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THE HANDS-OFF APPROACH

WHO'D HAVE THOUGHT IT? IT SEEMS THAT TAKING THE OPERATOR OUT OF THE EQUATION IS FRAUGHT WITH RISK! SO WHAT HUMAN FACTORS NEED TO BE CONSIDERED WHEN CREATING AUTONOMOUS VEHICLES OR AUTOMATED FUNCTIONS?

A few minutes before sunset over the Mohave desert in Southern California on 6 December 1999, a Global Hawk UAV (Unmanned Aerial Vehicle) in its ninth test flight detected a slight anomaly. Sensors indicated that the temperature inside a forward electronics bay was unusually low, probably due to a fuel bypass valve being too far open.

The autonomous aircraft's flight software determined that the test mission should be cut short, and automatically reprogrammed the pilotless plane to return to Edwards Air Force Base. As a consequence of other air traffic at the base, the UAV initiated a secondary contingency plan for an alternate approach to the runway. Minutes later, Global Hawk AV 3 descended from altitude and made a perfect autonomous landing and rolled to an uneventful stop.

Global Hawk doing what it does best, the odd glitch aside...

With the US$45 million aircraft now safely on the runway, the command and control officer seated in a remote control centre commanded the vehicle to autonomously taxi down the runway, onto the taxiway and back towards the hangers. The onboard program responded, referencing a look-up table for a target speed. But rather than look up the appropriate taxi speed of 6 knots, the mission-planning software referred to the look-up table for taking-off down the runway – with a target speed of 155 knots, or about 180mph.

What happened next occurred too quickly for the operators in the control centre to realise what was going on. Global Hawk AV 3 accelerated down the runway, headed for its assigned climb speed. As it neared the end of the runway, travelling at 90mph, its taxi program – operating under the assumption that the taxi speed was 6 knots – initiated a left turn onto the taxiway. Travelling far too fast to negotiate the turn, the aircraft careened off the asphalt and out into the desert. After jetting 150 yards across the sand, rocks, and scrub, the landing gear collapsed and the UAV's bulbous nose buried itself in the sand.

When all was said and done, the damage to the Unmanned Aerial Vehicle added up to US$5.3 million. The test program was halted for three months, and when Global Hawk AV 3 was sent for repairs, the programme managers learned something important about the need for thorough software testing and the potential for a small 'automation' error to balloon into a costly accident.

ABOVE AND RIGHT: **John Deere's AutoTrac technology enables hands-free operation while enabling greater precision**

LEFT: **Auto steering is now clever enough to counter the effects of gravity on a trailed implement**

The human factor

So as automation and autonomous operations become increasingly commonplace in industrial vehicles, it becomes ever more critical to address the human factors at play in their design, testing, operation, and maintenance. Even a masterfully autonomous system (glitches aside) such as the Global Hawk requires human designers, human programmers, and human testers, planners, monitors and maintainers.

The autonomous piloting system may have removed the human from the real-time control loop, but humans are still very much interfacing with the machine in ways that are even more complex than with a piloted vehicle.

Automation does not supplant or supersede human activity, but simply changes the form of the interaction with the machine. The source of error can easily be shifted from the real-time pilot or operator over to the system designer, programmer, controller, monitor, or maintainer.

Raja Parasuraman, the director of the Human Factors and Applied Cognition Program at George Mason University in Virginia, USA, has written extensively about humans and automation and co-written an excellent article on the topic which serves as the basis for this overview.

"System designers," Parasuraman writes, "should be aware of the potential for operators to use automation when they probably should not, to be susceptible to decision biases caused by over-reliance on automation, to fail to monitor the automation as closely as they should, and to invest more trust in the automation than it may merit. Scenarios that may lead to over-reliance on automation should be anticipated and methods developed to counter it."

Accordingly, the following pages summarise the key factors that system designers should consider when developing automated functions, semi-automated functions, and even so-called fully autonomous industrial vehicles.

Although the formal definition of 'automation' can be quite clear cut, people's perceptions of automation change with time as technology evolves and becomes more familiar. A starter motor on an automobile, an essentially universal component on modern cars, was once considered a form of automation that simplified the physically demanding and somewhat dangerous task of starting an engine with a hand crank.

Similarly, GPS automatic steering systems on tractors might soon become so commonplace that users no longer think of the functions they perform as being 'automated.' Automated functions on industrial vehicles have become exceedingly commonplace, but are often not given a second thought. Examples include automatic hitch systems on tractors that control wheel slip, plough depth, and other variables to optimise work in the field; sequencing of multiple control inputs such as when making a turn at the headland with a tractor and complex implement such as a sprayer; automatic travel and lift control in lift-trucks that optimise travel routes and reduce travel time; automatic parallel parking and emergency braking systems now available on some cars; and all manner of warning systems ranging from blind spot alarms to night vision alerts.

