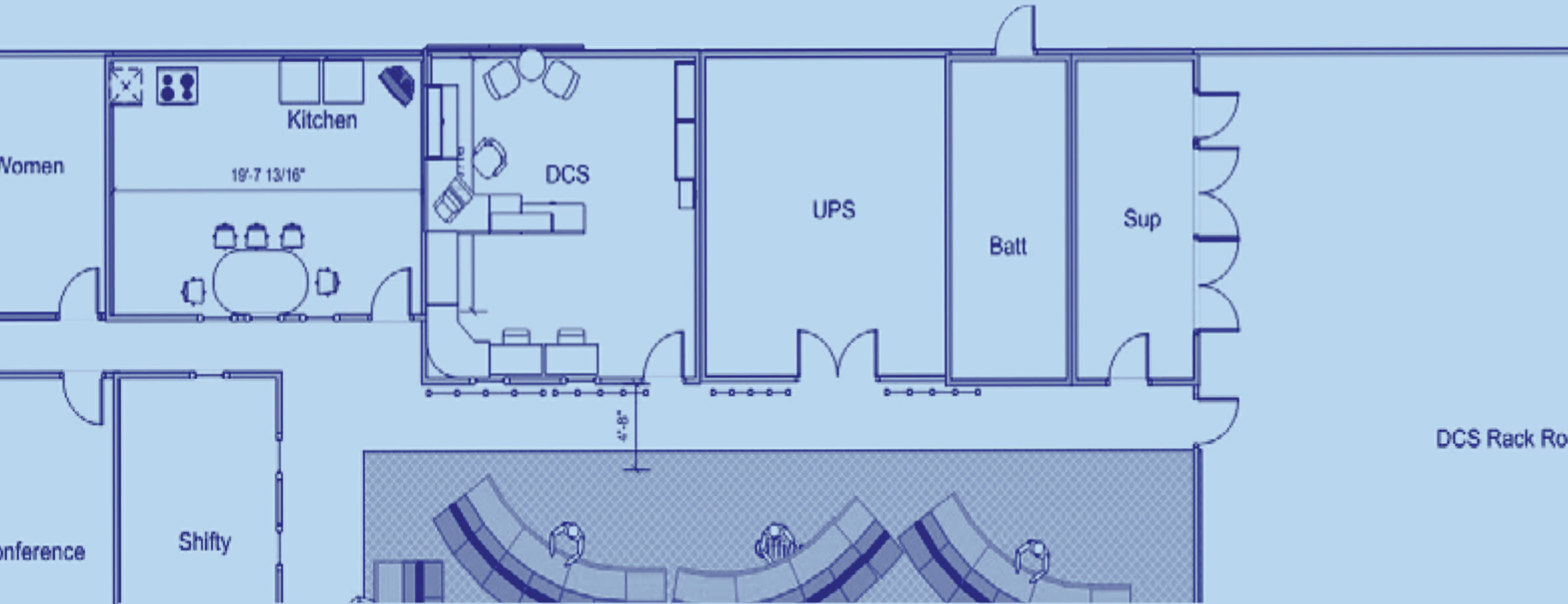
Operator consoles: growing old together

Ian Nimmo, User Centered Design Services LLC, USA, outlines how facility upgrades have changed in recent years.



All elements of process control systems grow old together. Either a major refurbishment project, a new process unit installation, or an instrument refurbishment is performed, and everything associated with the system is upgraded, including the control room; the operators' human machine interface; the field instruments; the wiring; and the process control equipment. 20 - 30 years later everything is ready for replacement again. That is what is being found on the majority of the projects being carried out. It is frightening to be one of the engineers to have installed the original technology.

Has anything changed, or is it all just business as usual? Certainly, alarm systems have changed. They have now advanced from controlled alarm modules that were physically restricted by the space available and what the operator would use, to DCS alarms; increasing to such a level that the operator has been overloaded just with the work to acknowledge alarms, without having time to respond to them. Silencing them was the first task, allowing the operator to respond to process upsets.

