Online Supplement to "Informing Visual Display Design of Electronic Health Records: A Human Factors Cross-Industry Perspective"

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Appendix A. Guidelines (Exact Text) From the Automotive, Aviation, and Nuclear Industries Related to Visual Display

** Note: The highly relevant guidelines from other high-risk industries identified in Table 2 are in **bold**.*

Automotive	Font Characteristics and General Notes A clear, simple, and conventional typeface with the following characteristics is used: • Open space inside and ample space between the letter forms to prevent blurring • Highly distinguishable shapes • Proportional horizontal spacing • No extended serifs (if using a serif typeface) • No internal patterning
Automotive	Abbreviations and signal words (words denoting the hazard) are presented in capital letters, or in mixed case when using fonts that maximize the text's visual angle.
Automotive	Messages are presented in mixed case, except for abbreviations and signal words.
Automotive	Width-to-Height Ratio After selecting appropriate character heights, characters have a width-to-height ratio range of 0.6 to 0.85.
Automotive	Strokewidth-to-Height Ratio Notes A strokewidth-to-height ratio range of 0.08 to 0.2 is acceptable, with 0.167 to 0.2 preferred for critical information.
Automotive	Optimum strokewidth for positive contrast (e.g., white text on a black background) is greater than that for negative contrast (e.g., black text on a white background).
Automotive	Provide sufficient display luminance and use high contrast display technologies to ensure adequate contrast.
Automotive	**The color is associated with the level of warning:** • Red is normally associated with danger or critical situations • Yellow is normally associated with caution • Green is normally associated with normal operation; however, other considerations about warning conspicuity may necessitate using a different color (see Design Issues on the next page)
Automotive	The colors that are used are compatible with symbols based on prior association, such as red for octagonal stop signs, and yellow for triangular or diamond warnings.
Automotive	**The quantity of colors used to code information is minimized; do not exceed 4 color codes.**
Automotive	The following color contrast combinations are avoided: green/red, green/blue, yellow/red, yellow/blue, violet/red.
Automotive	In some configurations, smaller display sizes can be easier to shade; however, care must be taken to ensure that other important design considerations, such as symbol size and conspicuity, are not compromised.
Aviation	Allow discrimination of similar characters. When presenting alphanumeric characters, displays shall allow discrimination of similar characters.
Aviation	Resolution for high reading speed. When high reading speed is required, high resolution monitors with at least 90 pixels per inch (90 dpi) shall be used.
Aviation	Character formation – vertical orientation. Characters in a vertical orientation should be formed from a matrix of at least 5 x 7 pixels minimum uppercase, 7 x 9 for continuous reading, 4 x 5 minimum for super/subscript or information not related to the task.
Aviation	Minimum character formation for nonvertical orientation. Characters in a nonvertical orientation should be formed from a matrix of at least 8 by 11 pixels, preferably 15 by 21 pixels.
Aviation	Character stroke width. Character stroke width should be between 1/12 and 1/6 the character height, with wider strokes preferred for positive polarity displays.
Aviation	Minimum spacing between characters. For maximum readability, characters should be separated by at least one stroke width or pixel, with two pixels or stroke widths preferred.
Aviation	Minimum spacing between lines of text. For maximum readability, lines of text should be separated by at least two stroke widths or pixels, with 50-100% of character height separation preferred.
Aviation	Character width-to-height relationship. The width of characters should be 0.5:1 to 1:1, with 0.6:1 to 0.9:1 preferred for maximizing legibility.
Aviation	Alphanumeric character and symbol size. The height of alphanumeric characters and geometric or pictorial symbols shall subtend a visual angle of at least 10 min arc for information not critical to the task or not time critical and 16 min arc for information critical to the task or when readability is important as measured from the longest anticipated viewing distance, with 22-24 min of arc preferred.
Aviation	Minimum display capability for producing characters. Displays shall be capable of producing a character height of 20-22 min of arc as measured at a normal viewing distance.
Aviation	Maintain uniform element size. The size of a display element (for example, an alphanumeric character or symbol) should not vary by more than 10 % regardless of its location within the display.
Aviation	Character height. The height of letters and numerals intended to be read should be not less than 16 min of arc, with 20-22 min of visual angle preferred at the typical viewing distance.
Aviation	Character height at longest viewing distance. The height of letters and numerals intended to be read shall not be less than 10 min of visual angle from the longest anticipated viewing distance.

Aviation	Minimize luminance variation across the display. Luminance shall not vary by more than 1.5:1 (LMax:LMin) from the center to the edge of the display.
Aviation	Provide adjustable contrast and brightness. Easy-to-use controls shall be provided that are capable of providing multiple step or continuously variable contrast and brightness consistent with the ambient environment.
Aviation	Luminance range. A control should allow the user to vary the luminance from 10% luminance to 100% luminance.
Aviation	Contrast ratio. The contrast ratio of the display foreground to background shall be greater than 3:1; a contrast ratio of 7:1 is preferred.
Aviation	Minimum contrast ratio for high ambient light. As the highest ambient light level is reached, the contrast ratio between the lowest intensity symbology and the background shall degrade to not less than 2:1 (unless a lower contrast has been manually selected).
Aviation	The luminance of black shall be ≤ 2 cd/m2 when the display luminance is set at the maximum brightness for critical displays and displays used in dark-adapted environments.
Aviation	Luminance ratio across the screen. The ratio of maximum to minimum luminance across the screen shall be not greater than 3:1. The optimum ratio of maximum to minimum luminance across the screen is 1:1, and the preferred limit is 1.5:1.
Aviation	Luminance ratio as a function of viewing location. The ratio of maximum to minimum luminance as a function of viewing location shall be not greater than 4:1. The optimum ratio of maximum to minimum luminance as a function of viewing location is 1:1, and the preferred limit is 2:1.
Aviation	Luminance ratio of ambient light to brightest image. The ratio of ambient light to the brightest part of an image shall not be greater than 1:10 for black and white images and 2:10 for images with gray scale or color, while maintaining optimum image luminance. The optimum ratio of ambient light to the brightest part of the image is 0:1, and the preferred range is 1:100 to 1:500.
Aviation	Average luminance. The optimum image luminance should be in the range of 27 to 48 cd/m2 (8 to 14 fL), with 35 cd/m2 (10 fL) preferred.
Aviation	Minimum luminance ratio for viewing charts and text. The minimum luminance ratio for viewing charts, printed text, and other line work shall be 5:1.
Aviation	Minimum luminance ratio for images with limited range of detail. The minimum luminance ratio for images that contain limited shadows and detail with a limited luminance range, such as animation or photographs, shall be 25:1.
Aviation	Minimum luminance ratio for images with a full range. The minimum luminance ratio for images that contain a full range of colors, or grays in black-and-white photographs, shall be 100:1.
Aviation	Color temperature. Each color shall have a color difference Δ u'v'≤ 0.01 when compared to Commission Internationale de l'Eclairage (CIE) u' and v' chromaticity coordinates for corresponding correlated color temperatures.
Aviation	Color uniformity. Δ u'v' shall be ≤ 0.01 for the maximum color deviation between measured active areas on the screen that are intended to maintain the same color.
Aviation	Off-axis color uniformity. Δ u'v' shall be ≤ 0.025 when it is measured at +/- 30 degrees from the center of the screen.
Aviation	RGB color settings. The display shall be able to reproduce at minimum, CIE RGB color settings of: Red: u', >.411 Red: v', >.503 Green: u', ≤ .140 Green: v', > .548 Blue: u', >.150 Blue: v', >.22
Aviation	Prevent color fringes. Displays should not have noticeable color fringes or moiré patterns.
Aviation	Chromaticity desaturation. When exposed to ambient illumination conditions of up to 6000 fc, the display primary color chromaticity shall not exhibit more than a 20% reduction in their color saturation.
Aviation	Color contrast. Color contrast should be greater than 40 ΔEYu'v' if absolute color classification is necessary, 100 ΔEYu'v' if relative color classification is necessary.
Aviation	Make displays legible under all conditions. Visual displays shall be legible under all anticipated viewing conditions.
Aviation	Evaluate through prototyping. The suitability and effectiveness of a display should be evaluated using representative tasks, users, and environmental settings before being incorporated in a new system.
Aviation	Aspect ratio. The aspect ratio of a display should not adversely impact displayed data.
Aviation	Simultaneous use. A visual display that must be monitored concurrently with manipulation of a related control shall be located so that it can be read to within required accuracy while adjusting the control.
Aviation	Group task-related displays together. All displays necessary to support a user's activities or sequence of activities should be grouped together.
Aviation	Arrange according to function and sequence. Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent.
Aviation	Locate critical displays in central visual field. Critical or frequently used displays shall be located in the central visual field.
Aviation	Arrange displays consistently. The arrangement of displays within a system shall be consistent from application to application.
Aviation	Resolution for complex symbols. Displays used for displaying complex symbols and graphic detail should have at least 100 pixels per inch (100 dpi).
Aviation	Minimize column and row linearity. Rows and columns shall be parallel and orthogonal to each other with the linearity of any column or row not varying by more than 2% of the length of the column or row.

