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# **Design of Visual Facilities Within Collaborative Decision Environments** Alex Clark, SAIC

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#### Abstract

"How big does the screen need to be?" This was the innocent first question asked near the beginning of a deployment of multiple collaborative decision environments (CDE). Slowly, the complexity of the problem surfaced as we were forced to consider the following questions:

- What are the limits of current display technology? •
- How will people be seated in the physical space and how many seats are required? .
- What is going to be on the display? How can we use that space most effectively?

A large quantity of information exists from vendors detailing the optimum size of display and placement for a television or cinema screen. A large body of data exists for individuals using computer monitors. Each has very different usage characteristics.

CDEs created a scenario that falls between these extremes — computer display characteristics (able to clearly read data) within a group environment (like a cinema). The display itself will be divided into sections, effectively providing users with a matrix of individual computer monitors that need to be examined both individually and as a whole.

To achieve this, there was a need to go back to first principles and answer some important questions. What is 20/20 vision? What are the ergonomics of the eyeballs, neck, and body? What types of information exist and how is it visualized? The final solution needs to be deployable in the office, to locations offshore, and perhaps even in a portable environment to teams ranging from a single user to 10 or more.

This paper examines this problem and provides some methodologies about how to determine the best display for a facility and where to place users within a room so that they can see clearly the full extent of the display. It also explores how this information should be laid out to maximize the usefulness of the display area. This information should prove beneficial to future CDE designers.

#### Introduction

When considering a CDE, there are several key design decisions to be made based on the requirements of the facility and the physical constraints of the environment:

- Design within the physical space camera, desk and chair placement, display size, resolution, and positioning
- Design of the computing and network environments to allow effective data sharing and resource management in a user-friendly manner

In this white paper, the first of these will be addressed in detail.

There is a substantial body of work freely available concerning the optimum size of display and the placement of that display for an audience viewing a television or cinema screen. There is a similar body of information for individuals using computer monitors. Each has very different usage characteristics that are well documented. For instance, the distance you sit from a computer monitor is very different from the distance you and your family sit from a similarly sized television. These usage

characteristics, coupled with human factors research, provide "rules of thumb" that are used globally in the design of cinemas, living rooms, and offices (e.g., when watching television, a viewing distance of three to six screen widths is recommended; a computer monitor should be around an arm's length away from the user).

When building a CDE, a new usage scenario is created that lies between these two options — computer display characteristics are required to enable data to be read clearly; however, this data needs to be viewed within a group environment such as that found in a living room or cinema.

Before embarking on a deployment of CDE facilities within the new headquarters of an oil major, we investigated existing research and found very little hard information concerning this type of usage scenario. This led to further investigation and the generation of this white paper.

Using the existing body of knowledge on optics and display ergonomics, it is possible to establish some solid methodologies for constructing a CDE once a thorough understanding of the room and its use has been developed with the end-user community. The design will be bound by several critical factors:

- Physical space available and how it is arranged
- Number of people required to work in the CDE
- Amount and type of data that needs to be displayed at any one time

With this information in hand, it is possible to develop the most cost-effective solution that will satisfy user requirements. This design will provide:

- Screen size, resolution, and placement
- Best seating arrangement in the facility
- Best design of furniture for the facility
- Placement of other resources within the facility
- Information that will enable the software designers to best use the space available

There is no "magic bullet" solution that will fit every CDE, because the needs and constraints of every design are different. However, the methods proposed here should provide readers with enough knowledge to design a facility that is fit for purpose.

## How CDE Use Determines the Display Characteristics

In a cinema or television environment, an observer is expected to resolve the viewing area as a whole and not see the individual pixels<sup>1</sup>. Generally, the user is expected to sit far back from the screen at a point at which pixels resolve into a single moving image that can be taken in comfortably without moving the head (i.e., ideally the entire image should sit within a  $30^{\circ}$  arc).

When viewing a computer monitor, there is a desire to resolve individual pixels in order to resolve the full detail of the monitor. Graphed data on the display may use lines only a single pixel wide and need to be differentiated clearly. Therefore, there is a tendency to use higher-resolution displays with the user sitting closer to the display in order to resolve the detail. Again, it is preferred that users do not have to move their heads for ergonomic reasons.

