IXEG

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737 CLASSIC

Tutorial Series
Autopilot and Flight Director

Autopilot and Flight Director

RESOURCES

There is a YouTube video of Captain Jan Vogel performing this lesson. The video can be found at:

http://www.youtube.com

INTRODUCTION

Our second tutorial flight will demonstrate the usage of the *Autopilot / Flight Director System* (*APFDS*). We assume you have developed some familiarity and proficiency with manual flying, common 737 cockpit nomenclature and basic usage of the FMS from the *Quick start* and *Tutorial flight 1* missions. If you have not worked through those flights, we highly recommend you do so before conducting this tutorial.

INSTRUCTOR BRIEFING

Todays flight will again take place in the United States as you fly from Tucson International Airport in Arizona (KTUS) to McCarran Airport in Las Vegas, Nevada (KLAS). Our route will take us from Tucson International, along airway J-11 to the Drake VOR (DRK), then via J-92 to Boulder City VOR (BLD), then via BLD R-305 radial to the SHAND intersection where we will join the ILS approach to runway 25L at Las Vegas McCarran Intl.

We will repeat the startup procedure from previous lessons, engage and utilize the auto-flight system in various modes of operation and then conduct an automatic approach and landing, or a go-around.

PREFLIGHT

FLIGHT SETUP

At *www.skyvector.com*

- via the Charts link, consult the chart *Enroute H-4*, to build the route/flight plan.
- Download the approach chart from www.skyvector.com for ILS25L at KLAS

Build a flight plan to help you visualize the routing we'll be using. Begin by right-clicking on the *KTUS* airport symbol to bring up a pop-up, then click *PLAN* to start the process. To add more waypoints, right-click on them to add them to the plan. The waypoints you want to add are (in blue). Keep the chart and plan handy as we will refer to it later in the tutorial.

KTUS TOTEC PXR DRK BLD SHAND KLAS

If you want to reproduce the visuals shown in this tutorial, you can download scenery for both airports. The default airports are bland and barren but will do the job for todays tutorial. Note that the scenery for KLAS, available on X-Plane.org, does not line up particularly well with the ILS, so you will be visually off by a few meters on final approach, but it is better than nothing. The screenshots in this tutorial flight use the HD terrain mesh, V3 by *alpilotX.*

- Place the aircraft at KTUS, using a *ramp start* location.
- Bump the main menu and select the *Ground Services* Menu
- Set the refuel setting to 8.0 tonnes, click *Instant* and then close the dialog.
- Using X-Plane's menus, set the weather for no wind. standard temperature and clear skies.
- Bump the main menu and select the *Preflight* menu.
- Select the Turn-around option and select *Apply Settings.*

COCKPIT PREPARATIONS

The plane is in a turn-around state with the APU running and already powering the aircraft. Make sure that the passengers (and you!) stay comfortable.

- Look at the air conditioning panel. Turn on the left pack by moving its switch from OFF to AUTO.

With the isolation valve in AUTO, the valve is now open and only the left pack is working. Do not use more than one pack when using APU power only (except for rapid heating in the winter). You can turn on the left pack and see the isolation valve close (the needle with the R on it falls), now air can´t flow to the right pack.

- Select a comfortable temperature - a 12 o´clock position of the temperature control switches usually works good initially.

The AUTO position will make sure that the isolation valve is closed, UNLESS one pack or one engine bleed switch is off. This maintains isolated sides, so a ruptured duct on one side will not affect the other side and pressurization can be maintained.

Air Sytstems Panel

Note that the master caution lit up again - due to the "DUAL PRESSURE" light of the bleed system. It warns you that both APU and engine bleed are on and "connected" - so high pressure from the engines could cause back flow into the APU. This is ok while engines are in idle - but not

for higher power settings. Play with the pack, isolation valve and bleed air switches to see how it works.

SETTING UP THE FMS:

Now we can prepare the flight at leisure. Refer to tutorial 1 if you have to. Set up the following systems with these parameters:

On the CDU:

- select the *PERF INIT* page by pressing the *INIT REF* button.

You can check your zero-fuel-weight using the *GROUND SERVICE* menu. It should be 40.0 tons or 88.3 thousand lbs.

- Set reserves of 2.4 tons (5.0 thousand lbs)
- Set a cost index of 20
- Set a cruising altitude of 24.000 feet (FL240).
- Press the EXEC key when it illuminates.

We will do a *flaps 5* takeoff this time and use a reduced power setting for the takeoff to spare the engines some stress.

- Click the N1 limit button to go the N1 Limit page.
- In the top left line of the CDU, *SEL/OAT*, enter an assumed temperature, TASS, of 55
- Observe the N1 dropping to about 87%.

