

Higher Efficiency in Operations Can Be Achieved with More Focus on the Operator

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1. Introduction

In the early days of industrial automation, system designers attempted to automate everything and remove the human operator – whom they considered the weakest link in the process control loop – entirely. Today, it is clear that the human operator is an integral part of any automated control loop in almost all industrial applications of any size. Understanding and maximizing collaboration between the control system and the human operator is therefore essential. Furthermore, a systematic design approach to this task is crucial for reasons of safety and optimum system performance (Pretlove & Skourup, 2007).

The operational phase of any project is typically the dominant part of the total life cycle. Therefore, it is logical to focus on the operational efficiency and economical aspects. The global process industry loses \$20 billion, or five percent of annual production, to unscheduled downtime and poor quality. ARC Advisory Group (www.arcweb.com) estimates that almost 80 percent of these losses are preventable and that 40 percent are primarily the result of operator error (Woll et al., 2002).

We can easily understand that our increased demand for higher productivity, better quality and increased safety has changed the situation for the operator over the last fifty years. More complex applications, more data to interpret and more alarms to process are some factors that affect the operator. With this increased responsibility for overall profitability and lack of continuous training, it has become harder to find operators willing to accept this burden and devote their working life to the control room. ARC Advisory Group estimates that most companies spend less than 2% of available hours on training (Wilkins, 2007). To make things even worse, operators are not always in focus when new control rooms are built. Lack of understanding of human factors, too much emphasis on technology and not enough involvement by operators in the planning phase of the control room all result in poor ergonomics and dissatisfied staff (Nimmo, 2007 and Ericson et al., 2008).

If we examine the consequences of this attitude, we find a very high employee turnover rate among operators. What's more, the costs of hiring and training new personnel are considerable. It is estimated that the cost of training one plant control room operator is at least \$100,000 (Wilkins, 2007).

A growing problem is also the fact that many of today's operators are approaching retirement and it is difficult to recruit replacements among today's younger generation. This is particularly acute within the Mining and Oil & Gas industries, where many of the production sites are located in very remote and unattractive areas. ARC Advisory Group estimates that almost half of the operators retiring before 2030 can not be replaced (Wilkins, 2007).

It is time to bring the control rooms to a new level where operator effectiveness is highest on the priority list. With today's technology it is possible to consolidate control rooms into control centers offering completely integrated solutions. It is possible to work with sound, colors, lighting, intelligent furniture's, smart textiles and micro ventilation to achieve much higher efficiency in the operations than ever before. Furthermore, the Distributed Control System (DCS) of today fully support integration of power- and process automation in one common environment together with support for safety applications and advanced alarm management.

Our challenge is to create an attractive, safe and effective environment with operators in focus. Questions like "why do we need a control room, what tasks are to be executed by whom and how can we implement an operator interface that works safely even in critical situations," must be asked. "How can we build the most impressive display wall for our visitors and how much money can we save by buying non-ergonomic furniture and skimping on good control room layout planning" are aspects that should never be raised.

2. Existing issues in many control rooms

Many sub-optimal issues can be identified in existing control rooms. The most obvious are listed here.

- Operators do not have a good overview of the complete process
- The control room environment is not optimized for the actual number of operators
- The Human Machine Interface (HMI) is not optimized for operator tasks
- Large displays are not implemented with the operator in focus
- Close Circuit TeleVision (CCTV) and Telecom equipment are poorly integrated in the operator environment
- The control room was built with limited focus on human factors and ergonomics
- The control room was not built for consolidation and collaboration
- No one is designated to be responsible for the total control room solution

2.1 There has always been a need for an overview

Let us take a look at some history. There has always been a need for an overview. Before the operator control room was available, the operator had to walk around the process and smell, feel and listen to the different parts of the plant. The first attempts to support the operator implied that all instruments, switches, etc. were gathered at one common location. See Fig. 1. Information and interaction were combined in the same piece of hardware. A switch could, for instance, be moved in different positions with direct feedback on the current status.