Nuclear	Numeral and letter styles should be simple and consistent. Additional Information: See Section 1.3.1, “Alphanumeric Characters,” for more guidelines regarding lettering style.
Nuclear	When critical text merits emphasis to set it apart from other text, that text should be highlighted by bolding or brightening, color coding, or some auxiliary annotation. Additional Information: Displays should limit the use of capitalization as a coding technique because it reduces readability. A single word might be capitalized for emphasis but capitalizing an extended passage should not be used for coding.
Nuclear	A standard text display format should be used from one display to another.
Nuclear	VDU displays of textual data, messages, or instructions should generally follow design conventions for printed text. Additional Information: Adoption of familiar design conventions for text displays will permit users to rely on prior reading skills.
Nuclear	When a user must read continuous text on a computer display, at least four lines of text should be displayed at one time. Additional Information: Four lines of text are the minimum that should be displayed when the reading material is simple in content. If the content is more complex, or if a reader will need to refer frequently to previous material, then more lines of text should be displayed.
Nuclear	Continuous text should be displayed in wide columns, containing at least 50 characters per line. Additional Information: When space for text display is limited, display a few long lines of text rather than many short lines of text. Line lengths of less than 50 characters result in slower reading times, but line lengths from 50 to 80 characters do not produce differences in reading time.
Nuclear	In a display of textual material, words should be kept intact, with minimal breaking by hyphenation between lines. Additional Information: Text is more readable if each word is entirely on one line.
Nuclear	Consistent spacing between the words of displayed text should be maintained, with left justification of lines and ragged right margins. A minimum of one character width (capital N for proportional spacing) should be used between words. Additional Information: Reading is easier with constant spacing, which outweighs the advantage of an even right margin achieved at the cost of uneven (nonproportional) spacing. Uneven spacing is a greater problem with narrow column formats than with wide columns. Uneven spacing handicaps poor readers more than good readers. Full justification slows reading time and should only be used if it can be achieved by parameter spacing, maintaining constant proportional differences in spacing between and within words, and consistent spacing between words in a line.
Nuclear	A minimum of two stroke widths or 15 percent of character height, whichever is greater, should be used for spacing between lines of text. Additional Information: The specified spacing is in addition to the space used for uppercase accent marks or for lower case descenders of characters.
Nuclear	Displayed paragraphs of text should be separated by at least one blank line.
Nuclear	Text should be formatted in a few wide lines rather than in narrow columns of many short lines when space is limited by the display of graphics or other data.
Nuclear	Within a text file or table, the use of a different font style should be preferred over the use of a different size for highlighting information. Additional Information: It is often not possible to introduce into displayed text differences in type size large enough to be readily discernable.
Nuclear	Columns of numeric data should be justified with respect to a fixed decimal point; if there is no decimal point, then numbers should be right justified
Nuclear	Text to be read (except labels) should be presented using uppercase and lowercase characters. Additional Information: Reading text is easier and faster when capitalization is used conventionally to start sentences and to indicate proper nouns and acronyms. There are several exceptions, however. An item intended to attract the user’s attention, such as a label or title, can be displayed in uppercase. In addition, uppercase should be used when lowercase letters will have decreased legibility (e.g., on a display terminal that cannot show true descenders for lowercase letters).
Nuclear	A clearly legible font should be used. Fonts should have true ascenders and descenders, uniform stroke width, and uniform aspect ratio. Additional Information: Preference should be given to simple styles. Script and other highly stylized fonts (e.g., shadow, calligraphy) should be avoided. Avoid typefaces that have extended serifs, internal patterns, or stripes; are italicized, stenciled, shadowed, or 3-dimensional; appear like handwritten script or like Old English script; or are distorted to look tall and thin or wide and fat. The basic evaluation criterion for font selection should be legibility.
Nuclear	**For a given font, it should be possible to clearly distinguish between the following characters: X and K, T and Y, I and L, I and 1, O and Q, O and 0, S and 5, and U and V.**
Nuclear	The height of characters in displayed text or labels should be at least 16 minutes of arc and the maximum character height should be 24 minutes of arc. Additional Information: Character heights of 20 to 22 minutes of arc are preferred for reading tasks. Slightly smaller characters are acceptable in high-contrast panel labels (see Section 11.4.1.5, “Label Lettering”). Characters should not be larger than 45 minutes of arc when groups of characters are displayed. Minutes of arc can be converted into height as follows: Height = 6.283D(MA)/21600 where MA is minutes of arc, and D is the distance from the user to the screen.
Nuclear	For fixed (as opposed to proportionally spaced) presentations, the height-to-width ratio should be between 1:0.7 and 1:0.9. Additional Information: For proportionally spaced presentations, a height-to-width ratio closer to 1:1 should be permitted for some characters; for example, the capital letters M and W. The height-to-width ratio of a given character is the vertical distance between the top and bottom edges, and the left and right edges of a nonaccented capital letter. Some letters, however, are customarily seen as narrower than are others. For example, in a given character set, the letter I, and sometimes the letter J, appear narrower than M and 2. Lowercase letters may similarly vary in width. Accordingly, the height-to-width ratio of a given character set should be the modal character width—that is, the width that occurs most often—in the set of capital letters. These measurements are to be made at the same luminance level as the resolution measurement.
Nuclear	A 4x5 (width-to-height) character matrix should be the minimum matrix used for superscripts and for numerators and denominators of fractions that are to be displayed in a single character position. Additional Information: A 5x7 (width-to-height) character matrix should be the minimum matrix used for numeric and uppercase-only presentations. The vertical height should be increased upward by two dot positions if diacritical marks are used. A 7x9 (width-to-height) character matrix should be the minimum matrix for tasks that require continuous reading for context, or when individual alphabetical character legibility is important, such as in proofreading. The vertical height should be increased upward by two dot (pixel) positions if diacritical marks are used. If lowercase is used, the vertical height should be increased downward by at least one dot (pixel) position, preferably two or more, to accommodate descenders of lowercase letters. Stroke width should be greater than 1/12 of the character height. A stroke width may be more than one pixel wide.

