



# How to Fly Using A Glass Cockpit

By Andrew Herd



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## INTRODUCTION

A **glass cockpit** is an aircraft cockpit that features electronic (digital) instrument displays, typically large LCD screens, rather than the traditional style of analog dials and gauges. While a traditional cockpit relies on numerous mechanical gauges to display information, a glass cockpit uses several displays driven by flight management systems, that can be adjusted to display flight information as needed. This simplifies aircraft operation and navigation and allows pilots to focus only on the most pertinent information. They are also popular with airline companies as they usually eliminate the need for a flight engineer, saving costs. In recent years the technology has become widely available in small aircraft.

This tutorial is intended to help simulator pilots figure out how the instrument panel of modern commercial aircraft works. As such, it is written from a lay-person's viewpoint and it is not intended to be any more than a 'starter' manual for beginners. I should point out that I have never flown a big jet, so I am not best qualified to write this from a technical point of view, but to my knowledge, no-one else has ever written a tutorial like this, so if any commercial pilot chances to read this and finds I have made some howler in one place or another I would be grateful for an email telling me what the problem is, so that I can put it right and help the many people who have emailed me asking for this tutorial to do things the right way.

But first, some history. In days of yore, aircraft manufacturers put instruments in wherever they could find space on the panel, as shown in the Cub panel opposite. This was fine in the barnstorming days, but it wasn't long before high accident rates caused by pilot error led to calls for standardisation and before long the primary flight gauges began to be arranged in the two rows of three instruments that we know so well:

- Airspeed indicator
- Attitude indicator
- Altimeter
- Turn coordinator
- Horizontal situation indicator
- Vertical speed indicator

These six so-called primary instruments were positioned slap in front of the pilot, where he or she couldn't miss them, while other gauges like the engine instrumentation was clustered around them. To begin with, there weren't many other gauges, but aircraft kept getting more and more complex, and as time passed there was further standardisation, and engine instruments, for example, began to be placed near the center of the panel. This was an important development, because it made it possible for pilots to be taught a scanning method that worked in every aircraft, and commercial pilots repeated this so often that it became second nature.





However, as more time passed and aircraft became more complex, additional flight instruments found their way onto panels, and the instrument scan became more and more complex, making a second pilot essential. Examples of these new instruments include Omega, Loran, INS, dual VOR and ILS instruments, extra ADF receivers and such wonderments as doppler navigation systems. Before long, it wasn't uncommon for an airliner

to have a couple of dozen separate dials on the center instrument panel, and eventually the proliferation of gauges became so great that a third crew member, the Flight Engineer, had to be added, just to keep track of what the power plants were up to at any given moment.

Paradoxically, the introduction of jet airliners, with their simpler engine instrument displays, meant that it was possible to reclaim space from the center panel and to introduce a further artificial horizon, another second altimeter and a second airspeed indicator. The driving force behind this was the need to avoid aircraft crashes caused by the failure of one or both sets of instruments, causing disorientation about which ones were giving the right information.



The standby instruments in a glass cockpit must have their own power sources and reference points, because in this day of electronic information, they may be the only instruments left to fly off of in the event of a complete loss of the electrical system. At the same time, unused space on the glare shield began to be used as for 'flight director' functions such as course entry, heading selection and airspeed settings, for aircraft with auto-throttles. But even with these changes, the increased landing speeds of jets had cut the crucial decision making time after crossing the middle marker from over twenty to around ten seconds or so, and with the authorisation of ever lower landing minima, right down to the 100 feet and less, the pilot in command was faced with an almost impossible amount of data on which to make his decisions - and hardly any time to take them in.