55 Degrees set on LSK1L

By entering a TASS you make the engine assume that the air is really hot. The FMS computes a lower N1 to avoid exceeding the maximum EGT on take-off. Since it really isn´t 55 degrees outside, the engine will output less thrust and suffer less stress. This saves A LOT on maintenance expense. Another bonus is the reduced thrust in the case an engine fails - initial yaw will be less and you can then increase thrust on the live engine smoothly to full takeoff power.

- Click LSK6R to go to the TAKEOFF REF page.
- Enter Flaps 5
- Click the top 3 LSKs on the right, LSK1R, LSK2R, LSK3R. This will cause the speeds to be displayed on the EADI during takeoff.
- Click the *NEXT PAGE* button.
- Enter 3000 ft for the thrust reduction altitude.

We want to save the people of Tucson some noise - so we decide to climb very steep to 3000´AGL (ca. 5600´MSL) before reducing to climb power and accelerating to climb speed. This is why we enter 3000 ft. as the thrust reduction altitude.

- Select the *NEXT PAGE* button to go back to page 1 of the TAKEOFF REF page.

- Set the bottom 3 speed bugs on the pilot side ASI to the *V1*, *Vr*, and *V2+15* values.

In our example they should be about 123, 125 and 150 kts. V2+15 is the *maneuvering speed*, a speed above which you can do normal, 25degree banked turns and have sufficient airspeed margin to the 1G stall speed. When below the maneuvering speed, your bank angle is limited to 15 degrees. You can also set up the first officer´s airspeed indicator in the same way.

SETTING UP THE AUTOFLIGHT SYSTEM

Next, you want to configure the mode control pane (*MCP*) for the departure. We will start on the very left side with the CRS 1 knob.

- Set the CRS knob to 308, which is the outbound radial from TUS VOR we want to follow.
- Turn the pilot side FD switch to *ON*. The MA light illuminates.

Now the left *F*light *C*ontrol *C*omputer (*FCC A*) is what is called the *master*. This will determine which of the two navigation radios the system will follow when the autopilot is in VOR/LOC mode. The auto-throttle stays off for the moment, we don´t want to accidentally toggle takeoff power while taxiing around!

- Set MCP speed to V2 (see the TAKEOFF REF page, if you forgot, its about 135kts).
- Turn the heading knob to runway heading (304).
- Set the MCP altitude to 8000 ft, which we choose as our first level-off altitude.

The MCP should now be configured as shown below.

MCP Configured before Takeoff

- Turn on the copilot side FD switch

Note that the MA light does not illuminate because FCC A is already the master! It is ***imperative*** to have both FD switches ON for the *flight director* takeoff mode to work, even though only one FCC can be master.

- Set the copilot CRS to 323, the inbound bearing to PXR VOR we will track later.

SETTING UP THE ELECTRONIC FLIGHT INSTRUMENT SYSTEM (EFIS MAP)

Next , we set the VHF NAV radios and EFIS modes on the pedestal console.

- Set the pilot side nav radio to TUS, 116.0.
- Set the copilot side nav radio to PXR, 115.6.

For the EFIS configuration, we suggest MAP mode and VOR/ADF + ARPT pushbuttons to display VOR and ADF bearings and the airports on the map, together with a 40NM range selection. You can complement these settings by setting up a slightly different mode on the FO´s side, such as NAVAID for example, and then glance over occasionally. Experiment with the different EHSI modes and map display options.

Note that some symbols (NAVAID, FIX) only display when the map´s range is fairly small to avoid cluttering. Also note the *EXCESS DATA* warning appear when too much information for the EFIS display to handle is requested. In such a case, reduce the EHSI display options and/or range so fewer entities are to be displayed.

EHSI Map Controls on Center Pedestal

- Turn both DH windows down to -20.

This is standard practice, since for most flights these will not be used, only for Category II and III ILS approaches. They default to 200 after every power loss, so you have to twist them down to -20 before every flight

Since we are overflying mountainous terrain, we want to display terrain data from the EGPWS (enhanced ground proximity warning system) on our map. This system uses the weather radar´s graphics processor, which we enable via the WX switch.

- Between the CDUs, Turn the *WX* switch to *ON*.

Even though the WX switch is ON, the radar unit will not emit radar energy until you actuate the *WXR* pushbutton on your EFIS control panel. Before you do that, we turn on the terrain processor.

- Push the *TERRAIN SELECT/DESELECT* pushbutton located just below the CDU keypad.

This will display terrain on your EHSI in most EHSI map modes and color coded the terrain to indicate terrain heights relative to the aircraft. It will also show the highest and lowest terrain altitudes within your maps coverage.

Note that the terrain directly below you is not shown below a certain height, in order to avoid cluttering the display. This is why there is mostly black on the EHSI, except for the mountains at about 15NM away from the aircraft.

