DeltaV@CMU Final Report

August 07, 2006

Jason Chalecki

Samantha Konwinski

Julian Missig

Karen Taxier

Daniel Zinzow

Executive Summary

Emerson Process Management challenged five Masters Degree students at Carnegie Mellon University (CMU) to focus on improving the user experience of plant operators by examining the visual language and navigation of their process control software products, DeltaV and Ovation. Beginning in January 2006, our team embarked on a mission to meet Emerson's challenge by studying how plant operators currently work with both DeltaV and competing systems. Guided by both user and literature research, as well as several rounds of user testing and prototype refinement, our final design aims to help users quickly assess process state and analyze historical process data, in order to make plant control more efficient. Key aspects of our design is summarized below.

Customized groupings of trends for comparison and review are displayed within the Trends & Events screen. On the trends are icons representing messages left by previous shift workers as well as any alarms that occurred. Detailed information is retrieved through a pop-up associated with a message or alarm.

To allow operators to view trend information from the operator screen, an integrated graph displays the data for components within the respective components. Operators may scroll the graph to inspect recent history.

We have also added the ability to add messages in the form of "stickies" to the layout screens. An operator can create a sticky to record a message and attach it to a component or have it apply, generally, to all components.

Trend information is displayed visually with bars directly on components. The values of the component are shown over time, with each time having an increasingly lighter shade. We expect this to aid in predicting where the current value is heading and showing rate of change.

We placed related variables onto one graph, known as a radar display. The connection of the variables produces an emergent shape, which we hope could ease the ability for operators to notice when the system is not functioning within normal ranges and where the fault lies. We believe this display may also help show the relationship between variables in a space-efficient form.

These interfaces were refined through several rounds of testing to produce our final design and recommendations. They can be further developed through additional user testing and refinement. They serve as ideas and recommendations of where and how to proceed to aid the ability of operators to assess process state and analyze historical process data.

Background

Emerson Process management challenged us—five Masters Degree students in Human-Computer Interaction at Carnegie Mellon University—to improve the user experience of plant operators by examining the visual language and navigation of their process control software, DeltaV. We learned general knowledge about process control theory and practice through reviewing books, publications, and other resources. We used contextual inquiry as our primary research technique in order to gain specific insights about the software system and the people who use it. We present these insights, which shaped our design work, below.

When relevant, a reference to a specific contextual inquiry is made in parenthesis following an observation. For example, "(CI3.2)" refers to the second user in our third contextual inquiry. "(CI3)" would refer to an observation in our third contextual inquiry that is not user specific. For more detailed information on the methodologies, please see Appendix II.

Domain

The research we performed provided knowledge about how plants that use DeltaV are composed and work with DeltaV. This information is the grounding and culture that the operators work within, affecting the way in which they perform their job. Therefore, it is important to consider this information when developing a design for these operators.

Software

Plant engineers and operators have a range of experience with DeltaV. Some plants are just adopting the software while others have been using versions of it for a long time. This is also true across different divisions of a single plant, where some operators use DeltaV and others use a competitor's software (CI3, CI4, CI5, CI6). Operators and engineers also use more commonly known software for their jobs, such as office productivity applications, email clients, and web browsing software (CI1, CI3, CI4, CI5, CI6).

While the perception of DeltaV's stability and robustness has improved over time (CI1), some facilities consider it too advanced for their needs (CI4). Complaints about DeltaV include concerns that there are too many plant component graphics (dynamos), which confounds the choice of how to select the best representation for components (CI1). While DeltaV's History Viewer is a useful tool for an audit trail, other third-party software is considered by some to be better for viewing trends (CI3.3, CI3.1, CI5). We consider "trends" to be any visualization of how a process, component, or measurement is changing over time, typically represented by a line graph.

Upgrading

In our user research, we have seen little evidence that companies choose to stay up-to-date with the current version of their control system. Instead, systems continue to run the same version since first installation (CI2), with cost being cited as a primary factor for lack of upgrade (CI2, CI4). Larger plants often contain multiple process lines that run at least somewhat independently of each other. One of the plants we visited staged their system upgrades across their lines, ensuring that the upgraded line runs smoothly before deploying the upgrade to the rest of the plant (CI5). Other plants have upgraded some process lines to DeltaV but not others due to the expense of upgrading (CI3, CI4, CI6). This means that all of the larger plants we visited had multiple different process control systems in operation.

People

There are usually marked differences in the personnel for large and small facilities. Small plants tend to have a more varied group working as operators, each person usually holding several responsibilities (CI1, CI2). We have spoken with an operator without expertise in process control who had to teach himself display configuration (CI1).

Stereotypically, operators are not thought to be highly educated so there is an inclination to keep control displays as simple as possible (CI2). However, we have talked with some operators who have an undergraduate engineering background (CI2, CI3) and some have more advanced degrees (CI1).

Training

At smaller facilities, the staff is often unable to receive formal training on DeltaV; they instead learn through exploration and trial and error (CI1, CI2). Although we found this to be the case, our team was told, “The most difficult part is the setup of the system. Operating it is relatively easy” (CI1). Although larger plants are more likely to offer formal training (CI3.1, CI4, CI5), a large percentage of training is on-the-job (CI4). The important take-away for us is that DeltaV and Ovation are not walk-up and use systems, which we did consider when planning our testing. No matter how it is accomplished, some form of training always takes place, even if it is self-learning.

Business & Research

All plants, even research and academic ones, operate like businesses. This means that knowing the key factors and variables is vital. Being able to optimize the process is important as well (CI1, CI2, CI3, CI5). The need to be aware of costs may affect how issues are resolved (CI4, CI6). We found that research tends to take place within smaller plants, so the overhead can be relatively high (CI2). Hence, small research plants may have to suspend operations when they do not have any contracts (CI2). The firms with which small plants deal with may be directly interested in the process and technology or just interested in an investment opportunity (CI2). It is important to note that these investors tend to be cautious due to the risky nature of research (CI2).

Roles

While consolidating the models from all of our users, it became clear that there were several distinct roles. These roles were determined by the interactions people have with one another as well as their responsibilities. These roles do not directly map onto the job responsibilities any one person has; in fact, one person may fulfill multiple roles. The three primary roles identified were the “monitor,” “configurer,” and “trend analyzer.” There was evidence for additional roles, such as “supervisor,” “field technician,” and “lab technician,” but we did not focus on these roles (See Appendix I.A).

Monitor

The role of the monitor is to observe the operator control screen and resolve problem situations. This person views one or more layouts of the process plant at a time and is able to switch between multiple layouts as needed. All monitors view their own set of layouts, with little overlap in the informal ownership of layouts between them. Monitors must consider the whole system and be aware of component interdependencies as well as the environment outside. During our contextual inquiries, we found that experience plays a key role in decision-making, with monitors relying on more seasoned co-workers for help (CI4) or bypassing instructions because they felt their own experience renders these types of written guidance unnecessary (CI2, CI3.6, CI4). Monitors are also the first line of defense against any alarms. While most alarms are resolved quickly and some are escalated to supervisors, others are acknowledged without any inspection or further action for an extended length of time (CI3).

Configurer

Configuration experts create control screens for monitors to use. These screens are created using DeltaV Configure with the application-provided graphics or with custom-made graphics. The configurer also controls alarm settings to signal problem situations. These workers may be hired as external contractors through another firm or may be in-house company employees. Because configurers are often third parties, changes are not always timely, and there is a risk that requirements might be miscommunicated (CI2, CI3).

Trend Analyzer

The role of the trend analyzer is to watch process data trends. This is done by looking at graphs of specific values and how the values change over time. This person evaluates this trend information to make sure that the plant remains stable. This information provides situational awareness for potential problems and allows preventive measures to be taken. The trend analyzer uses this data to inform the monitor of the plant status.

At several site visits, we observed that monitors also act as trend analyzers (CI1, CI2, CI3, CI5). We separated the roles to get a better idea of the detail each involves and how the roles interact with each other. More importantly, these roles are separated because the lack of integration between trend information and component layouts within the DeltaV software currently forces those monitors who also act as trend analyzers to use a separate interface in order to handle each role.

Communication

Updating the subsequent shift of plant status is one of the most important communications we observed. Operators provide situation awareness to their replacement at the end of a shift, which must include informing of any potential problems that may need to be addressed (CI3, CI6). Because of the nature of the work, this discussion may evolve into troubleshooting and collaborating on problem resolution before the shift change is complete (CI3, CI6).

While observing process control operators, Vicente and Burns (1995) found that operators would alter alarm signals to alert themselves or future operators of potential problems after a state change. In our user research, we found that operators also complete an end-of-shift report for their replacement to review (CI3, CI6). Operators at one site follow a similar model, but more informally leave notes taped to the screen with any instructions or problems to review for the next shift (CI2). However, the next shift often does not notice or acknowledge notes taped to the screen.

Focus

Through discussion with our client and evaluation of our user research, we decided to focus on methods in which to help operators better keep track of processes, make predictions, and investigate past problems. We explored the area of trend monitoring and analysis for possible methods and came up with three approaches to displaying trends and related information. The first is a way of showing small-scale trends within the plant diagram, for example, inline with existing text. The second is other forms of trends integrated within the operator screens, for example, as part of an on-screen component. Last is the ability to show a full screen view of the trends, enabling detailed analysis.

Another area that was explored was asynchronous, informal communication between operators. This type of communication provides situation awareness for the operators and prepares them for problems. We came up with two separate design proposals that incorporate the creation and display of messages created and left by operators. The first integrates messages into a full-screen Trends & Events display. The second integrates messages in the form of “sticky” notes into operator overview screens.

It is important to recognize that our testing involved a very small set of people, not all of whom are current DeltaV or Ovation operators. While engineers and system configurers have insight into, and experience with, process control systems, we still found there to be considerable differences between how operators and engineers perceived the prototypes. Because we were limited to a single testing site for operator feedback, we cannot conclude that these solutions are definite improvements over the existing interface. That said we do feel that some of the concepts have promise, but we would recommend further evaluation before introducing them into a commercial product.

When relevant, a reference to a specific prototype evaluation session is made in parentheses following an observation. For example, “(ES3.2)” refers to the second user in our third prototype evaluation session. “(ES3)” would refer to an observation in our third prototype evaluation session that is not user specific. For more detailed information on the methodologies, please see Appendix II. Also when relevant, a reference to a specific Usability Aspect Report, which is a report on the problems and good parts of the prototypes faced during the evaluation sessions, is made in parentheses following an observation. The reference is presented as “UAR”, then the evaluation session number and then the number of that report amongst the list of all the UARs within that session. For example, “UAR-01-01” refers to the first Usability Aspect Report written for evaluation session 1.

Trends

For trends, we noticed that there is tight and important integration between the roles of trend analyzer and monitor. It is important for both to have a complete understanding of the process to ensure that the plant remains stable and to prevent potential problems. Trends were clearly important at all of the sites visited. Two sites used DeltaV History Viewer and exported the data to Microsoft Excel to graph information in more detail (CI1, CI2). At one of these sites, a user actually noted that he used Excel to “make pretty graphs” (CI1). Other sites used third party software to observe trends (CI3, CI4, CI5, CI6). With the third party software, users customized all their graphs and viewed only what they wanted to see (CI3, CI4, CI5, CI6). They enjoyed using this software because they found the graphs easy to manipulate.

Trends are observed and evaluated to make sure that the plant remains stable. They are also observed to provide situational awareness for potential problems, which allows preventive measures to be taken.

The problem seen is that, even though trend information is very important, it is separated from the layout screens due to lack of integration within the current software.

Four aspects of our design aim to increase the integration between trends and the operator layout screens. The first is a way of showing small-scale trends within the plant diagram in the form of integrated graphs. The second is history shown on bars within components. The third is displaying the relationship between variables and state of the plant on a radar display. Last is the ability to show a full screen view of the trends, enabling detailed analysis.

Integrated Graphs

Our prototype proposes a constantly updated PV trend, displayed on a semi-transparent background as shown in the picture below.

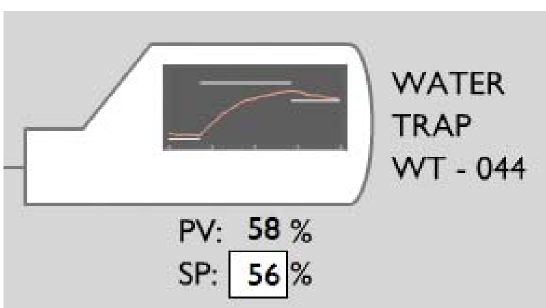


Figure 1: Trends Within Components

In **Error! Reference source not found.**, the orange line represents the PV, and the grey line represents the set point (SP). Our thought is that the colors could, and should, be customized to what the plant prefers to use for these two values. However, care should be taken to avoid colors that do not provide enough contrast against the background or are too similar to one another. Because the colors red and yellow are often reserved for an alarm state, it is recommended that they continue to be reserved for such a purpose. For example, within the prototype, the line representing PV changes to red or yellow if the value is at or past an alarm threshold. Because we wanted to include and promote the same types of interactions we had already seen between operators and graphs, we added a few controls onto the integrated trend, as seen below in **Error! Reference source not found.**.

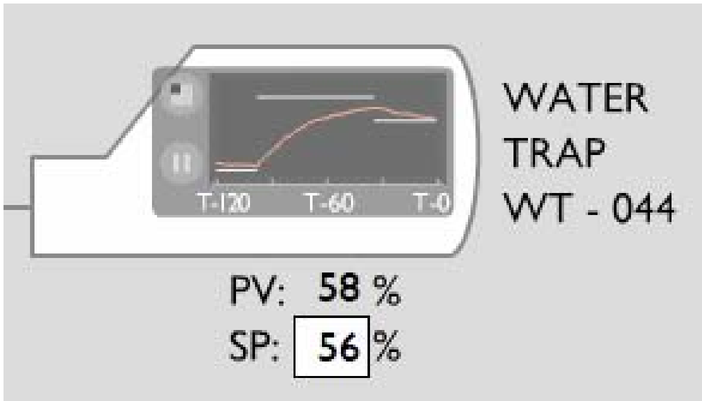


Figure 2: Trend Rollover

All of the controls in the picture below become visible upon rollover of the trend itself by the mouse cursor or other pointing device. The button in the upper left can be used to zoom in on, or magnify the graph

The button in the lower left can be used to temporarily halt the updating of the graph, or pause it at an instant in time (Figure 2: Trend Rollover). Naturally, the process will not be stopped, only the plotting of the trend itself. In order to avoid operators inadvertently leaving the graph in a paused state, once the rollover state is exited, the graph is unpaused automatically and snaps to the current time. In any of the states, operators can also click directly on the trend and pan back through history for the component.

If this type of interface was to be integrated within the current DeltaV or Ovation structure, it would be a supplement to the existing interfaces used to view full-screen graphs or trends, and there should be a quick way of getting from this integrated trend line out to an isolated, larger view.

During testing, participants also mentioned they would like to see a way to control the amount of time spanned by the graph window (ES3, ES4). For example, when viewing tank level, one operator may want the window to represent half an hour, whereas another may prefer to have the window span a full hour. In addition to being able to control this feature, participants also suggested that having the ability to directly jump to a time (either specific, such as 4:30, or relative, such as two hours ago) would be useful to them (ES3, ES4). Both of these ideas seem sufficiently worthwhile to warrant further design and testing of this interface.

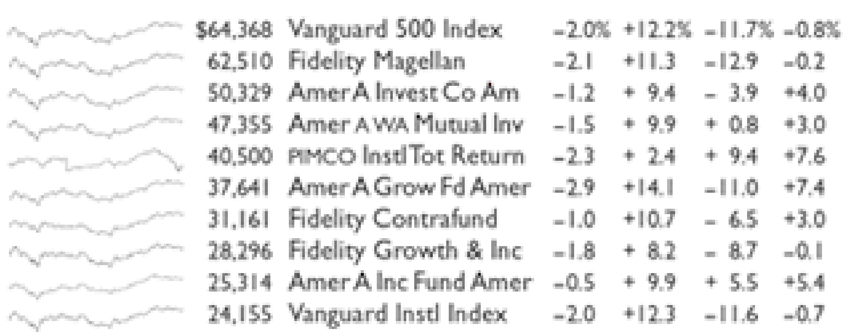
During our contextual inquiries (CI1, CI3, CI6), operators often viewed trends for multiple components on the same graph. If this is something that is also desirable at the smaller, integrated scale, it was suggested that the interaction be drag and drop (ES4), where a component could be highlighted, dragged, and dropped within the trend area for a second component in order to see the process for both components on the same set of axes. We feel these ideas all seem worthwhile enough to warrant further design, tweaking, and testing of this interface.

This concept was based on the “sparklines” concept promoted by Edward Tufte (2004), which are rich graphs that are about the size of a line of text displayed inline. While too small to show precise detail, they maintain characteristics that allow the detection of the slope, state, and stability of the process.

We initially tested an inline trend for a two-state component in which a dash was marked to represent a period when the component was on and an empty space represented a period when the component was off. Over time, the graph appeared as a continuous line with varying-sized gaps, similar to the following: – – - ——

In the first two rounds of testing, this trend went largely unnoticed (ES1, ES2). After these trends were pointed out to participants, they did express an understanding of what they represented, but still did not like the presentation (ES1, ES2). Part of the problem may be that the inline trend only depicted a small number of time intervals, as some participants noted it was difficult to notice the times when the component was off, trying to see “something that wasn’t there” (ES1). When shown for a longer interval, it may be more clear when the state of the component switches. Participants also expressed that for many two-state components, there was already a clear visual indicator of whether a component is on or off: the component itself changes color (ES1, ES2). They were unsure what benefit the additional history information would offer.

Our own concerns with sparklines are threefold. First, Tufte’s work is focused largely on sparklines that are integrated within text, such as newspaper articles. When he demonstrates how multiple sparklines can be used together, they seem to be shown in chart form (See Figure 3: Sparklines in Stock Market Context (Tufte 2004)).



$64,368	Vanguard 500 Index	–2.0%	+12.2%	–11.7%	–0.8%
62,510	Fidelity Magellan	–2.1	+11.3	–12.9	–0.2
50,329	Amer A Invest Co Am	–1.2	+ 9.4	– 3.9	+4.0
47,355	Amer A WA Mutual Inv	–1.5	+ 9.9	+ 0.8	+3.0
40,500	PIMCO Instl Tot Return	–2.3	+ 2.4	+ 9.4	+7.6
37,641	Amer A Grow Fd Amer	–2.9	+14.1	–11.0	+7.4
31,161	Fidelity Contrafund	–1.0	+10.7	– 6.5	+3.0
28,296	Fidelity Growth & Inc	–1.8	+ 8.2	– 8.7	–0.1
25,314	Amer A Inc Fund Amer	–0.5	+ 9.9	+ 5.5	+5.4
24,155	Vanguard Instl Index	–2.0	+12.3	–11.6	–0.7

Figure 3: Sparklines in Stock Market Context (Tufte 2004)

It is unclear if Tufte intended that sparklines be used in something as busy as an operator control screen, which brings us to our second concern.

Sparklines were designed in order to reduce visual clutter, and Tufte shows some nice examples that demonstrate this point. He also talks specifically about the areas surrounding sparklines, "Areas surrounding data-lines may generate unintentional optical clutter. Strong frames produce melodramatic but content-diminishing visual effects." He then refers to a set of framed sparklines, saying, "The most prominent visual elements are, of all things, the activated negative spaces between the sparkline frames" (Tufte, 2004).

Although we are not putting frames around the sparklines, we still question whether there will be room for the lines to stand on their own and be valuable, considering how many other controls, objects, and labels already exist on the screen. Past HCI research has shown that clutter is a quantifiable metric and a methodology for testing display screens for clutter is outlined in the paper "Feature congestion: a measure of display clutter" (Rosenholtz, Li, Mansfield, & Jin, 2005). It would be beneficial to test some representative display screens with and without these types of sparklines in order to direct future versions of DeltaV.

Our third concern is resolution. Sparklines were designed to be printed on paper, where a much higher level of detail can be achieved. As Tufte writes, "Sparklines work at intense resolutions, at the level of good typography and cartography. Currently such intensities can be found only on paper and film, where resolutions greater than 1200 dpi are both easy and inexpensive to achieve. Today's computer display-screens operate at much lower resolutions, producing rough typography and sparklines lacking in fine detail." (Tufte, 2004)

While computers and technology have evolved significantly since 2004, it is important to recognize that many of the DeltaV and Ovation systems are running on older machines, and may not be capable of producing an adequate resolution.

Based on these concerns we created larger, stand-alone trends referred to as integrated graphs.

Bar History

Bar graphs are commonly employed to show level-based PVs. One possible way of integrating trend information into this kind of display that we explored was overlaying the value of that variable at various points in time in the past. The chosen points would be determined by a fixed interval of time. The one exception would be the interval between the most recent history point and the current time. The history point would be plotted as soon as the current time reached it. Therefore, the current time would always be within one interval of the most recent history point. There would need to be a limit set for the number of history points to be plotted to avoid clutter. The current time would be shown in a dark color. Older values would be shown in increasingly lighter shades (See

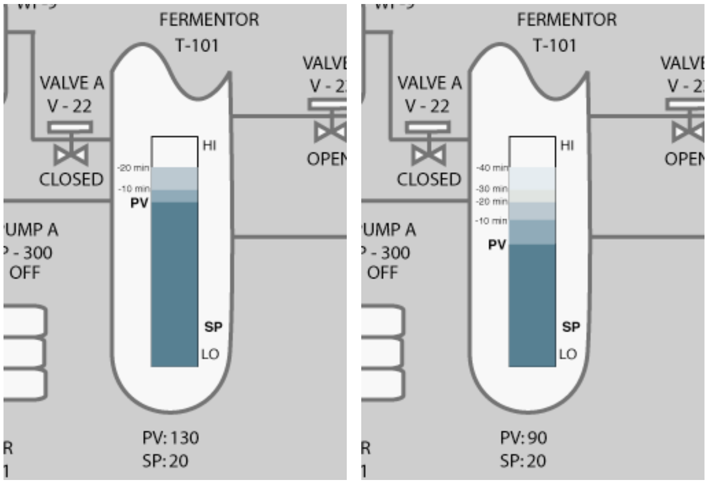


Figure 4: Bar History, as a process begins and history accumulates).

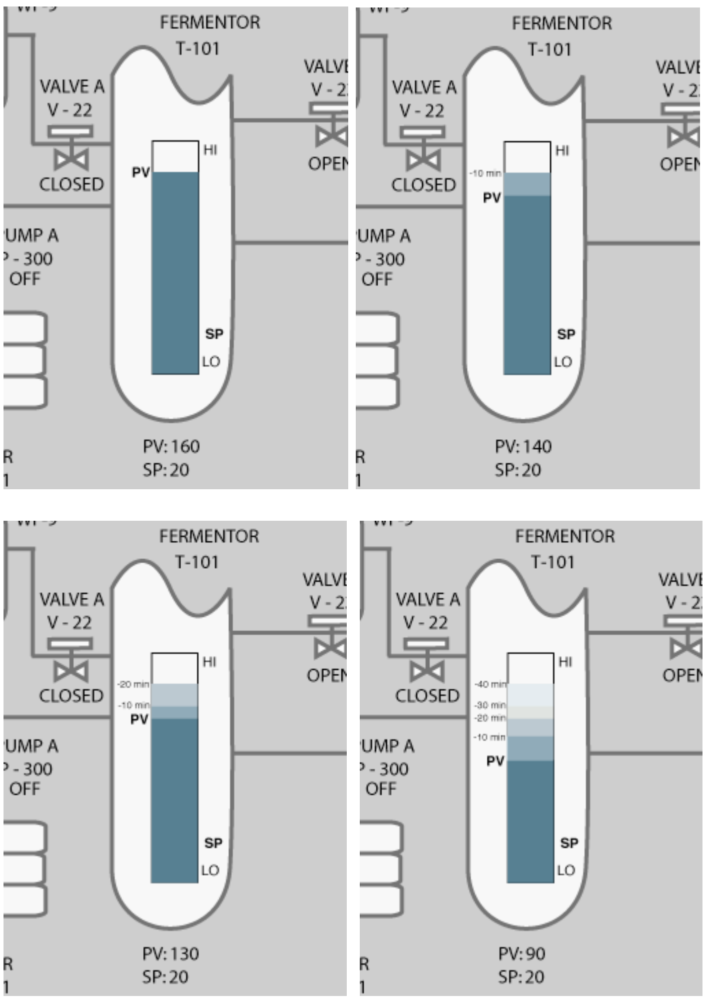


Figure 4: Bar History, as a process begins and history accumulates

The primary value of this display beyond just raw history is that, since the interval between points is constant, the difference between the sections of the bar graph would indicate the acceleration of the process. One of the clear limitations to this technique is that the process would need to behave in a generally monotonic fashion for the sizes to be comparable (ES1.2, ES1.4, ES2). While this type of history display could be used online to aid in monitoring or offline to aid in analysis, evaluation by process control experts suggested it would be helpful in offline use but not online use (ES1.1, ES1.2, ES1.3, ES1.4). It was felt that having the ability to control the amount of history was especially useful (ES1.4).

Several other pieces of feedback came out of our evaluation. There was concern that the overall size of the piece of equipment containing the bar graph might be larger than is practically found in operation (ES1.1). However, operator screens witnessed during prior research show this to not be the case (CI1, CI4, CI5). The labels for the times were found to be possibly too small (UAR-01-01, UAR-02-09). Additionally, it was expressed that there is frequently a need to know precise numeric values (ES1.1). We believe both of these issues can be addressed by the same technique. A form of transient information display, such as a tool tip, could be used to show the labels and numeric values. Since the tool tip would only be visible when needed, it can be shown bigger and on top of elements on the screen that are not pertinent at that time.

It was noted that the appearance of new labels as new points are shown could be distracting in a monitoring situation (ES1.4). However, if this graphing style is used in an offline mode to analyze history, which is when it was felt to be most useful, this would not be an issue. Finally, one of the experts did have some difficulty in understanding the graph and what the size of the segments signified (ES1.2).

Radar Display

Configural displays were the inspiration for the radar display. To aid in the description of our design, we have provided some background information on configural displays.

Configural displays arrange variables in both space and format so that a property of this configuration emerges to signal a significant, task-relevant, integrated variable (Wickens, Lee, Liu, & Becker, 2004; Hansen, 1995). This property is defined as an emergent feature (Pomerantz, 1986; Pomerantz & Pristach, 1989; Sanderson, Flach, Buttigieg, & Casey, 1989). According to Pomerantz (1986), figures with emergent features will be perceived faster in divided-attention tasks in which all parts have to be taken into account than figures without emergent features.

The rationale behind using configural displays is that operators must consider both the relationships among several variables, (e.g., monitoring performance) and the values of individual variables (CI1, CI3, CI6). Two principles, proximity compatibility principle and replace memory with visual information, about displays support the usage of configural displays for variables related to each other. The proximity compatibility principle (Wickens & Carswell, 1995) states that when two or more sources of information need to be “mentally integrated” to complete a task, then these information sources should have close display proximity. The concept of replacing memory with visual information (Norman, 1988) states that people should not have to retain important information in working memory or have to retrieve it from long-term memory. Therefore important information should be visually displayed. Instead of operators keeping several values in their head at a time to figure out their relationships with one another, showing these connections visually would be a great aid in freeing up that consumed memory.

Configural displays have been shown to significantly increase accuracy with tasks that require considering relationships between variables when compared with just bar graphs (Bennett, Toms, & Woods, 1993). With tasks that require knowledge of the values of individual variables, configural displays had the same accuracy as bar graphs. It has also been shown that for control and fault detection tasks, configural displays produced much better performance than just digital values (Bennett & Walters, 2001).

Examples of Usage

These concepts have been employed for plants similar to ones that DeltaV and Ovation are installed in. The first is a safety-parameter monitoring display that was developed by Woods, Wise, and Hanes (1981) for a nuclear power control room as displayed in Figure 5: Radar Display (Source: Woods, Wise, & Hanes, 1981, p.111). The eight critical safety parameters are configured in an octagon such that when all are within their safe range, the easily perceivable emergent feature of symmetry is observed. If a parameter departs from its normal value as the result of a failure, the distorted shape of the polygon can uniquely signal the nature of the underlying fault.

Another display was created for a boiler power plant supervisory display by Rantanen and Gonzalez de Sather (2003) as displayed in Figure 6: Bar Configural Display (Rantanen & Gonzalez de Sather, 2003). The 13 bar graphs that represent critical plant parameters are configured so that an imagined straight line across the middle of the display signals the key state that all are operating within the normal range. A parameter that is out of range is noticeable due to its break from the imagined straight line.

