How to choose an Electronic Flight Information System, Part 1

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 At the time of writing IMC flight in homebuilt aircraft is not permitted in the UK.

This is the first in a series of three of articles looking at Electronic Flight Information Systems, this one will concentrate on what to look for when buying a Glass Panel. In the second I have asked several Glass Panel makers what is going on behind the displays, and the third will concentrate more on flying behind an EFIS. Most people don't like acronyms, so I'll just call these devices Glass Panels – it might not be the best term, but it will probably make more sense to most of you than alphabet soup.

What's the big deal, you might ask? Isn't it quite straight forward … look through all of the advertising material, throw out those that are too expensive, compare features and make a decision. Where's the problem? Well, just about every other aspect of the aircraft we fly in has some kind of provenance. LAA Engineering assesses the airframes, the engines are often certified and the CAA (or EASA or FAA) must approve the radios. But glass panels are one area where it is very difficult for the average homebuilder to properly compare the competing products. The advertising material is very compelling with bright pictures, and long lists of features that sound like they're essential in your new wonder plane - but what is going on behind the pictures, what marks out a good glass panel from the also-rans? This article aims to provide the answer.

It has been suggested in these pages that there is nothing wrong with the traditional "six-pack" and no-one in their right mind would install a Glass Panel. I don't hold that view. Some of the reasons that I like electronic systems are:

Presentation of Information – A good Glass Panel presents all of the information needed to fly the aeroplane in one place in front of your nose. It should be intuitive to interpret, and to understand what the aeroplane is doing. The electronics allow functions, such as a Velocity Vector or Highway-in-the-Sky, to be provided that just are not possible with traditional instruments. The six-pack, by its very nature will provide 6 separate items of information that the pilot must integrate.

Adaptability – As new formats to display data are developed it is possible to update Glass Panels relatively easily and at reasonable cost.

Weight and Panel Space Saving – When comparing systems of similar functionality electronic systems are usually lighter and take up less panel space than their conventional counterparts. If an electronic system weighs the same it will very likely provide much greater functionality.

Reliability – There are very few moving parts in a Glass Panel system, and certainly nothing as unreliable as a vacuum pump. Although a continuous supply of electrons is required it is not difficult to ensure that is the case with good electrical system design well within the capability of most homebuilders, with a little help from men like Bob Nuckolls (www.aeroelectric.com). I do accept that it is difficult to prove the reliability of software intensive systems.

Cost – While a conventional 6-pack may be (very) slightly cheaper to buy initially, I suspect that something like a Dynon D10 will end up cheaper after the first vacuum pump replacement.

But if only life were that easy! While the manufacturers produce very alluring advertising it is almost impossible to use that to find out what is really going on to generate the displays that look so compelling. What is the performance of the system likely to be? How good is the basic hardware? How will you know if there is a fault affecting the data presented to you? How easy will your choice be to install? Should you care? I think you should care; the least expensive Glass Panel will cost over £1500 ($2400) and will be in your panel for many years. If it doesn't work as you imagined you will be mightily fed up!

There have been comparison articles before that list the obvious features of the various products. The author probably spent all of half an hour on the internet and threw the results into a table. Most homebuilders are motivated to do that for themselves so I hope to provide a little more insight about the various devices considered. But why not go to brand G? There's nothing stopping you, except a price tag of around $60,000. Most of us can't afford that kind of money so this article is not going to consider certified systems, such as the Garmin G1000/G900, Chelton or Avidyne. All of these systems are very costly, and being certified you can be reasonably sure that they will do what they say on the tin; you are buying peace-of-mind. The reason they are so expensive is that they haven't cut any corners on design, manufacturing or testing. The reason that non-certified systems are cheaper is because their manufacturers have cut some corners against the certification "gold standard". Non-certified Glass Panels do entail a certain amount of risk, to understand if those (usually small) risks, read on. If you are uncomfortable with the risks then start saving for one of the certified systems above.