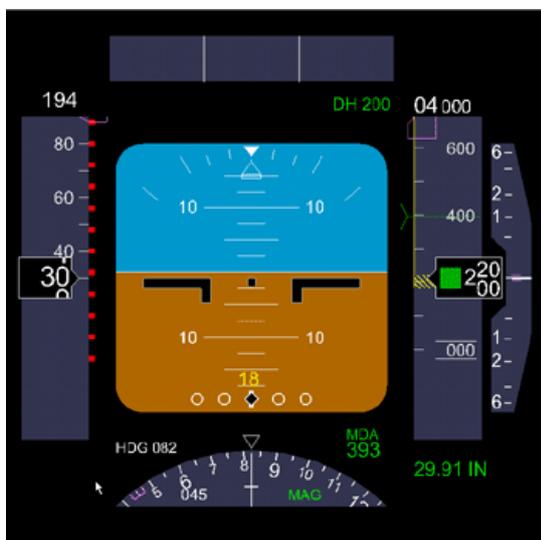
And then, just as it was beginning to look like a fourth crew member was going to be needed, the silicon chip came to the rescue, and it became possible to combine many instrument functions together. The result was the manufacture of large, clear CRT displays, a collection of which is known as a 'glass cockpit.' In this tutorial I am going to review the basic functions of the glass cockpit, so that pilots who are familiar with the 'standard six' instrument display can convert to

the modern fittings and fly the increasingly large collection of state-of-the-art airliners which are available for flight simulators.

## USING A GLASS COCKPIT

In a glass cockpit, the functions of the many of the six primary instruments are combined into one display, the **Primary Flight Display**. If you look at the instrument in the illustration, the benefits of this approach are obvious. No longer does the pilot have to scan six instruments at once; and on approach in particular, this makes for a huge reduction in the scope for pilot error. I have chosen to illustrate this tutorial with a PFD produced as part of Enrico Schiratti's Project Magenta, as this provides the most realistic PFD available for flight simulation at present. While the PFDs you will see in flight simulator panels may not include all the functions of the Project Magenta, they all work in the same generic way. Starting at the very top of the PFD, you

will see an area known as the **annunciator**, all three of which are blank with the aircraft at rest, but which are a major source of information later in the flight. The annunciator panels are commonly omitted from flight simulator PFD instruments.



While most simulator pilots of big jets tend to take off first and worry about instrument settings later, in real life the cockpit is extremely busy at take-off and there is no pause key, so airline pilots spend a great deal of time setting up the PFD before departure, chiefly because it is a good visual reminder of flight minima and other essential data.

For a typical departure of a heavy, the pilots would enter a speed of around 200 knots and an altitude of say 3 - 4000 feet in the Flight Director. Both these values appear on the PFD in magenta, to show that they are 'commanding.' Other less essential data is presented in green. The entry DH 200 won't be needed until you come into land again, as it is the decision height for a missed approach, but it could be set up to remind you to start retracting the flaps at a thousand feet, if you wanted. The PFD may also display other data such as the letters 'F/D' as a reminder that the Flight Director is on, 'VR' followed by a number to show rotation speed, and 'YD' to indicate whether the yaw dampers are deployed.

The center of the display should be more familiar to you, from 'steam' cockpits, and it duplicates the attitude indicator which has been present in aircraft since time immemorial, albeit with a few bells and whistles added. The attitude is shown by a symbol which varies according to the type of PFD in use. Here, on a Boeing display, it is a shallow black T and it shows that the aircraft is straight and level (which is good, since the snapshot was taken with the plane on the ground.) The graduations above and below the horizon show degrees of pitch up or down of the nose.



On either side of the attitude display are what are known as the 'tapes,' which take the form of vertical panels. On the left side we have the airspeed tape, and on the right side we have the altitude tape, which has a further tape on its right which shows the rate of climb or descent. The tapes spin up or down depending on speed and altitude and in the centre of each there is a box with a figure highlighting current airspeed (left) and current altitude (right). You will notice that even with this aircraft at rest, the current airspeed shows 30 knots, and this is because this speed has been set as the minimum this particular PFD can display.