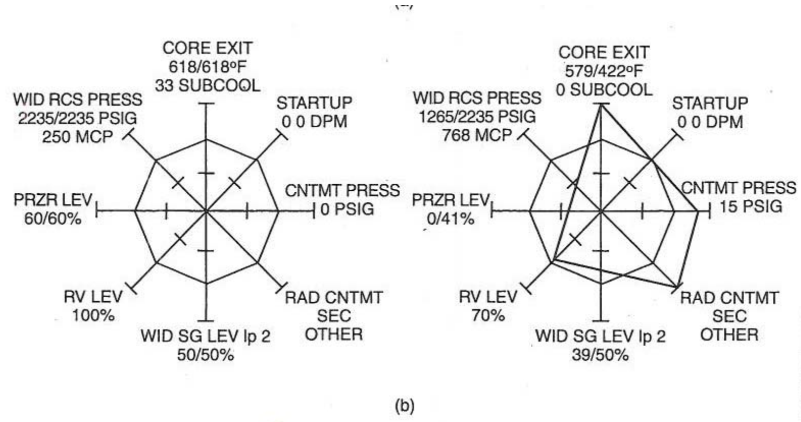


Figure 5: Radar Display (Source: Woods, Wise, & Hanes, 1981, p.111)

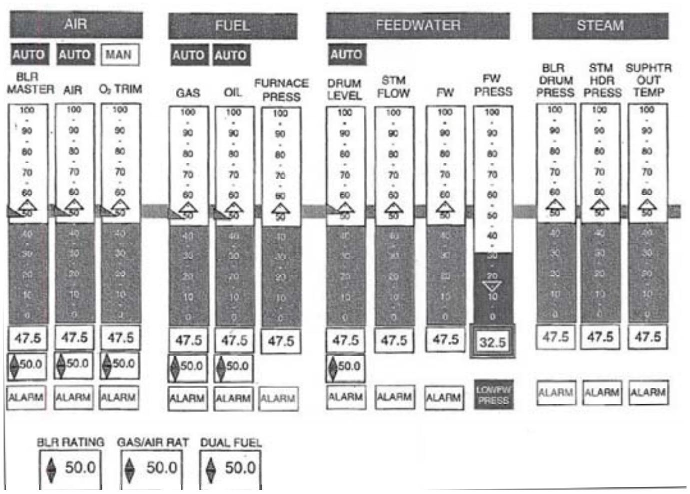
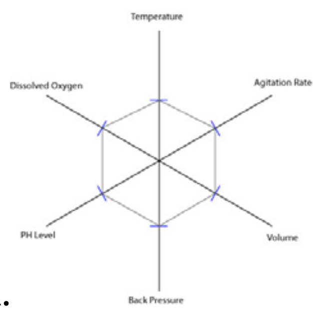


Figure 6: Bar Configural Display (Rantanen & Gonzalez de Sather, 2003)

Due to limited time, only one type of display could be implemented and tested. The radar display was chosen due to its unique form and efficient use of screen space. Variables of interest are placed as points on intersecting lines. All of the points are connected to form a shape, which is the emergent feature of the display. There are two types of points on the display: set point SP and current value PV. The shape formed by connecting all of the SP points is the ideal shape, as in the shape that is formed when all systems are good. In Figure 5: Radar Display (Source: Woods, Wise, & Hanes, 1981, p.111), the display on the left is during normal operation, whereas the display on the right is during a loss-of-coolant accident (Woods, Wise, & Hanes, 1981). There are also two methods in which a radar display can be constructed, absolute and relative, both with their benefits and costs.

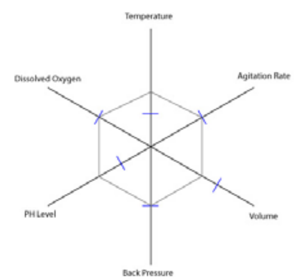
Absolute Radar Display

For the absolute radar display, the lines on which the points lie will be scaled from the minimum and maximum possible amounts for each point. When the operator changes the SP of a variable, its corresponding point will move along its line, as can be seen in Figure 7, number 2. This causes the shape at which everything is within normal range – the ideal shape – to change, requiring the operator to constantly update his memory of the ideal shape, which is now number 3 in Figure 7. This puts a heavy load on the operator's working memory which has a limited capacity and is already loaded by all the other information about the plant that needs to be kept track of (Miller, 1956). This load on working memory can cause the operator to forget the current ideal shape and therefore not notice when current values go out of range (Wickens et al., 2004). On the other hand, the SP point on the line moves along the line in a pattern that is compatible with the change in SP values made by the operator. This supports the expected relationship between the SP points on the radar display and the SP values that are entered in by the operator (Roscoe, 1968; Fitts & Seeger, 1953). It also provides supportive feedback of what the operator has done and makes the system status visible (Nielsen, 1994).



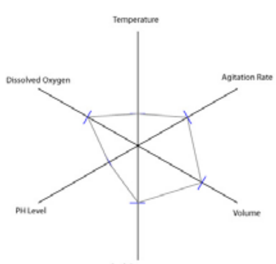
1.

Ideal shape



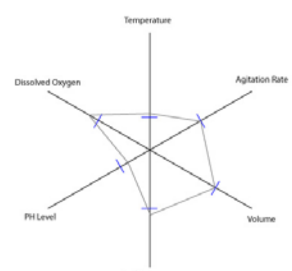
2.

Set Points changed



3.

System back to ideal (New ideal shape)



4.

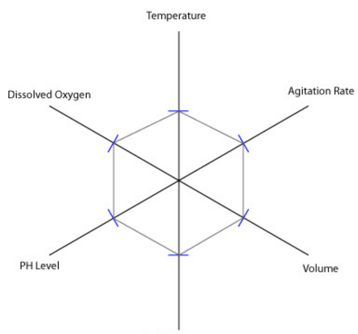
System not ideal

Figure 7

Relative Radar Display

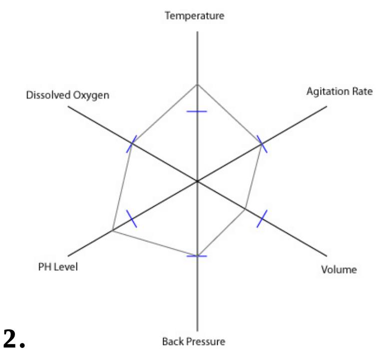
For the relative radar display, the point representing the SP never moves, keeping a consistent ideal shape displayed at all times. When changes are made by the operator, these SP points do not move and the PV points move in respect to the

SP points, as can be seen in Figure 8, number 1 and 2. Shape is the most obvious characteristic people use to identify objects, and regular shapes are expected when looking at shapes (Willingham, 2001). Therefore, irregular shapes drastically stick out (Willingham, 2001), making it is easy to note when the PV values are not lined up with the SPs due to the break from the ideal shape. According to Loftus, Dark, and Williams (1979), the rule of thumb is that the time and number of items that human operators have to keep in working memory during a task should be kept to a minimum. By having the ideal shape not move, the operator does not have to keep remembering the new ideal shapes and therefore puts fewer items to be kept in memory. However, when the operator makes changes, the set point on the line does not move, breaking the principle of making the movement of the display compatible with the changes made by the operator (Roscoe, 1968; Fitts & Seeger, 1953) and not providing feedback of system status (Nielsen, 1994). This may cause confusion for the operator as whether his changes were actually entered into the system.



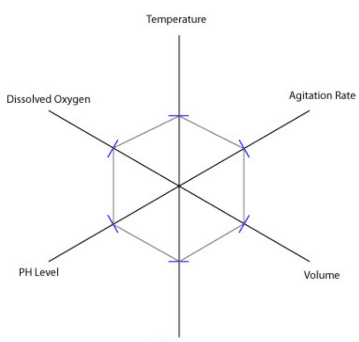
1.

Ideal shape



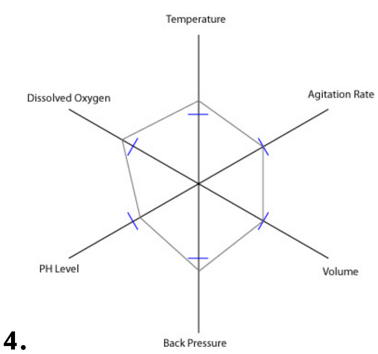
2.

Set Points changed



3.

System back to ideal



4.

System not ideal

Figure 8

User Testing

None of our user testing with DeltaV operators revealed whether the absolute or relative display is better than the other, with both types of displays having their advantages and disadvantages. Further testing will be needed to have a conclusive answer to which type of display to use or whether to allow both possibilities.

Further testing would also allow the opportunity to test whether a bar configural display similar to the one developed by Rantanen and Gonzalez de Sather (2003) is a better form of a display for presenting relationships between variables than the radar display. Another area to test would be what other information other than a visual display should be added to these configural displays. It has been shown by Bennett and Walters (2001) that adding bar graphs, extenders, scale markers, scale grids, and annotation with digital values to a configural display improves performance for quantitative estimates of individual variables and system control. The interest here is what is needed and not needed for operators.

Full-View Trends

The full-view of trends is similar to functionality that exists in related products, in which trends are shown in a devoted window. The key advantage to our design is a seamless integration with the rest of the operator console, enabling easy navigation between plant diagrams, events, and trends and back again. Additionally, these views can be synchronized to facilitate analysis of the plant from multiple perspectives.

From all of our research, we consider the following to be some of the essential capabilities of the full-view feature: to be able to switch quickly between history and current plant activity, to support arbitrary magnifying within a trend plot; to overlay multiple trend plots to support comparative analysis, and to easily add trend plots by dragging a component from the operator screen into the trend window.

The full-view trend has been integrated with the display of messages, which is one of the designs to aid communication. As a result, further description of full-view trends is contained under Trends & Events Display in the Communication section so as not to separate these two integrated ideas.

Communication

One of the areas of interest from our user research is asynchronous informal communication between operators. Typically, this takes the form of sticky notes being left for the next shift of operators. Communication has proven to be a very interesting area for exploration since little to no support of this practice exists in the current DeltaV Operate product.

Communication between the operators is necessary to keep plant systems under control. Frequent communication is important so that the operator can have situation awareness and be prepared for problems. At plants where dynamic systems are managed by a team of operators in control rooms, the state of the system changes autonomously due to the actions of other operators (Brehmer, 1992). Hence, the work that goes on in the control room is dependent on the performance of a team that works in a "collaborative way rather than a collection of uncoordinated individuals" (Garbis, 2000).

We developed two separate design proposals that incorporate the creation and display of messages. The first integrates messages into the Trends & Events display. The second integrates messages in the form of "sticky" notes into operator overview screens.

Trends & Events Display

The Trends & Events display offers several features, including a full-view of trends and messages (See Figure 9: Trends-Events Screen).

Messages can be associated with an alarm, a component, or for general notice, without an association. Messages contain details such as the author and time the message is created. These messages can be tagged or given multiple keywords to make searching easier.

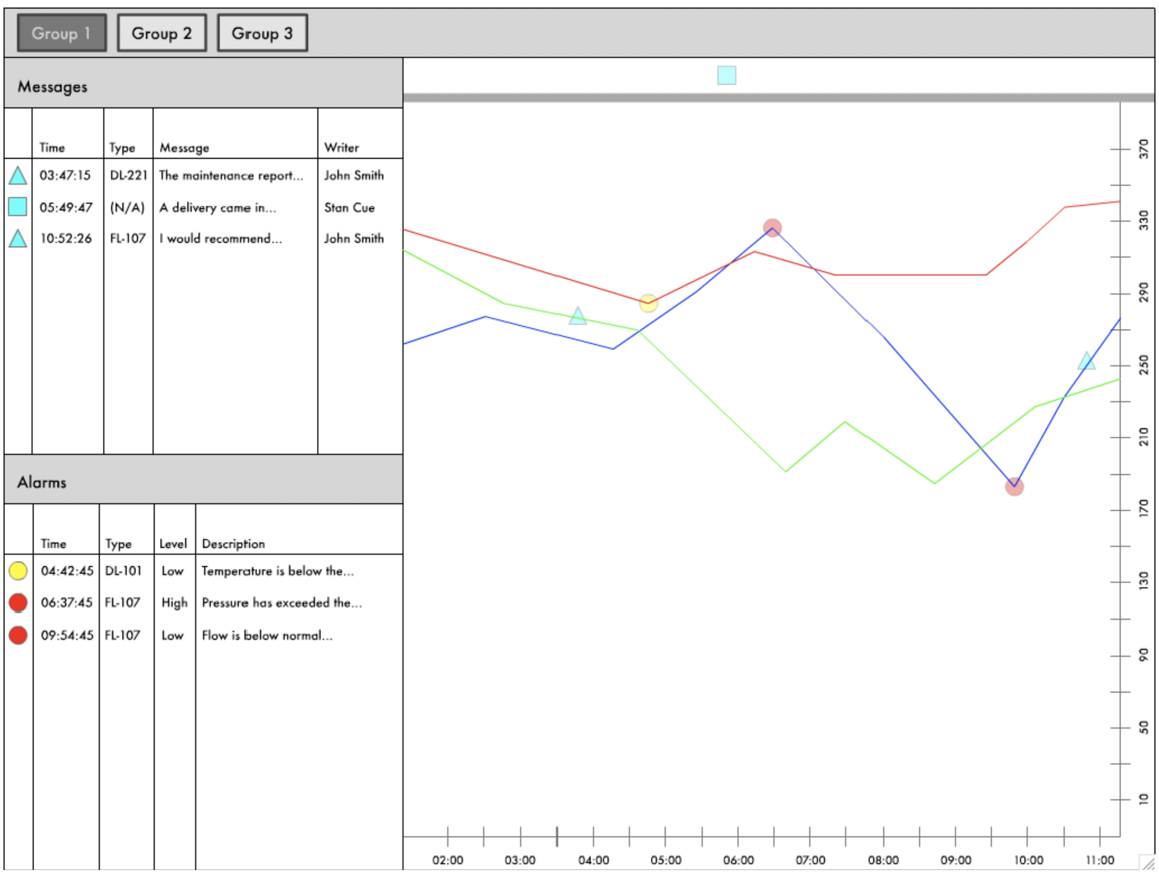


Figure 9: Trend-Events Screen

Trend-Events Suggestions

Message and Alarm Lists

Although plant control screens only represent the process at that moment in time, it is important for operators to be aware of past events. Because plants often run 24 hours a day, no one person is able to keep a constant eye on these events. Viewing historical data is one way to get at this information, but because it only shows values and not the steps people took or the causes for problems, it is an incomplete picture. For these reasons, communication between operators is key, particularly during a shift transition or hand-off.

To address communication problems identified during user research, we propose the addition of a message list to allow operators to inform their shift replacements of any concerns they had and increase situation awareness (See Figure 10: Messages List). The time and type of message is included in the list, along with a snippet of the message. When clicked, the message appears in the trend view for complete reading. The name of the person who wrote it is also listed.

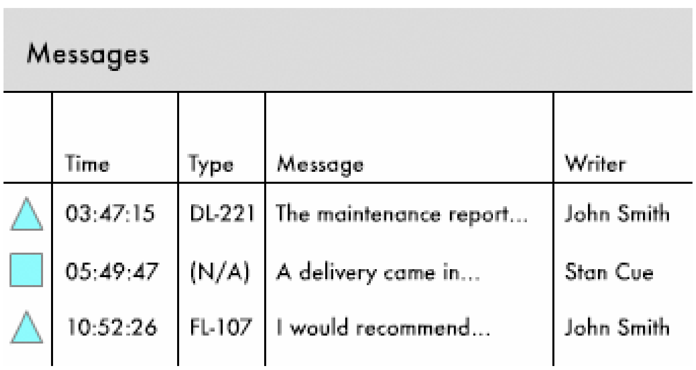
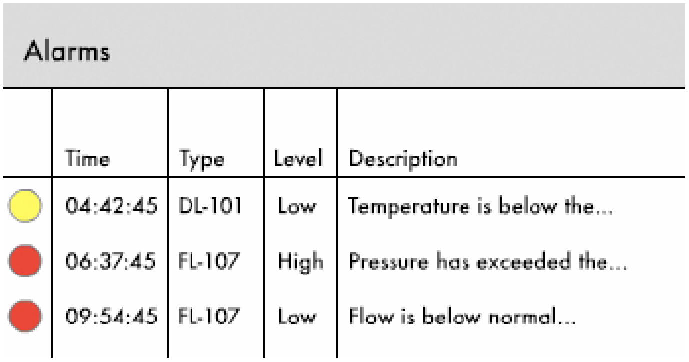


Figure 10: Messages List

In addition, to aid operators in understanding what took place during a previous shift, our design includes an alarm list (See Figure 11: Alarms List). Alarms are color-coded based on priority from the DeltaV Operate view. Time, type, and alarm level are included in the list. A short description is included for understanding of what happened to cause the alarm. Both the message and alarm lists are linked to respective trend lines and to the display of the actual message or alarm information.



Alarms

	Time	Type	Level	Description
(yellow)	04:42:45	DL-101	Low	Temperature is below the...
(red)	06:37:45	FL-107	High	Pressure has exceeded the...
(red)	09:54:45	FL-107	Low	Flow is below normal...

Figure 11: Alarms List

Color-coded Alarm and Message Roll-Overs

Alarms and messages are indicated by icons along the trend lines (See Figure 12: Alarm Roll-Overs). Hovering over the icon will display the message. When an operator clicks on an alarm or message in a list, it will pop up along the trend.

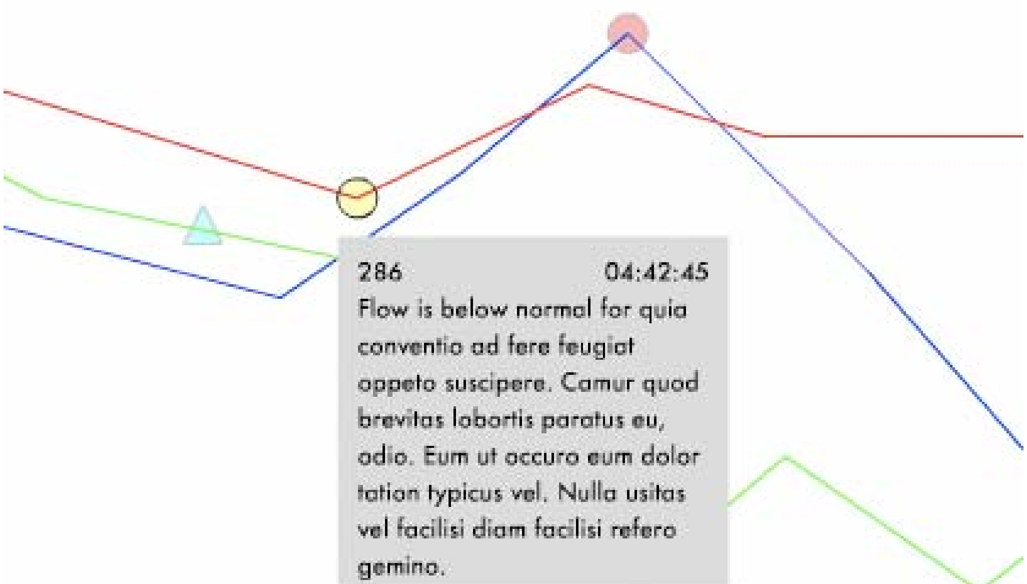


Figure 12: Alarm Roll-Overs

Vision researchers Cole, Maddocks and Sharpe (2004) note that “the target object is immediately obvious because of its colour and there is no need for serial search for the target”. In their study on conspicuity of targets, they found that for people without color vision problems, search time was reduced by one-third for people searching with uniquely color-coded objects compared with those uniquely identified by shape alone. “Color facilitates quicker information acquisition from graphical and tabular presentations” (Hoadley, 1990). Research by R.E. Christ (1975) showed that "color coding shortens search times compared to... brightness, shape and alphanumeric codes".

Evaluation with three regular DeltaV users showed that our design of alarm tracking and message display along trend lines might fulfill user needs for situation awareness (See UAR-02-04 in Appendix III.B). Further evaluation to gather quantitative evidence will be necessary to determine whether this design reduces time spent evaluating the status of the system at the beginning of a shift.

Stickies Attached to Components

Another method for increasing situation awareness among operators is to integrate virtual sticky notes into regular operator overview screens (See Figure 13: Stickies Overview).

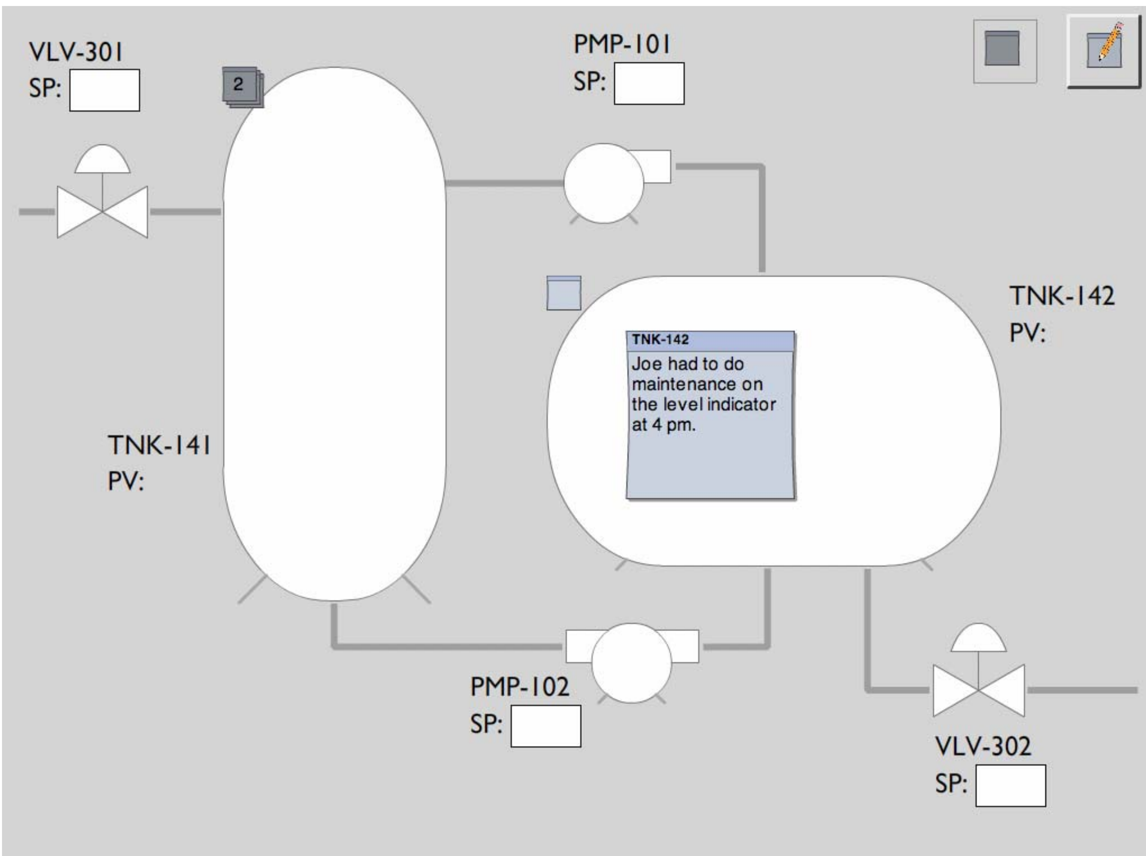


Figure 13: Stickies Overview

The prototype for this design was only presented during one testing session, so it has not been as well refined as some of our other prototypes. However, we do have some ideas as to what might be easier to use.

When a component has a sticky attached to it, an indicator appears. The indicator is dimmed and grayish when the stickies are not being displayed, but highlights when the stickies are displayed. In this particular design, stickies are only visible for one component at a time. When an indicator for a particular component is clicked, the stickies for all other components are hidden. There was a concern that this indicator may not stand out enough (ES4.1), but more testing will be necessary to determine whether this is the case. Testing also revealed that it is important to indicate how many messages there are (ES4.1), so this indicator also displays the number of hidden messages. Since stickies are only displayed for one component at a time and operators may have a message they do not necessarily want to attach to a specific component, we added an indicator for "general" stickies that are not attached to any particular component.

The traditional yellow color for stickies would indicate a warning or alarm, while straight grey stickies would not stand out from the interface as something user-created and special. We decided on a blue-grey color, which stands out from the grayscale engineer-created graphics, but is hopefully not loud enough to distract from anything in more urgent red or yellow.

The button for adding new stickies has a mini sticky on it. New stickies currently appear near the button that creates them. Ideally one should be able to click and drag out of the add button and have a sticky appear wherever one releases the drag.

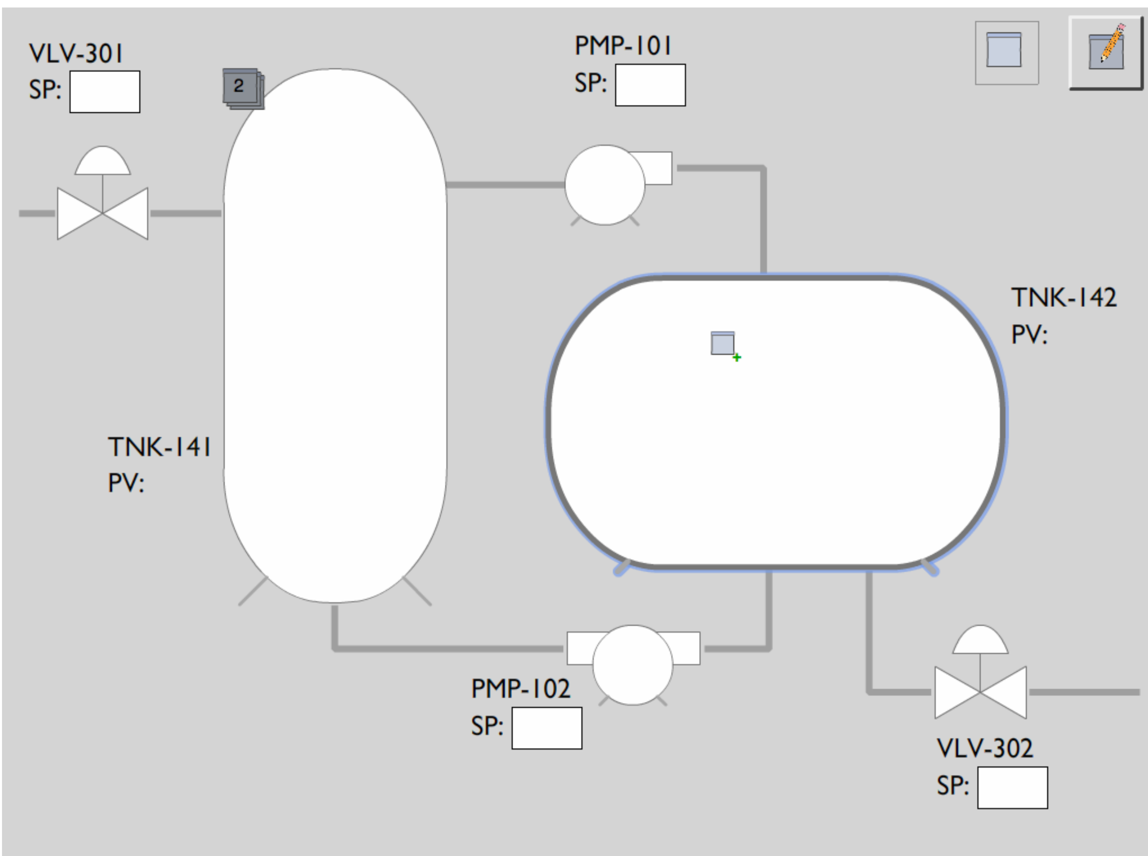


Figure 14: Dragging Stickies

Dragging a general, or unattached, sticky over a component causes the sticky to change into a small icon next to the mouse cursor (See Figure 14: Dragging Stickies). This icon indicates that this particular sticky can be attached to the component under the mouse cursor. The component is highlighted by bolding and increasing the width of the component outline, along with the addition of a blue-grey glow surrounding the component in order to make it clear exactly which component the sticky will be added to.

Two users did not discover the drag-n-drop functionality (ES4.1, ES4.2). If this proves to be an issue after further evaluation, one possible solution would be for the cursor to immediately enter a drop state. That is, the cursor would have the small "add sticky" indicator and the user would then click on a component to drop the sticky. This solution eliminates the drag-n-drop functionality in favor of a direct-select mechanism at the expense of being modal. Research would be required to determine which method is more obvious and useful.

Conclusion

In conclusion, our background research and contextual inquiries have led us to solutions that aim to provide operators with faster ways to evaluate any given moment in time and form a more complete picture of the current and past processes as well as better know how to predict what might happen in the future. While we feel our designs require further testing to provide more quantifiable results, our preliminary testing did show that operators and engineers responded favorably towards the new visualizations.

Future Work

There are several extensions to the prototypes that we were unable to finish and many ideas we have for future research. These two areas are places for future work.

The following include ideas of what to add to the already implemented designs or what to modify in the implemented designs. A number of these ideas were briefly mentioned in the Solutions sections, but they are further expounded upon within this section along with many other ideas that have not been presented yet.

There are sketches of other ideas that were not implemented, which are presented in Appendix VI.

Integrated Graphs

During testing, participants mentioned they would like to see a way to control the amount of time spanned by the graph window (ES3, ES4). For example, when viewing tank level, one operator may want the window to represent half an hour, whereas another may prefer to have the window span a full hour. In addition to being able to control this feature, participants also suggested that having the ability to directly jump to a time (either specific, such as 4:30, or relative, such as two hours ago) would be useful to them (ES3, ES4). Both of these ideas seem sufficiently worthwhile to warrant further design and testing of this interface.

During our contextual inquiries (CI1, CI3, CI6), operators often viewed trends for multiple components on the same graph. If this is something that is also desirable at the smaller, integrated scale, it was suggested that the interaction be drag and drop (ES4), where a component could be highlighted, dragged, and dropped within the trend area for a second component in order to see the process for both components on the same set of axes. A problem that arises with placing multiple components' trends on one graph is how to take into account the different units and scaling. The purpose of the integrated graphs is to be small and simple, yet extremely informative. Having multiple scales and units on an integrated graph could become an overload of visual information that would then make it difficult to even see the trends themselves (Nielsen, 1994).