This is probably a good time to talk about back-up instruments. The LAA require that a back-up mechanical air speed indicator, altimeter and compass are fitted. I think that is exactly the right position to take. When permit aircraft are approved for flight in IMC I expect that a back-up attitude indicator, or turn and slip, will be required. With all the advances in electronic technology let's assume that the hardware of any system you buy will be adequately reliable – all of the major manufacturers have a reputation for reliable hardware, we'll have to wait a few years to see if that reputation stands the test of time. By hardware I mean all of the electronics, wire, switches and displays. However, there is far more to a Glass Panel - they all rely heavily on software, the complex combination of instructions, databases and algorithms that produce the brilliant displays, maps and on-screen data. While the combined reliability of the hardware and the software defines the reliability of the system, the heavy reliance on software means that we really have to understand how both elements have been designed and tested in order to show to any level of assurance that un-certified Glass Panel systems are reliable. The design standards for software used in aircraft applications (described later) are not cheap or easy to comply with, one reason certified systems are so expensive. In fact, modern software is so complex that the standards require the use of specific design practices as it is not possible (read uneconomic) to fully test all even a moderately sized program. Thus the only way to be reasonably certain the software is of good quality, and will "do what it says on the tin", is to make sure the design is robust and that the code matches the design. In general un-certified systems cannot afford to do all of that. Therefore in buying an un-certified system you are taking something of a risk that it will fail to perform in some way or in some unforeseen combination of circumstances. As a consequence reliable back-up instruments that can be used to fly the aircraft home should always be fitted. Having said all of that, I have heard nothing in the homebuilt market place to suggest that, in practice, any of the systems considered for this article are at all un-reliable.

Before looking at individual systems in detail it is worth looking at the typical components of a Glass Panel system. But first a few words about working out what you want from such a system. After all, if you don't know what you want it is unlikely that you will buy something that will meet your needs. As you read the rest of this article, consider your answers to these questions. There are no right or wrong answers. The correct answer is the one that is right for you, but do work out what <u>your</u> answers are.

- Are you any good at wiring/crimping/soldering? If not is a pre-made wiring harness available? Does it include all the features that you want?
- Consider what kind of flying you will do, there are really two basic scenarios, in the clear or in the clouds. Yes, currently permit aircraft are limited to VMC only, but as Mike Barnard explained in the November issue there are significant efforts being made to change this situation. I firmly believe IMC in permit aeroplanes will be possible in the future.
- Are you into touring or will you mainly be flying locally?

- How much time are you prepared to put into learning how to use the functions of your Glass Panel? If the answer is not much, or you won't fly that much, then the more complex systems may not be appropriate.
- Why do you really want a Glass Panel?

