THE CHANGING FACE OF CONSOLE DESIGN

The emergence of new technologies, new ergonomic standards, and increased public awareness of workplace health issues have combined to inspire a dramatic shift in console design. Today's control workstations are smaller, more functional, and more aesthetically appealing than earlier generations.

The ergonomic approach to designing consoles into the layout of a control room should contribute to achieving the performance objectives established for the space in question, while ensuring that every aspect of interaction between human, machine, and the environment - from raised flooring to acoustical concerns, from indirect lighting to the overall well-being, health, and safety of each operator - is taken into account.

TOP-DOWN APPROACH

A top-down approach provides a framework for ensuring that decisions on such matters as equipment selection, operating practices, working environments, and furniture choices all derive from operating demands. No matter how well designed a workstation might be, the overall system will fail if operators are overloaded, undertaking tasks for which they are poorly trained, or straining to read displays that are illegible. With a top-down approach, the limitations of the operator are automatically included and potential mismatches between operator capabilities and system demands are minimized.

The international standard known as ISO 11064 is the backbone of ergonomic design of control rooms. The essence of this approach can be defined within a single term: user-centered design.

The top-down approach requires that you first spell out the goals of the control center in various situations, including normal, off-normal, emergency, outage, and startup conditions. Determine what systems are required to accommodate these conditions, then list the functions best undertaken by machines (e.g. repetitive calculations), followed by those functions at which human operators are superior (e.g. coping with unexpected situations). The result will define system specifications for computers as well as those tasks to be conducted by human operators.

In addition to forcing an evolution in console design, revolutionary changes in technologies are also nurturing improved console aesthetics. The arrival of digital technologies, system integration, and flat-panel displays have enabled console manufacturers to design a wider variety of consoles with smaller footprints. Simultaneously, console manufacturers are also discovering more and more about the way people use control rooms. Sharing that knowledge with architects ensures that ergonomic factors will be designed into the larger control environment as well as into the consoles themselves.

Well-designed control rooms balance efficiency with ergonomics. Winsted's corporate mission is to create, develop, and market new products for new applications in the video production, broadcast, security, power utilities, military, SCADA and transportation industries throughout the world. Since its founding in 1963, The Winsted Corporation has consistently been the pioneer in the design and development of ergonomic consoles and control room furnishings, and over the years, its modular design systems have become the industry standard.

In recent years, the company has broadened and expanded its product line with the development of specialized products for multiple industries. Winsted began expansion into overseas markets in 1975, primarily into the UK, and a year later, the company began establishing distribution in the Far East. Today, Winsted is a world leader in its industry.

After reading the content, one should be able to:

1. UNDERSTAND BASIC CONCEPTS OF CONTROL ROOM DESIGN AND CONSOLE PLACEMENT.

2. UNDERSTAND BASIC CRITERIA FOR VISUAL ERGONOMICS.

3. BE FAMILIAR WITH THE CRITERIA FOR ENSURING BOTH EFFICIENT WORKFLOW AND OPERATOR COMFORT IN ARCHITECTURAL SPACES DESIGNED FOR SYSTEM CONTROL OPERATIONS.

ERGONOMICS

Ergonomics is the study of the human factors relationship between workers and their environment. Most original console standards were set back in the 1960s, and have since been revised to accommodate both new technologies and new understandings of how our head, neck, and eyes operate.

Past ergonomic studies were done with a person in the "sitting tall position," with his or her hips, shoulders, and ears in a straight, vertical line. Realistically, no one would sit in such an uncomfortable position, especially for the duration of an eight-hour shift. Because we now understand more about how the neck, head, and eyes operate, today's ergonomic standards are based on more realistic assessments of how operators actually work at consoles. The latest ergonomic studies of people sitting in a relaxed position show that our heads tilt forward approximately 8 to 15 degrees at a viewing angle of minus 30 to 35 degrees, and we prefer an average viewing

ERGONOMICS CONT.

distance of 30" to 35" from the screen, based on screen size. With that in mind, newer consoles are lowering the target angle of the primary viewing displays.

