HOW CAN AVIONICS HELP REDUCE PILOT FATIGUE?

BY PAUL NOVACEK

Fatigue, a growing epidemic in modern cockpits, reflects our society's incessant drive to do more in less time. When office computers started to arrive on desktops they promised that we'd get so much more done that we'd have four-day work weeks. But noooo, now we gotta get nine days of work done in six days. They lied to us. But that's another story. Oh ya, fatigue.

Avionics are the direct link between the pilot and the craft, and as such contribute to the workload. A poorly designed cockpit interface, even if highly capable, often contributes to workload to the point that way too much time is given to the avionics instead of the aircraft situation.

But I'm an avionics shop, what can I do about pilot fatigue? Well, lots. Let's first start out with what causes or contributes to fatigue. Of course, lack of sleep is the major contributor, and scheduled operators deal with this on a constant basis. Other contributors are the physical environment and workload. As designers of cockpits, we can't do much about a pilot's sleep habits, and we have limited control over the flight environment. But there are many things we can do to reduce workload.

Fatigue Types

There are two classifications of fatigue: chronic and acute. Chronic fatigue accumulates over time and is caused by lack of sleep, stress and jet lag. A big problem when our modern go-go world meets aviation. The primary cure for this type of fatigue involves a lifestyle change to get more quality sleep. As cockpit designers we can't do anything about the state of the pilots before they strap into the pilot's seat, but we do have control over the second type of fatigue, acute.

Intense mental workload or physical activity causes acute fatigue. Climbing a long set of stairs is an example of acute physical fatigue, and hand flying on instruments in turbulence is an example of acute mental fatigue. A task that requires undivided attention for a prolonged period causes acute fatigue.

Acute fatigue degrades attention, coordination, concentration and just the overall decision-making process. Simple tasks become overwhelmingly difficult and all of the remaining energy is channeled into apparently menial tasks. Another name for this is tunnel vision, where the rest of the world is tuned-out to concentrate on a usually simple task.

Of course if a pilot is chronically fatigued before entering the cockpit, the onset of acute fatigue is that much more sudden. Hence the importance of getting enough sleep and eating right.

Luckily, as a cockpit designer, acute mental fatigue is something that we do have control over.

Fatigue Research

When fatigued, pilot performance disintegrates, which leads to a loss in the overall management of a complex task. Secondary activities, such as checking engine gauges, are overlooked and concentration is focused on one or two instruments—otherwise known as tunnel vision. This same effect is also brought on by lack of oxygen. Additionally, darkness is telling your body that it should be sleeping. So, flying high, at night when you're tired is a combination ripe for fatigue induced problems.

Measuring physical workload is easy and a known quantity, we just measure the work in kilocalories per minute and track oxygen consumption. We're all pretty much alike in that regard. But mental workload is another story. The scientists still have a difficult time measuring it and agree-

Continued on following page

Fatigue induced Tunnel Vision. Any remaining energy is focused on a single instrument.

PILOT FATIGUE

Continued from page 51

ing on a scale. This is where subjective measures and rating scales will vary among pilots. A pilot that flies every day, such as an airline pilot, will feel pretty relaxed when put in a tense situation. Whereas a low-time pilot presented with the same scenario might be taxed well past the breaking point. Many simulator studies bear this out.