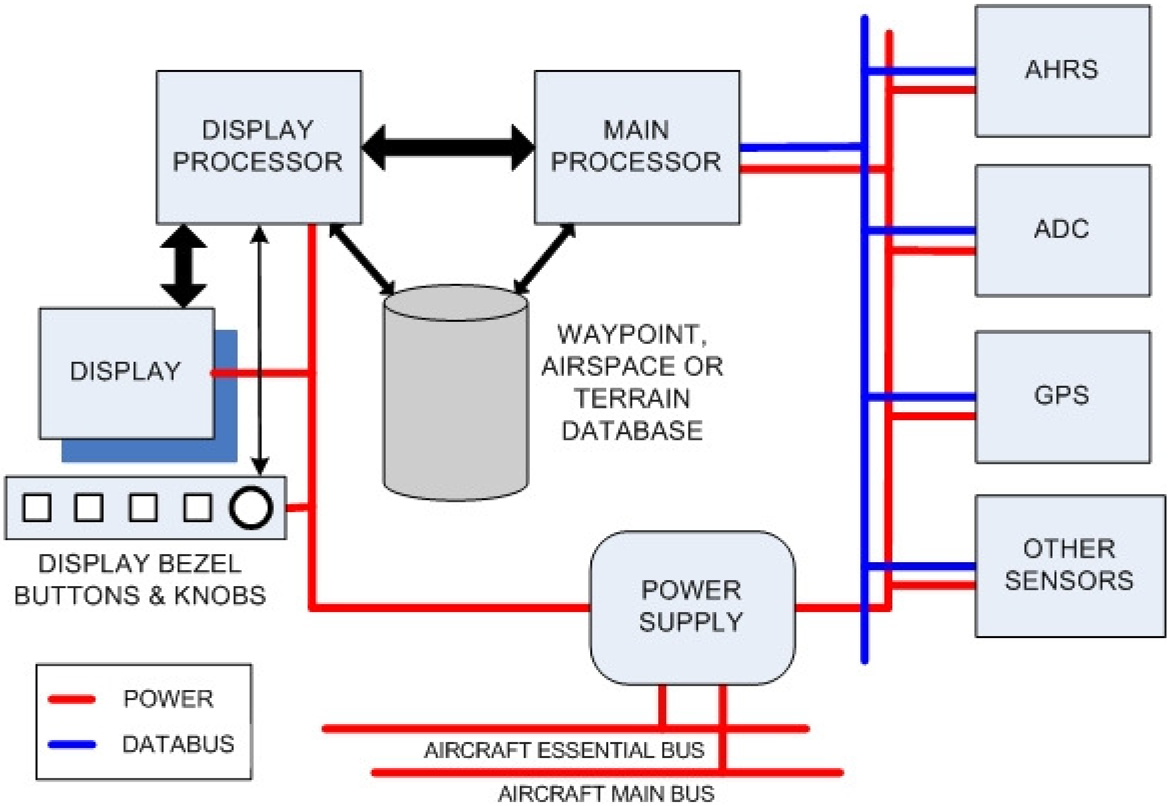
To answer some of there questions fully will take some time and thought. As I was putting this article together a piece was published in the Van's Aircraft house magazine *RVator* entitled "Equipment Redundancy – How Much is Enough?" written by Paul F Dye, who works at NASA. This is one of the very best articles on this subject I have read in a very long time and is written in a very accessible style. I would recommend Paul's article to anyone and have his permission to upload it to the Gloster Air Parts website at, http://www.glosterairparts.co.uk/Equipment_Redundancy.htm.

So what does the typical Glass Panel comprise of and what would a good quality example look like? A certified system would be designed, built and tested to comply with several standards, the main ones are DO-160 (for electronic hardware) and DO-178 (for software) issued by the RTCA (which used to stand for Radio Technical Commission for Aeronautics). Both standards are updated from time to time, the latest versions are DO-160F and DO-178B. Older equipment may be designed to older versions, there is rarely a need to update existing equipment to a new standard as the costs are usually prohibitive. These standards are not simple and compliance with them is not straight forward either – if you were to ask if a system complied with either standard and received a yes or no answer then the manufacturer probably doesn't understand the standard! While there is no requirement for non-certified systems to comply with them, they do represent the collective wisdom of the worldwide aeronautical community. So it would be really good news if any product fitted to your aeroplane at least aimed to comply with the goals set out in them. Even if the (expensive) test data to prove compliance is not available.

FAA Technical Standard Orders (TSOs), and their European equivalents, that invoke these RTCA standards establish a bar over which manufactures must jump to get their device approved for installation in a certified aeroplane. They do not always lay down what the device must do, but they often stipulate minimum standards for accuracy and temperature stability along with environmental tests that must be endured and methods that must be employed when the software is written. If a device has not been designed to comply with these standards (from the outset) it is almost impossible to pass the tests. The testing proves that the design meets the standards it was intended to meet. It is not possible to test quality into a system! Taking a commercial computer and subjecting it to TSO levels of testing will often result in failure as the device was not designed to withstand the tests in the first place. Software is a special case. A long time ago it became impossible to fully test most software applications – they are just too large and complex to be able to explore all possible permutations of inputs. The software that drives Glass Panels is no exception. Reliable software comes from using a good development process (amongst other things).

Most manufacturers cannot prove their systems meet any standard so the experience of the design team becomes significant. People experienced in designing systems (and writing software) for aircraft applications will have a good understanding of what is important for good airborne performance. What works on the ground may not work so well airborne. All systems have to make compromises, such as cost, complexity, weight, performance or power consumption. Experienced designers or design teams will understand which are worthwhile and which are not.

