How to choose an Electronic Flight Information System Part 2

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This article was first published in the UK Light Aircraft Association magazine '*Light Aviation*' in early 2009. At the time of writing IMC flight in homebuilt aircraft is not permitted in the UK. The original version included Blue Mountain Avionics in this comparison, but they have now ceased production of new systems so information on their system has been removed.

In the first article I looked at the factors that you might consider when selecting an Electronic Flight Information System, termed 'Glass Panel' for the rest of this article. By reading the promotional literature it is difficult to find out how the most popular Glass Panels stack up against the factors I suggested. I have therefore asked 4 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.

The firms were Advanced Flight Systems, Dynon, Grand Rapids Technologies and MGL Avionics. I believe these represent the market leaders at present. For Grand Rapids Technologies Greg Toman, the Chief Engineer, replied and for MGL Avionics Rainier Lamers, the CEO, replied. Rob Hickman the CEO of Advanced Flight Systems responded and Robert Hamilton, Sales and Marketing Manager, responded for Dynon. I would like to thank all of these people for taking the time to answer my enquiries. In the sections below any text in italics is a direct quote from the one of the companies, text in plain font is my summary of an answer. Plain text (in brackets) is my comments on an answer. Do bear in mind that the statements below are straight from the manufacturers and have been very difficult to verify.

The first area to look at the **hardware**. DO-160 sets out goals that design teams should aim for and run tests to confirm compliance of their systems. Testing is costly so many un-certified systems are not (very thoroughly) tested. I asked:

Has your product been designed to comply with design goals set forth in DO-160?
- If so, which levels and which chapters?
- Have any tests been conducted to confirm compliance?

GRT	Little information provided
MGL	DO-160 is used as a guide only, as MGL have found that the requirements are often not that representative of typical light aircraft – so have to design their products to requirements they believe are more appropriate to the severe environment of microlight aircraft. Some in house testing carried out.
AFS	*AHRS is based on one that was designed and has been tested to DO-160* [albeit repackaged]. *Each of our AHRS units is manufactured in a FAA monitored and controlled facility*. (No data provided on the other components)
DA	Instruments are designed to meet DO-160 requirements such as temperature, vibration, EMI emissions, shock, power input, voltage spike and electrostatic discharge with testing performed on the various portions of these requirements as design validation requires. (However, some low quality components are used – other systems use BAE Systems gyros - and testing could be more thorough)

Display What is the update rate of the primary flight display when displaying the most complex page using the full colour palate?

- Are all elements of the display updated at the same rate?

GRT	*15 frames per second. All elements are updated.* (A little slow, but everything is updated at the same rate)
MGL	50 Hz, but *"Individual elements update at whatever rate the underlying data becomes available"* (This comments makes me slightly uneasy as I would like to know that the basic flight data is updated at a reasonable rate)
AFS	*The screen is updated at 20 hz. Some of the data behind the screen is updated at a different rate, for example the GPS data is only updated at the rate the GPS sends it.* (This meets my criteria)
DA	*The most complex page … updates all PFD elements at about 10 frames per second. The normal use cases update faster, and can be 30 frames per second or higher.*

So AFS meet the criterion I set in part 1, GRT are getting close. MGL & Dynon might be there, but might not as their systems are not deterministic.

Latency What is the latency (in milliseconds) from the air data or attitude sensor sensing a parameter to it being displayed to the pilot when the system is displaying its most complex PFD page(s)?

GRT	*Max latency is 65 mSec* (This is an excellent figure an will result in good system performance)
MGL	MGL enable each customer to create his own page from a library of elements so the latency is variable but "*typically 50 -100ms*". I would like to see a more deterministic system that protects its users from doing something daft, there are plenty of research papers that discuss the optimum display layouts.
AFS	*We read the airdata sensors at around 1khz and then run them through filters before they get drawn on the screen*. (As with BMA with high sample rates latency is unlikely to be an issue)
DA	*The total latency is about 150 ms, and includes the time it takes to sample the sensor, then recalculate all display parameters, then display the data to the pilot.* (This is too long, in my experience, and will result in the pilot experiencing a small amount of added workload to control the aeroplane)

GRT provides a good, low latency, system while AFS probably does also. Personally I don't like the sound of MGL's customer re-configurable system, but some of you may revel in that kind of opportunity. Dynon's system seems rather slow to me, but for a purely VFR application will probably be adequate.