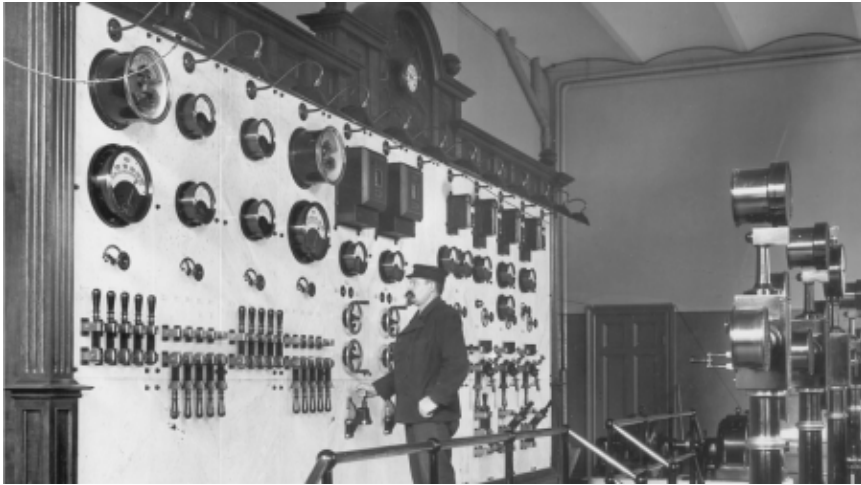


Fig. 1. Early attempt to create a plant overview.

The next step was the development of chart recorders, alarm enunciators and single-loop controllers mounted in large wall panels. It was now possible to get a very good overview of the process with recorded trends, differentiated alarms and loop status. Of course, all interaction could be carried out directly at the wall panels. See Fig. 2.

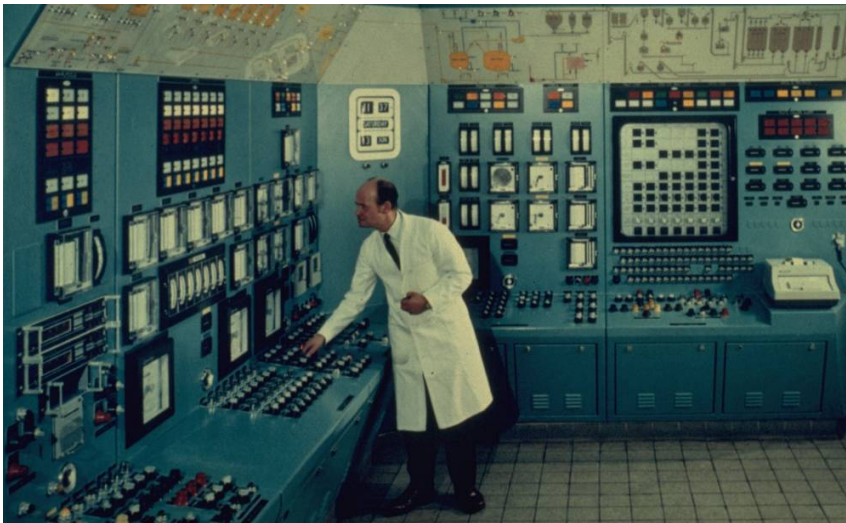


Fig. 2. Wall panels with a good overview and full interaction.

As computers were developed, it became possible to move the wall panels onto several process graphics with full interaction. However, the new problem created was that the total overview was now lost. Each operator screen became merely a keyhole into the process. See Fig. 3. Navigation was another subject for improvement. With only one screen (or possibly

two), it was difficult to find the required information and act in a timely fashion. In many installations, this was solved by adding absolutely everything possible to one single screen, thus avoiding the need for display navigation. The problem with this solution is obvious. If something critical happens on this screen, it is difficult to interpret the information in a secure way.



Fig. 3. Each operator screen is acting as a keyhole into the process.



Fig. 4. Large display walls make it possible to present a plant overview for the operators.

The solution to this shortcoming with computer screens and HMI software was large display walls. Finally, here was a way to replace the wall panel with an electronic version that could display the total process overview with support for modifications. It was even possible to use part of the large display wall as a CCTV monitor. Large display walls like these are still commonly found, particularly in control rooms in sectors like Oil & Gas and Utilities. See Fig. 4. Unfortunately, these large display walls have shown to create problems when designing a good layout in the control room. This is further discussed in section 2.4 below.