All Glass Panels are made up of several elements that must work together to create a cockpit display for you to look at. All of the elements may be built into one housing, or there may be several individual pieces. Often the flux gate sensor (compass) is located in the wing or aft fuselage for interference reasons.



Schematic Diagram of a typical Glass Panel System.
In some cases all of these parts may be housed in one instrument

Display (including any push buttons or knobs) – the most obvious part, it should be bright enough to be visible on even the sunniest of days. Bear in mind that touch sensitive screens give up about half their brightness to be touch sensitive. There should not be too many buttons of knobs on the front. Think about operations that you carry out often, such as setting QNH or the next way point, and look at how many button presses are required for those tasks. Well designed systems will make routine tasks easy.

Display Processor – similar to the video card in your computer this device draws the pictures and is sometimes combined with the main processor in cheaper systems. The picture should be refreshed at least 24 times a second (24 Hertz, Hz) preferably more (40 Hz is preferable), this is similar to the rate at which the picture is drawn on your TV. Any less than 24 Hz and the picture may appear jerky. Don’t confuse the display update rate with the rate at which the data that is displayed is calculated.

Databus – There will be a way to transmit data around the system, usually using a data bus rather than wiring each item directly to all the different elements it needs to talk to. Can the device you are considering accept inputs on a NMEA/RS-232 or ARINC 429 external databus?

Main Processor – Similar to the CPU of your computer, this will carry out all of the basic calculations that make the Glass Panel work. All processors use some kind of operating system, your home PC probably uses Windows or MacOS. If you have been a Windows user for any length of time you may have experienced one or two problems (aka ‘the blue screen of death’). Modern versions of Windows are much better, but perhaps not perfect. Some Glass Panels use Windows – often Windows CE for PDAs – as an operating system. If you are considering a system that uses Windows (or similar commercial operating system) and can envisage using the system when its reliability is paramount, for example in IMC, then I would urge you to fit 2 displays. Each display will generally be running its own operating system, if one should crash the second will provide data while the first re-boots.

AHRS (Attitude and Heading Reference System, usually pronounced 'A-hars') – This item is the heart of any Glass Panel as it senses the attitude of the aircraft using precision solid state gyroscopes. The reason that modern Glass Panels are possible is due to the development of low cost electronic gyros – 10 years ago we would have paid £10,000 ($16,000) or more for such a device. These gyros need to be kept still for a while, perhaps a few minutes, when they are switched on to work out what attitude they are in. Even the best will drift slowly, so over an hour the pitch or roll attitude may be come in-accurate by a degree or two (or more). Some systems rely on GPS signals to keep them aligned while others use airspeed and complex mathematical algorithms. Reliance on GPS is less robust than the other techniques. Sometimes a flux gate compass is added to the AHRS, alternatively it can be mounted remotely to avoid interference.

Air Data Sensors – Along with the AHRS the air data sensors (pitot and static pressure and OAT) are an essential part of any Glass Panel, sometimes they are called the air data computer (ADC). As cars have developed engine management systems so the price of low pressure sensors has tumbled again making reasonably priced Glass Panels a reality over the last few years.

GPS and Other Sensors – Even if your Glass Panel does not have any navigation functions it often uses GPS for wind calculations or to help align the AHRS. Other sensors, such as engine temperatures and pressures, or flap and trim position indicators can sometimes plug straight into the main box or interface through a separate unit.

Power Supplies – Most electronics operates at 5 volts so some kind transformer is required to take the aircraft bus voltage and reduce it down. As the aircraft bus voltage often varies between 12 to 15 volts, when on battery or alternator, and most electronics require a fairly stable voltage input – especially some of the sensors – some power filtering is usually included. To comply with DO-160 the unit should be able to handle 'power spikes', as are fabled to be produced during engine start, and also short periods (tens of milliseconds) of power cuts. Ideally it should be able to power the whole system from more than one power source so that it doesn't go blank if one component (say the main contactor) fails. The power consumption of a system is also important. If the Glass Panel takes more than 3 or 4 amps it will quickly take a large bite out of the battery capacity of most homebuilts when running on battery alone.