Unfortunately, the operator was unaware of higher priority actions due to the loss of the alarm notification in the avalanche of alarms presented and acknowledged during a disturbance. This has caused many companies to focus attention on removing duplications and configuration errors, and has started a new trend of intelligent alarming, suppressing unnecessary alarms using control logic. We are now seeing a 70% reduction in the number of alarms (and focused alarms); again with clear operator response.

One of the other impacts of this change is from a few alarms to an abundance, and now a more controlled engineering approach to alarm management (rather than the undisciplined 'fill in the box' configuration that has been used in the past).

This has led to a reconsideration of the operator or human computer interface (HCI), which was called the man machine interface (MMI) in the old days (no computers and predominantly men). It is interesting to witness the progression from the old pneumatic panels to VDU screens, but unfortunately little credit has been given to the original designers of the panels and the layout of the panel, perhaps because of the lack of management when changing the layout. Over the years, if a new instrument were required, the

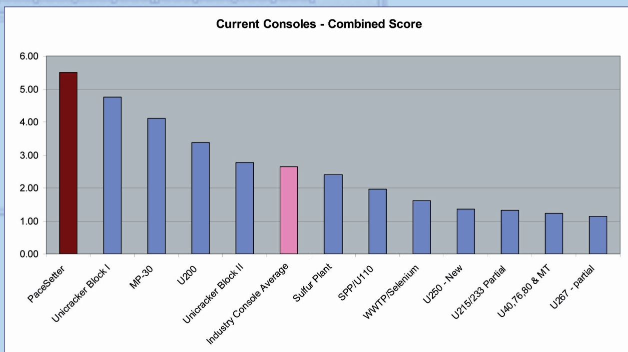


Figure 1. Typical console operator work loading.

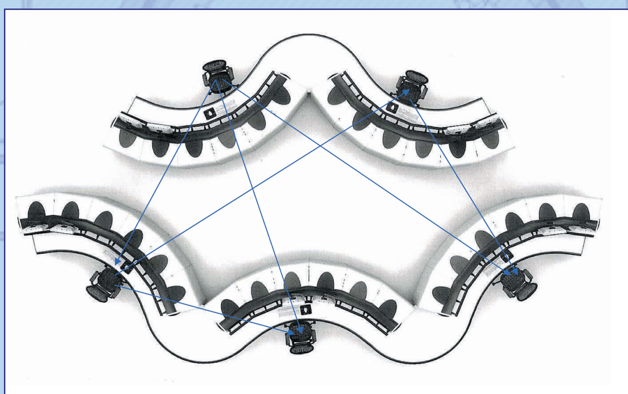


Figure 2. Line of communication and collaboration between console operators.

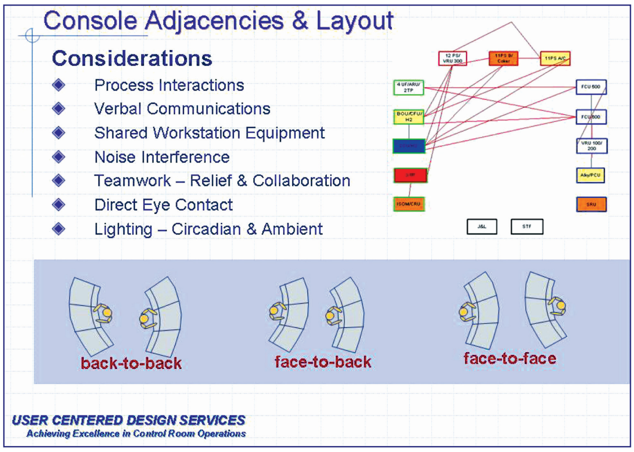
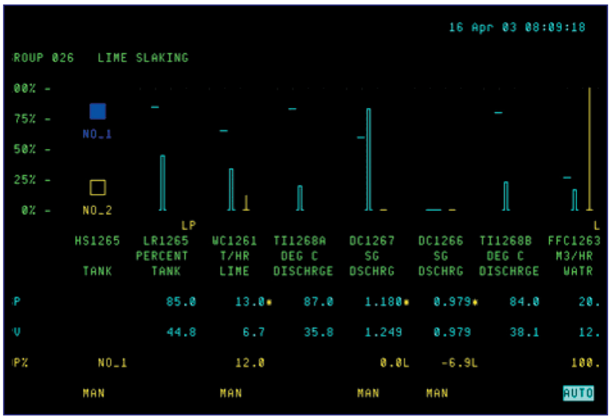


Figure 3. Design factors.