The latest solution to all of the above shortcomings is the interactive personal large display integrated with the operator console. In a 2011 report, ARC Advisory Group provides the Extended Operator Workplace (EOW) from ABB as a good example of this new type of console (Woll & Miller, 2011). See Fig. 5. The EOW is designed for highly complex 24/7 operation. A large display is mounted behind the normal monitors. All parts of the console, including the large screen, are motorized for optimum working conditions. The large screen is completely interactive for safe, fast and correct decision-making. This means that faceplates, trend information, operator instructions, maintenance records and any other object-related information can be accessed on the large screen, in the actual context, without any delay or need for separate browsing.

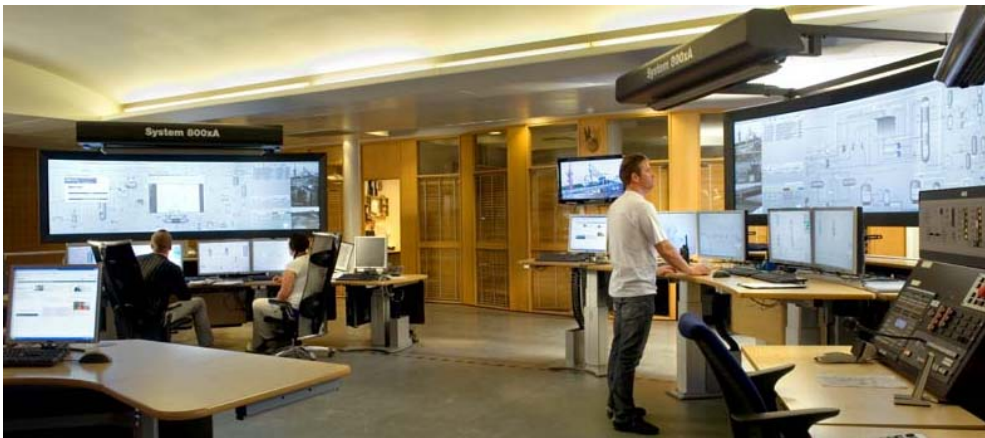


Fig. 5. Extended Operator Workplace from ABB with interactive large display.

2.2 Control rooms must be designed for the operator needs

Many times the control room is designed based on the actual process, not necessary with the needs of each operator in mind. The specification for the DCS system, Request for Proposal (RFQ) is often structured based on the different process sections in the plant. Each section is typically given an operator workplace with one or two monitors. When all this is combined on the operator console, we can typically see 8-16 monitors with many separate keyboards and mouse arrangements. In addition to these process monitors, the operator is exposed to several CCTV monitors, telecom equipment and other supporting systems. In total, each operator can easily be overwhelmed with information and different devices to interact with the process and other people. See Fig. 6.

When designing the control room, it is important to start from the correct number of operators and the different tasks at hand. Who needs to be in the control room? How many monitors can each operator handle? How many keyboards are needed? Is it possible to add one or two additional operators during critical situations? How much of the information can be integrated to avoid separate monitors and keyboards? These are all questions that must be asked. If there is an expansion to the operation, it is very important to go back to these questions instead of just adding one or several more operator workplaces with yet one or two more monitors for each process section that is added. The reality is that no more operators are added just because the operation is expanded.

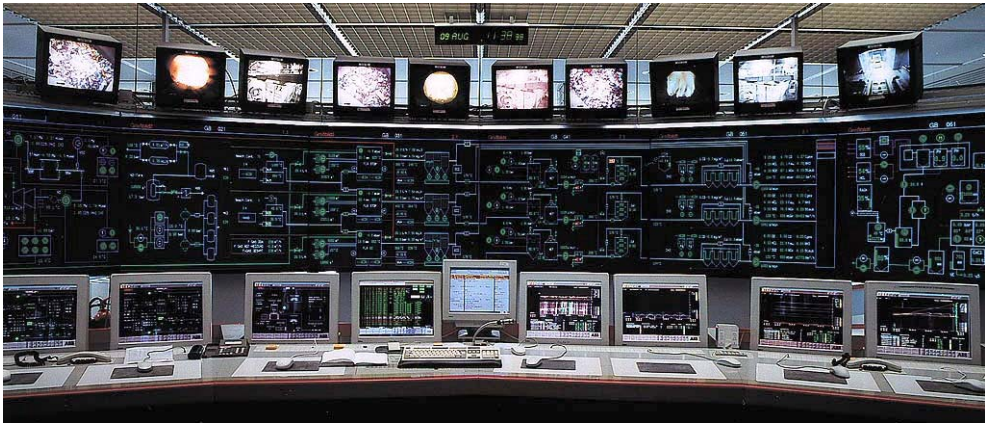


Fig. 6. The operator can easily be overwhelmed with too much information.

