THE USER-HOSTILE INTERFACE

BY WALTER SHAWLEE 2

Recently, while enjoying some sushi with a friend, we were talking about how systems work from the user's viewpoint. Maybe you talk about women, football and fast cars, but we both have deep technical and philosophical backgrounds, so we talk about world fiscal trends, technology and the great test gear we scored on eBay.

Eavesdroppers are no doubt utterly mystified by our discussions. My friend looks after the radio and computer networking gear for all the law enforcement in our city, and he is pretty much one of the smartest people I know.

During our recent conversation, he made a comment that really made me stop and think. He said neither he nor the pilot could figure out how to run the GPS/com radio installed in one of their helicopters. While they've had it for about three years, it has been used only in the most basic way.

The pilot has 20-plus years flight experience and my friend has about the same years of experience in electronics and communications, yet neither of them could make the radio do something simple the pilot wanted to do — and which the radio supposedly could do easily. They had to dig out the manual, and both spent an hour in the cockpit before they got it to work. Not really the perfect situation in a high-stress flight environment, but it illustrates one of the biggest problems lurking in our industry.

Having warmed to the subject and knowing how many years I have spent in the avionics world, he then went on to flambé me for another 15 minutes about all the other radio gear in this aircraft that was just as bad. In fact, they had less operational functionality than they had previously, and it was much harder for the pilots to use. I am happy to report I designed none of what he was unhappy with (and thus am fortunately blameless in this one, single case), but I couldn't help sympathizing with every word he spoke.

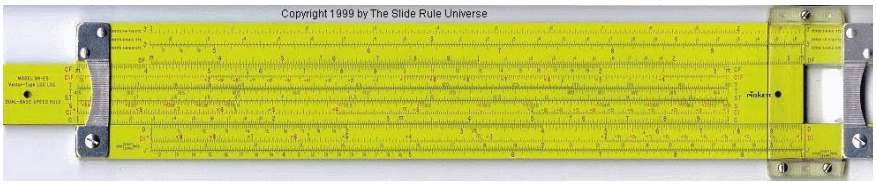
Illustration by Larry Stewart

The general state of all electronics interfaces today can best be described as ghastly, bordering on dysfunctional.

It All Started With the Slide Rule

How did we get to this unhappy spot? Actually, it was inevitable, because we produce engineers with literally zero background in the arts, human factors, philosophy, psychology or sociology. Then, we turn them loose woefully ill-equipped to make all the things we require in everyday life, from mops to cell phones, and they are mainly failures — perhaps not from a sales perspective, but at least from the user's viewpoint.

This trend started appearing publicly back in the early 1960s — even before



Pickett N4ES, courtesy of the Slide Rule Universe

The Pickett slide rule

electronics was all-pervasive — at a company called Pickett, which made slide rules. It was suggested to the company that rather than use arcane and cryptic slide rule scale names like A, C, K and CIF, they should use X^2, X, X^3 and 1/piX on the rule body, which people could at least puzzle out and, from there, grasp intuitively how the rule worked. A high school student also designed and offered them a brilliant multi-decade scale that solved the problem of "placing the decimal point" and allowed a gigantic dynamic range of 20 decades, perfect for electronics and engineering.

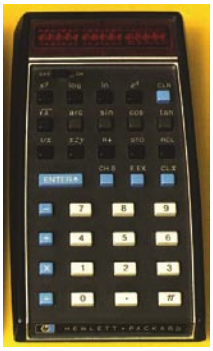
The reply from the company president at the time was anybody smart enough to use a slide rule could figure it out without those things; therefore, it all was unnecessary.

European and Asian makers went on to extensively mark their rules to be "self-documenting," but American makers resisted, with few exceptions, right up until the very end, when the debut of the HP-35 calculator made slide rules a memory in 1972. Most people couldn't wait to get something "easier to use."

Interestingly, many slide rules languish today in drawers because nobody can figure out how to operate them (so I guess it wasn't really that obvious), although they are painfully simple. (If you happen to need to know this information, visit these web pages: www.sphere.bc.ca/test/howto.html and www.sphere.bc.ca/test/2learning.html.)

The Genius of the Calculator

Ahh, the calculator. While many makers, such as Wang and Freiden, already made easy-to-use (but expensive) 30-pound desktop models with normal looking keys, such as x, +, - and =, Hewlett Packard leapt into the market with a tiny and miraculous hand-held, pocket-sized HP-35 and altered modern history.



HP-35, courtesy of Museum of HP Calculators

It is hard to truly appreciate the genius of this landmark design, but it is literally the birthplace of modern microprocessor applications and the first truly personal computer.