When determining the right sort of display for a CDE, it is important to establish which usage type is most relevant to the viewer. In a high immersion visualization environment showing multiple users moving 3-D graphics of oil fields, the experience is closer to that of cinema. The usual well-understood rules apply here when determining screen size and resolution. However, as soon as users are expected to read static text or points on graphed data, we move closer to the "computer monitor" scenario.

This results in a dichotomy when involving multiple users — we require the size of a cinema display with the resolution and perceived pixel size of a computer display. In recent years, this technology has become available for a reasonable cost and is one of the driving factors towards creation of useful collaboration spaces.

<sup>&</sup>lt;sup>1</sup> A pixel is a single point on a graphics display — the smallest colour-changing element available on a monitor. When a display is described as having a resolution of  $1280 \times 1024$ , it means it has 1280 pixels horizontally by 1024 pixels vertically, yielding a total of 1,310,720 pixels over the whole screen area.

When we talk about a collaboration space within a CDE, typically we are looking at a large screen broken up into multiple areas, each containing a piece of data to help a team resolve a problem. In effect we have an array of subscreens, each of which should obey the rules for viewing a computer monitor:

- User is able to resolve close to pixel level.
- User does not have to move head when viewing information on subscreen.
- User is allowed to move head when viewing other subscreens (but subscreens should be designed in a way to • minimize this effect)

There is no simple method for determining the content of these screens. The CDE project needs to embark upon an extensive requirements gathering exercise to establish which work processes will be managed through the use of a CDE. Once these have been established they need to be further broken down to provide:

- The information and data required to reach a decision
- The people who need to be involved in the decision making process and where these people are likely to be located

With this information it is possible to create a series of screen mock-ups for review by the user community, an indication of room size and if there is a requirement for video conferencing. Figure 1 shows a typical screen mock-up at this stage of design.



Fig. 1 shows a typical CDE collaboration screen layout.

Fig. 1 — CDE example.

In Fig. 1 the central image is the data currently under discussion, with relevant companion information laid out around it to help form a decision — in this case with an offshore team on a video link.

We do not require to resolve the full image at once; we just need to be able to resolve each subscreen clearly (five here, one large and four small) and flick our vision between them as necessary. The smallest of these is approximately one-eighth the total pixel space and serves as a good guide when designing a CDE display system.

Each subscreen must have the resolution needed to display the full extent of the data, but each needs to have a sufficient pixel size to be seen clearly by all users in the room — a formidable but resolvable task because these two factors are often at odds with each other.

#### **Resolution Versus Distance**

In an ideal world, a screen within a CDE would cover the wall and provide an "overly high resolution" that you would resize using software for a comfortable viewing experience. Within the next 10 years, this type of technology will be available at a reasonable cost, but in the short- to medium-term there is a trade-off to be made to provide an experience as close to this ideal within a cost-constrained environment.

When assessing the financial impact of display technology, two factors impact cost significantly:

- The larger the screen, the higher the cost
- The higher the resolution, the higher the cost

If a large, high-resolution display is required, costs escalate quickly to unreasonable levels.

Any pixel smaller than the human eye can comfortably perceive is effectively a waste of money. The perceived pixel size is a factor of pixel pitch of the display (physical size of a pixel) and the viewer's distance from the screen.

Father Ted: Now concentrate this time, Dougal. These
(he points to some plastic cows on the table)
Father Ted: are very small; those
(pointing at some cows out of the window)
Father Ted: are far away ...
Father Dougal: No sorry, Ted, I don't get it, can you show me again?<sup>2</sup>

The ability for the human eye to discern detail at a distance (such as pixels on a screen) is referred to as visual acuity.

"Visual acuity (VA) is acuteness or clearness of vision, especially form vision, which is dependent on the sharpness of the retinal focus within the eye, the sensitivity of the nervous elements, and the interpretative faculty of the brain.

"VA is a quantitative measure of the ability to identify black symbols on a white background at a standardized distance as the size of the symbols is varied. The VA represents the smallest size that can be reliably identified. VA is the most common clinical measurement of visual function. The well-known phrase '20-20 vision' refers to the distance in feet that objects separated by an angle of 1 arc minute can be distinguished as separate objects. The metric equivalent is 6-6 vision.