2.3 The HMI can be improved with high performance design

It is obviously important to use appropriate fonts, colors, shapes etc. when designing the HMI for operators. It is equally important to have all relevant information integrated to be able to work effectively in a consistent way. It is more important for the operator to easily read the actual information than to know where and how to find it. Operator workplaces should be possible to personalize for optimal operation for different individual needs. In today's advanced operator workplaces with many connected display channels and support for large displays, it is important to have a good navigation system and a predictive behavior for different categories of information. The operator should be able to focus on the information, not on moving and resizing windows. It is also important that open windows for different categories of information are reused to avoid overload with too many open windows on the screen. It should of course be possible for the operator to control the behavior and override any preconfigured rules.

2.4 Large display walls can make it difficult obtain a good control room layout

If the decision to use a large display wall is not coordinated with the operator needs, the resulting control room layout might reduce the possibility to achieve an optimal control room operation.

Unfortunately, large screens are not always implemented with the individual operator in focus. The main purpose of a large screen is to present an overview of the total process for everyone in the control room, with the emphasis on deviation from the normal process state. As soon as such a deviation is identified, the operator has to move his/her focus to the normal screens and translate the relative deviation to something measurable in real numbers. This can be very stressful, especially with many other people in the control room hanging over their shoulder.

Yet another problem is the way the display wall affects control room layout. The wall ends up defining the layout of the complete control room, and it thus limits possibilities for future changes. Valuable floor space is wasted on both sides of the wall. Space behind the wall is needed for maintenance access, but there is also a recommended minimum distance between the wall and the operator consoles. This latter space is normally used as a walkway that generates disturbing traffic in the control room. The fact that the display wall is fixed in position also makes it difficult to have adjustable consoles. For example, a large display wall mounted to allow consoles to be adjusted for standing operation would be too high for operators who prefer to sit. See Fig. 7.



Fig. 7. Large display walls have a great impact on the control room layout.

2.5 It is essential to integrate CCTV and telecom equipment

In critical situations, it is not effective to change focus from the task at hand, and try to find the actual CCTV monitor showing a specific process object or area.

There are typically two ways to implement CCTV in the control room. The most commonly used approach is to add a CCTV monitor for each camera. These monitors are then typically hanging down from the ceiling or positioned on the wall. See Fig. 8. A more sophisticated solution is to use a dedicated operator station with a camera switch and a joystick. The

operator can from this station select one or several camera images and control each individual camera with the joystick. The obvious problem with both these approaches is that the operator must change his/her focus from the actual process and keep unnecessary information about what camera to select and how to move it into position. An other, more serious problem is that the operator has no means to look at recorded information in any easy way.



Fig. 8. CCTV and Telecom equipment should be integrated with the DCS system.

The only acceptable solution to CCTV is to integrate the functionality into the DCS system. This way, the operator can get to the camera information, when needed, without knowing where the camera is located. It should of course be possible to operate the camera (Pan, Tilt and Zoom) from the DCS system and easily retrieve recorded information in a similar way as looking at trend displays. If needed, any video window should be possible to share with any other operator connected to the same network. This should even include field operators with wireless handheld terminals. ARC Advisory Group wrote a report in June 2010 that emphasized the importance of integrated real-time video. *"Integrated real-time live video into human machine interface (HMI) tools provides an excellent opportunity to maximize operator effectiveness and ergonomics..."* (Resnick, 2010).

If the live video is combined with audio communication, it is also possible to turn the DCS system into a video conferencing system. This would instantly turn the operator console into a true collaboration center where process specialists and field operators together can solve complex situations.

The same applies to Telecom equipment that must be integrated with the DCS environment to avoid unnecessary movements in the control room. Critical alarms should for instance be possible to broadcast over the Telecom system in different languages directly from the DCS system without losing the focus from the process. Selected alarms and events should also be possible to automatically distribute over email and Short Message System (SMS). See section 2.7 for more details about the consequences of control room consolidation.