There was just one tiny flaw in it, which Michael S. Malone, author of "Bill & Dave: How Hewlett and Packard Built the World's Greatest Company," described this way: "It was as if Alexander Graham Bell had invented the telephone, and then demanded that people only speak Hittite when they used it." Thus, in one swift stroke, the user-hostile interface was fully entrenched.

The HP-35 used RPN, or reverse polish notation, to enter commands — a technique known and understood by no one — and which had no "=" key. In a further assault on intelligibility, pressing the arc key would invert trig functions as a kind of hidden shift key. To add to the nightmare, later models would add both dedicated function and multi-colored shift keys to change functions to get more use out of every single key switch. It was at this moment the biggest engineering mistake perhaps in human history would emerge: It doesn't matter if people understand it or it's obvious, they will just learn to use it.

But most people didn't learn to use it; the HP calculators were a big hit in the engineering world (which should have set off alarm bells everywhere), but largely impenetrable to everyone else. HP sold nearly 10,000 a month right out of the gate (10 times HP's own estimate), but Texas Instruments and the Japanese, Taiwanese and Chinese would go on to sell hundreds of millions of calculators with normal keystrokes and an equal key — and RPN eventually would disappear.

Unfortunately, the damage already was done. The pattern of the cryptic and hard-to-figure-out tool (where proof of understanding was your techno-merit badge, just like Unix) was now set in the minds of engineers, and they would fall back on this exact lesson endlessly through the software and computer age. Let's face it, just what was the person thinking when he decided we should all click on a screen icon marked "Start" to shut down a computer?

Don't Forget the End-User

The concept of pushing a badly flawed but "technically better" design would prove to be the pattern for decades of development, generating a great deal of commerce but very little user happiness. It's no wonder people sometimes go berserk over the simplest things from Apple because it at least has devoted some significant energy to ease of use, actual utility and beauty in design. There's clearly no RPN spoken there.

What actually makes a good design or product? To answer this, I refer you to a wonderful book called "The Psychology of Everyday Things," which was later re-titled "The Design of Everyday Things," by Donald A. Norman. His understanding of the design process is so profound I think you owe it to yourself to read this book rather than take any edited summary from me. I used to give copies of this book to all the designers and engineers at NAT so they could truly understand there is a way of thinking about design that includes the end-users and what they want to do as critical elements.

As I put on the wall in R&D: "A good design should delight the customer, and depress the competition." I still believe this simple rule is the foundation of all good product development.

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At the end of the day, it's always the work that is important, never the tool. Toolmakers keep trying to change this situation by insisting you learn their arcane, tribal voodoo technique to do the simplest things; but really it's a huge misallocation of energy and resources. The work, the function you need to do, is everything.

We are in a bad state when the frustration with everyday items has become all-pervasive, and we seem unable to devote any energy to making good products but only to making new ones. I can't ever remember any problems with my old touch-tone phone (or a dial one either), but I can barely understand most people talking on a cell phone. The cliché of the cell phone not working when it's important is now so common we just take the problems for granted. It's a good thing you now can download music on them because they seem somewhat ineffective as actual phones.

Facing These Problems in the Cockpit

It's interesting to trace back these problems and see how they crept into everyday life, but it's really not so wonderful to face them in the cockpit. Here's where things get serious in a big hurry. Many modern and not-so-modern avionics products casually started out on the wrong path, then made a permanent home there.

Oddly, the first missteps were colors. We all accept, and the FAA likes to insist, on certain colors for certain tasks. Red is a warning; amber is a caution; green indicates normal operating condition; and blue or white for messages.

Yet, general aviation com radios used amber gas discharge displays for frequency displays, and FM tactical radio controls used red LED displays. Transmit condition was indicated by a green light, yet that is a caution. Receive was indicated by an amber light, yet that is a normal state.

The mixed messages were considerable and the rationale was varied, but it usually had something to do with the choices being "technically better." Hmm, sounds familiar.

Need some color assistance? See the NASA AMES color reference at http://colorusage.arc.nasa.gov/cockpit_1.php.

As cockpit devices became more complex, displays and panels were loaded with more data and legends, often abbreviated because of technical or space issues. Thus, the pilot's world suddenly became laced with ICS, VOL, LVL, XTRK, SCN, SQ, TX, MN, CTCSS, GD, TRK and BRG. Not only were these terms often unfamiliar to pilots when fully spelled out, but also were incomprehensible when the vowels were removed. Sadly, no magic decoder rings were issued to flight crews.

Radio systems shifted from just required AM com radios and nav aids to FM tactical radios, GPS, MLS, TCAS, electronic flight bags and a host of other complex items to make the pilot "safer," more efficient and better equipped to deal with his flight tasks. Each had its own design and appearance, as well as its special tricks to make it operate, a huge memory and operating problem for the user.