"In humans, the maximum acuity of a healthy, emmetropic eye (and even ametropic eyes with correctors) is approximately 20/16 to 20/12, so it is inaccurate to refer to 20/20 visual acuity as 'perfect' vision. 20/20 is the visual acuity needed to discriminate two points separated by 1 arc minute. The significance of the 20/20 standard can best be thought of as the lower limit of normal or as a screening cut-off. When used as a screening test subjects that reach this level need no further investigation, even though the average visual acuity of healthy eyes is 20/16 or 20/12."

This means if you have an individual with eyesight poorer than 20/20, that individual should be using corrective lenses of some type. Therefore, a display should be designed to satisfy the visual requirements of an individual with 20/20 vision and advise any person unable to make out the detail on the display to either sit closer to the screen or consider corrective lenses.

To cater to people with 20/20 vision in a cost-effective manner, a display system should have a resolution in which users are able to differentiate pixels with 1 arc minute of separation (1 arc minute = 1/60 of a degree) and no more. This is shown in **Fig. 2**.

 <sup>&</sup>lt;sup>2</sup> "Father Ted," Season 2, Episode 7, "Hell," by Graham Linehan and Arthur Mathews, first aired Friday, 8 March 1996.
 <sup>3</sup> "Visual Acuity," from Wikipedia, the free encyclopedia, extracted 8 November 2007,

http://en.wikipedia.org/wiki/Visual\_acuity.



Fig. 2 — 20/20 vision and its relationship to pixel pitch.

In this case, the pixel pitch (physical distance between pixels on a display) should be equal to  $1/60^{\text{th}}$  of a degree.

Using standard trigonometry: Tan  $\theta$  = Opposite/Adjacent Using Fig. 2 for reference: Opposite = Pixel Pitch Adjacent = Distance to Screen  $\Theta = 1$  arc minute =  $1/60^{\text{th}}$  of a degree =  $0.01667^{\circ}$ Therefore, the following holds true: Tan (1/60) = Pixel Pitch/Distance to Screen Rearranging this equation and resolving the math gives us Distance to Screen = 0.000291/Pixel Pitch or Distance to Screen =  $3438 \times Pixel Pitch$ In English this equates to the following: An ideal viewing distance for people with 20/20 vision should be 3,438 times the size of a single pixel. At the moment, I am writing this document on a monitor with the following characteristics: Display size 24 in. diagonal (16:10 aspect ratio) Resolution 1920×1200 Pixel pitch 0.270 mm (This has been helpfully provided on the technical specifications although it can be worked out from the

display size, aspect ratio, and resolution shown above.) Therefore, my comfortable viewing distance is 928 mm or just over an arm's length away. This is why the rule of thumb

provided to ergonomics people is based firmly on hard fact. Computer monitors vary in size and resolution, but generally they will have been designed to have a pixel pitch in the region of 0.25 mm to 0.29 mm for everyday use.

#### Choosing a Display System for a CDE

The prevalence of high-definition video sources in the domestic arena through digital broadcasts, Blu-ray, high-definition digital versatile disc (HD DVD), and game consoles has led to an explosion in very high-quality domestic video displays in the form of projectors and flat panels. Although businesses rarely use these domestic displays in a commercial environment, they use identical technologies and benefit from reduced production costs. The commercially orientated product range tends to use improved signal handling, extra ports, and better cooling for extended and prolonged use.

In space-constrained environments such as those offshore, these large flat panel displays are often a good way forward. For the rest of this paper, we will take these types of environments as examples, but the thinking can be applied equally to any kind of display system (e.g., projected or wall-mounted, single display or a matrix of displays, blended or edge-matched).

In our scenario, we will use the room shown in **Fig. 3**, a conference room offshore that needs to be turned into a CDE.



Fig. 3 — Proposed offshore CDE.