Automation use

The human factors of automation can be best thought of in terms of four general categories; the initial category being 'automation use' and what designers might encounter when the system they created is actually operated in the field, warehouse, or construction site.

LEFT: **John Deere's Command Center – an appropriate name given the increased role of automation**

BELOW: **Bruno Sap, designer at AGCO created this master and slave tractor combination for our Design Challenge in November 2010**

First, there are typically large differences between users in their acceptance – and use – of automation. These 'individual differences,' as they are commonly called, reflect the varying levels of comfort people have with technology, with automation, and the desire to be 'in control' of the machine. What this all means is that a designer who automatically assumes that his automated system and programs will automatically be used by all users will be quite incorrect.

The second, related, factor that will come into play with the adoption of automation is that operational policies are frequently necessary; policies that possibly require operators to learn and use automation under particular circumstances. Full instrument and automated landings of commercial airliners in heavy fog are a good example of an organisation having a policy governing use of automation.

A related factor is that automation must be easy to turn on and off. The mode that the system is in must be abundantly clear, while the actions required to change the mode must be straightforward.

Next, automated systems should not simply be handed over to operators without training. Proper and reliable use of automation usually requires that operators have a reasonable level of knowledge about how the automation system works. This can help avert events or accidents attributable to the operator's misunderstandings of what the system is doing, when it is doing it, and how it is doing it.

Knowledge of what the system is not doing is important as well. Just because a vehicle might detect the presence of

LEFT: **Case IH V2V system co-ordinates te steering and speed of two vehicles from one GPS guidance system**

ABOVE: **Toyota Material Handling recently developed this remote controlled lift-truck in association with MIT**

an obstacle ahead or an impending collision does not necessarily mean that it has the capability of automatically doing something to avoid it. The operator must be fully versed in these differences.

Lastly, system designers must recognise that it is often difficult to predict how automation will be used once it is introduced. Some operators may ignore it, some operators may use it when they should not, and some operators may use it excessively or inappropriately.

Automation misuse

The next general category of human factors related to the introduction of automation in vehicles address the misuse of automation.

Over-reliance on automation can be a form of misuse. In such instances an operator may place undue trust in the automated system and incorrectly assume that it will 'keep him out of trouble'. As a case in point, in 1973, Eastern Airlines flight 401 crashed in the Florida Everglades as the crew, focusing their complete attention on a possible landing gear issue, failed to notice that the autopilot had become disengaged during the process. The plane flew into the ground with no one at the controls.

Over-reliance on automation has, especially recently, become a common topic of conversation in the professional field of human factors and ergonomics. Do operators lose important psychomotor skills and knowledge when they turn over vehicular control to a computer for hours on end? Do they become less vigilant in their tasks when all they are asked to do is monitor a system and

Crown's QuickPick Remote Advance is a good example of an operator still being involved in – and being responsible for – the vehicle's automated functions

take over should something go wrong? Will they have an adequate awareness of the operating situation, sufficient to take over and operate the machine manually, if they have only been sitting 'idly by' while computers and machines run the vehicle? Recent events, including the loss of Air France 447 in the South Atlantic, give emphasis to these questions.

Automation disuse

One particularly popular use of automation is in the form of automatic alerting systems that sense vehicular and environmental states and warn the operator about an important condition. The frequency and accuracy of alarms can have a tremendous impact on how operators respond to them.

False alarms, for example, occur when an automated system incorrectly warns the operator of a hazardous condition when, in fact, one does not exist. Excessive false alarms can effectively condition operators to ignore the alarm – a problem when the alarm is, in fact, true. Excessive false alarms can not only lead to safety issues but also to issues of operator annoyance – or both.

For example, investigators of a major rail accident in Baltimore, Maryland in 1987 discovered tape over the alerting buzzer in the train cab. Operators had silenced the alarm because they found the alarms to be too frequent, usually false, and annoying. Designers of automated alarms must therefore fully understand the 'decision threshold' used for automated alarms and alerts.

Automation abuse

Finally, we must address the issue of automation abuse or, as Parasuraman has said, "the automation of functions by designers and implementation by managers without due regard for the consequences for human (and hence system) performance and the operator's authority over the system."

First and foremost in this regard, designers should not simply automate whatever they can and then give the operator responsibility for whatever is left over. The operator's role should be based on his capabilities and limitations – and not be only a by-product of a system that is otherwise automated.

Secondly, thought should be given to maintaining the operator's active role in the operation of the machine, even if at times overall system performance might be somewhat lowered. The safety benefits of keeping the operator involved in the process and the avoidance of major system failure can far outweigh the consequences of a small increment in system performance.

Finally, it must be recognised that automation has the potential of substituting 'designer error' for 'operator error'. Automation means that the decisions of the operator have effectively been replaced with those of the designer. The goal can never be to fully eliminate human error by removing the human, for, as we have seen here, the human is still very much a part of an automated system. **iVT**

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Pope Design's remote-controlled excavator concept – there may be no operator compartment but humans would still be required