Nuclear	Horizontal separation between characters or symbols should be between 10 and 65 percent of character or symbol height. Additional Information: Separation should not be less than 25 percent of character height when any of the following degraded conditions exists: (1) when character width is less than 85 percent of height, (2) when character luminance in less than 12 ft-L, (3) when luminance contrast is less than 88 percent, (4) when display is more than 35 degrees left or right of the straight-ahead line of sight, and (5) when the visual angle subtended by the character or symbol height is less than 15 minutes of arc.
Nuclear	Labels should be separated from one another by at least two standard character spaces.
Nuclear	Numeric values should ordinarily be displayed in the decimal number system. Additional Information: Maintenance, troubleshooting, or configuration tasks may use other systems (e.g., binary, octal, or hexadecimal).
Nuclear	**Leading zeros in numeric entries for whole numbers should be suppressed. Additional Information: For example, 28 should be displayed rather than 0028. A leading zero should be provided if the number is a decimal with no preceding integer (i.e., 0.43 rather than .43)**
Nuclear	A number should be displayed at the number of significant digits required by users to perform their tasks. Additional Information: Arbitrary conventions should not require that displays present more (or fewer) significant digits than necessary. The number of significant digits must be supported by the accuracy of the underlying sensors, instruments, and electronics.
Nuclear	**Numeric displays should accommodate the parameter's full range. Additional Information: The full range of the parameter means highest and lowest values that the parameter is expected to take on, under any conditions (normal or emergency operations) for the tasks the display is designed to support.**
Nuclear	All numbers should be oriented upright.
Nuclear	Coding by differences in brightness should be used for applications that require differentiation between only two categories of displayed items on a VDU and up to three on a transilluminated display. Additional Information: Brightness coding should not be used in conjunction with shape or size coding.
Nuclear	High brightness levels should be used to signify information of primary importance, and lower levels should be used to signify information of secondary interest.
Nuclear	Levels approximating 33 percent and 100 percent of the display luminance should be used for brightness coding. Additional Information: The intensities used should not be less than 20 cd/m² (6 ft-L). Intensity coding should not be used for displays with a maximum display luminance of less than 60 cd/m² (18 ft-L) or more than 100 cd/m² (29 ft-L).
Nuclear	If information must be mentally integrated, the display should use similar color codes for the information items. Additional Information: Information items may be easier to identify if a similar color coding scheme has been applied to them. This may be particularly important if the information items are spatially separated.
Nuclear	Where color is used for coding, it should be employed conservatively and consistently. Additional Information: The number of colors used for coding should be kept to the minimum needed for providing sufficient information. Once colors are assigned a specific use or meaning, no other color should be used for the same purpose. Note that the same color may be used for different purposes so long as its context of use in unambiguous (e.g., color coding high-priority alarms red and valve status of open as red). Casual, arbitrary use of colors on every display may cause displays to appear "busy" or cluttered. Casual use of color will also reduce the likelihood that significant color coding on particular displays will be interpreted appropriately and quickly by a user.
Nuclear	When a user must distinguish rapidly among several discrete categories of data, a unique color should be used to display the data in each category. Additional Information: Color coding of discrete categories (e.g., setpoint values and actual values) is particularly useful when data items are dispersed on a display. With some display equipment now providing a wide range of different colors, designers may be tempted to exploit that capability by using many different colors for coding. However, such a capability is not useful for coding discrete categories, except that it may allow a designer to select more carefully the particular colors to be used as codes.
Nuclear	When the relative rather than the absolute values of a parameter are important, gradual color changes as a tonal code should be used to show the relative values of a single parameter Additional Information: For example, in displaying tank depth, a saturated blue might be used to show the deepest point, with gradually desaturated blues to show decreasing depth. Gradual color changes should not be used when absolute values are important or to code data into discrete categories. For example, gradual color changes should not be used to indicate the level of a storage tank as it is drained or filled. Instead, a set of discrete codes indicating dangerous and acceptable levels may be more appropriate.
Nuclear	Brighter or more saturated colors should be used when it is necessary to draw a user's attention to critical data. Additional Information: Both intensity and saturation should be used to draw a user's attention to critical data. Although saturated or intense hues are useful for drawing a user's attention, their overuse will result in a display that is garish and difficult to view for long periods.
Nuclear	Colors for coding should be based on user conventions with particular colors. Additional Information: Color codes should conform to color meanings that already exist in the user's job. Color codes employing different meanings will be much more difficult to use.
Nuclear	Pure blue on a dark background should be avoided for text, for thin lines, or for high-resolution information.
Nuclear	When color coding is used to group or highlight displayed data, all of the colors in the set should be readily distinguishable from each other. Additional Information: Table 1.4 identifies the wavelengths of colors that can be easily distinguished. For example, on a light background: red, dark yellow, green, blue, and black, and on a dark background: desaturated red, green, and blue, plus yellow and white. If color coding is applied to symbols that subtend small visual angles, which makes color perception difficult, there will be a special need to limit the number of colors used. If colors are used for displaying text, care should be taken to ensure that colored letters are legible as well as distinguishable. Since the perception of color depends on ambient lighting, the use of color should be evaluated in situ under all expected lighting conditions.
Nuclear	Symbols should be legible and readily distinguishable against the background colors under all expected ambient lighting conditions. Additional Information: For adequate legibility, colored symbols should differ from their color background by an E distance (CIE Yu'v') of 100 units or more. The E distances (CIE Yu'v') are derived from the 1976 CIE UCS color diagram. As with the (CIE L*u*v) distances, caution should be used in assessing legibility for characters in colors having small luminance differences. This caution applies not only to characters in color but also to small luminance differences in background colors and for very small luminance differences between characters in color and background in color. Unusually large or small characters may lead to erroneous estimates of legibility. The elements required for the calculation are the luminance in cd/m² (Y) and the UCS coordinates (u',v') of the text and background. Equation 1.2 gives the metric.

Nuclear	When color coding is used, each color should represent only one category of displayed data. Additional Information: Color will prove the dominant coding dimension on a display. If several different categories of data are displayed, for example, in red, they will have an unwanted visual coherence that may hinder proper assimilation of information by a user.
Nuclear	**Color coding should be redundant with some other display feature. Additional Information: Pertinent information should be available from some other cue in addition to color. Displayed data should provide necessary information even when viewed on a monochromatic display terminal or hardcopy printout, or when viewed by a user with color vision impairment.**
Nuclear	Color coding should not create unplanned or obvious new patterns on the screen.
Nuclear	Whenever possible, red and green colors should not be used in combination. Additional Information: Use of red symbols on a green background should especially be avoided.
Nuclear	Simultaneous presentation of both pure red and pure blue on a dark background should be avoided. Additional Information: Such a presentation may result in chromostereopsis (an uncomfortable 3-dimensional effect).
Nuclear	Dominant wavelengths above 650 nanometers in displays should be avoided.
Nuclear	A uniform nondistracting background color should be used with a hue or contrast that allows the data (foreground) to be easily visible and that does not distort or interfere with the coding aspects of the display. Additional Information: Patterned backgrounds should be avoided. Background color can influence the way a user perceives a color symbol (e.g., shapes and lines). When a color is surrounded by another color, the surrounding color can change the appearance of the enclosed color. For example, green on a yellow background will appear bluer than the same shade of green on a blue background. Different colored backgrounds may be used as a coding method to meaningfully group information, if colors are chosen to maintain good contrast and legibility.
Nuclear	Displays should provide information at the levels of abstraction necessary to meet the operators' requirements relative to their task goals. Additional Information: Information should be presented in accord with the operator's goals and the information needed to address them.
Nuclear	The characteristics and features of the display used to represent the process should be readily perceived and interpreted by the operator. Additional Information: Coherence mapping addresses how comprehensible the representation is to the operator. Unambiguous relationships between the display and the process are of little value if they also are not readily perceived by the operators and easily understood.
Nuclear	The methods by which lower level data are analyzed to produce higher level information and graphic elements should be understandable to users. Additional Information: Users should be able to judge the acceptability of higher level information and how it relates to lower level information.
Nuclear	Displays should contain references to the values of normal operating conditions. Additional Information: With references showing normal-parameter operating values, the users are more likely to notice deviations from normal conditions. In such cases, the index might be displayed as a horizontal or vertical line, or perhaps as a reference curve of some kind. For example, a horizontal line representing normal operating conditions could be superimposed on the display.
Nuclear	**A display should include a reference index when the user must compare displayed information with some critical value.**
Nuclear	When task performance requires or implies the need to assess the currency of information within a display, the information should be annotated with time information.
Nuclear	Information that must be compared or mentally integrated should use similar physical dimensions to convey meaning. Additional Information: Physical dimensions are physical characteristics that are varied to convey information, such as indicating the magnitude of a parameter by the length of a line versus the volume of a shape. Using the same type of physical dimension to convey meaning requires less mental effort to interpret and integrate the information.
Nuclear	**Information should be displayed to users in directly usable form consistent with the task requirements. Additional Information: Users should not have to convert displayed data into another form to make it useful to the ongoing task. A user should not have to transpose, compute, interpolate, or translate displayed data into other units or refer to documentation to determine the meaning of displayed data.**
Nuclear	The display should use distinctive coding or highlighting when a user's attention must be directed to changes in the state of the system, critical or off-normal data, and hazardous conditions. Additional Information: Significant changes might include discrepant data exceeding acceptable limits or data failing to meet some other defined criteria. "Highlight" is used here in its general sense, meaning to emphasize or make prominent, and is not restricted to any particular method of display coding, such as brightening or inverse video. Highlighting is most effective when used sparingly, adding emphasis to a display that is relatively uniform in appearance except for just a few highlighted items. For some purposes, location coding (i.e., displaying important items consistently in a particular location) might be a sufficient means of highlighting, as when an error message appears in a space otherwise left blank. However, auxiliary codes may still be needed to highlight important items, even if they are positioned consistently. For example, line coding by color or bolding might be used to highlight displayed paths or the boxes or other graphic elements representing displayed states. (Color coding may be particularly appropriate in flowcharts because of the effective primacy of color for guiding the visual scanning required to trace paths.
Nuclear	Displays should use coding when a user must distinguish rapidly among different categories of displayed data. Additional Information: Graphic coding methods (e.g., symbols, boxes, underlines, use of color as a background to grouped items) can greatly aid users' assimilation of such information.
Nuclear	Displays should use meaningful or familiar rather than arbitrary codes.
Nuclear	Codes should have consistent meanings from one display to another. Additional Information: When coding is not consistent, the user's task of display interpretation may be made more difficult than if no auxiliary coding were used at all.
Nuclear	The user should have access to a dictionary that contains definitions for all display element conventions through the display or an online help system. Additional Information: Definitions should be available for all symbols, icons, and coding techniques. A legend on the display may show display conventions.
Nuclear	The system should support the user in identifying displays and indicators that should be monitored during upset conditions. Additional Information: The HSI design should help users determine where to look next within the display system for changes in information that are important to their tasks.