Figures 4 and 5. First design using groups.

local instrument technicians looked for a space and mounted the instrument, or installed the new one in parallel with the old ones during the upgrade from pneumatic to electronic, leaving the old redundant pneumatics (mothballed) on the panel. The result of this was a loss of the original thought process that went into the logical layout of the panel instruments.

The panels were divided into sections based on unit layout, and it was important to group controls that a single operator had to control. Otherwise the operator would be moving up and down the long panel. It has been found that this was due to poor design and a lack of understanding of how an operator controls the plant. A single operator found it difficult to run the panel, and hence the high speed roller chair was invented for operators to slide backwards and forwards along the panel. Alternatively, field operators came into the control house and took over a section of the board.

As VDUs gradually replaced the board, the control desk evolved from flat panels. The furniture was far from being ergonomic, and human factors had no influence in the design of the desk layout. In fact, the designers could not have done a better job doing the exact opposite. This has been identified as one of the reasons that operators rely on alarms; due to the poor design of the HCI.

The new control rooms are finally addressing some of the best practices associated with the panel design. They incorporate big screen HCI designs, bringing the 'big picture' back into the control room. Interestingly, a lot of the new control room designs are incorporating long thin buildings similar to those for the pneumatic panels, and consoles are being laid out in a theatre configuration.

The HCI is incorporating panel instrument symbols rather than just P&ID symbols, providing a powerful interface and more information than is currently provided by traditional displays. This is without the clutter and data overload that the designs of the 1970s and 1980s have produced. The new HCI design is impacting the console (desk) and control room designs. There is now also a move from computer designs with black backgrounds, to over-powering colours (with multiple coloured lines and no consistent colour coding). Important colours (such as red and yellow) are being used for multiple reasons, rather than just being reserved for alarms, and this makes it difficult to identify the new notification of an alarm. New designs of the HCI are incorporating grey backgrounds, with almost no colour except to draw attention to important information.

This is not a big step for companies migrating from panels, but it is more of a stumbling block for those companies that have been practicing operating with poor human factor designs. The operators have learned how to get the most out of them, and during 'normal' operation they do a good job. However, we are now seeing accidents and incidents due to loss of control during abnormal and emergency situations. Operators have adjusted to sitting in dark control rooms to compensate for the glare from the bright screens with lots of colours and black backgrounds. This has worked to shift operator advantage since the introduction of 12 hour shifts. It is difficult to catch them (the operators) sleeping!

It is not unusual for the company to want to review the number of operators, or more specifically the workload of each operator. Companies with some DCS and old panel boards will often have operators that have inside and outside responsibilities. They are planning on consolidating their control room operators into a single building, and they want to dedicate them to control only. After a study of their workload, it is found that control jobs are not distributed evenly, with some operators over-stretched and others having an easy job, which is also often boring. It does not challenge them, and they are not prepared for the times that the process demands more attention than usual.

A lot of these jobs therefore require multi-disciplined teams with knowledge of Field-bus; instrumentation; DCS design and configuration; HCI with human factors and subject matter expertise; alarms; control desk ergonomic design; and control room and building ergonomic design with functional design understanding. What is required more than anything is a subject matter expert who can pull the whole thing together and coordinate with other disciplines.

Many companies have carried out aspects of this type of project with individual elements of the overall scope, and some have tried to tackle all the elements and been challenged, but few have done all of them well. How does one set about tackling everything in a single project? How do you justify a renovation project of this scale? Where do you start?

To start a project of this scale requires sound project justification, which can only come from one of two places; an accident in which a company is forced to rebuild and fight off regulators from closing the doors (not a recommended route); or alternatively to have an abnormal situation gap analysis. The latter will examine current practices in each of the areas described above and will compare the site to industry best practices. The gap analysis will also be used to identify potential savings and performance improvements. These can be significant when compared to the research work of the Abnormal Situation Management® consortium, who determined that abnormal situations are costing the US industry over US$ 20 billion/y (confirmed by other studies since). Many sites have been identified with savings of US$ 20 million/y, as they removed the variability and poor performance of people and equipment.