The average minimum viewing distance is largely determined by three factors:

- *Eyesight accommodation is the distance at which our eyes focus when there is no object on which to focus. The eye muscles that focus the lens must work 2 1/2 times harder to focus at 12" than at 30", which contributes to eye strain.*

- *Convergence is when the eyes turn inward to focus on a near item. This actually contributes more to eye strain than accommodation.*

- *Depth of focus is the range of distances that do not require the eyes to refocus, which most frequently affects the over-40 operator, those of us requiring reading glasses.*

The solutions to problems arising from all three factors are similar: Lower the monitor height, keep items and screens to be viewed at similar distances, position displays at the proper angle to line of sight, increase task lighting on printed material, increase text size, and change tasks periodically. Accommodation and convergence are both shortened when the gaze is lowered. The average resting point of convergence is 35" at 30 degrees down angle, 45" at horizontal, and 53" at 30 degrees up angle. This data offers a significant justification for lowering monitor height. The other benefit of lower monitor height is a reduction in dry eye syndrome caused by eyelids opening wider when looking up.
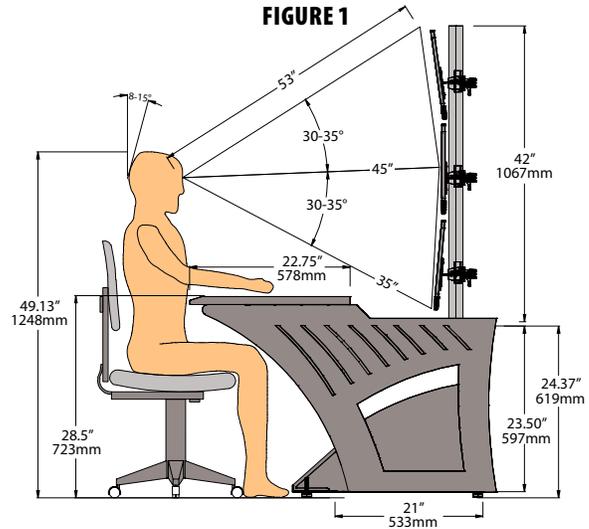
The vertical and horizontal eye and head movement diagrams in **Figure 1 & Figure 2** demonstrate best viewing angles for an operator. Ideally, there is no head movement and minimal eye movement for the most important and most common tasks. In the design of a console it is necessary to determine if the workstation will be used as an isolated unit or in conjunction with overview displays or other workstations. The height of the console should be calculated so the smallest operator can see over the top of any mounted electronics to remote monitor walls or displays, and the clearance beneath the worksurface should allow for the tallest operator to sit comfortably. The maximum eye height of the shortest 5 percent of operators may be as little as 42", depending on the range of chair adjustment.

Physical layouts should accommodate the use of non-electronic equipment and documents, such as operations manuals, log books, maps, and clipboards. An element of flexibility should also be allowed for positioning such items as telephones, keyboards, mice, controllers radio/intercom and writing areas. This will enable operators to change posture during their shift and minimize the effects of fatigue.

FIGURE 1

FIGURE 2

■ 15° - Ideal Eye Movement
■ 35° - Maximum Eye Movement
■ 60° - Maximum Head Movement (Ideal Movement is 0°)
■ 95° - Maximum Eye and Head Movement

DISPLAYS/MONITORS

When using the top-down approach to designing display layouts, start with management objectives rather than attempting to see how many monitors can surround an operator. Keep in mind that the amount of information that an individual can handle is limited. Maximizing operator performance requires that the designer knows the amount of activity associated with each monitor image and the size of detail, both of which affect the detection of significant events. Even with as few as four monitors, accurate activity detection in a busy environment decreases to 83 percent .

Displays that are used for close image inspection should be positioned directly in front of the operator, with sizes typically ranging from 19" to 24". Displays outside the workstation and positioned at a greater distance or behind the console should range in sizes from 24" to 42" and larger.

The introductions of flat-panel displays and touch-screen technologies have had a significant impact on console design. Large cathode ray tube (CRT) monitors have been replaced with flat-panel screens that take up considerably less space, reduce power consumption, and require less cooling within the console. Every year he resolution, refresh rate, and size of LCD screens increase on a per-dollar basis. Today, it is difficult to find displays with native mode resolution as low as the long standing VGA standard of 640 x 480 pixels. More commonly, today's displays range from 800 x 600 (SVGA) to 1280 x 1024 (SXGA), 1600 x 1200 (UXGA), or even greater.
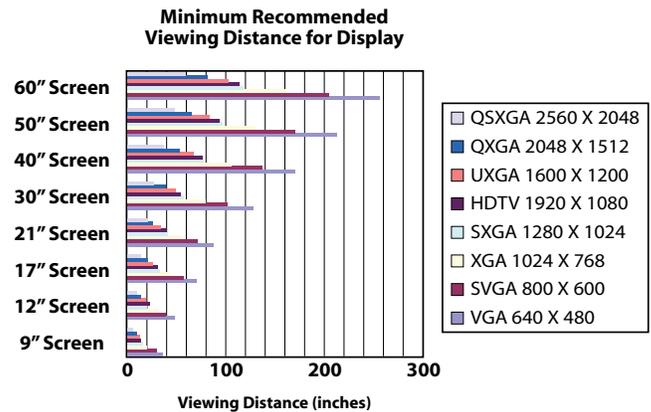
DISPLAYS/MONITORS CONT.