Nuclear	The available decision options should be displayed in logical order. Additional Information: For example, if options represent stages of a process, those stages should be listed in the order in which they would actually occur. The ordering of options should not be determined merely by the amount of space that is conveniently available to display them.
Nuclear	Labels should be uniquely and consistently highlighted, capitalized, or otherwise emphasized to differentiate them from other screen structures and data. Additional Information: The technique used should be easily distinguished from that used to highlight or code emergency or critical messages, such as by bolding, underlining, and use of capitals.
Nuclear	Digital displays should change slowly enough to be readable.
Nuclear	If users must rapidly discern directional change, digital displays should be provided with arrows to indicate the direction of change. Additional Information: Rapidly changing digital values are difficult to read, and directional indicators will help the user interpret the direction of trend.
Nuclear	**If users must evaluate the difference between two sets of data, the difference should be presented on the display. Additional Information: If it is important for the user to be aware of a discrepancy between two sets of data, the difference should be highlighted on the display.**
Nuclear	Size coding should be used only for applications where displays are not crowded. Additional Information: Size coding is achieved by varying the size of displayed alphanumerics, labels, and other symbols.
Nuclear	Highlighting should be easily recognizable and used to attract the user's attention to special conditions, items important to decision making or action requirements, or as a means to provide feedback.
Nuclear	Highlighting of information should be minimized. Additional Information: A rule of thumb for displays of nominal conditions is to limit the maximum amount of highlighting to 10 percent of the displayed information. If a large proportion of the displayed items are highlighted, the highlighting will no longer be effective for directing the user's attention.
Nuclear	A particular highlighting method should be used consistently. Additional Information: Highlighting methods associated with emergency conditions should not also be used in association with normal conditions.
Nuclear	If highlighting is used to emphasize important display items, it should be removed when it no longer has meaning. Additional Information: If highlighting identifies an error, that highlighting should be removed when the error is corrected.
Nuclear	The maximum update rate should be determined by the time required for the user to identify and process the changed feature of the display. Additional Information: The minimum and maximum update rate should be determined by the rate of change in the data, the requirements of the task, and the user's ability to process the information
Nuclear	The user should be capable of controlling the rate of information update on the display, but the allowable rate should not exceed that capable of being met by the information source and the processing equipment
Nuclear	Changing alphanumeric values that the user must reliably read should not be updated more often than once per second. Additional Information: Changing values that the viewer uses to identify rate of change or to read gross values should not be updated faster than 5 times per second, nor slower than 2 per second, when the display is to be considered as real time.
Nuclear	When the computer generates a display to update changed data, the old items should be erased before adding new data items to the display. Additional Information: This practice will avoid any momentary user confusion that might result from seeing portions of old data being overwritten and partially overlapped by new data.
Nuclear	Redundancy in the presentation of information items should be limited to cases where needed for backup or to avoid excessive movement.
Nuclear	Users working with multipage displays should be provided with a page location reference within the display sequence. Additional Information: Each page of a multipage display sequence should be numbered. Typically, the phrase "page x of y" is used for this purpose. A recommended format is to identify pages by a note immediately to the right of the display title. Leading zeros should not be used in the display of page numbers.
Nuclear	Users viewing a portion of a larger display should be provided with an indication of the location of the visible position of a display (frame) in the overall display. Additional Information: A graphic indication of the frame's location in the overall display will provide a visual context to help a user maintain a conceptual orientation between the visible part and the whole display. For example, in a corner of the frame, the computer might show a rectangle representing the overall display, in which a smaller rectangle is placed to indicate the position and extent of the currently visible portion of that display. Sectional coordinates should be used when large schematics must be panned or magnified.
Nuclear	General labels and row and column labels should remain along the top (or bottom) and left (or right) edges of the display. Additional Information: Display formats such as tables, lists, forms, and graphs may be scrollable. When this capability is available, all labeling information should be preserved.
Nuclear	Displayed information that temporarily overlays and obscures other display data should not erase the overlaid data. Additional Information: Overlay displays that are generated by the display system can allow additional information to be shown when needed and then be removed to reduce visual clutter. Overlays are acceptable when they improve the user's interpretation of displayed information. They should not distract the user or interfere with the observation of displayed information.
Nuclear	Consistent interface design conventions should be evident for all display features (such as labels). Additional Information: Consistent structure for data and labels should be used within and across displays. Even minor inconsistencies can distract a user and delay comprehension as the user wonders momentarily whether some apparent difference represents a real difference. Both the items on display and the displays themselves should be standardized. Although standardization is desirable, it should not take precedence over the grouping principles of frequency, sequence, locations, and importance.
Nuclear	Information should be displayed consistently according to standards and conventions familiar to users. Additional Information: The wording of displayed data, labels, and other information should incorporate the task-oriented terminology of the users and should avoid unfamiliar terms used by designers and programmers.
Nuclear	Displays should be consistent in word choice, format, and basic style with requirements for data and control entry. Additional Information: When entry formats are consistent with display formats, users are less likely to make errors.
Nuclear	Users should be able to control the amount, format, and complexity of displayed data to meet task requirements.