The room, its dimensions, and the number of people needing to see the display simultaneously will determine the size and resolution of the display; try to avoid the display determining any room characteristics. In this case, the requirement is that six to eight people will be involved in any meeting; however, occasionally up to 12 people may be involved. The initial requirements also have indicated that the CDE facility would need a large amount of "screen real estate" to show complex compound displays similar to those shown in Fig. 1. By experimenting with optimal resolutions, it is felt that a display in excess of 3000 pixels horizontally by 1000 pixels vertically would be able to show the information required in Fig. 1.

If we assume we will use commercial-grade flat panels in this room, we could satisfy the demands for screen real estate by using a pair of 1920×1080 panels ("1080p" in HD terms) sitting side by side. However, there is an acknowledgement that the proposed screen shot shown in Fig. 1 would have to change considerably, because it would be split down the middle with the monitor bezels. If this is not acceptable, then edge-matched or edge-blending projectors would be the preferred solution. In this example (to demonstrate the full design process), we will assume that the user community will accept a pair of liquid crystal display (LCD) or plasma panels.<sup>4</sup>

<sup>&</sup>lt;sup>4</sup> The choice between LCD or plasma is usually one of personal preference. Modern versions of both display types are very similar, although it is worth looking at image quality, power consumption, heat generation, and expected lifespan to help make a decision.

At this stage, it is a good idea to look at the optimal viewing distances of some common panel sizes to determine a good starting point, with the knowledge that the screens will be wall-mounted and the room is 6 m across.

**Table 1** shows the optimal viewing distances for users to be able to clearly differentiate individual pixels at these with 20/20 (6/6) vision.

Screen Size (16:9)	H Size	H Size (mm)	H Resolution	Pixel Density (mm)	Opt View (mm)	
	(in.)					
42 in.	36.72	932.7	1920	0.48579235	1669	
47 in.	41.09	1043.8	1920	0.543624772	1868	
55 in.	48.09	1221.4	1920	0.636156648	2186	
65 in.	56.83	1443.5	1920	0.751821494	2584	

 Table 1 — Optimal Viewing Distances for Common Sizes of LCD Panels

Distances much greater than this will mean pixels will start to merge together in the eyes of the average viewer. Distances much smaller will create inconvenience because viewers may have to move their heads to see different parts of the screen.

However, the nature of a CDE means that the screen will be broken up into many smaller subscreens, each containing a piece of information. One of these will hold the viewers' attention until they choose to look at a different piece of information on the screen, which may result in them moving their heads. Therefore, it is possible to site users far closer to the screen than would be normal in a living room or cinema.

Looking at Table 1, it is clear we will use the larger screens to satisfy our requirements offshore.

#### So What Is the Best Viewing Distance Range?

If the figures in Table 1 are "centre range," then viewer comfort will be a factor on either side. In the calculations above, we are determining the "finest detail" observable by someone with 20/20 vision, and we have three factors that work in our favour:

Most people have better than 20/20 vision, even with corrective lenses.

Most data viewed on the screen will not use the "finest detail" available (e.g., fonts and diagrams).

Much of the data will not require the user to resolve every pixel (e.g., video and graphic images).

Computer fonts are designed so that most screens are still readable even when you cannot resolve all the pixels. This is because fonts generally are made up of more than "single pixel lines" and use features such as antialiasing to produce an easier-to-read font even on relatively low-resolution displays. It is reasonable to assume that the majority of static data on a CDE subscreen will use this type of font. This gives us some leeway on either side of the optimal viewing distance based purely on pixel size.

Fig. 4 is a captured screen image showing a "default" font size within a word processor at 100 percent scaling.

Arial @ 8pt Arial @ 10pt Arial @ 12pt Arial @ 14pt Arial @ 16pt Shown @ 96dpi (Windows Default)	Γ	
Arial @ 8pt Arial @ 10pt Arial @ 12pt Arial @ 14pt Arial @ 16pt Shown @ 96dpi (Windows Default)		Arial @ 6pt
Arial @ 10pt Arial @ 12pt Arial @ 14pt Arial @ 16pt Shown @ 96dpi (Windows Default)		Arial@8pt
Arial @ 12pt Arial @ 14pt Arial @ 16pt Shown @ 96dpi (Windows Default)		Arial @ 10pt
Arial @ 14pt Arial @ 16pt Shown @ 96dpi (Windows Default)		Arial @ 12pt
Arial @ 16pt Shown @ 96dpi (Windows Default)		Arial @ 14pt
Shown @ 96dpi (Windows Default)		Arial @ 16pt
		Shown @ 96dpi (Windows Default)

Fig. 4 — Fonts as displayed on a monitor (actual size).

