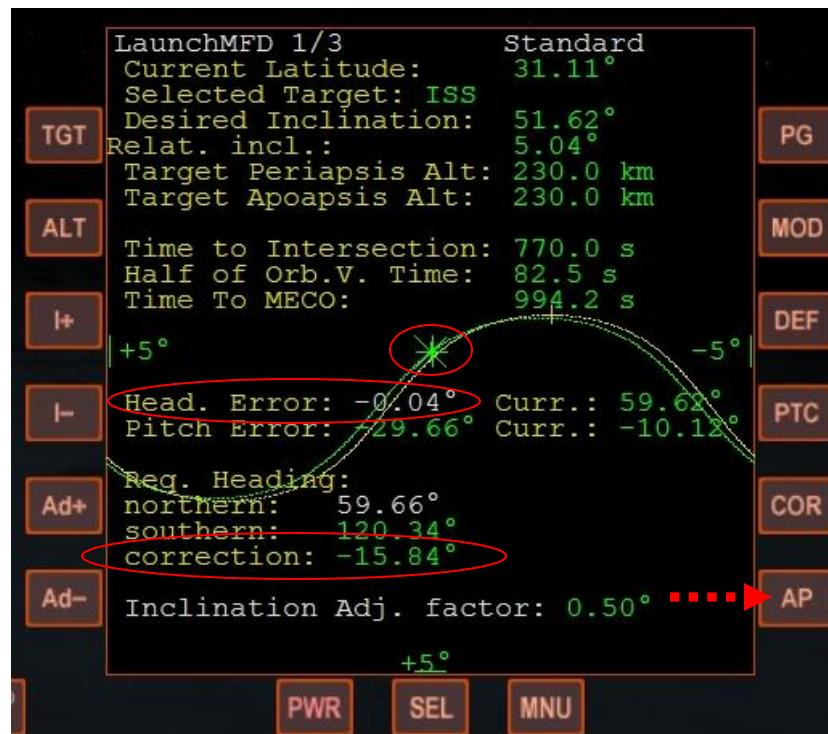4)   Open Multistage2015 MFD on the other side. Go to the **Control Display** and turn **YAW** control **OFF**.

5)   In Launch MFD, turn **PITCH** control **OFF**. For first stage flight, it *appears* that the Launch MFD autopilot works okay with the Multistage2015 autopilot, as long as pitch and yaw are not competing. So, turn the Launch MFD **AUTOPILOT** to **ON**, but be ready to take over if you see any problems.

LaunchMFD 1/3   Standard
 Current Latitude: 28.79°
 Selected Target: ISS
 Desired Inclination: 51.63°
Relat. incl.:   14.45°
 Target Periapsis Alt: 230.0 km
 Target Apoapsis Alt: 230.0 km

 Time to Intersection: 961.0 s
 Half of Orb.V. Time: 215.0 s
 Time To MECO: 128.2 s

|+5°   −5°|

 Head. Error: −0.00°   Curr.: 42.81°
 Pitch Error: −48.08°   Curr.: 31.82°

 Req. Heading:
 northern: 42.81°
 southern: −137.19°
 correction: −−−

 Inclination Adj. factor: 0.50°
 PID Autopilot Atmo
              +5°

TGT ALT I+ I− Ad+ Ad−

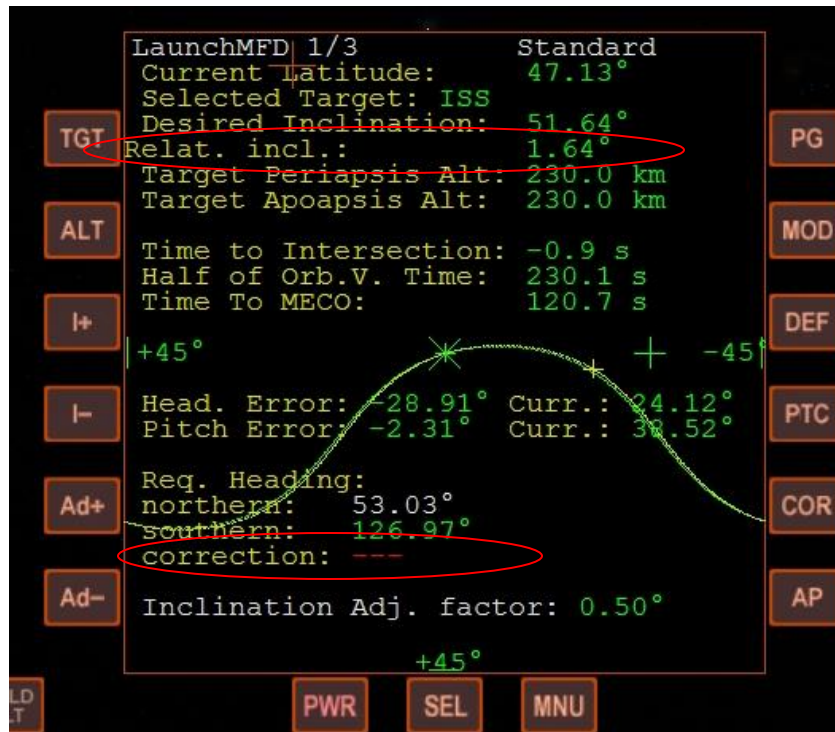**PG MOD DEF PTC COR AP**

PWR SEL MNU

6) It's probably better <u>not</u> to use the *correction* angle during <u>first stage</u> flight, so turn **correction** to **OFF**, if necessary, but be sure to turn it back **ON** before <u>second stage</u> flight begins.