Once in flight, a number highlighted in magenta should appear above each tape, showing on the left the airspeed set in the flight director and on the right the altitude towards which the aircraft should either be climbing or descending. A decimal below the left tape shows the Mach setting when this is set in the flight director. When the aircraft is in the air and has not reached the 'command' altitude or airspeed, a visual indication of the discrepancy appears on the left-hand tape (see illustration) and in addition, a green vertical bar may be present above or below the current airspeed or altitude showing the current rate of acceleration or climb/descent respectively, but the majority of simulation PFDs fail to implement this refinement. Finally, when the aircraft is in the vicinity of the ground, there is a visual indication of the runway at the bottom of the right hand tape. Incidentally, if the runway indicator appears at the top of the right hand tape, you are in big trouble.

Below the artificial horizon, there is a compass card, with a magenta heading bug and a numeric repeater for the present heading above left. The letters MAG on the rose indicate that the compass is showing magnetic heading and not true heading.

The green number on the far right is the altimeter setting and just left of this and slightly above is the Minimum Descent Altitude. Finally, the PFD also has two diamonds which show the position of the horizontal and vertical ILS beams and these indicators allow the pilot to fly the entire approach using this instrument alone.

The other instrument that dominates a glass cockpit is the Navigation Display. The ND on a real aircraft has a number of different modes which can be switched via the Flight Director, and it can also display data on several different range scales. It combines the functions of the VOR gauges, the ADF indicator (although few commercial flights use NDBs these days), and a moving map. You will rarely see a full implementation of an ND in a simulation, as most flight simulator displays settle for a couple of modes at the outside. Very commonly, variable range is omitted and many NDs fail to show the flight plan at all. The illustration shows the ND flight plan display, which is used to monitor the progress of the aircraft.



Another commonly used ND mode is the moving map display. Above the map, the ground speed (GS) and true airspeed (TAS) are shown, along with the track. If you look at the illustration above, you can see that below the speed information at top left there are two figures which show wind direction and speed, with an arrow as a visual indicator of wind direction.



Finally, at the bottom there are indicators showing the frequencies to which the NAV radios are tuned, along with VOR identifiers and DME distances. As you can see from the clutter on this display, the ability to adjust the display range is vital, and many flight simulator NDs fail at this particular hurdle.

By the way, before you start sending angry emails to aircraft designers asking why they don't provide fully implemented NDs, take a moment to reflect just how complex these instruments actually are. With even the most complex simulated panels costing only a few dollars, we have to make a few sacrifices here and there!



The moving map is only one of the ND modes which are available. In this case, the ND has been switched to show the ILS, and although this data is available from the PFD, the ND allows very clear presentation of the horizontal and vertical glideslope data. For those of you who are not used to glass cockpits, this is a pretty standard ILS display for a large jet. The magenta heading bug is lined up with the white bar which represents the runway heading, while the magenta side bar indicates that the aircraft is off course to port, and that an alteration of course to starboard is needed to line up with the runway. You can tell which way around the aircraft is facing by looking for the very short cross-bar on the white horizontal glideslope indicator - here it is facing towards the

heading bug, which is as it should be. The vertical row of dots on the right is the vertical glideslope indicator, showing that the aircraft is too low. Additional data shown by a properly tuned ND would include the distance to the beacon, but I have cheated and this display isn't tuned to any ILS in particular.

One of the biggest differences between a light aircraft and a passenger jet is the presence of an instrument known as the MCP on the jet. The reason private planes don't have an MCP is that there is no problem adjusting all the instruments individually, but this is not an option for commercial pilots faced with complex cockpits and high workload.



The MCP is a key part of any glass cockpit, to the extent that it is usually the only way to adjust the state of the major displays. In addition to controlling the instruments, the MCP receives data from the Flight Management Computer Central Display Unit (FMC/CDU), which allows it to coordinate aircraft position, flight plan data and other statistics such as fuel and passenger load.

Because the FMC/CDU is so complex, very few flight simulator aircraft have one, the exception being (as far as I am aware at the time of writing) the Phoenix Boeing 777; those of you who use EFIS98 will also be familiar with the functions of the FMC. The reason the FMC is so often left out isn't too hard to understand - a real FMC is programmed with several million lines of code and a simulated FMC could hardly get away with less than a few tens of thousands.