Regrettably, no radio training for flight crews ever materialized along with these items. The extent of available learning materials generally was a short "operator's guide," which promptly disappeared on delivery, and some cryptic information added to the flight manual supplement, which often failed to completely explain the system and addressed only FAA flight safety issues.

Because cockpit panel space is small, the multi-tasking of controls has set in with a vengeance; therefore, there is no body memory a pilot can employ that says, "I always turn this to select the frequency." Today, one control enters all kinds of data, depending on the mode of the unit, defeating a power memory tool for instinctive operation. Many functions are conducted by key-press operations with legends changing constantly.

As a result, the pilot has to watch carefully what he is doing, rather than just flip a familiar switch to activate some operation. And, of course, every unit in the panel has a different "obvious" technique, so running the entire avionics panel is now a virtual Mensa entrance exam.

How are pilots expected to truly learn this equipment? What about fleet operations, where many pilots have to use different machines and different systems on a regular basis? And, more correctly, why should a two-inch thick manual even be required to run a radio? How can it be that a computer and display is stuffed into the panel, but no thought is given to having the equipment teach the user directly with help and tour functions?

Well, it appears the old Pickett attitude of "anybody smart enough to use it can figure it out" is still with us.

Norman discusses this problem in detail in his book with his concept of "knowledge in the head," which explains many objects simply cannot be operated without extensive preparation and study because the design is so badly flawed it does not lead the user to do the right thing. Thus, our endless mistakes, accidents and "no fault found" service occurrences swiftly generated in the cockpit to the distress of everyone.

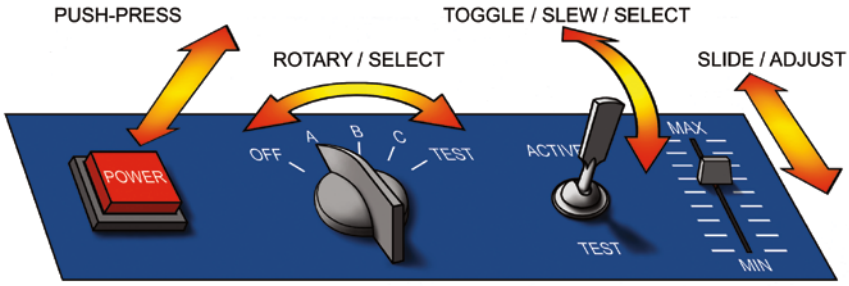
Now, enter graphical GPS and a host of new adjunct navigation services, including digital pictorial navigation with terrain, ADS-B, WAAS and all kinds of flight planning tools. The problem here is, many of these systems are really computer-based

products sitting in a cockpit container.

The software-driven computer workspace has its deep flaws, from nested menus to counter-intuitive operations, and generally relies on significant graphical user interaction with a mouse or other device to navigate functions and make selections, something not really possible in the cockpit — unless we plan to add a small card table there for the mouse.

What kinds of control operations are really possible for a pilot? If we are talking about a helicopter pilot, the answer is frequently none, as both hands are always busy. If we are discussing a fixed-wing (non-military) pilot, he usually can free up one hand and look to the side to see the radio gear. He can push something, if it's large and not too close to something else (although not reliably, as turbulence and vibration can make single key-press operations erratic), and he can turn something, which can be a potentiometer or a rotary switch/encoder. The pilot also can move the position of a toggle or lever through two or three positions, or push a slider or linear control. Don't forget, this all has to work in flight with gloves on, too.

All cockpit interfaces come down to just these four basic movements (a few devious designers have single controls you can both turn and push for added confusion) and all system results flow from them.



TYPES OF CONTROL MOTION

Illustration by Larry Stewart

Many equipment makers largely ignore the bigger issue of how the pilot is actually going to perform this movement, or whether or not he has enough time and attention to do whatever is required. Pilots simply do not have two free hands and unlimited time and attention to operate any radio device, no matter how critical.

Several years ago, I was at a trade show and a new GPS/com box was on display for people to try out. Being a confirmed equipment fan, I had to try it out for myself. It looked nice, but no one standing there could make it work and, several times, we got the unit locked up and had to power it down to escape from strange situations where we couldn't make it function any further. I happily deferred to some senior pilots (because this unit was making me look like a total idiot) who also could not make it run. After about 20 frustrating minutes, the entire group left to be replaced by another group who also had trouble.

This is a major storm warning. No person I have ever spoken with has said they like nested drop-down menus and tedious step interfaces to do what they see as the obvious thing. It is usually creeping "featurism" that brings on this visual control clutter.

Most people use only a small subset of functions for any product, from a cell phone and microwave to a laptop and nav aid, and for them, the rest is actually a problem — kind of an intellectual field of land mines through which they have to navigate to do simple but important tasks And, as they forget how things work, they use a progressively smaller group of functions.

