HUMAN FACTORS

PLANNING AND DESIGNING OF A CONTROL ROOM

THE EVOLUTION OF CONTROL ROOM DESIGNS

The advent of new technologies, updated ergonomic standards, and growing public awareness of workplace health have collectively spurred a significant transformation in control room design and subsequently the console design. Modern control room furniture are now more compact, functional, and visually appealing compared to previous iterations.

An ergonomic approach to incorporating consoles into a control room layout should aim to meet the performance goals set for the space.
It should consider every element of interaction between humans, machines, and the environment. This includes aspects like raised flooring, room dimensions, acoustic considerations, indirect lighting, and the overall well-being, health, and safety of each operator.

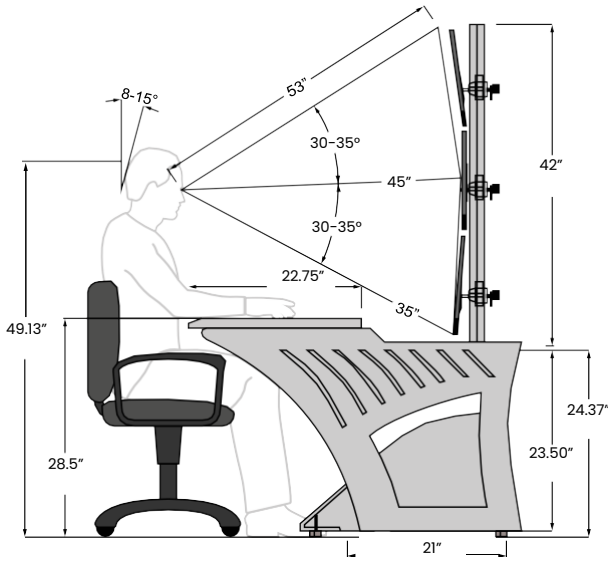
TOP-DOWN APPROACH

A top-down approach establishes a framework to ensure that the operator's limitations and requirements are what determine every other decision regarding equipment selection, operating practices, work environments, and furniture choices. Regardless of how well-designed a workstation is or how grand a piece of furniture looks, the entire system can fail if operators are overwhelmed, performing tasks they are inadequately trained for, or struggling to read unclear displays. By adopting a top-down approach, operator limitations are inherently considered, reducing potential mismatches between their capabilities and the system's demands.

The international standard known as ISO 11064 is the backbone of ergonomic design of control rooms. The essence of this approach is to ensure that the designs are user-centered.

The top-down approach begins by clearly defining the goals of the control center for various control room scenarios, including normal, off-normal, emergency, outage, and startup conditions. Next, identify the necessary systems to handle these conditions. Then, determine which tasks are best performed by machines (such as repetitive calculations) and which are better suited for human operators (such as handling unexpected situations). This process will establish system specifications for computers and outline the tasks for human operators.

Technological advancements are not only driving the evolution of console design but also enhancing their aesthetics. The advent of digital technologies, system integration, and flat-panel displays has allowed console manufacturers to create a diverse range of consoles with smaller footprints. At the same time, manufacturers are gaining deeper insights into how people utilize control rooms. By sharing this knowledge with architects, they ensure that ergonomic considerations are incorporated into the overall control room environment as well as the consoles themselves.



Well-designed control rooms strike a balance between efficiency and ergonomics. At CTF, our goal is to create and develop the best consoles in the world. Since our founding in 2016, we have led the control room console design industry in the UAE and are now expanding rapidly across the GCC. Our range of consoles fits any control room setup, and our expert team conducts ergonomic studies to design and deliver the ideal console for each client's specific needs.

CTF has re designed is entire range of consoles in 2024 for better ergonomics and aesthetics to meet the changing industry demands. CTF is also focusing on redesigning supporting accessories and on a remote-control room console management platform- C- Control TM, taking user comfort to the next level, preparing itself for the future of design and technology.

This paper focuses on educating the reader on:

1. Understand basic concepts of control room design, console configuration and placement.

2. Understand basic criteria for ergonomics.

3. Be familiar with the criteria that leads to both comfort as well as efficient operations as a function of the console in a control room.

UNDERSTANDING ERGONOMICS IN CONSOLE DESIGN

Ergonomics examines the relationship between workers and their environment, focusing on human factors. The original console standards, established in the 1960s, have been updated to incorporate advancements in technology and improved understanding of how our head, neck, and eyes.

Past ergonomic studies were conducted with individuals in a "sitting tall" position, where the hips, shoulders, and ears aligned vertically. However, this posture is unrealistic and uncomfortable, especially for an eight-hour shift. With a better understanding of how the neck, head, and eyes function, today's ergonomic standards are based on more realistic assessments of how operators actually work at consoles.

Recent ergonomic studies show that when sitting in a relaxed position, our heads tilt forward approximately 8 to 15 degrees, with a viewing angle of minus 30 to 35 degrees. We prefer an average viewing distance of 30" to 35" from the screen, depending on its size. As a result, newer consoles are designed to lower the target angle of primary viewing displays.