Nuclear	When a line is placed under an item to mark or emphasize it, the line should not impair the legibility of the item (e.g., by obscuring the descenders).
Nuclear	**It is important to distinguish between blanks (i.e. no value) and a value of zero. Additional Information: Some special symbol might be adopted to denote null entry.**
Nuclear	Label formats should be consistent across and within displays.
Nuclear	The time delay from when the sensor signal is sampled to when it is displayed should be consistent with the user's task performance requirements.
Nuclear	Each parameter should be displayed with an accuracy sufficient for the users to perform their tasks. Additional Information: The reviewer should determine the required accuracy by means of task analysis or discussions with users.
Nuclear	When forms are used for data entry as well as for data display, the formats of these forms should be compatible.
Nuclear	Clear visual definition of data fields should be provided so that the data are distinct from labels and other display features. Additional Information: Special characters (such as underlining) or graphics (such as "boxing") should be used to delineate data fields. A broken underscore, for example, could be used to indicate the number of characters available for an entry.
Nuclear	At least one character space should separate the label and the data entry are.
Nuclear	At least three spaces should appear between the longest data field in one column and the rightmost label in an adjacent column. Additional Information: Where space constraints exist, vertical lines may be substituted for spaces for separation of columns of fields.
Nuclear	When label sizes are relatively equal, both labels and data fields should be left justified. One space should be left between the longest label and the data field column.
Nuclear	When label sizes vary greatly, labels should be right justified and the data fields should be left justified. One space should be left between each label and the data field.
Nuclear	Field labels should be protected from keyed entry by having the cursor skip over them automatically when a user is spacing or tabbing. Additional Information: When a user must change a displayed form, including changes to field labels, then that user should be able to override label protection.
Nuclear	The current field to be entered should be highlighted. Additional Information: Irrelevant objects slow perceptual processing by competing for resources. Use of highlighting allows the current data field to be distinguished from other data.
Nuclear	If appropriate, labels should be used to help cue the user as to the expected data entry. Additional Information: For example, "DATE (MM/DD/YYYY): __/__/__."
Nuclear	At least five spaces should appear between groups of data fields.
Nuclear	When headings are located on the line above related screen fields, the labels should be indented a minimum of five spaces from the start of the heading. Additional Information: Scanning an inquiry screen will be aided if headings identify logical groupings of fields (see Figure 1.2). This permits scanning of headings until the correct one is located, at which point the visual search steps down one level to the items within the grouping itself. The above guideline is intended to provide easily scanned headings.
Nuclear	When headings are placed adjacent to the related fields, they should be located to the left of the topmost row of related fields. The column of labels should be separated from the longest heading by a minimum of three blank spaces. Additional Information: Scanning an inquiry screen will be aided if logical groupings of fields are identified by headings (see Figure 1.3). This permits scanning of headings until the correct one is located, at which point the visual search steps down one level to the items within the grouping itself. The above guideline is intended to provide easily scanned headings.
Nuclear	Displays should provide navigational links to and from high-level and lower levels of information and to reference and supporting information when needed for operators' tasks.
Nuclear	The display should organize related information into groups. Additional Information: Information needed by the operator to accomplish a task should be grouped and perceptually related, when possible. To minimize the disadvantages of divided attention, the number of attention shifts should be minimized, both within a display page and between pages.
Nuclear	**Information that must be compared or mentally integrated should be presented in close spatial proximity. Additional Information: If possible, the information items should be contained on the same display page and grouped together. Spatial proximity may also be achieved by presenting the display pages in adjacent display windows or on adjacent display devices that can be viewed together.**
Nuclear	Predefined information groupings should be available. Additional Information: Arranging displayed information may disrupt ongoing tasks or introduce new opportunities for error if the operator fails to recognize that the arrangement of displayed information has been changed. Predetermined information groupings may help reduce interface management demands.
Nuclear	**Information should be organized in some recognizable logical order to facilitate scanning and assimilation. Additional Information: If the data in the rows have order, the order should be increasing from left to right. If the data in the columns have order, the order should be increasing from top to bottom of the display. Items in lists should be arranged in a recognizable order, such as chronological, alphabetical, sequential, functional, or importance. Where no other principle applies, lists should be ordered alphabetically. It is the user's logic that should prevail rather than the designer's logic, where those are different.**
Nuclear	The ordering and layout of corresponding data fields across displays should be consistent from one display to another. Additional Information: For example, time records might be consistently punctuated with colons, as HH:MM:SS or HH:MM; dates might be shown as MMM:DD:YYYY. The convention chosen should be familiar to the prospective users.
Nuclear	A field group heading should be centered above the labels to which it applies.

Nuclear	A data entry form should have a logical organization. Additional Information: Data entry forms contain multiple fields in which the user enters information, usually by typing, to request information from the system. Logical organizations of entry fields may include conventional order (a generally accepted or customary ordering), sequence of use, frequency of use, data comparison (entries that must be compared are grouped together), functional grouping (related functions are grouped together), importance (task-critical items are located prominently), and general to specific (detailed fields proceed from more general topics, as in a hierarchic organization). Logical organizations can support user comprehension of the layout of the data entry form and facilitate its use. When it is not necessary to enter information in all fields to complete a transaction, placing the most frequently used entry fields at the top of the form can reduce the length of transitions across the data form.
Nuclear	The number of pages in a data form required to complete a transaction should be minimized to reduce the amount of navigation.
Nuclear	The available decision options should be displayed in logical order. Additional Information: For example, if options represent stages of a process, those stages should be listed in the order in which they would actually occur. The ordering of options should not be determined merely by the amount of space that is conveniently available to display them.
Nuclear	Each individual aspect of a display (e.g., data group, field, or message) should contain a distinct, unique, and descriptive label.
Nuclear	Numbers on a scale should increase clockwise, left to right, or bottom to top.
Nuclear	The display should not use unnecessary borders. Additional Information: Borders can add visual clutter to a display and add to information processing time. Borders should only be used for functional purposes, such as to facilitate grouping.
Nuclear	A border should be used to improve the readability of a single block of numbers or letters.
Nuclear	If several labels or messages are clustered in the same area, distinctive borders should be placed around the critical ones only.
Nuclear	A standard display screen organization should be evident when locating various HSI functions (such as a data display zone, control zone, or message zone) from one display to another. Additional Information: Consistent display screen organization will help establish and preserve user orientation. Reserved screen areas, for example, might be used for a display title, alarms, display control options, instructions, error messages, and menus. Display formats should be consistent with accepted usage and existing user habits.
Nuclear	The HSI functional zones and display features should be visually distinctive from one another, especially for onscreen command and control elements (which should be visibly distinct from all other screen structures). Additional Information: Different display areas can be separated by blank spaces, lines, or some other form of visual demarcation. Areas used to display data, control options, and instructions should be distinct from one another.
Nuclear	Every display should begin with a title or header at the top, briefly describing the contents or purpose of the display. Additional Information: The title may be incorporated as part of the display itself, as a window title, or as a label mounted on the display device. If the title is incorporated into the display, there should be at least one blank line between the title and the body of the display.
Nuclear	Where displays have several levels of titles (or labels or both), the system should provide visual cues to aid users in distinguishing among the levels in the hierarchy. Additional Information: Character size variation and indentation are two common methods of expressing a hierarchy. Bolding, underlining, and letter case are also frequently used, but conventions for their use have not been well established.
Nuclear	Displays should present the simplest information consistent with their function; information irrelevant to the task should not be displayed, and extraneous text and graphics should not be present. Additional Information: Displayed information should be tailored to user needs, providing only necessary and immediately usable data for any user action; displays should not be overloaded with extraneous information. Information not needed for the current task (e.g., patent notices, manufacturer's trademark or address) should not be displayed. In general, the fewest lines or objects in a graphical display should be used.
Nuclear	Displays should be as uncluttered as possible. Additional Information: Display packing density should not exceed 50 percent. Density should be minimized for displays of critical information. Displays consisting largely of alphanumerics generally should not exceed 25-percent density. Displays composed largely of graphics may be more dense. The unused area should be distributed to separate logical groups, rather than having all unused areas on one side. When a display contains too much data for presentation in a single frame, the display should be partitioned into separately displayable pages (multipage displays) or displayed through frames or viewports (such as scrollable windows).
Nuclear	When displays are partitioned into multiple pages, function or task-related data items should be displayed together on one page. Additional Information: Relations among data sets should appear in an integrated display rather than partitioned into separate display pages. When dividing a display, it is important to keep task-related data together to avoid (1) requiring the user to frequently switch back and forth between pages when performing the task or (2) requiring users to remember information from one page while looking at another.
Nuclear	Information on a display should be grouped according to principles obvious to the user (e.g., by task, system, function, or sequence), based upon the user's requirements when performing the ongoing task (see Table 1.5). Additional Information: Table 1.5 provides grouping principles and examples of their appropriate uses. Grouping conventions should be used consistently within sets of displays of a particular type. For example, grouping by function may take precedence over other grouping methods for mimic-type plant displays. Grouping for data comparison may take precedence over other grouping methods for displays that present only text. Since users' tasks can vary, advanced HSIs should provide the user with the flexibility to group information by alternative grouping principles to reflect changes in task requirements.
Nuclear	When information is grouped on a display, the groups should be made visually distinct by such means as color coding or separation using blanks or demarcation lines.
Nuclear	The salience of graphic features should reflect the importance of the information. Additional Information: The most salient features of a graphic display should be those aspects of the representation that are most important. Less important information should not be more perceptually salient than more important information.
Nuclear	When a special symbol, such as an asterisk, is used to draw attention to a selected item in alphanumeric displays, the symbol should be separated from the beginning of the word by a space.
Nuclear	The label for a specific graphical object (e.g., an icon) should be placed in close proximity to the object. Additional Information: When possible, the label should be on the component if it does not obscure the component. If multiple component parts of the graphic object are close to the label, a line should point from the label to the associated part.