When screen resolution increases, it means the operator can get closer to the display and still not be able to detect the individual pixels. Still, it is important to keep in mind that there are practical limits to the size of displays. A quick rule of thumb for viewing video images is that the operator should be at least twice the distance from the screen as the height of the largest image displayed (not the display itself), but not more than eight times. The sweet spot is four to six times, depending on text (closer) or video (farther) images. A more precise set of guidelines, based on screen diagonal size and image resolution, is explained in **Figure 3.** To calculate display width, remember that today's displays often employ a 16:9 aspect ratio. Using a 9:16:18 ratio (height: width: diagonal), the width of a 20" diagonal screen will be 18" and the height will be 10". Moderate to high-resolution monitors ranging from 19" to 24" diagonal measurements are typically appropriate for primary displays.

Touch-screen technology is also affecting the ergonomics of new console designs, especially in high-security or high-attention environments. While touch screens are not used in many applications, new studies show that when some operators get extremely nervous or come under high stress, they have trouble finding and clicking on an icon using a mouse. But typically they have less trouble pointing with their finger to an element on a touch screen. As a result, touch screens are becoming more and more prevalent in high-stress, control room applications. However, consoles incorporating touch-screen technology must offer a shorter distance between the operator and the screen - typically less than 28" from the edge of the console worksurface - so that the screen can comfortably be touched from a relaxed sitting position.

Whatever the hardware interface, the ideal is a design in which operator attention is focused on a single source of vital information relevant to each situation. To minimize head and extreme eye movement, the primary images to be viewed, whether displayed locally or on a distant video wall, should be centered within a 30 degree cone. To calculate the minimum distance, multiply the width of the display times 1.87. Thus, using our previous 9:16:18 example, a 20" diagonal display will have a width of 18", meaning that the minimum distance from the display should be 34", which is slightly less than the sweet spot calculation of four times the image height of 10".

FIGURE 3

Minimum Recommended Viewing Distance for Display

Legend:
- QSXGA 2560 X 2048
- QXGA 2048 X 1512
- UXGA 1600 X 1200
- HDTV 1920 X 1080
- SXGA 1280 X 1024
- XGA 1024 X 768
- SVGA 800 X 600
- VGA 640 X 480

Screen sizes: 60" Screen, 50" Screen, 40" Screen, 30" Screen, 21" Screen, 17" Screen, 12" Screen, 9" Screen

X-axis: Viewing Distance (inches) — 0, 100, 200, 300

CONTROL ROOM LAYOUT

Issues to consider when designing console placement in the control room include the room's dimensions, the number of stations, the dimensions of each station, the dimensions of any video wall, and the width of the aisles.

The distance from which to view a large-screen display or group of displays should not be less than twice the display's largest image height or greater than 6 times its height for normal video. However, if this is a primary monitor for the operator, where it should fit into the 30 degree cone of viewing, then the longer-range formula of screen width x 1.87, should take precedence.

As an example, consider a console that is 42" deep, and aisles that are also 42" wide between rows of consoles, for a total of 84". If the plan is to use one 80" diagonal display with 4:3 aspect ratio, here is how you would calculate the room layout:

The first row of operators will be 10'0" from the front (1.87 times the 64" width of a 80" diagonal screen).

The back row will be no more than 31'0" from the front (6 times the 64" width of a 80" diagonal screen). Be sure to add the last 42" aisle for a total depth of 34'6".

This will permit a maximum of four rows of consoles and three aisles, to keep within the maximum distance. To calculate the maximum width of each row with adequate viewing angles from each position, the first row at 120" deep may be up to 14'8" wide (2 x (distance from front - half the width of one screen) or 2 x (120 - 32)). The second row at 204" (102 + 84) may be up to 28'8" wide. The third row at 288" (120 + 84 + 84) may be up to 42'8" wide. The fourth row at 372" (120 + 84 + 84 + 84) may be up to 56'8" wide.

Alternatively, you might be asked to determine the proper size for a large screen display, given certain room dimensions. The same formulas apply.

