DESIGN DISPLAYS
For Better Pilot Reaction

BY PAUL NOVACEK

In an analog, or "steam gauge" cockpit, flight and system information is constantly presented to the pilot. Very little information is needed to be accessed by the pilot—everything is right in front. Although sometimes this required a third crew member, there was a sense of being in greater control of the aircraft. Data was presented to the pilot which was then gathered and interpreted into valuable information. So, in essence, the pilot "pulled" data from the instruments.

In the current generation of instrumentation, data (and sometimes information) is "pushed" onto the crew. Unfortunately, sometimes not enough, or misleading, information was "given" to the pilots. NASA's Aviation Safety Reporting System found that 70 percent of all the incident reports cited "information transfer" as a leading cause.

The nature of the data that is pushed onto the flight crew is determined by the cockpit designers with help from knowledgeable pilots. Therefore, we as designers are assuming what the pilots need to know and when they need to know it. Pilots are becoming "system monitors," which we humans don't do very well. Many studies highlight this phenomenon. If flight decks are going to be "human-centered," the pilots' strengths and limitations need to be addressed, both to provide the pilots with pertinent information while automating mundane tasks. This causes a few problems that need to be addressed.

A balance needs to be achieved between too little information and too much information. There needs to be just enough information available to allow the pilots to make sound judgments, but not too much information that it taxes the capacity to absorb and process that information.

First is the issue of the "pure condition" of the aircraft. If the crew does not have access to conditions on a continuous basis, there is an inherent trust that the designers are assuming that the pilots will give to the aircraft. Sometimes, a pilot may not give that trust to the aircraft, so a pilot may want to see all the information and then make the judgment from the data that is pulled from the instruments. For example, if a pushbutton switch position is not apparent, there may be some confusion as to the condition of the system. The pilot would be required to remember, from previous training, what the dark position of the switch indicates.

Quiet/Dark Philosophy

The quiet/dark design philosophy states that information is not displayed until something goes wrong. A screen or annunciator stays black until a system condition warrants notifying the pilot. Much of the typical cockpit already adheres to this philosophy. An annunciator panel light stays dark until the pilot needs to be notified of an abnormal condition.

A Citation annunciator panel in the dark, indicating a "normal" condition.

A Citation annunciator panel indicating the "non-normal" conditions for various systems.

A simple example is a warning annunciator that only illuminates during a failure condition. The annunciator is dark when everything is normal and then when the un-normal condition exists, lets the pilot know the problem. Sounds simple, huh. But, then what do you call normal? Philosophers have argued about what is normal for thousands of years and if you ask five people what is normal, you'll probably get five different answers. Luckily, in the technical world of designing a cockpit, we can pretty much agree on what is reasonably normal. So then the question becomes, normal during what phase of flight? High turbine temperatures may be normal during start-up, but not normal during cruise. So the indication system must accommodate different phases of flight.

According to this quiet/dark philosophy, if a pilot scans the instrument panel and sees that all the annunciators are dark, the assumption is that everything is OK. This may seem obvious for a typical annunciator light, such as a red light for low oil pressure, but when applied to avionics, there's not a clear cut method to apply.

Then there's the question of an indication that is normal for the conditions, but must still command a high level of alertness. For instance a GPS waypoint alert: It's perfectly normal to receive an alert when approaching a navigation fix, but it's still vital information that must not go unheeded.

Instruments of the Engine Indicating & Crew Advisory System, or EICAS, use the quiet/dark principle. They only display the information needed for the current task. For instance, during start-up the EICAS display only presents engine information that is needed for the start-up task. During other times, such as cruise, it presents more information that must be monitored.

Another example of the quiet/dark

The Boeing 767 EICAS display, showing only the engine parameters needed for the current flight phase. All unrelated scale numerals are removed to increase clarity.

philosophy that has been used to very good success are the Flight Director/Autopilot annunciations on the PFD. Only the modes selected are annunciated. This may seem obvious, but the careful design of these instruments adheres to a common design philosophy that should be carried throughout the cockpit.

Switch Positions

This quiet/dark philosophy not only applies to system annunciations, but also switch positions. Many attempts have been tried with varying degrees of success. It's most difficult with lighted pushbutton switches that need an annunciator to convey the status of the switch position or system status.

Let's take the quiet/dark cockpit issues one at a time. An absence of an annunciation for a "normal" condition could denote either OFF, ON or AUTO.

This philosophy leads the pilot to assume a certain amount of trust that the system has not failed. Additionally, if there is not an annunciation of the "normal" switch position, the lamp or LED could be burned-out. Short of testing all the lights, the pilot does not really know the status of the system. The pilot is unaware if the system is continuously-ON or even intermittently-ON. Although this could be trained into the pilot or a synoptic page could be queried, this would be a Band-Aid on a problem that could easily be rectified with proper and complete switch annunciation.

Legend switches have many distinct advantages. Because of the nature of the lighted legend either in the switch or adjacent to the switch, the controlled system can provide feedback to the switch itself, instead of relying on warning light or instrument indications. Unfortunately, many installations use the light to indicate the switch position, requiring the pilot to discern the state of the system by other panel indications. To aid in the proper feedback, the light in the legend switch should indicate the acknowledgement that the system is responding to the action, not just switch position. Many problems have been encountered where an indicator light falsely notified the pilot that a system responded correctly, when in fact it did not.