One heuristic to follow when developing a usable interface according to Jakob Nielsen (1994) is to give the user control and freedom. A couple of ideas stem from this concept. The first is to allow operators to reposition the integrated graphs on the diagram. In the current implementation, where the graph appears is where it stays. The problem without allowing the user to move the graph is that the graph could be covering important information needed by the operator. By being able to move the graph, the operator could prevent important information from being covered. The second idea is to allow the graphs to be sized to whatever size the operator desires. Currently, the graphs only appear in three sizes. The first is a small size on the screen. If the operator scrolls over the graph it enlarges a little bit. The operator can also click on an enlarge button that makes the graph even larger. The problem with this is similar to the previous problem, in that the graph may cover important information. By being able to resize the graph, important information can be prevented from being covered and the operator can choose whatever size of the graph that is desired by him. As we saw at all of the site visits, age and eyesight varies amongst all of the operators. Some might need to see a larger graph whereas others are fine with smaller graphs.

During one of the testing sessions (ES4), three of the operators explained that if they wanted to see more detail or go back further in time, they would want to use the full screen trend view that we presented them with. To make it easier for the operators to get to this screen, there should be a button on the integrated graphs that takes the operator to a full size view of that trend (Nielsen, 1994).

A couple of problems that exist in the current implementation are that, first, when enlarging a graph, the controls also become larger. These controls being the play/pause button and the maximize/minimize button. There is no need for these buttons to become larger and, actually, by them becoming larger more of the display is covered up than is necessary. The second problem is that the icon for maximize/minimize was confusing to the operators, causing them not to know what it did or that maximizing/minimizing was possible (ES4). As a result, this icon should be changed to represent more clearly what it does. At all of the sites visited, operators used Windows for various purposes, so a possible idea is to use the maximize and minimize buttons used by the Windows software that these operators are familiar with.

Bar History

One of the clear limitations to the current implementation of the Bar History design is that the process would need to behave in a generally monotonic fashion for the sizes to be comparable (ES1.2, ES1.4, ES2). If the process were to increase and decrease, it would be difficult to interpret the history and trend.

To overcome this, two ideas are proposed. The first is to have the history bars beside each other as presented in Figure 15: History Bars. In this figure, the leftmost diagram is the current implementation and the other is a way in which to implement this first idea.

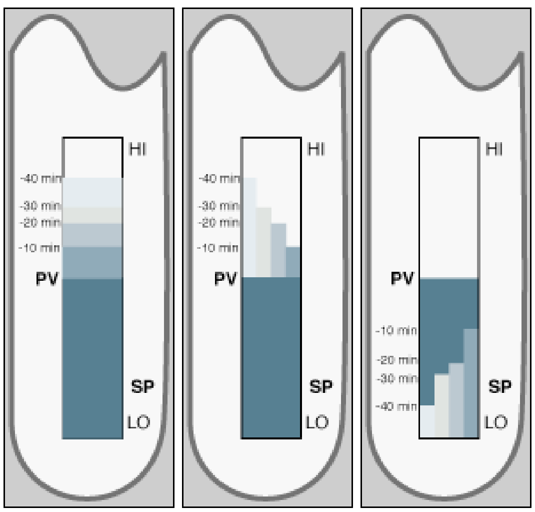


Figure 15: History Bars, with side-by-side history

The second idea is to overlay a line graph plotting the history. This final technique would much more accurately communicate history for processes that rapidly oscillate between increasing and decreasing. The area between the current value and the historical value could be colored to highlight the change. Two ways of implementing this idea are displayed in Figure 16: History plotted continuously. The first method is to have no coloring between the history and current PV and the other method is to shade between the history and current PV. The shading may aid in see the difference but at the same time may be too distracting.

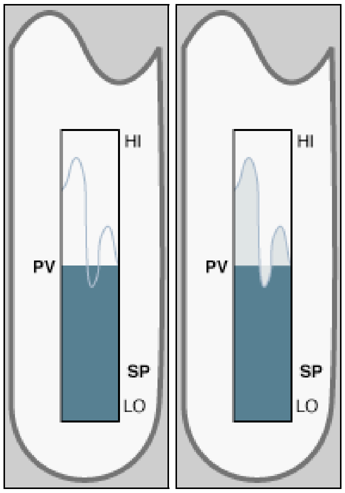


Figure 16: History plotted continuously

Radar Display

For all of the evaluations done on the radar display, its purpose and appearance brought great confusion. The main problem with this design is that the process and screen layout tested is not one the operators know as deeply as they do with their own processes and layouts. As a result, it was difficult for all of the operators to understand the relationships between the components and what was going on, which makes it difficult to comprehend the radar display. A more realistic process and one that the operators are familiar with will be needed to test the usefulness of the radar display.

Further testing would also provide the opportunity to test whether a bar configural display similar to the one developed by Rantanen and Gonzalez de Sather (2003) is a better form of a display for presenting relationships between variables than the radar display. Another area to test would be what other information other than a visual display should be added to these configural displays.

Messages on Trends

None of the operators that evaluated the Messages on Trends design understood that the general message icon represented general messages, which are messages that do not apply to a specific component. The placement of the general message icon on the trend graph at the top with a horizontal line beneath that spans the width of the trend did not help operators in interpreting what the icon represented. A possible solution is to label a section on the graph to be where general messages will be placed – having a section similar to the horizontal line across the width of the screen as is currently implemented. Another solution is to change the type from “N/A” in the message list to “General Message” for the general messages.

Currently, the message and alarm list is on the left side of the trend. We do not have any data supporting whether the list should be on the side of the trend or underneath the trend. It would be worthwhile to test which method is preferred by operators, and more importantly, helps the operators perform faster, more efficiently, and with less errors. Another addition to the message and alarm list would be to add the ability to minimize, maximize, increase/decrease width and height, and to undock the lists. These ideas would provide more control and freedom for the operators so that the appearance of the screen is one that is preferred and desired by the operator (Nielsen, 1994). The operators would also be able to change the size of the lists so as to give more space to what is important to them.

As we observed at several sites (CI1, CI3, CI6) during our contextual inquiries (CI1, CI3, CI6), operators often viewed trends for multiple components on the same graph. Therefore, it is crucial to allow operators to have control over what appears in trends. Ideas to support this need are to allow the operators to add new trend groups, add trends to a group, delete trends from a group, and edit the coloring of the trends themselves. These ideas would give operators more control over what information appears and how it appears according to what they desire and need.

Stickies Attached to Components

During our evaluation of this design none of the users discovered the drag-n-drop functionality (ES4.1, ES4.2). If this proves to be an issue after further evaluation, one possible solution would be for the cursor to immediately enter a drop state. The cursor would have the small "add sticky" indicator and the user would then click on a component to drop the sticky. This solution eliminates the drag-n-drop functionality in favor of a direct-select mechanism at the expense of being modal. Research would be required to determine which method is more obvious and useful.

Currently, there is no method in which to delete these messages that are in the form of “stickies.” This presents the obvious problem that the screen can become cluttered with too many “stickies.” There is the ability to minimize/maximize “stickies,” but this minimizes/maximizes all of the “stickies” that are attached to one component, which does not solve the problem of screen clutter. An easy solution is to provide a trash can icon on the screen that a “sticky” can be dragged onto to delete it. With the ability to delete messages comes the ability to accidentally delete the message. Accidentally deleting a message may cause frustration, which is not the goal of a usable interface. Therefore the reasoning behind not having an “x” on the “sticky” to delete it, as is done in Windows, is to decrease the chance of accidentally deleting a “sticky.” Dragging a “sticky” to a trash can icon we believe would require more effort and make it less likely for a “sticky” to be accidentally deleted. Testing would need to be done to find a method that makes it the most difficult to accidentally delete a message without making it difficult to delete a message on purpose.

One of the operators during the evaluation of the “sticky” design stated that it would be helpful to know when a “sticky” was created and if a “sticky” has been read. To aid operators to know what time a “sticky” was left by another operator, we propose placing the time a “sticky” is created on the “sticky” itself. The operator seemed concerned about knowing whether a “sticky” has been read or not because he wanted to know if the messages he left had been read by other operators. Also, it would allow him to know what messages are new and should be read. To aid in this, unread “stickies” should be highlighted by a noticeable color and ones that have been read should appear in the normal blue-gray color. The current icon for when “stickies” are minimized is a small “sticky” with a number on it representing how many “stickies” that are attached to that component are minimized. The unread “stickies” should be separated from these, having the same icon but colored with a noticeable color and displaying the number of unread “stickies.” What color to be used for the unread “stickies” will require testing, so as not to use a color that is distracting or causes confusion for the operators.

References

Andre, A. D. & Wickens, C. D. (1992). Compatibility and consistency in display-control systems: Implications for aircraft decision aid design. *Human Factors, 34(6),* 639-653.

Barfield & T.A. Furness III (eds.) (1995). *Principles and practice of aviation psychology* (pp. 239 – 263). Mahwah, NJ: Erlbaum.

Benbasat, I. Dexter, A.S., & Todd, P. (1986) The influence of color and graphical information presentation in a managerial decision simulation. *Human Computer Interaction*, 65-92.

Bennett, K.B. & Walters, B. (2001). Configural display design techniques considered at multiple levels of evaluation. *Human Factors and Ergonomics Society, 43(3),* 415-434.

Bennett, K.B., Toms, M.L., & Woods, D.D. (1993). Emergent features and graphical elements. Designing more effective configural displays. *Human Factors 35(1)*, 71-97.

Bergman, H. & Duijnhouwer, F. (1980) Recognition of VDU presented colors by color defective observers. In *Proc. Human Factors Soc.* (1980), 611-616.

Beyer, H. & Holtzblatt, K. (1998). *Contextual design: Defining customer-centered systems*. San Diego: Academic Press.

Brehmer, B. (1992). Dynamic decision making: Human control of complex systems, *Acta Psychologica*, 81, 211-241.

Burnell, E. and Dicken, C.R. (1997) Handling of Repeating Alarms. Stemming the Alarm Flood 136, 12/1-12/4.

Christ, R.E. (1975) Review and analysis of color coding research for visual displays. *Human Factors* v.17, 542-570.

Cole, B.L., Maddocks, J.D, & Sharpe, K. (2004) Visual search and the conspicuity of coloured targets for colour vision normal and colour vision deficient observers. *Clinical and Experimental Optometry*, 294-304.

Cole, Barry L. (2004) The handicap of abnormal colour vision. *Clinical and Experimental Optometry*, 258-275.

Edworthy, J., Loxley, S., & Dennis, I. (1991). Improved auditory warning design: Relations between warning sound parameters and perceived urgency. *Human Factors, 33,* 205-231.

Fitts, P. M. & Seeger, C. M. (1953). S-R compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46,* 199-210.

Garbis, C. (2000) Communication and coordination through public and private representations in control rooms. CHI 2000, pp. 67-68.

Grudin, Jonathan. Why CSCW applications fail: problems in the design and evaluation of organization of organizational interfaces. *Proc. of the ACM conference on computer-supported cooperative work* (1988), 85-93.

Hansen, J. P. (1995). An experimental investigation of configural, digital, and temporal information on process displays. *Human Factors, 37.*

Hoadley, Ellen D. Investigating the effects of color. In *Comm. of the ACM* v.33 n.2 (1990), 120-139.

Loftus, G. R., Dark, V. J., & Williams, D. (1979). Short-term memory factors in ground controller/pilot communication. *Human Factors, 21*, 169-181.

Long, T. & Davey, E.C. (1996) Darlington Annunciation: User Information Needs, Current Experience and Improvement Priorities. International Atomic Energy Agency Specialist Meeting on 'Experience and Improvements in Advanced Alarm Annunciation Systems in Nuclear Power Plants', Chalk River, Canada, 1-16.

Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63,* 81-97.

Montgomery, G. (1999). *Breaking the code of color: Color blindness, more prevalent among males*. Retrieved July 15, 2006, from Howard Hughes Medical Institute Web site: http://www.hhmi.org/senses/b/b130.htm

Nielsen, Jakob, & Mack, Robert L. *Usability Inspection Methods*. John Wiley & Sons, New York, NY, 1994.

Norman, D. A. (1988). *The psychology of everyday things*. New York: Harper & Row.

Parasuraman, R. & Riley, V. (1997). Humans and Automation: Use, misuse, disuse, abuse. *Human Factors*, 39(2), 230-253.

Parasuraman, R., Hancock, P., & Olofinboba, O. (1997). Alarm effectiveness in driver-centered collision warning systems. *Ergonomics*, 40, 390-399.

Patterson, R. D. (1990). Auditory warning sounds in the work environment. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 327(1241),* 485-492.

Pomerantz, J. R. (1986). Overview of visual form perception. In E. C. Schwab & H. C. Nusbaum (Eds.), *Perception of speech and visual form: Theoretical issues, models, and research* (Vol. 2, pp. 1-30). New York: Academic Press.

Pomerantz, J. R., & Pristach, E. A. (1989). Emergent features, attention, and perceptual glue in visual form perception. *Journal of Experimental Psychology: Human Perception & Performance, 15,* 635-649.

Pritchett, A. (2001). Reviewing the role of cockpit alerting systems. *Human Factors & Aerospace*, 1, 5-38.

Rantanen, E. M. & Gonzalez de Sather, J. C. M. (2003). Human factors evaluation for a new boiler control interface at the University of Illinois at Urbana-Champaign's Abbott Power Plant: An Avi/Psych 258/IE 240 special project, Fall 2002. University of Illinois Technical Report (AHFD-03-07). Savoy, IL: Institute of Aviation, Aviation Human Factors Division.

Roscoe, S. N. (1968). Airborne displays for flight and navigation. *Human Factors*, 10, 321-332.

Rozenholtz, R., Li, Y., Mansfield, J., & Jin, Z. (2005). Feature Congestion: A measure of display clutter. *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, 761-770.

Sanderson, P. M., Flach, J. M., Buttigieg, M. A., & Casey, E. J. (1989). Object displays do not always support better integrated task performance. *Human Factors, 31,* 183-98.

Schneiderman, B. (1992). *Designing the user interface: Strategies for effective human-computer interaction* (2nd ed.). Reading, MA: Addison-Wesley.

Seagull, F. J. & Sanderson, P. (2001). Anesthesia alarms in context: An observational study. *Human Factors, 43,* 66-78.

Sorkin, R. D. (1989). Why are people turning off our alarms? *Human Factors Bulleting*, 32(4), 3-4.

Sorkin, R. D., Kantowitz, B. H., & Kantowitz, S. C. (1988). Likelihood alarm displays. *Human Factors, 30,* 445-460.

Tufte, Edward. Sparklines: Intense, Simple, Word-Sized Graphics. Draft of chapter for *Beautiful Evidence* (2006), http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=0001OR&topic_id=1.

Vicente, K. and Burns, C. A field study of operator cognitive monitoring at Pickering Nuclear Generating Station – B. *Cognitive Engineering Laboratory*, (1995), University of Toronto.

Wickens, C. D., Vincow, M. A., Schopper, A., & Carswell, C. M. (1995). Cognitive issues in virtual reality. In W., & Lincoln, S. E. (1997). Computational models of human performance in the design and layout of controls and displays. Wright-Patterson AFB, OH: CSERIAC

Wickens, C. D. ., & Carswell, C. M. (1995). The proximity compatibility principle: Its psychological foundation and its relevance to display design. *Human Factors, 37(3),* 473-494.

Wickens, C.D., Lee, J.D., Liu, Y., & Becker, S. G. (2004). *An introduction to human factors engineering* (2nd Ed.). Upper Saddle River, NJ: Pearson Education.

Wickens, C.D., Vincow, M.A., Schopper, A.W., & Lincoln, S. E. (1997). Computational models of human performance in the design and layout of controls and displays. Wright-Patterson AFB, OH: CSERIAC.

Willingham, D. B. (2001). Visual Perception. In *Cognition: The Thinking Animal* (pp. 54–99). Upper Saddle River, NJ: Prentice Hall.

Woods, D., Wise, J., & Hanes, L. (1981). An evaluation of nuclear power plant safety parameter display systems. *Proceedings of the 25th Annual Meeting of the Human Factors Society* (pp. 110-114). Santa Monica, CA: HFS.

Xiao, Y. Mackenzie, C.F., Seagull, F.J., & Jaberi, M. (2000) Managing the Monitors: An Analysis of Alarm Silencing Activities During An Anesthetic Procedure. *Proc. of IEA 2000/HFES 2000 Congress,* 4, 250-253.

Appendix I

This appendix is a compilation of research results from the review of books, publications, and other resources, and from the contextual inquiries that we performed.

Section A: Roles

This section contains additional information from our model consolidation, specifically focused on the roles that people play in terms of job responsibilities and interactions with one another. As mentioned earlier, the roles do not necessarily map directly to job responsibilities, as one person may play several roles simultaneously.

Monitor

We have found that experienced monitors manage a system better than novice monitors do. One monitor we spoke with explained that when the system was first set up, there were many alarms to handle, but this allowed him to learn the intricacies of process control, so that now he is able to manage the system with fewer triggered alarms (CI4). In continuing conversation with this process control monitor, we learned that when there is a problem that he cannot resolve, he calls on a coworker or supervisor with more experience and knowledge for assistance (CI4).

The process control monitors we spoke with felt that their years of experience meant that they are experts, and because of that, they deliberately avoided instructions or other written guidance during their work process (CI3.6, CI4). One user commented, “I feel like I don’t need a checklist.” (CI3.6), while another user stated, “I don’t follow instructions.” (CI2) Although these were experienced monitors, we observed the occurrence of a problem after a user did not follow on-screen instructions. He acknowledged that this would not have happened had he followed the instructions (CI2).

We found that monitors tend not to stare at the screen during their entire shift since alarms are in place to warn of potential problems (CI2, CI3, CI4). When an alarm is triggered, the monitor pinpoints the problem for quick resolution. Should that be unsuccessful, a monitor will contact his/her supervisor for assistance. The decision of whether to acknowledge an alarm is made by evaluating how serious it is, by evaluating a sound that represents the complexity of the problem, by viewing the color-coded alarm bar, or by reviewing data on the layout screen. Not all alarms represent a serious problem, and as a result, a monitor will frequently acknowledge an alarm but leave the system to run its course without making any changes.

Monitors also feel they know their system so thoroughly that they frequently acknowledge several alarms at one time without hesitation. One user we observed continued to hit a custom keyboard button that silenced alarms without ever looking at the system screen (CI3). At that location, for that particular user, alarms were set with auditory warning levels; therefore, the monitor was able to identify the severity of the alarm without having to review the data visually.

There is some danger to consider because of monitors' confidence in their abilities to fix problems without guidance. They use the system without following instructions, determine which alarms need acknowledgement, and assume they understand the current state of the plant without constantly watching the monitor. All this combines into the possibility of reduced situation awareness and overconfidence, which could bring disaster upon plants.

Configurer

At three locations we visited, there was only one person acting as a configurer (CI1, CI2, CI4), Because of this, major difficulty ensues when this person leaves the company (CI2, CI4). After their configuration expert left the company, one site had to hire an outside engineering firm (CI2). Another site stopped sending their configurers to Emerson Process Management DeltaV training because they would leave for better jobs with their new experience (CI4). They learned this after their one configuration expert left and his replacement "was thrown in without [DeltaV] training" (CI4).

Trend Analyzer

It is important for trend analyzers to watch trends when changing component set points to avoid major spikes or drops in level. When left on its own, DeltaV will try to reach a set point as fast as possible, which is not necessarily the safest way. Even if the equipment is able to handle such a rapid increase, it may not make for the most stable process, which can in turn affect chemically sensitive materials.

Two sites used DeltaV History Viewer and exported the data to Microsoft Excel to graph information in more detail (CI1, CI2). At one of these sites, a user actually noted that he used Microsoft Excel to "make pretty graphs" (CI1). Other sites used PI software to observe trends (CI3, CI4). We observed a user at one site using PI to set up alarms to alert him of potential problems before DeltaV alarms would go off. Since only the configurer can set alarms in DeltaV, this gave the trend analyzer more control over his system.

Supervisor

The supervisor is the head of a team of configurers and/or monitors. The supervisor often represents the team when interacting with other groups (CI3). The supervisor is contacted when a member of the team has difficulty with the system.

At one site, a head configurer (supervisor) spoke with an outside engineering firm about construction of new projects at the plant (CI3). This user also gave guidance to the other configurers and was contacted when they needed help. At other locations, supervisors helped monitors resolve complex problems (CI2, CI4). Supervisors call to warn other departments so they could save time by bringing down their lines early instead of letting the process crash, which would require more time to restart later (CI4). This type of communication saves the company time and money.

Field Technician

The field technician works outside at a plant, monitoring physical components and making repairs. At one site visit, we witnessed a field technician setting alarms in the field, as well as checking pressures at the request of the monitor (CI3).

Communication between field technicians and monitors is a key part of the shared understanding of the state of the plant. Because of this, monitors often will contact a field technician to follow up in the field on a problem identified on screen.

Lab Technician

Lab technicians analyze samples from the field to provide updated information to monitors and trend analysts, which is then used to aid in calculating input conditions (CI2, CI3). Data reports go to monitors to help identify what is important to watch during a shift. (CI3). At two sites we visited, lab technicians analyzed and measured material, calculating input conditions for monitors to reference (CI2, CI3). At one location, lab technicians used a simulation program to aid in the analysis (CI3), while at another location, the technicians used slow, manual tools for the sake of accuracy (CI2). These technicians were also the ones to change input conditions, whereas at the former location, monitors used the information to determine how to change the inputs

Section B: Communication

Where dynamic systems are managed by a team of control room operators, the state of the system changes both autonomously as well as by the actions of the operators (Brehmer, 1992). Hence, the work that goes on in the control room is dependent on the performance of a team that works in a “collaborative way rather than a collection of uncoordinated individuals” (Garbis, 2000).

As a result, “it is essential that the operators receive efficient support for coordination and communication” (Garbis, 2000). They need to receive support in two ways, the first being the support in coordinating the resources available to them. To be able to do this, they need to communicate with people outside in the field. Second, they need support to coordinate tasks and share information within the team. Single user applications to support this need to collaborate obviously are not an adequate solution. Even groupware solutions are insufficient, since groupware is designed based on the criteria of single user applications (Grudin, 1988).

According to Garbis (2000), “It is legitimate to say that information is distributed between people as well as between people and the artifacts they make use of in the control room. Therefore, it is argued that it is more appropriate to shift the unit of analysis from the individual to the whole control room, and consider it as one cognitive system."

Instead of focusing analysis on what goes inside the heads of individuals, the focus should be on the representation of information and how this representation is transformed and moved throughout a whole system (Hutchins, 1995).

Garbis (2000) uses the concepts of private and public representations as an analytical tool. Public representation is the representational state or states of an artifact that are designed to be accessible to all team members at the same time and the same location. A private representation refers to the representational states of an artifact that is designed to be available only for individuals.

The research done by Garbis (2000) was at an underground line control and a national rescue service agency. At the National Rescue Service Agency (NRSA), the immediate availability of public representations displayed on maps served as referential anchoring points. The map with its continuous updates being made public, allowed the team members to gain a collective assessment and awareness of the situation. This public information also helped them to act in a concerted way.

At the underground line control, the public diagram was not updated. This diagram made it difficult to display historical information with the current information, which is very important to the operators. Since the diagram was developed only to display certain instantaneous variables, the possibility of assessing the traffic situation was lost. Due to the diagram being static, it was unable to support the dynamic nature of the work in the team. Operators also had access to a variety of localized perspective, but without being able to share this publicly and therefore not be able to coordinate information with others.

To aid this communication, it is important to have a public representation system as Garbis (2000) explains and did research on. At the NRSA, the team members worked well together because they had shared information that was up to date. If anybody added information, everybody would be able to see it. This team worked very effectively due to that and gained a collective assessment and awareness of the situations at hand. However, at the underground line control, where information was not publicly shared except for a static diagram that was not updated, the workers had difficulty in achieving shared understanding and simple understanding about the situation.

Monitor to Monitor

Updating the subsequent shift of plant status is one of the most important communications we observed. Monitors provide situation awareness to their replacement at the end of a shift, informing of any potential problems that may need to be addressed (CI3). Because of the nature of the work, this discussion may evolve into troubleshooting and collaborating on problem resolution before the shift change is complete (CI3).

At one location, monitors complete an end-of-shift report for their replacement to review (CI3). Another site follows a similar model, but more informally, leaving notes taped to the screen with any instructions or problems to review for the next monitor (CI2). A problem we identified in this case, however, was that often the next shift workers ignore the notes taped to the screen.

Monitor to Configurer

Monitors communicate with configurers frequently to discuss screen layout changes. Although configuration experts respect the opinion of monitors, there are still communication breakdowns that inhibit easy resolution of screen problems. At one site, language difficulties and the configurer wanting to do things "his way" created a communication breakdown that resulted in a display with which the monitors were unhappy.

At another location, monitors come together to reach consensus on all screen layout changes, mocking up an idea in Visio and providing a printout to the configuration expert. Because configurers are the only staff that can make changes, there occasionally is a struggle to define a display that pleases all monitors who work with it. However, things are still better than had been previously, when any monitor could request changes at any time. Often, the configurers would find themselves changing layouts back and forth to accommodate different monitors. Requiring consensus has reduced the amount of time wasted on minor updates (CI3).

Monitor to Supervisor

Although monitors are considered capable to handle most alarms, communication with supervisors does happen occasionally when a major problem occurs. We were informed by a one site's supervisor that monitors are able to resolve 90% of alarms.

Monitor to Field Technician

The monitor and field technician communicate with each other about plant status, often inquiring about a problem seen on the monitoring screen. It is difficult to make each other aware of the situation due to their physical separation, with the monitor in the control room and the field technician out in the plant.

In conversation with a monitor, we learned that there was a recent time when it took more than two hours to troubleshoot a valve with a field technician because they were communicating via radio in two different locations (CI3). Another example of this communication breakdown is a story told by a monitor with whom we spoke. An alarm had gone off indicating a problem with a valve at the plant location several miles away. The monitor tried to resolve the problem using his software system but was unable to control the situation. He radioed to the field technician asking him to check on the situation in person. The conversation went back and forth for several minutes before the field technician realized that the monitor did not know that a tornado had blown away a section of the plant, not just a valve (CI3).

Monitor to Lab Technician

Lab technicians analyze parts of the plant and inform monitors of the results so they can change values accordingly. In some situations, monitors cannot do some of their job tasks until they receive information from lab technicians (CI3.2).

Configurer to Supervisor

We only witnessed communication between the configurer and supervisor at one location. Several configurers were working on uploading data to the monitoring system and requested the assistance of their supervisor in completing the task. Because the supervisor was standing nearby, just a brief conversation resolved the problem (CI3).

Section C: Display Research

The design of operator screens is a large part of our project. One of the most important and interesting things to understand is that these screens are often created by just one person (CI1, CI2, CI4, CI4). This person can later leave the company or move on to another position in which they are no longer responsible for modifying or creating these screens, so someone else needs to pick up where that person left off and modify the screens as the process changes. This leaves a large disconnect between the initial creator of the screen and future modifiers of the screen. At the first site we visited, the user we spoke with voiced such a concern, stating worries that future configurers will not understand the motivation behind his layout (CI1). We even saw an instance of a person given the job of modification without any prior DeltaV training (CI4).

Simple and Clean

People sit in front of the operator screens for long periods of time, often observing data on multiple screens. They need to be immediately aware of any problems. Because of this, we found that some configurers design screens with simpler graphics and more subtle colors so that alerts will stand out to visually fatigued operators. All sites we visited used screen designs without using the photorealistic graphics available in DeltaV (CI1, CI2, CI3, CI4). This was not because of a lack of resources or knowledge of the capability of DeltaV, but because they used the display as a model, not as a high-fidelity representation of the plant. Additionally, we found at the first site visit that the engineer chose specific colors because of the importance of printing these screens for future reference, and certain colors just are not handled well by the printer (CI1).

Visio

In two observed situations, we found that configurers used Microsoft Visio to mock up a screen layout to use for guidance when finishing the design in DeltaV (CI1, CI2). In one case, a user tried to import Visio graphics into DeltaV Operate (Configure), but gave up on this process soon afterward due to the nonexistent support for such things from DeltaV (CI1). He was able to pull in a Visio diagram as a background, but was frustrated because if he wanted to make a change, he had to go back into Visio, change it, and re-import it. Furthermore, two users we spoke with mentioned that they would like DeltaV Operate (Configure) to work more like Visio in how the widgets and lines are easily manipulated (CI1, CI3).

Wickens, Lee, Liu, and Becker (2004) detail essential principles of good operator display design: make displays legible, avoid absolute judgment limits, top-down processing, redundancy gain, discriminability, pictorial realism, principle of the moving part, minimizing information access cost, proximity compatibility, multiple resources, knowledge in the world, predictive aiding, and consistency.

What we have seen thus far is that DeltaV is successful in allowing alarms to change tone and color depending on the level of severity. Wickens et al. (2004) suggest that alarms should "not require the operator to judge the level of a represented variable on the basis of a single sensory variable, like color, size, or loudness, which contains more than five to seven possible levels".

Roscoe (1968) states that a display should look like what it represents. When multiple elements are involved, these should be configured to appear as they do in the real environment. DeltaV offers 3D graphics and marketing materials suggest ways to configure an operator display to look almost photo-realistic (marketing graphic reference). We actually disagree with this research, believing that in process control, using a display that appears as demure as possible will allow alarms to be easier to identify as they occur.

