Putting a human face on the design of control rooms

Ian Nimmo

Plants are being monitored by sophisticated smart sensors that calibrate themselves, by process control devices that tune themselves based on plant situations, and by computers that predict and optimise based on market requirements. But is there an Achilles' heel to all this technology?

Technology has allowed industrial processes to be pushed to the limit while operating at maximum efficiency and achieving the most cost-effective use of energy.

I do not believe that technology has gone beyond the capabilities of today's operators, but I do feel that there are areas that are neglected and these can lead to unsafe production. Omissions are made in the design between the human and the machine. This can leave holes in an organisation's defences and allow human error to steal the very profits it has worked so hard to achieve through the use of the technology.

The Abnormal Situation Management Consortium[1] has identified "abnormal events" that cost $20 billion a year in the petrochemical industry alone. In fact, the annual total loss throughout the industry is equivalent to 7.3 days of unplanned total shutdowns costing, on average, $250,000 per hour. Not all of this is preventable but an improvement of just 5% could produce an extra $2.15 million a year.

As a result of site studies the consortium has concluded that most plants are not meeting their production targets, and losses of between 8% and 12% of production could be attributed to "preventable abnormal situations". It is easy to see losses that take away from the bottom line and reduce the effectiveness of the advances in automation technology. In some cases operators were observed backing the process away from its full potential in order to allow them to operate at a more comfortable and less stressful level.

Operator stress

Many operators appear to struggle because they work in badly designed central control rooms. Stress is the number one issue that impacts upon the operator's ability to perform, often leading to illness. It also is the major reason why operators decline jobs as console operators.

So what are the missing elements and why do we neglect them? The answer is easy and can be found by reading incident reports or many of the old stories warning us of the "ironies of automation" as British engineering psychologist Lisanne Bainbridge[2] put it:

- by taking away the easy parts of an operator's task automation can make the difficult parts of the job even more difficult;
- many system designers regard human beings as unreliable and inefficient, yet they still leave people to cope with those tasks that they could not think how to automate – especially the job of restoring the system to a safe state after some unforeseen failure;
- in highly automated systems the task of the human operator is to monitor the system to ensure that the "automatics" are working as they should. But even the best motivated people have trouble maintaining vigilance for long periods of time (12-hour shifts). They are, therefore, ill-suited to watch out for rarer and abnormal conditions;
- skills need to be practised continuously to preserve them. Yet an automatic system that fails only very occasionally denies the human operator the opportunity to practise the skills that will be called on in an emergency. Thus operators can become de-skilled in just those abilities that justify their marginalised existence; and
- as Bainbridge pointed out: "Perhaps the final irony is that it is the most successful automated systems with rare need for manual intervention which may need the greatest investment in operator training."

Since Bainbridge's paper was written a severe incident has occurred at the Phillips Petroleum chemical complex in Pasadena, near Houston, Texas. This resulted in the loss of the company's control room, followed by its inability to mitigate the incident.

At about 1:00pm on 23 October 1989, a chemical release occurred in the polyethylene plant. A flammable vapour cloud formed and then ignited resulting in a massive vapour cloud explosion. Following this initial explosion there was a series of further explosions and fires. The explosions caused 23 fatalities, and 300 people were injured. In addition, plant facilities were damaged extensively.

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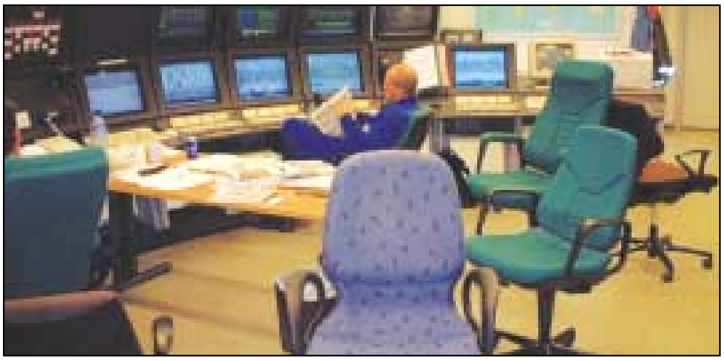
Texaco Pembroke suffered a serious incident and explosion in 1994 that affected hundreds of people, seriously injured 26 employees, and caused damage worth £48 million.

The major factors that contributed to this incident emerged in the Health & Safety Executive's investigation:

- too many alarms were poorly prioritised;
- control room displays did not help operators to understand what was happening;
- operators were inadequately trained for dealing with a stressful and sustained plant upset; and
- the work environment contributed to disruptions and stress.