However, the gap analysis deals with more than just hardware and software implementation. It also takes into account the people that interface with the technology, looking at management systems, practice and policy, and the effect that culture is having because of shared values and beliefs. Gap analysis works to identify what is working well; what leads to incidents and near hits; the roles and responsibilities of people; how they are hired, trained and how they perform; and the effect of the environment and workplace on the people, especially in the control rooms and field shelters.

Study of management systems

Many examples of what 'good' looks like are available to the industrial engineer, from the USA's OSHA process safety management standard (PSM OSHA 1910.119), which was based on studies of what was working well in the US industry, to the UK's H&SE's staffing assessments and the ladders and trees used to assess management systems. The ASM consortium also developed effective operations practices based on years of site studies of the top energy companies' 'best of' best practices.

Study of people and performance

The industry struggled to determine how to estimate operator workload for many years. In the early days, reduction of people was not a motive, with many more people hired than were required. The industry was people intensive, and as automation took route people were gradually displaced. In the 1960s and 1970s, work study attempted to measure workload by time and motion studies, which worked for the widget industry but became more of a challenge for the process industry. It was found that field operator positions could be somewhat determined by time and motion, especially if operators had clear rounds and regular time dependant tasks such as tanker loading and unloading. However, the technique was not so successful with permanent console operators, whose workload was unpredictable and (as once described) 80% the boredom of waiting for something to happen and 20% the sheer terror of fighting disturbances.

The industry tried to use some form of metric to measure the console operator's workload, and the industry unofficially adopted a control loop count as a measure. This was a very poor metric, as plants and control loop response times varied, and different processes required different responses from the operator. There were major differences between batch and continuous operations, and within an industry sector such as a refinery, the controls on a water treatment plant could not be compared to a crude unit, or the crude unit to a cat cracker, coker or hydrocracker. However, the industry has used this for many years, and the result has been that the console operator is overloaded in some units, and underloaded to the point of boredom in others.

A new approach was developed by an associate member of the ASM consortium (User Centered Design Services), who developed a three part methodology that examined all the process equipment under the console

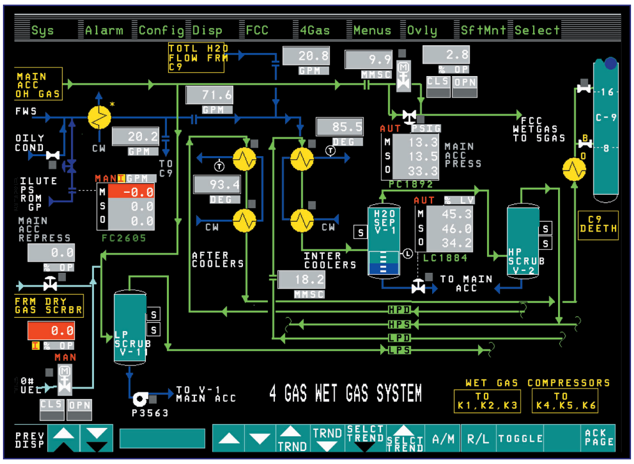


Figure 6. Operator designed graphic.

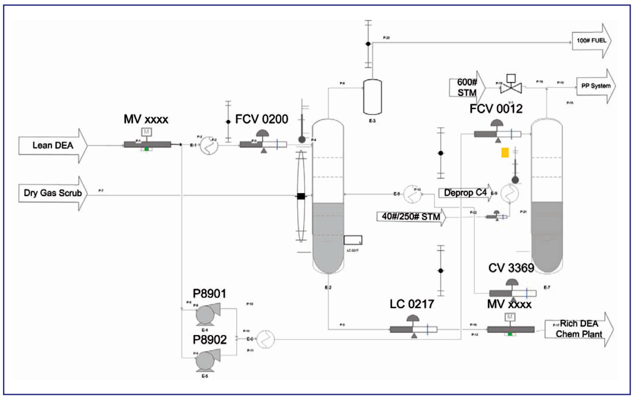


Figure 7. Next generation graphic.