For instance, when a panel switch is used to activate multiple relays (nav indicator switching), the indicator light circuit should pass through a single contact in each relay. Therefore, if four relays are controlled by one switch, and a single relay does not close, the indicator light does not illuminate. Thus the pilot knows that a failure has occurred and needs to act accordingly.

Indicator Colors

Colors play an important role in the quiet/dark philosophy. An indication can be "quiet" by just assuming a non-important color. There are five colors available for use in alert systems: red, amber, green, cyan and white. The colors used in a cockpit are carefully controlled and adhere to an industry standard, which goes a long way in helping pilots. Although, many cockpit and display designers don't adhere to the industry standards, and lead pilots astray with a conflicting use of colors.

A red annunciator light or display indication is a warning and used strict-

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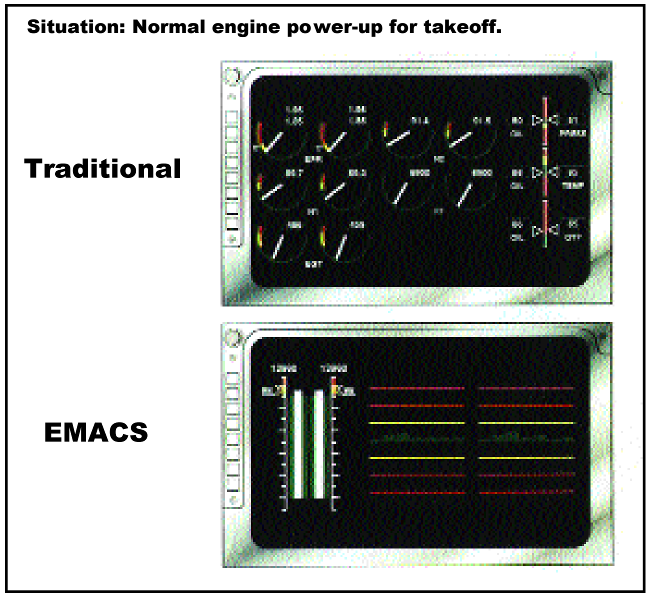

FIGURE 1
Displays of normal engine power-up for takeoff; top-traditional display, bottom-Engine Monitoring and Control System (EMACS) display, designed for easy reading. Courtesy NASA.

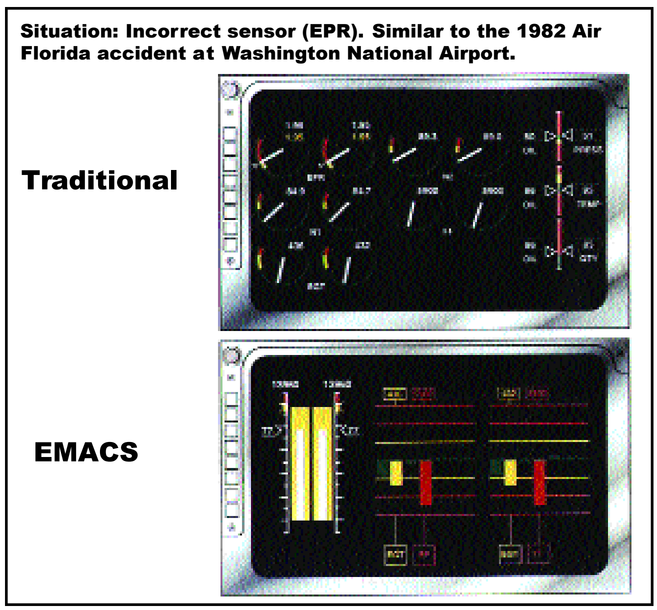

FIGURE 2
Displays of incorrect sensor readings during engine power-up for takeoff, similar to that experienced during the 1982 Air Florida accident at Washington National Airport. Note the visual superiority of EMACS to warn flight crews of hazard. Courtesy NASA.

DESIGN DISPLAYS

Continued from page 45

ly for an emergency condition that must be addressed immediately. A warning alert is always associated with an emergency checklist item that must be committed to memory. The use of a red annunciation is highly regulated and FAA AC 25-11 states: A "Warning" should be generated when immediate recognition and corrective or compensatory action is required.

An amber annunciation is cautionary, and needs to be addressed but not right away. An amber alert may involve a checklist item or can be just a very high-level information message. Again, when certifying an aircraft, the FAA is adamant about the use of an amber caution message. FAA AC 25-11 states: A Caution should be generated when immediate crew awareness is required and subsequent crew action will be required.

An amber alert does not imply an immediate impact on safety, but there may be possible aircraft damage or personal injury if an action is not taken. Operational procedures will possibly need to be modified to complete the flight, and the pilot will need to refer to the Flight Manual when a caution message is displayed.

Think of it this way: if a red annunciation is not addressed, people may die. If an amber annunciation is not addressed, the aircraft may be damaged. As for designing annunciators for avionics, be extra careful when considering the use of a red or amber light.