It is easy to single out Texaco because the incident occurred close to home, but careful review of the incident at Esso's



Designed to work in: Control rooms in nuclear (above) and process (left) plants have to be designed with operator needs in mind

Longford Gas Plant in Australia, which occurred on 25 September 1998, reveals that there was a release of 10 tonnes of flashing hydrocarbon which exploded and killed two, injured eight, and resulted in a crater 1.5m deep. The incident involved the evacuation of the control room and restricted the operator's ability to shut the unit down safely. It had a massive impact on the Australian community with loss of gas supplies for several weeks at an estimated cost to industry of A$1.3 billion.

Studying these human-related incidents – responsible for 80% of accidents – Bainbridge and others have concluded that training and the continuous practising of skills are critical. However, many companies continue to neglect training and give it low priority.

In addition, the studies have found that the design of operator workspace is directly related to the ability to perform to the standards required if problems are to be averted.

As the role of an operator changes minute to minute throughout a 24-hour operation, it is essential to have a building that supports multiple activities from optimisation to control to training to maintenance to planning to communication with different disciplines.

Instead, many are just "equipment shelters" – control rooms designed for equipment. Often, this has just basic features: perhaps a kitchen with a microwave but no stove or wash basin. Sites converted from electrical sub-stations are used to house instrumentation; sometimes they are pre-built instrument shelters. People are an afterthought. Sometimes such shelters do not even have a toilet yet operators are in such buildings for 12 hours at a time.

Situation awareness

Other research has shown that successful intervention is dependent on four stages of operations:

- orienting – sensing, perception, and/or discrimination;
- evaluating – information processing (thinking and/or interpretation);
- acting – physical and/or verbal response; and
- assessing – information processing (thinking and/or interpretation).

Orienting involves perceiving a problem and separating it from many other failure paths. It is commonplace for operators to receive many alarms (often an avalanche) but due to poor prioritisation of these during a process disturbance it becomes very difficult to handle them efficiently. The task is to try to separate data and turn it into useful information by working with the human-computer interface (HCI), investigating graphical representations of the plant in distributed control system (DCS) schematics and using trend information to achieve the next goal, evaluation.

This process has been called "situation awareness" and focuses the designer's attention on the workspace design – the functional layout of the control room, the layout of consoles, and adjacency for good communications and collaboration. It also includes the HCI, its detail, and how to navigate it.

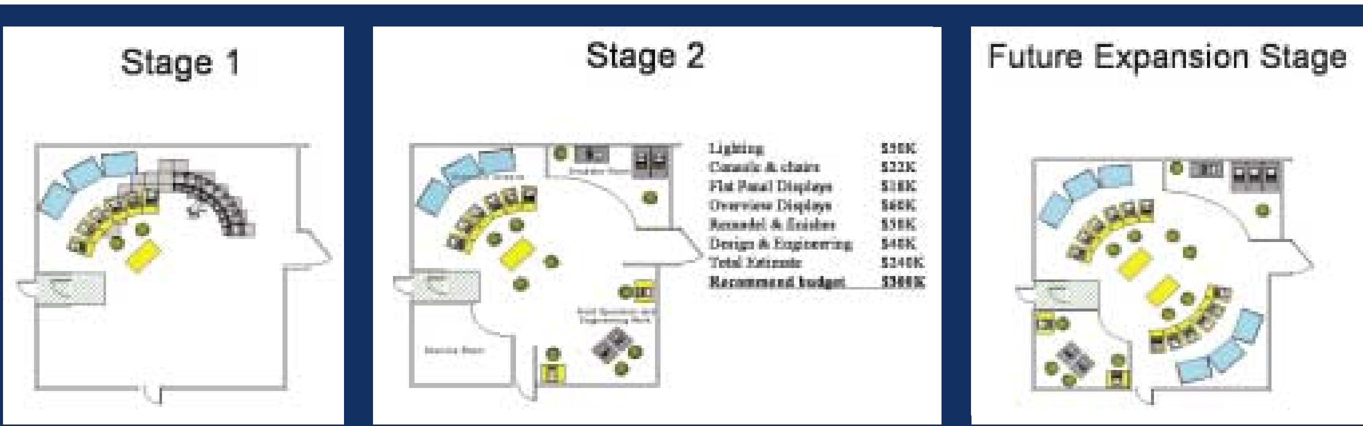
This stage can be improved dramatically by good alarm management practices, outlined in the EEMUA publication 191 Guideline, and by enforcing good human factor practices by using a company style guide for the HCI, as outlined in the EEMUA publication 201.

Having a good workspace design, which includes the functionality of the building as outlined in the ISO 11064 standard for Ergonomic Design of Control Buildings, correct design of consoles and a professional HCI will produce good situation awareness and, hence, focused orientation on what is happening and what is important.