operators' influence of control, providing a scoring system based on the amount and complexity of the equipment. The second measure was the connectivity of the equipment as feed comes into the operators' scope of control, and by which route it is either sent pumped from storage or hot from another unit and console operator column. Obviously, one will have a greater impact than the other, and they are therefore rated differently. Finally, the impact of a poor instrumentation and control system implementation has been observed. Metrics based on alarms, HCI and area for control valve movement are therefore also factored into the equation. All of this produces an overall rating system that can first compare workload across a facility and a company, and with the established database of many companies, an industrial standard for workload. Another benefit of working with Solomon 1st Quartile companies is that we can compare the pacesetters with any given site.

This is the first step in distributing workload across console positions. With the data units can be reconfigured until the workload is distributed evenly. Another consideration is changing the number of dedicated console operators, or if a site had a distribution of dedicated and inside/outside operator roles, and the decision has been made to just have dedicated, the site can go from 28 operators doing some control to six full time dedicated control operators. This is an extreme change, and will normally involve reducing the impact of the DCS workload by resolving alarm management issues, improving HCI displays, improving control system integrity and removing alarm bad actors. However, we still recommend completing a risk assessment based on the UK's H&SE staffing methodology to test staffing arrangements.

Having determined the correct staffing, the company should consider how to hire staff, to train them and to measure performance. TTS Performance Systems, another

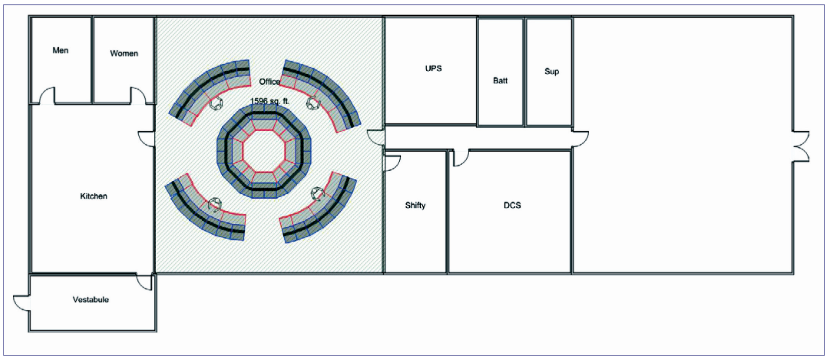


Figure 8. Typical central control room in a refinery.

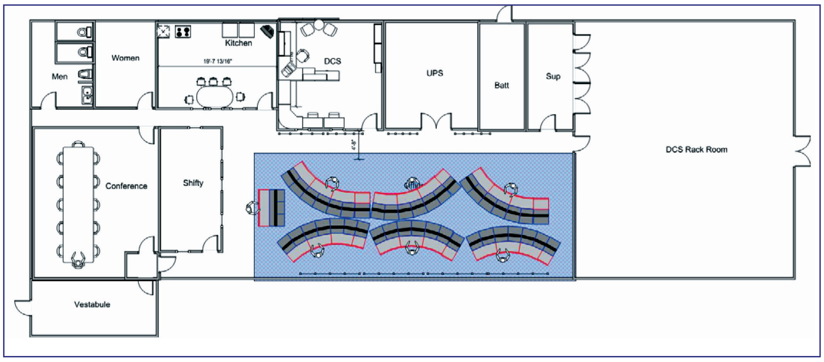


Figure 9. Revamp of the same control room.

ASM consortium member, recommends developing 'job performance profiles' for each position in an organisation, to cover:

- Job goals (what they are expected to do, and how well they are expected to do it).
- Job roles (the functions they are expected to perform, stating primary and secondary duties).
- Job responsibilities (define the specific activities that employees are responsible for performing).
- Job competencies (knowledge; skills; attributes; behaviour indicators; personal competencies - adaptable, critical thinker, etc.; interpersonal competencies; functional competencies).
- Job performance management (how job performance will be managed).