The three remaining colors, green, cyan and white, are basically just informational and don't have any strict guidelines in their use. Of course, green generally indicates a "good" or "safe" condition but it must be balanced with another color. You cannot have two switch positions that annunciate green for either position. White or amber is typically used opposite green for system condition annunciation.

Industry guidelines generally accept that the color cyan (blue-green) be used for "automated reversions." The FAA AC 25-11 recommends that a cyan message should be generated when crew awareness is required and subsequent crew action may be required. Generally a minor aircraft failure/malfunction that leads to a loss of redundancy, automatic reversion or degradation of a system.

A white annunciation is generally used as a "status" indication of a pilot-initiated action and used for information only. For example, the switching of fuel tanks or Comm transmitters. Unfortunately, this white annunciation may blend in with the panel label illumination of a blue-white color, reducing the contrast that color provides.

Other Quiet/Dark Issues

Another issue of information pushing is the human characteristic called accommodation—the effect of ignoring recurrent situations. If the pilot is used to seeing a dark switch to indicate a normal condition, that same dark switch could also be failed. This confirmation bias, seeing what is expected, leads a pilot into a false sense of security. Unfortunately, as cockpit designers, there's not much we can do about this problem.

Fatigue is also a major issue with long haul operations, and the quiet/dark philosophy is promoting complacency even further by saying, "We'll let you know if anything is wrong." One of the tools that pilots use to keep awake (besides caffeine) is constantly checking switches to verify positions. This keeps the pilot in-the-loop as to the condition of the aircraft.

Consideration must also be given to the evolution and initial requirement for the quiet/dark cockpit. The concept was initially designed and adopted by Airbus for use with third world airlines and comparably trained pilots. The concept forced the pilots to follow a strict procedure to avoid trouble. This Airbus information theory has gained much criticism over the years and has contributed to a few accidents. Boeing, on the other hand, has been commended for implementing automation while still keeping the pilot in control and in command of the aircraft systems.

Training costs may get expensive over the life of an aircraft if an excessive amount of the training is devoted to nomenclature. Additionally, the initial cockpit philosophy may get somewhat lost over the life span of an aircraft. For example, the automation philosophy initially trained to new pilots may not be carried on to the extended life of an aircraft. During the initial release of a new aircraft, there is an excitement over training and an extremely comprehensive training program is created, possibly covering an entire week or more. As the aircraft matures, possibly over 30 years or more, that week-long training program becomes a couple of days, because of the advancements in training methods and expense of a long class. Some foreign operators may not even have a class for a 30-year-old aircraft, just a few days with an experienced pilot on a few charter flights.

With this in mind, the cockpit philosophy that was so carefully implemented into the initial training is lost. Therefore, the cockpit should be designed to clearly convey how it should be operated. Rather a life of its own, able to tell the pilot how to operate the aircraft in the proper and safe manner. Although the transitional pilot will need assistance, this will be only a brief period during the entire pilot-aircraft relationship.

Normalized Displays

The quiet/dark philosophy can be taken one step further in the form of a "normalized" display. In the early '90s, the NASA-Langley research team pioneered the use of a display system that kept very quiet until a parameter was out of limits. The Engine Monitoring and Control System (EMACS) display was based on the philosophy of providing information that is directly related to a pilot's task. This display by exception readout only showed the result if the system detected a difference between the actual parameter value and the value predicted by a software engine model. **See Figure 1 and Figure 2.** The research results showed that the advanced display concept had shorter detection and response times. The majority of the subject pilots preferred the advanced displays and thought they were operationally acceptable.

The EMACS display format assumed that the actual numerical value of any engine parameter was not as important as knowing whether the reading was normal or not. The EMACS display presented the engine readings in a "column deviation graph" format. Each engine parameter was a separate vertical column on a common graph. The readings were "normalized" so that, regardless of the actual numerical value, the middle line of the display represented zero deviation from a "normal" reading for that particular condition of flight. Just above or below that "normalized" line represented a caution level. Beyond the caution level represented a warning level.

This display had several potential advantages. First, it enabled pilots to detect even small deviations in engine behavior easily, before they reached a caution level. Second, it allowed pilots to scan all the instrument readings quickly and almost instantaneously determine if all the parameters were within limits. Several behavioral studies had indicated, in fact, that a column deviation graph format allowed a user to process up to 18 different elements in the same amount of time it took to process one, because the entire graph was perceived as a single item.

Some current helicopter displays use this EMACS method to display engine parameters and provide a panel button to "normalize" the readouts so a parameter that is creeping away from the norm is quickly recognized.

As you can see, there are quite a bit of design issues related to a quiet/dark cockpit design philosophy. Some are conflicting. But the important point when designing any cockpit is to pick a design philosophy and stick with it throughout the entire cockpit. Retrofit cockpits are especially venerable to mismatching cockpit philosophies and often cause a lot of confusion.

The underlying issue here is that the cockpit displays need to provide a quick indication to the pilots that all is well and good for the current phase of flight. This is accomplished with careful consideration to switch or status annunciation and the control philosophy adopted by the original designers. ❑