Quite sensibly, most authors of simulation aircraft draw the line at a fully programmable FMC and so we will need to reconcile ourselves to aircraft which either lack an FMC/CDU at all, or at best have a small subset of the functions of this powerful computer implemented.

By now you won't be surprised to hear that I am not going to give you an exhaustive breakdown of the functions of the FMC/CDU, save to say that it exists, and if you want to learn more about how it works, you can buy an excellent manual written by Bill Bulfer and Skeet Gifford here, though I should warn you that this is written for real pilots, not simulated ones like you and I, and I had to read it about forty times before I got things clear in my head. So much for the CDU, then.

The MCP varies from aircraft to aircraft, so once again, I have chosen Enrico Schiratti's MCP as a representative example. If you scan across the MCP from left to right, it looks forbiddingly complex, but it can be broken down into three areas.



The first section, at the far left, controls the PFD and ND. The CRS knob at top left sets the correct radial on the ND to allow an interception. If the cockpit of your aircraft supports it, you can switch the ND to 'Rose' display and set the CRS to the radial you wish to intercept on the VOR to which your COM1 radio is tuned. The deflection of the central bar of the ND display shows how much left or right of the radial you are (page down to the screenshots at the very end of the tutorial to see this). Other settings of this knob allow switching of the ND display so that the aircraft is centered and also a display of the flight plan line. The DH knob at top right sets the decision height on the PFD and will trigger an alarm on departure or approach. The knob at middle right sets the range scale on the ND - useful when you need the moving map function. At the bottom, a series of buttons allows you to select what is displayed on the ND in map mode.

The central section of the MCP governs flight director, autothrottle and autopilot functions. The 'F/D on' switch is fairly self-explanatory and 'A/T arm' turns on the autothrottles, which allows the computer to take over control of the engines. If the autothrottles are not armed, you will have to manually control the engines - probably the single most common cause of airliner stalls in flight simulator is forgetting to increase thrust at higher flight levels where the air gets thinner. Engage the autothrottles and set up the FD correctly and you won't come back to earth with a bump so often. The 'IAS MACH' box is a key part of the FD, because it makes it possible to fly the aircraft at a constant speed and the flight director (if correctly implemented) will calculate the aircraft pitch necessary to maintain this at any given rate of climb after the function is selected by pressing the 'SPD' button. The 'LNAV' and 'VNAV' buttons engage the lateral and vertical autopilot modes respectively and the 'FLCH' button is used to obtain maximum climb rates to a given altitude. 'THR' automatically increases thrust to the takeoff setting.



The third part of the MCP is the remaining area on the right of the panel. 'HDG' is self-explanatory - it might be worth pointing out that commercial pilots would usually set HDG to runway heading for takeoff and dial in the first climb level commanded by ATC into the ALT box using the knob below (many flight simulator cockpits dispense with the knob, leaving you to make the adjustment using the familiar '+' and '-' selector with the mouse). The 'SEL' button should set the HDG display to the current aircraft heading.

The 'HDG' is self-explanatory - it might be worth pointing out that commercial pilots would usually set HDG to runway heading for takeoff and dial in the first climb level commanded by ATC into the ALT box using the knob below (many flight simulator cockpits dispense with the knob, leaving you to make the adjustment using the familiar '+' and '-' selector with the mouse). The 'SEL' button should set the HDG display to the current aircraft heading.

The CMD buttons engage the autopilot, and in general the only one that simulator pilots will need to use is the left hand CMD button. With simulator flights, it is rare for the autopilot to be disengaged before landing, but in real life, pilots sometimes have to change course and flight level at the request of ATC and this is done by reprogramming the CDU and then using VNAV or FLCH mode on the MCP to control the ascent/descent.

The LOC and APP buttons on the MCP are used when the aircraft is near enough to its destination to pick up the ILS. At that stage, the PFD on a real plane notifies the pilots that they are in range of the ILS by displaying 'LOC ARM' on the annunciator panel. At that stage the pilots would disengage LNAV and press the 'APP' button on the MCP to perform an intercept of the glide slope. They would also press the 'SPD' button to set the aircraft to the correct approach velocity, with gear and flaps down.