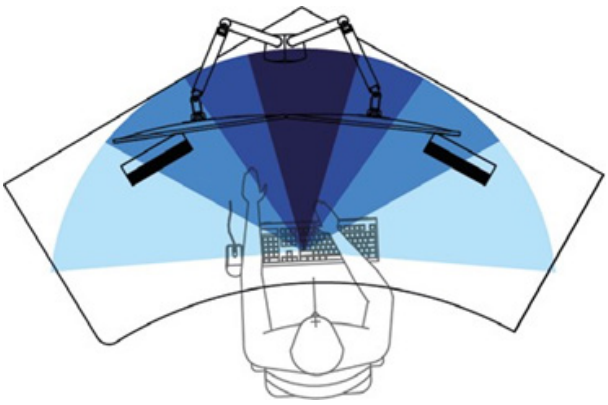
The average minimum viewing distance is influenced by three key factors:

- Eyesight Accommodation: This is the distance at which our eyes focus when there is no specific object to focus on. The eye muscles need to work 2 1/2 times harder to focus at 12" screens compared to 30" screens, leading to eye strain.

- Convergence: This occurs when the eyes turn inward

The solutions to problems arising from eyesight accommodation, convergence, and depth of focus are similar and include:

- **Lowering Monitor Height:** This adjustment helps reduce strain on the eyes and neck.
- **Maintaining Consistent Viewing Distances:** Keeping items and screens at similar distances minimizes the need for frequent focus adjustments.
- **Proper Display Angles:** Positioning displays at the correct angle to the line of sight reduces eye strain.
- **Enhancing Task Lighting:** Increasing lighting on printed materials aids in clearer visibility.
- **Increasing Text Size:** Larger text reduces the strain on the eyes.
- **Task Variation:** Changing tasks periodically helps prevent fatigue and strain.



15° Ideal Eye Movement
35° Maximum Eye Movement
60° Maximum Head Movement *(Ideal Movement is 0°)*
90° Maximum Eye and Head Movement

Accommodation and convergence are both improved when the gaze is lowered. The average resting point of convergence is 35” at a 30-degree downward angle, 45” at a horizontal angle, and 53” at a 30-degree upward angle. This data strongly supports the practice of lowering monitor heights.

When designing a console, it's necessary to determine whether the workstation will function as an isolated unit or along with overview displays. Key considerations include:

- **Visibility:** The height of the console must be calculated so that the shortest operators can see over any mounted electronics to remote monitor walls or displays. This ensures that all operators have a clear line of sight.
- **Comfort:** The clearance beneath the work surface should allow the tallest operators to sit comfortably, avoiding any ergonomic strain.
- **Height Adjustment:** The maximum eye height of the shortest 5 percent of operators may be as low as 42”, depending on the range of chair adjustment. This factor should be taken into account to ensure optimal visibility and comfort for all users.

Physical layouts should accommodate the use of non-electronic equipment and documents, including operations manuals, notebooks, and clipboards. Flexibility in positioning items such as telephones, keyboards, mice and writing areas is crucial. This flexibility allows operators to change their posture during their shift, helping to minimize fatigue and improve comfort.

DISPLAYS / MONITORS

When designing display layouts using a top-down approach, prioritize management objectives over the number of monitors that can be placed around an operator. It's essential to recognize that an individual's capacity to process information is limited. To enhance operator performance, designers need to understand the level of activity on each monitor image and the size of the details, both of which influence the detection of significant events.

Even with as few as four monitors, the accuracy of detecting activities in a busy setting can drop to 83 percent. Displays meant for close inspection should be directly in front of the operator and typically range from 19” to 24” in size. Those positioned further away or behind the console should be between 24” and 42” or larger.

The advent of flat-panel displays and touch-screen technology has revolutionized console design. Large CRT monitors have been replaced by flat-panel screens that save space, reduce power consumption, and require less cooling. Additionally, the resolution, refresh rate, and size of LCD screens have improved yearly, offering better performance for a lower cost. Today, it's uncommon to find displays with the old VGA standard resolution of 640 x 480 pixels. Modern displays typically range from 800 x 600 (SVGA) to 1280 x 1024 (SXGA), 1600 x 1200 (UXGA), or even higher.

Touch-screen technology is significantly shaping the ergonomics of modern console designs, particularly in high-security and high-attention environments. Although not universally adopted, research shows that operators under extreme stress or pressure often find it challenging to use a mouse to click on icons. Instead, they generally have less difficulty using their finger to select items on a touch screen. Consequently, touch screens are increasingly being integrated into high-stress control room applications.

For consoles that incorporate touch-screen technology, it is essential to have a shorter distance between the operator and the screen. The screen should typically be less than 28 inches from the edge of the console's work surface, allowing operators to comfortably reach the screen from a relaxed sitting position.

CONTROL ROOM LAYOUT

When designing console placement in a control room, several factors must be considered, including the room's dimensions, the number of stations, the size of each station, the dimensions of any video wall, and the width of the aisles.