A command control room should be designed for more than just day-to-day operations. You need to consider every situation in the initial design and for future upgrades. Enough space should be maintained in and around the console so that multiple groups of personnel, from supervisors to security professionals, emergency service personnel, or even government officials, can view and analyze information quickly and efficiently. Design for crisis - hope for routine.

ENVIRONMENTAL DESIGN

The provision of an appropriate working environment is essential for control rooms that must accommodate auditory or visual tasks. Where speech communication is important, all auditory needs of the environment must be appropriately specified. Ambient noise levels need to be controlled by considering such factors as room and console finishes, noise output of equipment, and control of external sources of noise. Ceiling acoustics should strive to achieve an NRC (noise reduction coefficient, a measurement of sound absorption characteristics) of 0.65 to 0.75 or better and an AC (articulation class, a measurement of sound attenuation) of 40 to 44 or better.

Air quality and air temperature can play an important part in keeping operators awake and alert. One of the most common criticisms of control room design is a lack of consistent ambient temperature. An example of how environmental design can contribute directly to operator performance is an air-conditioning system that is automatically set to increase the ambient temperature to compensate for natural early-morning drops in body temperature. Room temperature should range from 70 degrees to 72 degrees F, with relative humidity from 40 percent to 65 percent and minimal air movement not exceeding 4" to 6" per second.

To maintain the most consistent operator environment, a separate equipment room should be provided to house CPUs, servers, and other rack-mount equipment. This will remove the biggest sources of heat from disk arrays and processors and noise from cooling fans from the operators' area. It also has the benefit of locating the most sensitive equipment in a secure, limited access area that is designed for proper cooling.

Wherever extensive arrays of displays are used, lighting within control rooms should be sufficient and suitable for all visual tasks. A lighting scheme largely based on indirect ambient lighting, where the ceiling reflects light down into the room, has been found to offer an effective solution. In designing a lighting scheme, attention needs to be given to the range of tasks undertaken as well as the ages of the operators. Low levels of lighting may be fine for image monitoring but can pose problems with paper-based tasks. Operators of all ages, but especially older workers, will require adjustable task lighting to conduct small-scale visual tasks.

Ceiling materials should offer moderate to high reflectance of 0.8 or more to improve light distribution throughout the room and reduce energy costs for lighting. Walls should be an off-white matte or flat finish with a reflectance range of 0.5 to 0.6. Floor materials should have a lower reflectance of 0.2 to 0.3 for carpet or 0.25 to 0.45 for floor tiles.

Operators typically do not like working in windowless environments. Unless prescribed for operational or security reasons, it is strongly recommended that north-facing windows be included in a control room, primarily for psychological reasons. However, such light sources also pose potential security challenges and can contribute to reflections and glare. Windows and doors should be off the primary field of view but visible from a seated position. Allow circulation space around doors to minimize congestion.

A rectangular room provides the most possible options for equipment, display, and console positioning. In general, rooms with sharply angled walls or with support columns should be avoided. Designing a control room of the right size and shape can go a long way toward achieving an efficient, comfortable operating environment.

OPERATOR CONSIDERATIONS

When designing a control room, the following steps should be taken to ensure operator comfort and safety:

- *Test console layout with users for "Human Tasks" including sequential task simulations. If necessary, modify console layouts based on trial feedback.*

- *Develop workstation layouts designed around acceptable reach zones and visual limitations.*

- *Take into account maintenance requirements and removal of equipment from both the rear and front of the workstation.*

- *Provide ergonomic footrests where appropriate.*

- *Provide 24/7 chairs with full adjustment capabilities.*

- *Reduce excess heat and noise by locating electronics in an equipment room.*

- *In workstation dimensions, consider the full height range and size range of the users, utilizing height adjustment work surfaces where appropriate.*

REFERENCES

CCTV Control Room Ergonomics, E Wallace & C Diffley, PSDB Publication No 14/98.

The Ergonomics of Closed Circuit Television (CCTV) Systems, 1997, Proceedings International Ergonomics Association Congress.

ISO 11064 - Ergonomics Design of Control Centers.

CCD Design & Ergonomics Ltd
Bank House
81 St Judes Road
Englefield Green, Egham, Surrey, TW20 0DF

Taking Control, J Wood, CCTV Today, Volume 4, Number 2.

The Changing Face of Console Design, Neal Linnihan
615 1st Avenue NE
Minneapolis, MN 55413

We have addressed a few ergonomic considerations, but for the complete resource, refer to: Ergonomic Design of Control Centers, which is the International Standard
ISO 11064.