A closer look at these fonts reveals several features. **Fig. 5** shows this same screen capture but magnified significantly. Very small fonts are rendered in multiple colours that fool the eye into resolving an easy-to-read font despite not having enough pixels to display it entirely. Larger fonts use multiple pixels in each letter stroke. Both of these features have the effect of making text easier to read when displayed on screens with sub-optimal resolution by utilising this feature – called anti-aliasing.



Fig. 5 — Fonts as displayed on a monitor (zoomed in).

In a simple experiment using Word, we determined that you can still view documents at 60 to 70 percent scaling using the optimum distance data previously calculated. When the document is scaled down to 50 percent, the text started becoming unreadable.

With this information, we can assume that users can read text on a display if it is between 60 and 100 percent of the "optimum size." On the other side of this optimum range, users can read fonts between 100 and 140 percent of their original size. Applying this factor means that a display could still be read clearly in the range of distances shown in **Table 2**.

Screen Size	Opt View (mm)	Max View (mm)	Min View (mm)
42 in.	1669	2782	1002
47 in.	1868	3114	1121
55 in.	2186	3644	1312
65 in.	2584	4306	1550

 Table 2 — Range of Optimal Viewing Distances for Common Monitor Sizes

Again we are showing a range of commercially available flat panels as examples. The same rules hold for any display medium including front and rear projection systems.

#### Visual Fields and User Position Related to Screen

When viewing data on a CDE screen, another important factor is the user position relative to any point on the screen. Viewing a screen at an angle that is too oblique will cause the apparent pixel size to diminish or cause the user to move their heads in a way that could become uncomfortable. Taking into consideration the optimum horizontal visual field of an observer allows us to determine two factors:

- Eye rotation determines the maximum size for a single subscreen on the main CDE display, the area on which users will be concentrating at any one time.
- Head rotation determines the maximum size of the whole display, the area over which users can comfortably turn their heads to concentrate on a new area of interest.

Fig. 6 shows these ergonomic factors in diagrammatic form.



Fig. 6 — Optimum vertical and horizontal visual fields.<sup>5</sup>

The eye rotation limits on a subscreen present a software issue for the work space designers — any single piece of information on the display must minimize head rotation by maintaining it within a 30-degree arc of the viewer closest to the screen.

For this paper, we will assume that "optimum" head and eye movement is 50 percent of maximum to avoid potential strain to eyes and neck:

- 15 degrees either side of straight ahead for eye movement
- 30 degrees either side of straight ahead for head movement

This provides a combined 90 degree viewing arc (45 degree either side of straight ahead). We also will assume that the viewer seating is facing the centre of the screen. Furniture may have to be provided to facilitate this seating arrangement, including swivel chairs to allow total body rotation, providing viewers the ability to interact with each other in the room and take notes on a writing surface.

<sup>&</sup>lt;sup>5</sup> Sourced from the Human Factors Research and Engineering Group for the Federal Aviation Administration.

# Determining the Optimum Viewing Space in a CDE

Taking all of these factors into consideration, we have the following:

- Optimum viewing range
- Optimum viewing arc

Together, these provide an optimum viewing template, shown in Fig. 7.



Fig. 7 — Optimum viewing template.

Rather than overlay this viewing area on each seat in the room, we will drop the viewing arc into the room twice — one at either end of the screen (at the centre point of a likely subscreen) — to highlight the optimum viewing areas in the room. Large screens can present a problem in that viewers on one side of the room are too far away, so in this way we define several viewing zones.

Fig. 8 shows the methodology we will adopt for choosing the best seating areas.