System Design What precautions did you take with the software and hardware designs to ensure accurate and reliable data is always presented to the pilot?

- How do you ensure that unreliable or stale data is not displayed?
- Does your product feature any form of data integrity or reasonableness monitoring?

GRT	GRT uses some very sound techniques, similar to those used in airliner systems.
MGL	*Every data item tends to have a timeout (in case no new data is available) or has "reasonability" monitoring. It has to make sense.*
AFS	*Yes, we check all the data before we use it. The AHRS has a separate processor that is constantly running built in test software.*
DA	Dynon claim stale data is "impossible" in their system - I am often a bit of a skeptic when someone says something is 'impossible', especially when software is involved, but otherwise good**.**

Those companies using a separate AHRS with its own processor, such as AFS and GRT probably have the edge here. All companies run checks on the data provided by their sensors to ensure they have "good data".

Degraded Performance Are there provisions for useful, if degraded, performance if some feature of normal operations is no longer reliable?

- How obvious is it to the pilot that the system is in a degraded mode?

GRT	GRT believes they are particularly strong in offering robust performance in degraded modes. They have considered in detail the failure of each component of their system and provided back-up data sources where possible, in particular GPS failure does not affect AHRS performance. All failures are clearly annunciated to the pilot**.**
MGL	The MGL system does provide degraded performance, depending on the data item and the user settings. The warnings provided are also influenced by user settings, but my preference would be for a predictable warning to the pilot. I don't think warnings for degraded data, or the performance available, should be selectable or modified by the user.
AFS	The AFS warns the pilot if the BIT software detects an AHRS problem with a large red X and removes an engine readout if a sensor is bad but doesn't offer much in the way of degraded performance.
DA	Dynon clearly indicates degraded or error conditions, typically by screen color coding and text that describes the condition, but doesn't offer such good degraded performance as BMA or GRT **.**

"Graceful" degradation is a key capability that should be offered, such as GPS track information if the magnetometer fails. Such reversionary modes should be obvious to the pilot.

Sensor Performance Are there any manoeuvres that exceed the sensor/software ability to deduce true conditions?

- How does the pilot know those conditions have been exceeded?
- If the system exceeds its limits, how fast and under what conditions might the pilot expect the system to get stood up again?

GRT	Angular rates are limited to 200 deg/sec. When this is exceeded the attitude data is removed, the AHRS goes into in-air re-align. Within 2 minutes, attitude data is restored, there is no limitation on manoeuvring during this period, except to stay below 200 deg/sec. A solid approach, but 2 minutes is a little long.

MGL	The AHRS can become saturated, the horizon display will continue but change colour until the system can reacquire. Straight and level flight is needed for reacquisition, the time taken depends on the type of AHRS installed – it can be accelerated by using a "button push". Acceptable, but not as good as BMA or GRT
AFS	Once the AHRS is saturated the aircraft must remain steady in pitch and roll for 30-60 seconds. AFS also use a Kalman filter within the AHRS to assist in recovering the platform after saturation.
DA	*The EFIS units are limited to roll rates of 150 degrees per second. This condition is clearly annunciated on the display which a message that Horizon is Recovering, and [a change in colour]. Once conditions stabilize it takes about five (5) seconds for the attitude to self-recover, on its own, without any pilot intervention.*

A Kalman filter is an algorithm that takes inputs from more than one source and uses the characteristics of each source to build a mathematical model of what is really happening. One benefit is that if one source fails (such as the gyro becomes saturated) then the filter will still be able to figure out what is happening based on the model and other inputs. The down side is it takes a while to get the filter up to speed when everything is switched on, and takes some serious software development to make it work well. The platforms the recover quickly from the gyro being saturated, such as Dynon, may not have very sophisticated filters.

IMC/IFR? Do you recommend your system for flight in IMC/IFR conditions, what kind of back up instruments do you recommend?