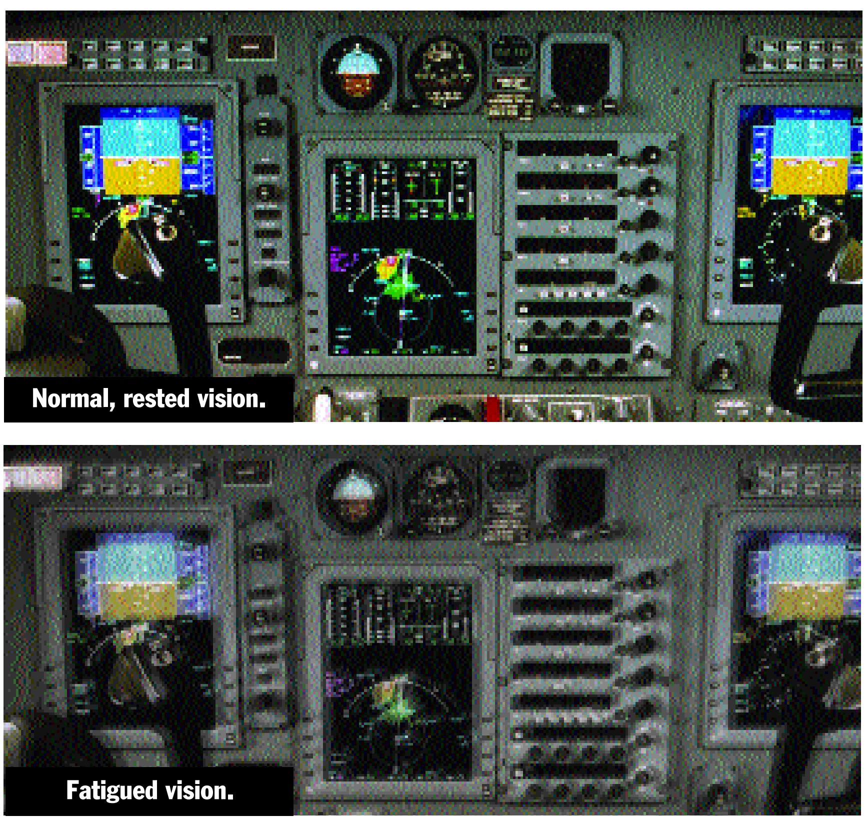
An excellent indicator of mental workload is the observation of a secondary task. A pilot experiencing tunnel vision because of mental fatigue will not perform the secondary task nearly as well. This phenomenon is aggravated by poorly designed displays that are difficult to read or interpret.

The FAA, NASAand other research houses have spent many years studying the effect of fatigue on cockpit duties. Their results drive crew duty regulations and airline policies.

The Flight Environment

There are three major contributing factors to physical fatigue in the flight environmental: heat, vibration and noise. The first two usually don't involve the avionics, but the third, noise, is greatly affected by the avionics. Generally, noise is one of the products of avionics, both in a good way and bad. Lots of times the bad is a byproduct of the good. For example, the Comm receiver supplies voices from the airwaves, but also unwanted white and pink noise.

White noise is the noise generated by all the electrons bouncing around inside the radio and is just the nature of electronics. Pink noise is all the atmospheric junk out there. The stuff that SETI (Search for Extra Terrestrial Intelligence) is monitoring for patterns and hoping for extra terrestrial intelligence. I think the little green men just want us to put "I Love Lucy" back on the air.



Fatigue causes loss of color vision, blurred and double images.

Added to the radio clatter is wind noise, the major contributor of cockpit noise in jets. Noise is not well tolerated by the body for long periods of time. This is where a good headset is one of the best preventative measures for reducing fatigue and long-term hearing loss. Active noise-canceling headsets are even better at reducing noise, but if not used properly may mask those unusual noises that foretell problems.

Many pilots keep their noise-canceling headsets active for the entire flight. A strange noise could go unheard for hours. During take off and landing and a few times during the flight, the active noise-canceling circuits should be turned off. Then any strange noises can be recognized, such as landing gear problems, pressurization leaks or abnormal engine noises. Avionics shops should always recommend that these noise-canceling headsets be used wisely and not left on for the entire flight.

Vibration is a major contributor to fatigue on both a whole body and localized scale. Vibration frequencies below 100Hz have been found to cause fatigue and frequencies below 10Hz can cause major internal organ damage, even at relatively low amplitudes. Vibration also affects the body's extremities. From personal experience, a slightly unbalanced prop induced enough vibration to cause my feet to fall asleep. Racecar drivers are keenly aware of this, and don't want their feet falling asleep during a race. Pilots can keep their feet on the floor most of the time, but imagine racing around Daytona at 200 miles-per-hour and your foot falling asleep.