The ideal viewing distance for a large screen display or group of displays should be at least twice the height of the largest image and no more than six times its height for standard video. However, if this display serves as the primary monitor for an operator and needs to fit within their 30-degree viewing cone, the longer-range formula of screen width multiplied by 1.87 should be used.

When designing a control room, consider a console that is 42 inches deep with 42-inch-wide aisles between rows, making a total of 84 inches. If planning to use an 80-inch diagonal display with a 4:3 aspect ratio, here's how to calculate the room layout:

First Row Placement: Distance from the Front: 10 feet (calculated as 1.87 times the 64-inch width of the 80-inch diagonal screen).

Back Row Placement: Maximum Distance from the Front: 31 feet (calculated as 6 times the 64-inch width of the 80-inch diagonal screen).

Total Depth: Adding the last 42-inch aisle results in a total depth of 34 feet 6 inches. This setup allows for up to four rows of consoles and three aisles while maintaining the optimal viewing distance.

To determine the maximum width of each row with proper viewing angles:

First Row:
Depth: 120 inches (10 feet).
Maximum Width: 14 feet 8 inches (calculated as 2 x (distance from the front - half the screen width) or 2 x (120 - 32)).

Second Row:
Depth: 204 inches
(120 inches + 84 inches).
Maximum Width: 28 feet 8 inches.

Third Row:
Depth: 288 inches
(120 inches + 84 inches + 84 inches).
Maximum Width: 42 feet 8 inches.

Fourth Row:
Depth: 372 inches (120 inches + 84 inches + 84 inches + 84 inches).
Maximum Width: 56 feet 8 inches.

A command control room should be designed to handle more than just routine operations. It's crucial to consider various scenarios from the outset and plan for future upgrades. Ensure there is sufficient space around the consoles to accommodate multiple groups, including supervisors, security personnel, emergency responders, and government officials, enabling them to view and analyze information swiftly and effectively.

ENVIRONMENTAL DESIGN

Creating an appropriate working environment is crucial for control rooms that handle auditory or visual tasks. When speech communication is vital, the auditory requirements of the environment must be carefully specified. Ambient noise levels should be managed by considering factors such as room and console finishes, equipment noise output, and external noise control. Ceiling acoustics should aim for a Noise Reduction Coefficient (NRC) of 0.65 to 0.75 or higher and an Articulation Class (AC) of 40 to 44 or better to ensure effective sound absorption and attenuation.

Air quality and temperature are critical for maintaining operator alertness and wakefulness. A frequent complaint about control room design is inconsistent ambient temperature. A well-designed environmental system can directly enhance operator performance, such as by using air conditioning that automatically adjusts to increase ambient temperature to counter natural early-morning drops in body temperature. The optimal room temperature should be between 21°C and 22°C, with relative humidity ranging from 40% to 65% and minimal air movement not exceeding 10 to 15 centimeters per second.

To maintain a stable environment for operators, it is advisable to have a separate room for housing CPUs, servers, and other rack-mount equipment. This setup removes significant heat sources, such as disk arrays and processors, and reduces noise from cooling fans in the operators' area. Additionally, it provides the benefit of placing sensitive equipment in a secure, restricted access area that is optimized for proper cooling.

In control rooms with extensive display arrays, lighting must be adequate and appropriate for all visual tasks. A lighting scheme primarily using indirect ambient lighting, where the ceiling reflects light into the room, has proven effective. When designing this scheme, consider the range of tasks and the ages of the operators. Low lighting levels may work for monitoring images but can be problematic for paper-based tasks. Adjustable task lighting is essential for operators of all ages, especially older workers, for small-scale visual tasks.

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

Operators generally prefer not to work in windowless environments. Unless necessary for operational or security reasons, it's strongly recommended to include north-facing windows in a control room for psychological benefits. However, such light sources can create security challenges and cause reflections and glare.

Windows and doors should be positioned outside the primary field of view but visible from a seated position. Ensure there is circulation space around doors to minimize congestion.

A rectangular room offers the most flexibility for equipment, display, and console positioning. It's best to avoid rooms with sharply angled walls or support columns. Designing a control room with the right size and shape greatly contributes to creating an efficient and comfortable operating environment.

OPERATOR CONSIDERATIONS

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

- **Test Console Layouts:** Conduct "Human Tasks" simulations, including sequential task scenarios, with users. Adjust console layouts based on their feedback.
- **Develop Workspace Layouts:** Design around acceptable reach zones and visual limitations to ensure ease of use.
- **Consider Maintenance Needs:** Ensure that equipment can be accessed and removed from both the rear and front of the workstation.
- **Provide Ergonomic Footrests:** Include footrests where appropriate to enhance operator comfort.
- **Use 24/7 Chairs:** Equip workstations with fully adjustable chairs suitable for continuous use.
- **Reduce Heat and Noise:** Place electronic equipment in a separate equipment room to minimize excess heat and noise in the operator area.
- **Account for User Dimensions:** Design workstation dimensions to accommodate the full height and size range of users, incorporating height-adjustable work surfaces as needed.