GRT	*Yes, absolutely, because of the integrity of our AHRS. We recommend that customers that are flying IFR not use the latest software release until we have had sufficient experience with our customers, as our customer base averages more than 10,000 flight hours per month, providing us with excellent feedback as to the stability and functionality of our software.*
MGL	*Any system that is used in IMC requires independent backup. Note: This applies for mechanical "steam gauges" as well. Backup should include everything that you need to fly the aircraft safely. This depends highly on the type of aircraft and mission profile.* (This is a very sensible attitude to take)
AFS	*With proper training and backups yes, you need to have the instruments and training to fly the aircraft without the EFIS.*
DA	*Dynon instruments meet the qualifications for each of the analog instrument they replace. We recommend customers equip their aircraft such that any single point failure - including the failure of the EFIS, will not jeopardize the completion of any flight. Separate gauges or a second EFIS can provide this redundancy.* (Based on information on the behaviour of the Dynon system if the pitot becomes blocked (for example with ice) I am not so sure this system is suitable for IFR).

This point may not be relevant to many of you, but if you have an attitude indicator in front of you it really should tell the truth if you ever have to use it. I know that AFS and GRT systems are regularly used in the US by pilots flying IFR. I have not heard of Dynon or MGL systems being so commonly used.

Autopilot Functions If your product includes an autopilot functions have you partitioned the flight control and display handing software?

- Would it be possible for an error in the navigation or Glass Panel software to corrupt the autopilot functions?

GRT	*We provide an autopilot interface [and] interface to autopilots that include their own "attitude" source. The autopilot is required to provide envelope limiting (roll and*

	min/max speed). (I think this is a very sensible approach to take)
MGL	MGL uses an autopilot interface box to link the EFIS to the servos, this effectively providing the partitioning I was looking for, although the algorithms in the EFIS are the same as drive the display. The servos also provide some rate and range limiting.
AFS	*We use a separate autopilot controller with its own gyro & sensors.*
DA	*The Dynon Autopilot control logic is built into the EFIS system, the EFIS is the controller.* (No partitioning is evident)

Some background on this question may be helpful. To some the functions of a Glass Panel and an Autopilot are very similar, most aircraft manufacturers disagree (so do I, for what its worth). In professional aircraft design organisations the autopilot is usually the responsibility of the flight controls or aircraft stability & control department while the cockpit displays would be the responsibility of the avionic systems team. It would be very unusual for the two functions to be combined in the same box. With good reason, the task of an autopilot is to control the aircraft while a Glass Panel provides data to the pilot to control the aircraft (along with data from the back-up instruments). The autopilot algorithms would be expected to change only very rarely while avionic upgrades are more frequent. Corruption of the autopilot data can be very serious while that of the avionic data should less critical as it should be compared to the back-up data. Clearly most pilots would like their navigation system to be able to drive the autopilot; the safest method is for the navigation system to request the autopilot to fly a new heading or altitude rather than directly trying to control the aircraft. My strong preference is for the autopilot to be a separate box to the Glass Panel. If the two are combined the processing for the two functions should be separated to avoid any possibility of a failure in the avionics software taking out the autopilot. The two companies who include an autopilot with their glass panel, Dynon and MGL, make little attempt at partitioning, although the MGL external interface box may help. My opinion is that the AFS and GRT policy of close integration with autopilots from other makers is a far superior way to go.

Design Team Experience What kind of experience does your design team have of designing aircraft systems?

GRT	*Most of the engineers are very experienced in their area of expertise. The chief engineer, myself, spent his entire career in the aerospace business, including 10 years with Boeing and a supplier to Boeing (Smiths Industries).*
MGL	*Approximately 9 years from first instrument (Stratomaster Flight) and approximately 65 instruments to date with about 25 in development.*
AFS	*We have six full time engineers with extensive aerospace experience. We also do contract design work, we currently are working on a certified EFIS project for one of the largest avionics companies in the world.*
DA	*The Dynon engineering staff has sixteen people, with over 80 man-years of aircraft systems experience. Along with the Dynon Avionics suite of products, they engineered a line of remotely-piloted vehicles for a sister company.*

Some background again – as there are no standards set for un-certified glass panels, a design team with a long history of designing airborne systems is more likely to understand the particular needs of an aircraft system and specify a good design than one without. Clearly software engineering and electronics skills are required, but these must be integrated with a very good understanding of what makes an aeroplane fly to result in a useful glass panel.