Norman (1988) recommends that people should not have to retain important information in working memory or have to retrieve it from long-term memory. However, too much information can lead to clutter, so the amount of information presented needs to be thoroughly considered. At all sites we visited, screen layout was as simple as possible, avoiding unnecessary information. We intend to conduct further research to identify the different information needs of novice and experts in the field.

Principles of display design

These principles are taken from (Wickens et al., 2004). Some of these principles are already being used by users of DeltaV whereas others are not. These principles do not necessarily just apply to displays but also apply to alarms, which will be discussed in a later section.

1. Make displays legible – This takes into account contrast, visual angle, and illumination. Refer to Contrast Sensitivity below for further detail and recommendations.

2. Avoid absolute judgment limits – "Do not require the operator to judge the level of a represented variable on the basis of a single sensory variable, like color, size, or loudness, which contains more than five to seven possible levels" (Wickens et al, 2004).

3. Top-down processing – Signals are interpreted and perceived in accordance with what the operator expects to perceive based on their past experience. If a signal is presented that is contrary to these expectations, it is necessary to have more physical evidence of that signal presented to guarantee that it is interpreted correctly.

4. Redundancy gain – When viewing and listening conditions are degraded, having a message expressed more than once and especially in different forms increases the likelihood of it being interpreted correctly.

5. Discriminability – Similar appearing signals are likely to be confused. The only way alarms change is by color and sound. There are labels for what component is having problems, but that is the only thing that discriminates the alarms for different components from each other. However, adding more information can cause clutter, so it is important to learn if operators actually need any more information than what is already provided.

6. Pictorial realism (Roscoe, 1968) – A display should look like what it represents. If there are multiple elements, these elements should be configured in a way that it looks how they are configured in the real environment.

7. Principle of the moving part (Roscoe, 1968) – Moving elements of dynamic information should move in a pattern and direction that is compatible with the user's mental model of how the element moves.

8. Minimizing information access cost – There is a cost in time and/or effort to move one's selective attention from one display location to another to access information. Good designs are those that minimize the net cost by keeping frequently accessed sources in a location where cost of moving is low.

9. Proximity compatibility principle (Wickens & Carswell, 1995) – Two or more sources of information may be need to be "mentally integrated" to complete a task. These information sources should have close display proximity so that information cost will be minimized. Solutions to proximity are nearness in space, display in common color, link together with lines, or configure into a pattern.

10. Principle of multiple resources – Processing a lot of information can sometimes be facilitated by dividing the information across resources, such as visual and auditory.

11. Replace memory with visual information: knowledge in the world (Norman, 1988) People should not have to retain important information in working memory or have to retrieve it from long-term memory. Sometimes too much knowledge in the world can lead to clutter, though, so the amount of information presented needs to be thoroughly considered.

12. Predictive aiding – Prediction is a difficult cognitive task. It involves thinking about current conditions, possible future conditions, and then running a

mental model of the current becoming the future condition. When mental resources are consumed with other tasks, prediction falls apart. A person then becomes reactive, which is responding to what has already happened. It is more effective to be proactive, responding in anticipation of the future. Displays that can explicitly predict what will happen remove a heavy cognitive task and replace it with a simple perceptual one.

13. Consistency – Displays should be designed in a manner that is consistent with other displays that a user may be using concurrently or may have used in the past. As a result, old habits from other displays will transfer positively to supporting processing of the new display.

The Eye and Contrast Sensitivity

When designing for displays on a screen, it is important to take into account the capabilities and limitations of vision and cognitive processing.

As we grow older farsightedness becomes more evident because the lens becomes less flexible (Wickens et al., 2004). Hence, the older control operators will have difficulties with displays that have fine text that may be suitable for younger workers. The ability to read and focus on text is also dependent on the amount of visibility an image has, which is determine by its brightness and contrast (Wickens et al., 2004).

As stated above, subtle colors are used for the graphics so the alarms can stand out, but this is done at the risk of making the components difficult to distinguish on the screen. Contrast sensitivity should be taken into account when developing graphics. "The ability to detect contrast is necessary in order to detect and recognize shapes" (Wickens et al., 2004).

There are five influences on contrast. First is spatial frequency of the grating—the width of alternating vertical white and dark lines. Smaller line width leads to higher spatial frequency, and greater contrast means greater sensitivity across all spatial frequencies. This example is with white and black bars, so the amount of space will be much less than bars of similar color. A display's colors should be tested by this method to measure the special separation between colors that are needed or the level of contrast between colors that are needed for objects to be discernable. This leads into the second influence, which is that lower contrasts are less easily discerned (Wickens et al., 2004). Therefore, it is better to use higher contrast if possible.

The third influence is the level of illumination of the stimulus (Wickens et al., 2004). Lower illumination reduces the sensitivity and "does so more severely for sensing high spatial frequencies than for low frequencies" (Wickens et al., 2004). As a result, reading fine print becomes even more difficult under low illumination. Low illumination also reduces the ability to see colors due to the inner workings of the eye.

The last influence is the resolution of the eye (Wickens et al., 2004). As age increases, the amount of light passing through the cornea is reduced, which greatly reduces the sensitivity of the eye. Once again, as the workers are getting older and younger people joining the ranks is reducing, it is important to take into account the lighting of the area.

With this information about contrast sensitivity, it is necessary to make sure that there is high contrast and high illumination, so that words and objects and screen layouts are much easier to discern. These factors are "critical for predicting whether or not detail will be perceived and shape will be recognized in a variety of degraded viewing conditions, and hence these factors are critical for indirectly informing the designer of certain standards that should be adhered to in order to guarantee viewability of critical standards," (Wickens et al., 2004). To know what level of contrast is needed or illumination will require testing with users in their environment.

Along with age being an issue upon design, it should also be noted that approximately 7% of males are unable to discriminate certain hues from each other. The most prevalent is red-green color blindness. Because color vision is weakened in the dark and a percentage of people are color blind, a most important human factors guideline is to design for monochrome first (Shneiderman, 1987).

Multiple Displays

Plants are extremely complex. Even small research plants still have many components that interact in various ways, requiring multiple screens to capture it all. As (Wickens et al., 2004) states, "an important issue in designing multiple displays is to decide where they go, that is, what should be the layout of the multiple displays" (Wickens, C.D., Vincow, M.A., Schopper, A.W., & Lincoln, S. E., 1997).

It is critical to define the primary visual area (PVA) because the first of six guidelines for display layout is frequency of use, which dictates that frequently used displays should be adjacent to the PVA. This follows the guideline of minimizing access cost. Sometimes a very frequently used display can itself define the PVA, which is the case with the operators. At two sites we visited, the PVA was the component layout screen, whereas at two different sites, the PVA was the trend screen.

The second guideline is importance of use, which dictates that important information should be displayed in a way that captures attention when it is presented. This information can be displayed near or even in the PVA, or other techniques can be used, such as an auditory alert that guides the user of where to look.

The third guideline is display relatedness or sequence of use. This dictates that related displays and those that are often used in sequence should be close together. This follows the guideline of the proximity compatibility principle.

The fourth guideline is consistency, being related to both memory and attention. If displays are laid out with the same items in the same spatial location, then memory of where things are will greatly aid in guiding attention to the items that we need. There can be problems with this consistency guideline, though, as variables that are important and frequently used in one phase may be very different in other phases. An example given by Wickens et al. (2004) is that the information that is important during the startup and shutdown of nuclear power plants is different from what is important during routine operations. Under such circumstances, it is possible to use “soft” computer-driven displays that allow flexible formats to be created in a phase-dependent layout. However, if such a method is employed, three design guidelines must be kept in mind. First, salient visible signals should be used to make it very clear to the user which configuration is in effect. Second, where it is possible, some consistency across all of the formats should be used. Third, one needs to resist creating excessive flexibility (Andre & Wickens, 1992).

The fifth display layout guideline is organizational grouping. Displays that are related should be grouped, or “clustered”, together, for this provides an aid that can easily guide visual attention to particular groups as needed. The displays within a group should be functionally related and the relatedness is clearly known and identified by the user.

The sixth guideline is stimulus-response compatibility, which dictates that displays should be close to their associated controls. The seventh and last guideline is clutter avoidance, which dictates that there should be “a minimum visual angle between all pairs of displays” (Wickens et al., 2004).

Section E: Alarm Research

Most alarm designers set the alarm’s criterion to go off as low as possible to minimize the miss rate for safety reasons. An alarm system that guarantees detection will produce a fair number of false or “nuisance” alarms (Parasuraman, R., Hancock, P., & Olofinboba, O., 1997). As a result, the users may come to distrust the alarm system and even ignore it even when it does provide valid information (Pritchett, 2001; Parasuraman & Riley, 1997). Even worse, users may try to disable the annoying alarms (Sorkin, 1989). This was seen at all of the sites except one (CI1, CI3, CI4), where the user made it so the alarms only occurred if there was a real emergency (CI2). At the other sites, the users would just continuously hit the acknowledge key. A user at one location did not even look at the screen when hitting the “acknowledge” key; he actually just kept talking and looking at us (CI3).

Our training on alarms was somewhat limited, and we really only looked at a very small-scale system with two possible alarms. We were told that in the field, many times alarms are ignored or are quickly acknowledged to make the noise stop, sometimes without getting a close look at the alarm and the conditions that might have caused it. Some sites do anything to avoid having to hear the alarm sounds. If they cannot adjust it within the software, they will turn down the volume on the speakers. When knobs were taken off speakers to prevent such behavior, some individuals still found new, creative ways to shut the sounds off again.

Again, we were surprised when we went out into the field. The very first site we visited had embraced the idea of alarms, and used them at almost every opportunity to indicate that things were changing. Subsequent site visits seemed to be a bit more in line with what we had read. At these sites, alarms were often thought of as a nuisance, and the design of a new DeltaV system was often intended to minimize the amount of alarms one encountered. It is yet another area that people use to customize their workspace and get the most out of their DeltaV system. Similar to what we have seen at our own plant visits, operators at the Darlington nuclear power plant near Toronto have the ability to control the entirety of unit operation within certain limits. The plant has instituted a number of automated processes to aid process control. They use automation, just as DeltaV does, to provide “continuous control of process values to “set point” and to alert operators of potential discrepancies (Long & Davey, 1996).

Because studies have shown that operators spend more than 80% of their time working on tasks other than process monitoring, “operators depend on the plant annunciation systems to alert them to plant changes requiring intervention and to assist them in maintaining an up-to-date awareness of all important changes in plant conditions” (Long & Davey, 1996).

Long and Davey (1996) suggest “desirable properties of annunciated information”:

Time-stamp changes to support diagnoses and later analysis.

- Distinguish between changes in plant status and instrument failure.
- Only alert the operator to relevant information.
- Allow operators to access all information as they choose to view it.
- Organize change data in a way that operators use it; be sensitive to user need.

The Long and Davey (1996) reading includes several design ideas that might interest us. One would be to continuously display the operation mode on screen to aid in plant state awareness. We could allow operators to customize views of current and past alarm state. We may want to consider replacing multiple alarms representing the same problem with a single alarm that can link to additional information. This additional data should be easy to find to prevent additional mental strain on operators, to avoid operational inefficiency. (Long & Davey, 1996)

One problem that we saw at Honeywell was the overwriting of alarms as new ones came in. This overriding was not particular to priority or relevance, making it more difficult for the operator to diagnose problems with his area of the plant (CI3.1). Long and Davey (1996) also mention this problem with the nuclear plant in Toronto. The operator must search through alarms to find the relevant ones as many in the active list are actually irrelevant (Long & Davey, 1996). Burnell and Dicken (1997) point out, “In the more difficult situation of high alarm activity, usually associated with a fault condition or trip, where alarms may be occurring at the rate of 10 alarms per minute, the operator’s job becomes more demanding.” This can lead to important alarms being missed because repeating alarms continue to overwrite less important ones.

Burnell and Dicken (1997) recommend some solutions for the repeating alarm scenario. First, if an alarm initiates more than a set number of times in a short time span, it will be placed on a separate list or categorized differently. Second, after the alarm has been there for a length of time, it is placed back in the system for a trial period, followed by re-categorizing as necessary. They recommend 20-minute time lengths.

In a study by Xiao, Mackenzie, Seagull, and Jaberi (2000), it was found that in operating rooms, alarms were often silenced before the alarm was resolved. This may be in part because the auditory signal does not reflect the urgency or importance of the problem and does not indicate how relevant it is to the process at hand. Xiao et al. (2000) suggest a one-time alarm sound when limits are reached with further details accessible by a visual display. In process control, operators use several displays, therefore having both the auditory and visual feedback of an alarm. We found that operators often try to avoid the alarm noise by removing knobs from speakers (CI2). Perhaps this suggestion from an operating room study might inspire future process control alarm solutions.

Criteria of Alarms

The following five criteria of alarms come from Patterson (1990).

1. The alarm must be heard above the background ambient noise. The noise spectrum, therefore, must be measured at the location of the users that must respond to the alarm. The alarm should be 30dB above the noise level in order to guarantee detection. It is also wise to include several frequencies in the alarm so that in case the noise level changes, the alarm can still be heard.

2. The alarm should not be above the danger level for hearing. This level is around 85 to 90 dB.

3. The alarm should not be overly startling or abrupt. This can be fixed by tuning the rise time of the alarm pulse.

4. The alarm should not disrupt the perceptual understanding of other signals or background speech communications that may be important for dealing with the alarm.

5. The alarm should be informative, signaling the nature of the emergency and if possible what needs to be done to fix the alarm.

Design Recommendations for Different Alarms

Stay within the limits of absolute judgments. Within these limits, however, one can make the parameters of the alarms different from each other by capitalizing on the various dimensions of sound. Several possible dimensions to work with is "pitch (fundamental pitch or frequency band), their envelope (e.g., rising, woop woop, constant beep beep) ... rhythm (e.g., synchronous da da da versus or asynchronous da da da da) ... timbre of the sound" (Wickens et al., 2004).

False Alarms

Most alarm designers set the alarm's criterion of when to go off as low as possible to minimize the miss rate for safety reasons. An alarm system that guarantees detection will produce a fair number of false or "nuisance" alarms (Parasuraman et al., 1997). As a result, the users may come to distrust the alarm system and even ignore it even when it does provide valid information (Pritchett, 2001; Parasuraman & Riley, 1997). Even worse, users may try to disable the annoying alarms (Sorkin, 1989).

There are five steps to prevent alarm ignoring. First, it is possible that the alarm criterion is set too low and changing the criterion to reduce the false alarms will not appreciably increase the miss rate. The second is that a better decision algorithm may be developed to improve the sensitivity of the alarm system. Third, users can be trained about the tradeoff between misses and false alarms. However, the acceptance of this will be more likely if the alarms are made noticeable by means other than shear loudness (Edworthy et al., 1991). The fourth is that the designers should present the users with the data that triggered the alarm. The fifth and last step is to use graded or likelihood alarm systems in which more than one level of alert is provided (Sorkin, Kantowitz, & Kantowitz, 1988). Two or more levels can then signal the system's own confidence that the alarming conditions are present. This is similar to the fuzzy signal detection theory (Parasuraman et al., 2000). In this theory, instead of a signal being either present or not there is a degree of signal present, or the degree of danger or threat.

A noticed area of alarms is that experienced users often employ alarms for uses beyond the designers' intentions. An example is one anesthesiologist who used alarms as a means of verifying the results of their decision or even a reminder for when to start a procedure (Seagull & Sanderson, 2001).

Appendix II

This appendix is an explanation of the user research methods used to gain understanding of the users and to test and refine prototypes.

Section A: Contextual Inquiry

Contextual inquiry is a data-gathering method where researchers gain insights about their users and how they work by carefully observing and interviewing the user on-site, while they are doing work. Because not all of our sites were active while we were visiting, we also used a combination of directed storytelling (asking about specific instances, such as “Tell me about the last time an alarm went off), retrospective accounts, and artifact walkthroughs; which is where we might look at something like an operator control screen or a printed graph and ask about the process that led up to it. After gathering information, we used the methods described by Beyer & Holtzblatt (1998) in *Contextual Design: A Customer-Centered Approach to Systems Designs*, to create models from the data. These included flow (information transfer), cultural (inner and outer influencers, such as people or policy), artifact (diagramming tools used on the job), and physical (diagramming the work environment) models.

Our biggest take-away from the CIs was that the roles in which people acted were not necessarily the same ones that the DeltaV system expects people to have. Of further interest was the way in which these roles communicated (or failed to communicate) with one another. As detailed earlier in the paper, we also saw how operators use the on-screen information, including trends for decision-making. More detailed information on CI findings can be found in Appendix III.

Section B: Think-Aloud Studies

Think-Aloud usability studies are a tool for evaluating an interface, prototype, interaction, or concept. They generally involve asking the participant to complete tasks with the material being tested, and looking for quantitative data such as speed or number of errors, as well as qualitative data that they provide by verbalizing their thought process as they go through the task, known as thinking aloud.

Think-Aloud Test Protocols

Test protocols are the official descriptive procedures of how the experimenter introduces themselves, the prototypes, and the tasks that are to be accomplished by the participant. The section on the description of the tasks are given to the participant to review over while the experimenter explains the task and while going through the task itself.

Rounds 1 and 2 Testing Protocol

INTRO:

Hi. First of all, I'd like to thank you for helping us out and agreeing to participate. As you know, we're working with Emerson on improving their operator screens, and are focusing our attention on trends, or how we can best convey process change, both from a real-time and historical perspective. Today, you're going to be looking at a couple of different proposals for we might show this information. Because this work is still in the early development phases, we'll be using some simple Flash prototypes. For some parts of this session, we'll be asking you to interact with the prototypes, and other times we'll just ask you to observe something on-screen. As you're going through the proposals, I'm going to ask that you think aloud – or verbalize your thought process.

For example, if I were to think aloud as I was going to load a stapler, I might say "First, I'm going to get out the staples. Then I'm going to open the stapler by pulling the top back so that I can make sure I've got the right size staples. Next, I'm going to take out a row of staples, and put them into the stapler, point down. Then I'm going to close the stapler, and try stapling the corner of a scrap piece of paper to make sure that it works." Does that make sense?

Next, I'm going to tell you a little bit about our process. What you're looking at is a very simple brewing, or beer-making facility. The first step in the brewing process is to boil the ingredients, or wort. In order to ferment the beer, we have to add yeast. But since yeast can't withstand high temperatures, we have to mix the hot wort with chilled water inside a larger tank. Once the yeast is added, the tank is sealed and left to ferment for however long the recipe dictates. Because gas is produced as a byproduct of the fermenting process, we have to let it escape somehow so that our tank doesn't explode. So we have a water trap up at the top for the gas to bubble through. Once the fermentation process is complete, we want to separate the beer from any sediment that might be in the tank, so we pump the liquid down into a holding tank. Lastly, we want to send the beer off to be bottled and distributed. Do you have any questions on that part?

Ok. As we're going through the proposals, it's important to remember that we're testing the interface, and not you. In no way is this a test of you or your abilities or skills. Also, please don't worry about offending anyone – we want your honest feedback! Before we get started, do you have any questions?

Prototype 1: Levels – real time view

What you're looking at on this screen is representative of an integrated trend. This prototype is meant to simulate a real-time display. The clock-like control in the upper right corner is not meant to be part of the operator screen, it's just a way of speeding up time. I'm going to ask that you watch the screen as I jump through time.

What can you tell me about this process?

Additional things to probe on if they don't come up:

What do you think about the labels? The colors? How else might you represent this? What do you think about the trend line below the pumps? How else might you represent this? Would this type of diagram add value?

Prototype 2: Levels – historical view

Like the first, this is representative of an integrated trend. In this one, we're assuming the clock *is* part of the operator display, and an operator is viewing history information. The levels on the tanks are 'frozen', and the operator uses the clock to select how much history information they want to see. I'm going to ask you to use the control to look at this display over time, and ask that you think aloud as you're going through this.

What can you tell me about this process?

Additional things to probe on if they don't come up:

What do you think about the labels? The colors? How else might you represent this? What do you think about the trend line below the pumps? How else might you represent this? Would this type of diagram add value?

Prototype 3: Radar – moving set points

The next prototype represents a way of getting a system overview, in this case for four connected components. You're going to be watching a movie of this process changing in real time, and again – I'd ask that you share your thoughts as we go through this.

What can you tell me about this process?

Additional things to probe on if they don't come up:

What do you think the blue lines represent? How else might you represent this? Would this type of diagram add value?

Prototype 4: Radar – fixed set points

The next prototype is another variation on the type of diagram you just saw. You're going to be watching a movie of this process changing in real time, and again I'd ask that you share your thoughts as we go through this.

What can you tell me about this process?

Additional things to probe on if they don't come up:

What do you think the blue lines represent? How else might you represent this? Would this type of diagram add value?

Feedback from 1st round of testing – replace with UARs?

Round 3 Testing Protocol

Prototype 1: Integrated Graphs (Task 1)

In front of you is a sample process control screen. We're not interested in the process itself, since this task will be focused on a specific part of the screen.

Notice that in the component labeled Primary Fermentor there is an embedded graph of the trend. This is the focus for the following questions.

Without moving the mouse, what do you think you can use this graph to do?

How would you display a bigger version of this graph?

How would you momentarily "freeze" the graph?

How would you view history using this graph?

Prototype 2: Integrated Graphs (Task 2)

As you can see, there are a lot of components on this screen. It is not necessary to be familiar with the exact process since our task will be focused on just specific components.

The focus is on six components and their interactions with each other which is described in the following sentences. Incoming water is controlled by the valve on the left, and flows into the left tank. Outgoing water from the right tank is controlled by the valve on the right. Flow between the two tanks is controlled by a set of pumps. The upper pump is a two state pump. It can either be off (no water passing through the pump into the other tank) or on (water passes from left to right). The lower pump has three states. It can also be off (no water passing through the pump into the other tank), but the flow can be directed from left to right or right to left.

The two tanks levels will change in response to your actions with the other components.   The graphs on the tanks provide trend information for the corresponding tank. The goal here is to: Make the levels of both tanks equal within a margin of +/- 10.

After you complete this task, repeat it for the next screen that will be shown to you.

Prototype 3: Stickies on Layout (Task 1)

The focus for this task is leaving a message for the next shift worker.

The valve has been fluctuating back and forth, and triggering alarm messages all day. You have talked with the maintenance workers out in the field and they said the valve is leaking a little bit. It isn't worth shutting the valve off line, so the alarms will continue until the problem is fixed. Your goal here is to: Let the next shift worker know about this, so they will be aware of the maintenance issue with the unsteady valve.

Prototype 3: Stickies on Layout (Task 2)

The focus for this task is leaving a message for the next shift worker.

A storm hit that brought in cold wind and rain. This has affected several components drastically, causing a lot of the values to change suddenly and set off several alarms. You work with the maintenance workers to make everything is alright. Your goal here is to: Let the next shift worker know what happened to help him understand why there was a drastic change in values.

Prototype 3: Stickies on Layout (Task 3)

The focus for this task is leaving a message for the next shift worker.

One of the pumps is not working too well and the maintenance workers have decided to take it offline to fix it. Before you can enter a message about this for the next shift worker, the telephone rings and you answer it. Your goal here is to: Flag the component so that you can add your message when you are done with the phone call.

Protocol for Future Rounds

The protocol from round 3 testing is included with the following ones.

Prototype 1: History Trends

This screen displays information from the previous shift; it provides information on messages left from the previous shift worker and alarms. The goal here is to: Read the comment left by Joe Roberts around 07:00.

Prototype 2: Bars in Current Time

(Have several tanks with bars in them. Have control to change time. Use same idea as the current Bar prototype. Present the information in three different ways as was done with the "Trend in Components" tasks)

Have the same tasks as the "Trend in Components"

Prototype 3: History Bars

(Have several tanks with bars in them. Have control to change time. Use same idea as the current History Bar setup. Present the information in three different ways as was done with the "Trend in Components" tasks)

Goal: Give a description of how these two tanks interact – the rough speed of flow between the two

Goal: Find the value for this tank at 14:00

Prototype 4: Radar Graph

Apply the same things done with the trends on the components with the radar graphs (except for Goal 2).

Prototype 5: Integrated Graphs

Goal 2: Find value for tank component at 14:00

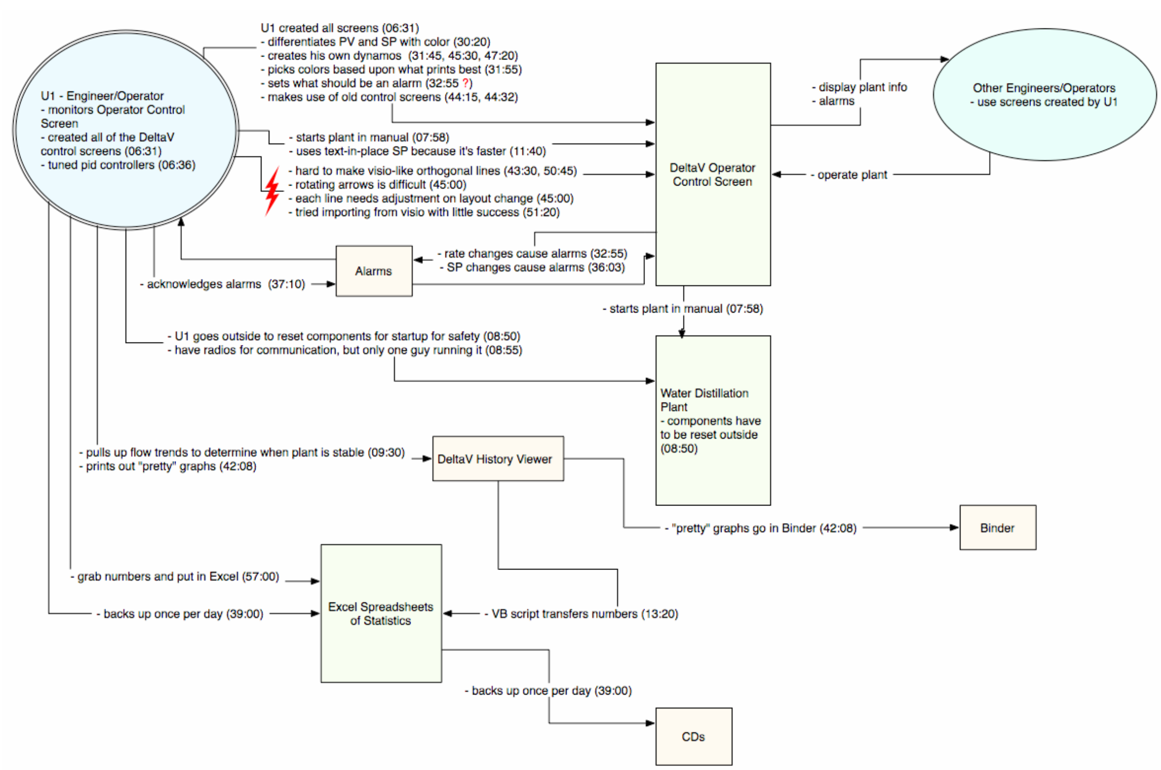
Appendix III

This appendix includes the results from the user research, which includes models from the contextual inquiries, observations from the think-aloud tests, and Usability Aspect Reports from our think-aloud tests.

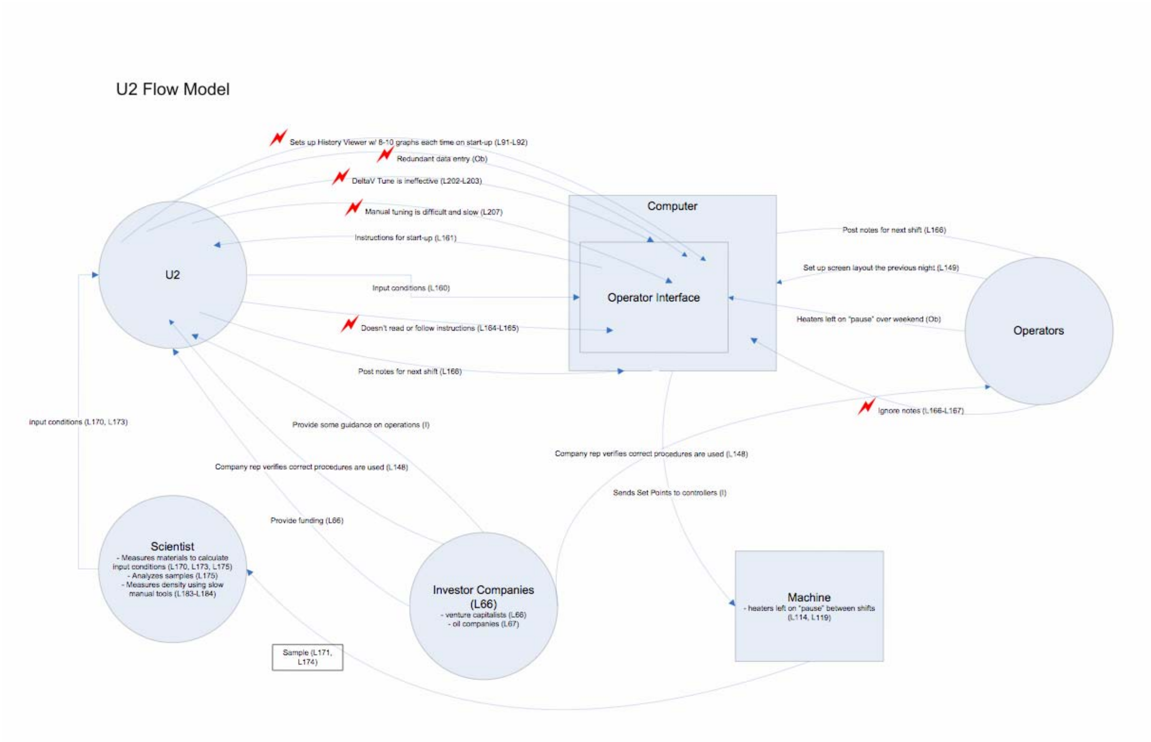
Section A: Contextual Inquiry Results

This section includes the models that were created from the data found from the contextual inquiries. These models include flow (information transfer), cultural (inner and outer influencers, such as people or policy), artifact (diagramming tools used on the job), and physical (diagramming the work environment) models.