Nuclear	The primary use of icons in graphic displays should be to represent actual objects or actions. Additional Information: Icons may be used to graphically represent operations, processes, and data structures and may be used as a means of exercising control (e.g., by selecting an icon and commanding operations) over system functions, components, and data structures.
Nuclear	**Icons should be designed to look like the objects, processes, or operations they represent, by use of literal, functional, or operational representations. Additional Information: Some pictorial symbols have conventional meanings within a user population, which must be followed to ensure their correct interpretation. The following are examples of representations: literal, a figure of a pump; functional, a figure of a file cabinet; and operational, a hand on a switch.**
Nuclear	Icons should be simple, closed figures when possible. Additional Information: When icons are too visually complex, they are not quickly recognized. This eliminates the primary advantage of using icons (i.e., quick recognition). Simple, closed figures (i.e., ones with a continuous outside border) are processed more efficiently than are open figures.
Nuclear	Abstract symbols should conform to user conventions or to common electrical and mechanical symbol conventions when user conventions do not exist. Additional Information: Symbols used on displays should not be inconsistent with those of other information sources used in the work area, such as piping and instrumentation diagrams and logic diagrams.
Nuclear	Each icon and symbol should represent a single object or action and should be easily distinguished from all other icons and symbols. Additional Information: The distinguishing feature between icons should be the external geometric configuration of the icon.
Nuclear	**Special symbols to signal critical conditions should be used exclusively for that purpose.**
Nuclear	Icons and symbols should always be oriented upright.
Nuclear	Words and symbols should not be used alternately. Additional Information: Alternating use of symbols and words could cause confusion and impair task performance.
Nuclear	Icons and symbols should be large enough for the user to perceive the representation and distinguish it from other icons and symbols. Additional Information: When a displayed symbol of complex shape is to be distinguished from another symbol shape that is also complex, the symbol should subtend not less than 20 minutes of arc at the required viewing distance. VDU-displayed symbols that must be distinguished from other complex shapes should have a minimum of 10 resolution elements for the longest dimension of the symbol.
Nuclear	An icon or symbol should be highlighted when the user has selected it.
Nuclear	**Icons should be accompanied by a text label. Additional Information: To the extent that it does not clutter or cause distortion of the icon, the label should be incorporated into the icon itself. When icons are designed such that the label is inside the icon, the number of perceptual objects is reduced, resulting in enhanced processing of the label and the icon. The text label may be omitted for icons having unambiguous meanings to users (e.g., standard piping and instrumentation diagram symbology).**
Nuclear	If icons are used to represent control action options, a label indicating the action should be associated with the icon.
Nuclear	A maximum of three size levels should be used. The major dimensions of the larger symbol should be at least 150 percent of the major dimension of the smaller symbol. Additional Information: An increase in symbol height must usually be accompanied by a proportional increase in width to preserve a constant aspect ratio and so facilitate symbol recognition.
Nuclear	When the symbol size is to be proportional to the data value, the scaled parameter should be the symbol area rather than a linear dimension such as diameter. Additional Information: A user's judgment of the "size" of a symbol will correspond more closely to its area than to its diameter.
Nuclear	When shape coding is used, codes should be based on established standards or conventional meanings. Additional Information: Coding with geometric shapes should be used to help users differentiate different categories of data on graphic displays. Although shape codes can often be mnemonic in form, their interpretation will generally rely on learned association as well as immediate perception. Existing user standards must be considered.
Nuclear	Shapes used in coding for data groups should be clearly distinguishable. Additional Information: When shape coding is used, the shapes should vary widely and the number of basic shapes should be limited. For example, the elements of one group in a display might be triangles and the elements of a second group might be circles. Approximately 15 different shapes can be readily distinguished, provided the shapes are properly designed. Under adverse viewing conditions, no more than 6 shapes should be used. When needed, other highlighting and graphic techniques (color, filled or unfilled, and other "modifiers") should be used to display different states or qualities of the basic symbol.
Nuclear	When patterns are used to code displayed areas, simple rather than elaborate patterns should be used. Additional Information: To aid visual discrimination and identification, simple patterns, such as hatching, should be employed rather than complex patterns.
Nuclear	Pattern density should vary with the value of the coded parameter so that the least dense pattern is associated with one extreme and the most dense pattern with the other extreme.
Nuclear	The display should clearly indicate scale multiplication factors.
Nuclear	When precise reading of a graphic display is required, the display should be annotated with actual data values to supplement their graphic representation. Additional Information: For example, adjacent numeric annotation might be added to the ends of displayed bars on a bar graph; numeric data might be displayed to mark the points of a plotted curve.
Nuclear	When a graphic display contains some outstanding or discrepant feature that merits attention by a user, it should include supplementary text to emphasize that feature. Additional Information: For example, a flow diagram for process control might include a current advisory message, "Possible Pressure Valve Failure," as well as appropriate graphic indications of the problem.
Nuclear	A table should be constructed so that row and column labels represent the information a user has before consulting the table. Additional Information: The far-left column should contain the labels for the row parameters, and the top row should contain the labels for the column parameters. When tables are used for reference, the reference item should be displayed in the left column, and the material most relevant for user response should be displayed in the next adjacent column.
Nuclear	Each row and column should be uniquely and informatively labeled and should be visually distinct from data entries.
Nuclear	**Labels should include the unit of measure for the data in the table; when cells have the same measurements, the units of measurement should be part of row or column labels.**

Nuclear	Consistent column and row spacing should be maintained within a table and from one table to another. Similarly, spacing between rows should be consistent within a table and between related tables. Additional Information: As an exception, when columns are grouped under superheadings, extra space between superheadings may help to emphasize that the columns under any single superheading are related.
Nuclear	The spacing between columns should be greater than any internal spaces that might be displayed within a tabulated data item. Additional Information: The columns in a table should be separated by enough blank spaces, dots, or some other distinctive feature to ensure separation of entries within a row. When columns are not separated by vertical lines, the columns should be separated by at least two character widths.
Nuclear	In dense tables with many rows, a blank line, dots, or some other distinctive feature (to aid horizontal scanning) should be inserted after a group of rows at regular intervals. Additional Information: For many applications, it will suffice to insert a blank line after every five rows.
Nuclear	The font and size of alphanumeric characters should be consistent within a table and between related tables. Additional Information: An exception to this guideline is when a word or set of characters is highlighted by varying the typeface; for example, with italics or a bold font.
Nuclear	Columns of alphabetic data should be displayed with left justification to permit rapid scanning. Additional Information: As an exception, indentation can be used to indicate subordinate elements in hierarchic lists. In addition, a short list (of just four or five items) could be displayed horizontally on a single line, in the interest of compact display format, if done consistently.
Nuclear	Arabic rather than Roman numerals should be used when listed items are numbered. Additional Information: Arabic numbers are more familiar to most users and require less interpretation than Roman numerals do. The advantage of Arabic numbers becomes greater when large numbers are used.
Nuclear	Item numbers should begin with one rather than zero.
Nuclear	When a list of numbered items exceeds one display page, the items should be numbered continuously in relation to the first item on the first page. Additional Information: For example, items continued on the next page should be numbered relative to the last item on the previous page.
Nuclear	Complete numbers should be displayed for hierarchic lists with compound numbers (i.e., repeated elements should not be omitted). Additional Information: Implicit numbering may be acceptable for tasks involving perception of list structure. Complete numbering is better, however, for tasks that require searching for and identifying individual items in the list.
Nuclear	Lists should be formatted so that each item starts on a new line. Additional Information: A list should be displayed as a single column. As an exception, listing in multiple columns may be considered where shortage of display space dictates a compact format.
Nuclear	When a single item in a list continues for more than one line, items should be marked in some way so that the continuation of an item is obvious. Additional Information: A continued portion should not appear to be a separate item. Items might be separated by a blank space, or continuing lines within an item might be indented, or each item might be numbered or marked by a special symbol such as an arrow or bullet.
Nuclear	Where lists extend over more than one display page, the last line of one page should be the first line on the succeeding page.
Nuclear	For a long list, extending more than one displayed page, a hierarchic structure should be used to permit its logical partitioning into related shorter lists.
Nuclear	If a list is displayed in multiple columns, the items should be ordered vertically within each column rather than horizontally within rows and across columns.
Nuclear	When lists or tables are of parameter length and may extend beyond the limits of one display page, the user should be informed when data are continued on another page and when data are concluded on the present page. Additional Information: For example, incomplete lists might be marked “continued on next page,” “continued,” or “more.” Concluding lists might display a note such as “end of list” or “end.” As an exception, short lists where the conclusion is evident from the display format need not be annotated in this way.
Nuclear	Each bar on the display should have a unique identification label. Additional Information: The label provides a positive identification of the parameter each bar represents. A user should not have to memorize the position of each parameter on the display.
Nuclear	When bars are displayed in pairs, they should be labeled as a unit, with individual distinguishing labels for each bar. Additional Information: Direct labeling of bars will make the information easier to use. If the user has to refer to a separately displayed legend, interpretation of the chart will be slower and more subject to error.
Nuclear	When data must be compared, bars should be adjacent to one another and spaced such that a direct visual comparison can be made without eye movement. Additional Information: Figure 1.4 illustrates a horizontal bar chart. The spacing between bars should be less than the bar width. If many bars are displayed, then spacing may produce an alternating pattern of bright and dark bands that could prove visually disturbing. In this case, it is preferable to arrange the bars contiguously (i.e., without spaces).
Nuclear	In a related series of bar charts, a consistent orientation of the bars (vertical or horizontal) should be adopted. Additional Information: If bar length is used to represent time duration, then it might be more appropriate to orient the bars horizontally, in accord with the general convention of plotting time on the horizontal axis of a graph. Vertical bars can be used to display frequency counts or a large variety of other measured attributes.
Nuclear	If one bar represents data of significance, then that bar should be highlighted. Additional Information: If one bar represents critical or discrepant data, then that bar might be coded differently. However, if bar coding is already used for other purposes, such as to distinguish among different sets of grouped bars, then no additional highlighting code should be superimposed on the bars themselves; some other means of highlighting (e.g., an arrow) might be adopted.
Nuclear	The zero reference should be the center of the deviation bar chart. Additional Information: An example of a deviation bar chart appears in Figure 1.5.
Nuclear	On a deviation bar chart, the range of normal conditions for positive or negative deviations should represent no more than 10 percent of the total range. Additional Information: An example of a deviation bar chart appears in Figure 1.5.
Nuclear	The magnitude of each parameter should be displayed when a deviation bar display is used as a main display format for safety function parameter. Additional Information: The actual values of critical parameters should appear on the deviation bar display in addition to percent deviation.