Integration Testing How much testing of a new software release do you carry out before you release it to customers?

GRT	*Our testing is mostly targeted to the areas were development has occurred. Regression testing is also performed. Our software testing is very effective, but it is further*

	enhanced with the feedback we provide from our large customer base.
MGL	*Customers are included in the testing (beta releases). We maintain a public forum where anybody can have design influence on our instruments. In effect we are one step away from open source. The development of our panels never ends and is not intended to. We typically release new firmware (at no charge) every 2-3 weeks.* (There is always a great debate between getting the latest features to customers against making sure that everything works properly and nothing has been broken by the new enhancements. My preference would be for a more measured update rate, but some may appreciate the rapid turn-around. I wonder if a little more in-house testing would limit the number of updates that are required?)
AFS	*We have extensive test equipment and three aircraft that we use for flight testing. Most testing is done in our RV-4 and our RV-10, we routinely fly our RV-10 in actual IFR conditions. We have* [and test our system with] *a SL30, 480, 430W, 195, 295, 396, 496, GTX330, GTX327, Zaon, Avidyne TAS600, Dynon D10A, D100, GRT Horizon, and most if not all of the latest Bendix Kind radios.*
DA	*A thorough internal testing program [is used], and releases it to a select group of Beta testers for extensive flight testing. Typically the time between code complete and release is three or four months. Our reputation is that code is thoroughly tested and polished before our broad customer-base receives it for their aircraft.* Newsgroup evidence suggests that Dynon's software updates usually work, but when interfacing their system with external equipment, such as radios, some problems can be experienced.

Here we are taking about updates to the basic software that runs the glass panels, not the navigation data bases which are separate. Any testing is expensive and time consuming. There is always a temptation to issue new software to customers to provide the latest features, but this can be problematic if some of these 'beta' customers don't understand the state of development of the release – in that it may still contain a few bugs. In this context regression testing is carried out on a new software release to ensure that functions that previously worked have not been unraveled by any of the new changes. Testing costs any manufacturer a significant amount of time and money to do well, as the cost of these systems is less than certified units it is likely that the testing is less extensive. My preference would be for slower software updates that have been thoroughly tested, rather than faster but untested releases. I like the fact that AFS tests with several different radios and GPS/EFIS units.

After Sales Service What kind of in service support do you offer your customers?

GRT	*Typically phone support is all that is required. Our customers have access to our technicians, and engineers are also available if needed. The system is designed so that it is not damaged if it is wired incorrectly. We also provide support at the Oshkosh and Sun 'n Fun airshows*. (But less support available outside the US)
MGL	*This varies from country to country and distributor to distributor. Our systems are mostly intended for those who are willing and wanting to install their own systems and configure the systems to their own exacting needs (hence the very large flexibility built into our panels). This in effect means that these customers are their own support as they know their systems much better than anybody else (including us).* *As many of our instruments are starting to get used in factory made aircraft, the aircraft manufacturer becomes the configuration authority of the panels and thus becomes responsible for support - unless the customer decides to alter this configuration.*
AFS	*We have a support forum, email, and phone support*. (Once again less support available outside the US)
DA	*Dynon products are Warranted for a full three years. Because of the extensive calibration and test routines required to assure airworthiness, units being returned for*

	service are sent back to the US-based factory. (Support is US based, although I know that "Dynon Support" is active on several email bulletin boards and internet forums)

It is also worth considering the power of existing customers. All of these glass panels are complex systems, buying something that is popular will increase your chances of finding someone nearby who can help you solve your problem, and a local dealer can often help a lot.

Training Do you provide any ground based or airborne training to help your customers learn to get the most from your system?

