DESIGN STANDARDS
Their Evolution and Value

BY PAUL NOVACEK

Standards. We all deal with them even if we don't readily know it. A pilot instinctively pushes the throttle forward to increase power—that's a standard. An avionics technician mounts the artificial horizon gyro above the HSI—that's a standard. A bolt is turned to the right to tighten it—that's a standard. Standards are everywhere, but most have been around for so long that we just take them for granted. Did you ever notice that you can rent a car anywhere in the world and figure out how to operate the controls without much effort? Well, that's a set of standards at work. Without those long established standards, a Ford may have the gas pedal on the right and a Dodge may have the gas pedal on the left. That would be really fun around an airport rental car lot—like carnival bumper cars!

Design standards cover many facets of a component or procedure. As for avionics, the design of the inside as well as the outside of the box are regulated by standards. But every standard is created out of necessity and the anticipation to make life easier in the future. For a standard is ensuring that the future will be a predictable place.

In the avionics world there are two kinds of standards: construction and technique. A construction standard dictates the physical layout or method to design a product or software. A TSO (Technical Standard Order) is an example of a construction standard and describes the construction and testing requirements needed for FAA approval. The FAA Advisory Circular 43-13 is a design standard but more importantly, it's a technique standard that technicians adhere to when repairing aircraft. In both cases, the standards were thoroughly developed and approved by representatives from interested parties.

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The evolution of a standard is a long and often drawn-out process often begun by the pioneers in our industry. It all begins with a new idea; either a new method to accomplish a task, or new technology. Usually a company or research institute devises a new product that progresses to a point that other people catch on to the new idea and begin a development program of their own. If these companies are open and forthcoming with their ideas, the government steps in and rightfully so gets all the parties together in a committee to devise a standard.

This committee usually consists of members from industry, research institutions (NASA, FAAand universities) and regulatory arenas. The issues are worked out and a set of standards are born. Many times the FAA contracts out the writing of these standards to private institutions such as the Radio Technical Commission for Aeronautics (RTCA), Society of Automotive Engineers (SAE), Aeronautical Radio Incorporated (ARINC) and on an international scale the International Civil Aeronautical Organization (ICAO).

A set of standards is not written by a few engineers huddled in Washington, D.C. cubicles, but a broad spectrum of people—engineers from avionics manufacturers, researchers from universities and government institutions, user groups, trade organizations and government regulatory offices. All the interested parties attend meetings to work out issues and develop standards that everybody can live with. This lengthy process takes time though. Often the technology needs to catch-up with the needs of the committee before specific standards are written. Additionally, the committee members are not dedicated to this process on a full-time basis, but rather when time allows away from their primary duties in their organizations. Therefore, the process of developing standards seems to take a long time, but it's rather a case of waiting for the technology to catch-up and getting all the interested parties to agree.

Let's use TCAS as an example—a true triumph of standardization. Back in the '70s when TCAS started to evolve in the FAA research labs, a CRT display was used to depict traffic around the host airplane. Since these systems needed to negotiate escape maneuvers between opposing aircraft, all the systems made by different manufacturers needed to work together. Therefore, a standard was born that described in great detail the software requirements. This software and hardware standard (RTCA DO-185A) was then published so avionics manufacturers from across the globe would use the same reference document. The international community adopted these standards for TCAS (ACAS in Europe) and it is now mandated for most of Europe and other countries such as Japan and Australia.

Not only is the TCAS software standardized, but the display symbology is standard also. Many symbols were tried and due to necessity, the developers of TCAS knew that a standard set of symbols would be crucial. Imagine what would happen if a pilot flew an aircraft with an MFD that depicts non-threat traffic as a circle, and then the next day hop in another aircraft where that same symbol depicts an impending mid-air collision. A pilot seeing a circle would not treat it with the importance it deserves and something terrible may result. This condition is called "negative training transfer," where previously learned knowledge or techniques are applied incorrectly in the new environment. The diamonds, circles and squares seen on EFIS and MFD displays are standardized so a pilot that flies many different types of avionics knows exactly what the symbology means.

Some design standards develop without much forethought as to any future problems. For instance, an early aircraft designer was baffled by say the placement of a control lever and looked over to his competition. "Hey, how are the Boeing guys doing this?" After seeing how others were doing it, the designer adopted the same technique. And viola, a standard is born. Often these standards get so ingrained that changing them would be disastrous.

For example, let's look at the use of an "inside-out" presentation of an artificial horizon instrument. Way back in the early '30s, Laurence Sperry and James Doolittle devised a way to display the movement of the airplane against the rigid representation of the horizon. This gyro instrument is commonly called the Artificial Horizon. Due to mechanical limitations of the early gyro gimbals, the easiest presentation was to keep the airplane symbol fixed in place to the instrument and move the background in response to a rolling or pitching movement. Hence, the instrument mimicked looking through a tube mounted on the glareshield and pointing forward. This display technique was called the "inside-out" presentation, and we still use this presentation to this day.