2nd Stage Flight


```
LaunchMFD 1/3                Standard
 Current Latitude:      31.11°
 Selected Target: ISS
 Desired Inclination:   51.62°
Relat. incl.:           5.04°
 Target Periapsis Alt:  230.0 km
 Target Apoapsis Alt:   230.0 km

 Time to Intersection:  770.0 s
 Half of Orb.V. Time:   82.5 s
 Time To MECO:          994.2 s

|+5°                               −5°|

 Head. Error: −0.04°  Curr.: 59.62°
 Pitch Error: 29.66°  Curr.: −10.12°

 Req. Heading:
 northern:     59.66°
 southern:    120.34°
 correction:  −15.84°

 Inclination Adj. factor: 0.50°

              +5°
```
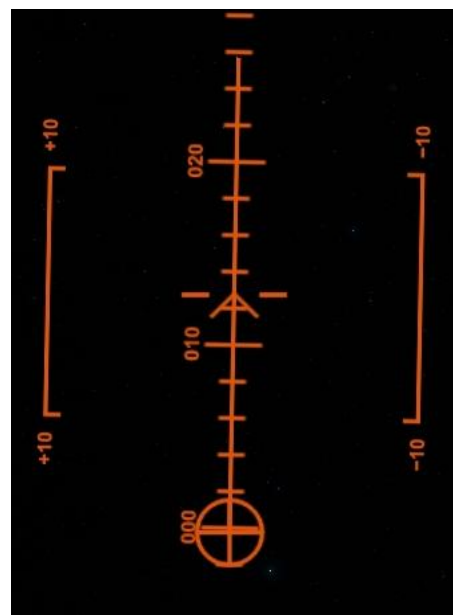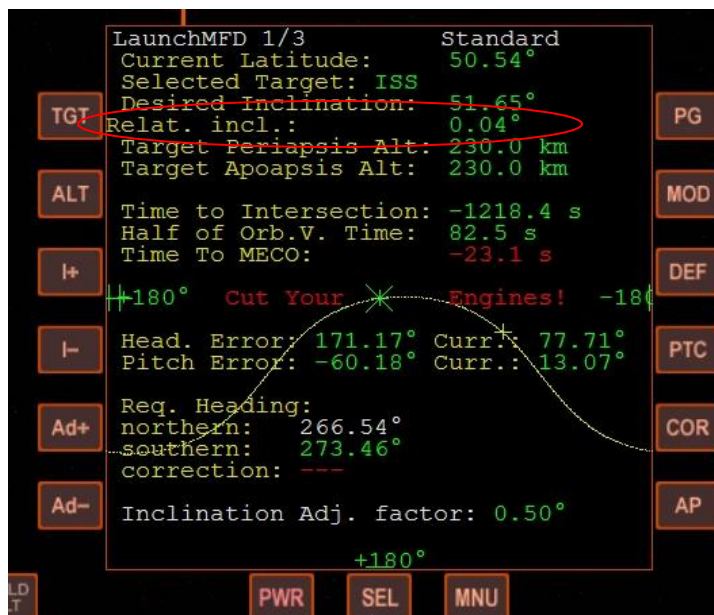
7)   The Launch MFD autopilot *appears* NOT to work as well for <u>second stage</u> flight. Turn the Launch MFD **AUTOPILOT** to **OFF**.

8)   At this point, Launch MFD should provide a *correction* angle. This will vary over time, and constantly following the *Req. Heading* will cause your orbital plane to nearly align with the ISS, making "early" or "late" launches possible. Use **manual** fine yaw RCS control to keep the cross centered on the X and the *Head. Error* near 0°.

```
LaunchMFD 1/3              Standard
Current Latitude:        47.13°
Selected Target: ISS
Desired Inclination:     51.64°
Relat. incl.:            1.64°
Target Periapsis Alt:    230.0 km
Target Apoapsis Alt:     230.0 km

Time to Intersection:   -0.9 s
Half of Orb.V. Time:     230.1 s
Time To MECO:            120.7 s

+45°                    ✳         +   -45

Head. Error:  -28.91°  Curr.:  24.12°
Pitch Error:  -2.31°   Curr.:  38.52°

Req. Heading:
northern:      53.03°
southern:     126.97°
correction:   ---

Inclination Adj. factor:  0.50°

                +45°

         PWR    SEL    MNU
```

9) In the last few minutes of the second stage burn, Launch MFD may stop providing a *correction* angle. If this occurs, hold your current yaw angle and observe *Relat. Inclination*. It should continue to decrease.

Otherwise, if Launch MFD continues to provide a *correction* angle, keep following the *Req. Heading* until cutoff and skip Step 10.

10) A few moments before second stage cutoff, *Relat. Inclination* will reach a minimum value and then begin to increase. When this occurs, quickly yaw to point back into the orbital plane to prevent any further increase. (The orbital plane can be seen in the Orbit HUD.) Allow the Multistage 2015 autopilot to finish and cutoff at the proper time. Jettison the Enhanced Cygnus payload.

The outlined off-plane technique in not quite perfect and the final *Relat. Inclination* may be several hundredths of a degree from zero. This can be cleaned up with a later plane change maneuver and should not consume too much fuel.

Continue the mission and rendezvous with the ISS using whatever techniques you find suitable. Good luck!