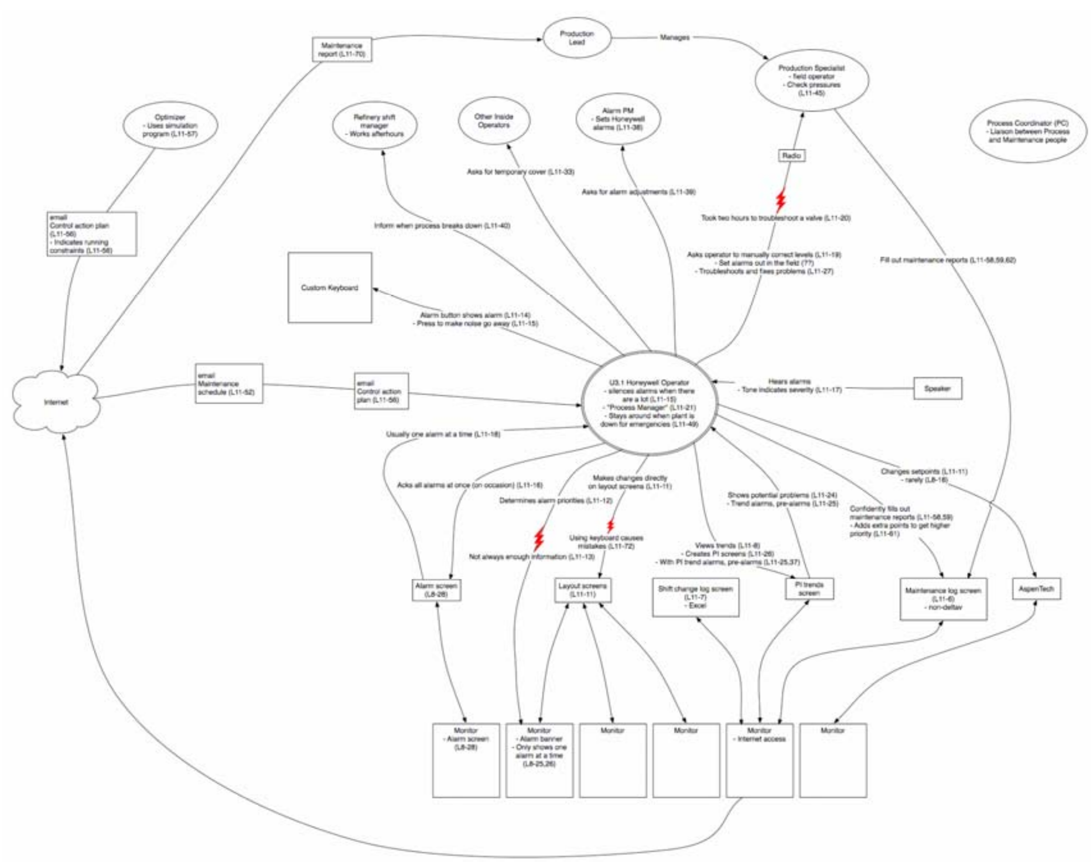
Work Flow Models



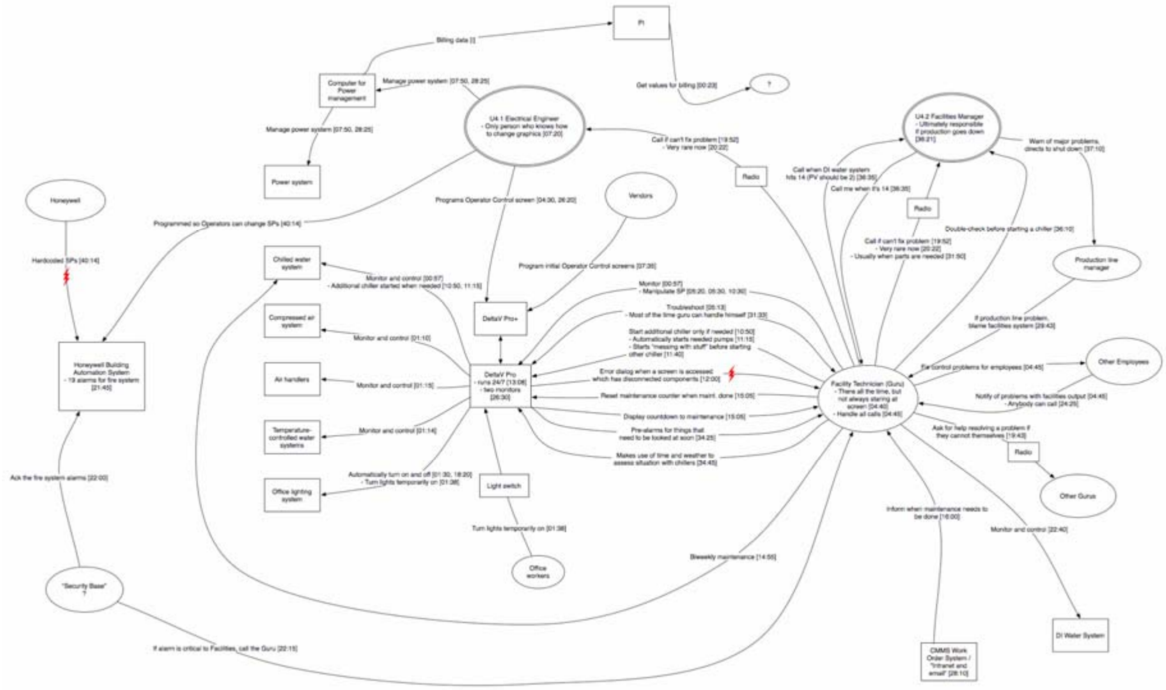
C1.Flow Model



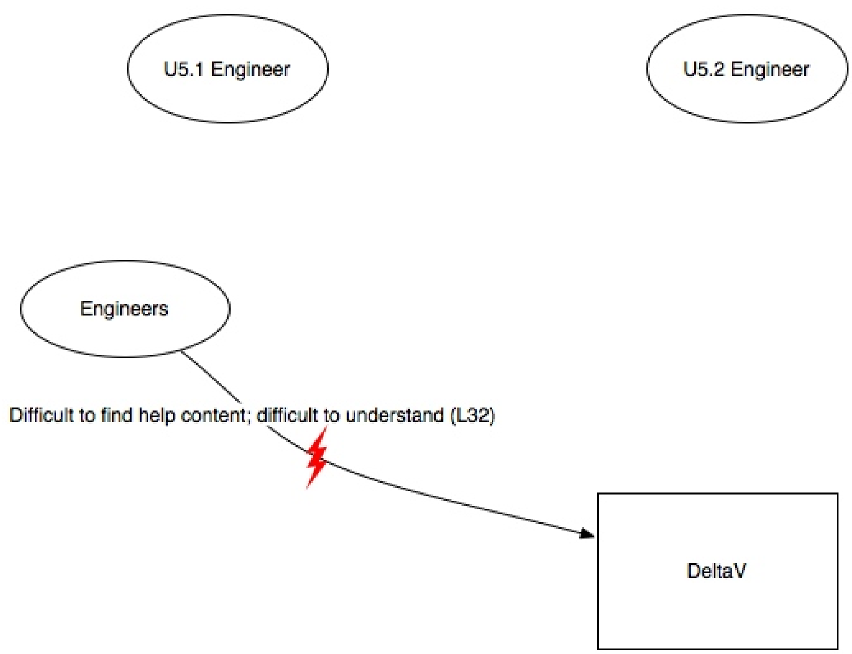
C2. Flow Model



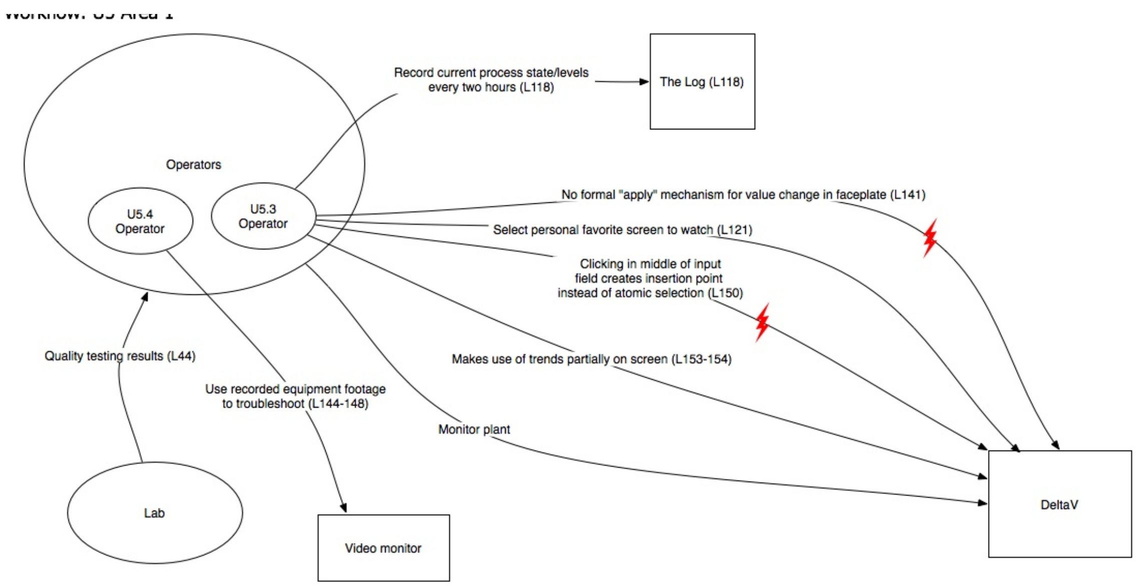
C3. Flow Model



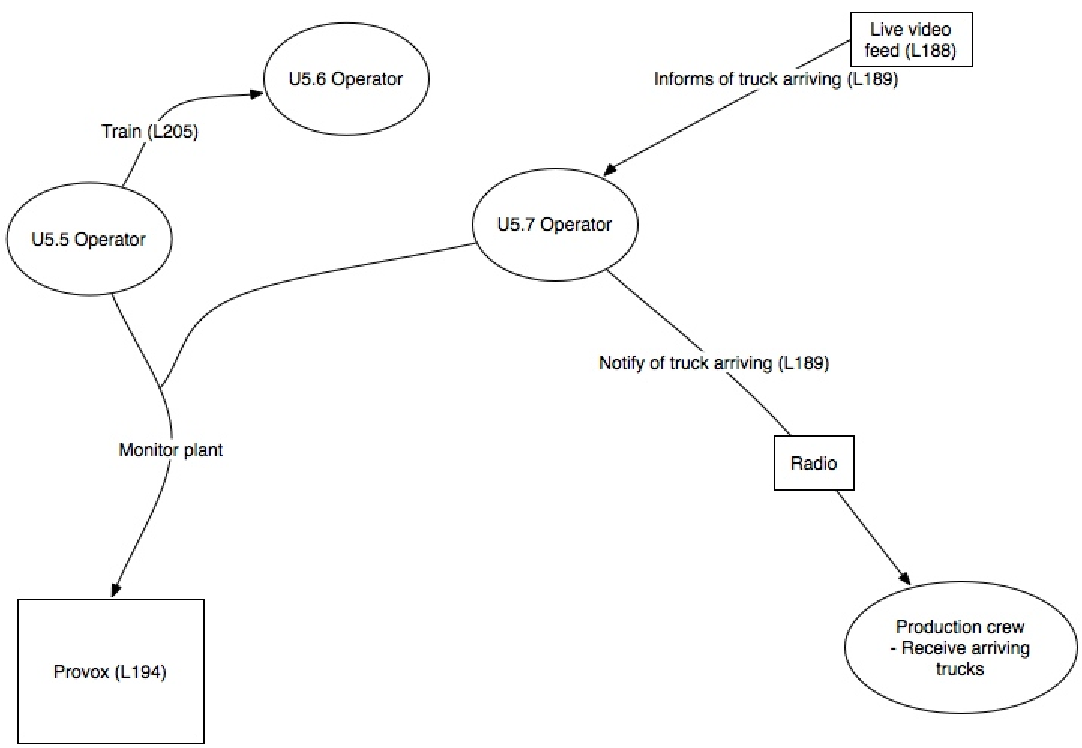
C4. Flow Model



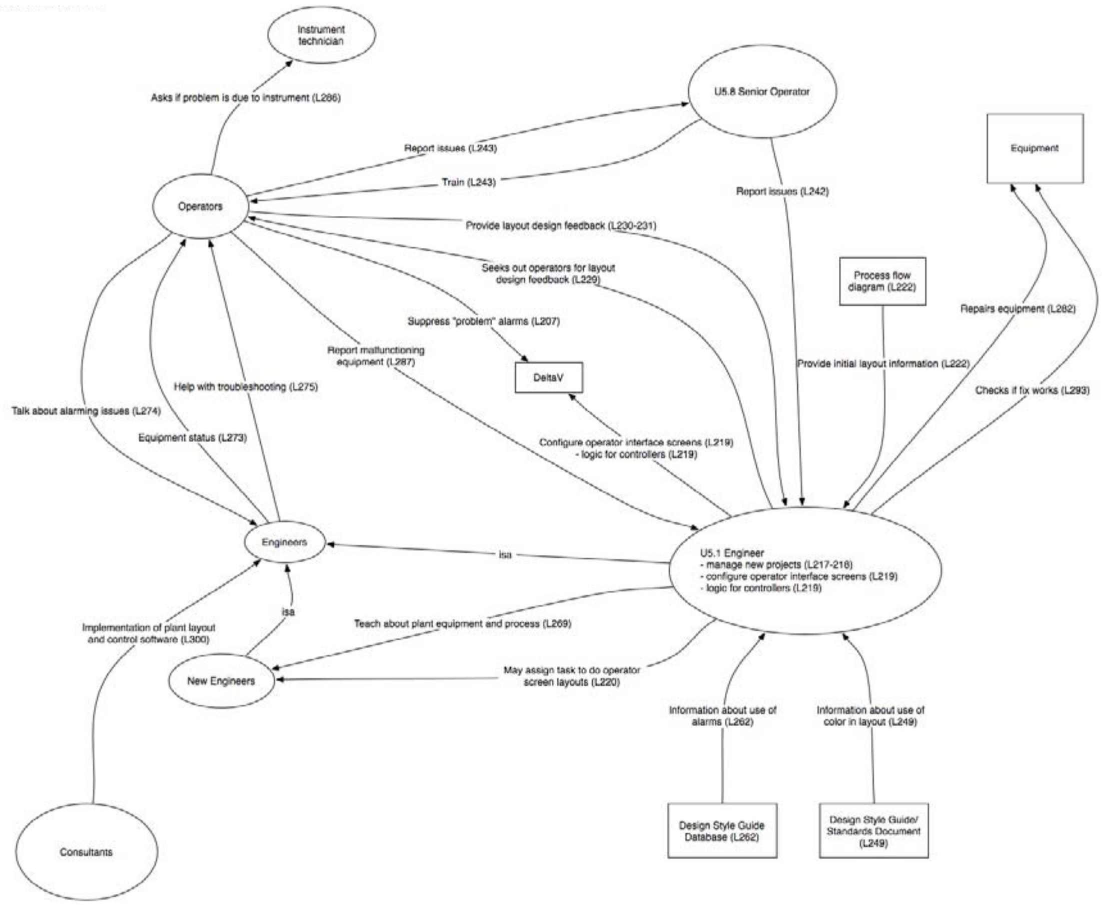
C5.1 Flow Model



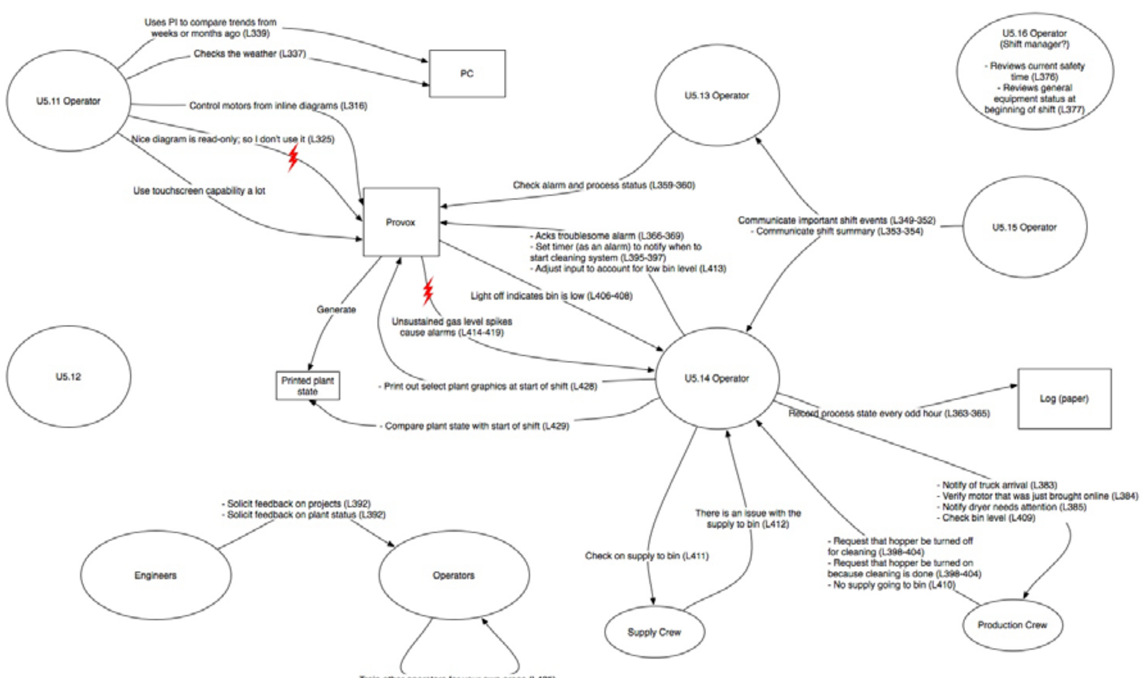
C5.2 Flow Model



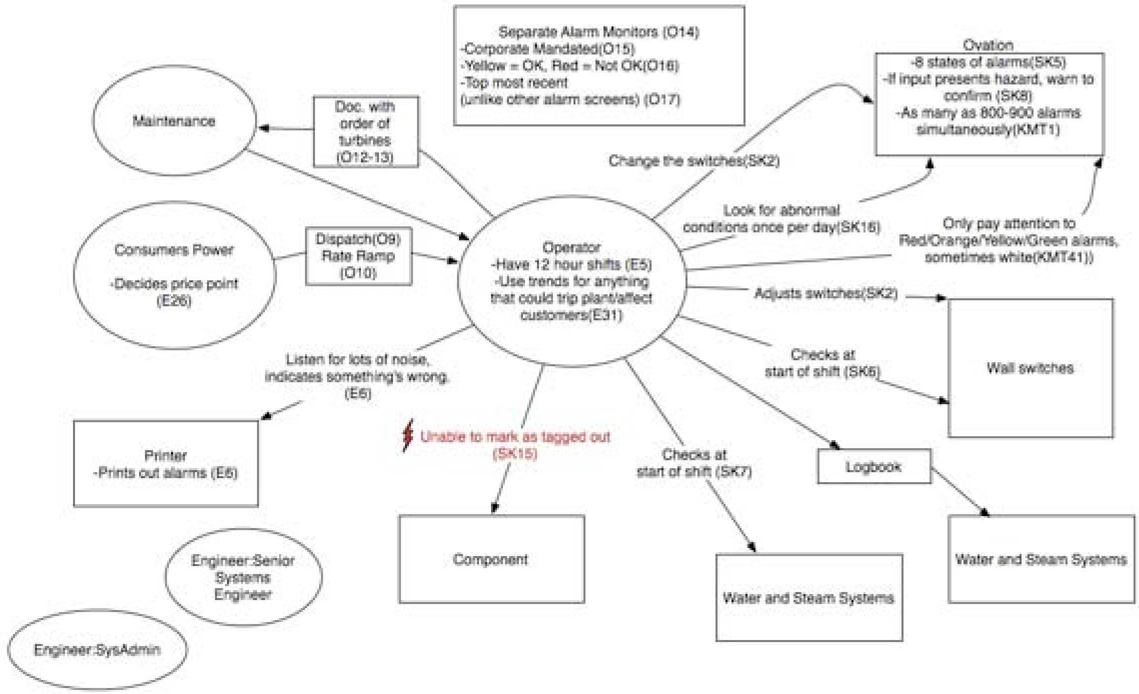
C5.3 Flow Model



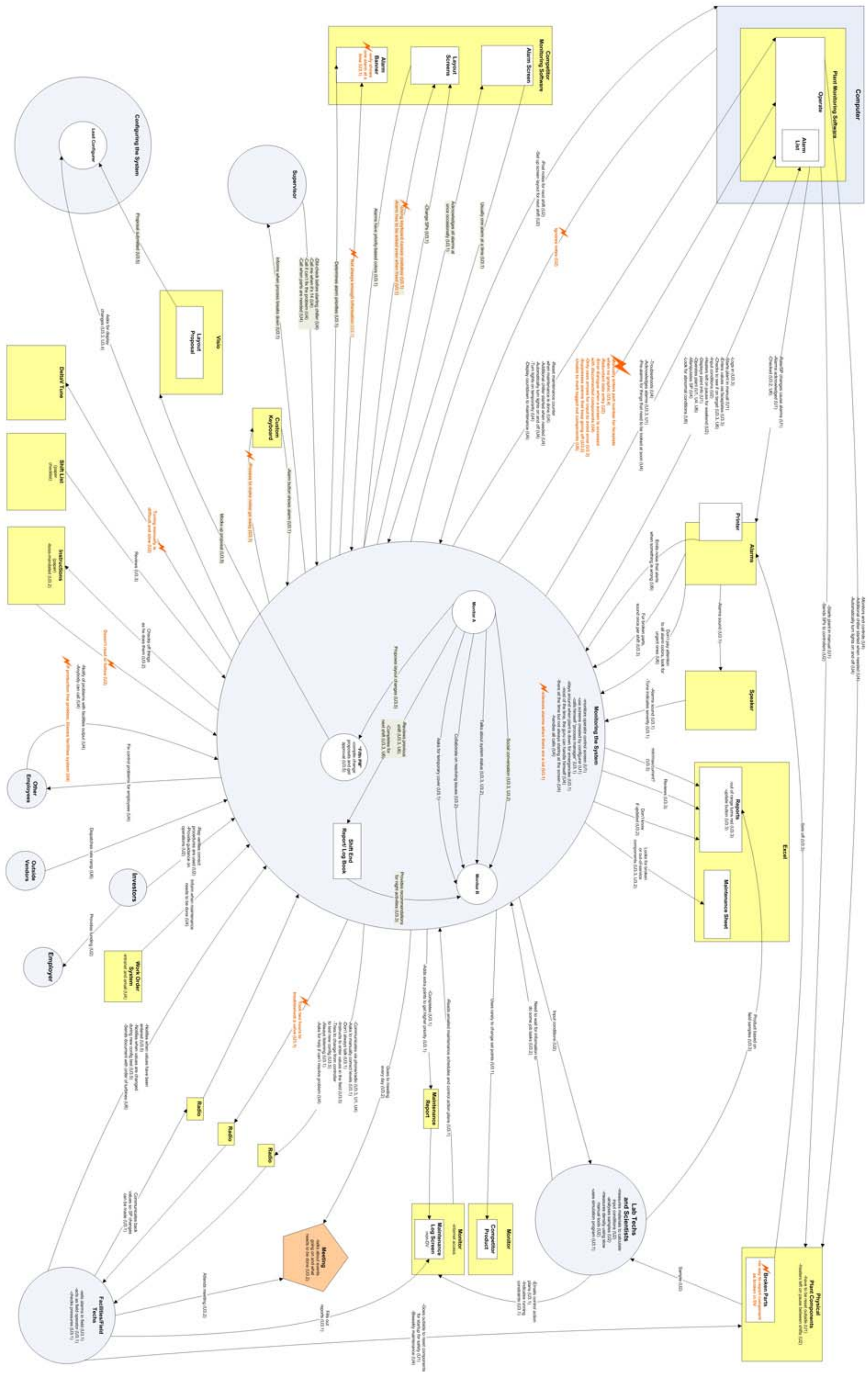
C5.4 Flow Model



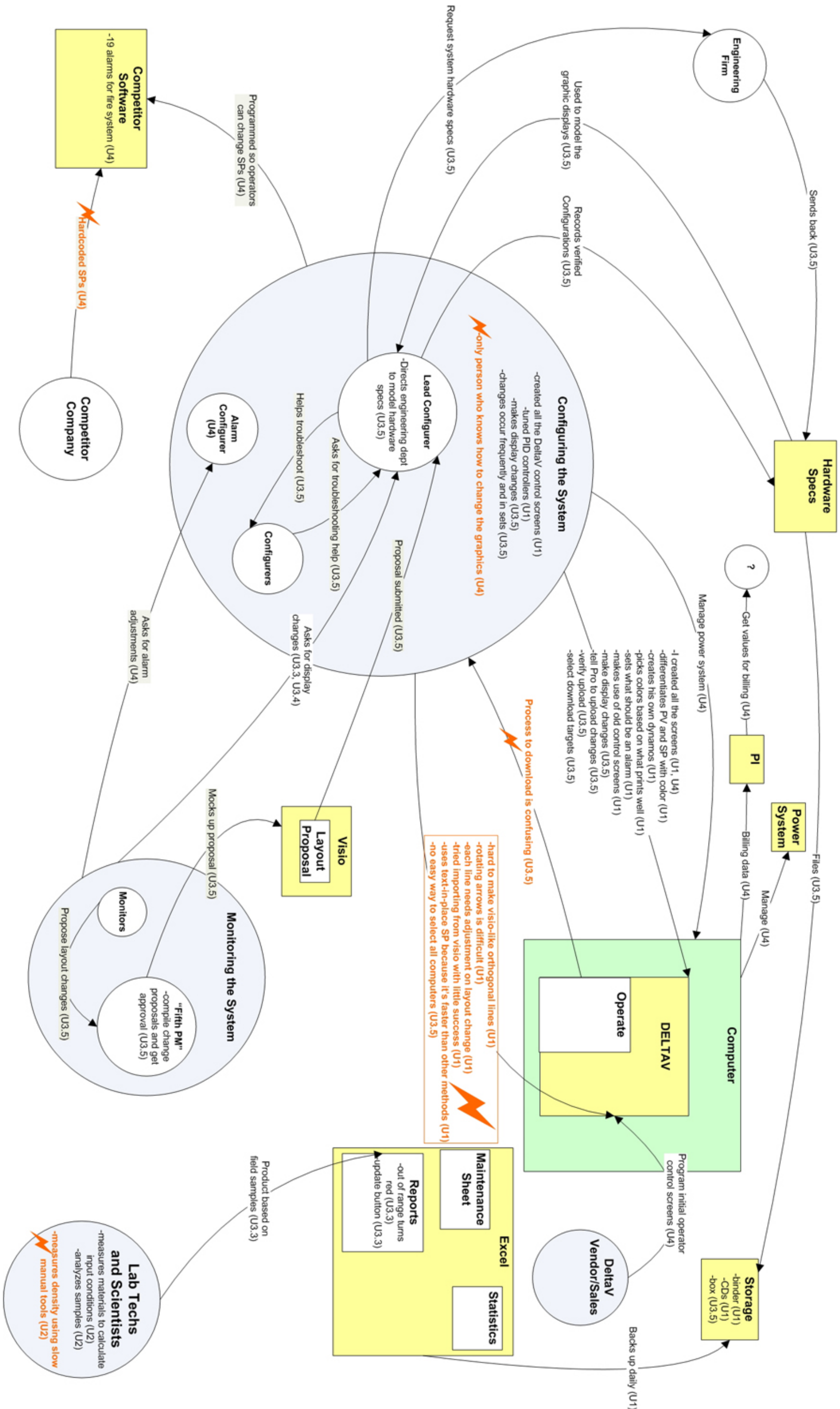
C5.5 Flow Model



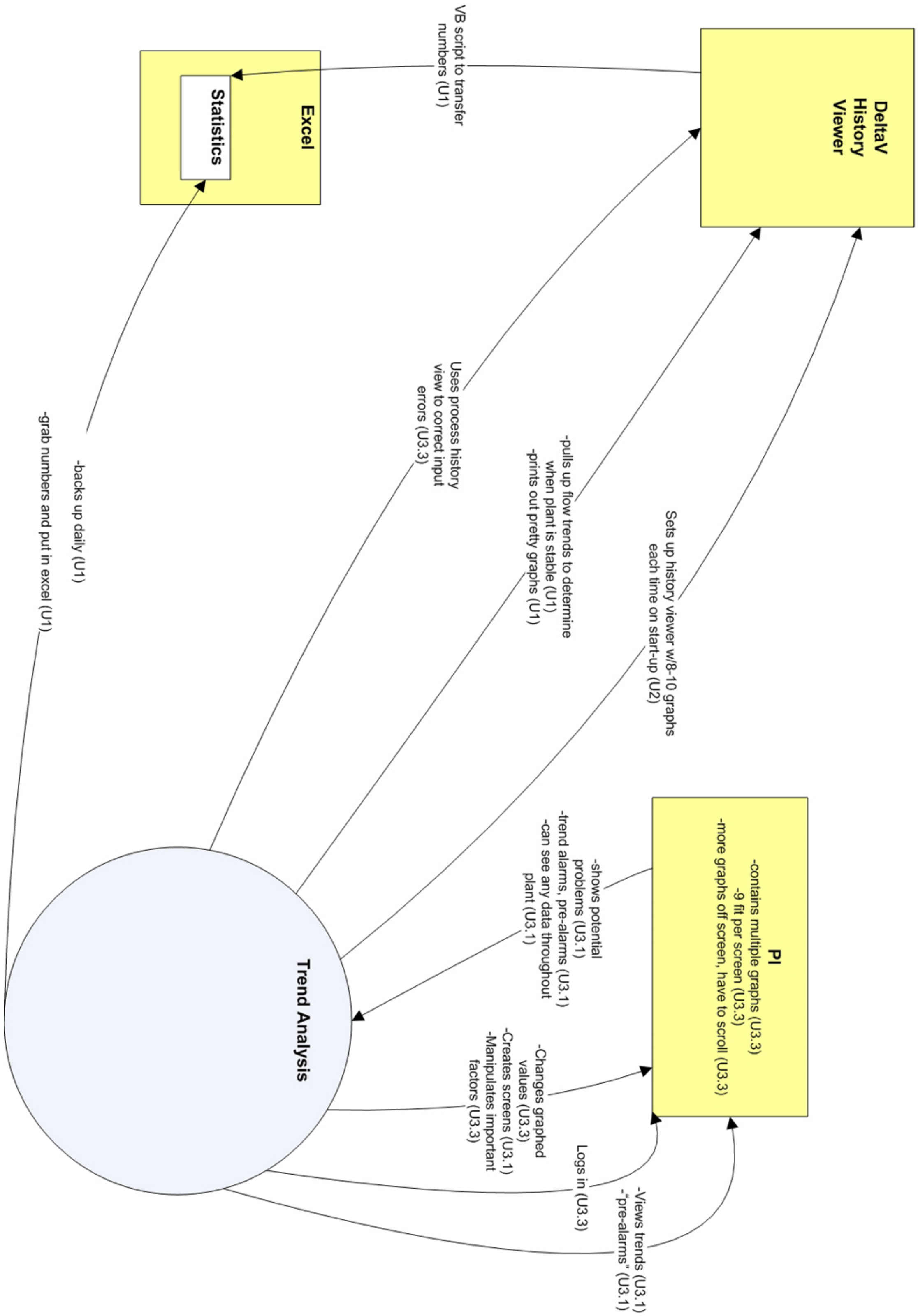
C6. Flow Model



Consolidated Flow Model – Monitor Perspective

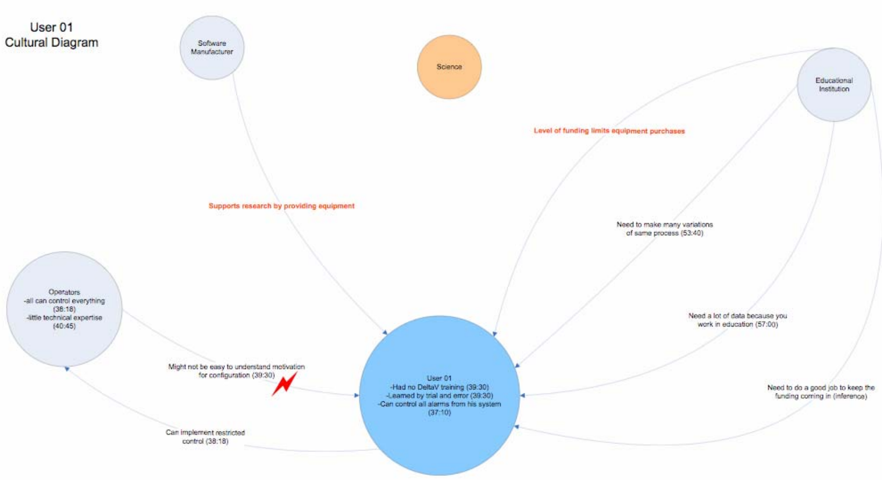


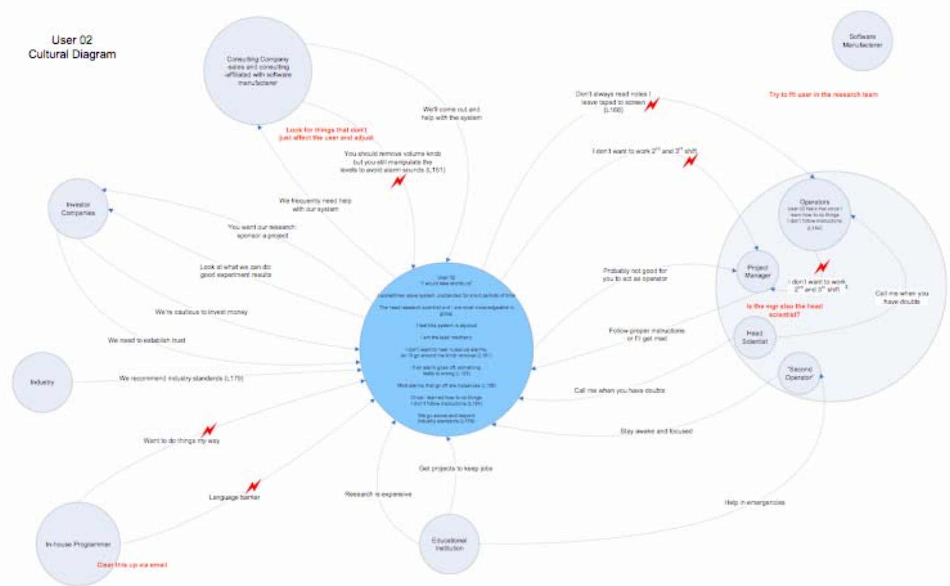
Consolidated Flow Model – Configuration Perspective



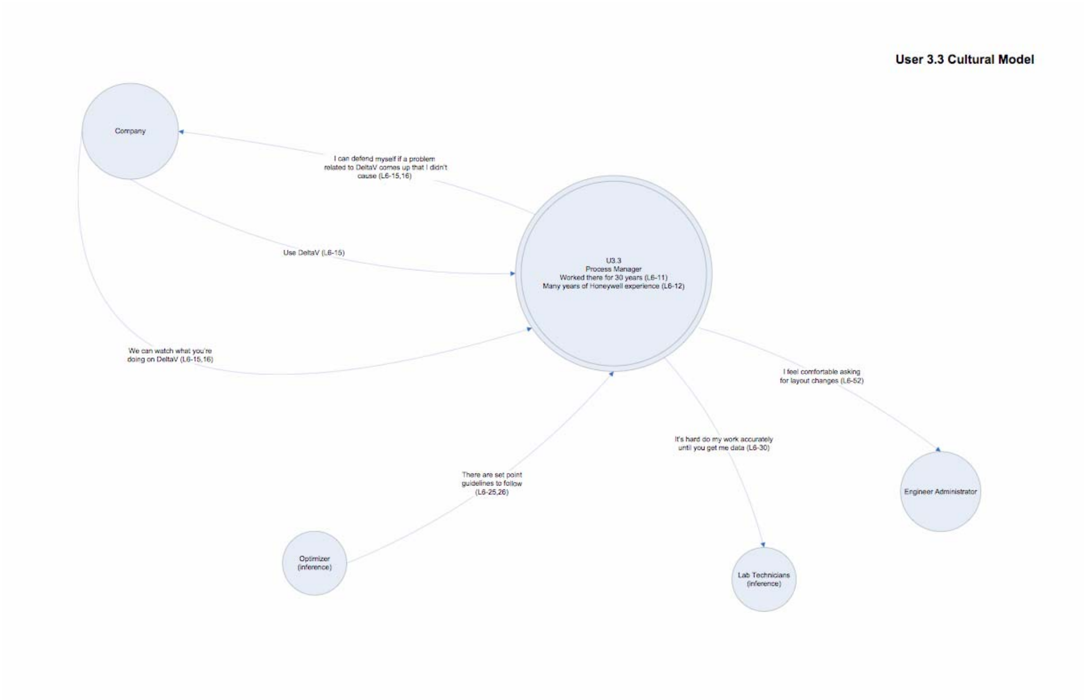
Consolidated Flow Model – Trend Analysis Perspective