But, there are problems with this "inside-out" presentation. The moving part of the instrument, the background, moves in opposition to the airplane. When the aircraft rolls right, the instrument rolls left and when the aircraft pitches up, the instrument moves down. In numerous research studies on the subject since the 1940s, this movement reversal has been found to be confusing, especially to pilots with rusty or fledgling instrument scanning skills. Few people want to admit it, but this "inside-out" presentation has contributed to many fatal accidents. As an instrument flight instructor, I've seen first hand pilots turning the wrong way when trying to recover from an attitude upset.

The research studies have found that an "outside-in" presentation produces much less confusion and spatial disorientation. An "outside-in" presentation shows the horizon line fixed with respect to the instrument face and moves the little airplane in response to roll and pitch movements. When the aircraft rolls right, the little airplane in the instrument rolls right. Just as if you were looking at the airplane from behind. In fact, Soviet aircraft have used this presentation successfully for decades. But, since we have been using the "inside-out" presentation technique since the 1930s, everybody is used to it and changing it would cause havoc, even if it does lend itself to accidents. This is a classic case of an ingrained standard that we must just live with.

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Just to confuse things further, have you noticed that the Turn Coordinator

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instrument is an "outside-in" presentation? So, on a typical instrument panel are two instruments that provide similar information but move in opposite directions to each other. Go figure!

Not following an existing standard often leads to tremendous problems, especially with the human interface. Human Factors design standards cover issues such as label placement, instrument sizes, switch configurations, menu structures, color coding and many more issues. A common misconception from a design engineer is that, "…well, I'm a human, and I designed it so I can use it, so therefore, the human was considered in the design." Nothing could be further from good design practices.

The discipline of Human Factors design is not new. It was first created during WWII in response to the many different cockpits entering service. Every airplane model had similar functioning controls or instruments in different places. A technique used in one airplane did not work in another airplane. There needed to be some cockpit standardization across aircraft types.

A good example is the standardized layout and feel of engine control levers in multi-engine airplanes. There were many cases where a pilot reached for what he thought were the throttles and grabbed the prop levers instead. You can imagine the result. Therefore, Human Factors design standards were adopted that called for the throttle handles to be smooth and round, the prop handles to mimic a crown, the mixture control handles to be bumpy knobs and so forth. This simple design standard is still in use today and a pilot will have no doubt as to the function of a control lever with a smooth round handle.

One of the marketing mantras over the years, "Designed by pilots for pilots," usually runs shivers down the spine of a Human Factors specialist. Pilots who have followed the traditional training techniques are creatures of habit. It's not their fault, that's just how they were trained. Countless research studies have found that what pilots perceive as their preference does not mirror their best performance. There are many reasons for this effect, but it really boils down to how we as humans are more comfortable with the familiar. Take the example again of the artificial horizon instrument. Given all factors equal, a typical pilot will perform better (fewer errors and lower workload) with the "outside-in" presentation, but still prefer the "inside-out" instrument because it's more familiar and it's the instrument used throughout their training.

So, asking a pilot to design an avionics interface may be asking for more of the familiar archaic ways and not of design based on hard research. Don't get me wrong, pilots make great evaluators of human interface designs and should always be inside the design loop, but unless they are exposed to the science of the human interface, their input should be limited.

Even if a box has been certified by the FAA, it doesn't mean that good Human Factors design standards were applied. A recently approved WAAS GPS receiver was actually certified that greatly diverted from established and published Human Factors design guidelines. Although highly capable, the human interface was contradictory to existing guidelines and the inevitable confusion resulted. Especially with pilots familiar with a more standardized control philosophy. Thankfully, we as humans are good at adapting to the unfamiliar and extensive training is usually used to close the gap.

This is where published standards come to the rescue. By implementing accepted standards, much of the guesswork is eliminated. The Human Factors science and research has already been considered when writing these design standards, and if every avionics/cockpit designer followed the standards, there's no doubt that the accident rate will be reduced.

So, where do you find these "Standards"? There are many sources, often as close as your local technical library or Internet. Design standards are published by many groups including SAE, RTCA, ARINC, ICAO, FAA and the U.S. military. They often go into excruciating detail though and gleaning useful and specific information is often a lengthy process. The non-government groups also charge for their publications. But there is hope. Previous issues of *Avionics News* have contained articles on specific design subjects such as knob placement and placard use, but a complete guide is available for free.

The FAA publishes an excellent Human Factors Design Standard document, which is the same document that the FAA personnel consult when approving a design for certification. These set of standards compile much of the military and industry group research into a convenient, one-stop package. Many of the past Human Factors articles in previous issues of *Avionics News* were based in part on this document. The free Design Standard document is available from the FAA as downloadable files from the Internet at this address: www.hf.faa.gov/Portal/ShowProduct.aspx?ProductID=69

Without the evolution of standards, we may still control some airplanes with our hips like the Wright Brothers. So, give standards some respect and when in doubt, look it up or ask. Design standards were created with a lot of hard work and for good reasons, so let's seek out those design standards and abide by them. Lest we create confusion. ❑