The Evaluation stage includes the development of a hypothesis regarding the cause of the plant problem. This stage can be improved with good problem-solving training such as the Kepner-Tregoe methodology.

This is a continuous, step-by-step approach to successfully solving problems, making good decisions, and analysing potential risks and opportunities. The methodology maximises the critical thinking skills of people. It helps individuals who are working alone or in teams to systematically organise and prioritise information, set objectives, evaluate alternatives, and analyse impact.

Having the ability to test a hypothesis is recognised as a Best Practice – this means that an operator first has to have time to respond and to study a problem. Waiting for late alarms will not provide this. If either systems (state estimator technology) or operators (tracking trends and displays) provide early detection of an impending failure, operators should be able to go to a room near to the control room close enough to allow them to track the event while at



1. Existing control room.
2. Proposal
3. Future expansion

Review of a control room and identification of best practice designed to allow a chemicals producer to move from a single unit that would allow a theatre style control room with future expansion of an additional unit. The existing console size was reduced by using off-workstations and a more ergonomic console with single height screens and fatigue-countermeasures in the form of exercise equipment. Improvements were also made to other performance shaping features such as lighting and HVAC

the same time testing theories on a real-time dynamic simulator, even rehearsing procedural responses.

The next stage is that of Acting. The operations and the technical support team must take corrective action which may entail the use of the automation control system or the control operator verbally instructing a field operator to make an adjustment to equipment. Many incident reports show how an inappropriate action by an operations team can initiate or escalate disturbances.

This is an area in which good training (based on competency models) and continuous skill development, ideally with the aid of simulators, can make a big impact. Having good procedures that interface with the automation system can bear fruit.

The final stage – Assessing – is, once again, an area in which many failures are encountered as the operations team make a move and, instead of assessing and continuously monitoring the actions taken until a confirmed success and stable process is achieved, leave the monitoring to the automation system and wait for the next wake-up call – probably another alarm. This is how operators miss the knock-on effects of a failure and orient themselves late in the process event and, as a result, get themselves in continuous fire-fighting.

This reinforces the need for training and for good workspace design, both of which can be tied together in a Console Operator Performance Standard. This helps identify the right people to recruit into such jobs, using psychometric testing as part of a skill-measurement assessment programme, and comparing a job competency profile and entry level qualifications with the suitability of candidates for the console operator job.

Development of a mental model of the process has been recognised as a Best Practice. Current practice to achieve this requires console operators to be competent in all of the existing field operator positions, achieved by learning and by job experience.

Development of staffing workload assessments against each console operator position and balancing workload based on experience and competence will allow a formal training system to deliver the performance required backed by observation and analysis of DCS data.

Critical response

Operator training should be based on competency models and include the opportunity to practise skills regularly by rehearsing critical response and practising standard operating procedures and emergency response actions.

Console operators function as process control specialists and effectively control, optimise, and troubleshoot the process to meet production goals. They should be able to manage abnormal situations, directing outside operators in routine and abnormal responses. The control room and adjacent support rooms should be a continuous learning environment.

Workspace design usually is addressed only if a new control room is being proposed or built or if significant change is occurring due to a technology upgrade or reduction in personnel. Some designs have been carried out due to a changing philosophy of risk exposure based on recommended industrial practices or a change following a minor infringement of regulations which has been part of a negotiated settlement.

Generally, the workspace design relates to the control room. These have evolved from equipment shelters through sophisticated computer rooms to control centres for people, with equipment and computers taking a second place.

Now, there are different styles of buildings from what I call "functional designs", in which console layout is the primary focus and communication and collaboration drive the layout, to "theatre style" which, as the name suggest, provides a theatre environment with all consoles facing a video wall and the off-workstations providing a panoramic view of the whole plant. Each console has its scope of control on one or two of these off-workstations – the operator sits at the console with an overview of the control, an overview of adjacent units, and the capability to monitor units, sub-units, trends, procedures, and alarms.

The control room should address operator vigilance and other performance-shaping issues and should be specified as part of a Console Operator Performance Standard. One company with which I am familiar has adopted a fatigue counter-measure programme. This involves education and workspace design issues such as circadian lighting, nap rooms, noise reduction, and heating, ventilating, and air-conditioning (HVAC) systems that have people-zoned areas and ergonomic furniture and software that addresses common human factor issues and stresses.

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[1] ASM and Abnormal Situation Management are U.S. registered trademarks of Honeywell, Inc.
[2] Lisanne Bainbridge, pp 271-283 of "Ironies of Automation" edited by J. Rasmussen, K. Duncan, and J. Lela, New Technology and Human Error, Wiley, Chichester, 1987.