Connections – All the different parts of the system must be connected together in a reliable way - most manufacturers now use multi-pin D-sub connectors. Crimped pins are far superior to soldered connections when making up these connectors.

Software – As well as all of the hardware no Glass Panel would do much without its software. There are really at least 4 parts to the software,

- The operating system (see Main Processor above),
- The main processor software that calculates attitudes, speeds and so on from the sensor inputs,
- The display processor software that takes the main processor outputs and assembles them into a pleasing and informative presentation for the pilot to look at, and
- The navigation database containing waypoints, airspace boundaries and cultural information.

Often vendors advertise regular software updates. While the ease with which the software in most Glass Panels can be updated is often a real bonus, it can sometimes be a curse as it is all too easy to break a feature while fixing another. When regular software updates are offered ask what is being updated. Clearly everyone wants up-to-date waypoint and airspace information so there should be a provision to supply that information regularly, perhaps on a data card for ease of installation. New methods for presenting data are sometimes found while it is unusual to update the basic algorithms that drive the system - the way to calculate airspeed from pitot and static pressure does not change from one year to the next. The problem is that software updates are not always a reliable process, especially when carried out on an airfield, or even in a hangar. An error in a database is merely annoying, an error in a display or a basic calculation may be more serious – most owners don't have the facilities to fully check out their system once it has been updated.

The performance and reliability of any Glass Panel is dependent on the integrity of the hardware, the skill with which the software has been written and the aircraft builder's wiring ability. I'll assume for now that the installation is perfect and the hardware will last the life time of the aeroplane (which for a privately owned light aircraft may only be a few thousand flying hours over many years). There are 3 factors that impact the performance of the system,

- the rate at which the data items to be displayed are refreshed,
- the rate at which the sensors (AHRS, air data, etc) sample the basic data
- the time taken to transmit and display the sensed data (latency)

I have already mentioned the rate at which the display is re-freshed is not the same as the rate at which the displayed data is calculated. Here we are talking about the rate of data calculation. In round numbers, the display data must be refreshed at a minimum of 20 times a second (20 Hertz, Hz) and the sensors must measure fast moving data (attitudes, airspeed, altitude) at least at the same rate (preferably faster) to avoid jumpy displays, faster is better, 40 Hz would be preferable. It is acceptable to refresh slower changing data (such as heading) or state data (such as flap position) at a slower rate, say 5Hz to save computing time. The delay between any quantity being sensed and it being displayed must be less than 100 milliseconds (that's 0.1 seconds) to avoid the pilot experiencing handling problems – this may sound like a very short period of time, but many studies have show that if the latency exceeds 100ms then most pilots find it more difficult to fly the aircraft, especially during any kind of dynamic manoeuvres. The issue here is that moving data through the system, from sensor to display, takes time. The processing is often the speedy part, the data transfer often is more of an overhead - so fitting a faster processor is not always the answer. Good design of the overall system, coupled with not presenting too much data and sensible update rates – perhaps with the slow moving data not being updated every cycle – is the key to a high performance system. Don't discount a system because the pictures aren't quite as pretty as the competition. They may have made a conscious decision to have a lower resolution display (but still adequate for the task in hand) to achieve good performance.

While we want a Glass Panel to be very responsive it should also check the data presented to make sure it has not become corrupted. If components fail it would be good if the system can retain some functions while informing the pilot that some of the data is unreliable – or perhaps removing it from the display altogether. There are many ways to achieve this monitoring, from looking at the rate of change of the data to comparing two similar data sources (for example airspeed and GPS ground speed), but it does take time and money to do well and does not add any obvious functionality for the pilot.

It is difficult to find out how the most popular Glass Panels stack up against the issues above by reading the promotional literature. I have asked 5 of the top manufacturers some relevant questions to look at how their systems have been designed and built in an effort to understand how they will perform in service. In the 2nd article of this series the answers to these questions will be published so that you can compare for yourself.