Terrain Display on the EHSI Map

SETTING UP THE CABIN PRESSURIZATION CONTROL:

Last but not least we set up the cabin pressure control again:

- Dial 24000 in the *FLT ALT* window (should be there by default) and
- Dial in the *LAND ALT* of 2100´as well.
- Ensure the *FLT/GRD* switch on the pressurization panel is set to *GRD*.

The FLT/GRD switch tells the pressure controller when to start pressurizing the aircraft. We will set it to FLT during taxi-out later on.

Pressurization Panel at Lower Right of Overhead

FLIGHT OPERATIONS

ENGINE START

It is time to get the engines started. For this we need bleed air from the APU to turn the starter, which, in turn, spools up the engine. The APU does not provide enough air flow to both start an engine AND supply air conditioning. If you have ever been on a real 737 and notice the air conditioning stop as the engines are started, this is the reason why. It is not hard to notice, it gets quite hot in the cabin for those few seconds. Just watch everyone reach up to adjust their air-condition vent when this happens :)

- Turn off both AC packs
- Ensure the isolation valve is set to *AUTO* or *OPEN*

If you do not open the isolation valve, then you will not get enough air pressure to start engine 2, since the APU bleed air enters the system on the LEFT side of the isolation valve, so it needs to be open for air to get across to the right side.

Air Systems Panel on the Right Side of the Overhead

Before you start the engines:

- Turn on the anti-collision light.
- Ensure the parking brake is set.

- Verify that all ground equipment clear.

For the ultimate in realism, utilize the laminated checklist

- Click on the small pouch opening on top of the MCP dashboard.
- Read the PREFLIGHT and BEFORE START checklists.

After completing the checklists.

- Move the engine start switch for the right engine to GRD (see image below)

Observe how, on the bleed air panel, the air pressure begins drop as the start valve opens and air rushes into the starter to spool the engine. This is positive confirmation of air flow to the starter.

Engine Start Switch to GRD

On the engine instrument panel:

- Observe the *START VALVE OPEN* light illuminate.
- Observe the N2 spin up. The N1 will begin to spin up a few moments later.

When N2 is at a minimum 20%, (prefer 25%)

- Move the corresponding engine start lever on the throttle quadrant to *IDLE*.
- Observe the EGT rise, indicating successful combustion.

The engine will run up to idle power and the *START VALVE OPEN* light will extinguish after the starter cuts out at about 46% N2. The start switch will snap to off.

- Repeat the engine start procedure above for the left engine, *engine no. 1*.

With both engines running at idle, we now prepare the aircraft for flight.

- Move both engine generator switches on the overhead electric panel to *ON.*
- Turn on both air packs again.
- Turn off the APU bleed air switch.
- Move the *AIR/GND* switch on the pressurization panel to *FLT*.

Observe how the outflow valve now closes to pressurize the airplane slightly for takeoff.

> If the outflow valve is wide open through the rotation portion of the takeoff, then the change in airflow over the outflow valve would cause an abrupt pressure change inside the cabin and can hurt passengers ears. This is called a *pressure bump*. The outflow valve mostly closes to allow only a little air in and therefore maintain a slight pressure.

Illustration 1: Air Systems after Engine Start

- Turn off the APU (it uses fuel),
- Move the auto-brake knob to *RTO* mode. (*R*ejected *T*ake *O*ff),
- Extend flaps to 5 for takeoff, to match what we put into the FMS TAKEOFF page.
- Ensure that the trim is set at about 4.0 units.
- Read the BEFORE TAXI checklist.

TAXIING

- Turn on the taxi light.
- Release the parking brake (default key, *V*).

Taxi to runway 29R and get lined up for takeoff. Begin with a left or right turn to an initial heading of about 160 degrees. This will take you to the parallel taxiway, *A* that you will follow with heading 124 until the end of the taxiway. You might need to add a little power to start taxiing, @ 40% N1 should do it, but less power is required to maintain taxi speed. At light weights, idle power is be enough to get moving. Tap the brakes as needed to slow down. A good rule of thumb for taxi speeds is 10 kts on turns and up to 30kts on straights. The GS *speedometer* is in the upper right corner of the EHSI.

Ground Speed of 5 kts on the EHSI

Before lining up on runway 29R:

- Turn on the landing lights,
- Turn on the the strobe lights.
- ARM the auto-throttle.
- Turn off the taxi light.
- Read the TAXI checklist on your yoke.

TAKEOFF

- On the chronometer, Turn the bottom left knob to RUN and push the left top CHR button. This will start the clock.
- Advance the thrust levers manually until N1 is about 40%
- Push the TO/GA buttons on top of the thrust levers (or via mapped joystick button). The auto-throttle will advance the thrust levers to achieve takeoff N1.