In Fig. 8, the screen can be a single display or a composite display made up of several screens. The zones within the diagram depict the viewers' ability to see the screen from the proposed seating position:

- Zone A is the sweet spot; anyone located there will be able to see all parts of the screen clearly.
- The two **Zone Bs** are fine for viewing one side of the screen, but viewers will have difficulty seeing the opposite side. People with poor eyesight may have problems.
- In Zone C, viewers will be unable to see any of the screen clearly, so you do not want to place seating there.

#### A Worked Scenario

In Fig. 3 we were provided with a conference room offshore that must be converted to a CDE through the addition of a screen, video cameras to provide videoconferencing links, and seating for six to eight people. As we discussed the detailed room requirements with the user community, we determined that there was a need for a large video canvas to display several information sources similar to those shown in Fig. 1.

When estimating the resolution needed to display this information in a meaningful way, we determined that we needed in excess of 3000 pixels horizontally by approximately 1000 vertically. Looking at the available equipment on the market, we

determined this would best be met through a pair of 1080p screens mounted side by side. These have a native resolution of  $1920 \times 1080$  pixels, providing a combined resolution of  $3840 \times 1080$  pixels — more than adequate for our anticipated needs.

Due to the remote location, we decided that LCD or plasma screens would be preferred to projectors because they tend to require less servicing (e.g., lamp replacement, colour correction, alignment) and less space than a rear projected solution. However front facing projectors may be the only option if we require a larger screen than can be supplied using a flat panel.

Initially it was suggested that we install a pair of 47-inch 1080p flat panels to provide a cost-effective solution. Using the information and data, we determined the optimal viewing arc for these types of screens and further determined that it is possible to overlay them onto a scale diagram of the room, then place furniture in the space to determine viewing characteristics. This is shown in **Fig. 9**.



After overlaying the table and chairs onto the room diagram, it is possible to rate the viewing experience in each seating position. Green shows a good seating position from which to view the whole screen area (corresponding to Zone A in Fig. 8). The orange seating is not optimal because it is on the edge of comfortable viewing and generally falls within Zone B. The remaining seating, which is colour-coded red, corresponds to Zone C in Fig. 8 and would be problematic for all but the best eyesight.

In the example in Fig. 9, it is clear that the screens are not large enough for the desired audience. Fig. 10 shows the same room and seating but with larger 65-inch panels.



In Fig. 10 the panels have the same resolution as before  $(1920 \times 1080)$ , but they are larger and therefore have a more favourable pixel density for viewing at a distance. In this case, six seating positions are within the optimal range and a further two seats are on the edge of comfort. This would satisfy the project requirements. However, the table design should be addressed at this stage. Each person is aligned in front of someone else; users of the room would be tempted to push back their chairs to get a better view of the screen.



Fig. 11 — Proposed offshore CDE with alternate table design.

**Fig. 11** shows an improved table design to prevent users of the room from blocking one another's view, while providing optimal seating positions to enable viewing the whole of the screen. Here we can seat six to 10 users, and we can add extra chairs to the optimal viewing zone to handle any temporary overflow. With the physical design of the room finalized, there is a need to look at the other facilities the room will require.



**Fig. 12** introduces a whiteboard and videoconferencing cameras. Video camera positioning is an important consideration. In this case we need two cameras at the front of the room to maintain full coverage of all likely attendees. The camera to the left of the screens usually will be focused on the attendees to the right, and the right-hand camera will focus on those to the left of the screen. If cameras with pan-tilt-zoom functionality are used, then it would be possible to keep one on the meeting attendees and focus the other one on the whiteboard towards the rear of the room.

An additional camera in the rear of the room is very beneficial. Attendees at the other end of the videoconferencing link are able to have a view of the proceedings that is similar to that of an attendee within the room. Providing remote attendees a view of the screens within the room ensures that all meeting participants can see the screens when sharing content between CDEs. Without this, you get the inevitable questions (e.g., "Okay, I have brought the spreadsheet up on the screen ... can you see it on your end?") that break the free flow of ideas and undermine the effective use of this type of facility.

One final design consideration is the actual layout of information on the screens to maximize clarity to the largest number of people in the CDE.

In Fig. 1, we presented an example screen layout based on the room's usage scenarios. This assumed a continuous unbroken display; however, in our design we have used two screens side by side, leaving a gap of two monitor bevels down the centre of the display. This is shown in **Fig. 13**.