Cultural Models

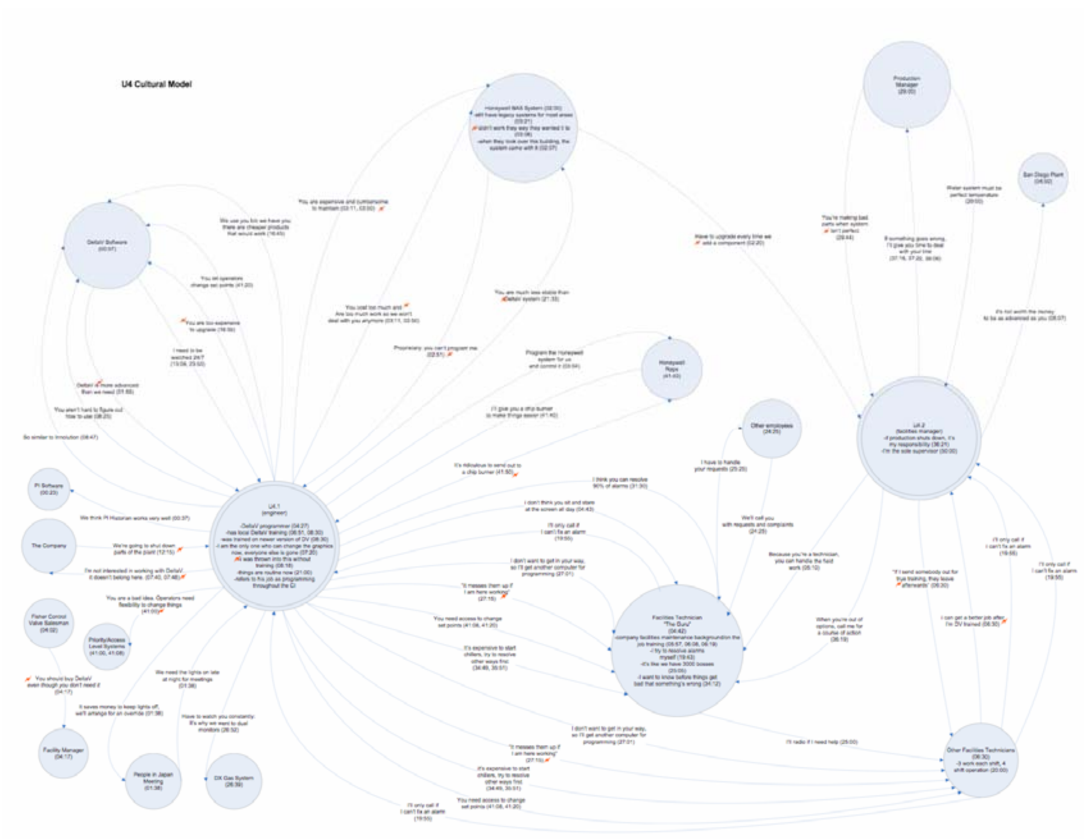




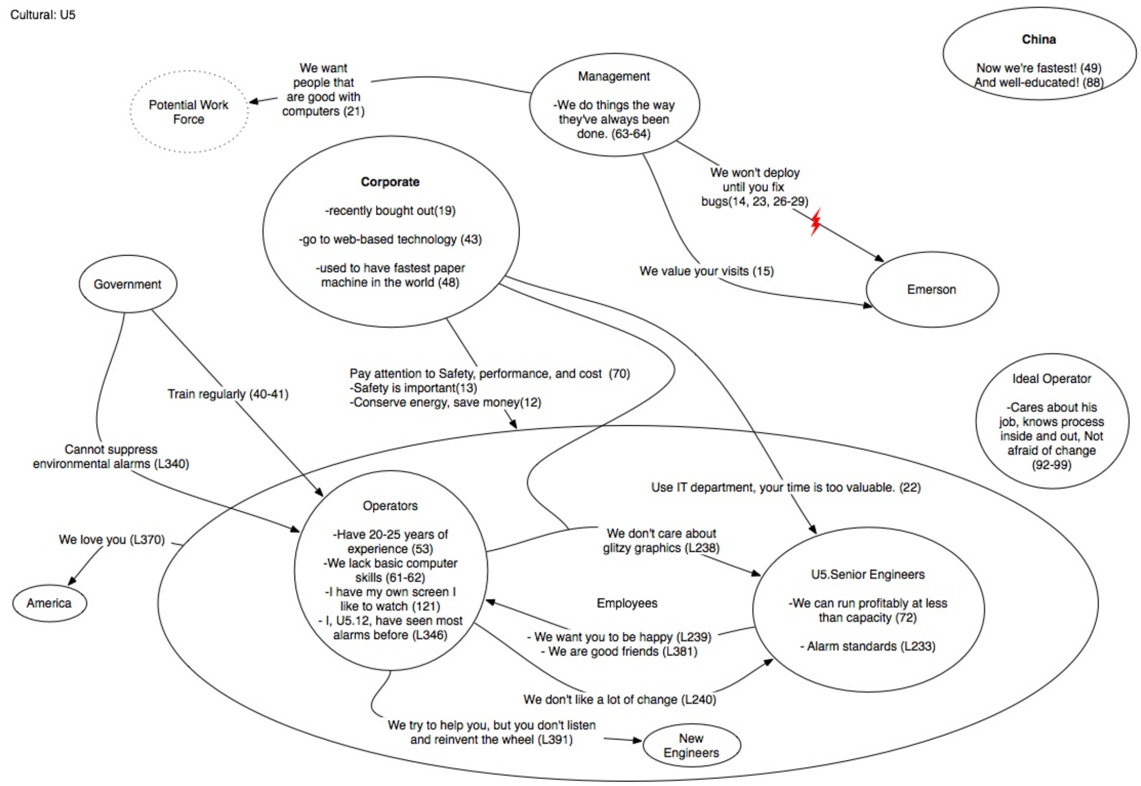
C2. Cultural Model



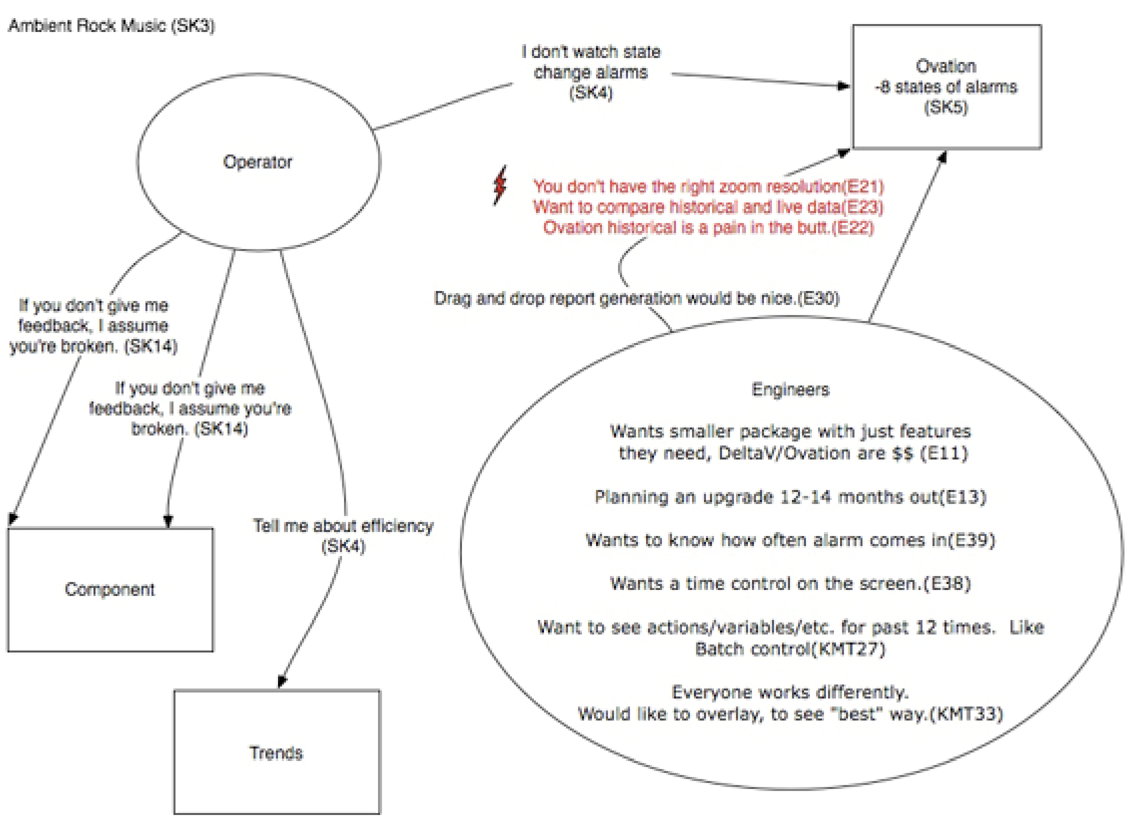
C3. Cultural Model



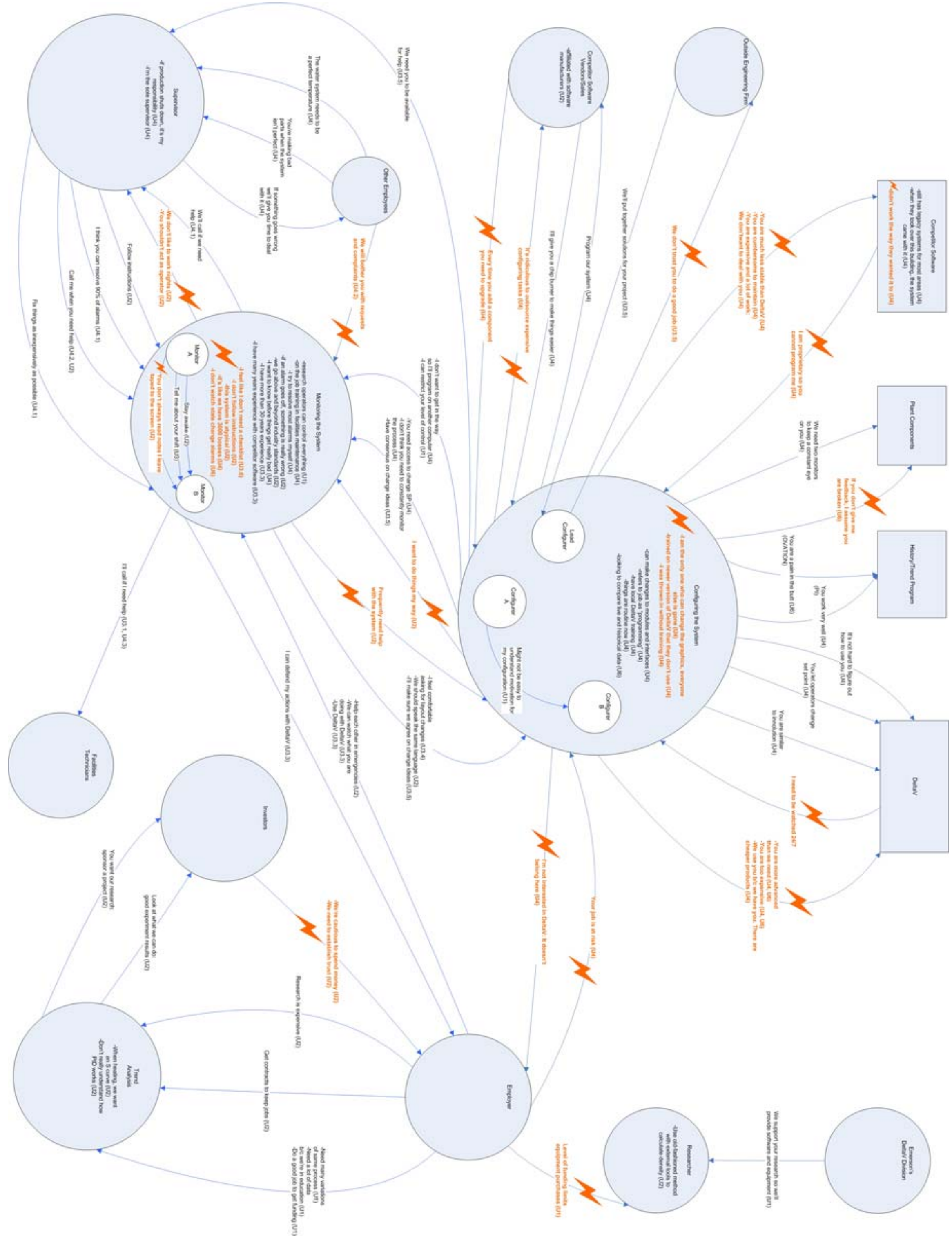
C4. Cultural Model



C5. Cultural Model

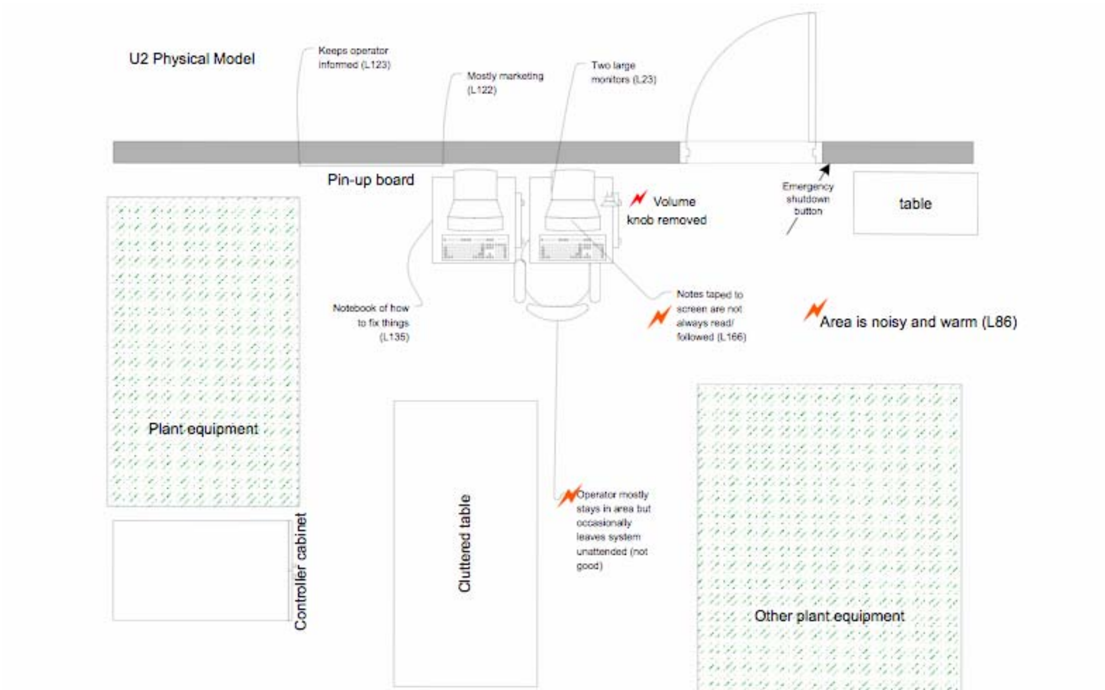


C6. Cultural Model

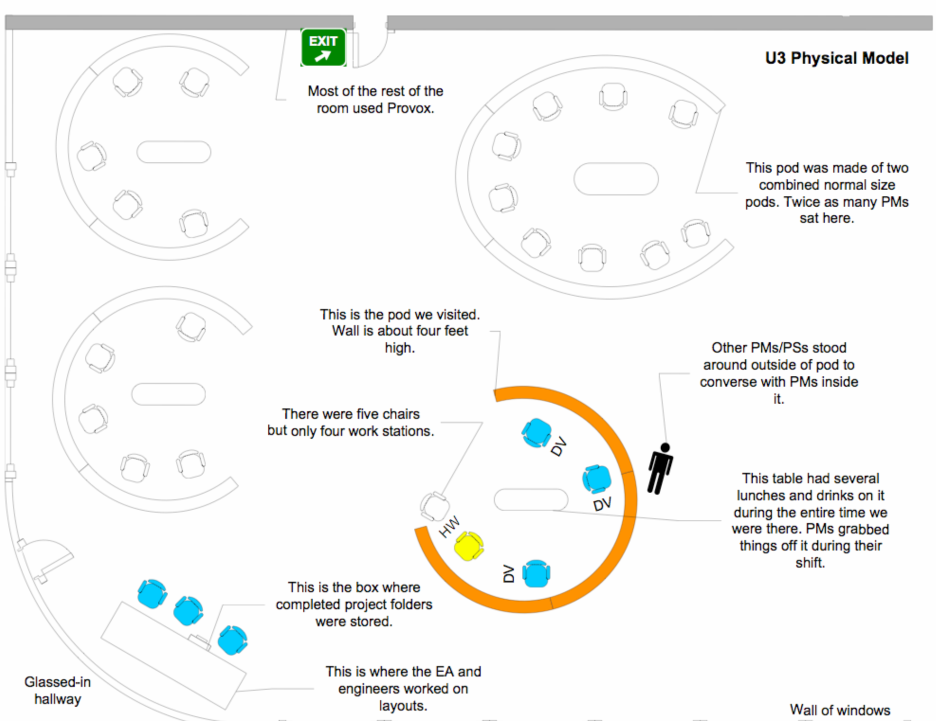


Consolidated Cultural Model

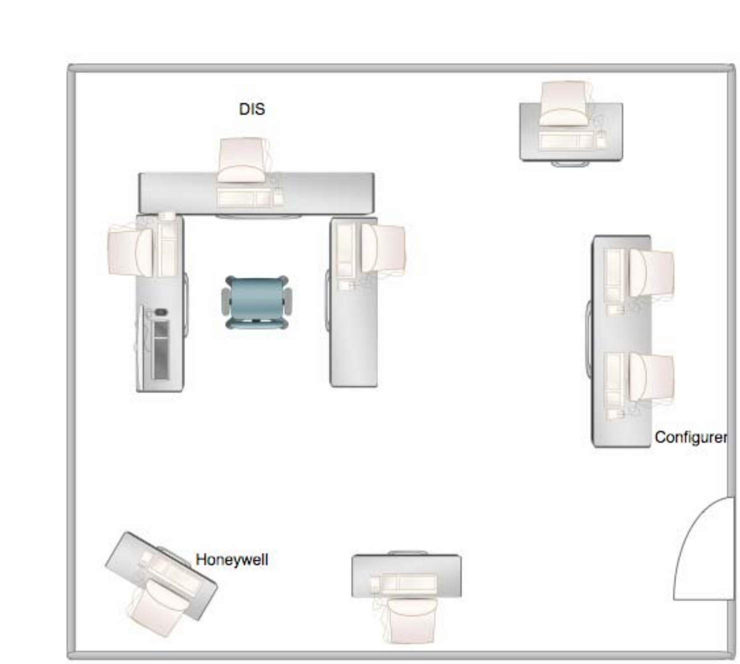
Physical Models



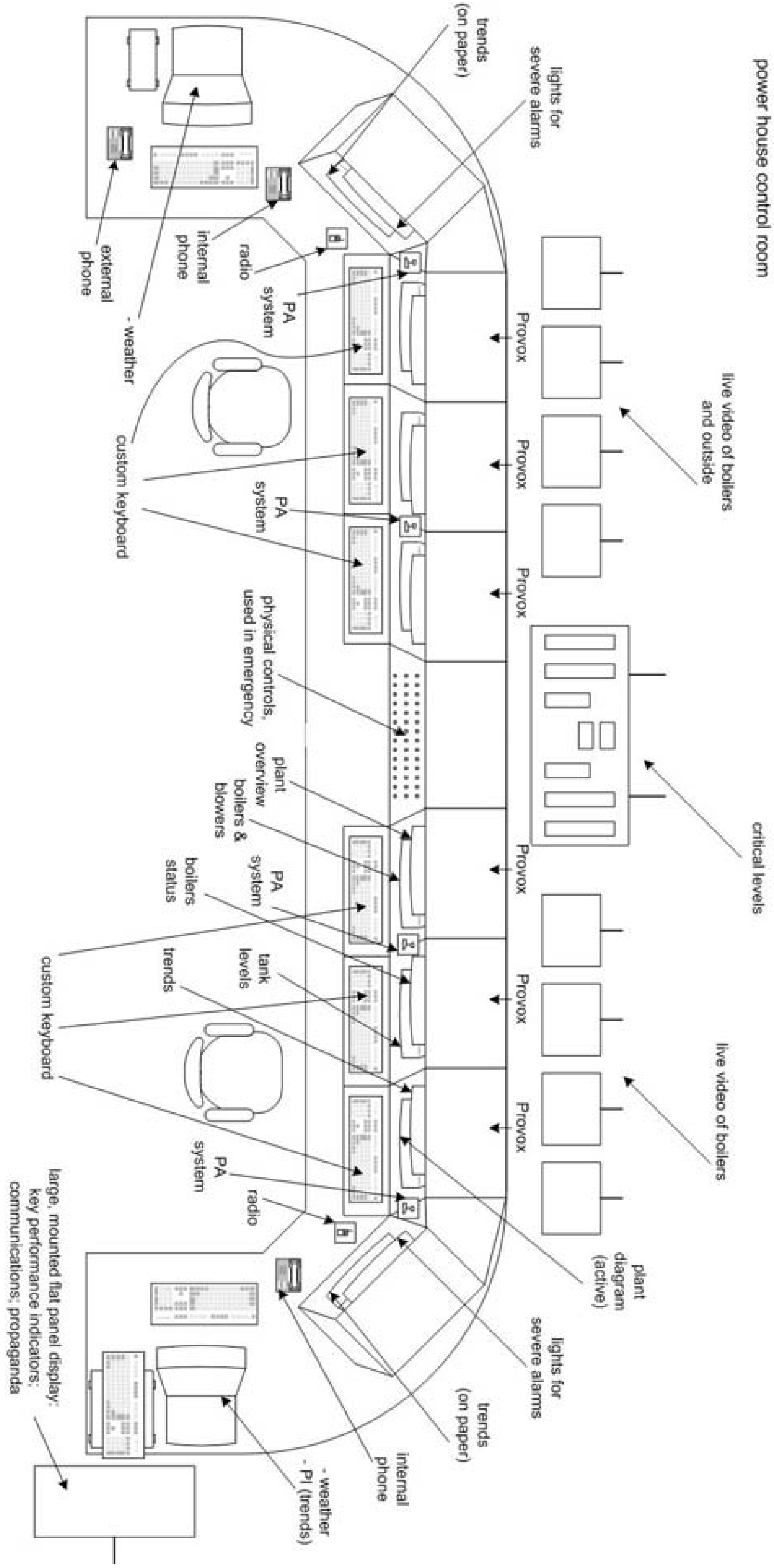
C2. Physical Model



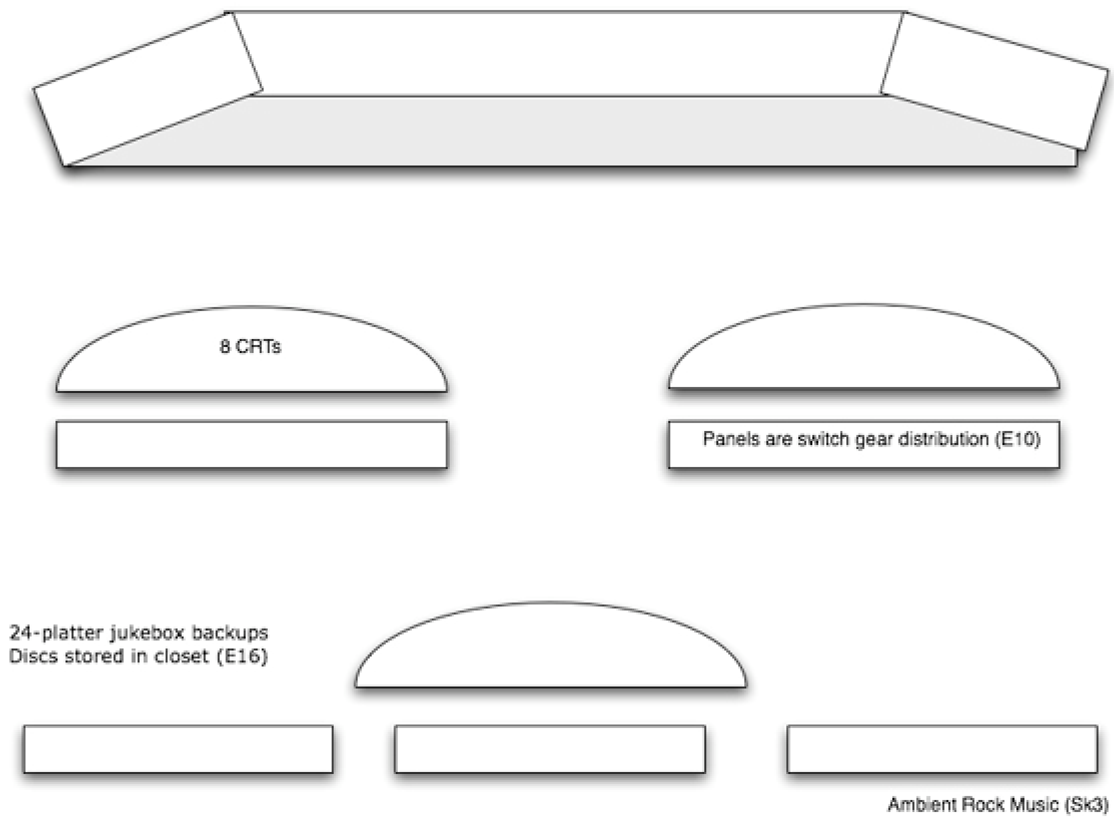
C3. Physical Model



C4. Physical Model

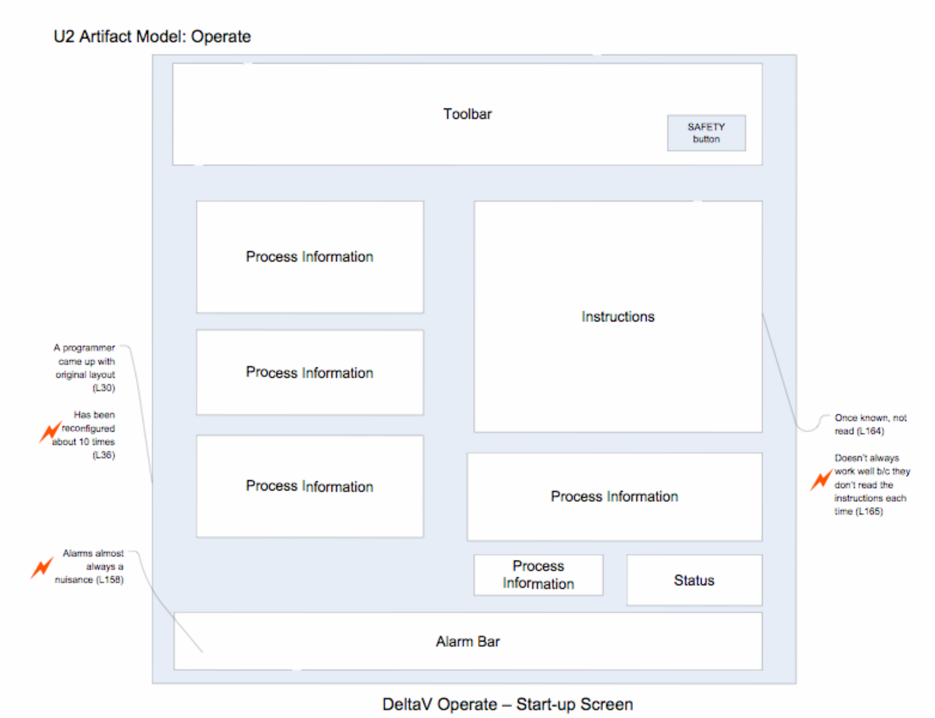


C5. Physical Model

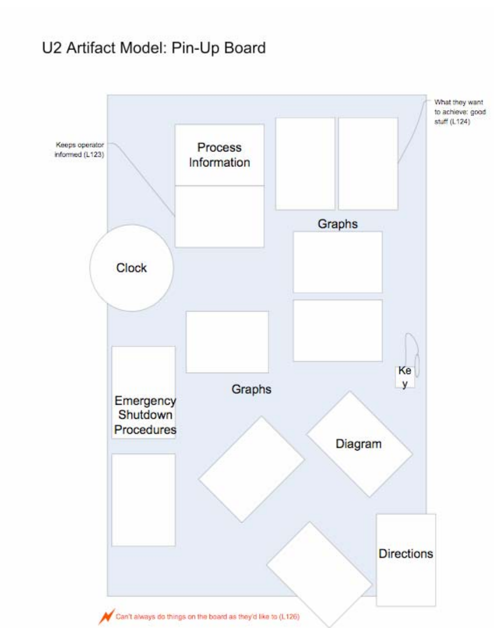


C6. Physical Model

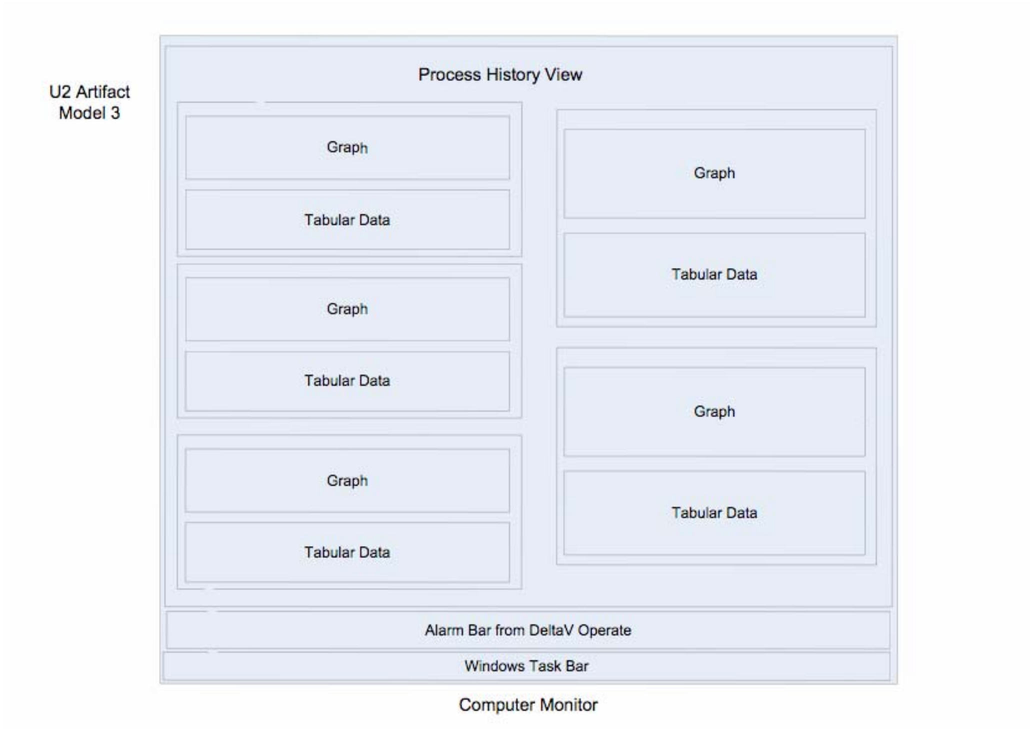
Artifact Models



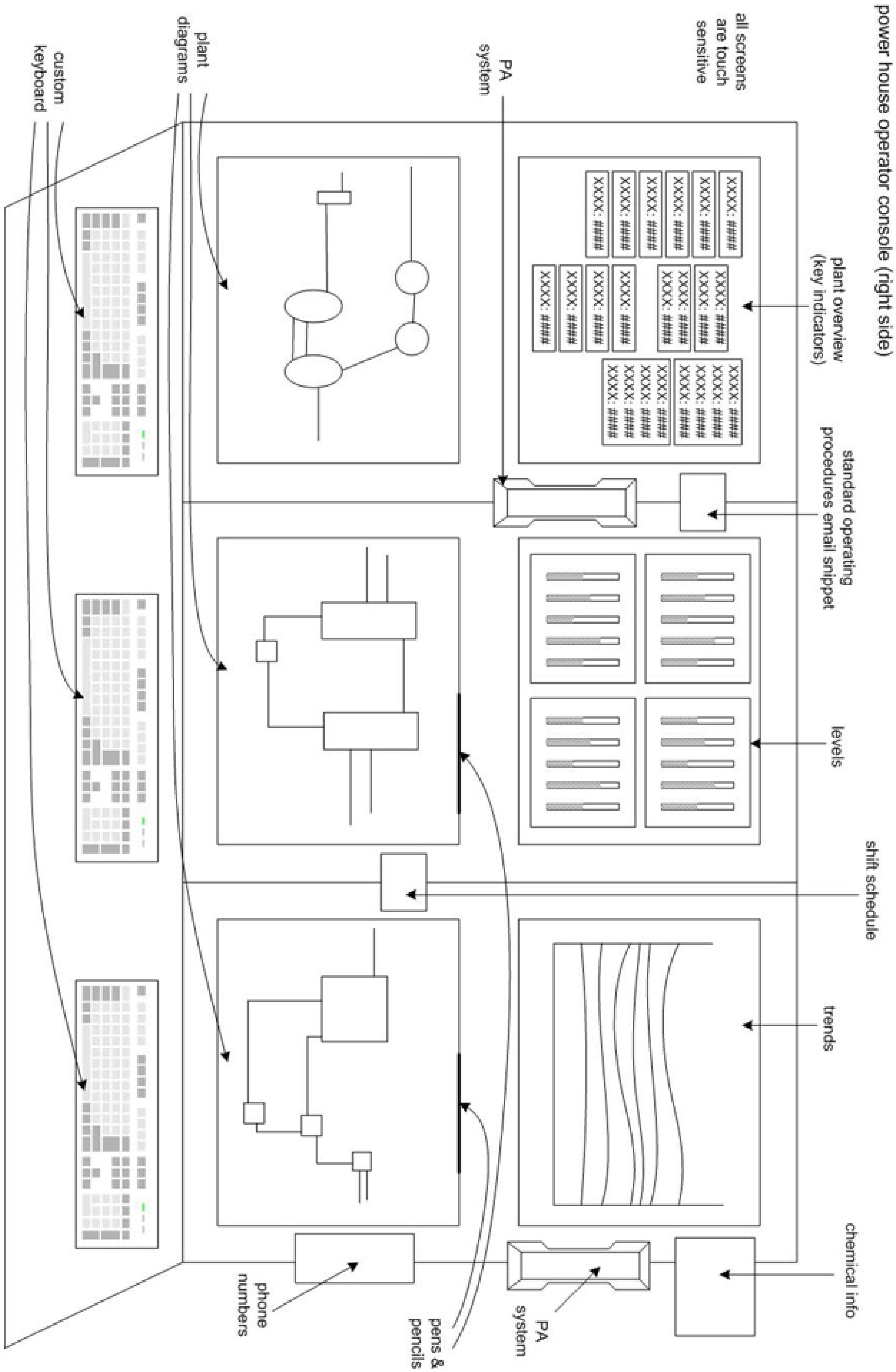
C2. Artifact Model



C2. Artifact Model



C2. Artifact Model



C5. Artifact Model

Section B: Think Aloud Usability Aspect Reports (UAR)

This section includes the results and observations from the think-aloud tests in the form of Usability Aspect Reports (UAR). A consolidation of the UARs is presented first, followed by the individual UARs from each think-aloud user test.

Consolidated Usability Aspect Reports

Test Session	UAR	Short Description	Rating
1 (Bars)	UAR-01-01	Font is hard to read	2
1 (Bars)	UAR-01-02	Rate of change isn't obvious	2
1 (Bars)	UAR-01-03	Monochromatic colors aren't good for everyone	2
1 (Bars)	UAR-01-04	Pump status should be displayed with color	2
1 (Bars)	UAR-01-05	Need way to get at specific values	4
1 (Bars)	UAR-01-06	Doesn't work for 2-directional process	3
1 (Bars)	UAR-01-07	Concern for screen real-estate and clutter	2
1 (Bars)	UAR-01-08	Sparklines aren't noticed	4
1 (Bars)	UAR-01-09	Sparklines are hard to interpret	2
1 (Radar)	UAR-01-10	Too much stuff changing simultaneously	2
1 (Radar)	UAR-01-11	Want to see in separate window	N/A
1 (Radar)	UAR-01-12	Moving set points preferred over stills	3

1 (Radar)	UAR-01-13	Unsure if practical use exists	3
1 (Radar)	UAR-01-14	Use as History Viewer	N/A
1 (Radar)	UAR-01-15	Concern it may be too much for operators	3
2 (Radar)	UAR-02-01	Meaning of radar graph is difficult to understand.	3
2 (Radar)	UAR-02-02	Radar graph does not provide enough details about the set point.	3
2 (Radar)	UAR-02-03	Main viewing area of DV Operate prototype does not meet user expectations.	2
2 (Trends)	UAR-02-04	Trending with alarm tracking meets user need.	N/A
2 (Trends)	UAR-02-05	Trend graph should have more details on the increments.	3
2 (Trends)	UAR-02-06	Labels differentiating each trend group are not clearly marked to distinguish each one.	2
2 (Trends)	UAR-02-07	It is difficult to match trend line messages with the list items.	2
2 (Trends)	UAR-02-08	Alarm/Message list is considered redundant and unnecessary.	1
2 (Bars)	UAR-02-09	Tank history graphic values are too small to read by a person over 40.	2
2 (Bars)	UAR-02-10	Being able to control history graphics is pleasing.	N/A

2 (Bars)	UAR-02-11	History in objects does not provide enough visualization for evaluation.	3
2 (Bars)	UAR-02-12	Tick marks on radar graph representing set point are clearly understood.	
2 (Bars)	UAR-02-13	Sparklines concept considered too vague.	N/A
2 (Radar)	UAR-02-14	Need for radar graph not apparent.	N/A
3 (Sparklines)	UAR-03-01	Play/Pause confusion	4
3 (Sparklines)	UAR-03-02	Colors/Contrast are bad	4
3 (Sparklines)	UAR-03-03	Timeframe is missing	4
3 (Sparklines)	UAR-03-04	Add ability to change timeframe	N/A
3 (Sparklines)	UAR-03-05	Add ability to zoom	N/A
3 (Trends)	UAR-03-06	General level message unclear	2
3 (Trends)	UAR-03-07	Selection should be mirrored	N/A
3 (Trends)	UAR-03-08	Sticky-Select isn’t the best	2
3 (Trends)	UAR-03-09	No timescale	4
3 (Trends)	UAR-03-	No Legend	3

	10		
3 (Trends)	UAR-03-11	Include link to relevant documentation	N/A
3 (Trends)	UAR-03-12	Add Splitter	N/A
3 (Trends)	UAR-03-13	Want to see values	4
3 (Trends)	UAR-03-14	Want double-click or Right-click to view full message	N/A
3 (Trends)	UAR-03-15	Line should change color for alarm state	N/A

Individual Usability Aspect Reports

Round 1 Testing

Study Type: Think Aloud Evaluation: Session One
Date of Study: June 29, 2006
Subject ID: P1.1, P1.2, P1.3, P1.4

<table>
<tr><td>No. UAR-01-01</td><td colspan="2">Problem</td></tr>
<tr><td colspan="3">Name: Font is hard to read</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>P1.1</td><td colspan="2">It is hard to read the words next to the bar graphs; is this minus 40 minutes?</td></tr>
<tr><td>P1.2</td><td colspan="2">-Font is not good</td></tr>
<tr><td colspan="3">Explanation:

Two of the four testers mentioned specifically that the font used to label the graduations within the tanks was small and hard to read.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: 2 – Minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Just because the other two participants didn’t mention it, doesn’t mean we can’t assume it’s fine for everyone. It seems likely that this could affect a wide number of operators, as their overall population is older, and we know that vision worsens with age.

Impact: If the labels are hard to read, people may not bather using the graph, so why have it in the first place?

Persistence: It depends. If the time intervals are always at 10-minute intervals, it’s quite possible for people to memorize positions and count accordingly. Knowing that the time interval is likely to be different for different components, it seems this problem will continue to persist for all affected users whenever they see this interface.</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

Enlarge the font; on consider having a preference that allows the user to customize what size they’d like the font to be. The trade-off is that this requires significant on-screen real estate, and possibly extra coding.</td></tr>
</table>

No. UAR-01-02	**Problem**
Name: Rate is not conveyed well	
Evidence:	
1.2	One thing I do care about is speed of change – from these bars I cannot tell how slow or fast the change was. This is critical for some processes
1.3	The amount of change was not obvious at first

Explanation:

While this prototype was designed specifically to show rate of change, the way in which it was displayed was not immediately intuitive for two of the four participants.

Severity or Benefit:

Rating: 2 – Minor Usability Problem

Justification (Frequency, Impact, Persistence):

Frequency: It seems like this may be something that effects primarily new users, as it's a deviation from what they have now, and takes some getting used to. It's hard to know if the value is still there, and just going unnoticed, or if it requires major reworking.

Impact: This has a high impact – the intent behind putting this in was to show the rate of change, so if that's not coming through, then the added display elements are pretty much useless.

Persistence: This seems like something that would be taught, or could be learned over time. For that reason, this has low persistence.

Possible solution and/or trade-offs:

Provide training to operators as to what this interface adds to the operator screen, so that they understand how rate of change is being conveyed. The trade-off is that the extra training will require time to develop the training material as well as a means to ensure it's distributed to all operators so that they understand how this display is being used.

No. UAR-01-03	**Problem**
Name: Monochromatic colors aren't good for everyone	
Evidence:	
1.1	-I would like to see the same color for what operators are used to seeing
1.3	-When you have so many shades it is hard to correlate what went where (from one tank to the other) – so same colors are correlated for the two tasks
1.4	-The colors are interesting; the current level in tank 1 is dark and the current level in tank 2 contains other levels which makes it difficult to read/interpret
1.4	-We try not to use colors because of color blind people
Explanation: The concerns with the monochromatic color scheme presented were twofold. One, participants wanted to be sure that colors could be customized to be more inline with individual systems. Two, the differences between some of the colors was too small to discern.	