As you begin to accelerate down the runway, we recommend you advance your hardware throttles all the way to the *forward stops*. This will give you the option to trigger the *RTO* mode by pulling your throttles back to idle if a RTO is needed. Also, this makes it easier to capture the *ghost throttles* later on.

A few autopilot modes will come online during the takeoff roll, such as *TOGA* and *HDG SEL*. Also the FD bars will come up at this time. Disregard these AP elements completely and focus on the takeoff until you are done with the rotation and have achieved a stable climb pitch attitude @ 15 degrees nose up.

At 84kts the auto-throttle will switch to *THR HOLD* to protect the takeoff power setting and ensure the takeoff. Shortly after takeoff, it will switch to *ARM*.

At *Vr* start rotating smoothly. This requires some practice as you first need quite a bit of input to start the rotation, then relax to almost neutral stick, then pull back some more around 10deg nose-up, then relax again.

Aim for 3 deg/second and rotate to 15 - 20 deg nose-up. This should take about 6-7 seconds. If you rotate early/too fast you will have a tail-strike. If you rotate too late/too slow you will waste performance on takeoff which could be very dangerous if the engine fails at this stage.

Ideally your speed after rotation should stabilize at V2 + 20kts! (In this case about 160kts) This allows full bank angle of 30 degrees and good climb performance.

- Raise the landing gear when climb rate is positive.

Some FWD fuel pumps may have their inlets exposed to air as fuel moves about the fuel tanks and possibly trigger *LOW PRESS* warning lights during acceleration and steep climb angles. This is completely normal and will not trigger the master caution.

CLIMBOUT

When you exceeded about 500 feet AGL and have stabilized the plane in the climb, you can turn on the autopilot *A* by pushing the button on the MCP where it says CMD A.

Autopilot A & B Engage Buttons on the MCP

The vertical AP mode will change from *TOGA* to *MCP SPD* and the autopilot will now follow the selected speed and heading dialed into the MCP fields.

EADI Display during Climb showing AP modes

The top row of the EADI display is called the FMA or *F*light *M*ode *A*nnunciators. These annunciators will always show you what is happening with the auto-flight system. Do not let the highlighted buttons on the MCP fool you, ALWAYS look at theses FMAs if you want to know what the Autopilot is actually doing.

The leftmost FMS annunciator is the auto-throttle FMA. To its right is the vertical mode FMA, then the lateral mode FMA and finally, on the very right, the active AP mode. The AP mode might show blank (*manual flight*), FD (*flight-director*), CWS (*control wheel steering*) or CMD (*autopilot control*). Green boxes are drawn at the point a mode becomes active to alert you of the activation. The green boxes show for about 10 secs and then disappear.

At the thrust reduction altitude of 3000 ft, which we entered into the FMS earlier in the tutorial, the auto-throttle will automatically engage the N1 auto-throttle mode and set the throttles to climb thrust power. We now focus on an efficient climb to our target altitude. To do so, we need to get the flaps retracted and increase our speed.

- Turn the speed knob on the MCP to 220 knots.

We accelerate to 220kts first because this speed is below the maximum speed allowed with flaps extended to *flaps 5*, which they currently are. In this way, if you are are slow retracting the flaps, or forget, then you won't break the flaps or upset the climb profile.

The autopilot will pitch the nose down to accelerate. The engines are at full climb power so you cannot add more power to accelerate, ergo nose down pitch.

- Raise flaps to *flaps 1* as the nose pitches down and you start to accelerate.
- Raise flaps to *flaps up* at 190 knots.

Shortly, you will be approach 8000 feet. The autopilot will capture this altitude since we dialed it into the MCP earlier and the plane will level off.

- Dial the MCP speed to 250, the plane will accelerate and the throttles will retard a bit as you approach 250 knots.

FMAs showing Altitude Capture and MCP SPD mode activating

INITIAL NAVIGATION:

Now its time to turn towards the TUS 308 outbound radial as planned.