Nuclear	Segmented bars, in which differently coded segments are shown cumulatively within a bar, should be used when both the total measures and the portions represented by the segments are of interest. Additional Information: An example of a segmented bar chart appears in Figure 1.6.
Nuclear	The data categories should be ordered within each bar in the same sequence, with the least variable categories displayed at the bottom and the most variable at the top. Additional Information: Sometimes there are independent logical grounds for ordering data categories. If a segmented bar graph that is constructed on a logical basis produces a confusing irregularity of segments, then it might be better to display the data in some other graphic format. Any irregularity in the bottom segment will "propagate" throughout the segments above it, which will make it difficult for a user to examine irregularities in the upper segments.
Nuclear	**Graphs should convey enough information to allow the user to interpret the data without referring to additional sources.**
Nuclear	When multiple curves are included in a single graph. Additional Information: As an exception, where displayed curves are too close for direct labeling, an acceptable alternative might be to distinguish the various curves in some way, perhaps by color coding or line coding, and identify their codes in a separate legend. Direct labeling will permit users to assimilate information more rapidly than displaying a separate legend.
Nuclear	If a legend must be displayed, the codes in the legend should be ordered to match the spatial order of their corresponding curves in the graph itself.
Nuclear	Coding should be used when multiple functions are displayed in a single graph. Additional Information: Coding should be provided particularly if curves approach or intersect one another. Coding is required to distinguish one curve from another.
Nuclear	Line coding should be used consistently across graphs.
Nuclear	In displays of multiple curves, if one curve represents data of particular significance, then that curve should be highlighted. Additional Information: If one curve represents critical or discrepant data, for example, that curve might be displayed with a noticeably thicker line stroke or in a different color. If line coding is already used to distinguish among multiple curves, then the means of highlighting any particular curve should be selected so that it will not be confused with coding for visual separation. For example, if displayed curves are distinguished by line codes (solid, dashed, or dotted), then one curve might be highlighted by displaying it in a different color.
Nuclear	Trend displays should be capable of showing data collected during time intervals of different lengths. Additional Information: A short time base of just a few minutes is needed to study fast changing trends, while other trends may not show significant changes for several hours.
Nuclear	When the user must compare data represented by separate curves, the curves should be displayed in one combined graph. Additional Information: Combined plots should be related, so the user can correlate changes in one parameter with changes in other key parameters. Only those curves requiring comparison should be combined, because, as the number of curves on a graph increases, the user's task of comparison will become more difficult.
Nuclear	Trend rates should not fluctuate because of minor fluctuations in data or oscillatory behavior that may be superimposed on a well-defined trend.
Nuclear	When a simple quantitative rate-of-change value is used, an indication should be provided to inform the user when, as a result of minor fluctuations or oscillations, the rate value does not accurately represent the trend.
Nuclear	Curves representing planned, projected, or extrapolated data should be distinct from curves representing actual data. Additional Information: Curves representing projected data, for example, could be depicted as broken, dashed, or dotted lines, while curves representing actual data could be represented as solid lines.
Nuclear	Several individual curves should only be combined into a single average curve when users do not need to know the pattern of individual curves or when curves differ based on minor irregularities. Additional Information: Curve averaging should be performed with caution since averages tend to "wash out" local variations.
Nuclear	Where curves represent cyclic data, the graph should be extended to repeat uncompleted portions of the displayed cycle. Additional Information: This will allow users to scan any critical portion of the displayed cycle without having to return visually to the beginning of the plot. How much extension is desirable will depend on the particular application.
Nuclear	The target area, preferred combination of X- and Y-axis values, should be graphically defined. Additional Information: Monitoring a pressure-temperature display, which presents a saturation curve that bisects the subcooled water region and the superheated steam region, is an example of a task situation where graphic depiction of a target area should be provided. This sort of display is best used for detecting deviations from normal if a target area can be defined. By plotting a brief time history, one may be able to predict where the values are headed. Care should be taken to distinguish the current value from past values, especially when the values change slowly. This can be done by placing a symbol or code for the current value.
Nuclear	**Old data points should be removed after some fixed period of time. Additional Information: Ideally, as one new point is plotted, the oldest point should be removed, thereby maintaining a constant number of displayed points.**
Nuclear	The graph should form recognizable geometric patterns for specific abnormal conditions. Additional Information: An example of a linear profile graph appears in Figure 1.7. The irregular profile is indicative of abnormal operating conditions.
Nuclear	The area below the profile line should be shaded to provide a more distinguishable profile.
Nuclear	Labels should be provided along the bottom to identify each parameter.
Nuclear	All segments in a segmented curve graph should be related to the total value. Additional Information: A segmented curve graph contains a series of bands depicting the components of a total series (see Figure 1.8). The values of the bands, segments, or strata are plotted on an X–Y plot. The bands are added to one another so that the topmost boundary represents the sum of all bands. For example, segmented curve graphs can be used to show how much each pump is contributing to total flow. This format is most useful when all elements contribute equally to the total under normal circumstances. Segmented curve graphs should not be used when changes in the movement of a series are abrupt or where accurate reading of a component is of paramount importance.
Nuclear	The data categories in a segmented curve graph should be ordered so that the least variable curves are displayed at the bottom and the most variable at the top. Additional Information: Sometimes there are independent logical grounds for the ordering of data categories. If a segmented curve graph that is constructed on a logical basis produces a confusing irregularity of curves, then it might be better to display the data in some other graphic format. Any irregularity in the bottom curve will "propagate" throughout the curves above it, which will make it difficult for a user to evaluate irregularities in the upper curves.