It is important to understand these design errors translate into huge support costs over the life of avionics systems, consuming thousands of man-hours in chasing and troubleshooting non-existent problems. They also trigger many operational problems, some very serious, such as when communications or navigation simply do not function as

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Control Motion Summary

Motion:	Push/Press	Rotate	Toggle	Slide
Best For:	Simple momentary or latching function.	Source/data selection or level adjustment.	Important single function or selection.	Level adjustment.
Problems:	Vibration can cause multiple entry on momentary switches even if de-bounced. Momentary selection switches very hard to operate blind.	Expensive, often have to pass through unwanted steps. Knobs often are too small for a good grip or proper resolution.	Hard to move or select if tightly spaced	Hard to seal unless lever is operated, which is expensive.
Key Features:	Momentary switches are inexpensive.	Positive feel; easy to operate without looking.	Positive feel; easy to operate without looking.	Easy to operate without looking.

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needed in critical situations.

These costs and loss of functionality are not trivial, plus they inevitably lead to a loss of confidence in the support service and equipment itself. As we move into a deeper reliance on complex systems for flow control and safe flight, the stakes for good design get much higher and more important.

I spent many years running avionics services for fleet operators, and there are a few things I can share with you that might prove useful. First, most pilots will never admit they have made a mistake with a radio; it always "didn't work."

Second, pilots often will say they understand something when they do not. This is reality; so you need to adapt your support strategy around this reality. Pilots prefer to study and experiment in private, and the best thing you can do is to give them truly useful (and highly visual) operating information, as well as a way to run the gear by themselves to let them reach their own understanding.

Finally, all the things and terms we take for granted, from modulation to sideband, mean nothing to pilots. We might as well be speaking Urdu to them. They are not technicians and they do not pretend to be; yet we continue to treat them and speak to them as if they were.

Many years ago, I realized these operational problems would not just go away, so I wrote a small booklet called "The FM Radio Guide," which was meant to explain to customers the underlying concepts behind the complicated world of tactical radio. We gave away thousands of copies to anyone who wanted one. No doubt, many went to users of other radio gear, but that was OK; I liked the irony.

The guide had two important results: It greatly reduced our nuisance system problems from users and it made them feel more confident about what they were doing, which improved their experience and happiness with our gear. Mind you, almost 20 years ago, we already had put a "Help" button on our control systems and had the units wake up asking if the user wanted a tour of the operation. If we could do it then with a simple text display, it certainly can be done today on almost any system. Those control systems even had "context-sensitive help" for all the detailed data entries.

Design is an art; engineering is a science. Good product development requires both — and in the right sequence. Design is the operational concept and the interaction with the user; engineering is calculating the size of the required heatsink and laying out the circuit boards.

These are very different fields of study, and only rarely can people do both well. The product has to move back and forth between these two disciplines until a workable system emerges.

Design problems creep in mainly because of an elemental error in who should steer the primary design concept. The avionics world is cluttered with engineering people with flight experience, and they inevitably drive the process with a technology focus. However, these people often know too much about the systems and are unable to understand the problems new users will encounter in learning or operating the system.

Customers and willing co-workers who do not really understand all the concepts are the ideal source of test guidance and, if that fails, I suggest using your receptionist. If he or she can't figure it out, it is almost certainly doomed in the real world of users. From personal experience I can verify this final test actually works very well. When someone who never has seen it before can just sit down and make it work, you have the right recipe.

To really improve design, here are some simple strategies:

- Be certain colors are appropriate and legends are fully understandable.
- Never abbreviate unless it is impossible to do otherwise, and be certain the word you use is really the correct one.
- If possible, remove any high-use function out to the collective or yoke so it is not necessary for the pilot to let go of everything to run the system.
- Make the system serve as its own manual so any user can figure it out without a manual.
- Make functions clear, obvious and easily understood.
- Data entry should be clean and simple without any multiple operation steps.
- If you absolutely must add a host of secondary functions, make it possible to shut them off or for them to disappear from sight when not wanted.
- Consider a layered approach to operation, with high-use operations on top and strong physical mapping to controls.
- Watch out for pushbutton inputs; these are hard to carry out in flight.
- If the control is a selector, consider rotary encoders and a feedback beep for stepping through operations.
- When writing the manual for a system, explain everything clearly, including the underlying science — and be generous with illustrations.
- Let others who do not know the system try to run it, and don't let the design escape into the world until they can do it with no prompting from you.

We always can do better; our challenge is not to become lost in the technology and forget that functionality comes first. It's only the user who defines what is satisfactory. ❑

If you have comments or questions about this article, send e-mails to avionicsnews@aea.net.