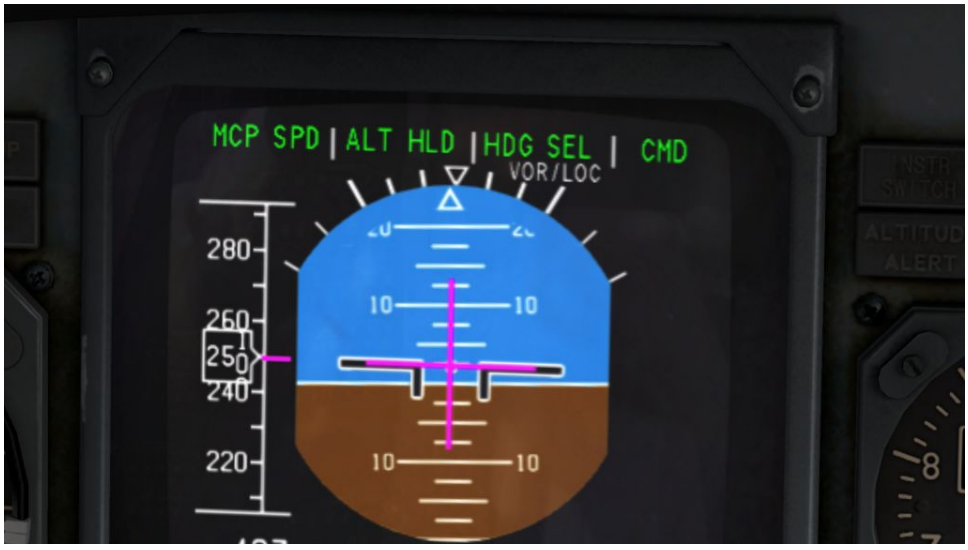
- Change the EFIS map mode to EXP VOR/ILS
- Select a map range of 80NM. This allows you to see your offset from the course we dialed in and also a better range for displaying terrain.
- Turn right, heading 320 to intercept the TUS 308 radial.

Right Hand Turn to 320 to intercept TUS 308 radial.

Since this is an Autopilot tutorial, we do want to use the *VOR/LOC* capability of our autopilot.

- Arm the *VOR/LOC* mode by pressing the VOR/LOC button on the MCP.

The EADI will display, in small white letters (*white means armed*) that the VOR/LOC mode is armed and awaiting capture of the radial. When capture criteria are met and the autopilot turns and intercepts/acquires the radial, the lateral FMA will switch from HDG SEL to VOR/LOC.



VOR/LOC mode armed

After radial acquisition, lets continue our climb.

- Dial in 24000 in the MCP ALT selection window.

As you turn the altitude dial, observe how the *ALT HLD* button on the MCP illuminates. This does not indicate that ALT HOLD mode just now became active, as it has actually been active all along, as indicated by the FMA. What it means is that if you press the illuminated button, then the mode will be disengaged.

AP PITCH MODES

So lets play with the AP, beginning with some pitch modes. We'll start with the *C*ontrol *W*heel *S*teering (*CWS*) mode.

- Press the illuminated *ALT HOLD* button.

Remember, an illuminated button on the MCP means *it can be deselected.* It does NOT mean that mode is currently active. Note on the EHSI, the vertical FMA will change from ALT HOLD and show blank. This indicates that pitch control is in manual mode under your control. Also, the horizontal flight-director bar also disappears as the AP now has no stake in the control of pitch.

The CWS P annunciators on the right will display in yellow, indicating that Control Wheel Steering is active for the pitch axis. Whatever pitch angle you set using the yoke will now be held. This is the simplest of AP pitch modes.

EHSI showing CWS P mode as the active pitch mode.

- Pull back on the yoke to set the pitch angle to about 5 degrees nose up and relax the yoke pressure. The autopilot will maintain this new pitch angle. What is cool though is that the auto-throttle will increase thrust to maintain speed at 250, which we set on the MCP earlier.

Lets try the Vertical Speed (*V/S*) mode.

- Press the *V/S* button on the MCP. Observe the CWS P FMA disappear and the V/S mode go active.
- Adjust the V/S with the scroll wheel to +2000 feet per minute.

Vertical Speed Mode becoming active (green rectangle)

Once you have passed 10.000 feet:

- Turn off the landing lights.
- Set the seat belt switch to auto.
- Place the gear lever to OFF
- Set the auto-brake to OFF.

Now lets use flight level change mode to climb to FL240.

- Hit *LVL CHG*, observe the modes change on the EADI.
- Dial in a speed of 290 on the MCP. The airplane will accelerate.

Level Change. AT in N1 mode to maintain MCP Speed

AP ROLL MODES

Lets look at some roll modes other than the VOR/LOC mode we are currently in. First, go back to *skyvector.com,* and look at the enroute chart again. Note at about 40NM inbound to PXR (*waypoint TOTEC*), we want to turn right to fly R-143 inbound (*CRS 32*3). Recall that we set this into the CRS-2 field on the MCP earlier in the tutorial.

Back in X-Plane, you can switch to the local map view to see where you are in comparison to the *skyvector.com* map. In X-Plane, select the *Low Enroute* tab view and enable the *show fix* options on the right side of the local map view.