Ergonomic design of operating desks or consoles

Once the number of people doing control duties has been determined, the number of consoles or desk positions can also be considered. Unfortunately, at this stage the number of screens has not yet been determined. This is where most companies stop the design process. They take the number of screens that the operator had originally, and if they obtain extra units and equipment to control, determine whether it can be added to an existing piece of glass or whether an additional screen should be added. This is a poor way of designing a system, and the correct way would be to detail the HCI style and navigation techniques. A task analysis would be completed to determine what information an operator requires, and how it will be presented during startup, normal operations, disturbance or abnormal situations and shutdown/emergency operations.

The EEMUA 201 publication (addressing the process industry HCI) provides guidance on selecting the number of screens for a single or dual control operator position. In some ways, the HCI has to be specified before this step can be made with some confidence. The actual layout and relationship to other consoles needs to be determined based on communication and collaboration requirements. Functional relationships can be determined from the process flow diagrams developed during the staffing analysis, showing feeds into an operator's scope of control and products produced and transferred either to another operator or a storage handover. With this knowledge, the ISO 11064 ergonomic design of control rooms standard can be used to determine the ergonomic associated with the console or desk design.

Human computer interface

The human computer interface (HCI) has evolved as the control panel has changed to the DCS VDU style. Early versions only provided a set of group displays, which meant operators had to memorise loops based on group location. Operators adapted very quickly, and worked very well with the interface, similar to the old panel board, but they lost the big picture, and experienced difficulty tracking what was happening in abnormal situations. They therefore demanded more screens and alarms.

The DCS vendors responded and provided graphical interface screens, but again these only provided a limited view. It was like looking at the world through a keyhole. The design the DCS vendor introduced was poor, with a number of human factor issues. The black backgrounds drive the lights out in the control rooms as the operators match the lighting to the display backgrounds to reduce glare on the screens. Many lighting designers have tried to design bright colours and glass around these black screens, and all have failed.

The graphics implementation has also evolved. Initially, control engineers designed the graphics, and the operators complained that they were far from usable, as they were just copies of the P&IDs spread over a few hundred screens. The engineers therefore gave the job to the operators, and used the same designs, but made the graphics more accurate and plant structured.

The graphics have a tendency to resemble a Christmas tree, and spotting a new alarm is like trying to find the one lamp on a string that has gone out. The designs showed no human factor considerations at all, as colours were used for multiple coding. For example, green was used for pump running, process lines, text, etc. Colours with meaning should be reserved for that purpose, for example yellow should only be used for low priority alarm, red for high priority, etc.

The next generation of graphics is built with the control and structure defined in a style guide, with every symbol consistently applied as designed, documented and specified in a symbol library. The graphics are designed by a team consisting of a human factors engineer (or an engineer with human factors experience), an operator and a control engineer. The human factors engineer usually has the lead, and will conduct a task analysis to understand the 'what, why and when' of the display.

Process problems and abnormal situations are identified, and information and data are made available to allow the operator to identify the problem, diagnose the causes and provide an action plan to resolve the issue. The navigation of the graphics is as important as the graphic. The displays follow a hierarchy, which is described in the EEMUA 201 publication. This hierarchy follows five levels:

- Process overview (scope of operator control).

- Unit overview.
- Detail sub-unit view.
- Critical controllers or diagnostics.
- Detail diagnostics, trends, alarms (often combined with the above).

The new graphics utilise a lighter colour background (usually grey) and the graphics only use colour to emphasise information such as an alarm or something important.

Alarm management

The reorganisation of console operators usually demands the resolution of bad alarms and alarm floods. The HCI enables reduction, as the operators have large overview displays (such as the panel) and user-friendly navigation, to keep them aware of the situation. This allows the engineer to design the alarm to do what was always intended: protect people, equipment and the economics of the processing. This can be achieved using approximately 30% of today's typically installed alarms.

To achieve this target, the alarm management system has to be designed in accordance with today's best practices and the metrics therein defined. The EEMUA 191 publication is the best document currently available to aid in achieving these goals.