When purposing data for this type of screen arrangement, it is best to consider the displays as two separate screens to avoid information being broken across the gap between the screens. Even if there is no gap (e.g., as a result of using edge-matched projectors), computers still see the large display as multiple screens, and some applications do not work correctly on more than a single screen.

Looking back at Fig. 7, we know that a single subscreen should be no larger than one-third of the total display to avoid the ergonomic impact of unnecessary head movement. So in this scenario, to avoid the gap between monitors our ideal width for a sub-screen should take up between half and two-thirds of a single screen (i.e. between a quarter and one-third of the whole display)

Taking these factors into consideration, the minimum screen size should be no smaller than one-quarter of one screen, giving  $960 \times 540$  pixels; a smaller screen is impractical. This is comparable to an older projector ( $800 \times 600$ ) or a high-quality TV/DVD signal ( $720 \times 576$ ).

From these constraints, we can recommend screen layouts that would work effectively in this environment. **Fig. 14** shows some of the proposed screen layouts that are possible, providing enough flexibility for all eventualities.

Basic Display:	1	2	]		
Recommended Screen E (with ratios)	lements:	16:9 large		16:9 small	
		8:9			
		32:9			
Example Displays Preset	s:				
Simple:	1 2	3 4	1 3	2 4	1     2     3     4       5     6     7     8
Combination:	1	2 3	1	2 3	1 2 3 4 5
	1	2 3 4	1 2 3	4 5 6	1 2 3 4

Fig. 14— Recommended screen layouts.

The screen has been positioned and sized for the room, so all users should be able to see the whole screen space clearly. However moving seats, adding extra participants or users with poor eyesight who are placed at an oblique angle to the screen may have difficulty seeing the far edge of the screen.

This is taken into consideration when designing CDE screen content; certain content can be placed in certain areas of the screen to maximize effective viewing by the largest number of participants in the meeting. Fig. 15 shows the screens again with the edge areas highlighted (in orange); these should be used for content in which a pixel-perfect view is not required.



Fig. 15 — Placing content on a CDE screen.

In these orange areas, we should avoid

- Graphs and fine-detail diagrams
- Small type and spreadsheets

We should not avoid

- Navigation tools
- Video screens
- Large type or graphic icons

Using these guidelines, it should be possible to create an array of flexible screen layouts that can be read clearly by the majority of users in the room.

Taking the example screen in Fig. 1 and using the information and tools above, it can be refactored to better suit the environment and to maximize the ability of meeting attendees to see all content on the screen clearly.



Fig. 16 — Redesigned CDE screen to fit environment.

Fig. 16 shows the same screen shown in Fig. 1, but modified to better suit the intended environment. No data bridges the centre of the display, allowing for the monitor bevels. Detailed textual data has been enlarged and put towards the centre of the screen. Diagrammatic reference data has been pushed to the right-hand edge. The left edge shows the navigation panes and the videoconference display.

### Conclusion

Using the existing body of knowledge on optics and display ergonomics, it is possible to establish some solid methodologies for designing a CDE. To create a CDE that will satisfy all user requirements, we must develop a solid understanding of the room's use — worked scenarios of the uses of the room, the information required to make a decision, and the people involved in the decision-making process. This will provide a series of work flows for the CDE room.

With this information available, we can develop screen mock-ups (similar to those in Fig. 1) to demonstrate how things will work for the end-user community. Once mock-ups have been developed and agreed upon, we can begin to design the room.

This design will be bound by several critical factors:

- Physical space available and how it is arranged (unless you can build a room to purpose)
- Number of people required to work in the CDE (determined by the work flows being managed)
- Amount and type of data that needs to be displayed at any one time (developed through the mock-ups)

These factors can be used to determine the smallest (and therefore most economical) display technology that will be required for the CDE. Once this is determined, a seating plan can be drawn up and a recommendation made on the furniture and videoconferencing cameras provided.

Finally, once the hardware is settled, it will be time to revisit the initial screen mock-ups and refactor them for the actual screen design, because the most cost-effective solution may introduce limitations on flexibility. If properly managed, however, these limitations will not affect the effective operation of the facility.