2.6 There must be more focus on ergonomics and human factors

The control room environment must be designed for the operators, not for the technical equipment. It is a known fact that we are all different. We have different length, we have different preferences when it comes to sitting or standing, we have different vision with different requirements when it comes to lighting, distance to the screens etc. We have also very different perception of temperature. Some operators like it a little bit warmer, while other operators like it a little bit cooler. Without focus on the operator environment, it is obvious that we easily are introducing problems in the control room. If these problems are causing personal injuries and avoidable sick leave or unexpected turn around, we really need to look for a better solution. See Fig. 9.



Fig. 9. It is important to focus on ergonomics and Human Factors.

Today, it is possible to find operator desks that are motorized and height adjustable from 650 mm up to 1300 mm. The freedom to vary posture is known to be beneficial for operator health and thus effectiveness. The monitor boards used for regular wide screen monitors can be individually motorized and height adjustable from +70 to -130 mm independently of the working board. All wide screen monitors, on the monitor board, can be tilted simultaneously from +5 degrees down to -45 degrees through a unique motorized monitor support. The distance between the monitor board and the working board can also be motorized and adjustable up to 150 mm. Achieving a perfect viewing distance and angle is at all times easily secured with this sophisticated arrangement. See Fig. 10.

It is also possible to integrate a large overview screen with the console and that way avoiding wasted space on either side of it. Disturbing traffic is eliminated and the consoles can be moved around as conditions change. Furthermore, as the consoles are ergonomically designed they can be adjusted for individual operators. It is not far fetched to imagine that

the console adjusts to individual preferences as part of the login process and then automatically adjust to various situations during the working shift.



Fig. 10. The operator console must be ergonomically designed to fit different people.

To minimize the need to move around in the control room between different computer screens and CCTV monitors, there are keyboards that can serve several computers. This way, it is possible to operate an advanced operator console without leaving the operator chair and lose the focus on the process. It is also possible to have directed speakers located above the operator to secure that the operator can hear alarm sounds or background music without disturbing the other operators in the control room.

All computers should normally be removed from the control room and placed in a separate computer room with a controlled environment. In this way, the noise level can be kept to a minimum, and it is much easier to keep the control room floor clean. All of these factors work in favor of attracting new and hopefully younger operators into the control room.

The latest trend is to control the ventilation system in the control room to create different temperature zones around each operator. This is an efficient way to save energy as the temperature can be individual adjusted. It is even possible to connect the temperature control to the DCS system such that certain alarm levels can trigger more cold air and keep the operator alert in critical situations.

2.7 It is important to understand the consequences of consolidation and collaboration

There is a clear trend today to consolidate many separate control rooms into intelligent control centers. This way we can utilize the expertise from several experienced operators in one common center that can be remotely located from the actual plant(s). See Fig. 11.

With today's technology, it is possible to operate remotely without any visual contact with the actual process. It is possible to utilize integrated CCTV and telecom equipment to communicate over long distance. It is also much easier to recruit operators in an attractive area compared to living in a camp far away from the nearest city.

When consolidating control rooms, more operators from different parts of the process, must be able to work side by side collaborating in an efficient way. There are technical solutions available today that make it possible to shower the operator with personal sound without disturbing the other operators in the same room. With this technology, it is even possible for the operators to listening to their personal favorite background music.

As discussed earlier, it is essential that that the operators can get all relevant information from one single location in the control room. This implies that all information must be integrated in the DCS system to avoid unnecessary movements in the control center. If several operators need to see the same information e.g. a CCTV image, the information can be sent by one operator to other operators for sharing. This even includes field operators with wireless handheld terminals.

One other important aspect of working in a collaboration center is that you must be able to solve critical situations in a group. Therefore, it is crucial that the operator console can be operated to standing position to allow all involved operators to work on the same level. To have several people standing behind you looking over your shoulder can be very stressful in a critical situation where you can not afford to make a wrong decision.



Fig. 11. Several experienced operators in a consolidated control center.

2.8 Someone must be responsible for the total control room environment

There are many challenges during the total life cycle of a control room project. The process is expanded with more process sections, the existing computer monitors are getting obsolete, changed standards are requiring modified safety measures etc. Without someone being responsible for the total control room, the environment will very quickly decay when many different vendors are implementing different systems without coordination. The result from this are different types of monitors, different screen resolutions, different viewing angles many different keyboards and other input devices. See Fig. 12. Even if the actual operator is used to this situation, it can be devastating if someone new without the experience is exposed to this environment in a critical situation.