### FLYING WITH A GLASS COCKPIT

OK, so now you know enough about how the glass cockpit works - let's go! After a long period of racking my brains about this, I decided that the easiest way to illustrate how a glass cockpit works was to fly a departure and approach, and switch from a light plane to a jet at key intervals, taking screenshots to show how the instruments in each cockpit look.



I used the Cessna 172 from Abacus' Private Pilot package and the Microsoft default Boeing 737 for the screen shots, and in this first pair, the aircraft are on runway 8R at London Gatwick (Sure, we are to the right of the center line, but that's just tough. You try drinking beer and flying down a narrow white line like that and see how hard it is). NAV1 is set to 117.00, which is the Seaford VOR, and once we are off the runway and cleaned up, we will attempt to intercept the VOR 347 degree radial, which involves setting a course of 167 degrees. The OBS on the Cessna and the course selector on the 737 MCP have been set up accordingly.



The screenshots above show the aircraft off the runway. Alert readers will notice that the 172 is going quicker than its designers ever intended, which is because I flew the whole departure in

the 737 and only swapped to the 172 to get the shots. If you compare the OBS in the 172 with the PFD in the 737, you will immediately appreciate the advantages of the glass cockpit. Intercepting radials with the OBS isn't that difficult, but the PFD gives a far better visual indication of how far the aircraft is off track. All we have to do is stay on course until the white central bar begins to line up on the central PFD display, and then begin a gentle turn to starboard to bring us on course for Seaford.



The third pair of images show the aircraft making that turn to intercept the radial. The Cessna, by now at terminal velocity, with rivets popping and the wings beginning to strip off, is beginning to show the OBS needle swinging towards the center, while the 737 PFD again shows how clearly the glass cockpit can display data - which instrument would you prefer in a tight spot, the OBS or the PFD? One glance at the PFD and a monkey could appreciate that it won't be long before the aircraft will be flying down the radial.



In the final pair of screenshots, the aircraft are near enough on the radial. Take a moment to compare the cockpits. Even with the very cut-down PFD that Microsoft have implemented for their 737, there is much less eye movement involved in assessing the situation. With a fully implemented PFD, almost everything you needed to know would be there in that one instrument.

Now we are going to do the same thing again, but this time we are going to fly an approach to London Gatwick 8R, from the Mayfield VOR. This approach involves flying on a course of 278 degrees from Mayfield, and then making a procedure turn through very nearly 180 degrees at 23 miles from the VOR to intercept the glideslope on a course of 082 degrees. Technically the outward leg from Mayfield should be flown at 3000 feet, but we aren't all perfect.



We begin with two screenshots showing the aircraft at 23 miles from the VOR, with the instruments set up to make the turn. For some reason I chose to fly this approach the hard way with manual throttle control, but everything else is set up OK and if you look at the PFD in the 737 you will see that the 'needle' is pointing almost backwards, and that the ILS beam is to our right with the runway 'behind' us. Let's make the turn.



In the shots above, we are about halfway through the turn, with the glideslope to our left and above us.



Now the aircraft are lined up, horizontally and vertically on the glideslope, having intercepted it from below. If you look carefully, you will see that the magenta triangle on the right hand side of the 737 PFD has descended to the central bar, giving a clear indication that we are on the glideslope - in the second pair of shots, the triangle was high, showing that we were below the glideslope. Isn't it great how the slew keys allow you to fly perfect approaches every time?



In the final pair of screenshots, I have deliberately placed the aircraft slightly low and to the right of the glideslope. Again, compare the OBS and the PFD to see how the latter instrument works, and how easy it is to fly with one of these new-fangled glass displays. All you have to do is land now.

And that folks, is it. For those of you who are interested to know, I am going to have a beer now. If you enjoyed this tutorial, please email me another one - I prefer it cold (-:

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