EEMUA first discusses developing an alarm philosophy document that describes the 'what, why, where, when and how' of alarms. It demands a multi-disciplined team to resolve bad alarms, revamp the configuration in line with the philosophy, fix broken instrumentation and resolving control system design errors. Once these issues have been resolved, the team can move on to more advanced techniques described in the EEMUA document, such as dynamic alarm management and suppression, shelving and eclipsing techniques to eliminate alarms out of context.

The examination of alarm problems identifies problems in instrumentations and control. Typical symptoms of poor control are highlighted in 'The Carbon Trust - Improving the effectiveness of basic closed loop control systems', including:

- Routine overriding of automatic systems by operators.
- Excessive or variable energy use.
- Over-purification of product and/or intermediate materials.
- Production restrictions due to energy limitations.
- Excessive stockholding and off-specification production.
- Frequent control disturbances, alarms or plant trips.
- Inconsistent or sluggish operation.
- Excessive variability in operating parameters.
- Unreliable measurements and frequent calls for maintenance.

The Carbon Trust Good Practice Guide GPC346 goes on to describe how these issues should be resolved. The techniques described in this guide enable any good alarm system to operate effectively.

Design of the control room

The final step is to take the badly designed, dark, noisy control room, with the many issues that impact on the performance of the operators, limit situation awareness, and transform the existing building or build a new building to the ISO 11064 'Ergonomic Design of Control Buildings' document. With the cooperation of the building's primary and secondary users, it is possible to produce a building that is fit for purpose and that enables the new organisation; console layouts; the use of good HCI navigation and overview. It is designed to minimise noise, and provide lighting levels that supports operator vigilance.

A typical central control room design for a refinery resembles Figure 8. Some are a lot larger, but will be sufficient for the purpose of this exercise. The design shows access through a vestibule into a blast resistant building, and then into the kitchen area, which doubles as the morning meeting room. This prevents operators from using the kitchen during meetings, and also becomes a distraction as the door is always left open and is noisy, and the lighting in the kitchen is several hundred lux brighter than the control room. Nor do the glass windows between the kitchen and control room help. A secondary user of the building going to the rack or DCS room at the very end of the building, the DCS development room or Shift Supervisors office, walks behind the operators and through the middle of the control room, often stopping to talk to (and disturb) the operators.

The operators cannot see one another, and often cannot communicate effectively, as they are sat back to back and have a large desk cluttered with books, radios and an entertainment system that prevents a sitting person from seeing another person in an adjacent corner. The designer of the centralised control building missed the point of putting operators together to improve communications and enable collaboration. This layout put them in the same room, but did not facilitate the functional requirements.

The control room was modified during one of these multipurpose projects, requiring additional console operators as the plant is extended to meet new environmental projects. The DCS is being upgraded and the graphics are moving to a web based technology, so the existing HCI will have to be upgraded. The existing system has poor control and instrumentation issues, and alarm management is a major issue.

Some rooms in the building are off-limits for modification such as the DCS rack room, the HVAC, UPS & Battery rooms, and the fire fighting suppression system room. Toilets are often difficult to move, but with money and determination they too can be relocated. In this re-design it was decided to leave them in their current location.

However, building access was modified. There was an additional vestibule with access to a dedicated conference room for morning meetings, etc., and another door into the control room with easy access to the shift supervisor's office.

Secondary users of the building are now provided with a dedicated walkway that guides them to the kitchen, the DCS development office and electrical rooms, UPS, battery and DCS rack room, with minimum disturbance to the operators. Operators have full access to their kitchen and the bathrooms 24 hours/day. The conference room also has access to the bathrooms, so again operators don't have to be disturbed by meeting attendees.

The operators have a new console design with single height screens so they can see one another. Large 70 in. overview displays are mounted from the ceiling for the operator controlling the unit and reference to adjacent operators. Noise from communication equipment and alarms is now directed to the wall with noise suppression materials to kill reverberation.

The design is not perfect, but it is an improvement without rebuilding the control room. It is sometimes necessary to live with design limitations, and hence it is important to get it right first time when designing a control building and designing with a lifecycle view. Each building often has a minimum 30 year life, and will have to accommodate changing technology, changing organisations and sometimes different processes. ■