Fig. 12. Someone must be responsible for the total control room environment.

Today, there are many good tools available that simplify the planning of a control room with support for change management. It is important that we take control room planning serious over the whole life cycle of the operation. See Fig. 13.

3. CPAS and operational excellence

ARC Advisory Group introduced a new vision for Collaborative Process Automation Systems (CPAS) in 2002. The intention was to create an environment in which everyone could access all relevant data in context in a secure way. According to ARC, the definition of the HMI part of Operational Excellence is *"A single unified environment for the presentation of information to the operators as well as the ability to present information in context to the right people at the right time from any point within the system"* (Woll et al., 2002). See Fig. 14.

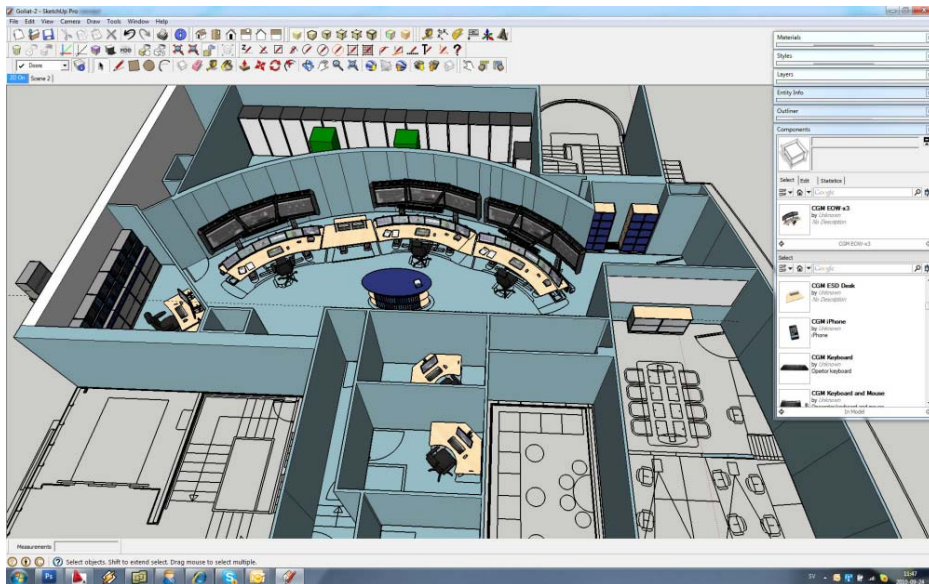
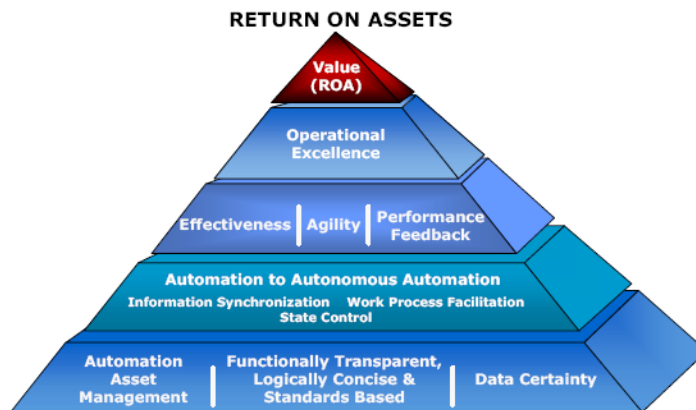


Fig. 13. Free tools like Google SketchUp make it easier to plan the control room.



Collaborative Process Automation System (CPAS) Guiding Principles

Fig. 14. ARC Advisory Group CPAS Guiding Principles.