Nuclear	The different bands of segmented curve graphs should be made visually distinctive by coding, such as by texturing or shading bands.
Nuclear	Where space permits, the different bands of segmented curve graphs should be labeled directly within the textured or shaded bands.
Nuclear	If some plotted points represent data of particular significance, they should be highlighted to make them visually distinctive from others. Additional Information: Significant data points might be highlighted by bolding, color, blinking, shape coding, or other means, or might be designated by supplementary display annotation.
Nuclear	When relations among several parameters must be examined, an ordered group (matrix) of scatterplots should be displayed, each showing the relation between just two parameters. Additional Information: The ordering of several scatterplots in a single display might help a user discern relations among interacting parameters.
Nuclear	When scatterplots are grouped in a single display to show relations among several parameters, an interactive aid should be provided for analysis so that if a user selects a set of data in one plot, the corresponding data points in other plots will be highlighted. Additional Information: Data selection might be accomplished with a superimposed box of controllable size to define the data set of interest. That technique can exploit the capabilities of interactive graphics to permit a range of data analysis not possible when using printed graphs.
Nuclear	Pie chart segments should be labeled directly rather than by a separate legend. If a segment is too small to contain the label, the label should be placed outside the segment with a line from it to the segment. Additional Information: The label should be in a normal orientation for reading text.
Nuclear	If the task requires precise values, numbers should be added to pie chart segment labels to indicate the percentage or absolute values. Additional Information: Alternative display formats are preferred when users require precise data.
Nuclear	If a particular segment of a pie chart requires emphasis, it should be highlighted by special hatching or displaced slightly from the remainder of the pie.
Nuclear	Only a single decision should be required at each step. Additional Information: Decisions should not be combined to reduce flowchart size.
Nuclear	When a flowchart is designed so that a user must make decisions at various steps, the available options should be displayed in some consistent order from step to step. Additional Information: For example, “yes” might always be on the left and “no” on the right. Another scheme is always to have the desirable path lead downward and the “problem” paths lead out to the side. Consistent ordering will permit a user to review a flowchart more quickly.
Nuclear	While flowcharts should display only the data immediately required by the user, a simple action should produce more detailed data.
Nuclear	Flowcharts should be designed so that the path of the logical sequence is consistent with familiar orientation conventions. Additional Information: For example, a logical path could flow from left to right and from top to bottom.
Nuclear	There should be a standard set of flowchart symbols.
Nuclear	The annotation of graphic displays, including labels for the axes of graphs, should be displayed in a normal orientation for reading text. Additional Information: Users should be presented with horizontally displayed labels, even for the vertical axis of a graph. A conventional text orientation of labels will permit faster, more accurate reading. While it may be possible to tilt the page to read a disoriented label on a printed page, a user usually cannot tilt a VDU display screen.
Nuclear	Nine should be the maximum number of tick marks between numbers. Additional Information: Major and minor graduations should be used if there are up to four graduations between numerals. Major, intermediate, and minor graduations should be used if there are five or more graduations between numerals. The use of these graduations on a conventional meter face is shown in Figure 1.10, while Table 1.2 shows graduation dimensions as a function of viewing distance for a conventional meter face.
Nuclear	Scales should have tick marks at a standard interval of 1, 2, 5, or 10 (or multiples of 10) for labeled divisions; intervening tick marks to aid visual interpolation should be consistent with the labeled scale interval. Additional Information: Users will find it difficult to interpret scales based on odd intervals. It is not advisable to let the computer divide available scale space automatically if that results in a scale labeled in unfamiliar intervals such as 6 or 13. In special instances, the X-axis might be scaled in odd intervals to show customary divisions, such as 12 months in a year.
Nuclear	For one-revolution circular scales, zero should be at 7 o’clock and the maximum value should be at 5 o’clock.
Nuclear	Axes should be clearly labeled with a description of the parameter represented by the axis. Additional Information: Labels should be displayed in upright orientation on both the X- and Y-axis for ease of reading.
Nuclear	The axis label should include the units of measurement represented by the scale.
Nuclear	Conventional scaling practice should be followed, in which the horizontal X-axis is used to plot time or the postulated cause of an event, and the vertical Y-axis is used to plot the effect. Additional Information: When the X-axis represents time intervals, the labeled scale points should represent the end of each time interval. This consistent usage will aid interpretation of all data plots, including scatterplots, line graphs, and bar charts.
Nuclear	If users must compare graphic data across a series of displays, the same scale should be used for each. Additional Information: Note that, in many applications, it may prove more effective to display data for comparison in a single combined chart, rather than requiring users to compare data across a series of charts. Users will find it difficult to compare data sets that are scaled differently. Moreover, users may overlook differences in labeling and assume that the same scale has been used, even when displayed scales are actually different from one another.
Nuclear	The scales should be consistent with the intended functional use of the data. Additional Information: Scales should be selected to (1) span the expected range of operational parameters, (2) employ appropriate scale-ranging techniques, or (3) be supported by auxiliary wide-range instruments. For example, the monitoring of neutron flux at reactor trip must have a parameter scale of 0 to 100 percent of the design value and a time scale resolution of seconds. However, post-trip monitoring may have a parameter scale of 0 to 10 percent with a time-scale resolution of minutes. Finally, operational log data of neutron flux may have a time-scale resolution of hours.
Nuclear	A linear scale should be used for displayed data, in preference to logarithmic or other nonlinear methods of scaling, unless it can be demonstrated that nonlinear scaling will facilitate user interpretation of the information. Additional Information: Most users are more familiar with linear scales and will interpret linear scales more accurately than other methods of scaling. However, since logarithmic scales show percentage change rather than arithmetic change, they may be appropriate for some special applications.

Nuclear	When users must compare aggregate quantities within a display, or within a series of displays, scaling of numeric data should begin with zero. Additional Information: Numerical scales generally should have zero at the bottom as the first number on a vertical scale or at the left as the first number on a horizontal scale. The exceptions to this organization would be: (1) if the numbers are used for naming categories, (2) if zero is not a plausible number on the scale, or (3) if the scale contains negative numbers. If, for any reason, the zero point is omitted, the display should include a clear indication of that omission, and the scales on which quantities are to be compared should be the same.
Nuclear	When graphed data represent positive numbers, the graph should be displayed with the origin at the lower left, such that values on an axis increase as they move away from the origin of the graph. Additional Information: When the data include negative values and the axes must extend in both directions from a zero point, that origin should be displayed in the center of the graph.
Nuclear	Only a single scale should be shown on each axis, rather than including different scales for different curves in the graph. Additional Information: Single-scale graphs will generally permit more accurate reading than graphs displaying several scales. Many users will be confused by multiple-scale graphs and make errors when interpreting them. Moreover, by changing the relative scale factors of multiple-scale graphs, it is possible to change radically their apparent meaning and bias interpretation by users.
Nuclear	If different parameters on a single graph require different scales, they should be scaled against a common baseline index, rather than showing multiple scales. Additional Information: Rather than showing power in megawatts and profits in dollars, both might be graphed in terms of percent change from a baseline. An indexed chart can permit comparisons among different parameters when multiple scales would otherwise be needed. However, care should be taken in selecting an appropriate baseline against which to index, to ensure that comparisons will not be biased. Index scaling may also be appropriate for showing the effect of a single parameter where units of measurement change in real value with time.
Nuclear	When a graphic display has been expanded from its normal coverage, some scale indicator of the expansion factor should be provided. Additional Information: Scale ranges may be expanded (or contracted) by multiplying or dividing indicated scale values by powers of ten. All such scales should be clearly marked as to whether the indicated values should be multiplied or divided and the factor to be used (e.g., 10, 100, or 1000).
Nuclear	Users should be able to manually change the scale to maintain an undistorted display under different operating conditions.
Nuclear	If the system is designed to automatically change scale, an alert should be given to the user that the change is being made. Additional Information: Automatic rescaling can lead to confusion if the change in scale is not recognized.
Nuclear	If interpolation must be made or where accuracy of reading graphic data is required, computer aids should be provided for exact interpolation. Additional Information: It might suffice, for example, to allow users to request a fine grid as an optional display feature. It might be better to display vertical and horizontal rulers that a user could move to intersect the axes of a chart. It might prove best simply to let a user point at any data item and have the computer label that item with a readout of its exact value(s).
Nuclear	When data comparisons of interest fall within a limited range, the scaled axis should emphasize that range, with a break in the displayed axis to indicate discontinuity with the scale origin. Additional Information: Note, however, that a broken axis distorts the displayed value in relation to a base value and so risks confusing users. In effect, a user will expect that a scale marked in regular intervals will continue in a consistent fashion. If an axis must be broken, the break should be labeled clearly, perhaps with some indicator that extends across the displayed graph.
Nuclear	When scaled data will contain extreme values, duplicate axes should be displayed, so that the X-axis appears at both the top and bottom and the Y-axis at both the left and right sides of the graph. Additional Information: Extreme data values may be located far from conventionally placed axes. When duplicate axes are displayed at the top and right side, users will find it easier to read the extreme values.