- Set the First Officer's (FO) EHSI map mode to *EXP VOR/ILS.*

Keep and eye on DME2 and when you are 45NM inbound to PXR, deselect the VOR/LOC mode on the MCP by pressing the illuminated button. The roll mode FMA changes to *blank* and CWS R becomes active. (See image next page)

This roll mode works similar to CWS P mode. If you gently roll the yoke to bank the aircraft, then relax yoke pressure, the CWS R mode will hold the bank angle . If the bank is particularly shallow though, the AP will automatically level the wings.

- Use CWS R to turn and intercept, then follow the radial inbound to PXR. Check on the FO EFIS or the RMI and ensure the *double needle* is pointing to VOR 2.

Disengaged VOR/LOC with CWS R active

- Set *PHX VOR* frequency (115.6) on VHF NAV 1
- Set *CRS 1* on the MCP to 323.

You can now track the inbound radial on your side, and can use the autopilot VOR/LOC mode again. Remember, the FCC A is master flight director and will not track inputs set on the copilot side, and vice versa.

- Set the frequency for the next VOR on the route (DRK 114.1) on VHF NAV 2
- Set *CRS 2* on the MCP to 327.

CRUISE FLIGHT

By now, you should have reached the target cruise altitude of FL240 and leveled off. Time to give the autopilot a break and practice a bit of manual flying using the flight director to guide us like it does the AP.

- Disengage the speed mode on the MCP. The auto-throttle reverts to ARM.
- Capture the ghost throttles to regain control of the throttle. Memorize N1 before you do as you will want to adjust the throttles to maintain that N1 value manually.
- Disengage autopilot A , either with the switch on the yoke, or via the MCP button. Note that the disengage bar below the autopilot is only used in an emergency!
- Extinguish the red flashing P/RST warning light by pressing it.

Now fly manually and follow the commands (*the magenta bars on the EADI*) of the flight director in order to maintain level flight and track the VOR. Keep the magenta bars vertical and level by adjusting pitch and roll as needed.

At our current speed and altitude, the aircraft is very sensitive, so use very gentle inputs only. After a few minutes you will understand why pilots use the autopilot for the enroute part ;-). So lets revert back to it.

ENROUTE NAVIGATION:

- Turn on the *Autopilot A* on the MCP.
- Re-engage the auto-throttle by hitting the *SPEED* button on the MCP.

Check your position with regards to the PXR VOR (DME 1), you should be close.

> When you pass overhead the VOR, you will enter the *cone of silence.* The VOR signal gets erratic and weak over its head. The plane might wobble a bit as it tries to follow the erratic signal, but when you come out on the other side, the signal with strengthen and the plane will course cleanly again.

- Turn CRS 1 from 323 to 330, the plane will bank to re-intercept the new outbound course.

CRUISE CLIMB:

About 220NM out from Las Vegas. ATC offers us a higher level cruise altitude to save some fuel. "*Climb to FL 290*" ATC comands.

- Dial 29000 on the MCP ALT window.
- Dial 29000 on the FLT ALT field of the cabin pressure controller to inform it of the new cruise level. Observe the cabin altitude starts climbing immediately to cater for this.
- Press the *LVL CHG* to initiate the climb.

Somewhere around FL260 the speed will change from 290 to .71. This changeover from IAS to Mach is automatic, and is a safety feature because the pilot might forget to switch over manually using the C/O button on the MCP.

Once you reach FL290, turn off the flight directors. This gets rid of the magenta bars on the EADI, but of course the AP will steer the aircraft just the same. In other words, the autopilot will fly the aircraft exactly like a human pilot would when always centering the flight-director bars.

We are approaching DRK VOR. Switch to EHSI map mode to *MAP* and a map range of 80NM. Since we are still tracking PHX R-330 outbound we would just about miss DRK VOR. Lets use the AP heading mode with bank angle limiter and map to pass overhead Drake.

EHSI set to MAP mode and 40NM range, showing DRK VOR.

BANK ANGLE LIMITER:

The bank angle limiter, simply enough, limits the angle of bank for AP commanded turns. its control is on the MCP and is a bit hard to see as it sits UNDER the Heading knob.

- Turn the ring underneath the HDG SEL knob to the leftmost limiting position.

Bank Angle Set to 5 Degrees

- Engage *HDG SEL* on the MCP
- Adjust the *HEADING* on the MCP until the white *track line* on the EHSI passes directly through the green VOR symbol labeled *DRK*.

When almost overhead DRK, just a bit before:

- Set the *HEADING* to 290 to initiate a turn.
- Set *CRS 2* to 290 (remember, DRK is tuned NAV2)

Use the Autopilot HDG SEL mode to intercept and track the DRK 290 radial while sneaking a peak at the copilot EHSI to reference the VOR/ILS course deviation indicator (CDI). Recall we set the copilot side to VOR/ILS mode earlier.