What ARC means is that the operator environment has to be in focus if maximum Return on Assets (ROA) is to be achieved. The operator must have access to all relevant data and tools that help him/her make decisions and act quickly in relation to a situation in the process. All data must be synchronized and presented in a unified way, in context, and without the need to login and browse in separate systems. Navigation must be quick and intuitive to avoid delays when searching for data. Once again, we need to think about how we use a mixture of large screens and normal monitors. The large screen has to be interactive to allow

for immediate display of critical information with tools to act. It is also important that all screens support transfer of information. If, for instance, an operator finds something important that he/she must share with others, there must be a way to send this information (duplicate) to any other screen (workplace) in the system. It could be a trend display that must be shown on someone's large display for further investigation, or a live video window that must be possible to see on multiple screens, even over a long distance. (It can be very limiting for operators if a video window is presented in the corner of a display wall without being able to move it or duplicate it to any other location on any other screen.)

ARC Advisory Group also emphasizes the importance of ergonomics in the control room. In a report written in July 2007, it recommends that *"Design and implementation of control room and HMI, should include ergonomics and change management"*. It is further recommended that *"Technology providers should ... propose solutions and implementation approaches that include ergonomics and change management skills"* (de Leeuw, 2007).

In a report written in October 2008, ARC Advisory Group introduced a new trend. *"... This is part of a trend that ARC refers to as "Ergonometrics", where increased ergonomics leads to increases in KPIs and metric results. The objective is to offer the operator an attractive working environment with extended functionality, which better enables functional consolidation and increases collaboration. The key component of this offering is the Extended Operator Workplace, which provides detailed overview images of the entire process with high definition graphics. This solution creates an optimized working environment for the operators and meets high ergonomic standards, making it more possible for the operators to act fast in critical situations and avoid expensive shutdowns"* (Resnick, 2008).



Fig. 15. Operator environment with focus on ergonomics and human factors.

Operational excellence and operator effectiveness means a lot more than just functionality in the DCS system. Ergonomics and focus on human factors are equally important to keep the

operator alert, healthy and ready to act. So what do we mean with ergonomics and human factors? Let us repeat some of the most important factors that affect the operator in the control room:

- Physical factors like: working height, viewing angle, legroom and sitting comfort
- Ambient factors like: lighting, noise level, temperature, humidity and air quality
- Number of screens per keyboard and resolution on different screens
- Lighting and color depending on process state (smart textiles and daylight control)
- Sound systems for public and personal information
- Traffic control (field operators, visitors and other control room personal)
- Access to other functions or rooms (printer room, rest room, kitchen, toilet, meeting room, offices, computer room, library, exercise room, emergency room etc.)
- Console proximity (communication and collaboration)

See Fig. 15 for a modern operator working environment with focus on ergonomics and human factors.

4. Conclusion

The fact that we need to change the way we plan control rooms and move from a technology-driven approach to one that is operator-focused is quite obvious. We need to create a safer and securer environment that will attract new operators into the control room. To do this, we need to challenge ourselves. Are there other new ways to plan the control room? Are there other new technologies that allow us to think differently than before? Can it be that the younger generation has different demands and requirements?

Let us look at an example. In a typical bid specification, all operator seats are specified as two-monitor seats with no information about any human factors or how these seats are supposed to fit into the control room layout. Sometimes we see a specification for a large display wall with a number of projection cubes and an overall size. What are missing in these specifications are the reasons behind these numbers. Why only two monitors per operator seat? Why should the display wall have a certain size? What is the purpose of the large display wall? What information will be presented on the monitors and what on the wall? How should information be presented and how should the different screens and monitors interact with each other?

This bid specification typically illustrates a technology-driven approach. We start with the known hardware facts without any thoughts about the operators and soft factors.

For the next control room project, therefore, we should change our focus from technology and cost-fixation to a complete focus on the operator and the total control room solution. With this approach, we will find that it is possible to combine higher productivity with better quality and safer operation. Operators will be more satisfied and we will lower the turnover of new workers.

5. Acknowledgment

I would like to thank the following companies and organization for their contribution to this chapter about Operator Effectiveness.

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Chalmers University for their contribution with research projects to find the optimum operator environment for more alert operators in critical situations.

ARC advisory Group for their contribution with several reports in the area of Ergonomics; the teamwork between human operators and technology.

6. Nomenclature

CCTV	Closed Circuit TeleVision
CPAS	Collaborative Process Automation Systems
DCS	Distributed Control System
EOW	Extended Operator Workplace from ABB
HF	Human Factors
HMI	Human Machine Interface
RFQ	Request For Quotation
ROA	Return On Asset
SMS	Short Message System

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