Avionics Induced Fatigue

The addition of avionics to a panel often adds workload, even though they're designed to decrease workload. GPS is a good example. Contrary to what they promise, GPS adds workload in one area but decreases it in others. Enroute, the direct capability of a GPS does reduce workload and therefore fatigue because of the elimination of the need to constantly retune navigation radios. But in the approach phase, a GPS increases workload because of the multiple programming screens that need to be accessed. And you can guess where the busiest time of the flight is—approach, exactly where a GPS is the most difficult to use. Granted though, is the requirement for modern navigation techniques (GPS) to operate in an old ATC system designed for VORs. So, until the ATC system adopts the Free Flight infrastructure, we're stuck with overlay navigation techniques.

Display interpretation is another growing problem. The recent move to provide digital displays for information may be easy for the engineer to provide exacting information, but the brain still must process information in an analog fashion. The move to display information digitally may be going the wrong direction, because we don't process information digitally, we are analog processors. Luckily we are parallel processors, much more so than any silicon computer.

A good example of this is the move to provide a digital readout of exhaust gas temperature. Since exhaust gas is a self-limiting quantity (non-turbine), there is no upper limit and therefore the exact number is not critical. But, the relationship of each reading to the other cylinders is worthwhile information and can foretell of impending problems. Trying to process all of the temperatures in a digital presentation is highly taxing to the brain, which leads to fatigue. Therefore, providing all of the temperatures in an analog display is much less fatiguing, and lately manufacturers are providing this information in a vertical comparison meter. Much easier to interpret.

Cockpit Design Philosophies

The addition of certain avionics really can reduce fatigue. For example, HUDs and fuel computers reduce manual calculations and increase confidence. A HUD reduces eyestrain because information is superimposed over the outside world and focused at infinity. This eliminates the constant need to switch focus between a close instrument panel and a distant runway. The constant refocusing is very fatiguing.

The fuel computer gives the fuel reserve situation at a glance, almost eliminating fuel computations. The integration of a fuel computer and air data source into a GPS provide the pilot with real-time fuel state information, a real time saver and confidence builder. Thus, the reduction in mental workload contributes to reducing fatigue.

Along with good headsets, a good intercom makes communication easier between crewmembers. No more yelling over the engine and wind noise to speak to the person sitting two feet from you. Some of the more capable intercoms allow piped-in music to mix with the communications. Nothing soothes the beast, err pilot, better than a little Mozart. Flight instructors use this tactic pretty effectively when trying to calm a nervous student.

Moving map displays reduce fatigue because the complete navigation situation is displayed in a graphical format. Thereby greatly reducing mental strain and improving situational awareness.

Of course the biggest contributor to reducing fatigue is the autopilot. No other piece of avionics does more to keep the workload down. Fighting turbulence in a small airplane can be very strenuous, causing fatigue. Combined with trying to hand fly the airplane in the soup taxes both the physical and mental limits of any pilot. This is where the autopilot really earns its keep.

Lighting

A pilot that is having difficulty focusing on an instrument and struggling with light that is either too bright or too dim leads to eyestrain. Sorting out blurred or dimmed images can be very fatiguing.

Proper lighting is paramount to reducing fatigue. Excessively high or low light levels cause fatigue. A localized light source that is extremely brighter than its surroundings causes a glaring effect called blooming, which then causes discomfort and fatigue. People feel tense and restless when a bright light is staring them in the face. The effect causes the eye to reduce light intake from the bright source and anything around it. The dark areas around the blooming light are effectively in the shadows. If critical displays are near a blooming light, they may be overlooked.

Conversely, areas that are too dim cause eyestrain and increase fatigue. Circuit breaker panels are notorious for inadequate light and shadowing. Additionally, low light levels shutdown our color vision—another reason not to use colors exclusively to differentiate controls or switches. So, EVERY light source in a cockpit should be infinitely variable not just switched between high and low brightness as is often the practice.