GRT	*Yes. Demos can be played on the EFIS. User manual*
MGL	*No. This appears to be not necessary considering the target market we aim for. Our instruments are not suited for and are not intended to be used in traditional fashion where an instrument provides a fixed function platform. They are expressly not suited for pilots/owners who are not able to perform basic operations on a PC.*
AFS	*We have done ground training and some limited airborne training. We currently have an AOA training DVD and we are working on one for the EFIS.*
DA	*As with installation, Dynon offers live technical telephone and email support, as well as extensive printed installation manuals and other online resources such as a forums and "wikis". Additionally, due to our products' popularity in the experimental/homebuilt markets, it is often not hard to find other Dynon customers to learn from as well!* (Because of the market penetration and likelihood of support from other local users I think this area will not be a problem with Dynon equipment)

I was a little surprised that more training was not available. The DVD that will be available soon from AFS and the ability to play demos on GRT seem to me to be worthwhile.

History To account for an organisation's track record I have made some comments based on how I perceive their track record over the last few years. This is a little subjective, but I have been a very interested observer of the homebuilt/experimental Glass Panel industry for the last several years. One issue to bear in mind is that of a local dealer. Some of these companies have a UK dealer who will deal with any warranty claim. It might be more expensive to buy locally rather than from a discount house in the US, but do you want to be shipping your unit across the Atlantic or around the corner? I cannot offer any insight into the stability of these companies; they have all been around for a while and I hope they all remain in business for a good few years to come.

GRT	GRT have a very solid reputation for reliability from people who regularly fly IFR in the USA. They have recently introduced a double AHRS/ADC option to further increase the redundancy of their systems. To reduce the current draw of the screen and processor until recently their displays were not as high resolution as some, although apparently it was easy to get used to. The more recent models have taken advantage of display technology improvements to increase screen resolution without huge power requirements.
MGL	MGL are relatively new to the EFIS market although they have been making stand alone flight instruments for some time. They have taken the very unusual step of writing their own operating system and complier, time will tell if this is money well spent. Some of their design decisions strike me as unusual, such as the ability for the user to change many parameters and keypad on the panel display, but some of you may like that. Again I would talk to existing customers and also look at an un-installed system before buying.
AFS	AFS started with an engine monitor and have progressed into Glass Panels, acquiring an AoA manufacturer along the way. Their displays certainly look good with high

	definition screens providing a wide range of functionality. They also use an AHRS built by Crossbow who also make certified units. There appear to be very few stories on the internet newsgroups of any problems with AFS equipment, perhaps because of their extensive testing. They are very popular in the US and possibly out sell all the other brands put together, so there is no lack of users out there. The company is solid as it has contracts from outside the homebuilding/experimental market.
DA	Dynon have been around for some time and are probably the market leaders in terms of units shipped, perhaps because they are amongst the least expensive. Their switchology has been a little strange and I find some of their display formats a little odd. There are reports of unreliability, especially straight out of the box, but against that there are many satisfied buyers who are usually not heard from. The service from the factory is usually reported to be good from those who have had to return units.

I have presented an awful lot of information here. Most of it is based on what the manufacturers think of themselves as I have not been able to validate any of the responses. After reading this article I hope that you have some idea of the questions that you might like to ask the various suppliers. Any answers that might be glib or condescending would cause me to consider whether I wanted to enter into a relationship with a supplier that will last many years and which you will be locked into (but he will not).

If at all possible you should try to fly behind the Glass Panels on your short list before parting with any cash. Pre-flight, write out some manoeuvres and functions that you would like to try out and try the same things for each Glass Panel you fly behind to provide an objective comparison; try not to be sucked in by the pretty pictures! As with many things you get what you pay for. All these manufacturers write a large proportion of their own software and build their own hardware, so have largely the same costs. Lower prices come from specifying less good components, spending less time writing software or carrying out less testing.

If you will never have to rely on your Glass Panel to keep you safe – perhaps because you will only ever fly in good VMC and don't venture too far from home – then any of the products offered by any of these manufacturers will probably meet your needs. A straight comparison of features against cost may be all that you need to do. If you are a little more adventurous, particularly if you might find yourself inadvertently in limited VMC or even IMC, then your choice needs to be very much more centred on what lies behind the screen. If you would like to know which unit I would bolt into my panel you will have to ask me at a fly-in this summer or have a look at my panel in a few months time when I have had time to complete a panel upgrade.

In the next article I will look at some of the operational aspects of flying with your Glass Panel.