Severity or Benefit: Rating: 3 Justification (Frequency, Impact, Persistence): Frequency: Depending on how often this component is used, this problem has the potential to happen every single time it's used, giving it a rating of high. Impact: As one of the users pointed out, this would have a huge impact on color-blind users, but as it is, it seems more like a medium-low impact at this time. More testing would be good to really confirm (or deny) this. Persistence: This problem will continue to persist every time the component is used, making this high priority.	
Possible solution and/or trade-offs: N/A	

<table>
<tr><td colspan="2">No. UAR-01-04</td><td>Problem</td></tr>
<tr><td colspan="3">Name: Pump status should be shown with color</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>1.3</td><td colspan="2">-(When asked about the idea of red and green dashes) red, green lines may get too colorful on a history basis. I would expect changing color for device running or not – used to seeing it that way</td></tr>
<tr><td>1.1</td><td colspan="2">- I would like to see the same color for what operators are used to seeing. We normally use color, with red be running and open and green as not running and close</td></tr>
<tr><td colspan="3">Explanation:

Here, the engineers are suggesting something they know the operators are used to – the red/green coloring system currently used to indicate on/off status in plants.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: 2

Justification (Frequency, Impact, Persistence):

Frequency: Because this is something that would constantly be present on the screen, it's consider to be a high priority

Impact: Certainly, if operators are used to the new system, this should have a relatively low impact over time.

Persistence: Like frequency, this will exist every time. However, it seems like it would have a low persistence, as people will eventually learn what the new graphics/items are used for.</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

N/A</td></tr>
</table>

<table>
<tr><td colspan="2">No. UAR-01-05</td><td>Feature Request</td></tr>
<tr><td colspan="3">Name: Want to be able to get specific values</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>U1.1</td><td colspan="2">-Is there a way to get numeric values of past values? Can I pick it and get its value

-In our applications it is very important to get values at that time</td></tr>
<tr><td colspan="3">Explanation:

Here, the operator is asking how one would get the specific values (for PV and SP) from within the bar diagram itself.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: N/A</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

N/A</td></tr>
</table>

No. UAR-01-06	**Problem**
Name: This doesn't work for 2-directional processes	
Evidence:	
U1.2	-These bars only go in one direction. If this were applied to a furnace, it would go up and down and look fuzzy
U1.4	-When a level changes up and down would be hard to show
Explanation: One of the big flaws of this prototype was how limited it was, in that this type of visualization really only worked for certain processes, and within that set of processes, only for those that moved in only one direction.	
Severity or Benefit: Rating: 1 Justification (Frequency, Impact, Persistence): Frequency: It's really tough to know how often this would come up. Ideally not at all, because it should be clear up front that this won't work for all components, and therefore should not be used for components where it won't work – making this low frequency. Impact: Again, this is something that would hopefully only be used in the right instance, so it should have a low impact. Persistence: Assuming that this type of visualization is properly used, the problem should not persist, giving it a rating of 1.	
Possible solution and/or trade-offs: N/A	

No. UAR-01-07	**Problem**
Name: Concern for screen real estate and clutter	
Evidence:	
U1.1	-Our graphics are way more populated than the information presented here. -This idea is just adding more dynamics; there are already a lot to begin with.
U1.1	-We don't have this much real estate on the screen to have this kind of information.
U1.3	-In the current time view, numbers keep popping up all the time – you would have to keep a constant watch to see the trend. It will also distract you and grab your attention away from other things
U1.4	-In the current time view, numbers keep popping up all the time – you would have to keep a constant watch to see the trend. It will also distract you and grab your attention away from other things
Explanation: More of a concern than an actual problem. Participants suggest that there's not enough space as it is, and anything that's dynamically changing may be more of a distraction than help.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-01-08	**Problem**
Name: Sparklines aren’t noticed	
Evidence:	
Explanation: The big problem we had with testing out the sparklines was that they simply weren’t noticed – or if they were, they weren’t remarked on until the end of the session, and only then when the test moderator asked explicitly about them.	
Severity or Benefit: Rating: 3 Justification (Frequency, Impact, Persistence): Frequency: These were missed, every time, by every participant. It’s very hard to put a qualifier on why, whether it’s the particular visualization, or perhaps the placement that wasn’t sitting properly with users. Impact: The impact if these continue to be missed is huge. It defeats the purpose of adding in the sparklines if they’re not even spotted. Persistence: It may be that this is one of those training things that people just learn. The thought is that once people learn that the sparklines are always found in a certain zone, the problem of persistence will no longer occur.	
Possible solution and/or trade-offs: N/A	

No. UAR-01-09	**Problem**
Name: Sparklines are hard to interpret	
Evidence:	
U1.2	People don't normally look for something missing (in response to the particular visualization itself)
U1.4	-Is that a gap in the bottom one (bottom one of the dash lines) or is that just the way it is -I'm not sure if I would find it useful -(He got closer to the computer) Dashes are small – size is important
Explanation: The comments on this problem were centered around two gaps: the first, the gap with not noticing the sparklines, then feeling pressured to interpret their meaning. The second was on the visualization itself, which used dashes and spaces to represent periods of on and off, respectively.	
Severity or Benefit: Rating: 3 Justification (Frequency, Impact, Persistence): Frequency: Despite the sparklines not being noticed in the first place, it really seemed like the visualization was such a problem that there would continue to be interpretation problems every time this is viewed, giving this a high frequency rating. Impact: Again, this is one of those things where if the visualization isn't interpreted correctly, it's tough to know why it was implemented in the first place, making this a high impact. Persistence: At this point, I'd consider this to be a high persistence for newer users. As someone becomes more familiar with the system, I believe that the persistence would go down, making this a rating of 3.	
Possible solution and/or trade-offs: N/A	

<table>
<tr><td>No. UAR-01-10</td><td colspan="2">Problem</td></tr>
<tr><td colspan="3">Name: Too much stuff changing simultaneously</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>U1.1</td><td colspan="2">Difficult to concentrate on this & this in real-time.</td></tr>
<tr><td>U1.4</td><td colspan="2">Too much changing. Hard to figure out focal point.

No big easy things to look at. Have to quickly look and get a feel for how stuff is.</td></tr>
<tr><td colspan="3">Explanation:

In addition to participants outwardly commenting on the amount of on-screen movement, all participants asked to watch the animation at least one additional time, and sometimes more in order to fully take-in everything that was simultaneously changing on screen.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: 2

Justification (Frequency, Impact, Persistence):

Frequency: The amount of movement won’t change, so this problem has the potential to happen every time the interface is viewed, though with time it may become less of an issue.

Impact: This is a fairly high impact problem. If the animation and changing values are such that they distract from other things on the screen when there aren’t really problems, then we’ve potentially created a worse situation than by not having the extra information and animation to begin with.