Copilot EHSI set to VOR/ILS mode

While making shallow turns is great for passenger comfort, it is easy to forget to set the bank angle limiter back to normal. Both the LNAV mode (*introduced in a later tutorial*) and the VOR/LOC mode ignore the bank limit selector, but the HDG SEL mode honors it. When ATC gives you a turn however, they expect it to be at a standard bank angle, certainly not 5 degrees.

- Set the bank angle limiter back to 30 degrees

THE DESCENT

- Set EHSI *MAP* range to 160NM
- Set *NAV 1* frequency to BLD VOR 116.7
- Set *NAV 2* frequency to Las Vegas LAS VOR 116.9

EHSI Map range set to 160 with NAV1/NAV2 tuned to VORs

At FL290 we need about 88NM (290 / 3.3) to descend. Las Vegas is at 2500 feet MSL, so this calculates to 80NM of descent distance or so. We add a tiny bit of distance to account for the right turn onto the ILS and so will start our descent 85NM from LAS VOR (referencing DME-2). This will give us a bit of room to play with some descent modes on the way down.

- Set the MCP ALT to 4900 ft.

This is the final altitude at *SHAND* intersection (*see skyvector approach chart*) and should clear us nicely above the mountains near BLD VOR.

When the right side DME to LAS reads 85:

- Engage *LVL CHG* on the MCP.

The auto-throttle will reduce thrust to idle and then enter ARM mode. The autopilot will pitch down to maintain Mach 0.71. Explore what happens when you add thrust manually now (*capture ghost throttles to gain throttle control*), the autopilot will pitch up to maintain the set speed. You can use this technique to *stretch* your descent distance. Alternatively, use can use the vertical speed mode and the auto-throttle will enter MCP SPD mode automatically.

- Select LVL CHG again - we need to come down in time.

Today we plan to do a low visibility approach with an automatic landing (*even though the weather is fine*). Let´s plan for that. The big difference with an automatic approach is that both autopilots will be connected to the flight controls. This is called *fail passive,* If one AP freaks out, then the other AP can counter it. Normally you can not engage both autopilots at the same time. Lets see this in action.

- Engage AP-B. Observe that AP-A will disconnect.
- Engage AP-A again to disconnect AP-B, since it will not track the NAV1 frequency, which we will be using for the ILS approach.

APPROACH

The whole process of flying a safe auto-land approach is relatively complicated, so we will pare it down to only the essential parts.

- Set the correct inbound course for the ILS on BOTH CRS selectors (255) now.
- Select a decision height of 50´radar altitude on both (CPT + FO) side.

NAV 1 radio, shown tuned to BLD VOR

We will need both VHF NAV radios set to the same ILS frequency to engage a second autopilot. The plan is to set the ILS freq on NAV 1 when we are outbound BLD and then set the ILS frequency on NAV 2 once established on the localizer with NAV 1.

- Set the approach speed, *Vref* for flaps 40 using the APPROACH page on the CDU. (*INIT REF* button to access).

The Vref speed should be about 122kts. Click on the button next to the speed value, and then click the same button again to insert this number on top of itself.. The number will change to a big font to indicate it is selected.

- Move one of the plastic speed bugs on the MASI (Mach-airspeed indicator) to that Vref speed.
- Set another speed bug to the *Vref* speed + 15 knots more, (*Vref+15, maneuvering speed*).
- Set the auto-brake knob to *3*
- Read through the APPROACH checklist on the yoke.
- Reduce range on the map as appropriate to have a clear picture of BLD and LAS

Range settings too small will not show everything and range settings too high will clutter relevant information at the bottom of the EHSI.

- Review the approach chart again.

At BLD we will turn right, heading 320 to simulate *radar vectors to final*. When descending through 15.000 feet:

- Turn on the seatbelt signs again
- Turn on landing lights while you are at it.
- At 12000 feet, reduce speed to 250kts.

Regulations require the flight-directors to be on during an auto-land approach

- Turn on both flight directors on the MCP.

INITIAL APPROACH:

As you approach BLD VOR, reduce speed to 210 knots. When over BLD:

- Set the *HEADING* to 320 on the MCP.
- Set NAV 1 to ILS frequency 111.75 MHz

You are cleared for ILS APP RWY 25L!

HEADING set to 320, turning towards ILS capture

- Arm the approach mode (*hit APP on MCP*). Observe LOC and GS getting armed (*white*).
- Select the pilot side EXP VOR/ILS mode to check orientation of the inbound course.
- Reduce speed to 180kts (*Flaps 1 at 210, Flaps 5 at 190*).

Preparing to Intercept the ILS

FINAL APPROACH:

Observe the AP capturing first the localizer, the white VOR/LOC changes to green – the plane turns to the centerline.