Flicker is another fatigue inducing problem. Helicopter pilots just deal with it, but an intermittent panel light has the same effect. Just checking a light bulb to make sure it lights is not enough. It must be vibrated in some manner, by touching it and moving it within the socket or bumping the structure around it. A flickering light bulb may not show up on the ground, but inflight that loose socket may cause a

Continued on following page

PILOT FATIGUE
Continued from page 53

flickering light to become very distracting and cause fatigue.

Aircraft that cross many time zones in a single flight always encounter jet lag problems. Often a night flight to Europe has the pilots approaching the destination when their bodies are telling them that they should be asleep. To combat the problem, extremely bright lights in the cockpit are used to trick the body awake. These bright lights, sometimes called storm lights, serve a dual purpose. These extremely bright lights raise the ambient light level and cause the iris in the eye to reduce the amount of light entering the eye, thus reducing the chance that a pilot may be temporarily blinded by an extremely bright lightning strike. These storm lights are also used on long flights to trick the body into thinking that it's daytime, and time to be awake.

Blinking Lights

Blinking lights on an instrument panel are often used to convey information, although this also contributes to fatigue. A steady light means one thing and the same light blinking means another thing. The use of a blinking light to supply information is highly frowned upon in the Human Factors circles. Our brains are wired to treat "changing" images with a higher priority than color or size. So naturally, a blinking light gets our attention, which is where the function should stop.

That blinking light should just get our attention and direct our gaze to another element that is actually giving the information. An excellent application of a blinking light is the "Master Caution" light in the glareshield. It gets the pilot's attention and directs it towards the annunciator panel. The blinking light does not itself provide information. A poor design would use blinking text to convey information, causing eyestrain and fatigue in trying to decipher the information between blinks. A blinking box around the text is a much better design.

Blinking lights can also aggravate latent health problems such as epileptic seizures. Blinking lights on a dark background, such as a black instrument panel at night, between the frequencies of 4 to 59 Hz can cause seizures in individuals with photosensitive epilepsy. Unfortunately, pilots might not know that they have this condition until it happens. Another good reason to keep the blinking lights to a minimum and provide floodlighting for the entire instrument panel.

The Other Side of the Coin

Then there's the effect of reducing the workload to a point of boredom. Now that we've designed the cockpit to reduce mental load and fatigue, we've essentially put the pilot to sleep because there's nothing to do. Global reach airplanes have a big problem with this. Increased automation definitely reduces the potential for errors, but the complacency that sometimes results is a cause for concern. The slip of one digit in programming an FMS waypoint may cause huge navigational errors many hours into the flight. This scenario was a contributing factor in the Flight 007 shootdown over Kamchatka. An incorrect digit was entered into the flight management system from a fatigued crew, which led the airliner over hostile territory.

This overreliance on automated systems increases pilot, or crew, boredom. Once a pilot's guard is down, it's difficult to bring it back. Especially when the situation has progressed to the point of no return.

Fortunately these long-range aircraft require a second crewmember, which helps keep everybody awake. But the problem still exists to the point that some aircraft manufacturers have implemented "Keep Awake" routines. Events strategically inserted into the slow portion of a flight. This little engineer's secret actually causes a false problem or starts a routine that requires the pilot's full attention. It's a secret, because if the community knew exactly what the routines were, they would ignore them.

A complicated user interface contributes to mental workload and causes fatigue. Designing a better label for a switch or using a dimmable light may not seem to contribute to a safer cockpit, but every little Human Factors improvement helps contribute to a reduction in fatigue and overall increase in safety. So every little bit helps.

There are a few specific design principles that can be used to reduce acute fatigue, but an overall cockpit design philosophy that adheres to good Human Factors principles will not only reduce fatigue, but also reduce mistakes and contribute to flight safety.

Little things make a big difference and although changing one item may not totally wake up the pilot, the little things add up to provide a fatigue reducing philosophy and a safer flight. q