Turning to Intercept the ILS

- Set the *HEADING* to 255 to track the ILS.
- Set NAV2 to the ILS frequency 111.75 also.
- Engage AP-B quickly.

Now both APs are on, but only AP-A is in control. You can tell by the *1 CH* indicator in yellow on the EADI as soon as the glide-slope is captured. Thing start to move a little bit quicker now.

- Arm the Speedbrake, pull back slowly on the lever until the green *SPEEDBRAKE ARM* light comes on.
- Reduce speed to Vref + 5 (127 knots) when the GS is captured. (*white GS turns to green*)
- Drop the landing gear.
- Set *flaps 15* (skip over flaps 10).
- At 150kts extend flaps to *flaps 25*
- At 140kts extend flaps to *flaps 40* (skip flaps 30)
- Set the *MCP ALT* to 6000 feet (*level-off altitude in case of go-around*).
- Read the *FINAL* checklist on the yoke.

Observe the ILS self-test (*blinking yellow scales*) at 1500 feet AGL. In the real plane, we call out *Flare armed* when the blinking self test is completed and the words in white, *FLARE* is shown on the EADI FMA.

EADI showing FLARE after the ILS self test

As of now, both autopilots are engaged. Also the automatic go-around mode is armed (*not shown*), If you hit the TO/GA buttons on the thrust-levers at this point, the plane would automatically fly a go-around for you.

> If you pay attention you can see the *mistrim* at about 400 feet radar altitude. The autopilots trim quite a bit *nose up* at this time. You can see the control columns move forward as the autopilots *push* agains that added trim. This is a safety feature in that if something goes wrong and the autopilots disconnect, then the nose will rise away from the ground instead of diving into it. This also makes flying a *manual* go-around difficult under 400 feet because you have to push on the yoke a bit to compensate for this mis-trim.

LANDING AND ROLLOUT

During the landing, its normal to observe the following sequence:

- At about 150 feet RA, call out *approaching minimum*. In real fog you would get ready to

spot the lights below!

- At 50 feet, call out *minimum* followed by *continue* if you see lights, or *go-around* if you do not. If you continue you will see the AP engage *FLARE* mode, followed by *RETARD* in the auto-throttle channel at 27feet RA.

After touchdown:

- Immediately disconnect the autopilot
- Engage reversers.

Note that the autopilot has NO control over either rudder or the nose wheel. After touchdown it is only YOU who keeps the plane on centerline. That is why the 737-300 is restricted to CAT3a approaches with decision height of 50´ AND a minimum RVR of 200m. You need to see something to control the rollout.

Final Approach

GO-AROUND AND MISSED APPROACH

Alternatively, you can try a go-around if you are feeling adventurous. If so, push the TO/GA buttons and see what happens! The nose will go up and power goes to GA (*reduced go-around power*).

TO/GA mode enabled

If you need more power, push TO/GA a second time (GA would change to N1). The speed display on the MCP blanks and assumes a fixed speed setting in relation to flaps. You will see the speed cursor move automatically when you retract flaps!

- Retract flaps to 15 immediately (it is really one command: GO AROUND, FLAPS 15!)
- Raise gear when climbrate is positive.

At 1000 feet above ground you can raise flaps to 5, then at 170kts to 1, then up at 190. When a new pitch mode gets engaged, the second autopilot that was engaged (*in our case B*) disengages again automatically. Select HDG mode to fly around the airport and try a second time...

AFTER LANDING

If you decided to land:

- Taxi off the runway
- Turn on taxi light
- Turn off landing lights and strobe lights.
- Lower the speed brakes. If you are a sly Captain you will advance your thrust leversabout halfway as this triggers the auto retraction of the speed brakes, which is actually a go-around feature.

- Raise the flaps.
- Move the air-ground switch to GRD, this will depressurize the aircraft by opening the outflow valve.
- Turn off the auto brake and the flight directors.

You can start the APU during taxi-in so that you can have electricity and air conditioning once you turn off the engines so as to keep the passengers happy and cool. Alternatively, have the ground crew connect a ground-power unit to supply power as soon as you stop. They also have fixed air conditioning hoses to connect to the aircraft in hot places like Las Vegas!

Before you turn off the engines:

- Set the parking brake
- Connect the generators busses to either the APU or GPU, depending on which one you are using for power.

> An interesting tidbit about the APU. On ground it can power both busses but in the air, it can power only one. Give it a try on our sim if you like!

We recommend you repeat this flight until you are familiar and proficient with it´s contents. Experiment a lot, sim fuel is cheap, sim engines are reliable and sim airplanes are tough. Try different modes of the autopilot. Choose a different runway, different airports. Fly in lousy weather, change the weights, winds, etc. When nothing can shock you anymore, go to tutorial flight no. 3.