Persistence: This problem will continue to persist, potentially for all users, every time the interface is shown.</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

N/A</td></tr>
</table>

No. UAR-01-11	**Feature Request**
Name: Want to see in separate window	
Evidence:	
U1.1	Only thing is – can we have in pop-up type format so doesn't chew up screen real estate, Only thing is to pop-up window so operator has to click somewhere to get it to show up.
U1.1	Pop-up – so operator can have choice. Typically only have one pop-up active per process graphic.
Explanation: For concerns of real estate as well as user choice, one participant was quite adamant about this feature being something that could be potentially useful, but only as an additional window.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-01-12	**Problem**
Name: Moving set points preferred over stills	
Explanation: When asked, all participates indicated they preferred the moving set point to the still set points. The explanation most gave was that even though set points don't often move, when they do move, people wanted to actually see feedback that the point moved. This seemed to be especially true if the user manually changed the set point. However, it is important to recognize that this testing was done with unlabeled axis and without the ability for the user to manipulate the set point directly themselves. With labeling, a more realistic problem, and the ability for a bit more direct manipulation, it's possible that the results would be different.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-01-13	**Problem**
Name: Unsure if practical use exists	
Evidence:	
U1.2	It's really cool. I'm not sure where you'd use it, but it's really cool. Polar grid? What is color change for? Usually change in color is alarm condition. I'm trying to think of application where you could use it.
U1.3	Suppose it could be useful, the things that you have to...you wouldn't necessarily have a perfect, depending on where you put SP. Hard to think of any use.
Explanation: Participants had a hard time extrapolating out from the 4-way graph and specific example to other combinations or variants of this graph. Part of this is likely due to the prototype not showing a great model scenario, and part is likely due to this just being a tough concept to sit down, see, and fully comprehend in just a few minutes. It's quite possible that after some exposure to the concept, or more explanation or training, that participants could see this being used for 3, 5, or possibly more components simultaneously.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-01-14	**Problem**
Name: Use as History Viewer	
Evidence:	
U1.1	If was on historical basis, would be very good – could go back and say Oh, this SP changed & this one didn't. If unit trip – would want to go back and see what went wrong. So historical would be real good. Particularly a freeze @ certain time points. Very good troubleshooting tool.
U1.2	Use for historical data – could feed it lots and lots of data and watch movie to see where the shape distorts. Then would know where to dive into data.
Explanation: As per above, participants suggested that this type of diagram would be best used for history. Once they'd grasped the concept that the shape formed by the process variables would indicate how close to process they were tracking, they determined that if there was a way for the diagram to "play through" a large amount of data, they could quickly determine where a problem happened by pausing the movie at the point where the shape first starts to distort.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-01-15	**Problem**
Name: Concern it may be too much for operators	
Evidence:	
U1.4	For engineers – it might work. Operators aren't going to get that. Even the stock exchange-like graph, or candlestick chart is too much for some operators with high-school education.
Explanation: As per above, one of the participants is expressing concern with the radar graph, and assuming that it would be considered too complicated for operators. It's worth pointing out that while others did not explicitly express their concern for this, the amount of confusion that this generated, and the extra time spent watching the graph over and over up front, that there may have additional concerns they would express if asked.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

Round 2 Testing

Study Type: Think Aloud Evaluation: Session Two
Date of Study: July 6, 2006
Subject ID: P3.1, P3.2, P3.3

No. UAR-02-01	**Problem**

Name: Meaning of radar graph is difficult to understand.

Evidence:

03:15	After looking at the radar graph for some time, participant 1 states, "I don't have a clue." (P3.1)
04:56	Getting frustrated, participant states, "I don't really know. I don't understand." (P3.1)
05:16	"The lines themselves? I really don't know." This refers to the lines representing set point within the radar graph (P3.1).

Explanation:

The participant spent several minutes reviewing the prototype, becoming increasingly frustrated trying to understand the meaning of the radar graph and how it related to the rest of the interface. After several minutes, the tester had to step in and explain in more detail what the purpose of the graph is and how it related to the rest of the application.

Severity or Benefit:

Rating: 3 – major usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Common – Assuming little training, this problem will appear frequently with operators as they transition to a new operator interface.

Impact: Significant – The participant was not able to interpret the graph and became very frustrated. Being unsuccessful, the tester had to step in to help.

Persistence: Low – Once properly trained, this problem will not persist.

Possible solution and/or trade-offs:

Very clear training may be necessary to ensure all users will understand the purpose behind the radar graph. The trade-off is that we have seen that not all operators receive comprehensive training, so we cannot expect that all users will get the chance to learn how to use the graph quickly.

No. UAR-02-02	**Problem**
Name: Radar graph does not provide enough details about the set point.	
Evidence:	
06:46	"By looking at these, the way they're moving, how do you determine the set point?" (P3.1)
07:13	"Maybe if there was a graph or something on there..." Participant is unable to figure out what the set point numbers are from the radar graph (P3.1).
08:29	Participant reiterates wanting to see a more traditional graph style with labels for set points (P3.1).
15:41	"I like details." (P3.1)
Explanation: The participant expresses a goal of figuring out what the set points represent on the radar graph but is unable to achieve this goal. He expresses displeasure in the lack of labels and makes statements that suggest alternative data presentations.	
Severity or Benefit: Rating: 3 – major usability problem Justification (Frequency, Impact, Persistence): Frequency: Common – As long as the user's goal is to figuring out what is going on with the set points on the radar graph, this problem will be frequent among all users. Impact: Medium – Although the participant was not able to achieve his goal, the purpose of the radar graph is not to interpret the little details. It is designed for an overview. Persistence: High – This problem does not go away with time or training.	
Possible solution and/or trade-offs: A simple solution would be to add labels and a few values for the set points in the radar graph; however, our goal is to keep it simple for quick interpretation.	

No. UAR-02-03	***Problem***
Name: Main viewing area of DV Operate prototype does not meet user expectations.	
Evidence:	
10:54	"Everything we have on the DeltaV is labeled 'temperature'..." (P3.1)
01:41:11	P3.3 stated that he doesn't understand all the moving numbers on the screen and thinks they are too far from the source for him to be sure what they relate to.
01:42:18 – 01:42:43	"All I see is words. Need colors. Green... safe, closed. Red... open, dangerous." (P3.3) "It doesn't stick out there," referring to lack of color for on/off. (P3.3)
01:43:20	"Visuals are better than words sometimes." (P3.3)
Explanation: Along the lines of a heuristic problem, P3.1 points out how our design does not match his idea of a real world product that he has used. P3.3 is very concerned that he is having so much difficulty interpreting our prototype. He doesn't relate the numbers/values to the components easily.	
Severity or Benefit: Rating: 2 – minor usability problem Justification (Frequency, Impact, Persistence): Frequency: Common – Two out of three users tested on the prototype had problems related to this UAR. Impact: Medium – In a real world setting, labels would most likely be included by the engineer designing the system. Persistence: Medium – This problem does not go away on its own..	
Possible solution and/or trade-offs: Although in the real world, there may or may not be labels for everything on screen, given that it is important for operators to be aware of everything in their section of the plant, we recommend adding labels.	

<table>
<tr><td>No. UAR-02-04</td><td colspan="2">Problem</td></tr>
<tr><td colspan="3">Name: Need for radar graph not apparent.</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>23:38</td><td colspan="2">“In a system like this, I would rather see this screen.” Participant refers to the part of the layout that does not include the radar graph (P3.1).</td></tr>
<tr><td>65:30</td><td colspan="2">“I wasn’t watching the graph. I was watching all this.” Participant points to the remainder of the operate screen (P3.2).</td></tr>
<tr><td>72:25</td><td colspan="2">“If everything is on one page, I really don’t see that (radar graph) as being significant, but if some of this was on another page then that would be great.” (P3.2)</td></tr>
<tr><td>01:46:12</td><td colspan="2">After staring at the radar graph for more than three minutes, P3.3 noted, “That’s probably good for engineers but as an operator, an operator isn’t gonna wanna see that.”</td></tr>
<tr><td colspan="3">Explanation:

P3.1 did not want to use the radar graph to make plant diagnoses. He preferred the screen he was accustomed to because he felt it had more of the detail he needed to understand what was going on.

With P3.2, he is used to reviewing screen data in the traditional way of looking at various components, colors, and values, and therefore did not make use of the radar graph.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: N/A

Justification (Frequency, Impact, Persistence):

It is hard to justify this as a usability problem at this time. More data and testing might show whether the radar graph would be used in a real setting, but at this time, participants feel it is not something they were interested in.</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

P3.2’s suggestion of having the radar graph be used to analyze components relating to ones on screen might be something to look into for the future.</td></tr>
</table>

<table>
<tr><td>No. UAR-02-05</td><td>Good Aspect</td></tr>
<tr><td colspan="2">Name: Trending with alarm tracking meets user need.</td></tr>
<tr><td colspan="2">Evidence:</td></tr>
<tr><td>26:01</td><td>Participant likes trend/alarm tracking because things are easily forgotten (P3.1).</td></tr>
<tr><td>31:41</td><td>Participant talks about how this is good because he comes in to work and wants to know what happened on the previous shift (P3.1).</td></tr>
<tr><td>32:15</td><td>“I like the alarm list.” (P3.1)</td></tr>
<tr><td>32:22</td><td>Participant said he would use the trend events to look back at the previous shift to see if some problems he was currently having were also a problem earlier in the day (P3.1).</td></tr>
<tr><td>79:19</td><td>“I like that.” Participant refers to mouse over messages on trend lines (P3.2).</td></tr>
<tr><td>01:54:22</td><td>“I like the message board.” (P3.3)</td></tr>
<tr><td colspan="2">Explanation:

P3.1 stated examples of how the alarm tracking and trending would be useful for him in his role as operator. He clearly liked having this capability. P3.2 concurred with P3.1 that being able to refer to messages in trends/history would be beneficial to his job.</td></tr>
<tr><td colspan="2">Severity or Benefit:

Benefit:

This is valuable feedback for what seems to meet user need. We can use this information to remind ourselves of what should be kept from previous iterations as we work on new versions.</td></tr>
<tr><td colspan="2">Possible solution and/or trade-offs:

N/A</td></tr>
</table>

No. UAR-02-06	**Problem**

Name: Trend graph should have more details on the increments.

Evidence:

29:21	Participant is looking for more detail with the trend graph. Says he would like to have numbers on the side representing increments. (P3.1)
01:54:46	Participant notes that there is nothing on the side of the graph with more details on the trend. (P3.3)

Explanation:

Two participants were not able to determine levels based on the data we provided in our prototype. Although times are there, levels/temperatures were not listed. Both felt they could not evaluate the trends without this information.

Severity or Benefit:

Rating: 3 – major usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Common – All users will encounter this problem when they try to evaluate a trend using our prototype. Two of out three verbalized their concern when testing the prototype.

Impact: Medium/High – Trends in this design are not required to run the plant. Therefore, the impact is not significant. However, the product will probably go less used unless the problem is resolved, therefore, the rating is not low or minimal.

Persistence: High – Participants will either look for work-a rounds or not use the product. Unless the problem is resolved, the problem will persist.

Possible solution and/or trade-offs:

We should consider adding increments to the trend graph. We can look at what is available in DV History Viewer and Ovation products as examples.

No. UAR-02-07	**Problem**

Name: Labels differentiating each trend group are not clearly marked to distinguish each one.

Evidence:

34:20	Participant did not notice there are three trend groups until he had spent several minutes with the prototype and a tester then pointed it out (P3.1).
34:33	"Looks the same." Participant can't immediately distinguish between groups of trends (P3.1).

Explanation:

Unless we have more clear indication that there are trend groups, and have them labeled appropriately for their content, we will continue to have to inform participants about this capability during the evaluation process. This also means that unless well trained, this option will likely go unused.

Severity or Benefit:

Rating: 2 – minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Medium – The problem will probably not impact all users, mainly those less curious about the software, who just stick to their role and not explore much through the system.

Impact: Medium – If a user is not aware of the additional views, he won't get a chance to full experience the product. However, this would not make his job impossible or necessarily dangerous.

Persistence: Low – Once aware of the trend views, the problem will not persist.

Possible solution and/or trade-offs:

We should clearly label the trend views and be sure to provide some indication in our report that training may be required, even minimally, to ensure best use of the system.

No. UAR-02-08	**Problem**
Name: It is difficult to match trend line messages with the list items.	
Evidence:	
34:24	Participant notes that it is confusing to pinpoint which alarm/message is which on the trend line when comparing to what he reads in the list (P3.1).
35:33	Participant requests more specific labels with the trend line messages (P3.1).
Explanation: When reviewing messages and alarms, it was difficult for the participant to jump back and forth from the list to the trend line. He had a hard time recognizing that alarms and messages were about what topic.	
Severity or Benefit: Rating: 2 – minor usability problem Justification (Frequency, Impact, Persistence): Frequency: Medium – Probably not a problem with all users, but could be concerning for older users with less accurate vision. Impact: Medium – For users who have poor vision, this would be a major annoyance, but not all users will be impacted. Persistence: High – This problem does not go away on its own.	
Possible solution and/or trade-offs: We should try to be more clear with how trend line messages are identified after reading or clicking on the list. If there was a clear message title within the pop up, that might help in linking back to the list.	

No. UAR-02-09	**Problem**
Name: Alarm/Message list is considered redundant and unnecessary.	
Evidence:	
37:28	"I know there are messages so they really don't need to be on the trend." (P3.1)
38:28	"Do you really need this and this at the same time." Participant points to the trend line messages and the list of messages (P3.1).
80:21	P3.2 found the list of alarms and messages to be unnecessarily redundant. He commented, "You just need a key explaining what each dot is."
Explanation: Participants felt that it was unnecessary to display the message and alarm information in two places on the trend-viewing screen. They felt that having the messages within the trend lines was enough. (P3.1, P3.2)	
Severity or Benefit: Rating: 1 – annoyance-level usability issue Justification (Frequency, Impact, Persistence): Frequency: Common – This will affect all users of the prototype. Impact: Low – Although redundant, this is not a problem, just an annoyance of low-level priority. Persistence: High – This isn't a problem that will go away. Most users will not be affected by it negatively.	
Possible solution and/or trade-offs: We could consider removing the list of messages but would need more user data to support making such a change on an annoyance level concern.	

No. UAR-02-10	**Problem**

Name: Tank history graphic values are too small to read by a person over 40.

Evidence:

43:47	"It's hard to see that." Participant has difficulty reading the values by the history graphics on the screen (P3.1).

Explanation:

The demographic of process control operators is largely over the age of 40, with many over 50. It will be important to take into consideration any problems related to eyesight or hearing as those senses decline with age.

Severity or Benefit:

Rating: 2 – minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Common – Many operators are over 40; therefore, many are likely to encounter this problem.

Impact: Medium – Depending on how the operator interacts with the system, it is likely that some may be impacted more strongly than others. If an operator cannot read what is on the screen, it will take him more time to diagnose a problem. He will have to find other means to resolve the issue.

Persistence: High – This problem does not go away on its own. Some operators will find a workaround but this does not resolve the issue.

Possible solution and/or trade-offs:

We should consider increasing the font size of data values on screen, especially within widgets (tanks, pumps, etc.). However, the more we increase font size, the less space we will have to work with and space is already at a premium.

No. UAR-02-11	**Good Aspect**
Name: Being able to control history graphics is pleasing.	
Evidence:	
51:25	When comparing the "real time" version of the history graphic screen with the one participant 1 was able to control, he commented that although he couldn't explain why, he liked the one he can control better (P3.1).
87:20	P3.2 likes having history with current data in the components on screen.
88:40	P3.2 likes the idea of being able to look back in time.
Explanation: From this, we can determine that at least two instances, users prefer having control over viewing history within the widgets on screen, liking this better than having it run real time beyond their control.	
Severity or Benefit: It is nice to have positive qualitative feedback to help the design team recognize when an idea should continue through to the next iteration.	
Possible solution and/or trade-offs: N/A	

No. UAR-02-12	**Problem**
Name: History in objects does not provide enough visualization for evaluation.	
Evidence:	
53:43	"I'd rather see this on a graph." Participant points to the history in the components and says he would see more of a fluctuation in a traditional graph (P3.1).
93:25 – 95:35	P3.2 felt that he would need to see run hours, and when pumps started on/off in history to make a full evaluation of system.
02:01:44	P3.3 spent several minutes evaluating the history, becoming frustrated that he could not make sense of it.
02:05:23 – 02:07:12	P3.3 would like more flexibility with the history increments and possibly a date area as well.
02:10:18	P3.3 wants more freedom to select components to view history, to "put the history clock on it."
Explanation: Although the participant (P3.1) understood the meaning of the history representation within the components on screen, he felt he wouldn't get enough intricate fluctuations necessary for accurate evaluation of the process.	
Severity or Benefit: Rating: 3 – major usability problem Justification (Frequency, Impact, Persistence): Frequency: Common – All tested participants considered this a problem. Impact: Medium – In this case, the operators were willing to review the history in each component, but felt they would look elsewhere for details. Persistence: High – This problem does not go away on its own.	
Possible solution and/or trade-offs: At this point, the problem may be more related to a lack of understanding by operators of our new design.	

No. UAR-02-13	**Good Aspect**
Name: Tick marks on radar graph representing set point are clearly understood.	
Evidence:	
67:30 – 67:39	P3.2 recognizes blue tick marks being the set point and understands that the area shows where the process variable is in relation to the set point.
Explanation: A participant was able to interpret the radar graph without instruction from the prototype tester.	
Severity or Benefit: Benefit: This information may help identify whether there is a difference in how younger, less experienced operators are able to use the new prototype, compared with older DeltaV users who have many years with a particular system.	
Possible solution and/or trade-offs: N/A	

No. UAR-02-14	**Problem**
Name: Sparklines concept considered too vague.	
Evidence:	
02:13:08	The dots and dashes are unlinked by P3.3. "It's too vague."
Explanation: P3.1 and P3.2 did not notice sparklines without being prompted. P3.3 wanted to know what the dashes were about and found them to be too vague to provide any real data.	
Severity or Benefit: Rating: N/A Because we didn't concentrate on testing the sparklines concept, more testing will be necessary before an evaluation of the severity can be made.	
Possible solution and/or trade-offs: N/A	

Round 3 Testing

Study Type: Think Aloud Evaluation: Session Three
Date of Study: July 13, 2006
Subject ID: P3.1, P3.2, P3.3

No. UAR-03-01	**Problem**

Name: Play/Pause Confusion

Evidence:

ES3.4	Play/Pause control seems to indicate the desired not the current state. This seems more DVD esque.
ES3.1	When the pause sign is showing, it's paused.
ES3.2	Change look of button to indicate frozen/running state. So if it's showing the arrow, it's running.

Explanation:

Two of the three participants (plus our extra observer) misidentified the play/pause state of the graph. While all participants mentioned that they really liked the ability to "freeze" the trend at a moment in time, their not being able to detect the difference between a playing and paused state is a cause for concern.

Severity or Benefit:

Rating: 3

Justification (Frequency, Impact, Persistence):

Frequency: For people who are misinterpreting the symbol on the button, this problem occurs every time they look at the trends, so the frequency is high. It is tough to know with such a small group of users whether we could expect to see such a high-rate of misinterpretation with a larger population.

Impact: The impact here is high. If someone mistakenly believes a graph to be "playing" when it is in a paused state, then they run the risk of missing something that they would have seen had the graph actually been playing.

Persistence: It's hard to tell within a single test session. Even though participants are misinterpreting this control, it is our hope that over time, they'd catch on to the fact that the graph should be changing, and realize that they'd been reversing the state.

Possible solution and/or trade-offs:

N/A

No. UAR-03-02	**Problem**
Name: Colors/Contrast is bad	
Evidence:	
ES3.1	More contrast needed. Blue is bad.
ES3.2	Greens/blues don't stand out enough Maybe change background or colors?
ES3.3	Blue on black is tough to see I want to see right away I'm controlling well, then numbers can be secondary way of showing.
ES3.4	Blue on black hard to see.

Explanation:

Participants made it clear that the thin blue and green lines on a solid black background simply didn't stand out enough, and that some change was necessary. As an observation, several participants were leaning in in order to get a good view of the trends.

Severity or Benefit:

Rating: 3

Justification (Frequency, Impact, Persistence):

Frequency: This was consistently a problem for all participants, so this has a high frequency rating.

Impact: This has a high impact – if the graphs are difficult to read, they're not going to be used, and if they're not getting used, they're not able to provide any value.

Persistence: This problem persists every time a user uses or looks at this particular control, so it has a high rate of persistence.

Possible solution and/or trade-offs:

N/A

No. UAR-03-03	**Problem**
Name: Timeframe is missing/Add ability to choose timeframe	
Evidence:	
ES3.2	I want to know time frame of the window. Is it 5 minutes? 10 minutes? I would like to see some indication of the time base.
ES3.3	I'd like to see a timespan – I should be able to choose. So can account for slow & fast processes. Tank vs. turbines
Explanation: Both of these participants are looking for some context supporting the graph, so that they're aware what kind of time range is covered within the window itself. Additionally, one of the participants suggested having the ability to change the time interval spanned by the window, so that different processes could be taken into account.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-03-04	**Problem**
Name: Add ability to zoom.	
Evidence:	
ES3.3	I want to be able to explode this, make the window bigger
Explanation: Pretty simply, the user wants to have the capability to bring up a larger or zoomed in version of the graph.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-03-05	**Problem**
Name: General level message is unclear	
Evidence:	
ES3.1	Not sure why blue circle is up top. Denotes event outside of cycle? Rather than mark each line, could mark time.

Explanation:

For one participant, the elongated blue dot at the top of the screen was confusing, though they did eventually pick up on the fact that it was a general level message.

Severity or Benefit:

Rating: 2

Justification (Frequency, Impact, Persistence):

Frequency: This only seemed to pose a problem for one of the participants, as the other two seemed to figure it out fairly quickly, or didn't vocalize anything on the general level message until they had already worked out what it meant. So it seems to have a low frequency.

Impact: This has a moderate impact – it's important for operators to know what a message in that area indicates, and it's important for them to pay attention to that area to check for messages from previous shifts.

Persistence: This does seem to have a low persistence, as even the participant that this was bothering did eventually hit upon the intended meaning.

Possible solution and/or trade-offs:

N/A

<table>
<tr><td colspan="2">No. UAR-03-06</td><td>Problem</td></tr>
<tr><td colspan="3">Name: Selection should be mirrored</td></tr>
<tr><td colspan="3">Evidence:</td></tr>
<tr><td>ES3.3</td><td colspan="2">Why doesn’t the link go two ways? If roll-over, should highlight message.</td></tr>
<tr><td colspan="3">Explanation:

This participant suggested that the highlighting work in both directions. Currently, when you click to select something from the list on the left, the corresponding point is highlighted on the graph. The feature request is for the reverse to happen as well, so that when people click on specific points on the graph, or have brought up the full message via a roll-over, the corresponding message in the list on the left is highlighted.</td></tr>
<tr><td colspan="3">Severity or Benefit:

Rating: N/A</td></tr>
<tr><td colspan="3">Possible solution and/or trade-offs:

N/A</td></tr>
</table>

No. UAR-03-07	**Problem**
Name: Add additional labels	
Evidence: All of the participants did try and treat this like an actual problem in that they wanted to know more information from the graph, such as the timescale used and what each line represented.	
Explanation: It's not clear how much of the information participants were looking for would be things they wanted for this particular prototype problem vs. things they would want long term, as it is possible to find out some things (such as which component a line represents) by looking at the message list. Still, it doesn't seem like they're asking for things that are out of scope, or things that you wouldn't want to see in a regular graph – showing a timescale & legend make sense.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-03-08	**Problem**
Name: Include a Link to Relevant Documentation	
Evidence:	
ES3.3	If live, want way to link what you're supposed to do. Link to operator procedures fro telling how to do something.
Explanation: One participant was very interested in the potential for embedding more cause/effect type messages, and thinking about using this type of display as a live instead of a historical view thought there would be benefit to having the message and alarm notes link back to some sort of dynamic help system that could inform operators of what steps	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-03-09	**Problem**
Name: Include a splitter bar	
Evidence:	
ES3.3	I want a splitter so I can see a bigger picture.
Explanation: One participant suggested using a vertical splitter bar between the message list on the left and the graph area on the right, so that the user could devote more space to the graph when they were focusing on that area, and also devote more area to the message space – their thought was that if the message space was given the screen real-estate to fully expand, the full messages would be visible, so someone could read through the list in that way.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

No. UAR-03-10	**Problem**
Name: Show values of points on graph	
Evidence:	
ES3.1	Should give a value when clicked. That should be true for all points, not just the called-out ones. Drag and hold & slide to see a table of values as move across graph. Can go forward and backward.
ES3.2	Same way of showing value at any point by clicking on a line.
ES3.3	Want to see value on click, or maybe roll-over on specific parts.

Explanation:

All three participants felt the graph was lacking in that it did not show values for any of the points. They suggested adding the value to the pop-up for a message/alarm mouseover, but also suggested that they should be able to see the value for any point on any line in the graph, even if it didn't have an associated message or alarm. They suggested doing this on-demand via a single mouse click somewhere on the line as well as doing something more continual where a tool tip would dynamically track the value of the points on the line as a user moved their mouse around the graph.

Severity or Benefit:

Rating: N/A

Possible solution and/or trade-offs:

N/A

No. UAR-03-11	**Problem**
Name: Use double or right-click to view full message in list	
Evidence:	
ES3.1	How do you see full message? (tried click/right click)
ES3.2	Would expect full message to show up on left-click in message area.
ES3.3	Double-click to bring up message, maybe right-click?
Explanation: It should be mentioned that there was a problem with the prototype. The prototype showed three groupings of graphs, 2 of which had the intended behavior where if a message on the left was selected, the corresponding point (and tool tip) would pop pup on the graph in the right. Unfortunately, one of the groups did not correctly display the pop-ups, and it happened to be the first, or default group – so it's tough to know if we should attribute the request to a faulty prototype or if this is something our users truly do want. In any case, all three participants expressed that they should be able to somehow "Open" or otherwise see the full message from the message list on the left. One participant suggested the context menu, one thought a left-click would be sufficient, and one suggested the more standard OS cue to "open" something- a double-click.	
Severity or Benefit: Rating: N/A	
Possible solution and/or trade-offs: N/A	

Round 4 Testing

Study Type: Think Aloud Evaluation: Session Four
Date of Study: July 20, 2006
Subject ID: P3.1, P3.2, P3.3

No. UAR-06-01	**Problem**

Name: Pressing “Enter” to enter SP value

Evidence:

P6.1	Typed in value for SP and pressed the “Enter” key on the keyboard, but the value was not entered

Explanation:

When the participant changes a SP value with his current system, a dialog pops up, the participant enters the desired value, and then presses “Enter” on the keyboard. The participant uses this same method to the interface, but for this interface, the only way to enter in an SP value is to type it and click outside of the text box. As a result, the participant becomes confused as to how to enter an SP value.

Severity or Benefit:

Rating: 2 – Minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Operators enter SP values all the time, so this problem will be very frequent.

Impact: This will cause initial confusion, therefore slow down the time it takes to enter SP values. Impact is mild.

Persistence: After the operator learns that he must click outside of the text box to enter the value, it will no longer be a problem. Little learning is necessary to take care of this problem.

Possible solution and/or trade-offs:

Allow the participant to press “Enter” on the keyboard to enter an SP value.

No. UAR-06-02	**Problem**
Name: Cannot go back in History	
Evidence:	
P6.1, 6.2	Cannot figure out how to go back in time to look at history of the trends using the inline graph
Explanation: The participant is given the task of going back in time to find information on the trend. The participant is unable to figure out how to do this. The participant expects the ability to enter time and date to go back in time.	
Severity or Benefit: Rating: 2 – Minor usability problem Justification (Frequency, Impact, Persistence): Frequency: How often operators do look back in time on trends is an area that is still unknown and is being tested, so frequency right now is unknown. Impact: Operators cannot go back in history, so such a need will not be fulfilled, creating a large impact. Persistence: After the operator learns how to go back in time to look at history, this problem will not longer be persistent.	
Possible solution and/or trade-offs: Add ability to enter time and date. Add rewind and fast forward buttons. Add a scroll bar to move back and forth in time.	

No. UAR-06-03	**Problem**

Name: Automatic closure of enlarged integrated graph

Evidence:

P6.1, 6.2	Enlarged view of the integrated graph repeatedly goes away, requiring participant to click on enlarge icon

Explanation:

To enlarge the view of the integrated graph, the participant clicks on the enlarge icon. When the focus is outside of the graph, the enlarged view goes away, requiring the user to click on the enlarge icon to reopen it.

Severity or Benefit:

Rating: 3 – Major usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Every time the cursor moves away from the graph, the enlargement goes away. The cursor moving away is a rather frequent activity, therefore this problem is very frequent.

Impact: Create great difficulty for operators to keep enlarged view up.

Persistence: This will continue to be a problem, there is no learning that can be done to stop it.

Possible solution and/or trade-offs:

Have the enlarged view remain open until the operator clicks on a minimize button.

No. UAR-06-04	**Good Aspect**
Name: Closure of enlarged integrated graph starts graph	
Evidence:	
P6.1, 6.2	Participant enjoys the fact that when the enlarged integrated graph is closed, the graph starts running even if it was paused. This is good in case he forgot to unpause the graph before closing and also because it is hard to tell if the graph is running or not when minimized.
Explanation: If the enlarged integrated graph is paused and then the participant goes outside of the graph and it minimizes, the graph will start to run again.	
Severity or Benefit: Good error prevention.	
Possible solution and/or trade-offs: N/A	

No. UAR-06-05	**Problem**

Name: Integrated graph is too small

Evidence:

P6.1	Participant finds the graph to be too small to show numbers or any useful information.

Explanation:

The integrated graph displays just a line that moves accordingly with the PV. There are no numbers attached to the graph.

Severity or Benefit:

Rating: 1 – Cosmetic

Justification (Frequency, Impact, Persistence):

Frequency: How often operators would look at a graph on a component is an area that is still unknown and is being tested, so frequency right now is unknown.

Impact: The impact is also unknown, since it is not known how necessary such a graph is.

Persistence: This will continue to be a problem, there is no learning that can be done to stop it.

Possible solution and/or trade-offs:

Add values, such as PV and time to graphs.

Increase the size of the graphs.

No. UAR-06-06	**Problem**
Name: Integrated graph is difficult to interpret speed	
Evidence:	
P6.1	Participant finds it more difficult to figure out speed from a graph than from just observing how fast the PV is changing.
Explanation: To figure out speed from a graph, the participant needs to line up time marks with graph values, whereas the participant can figure out speed by watching how fast the PV numbers are changing. This latter method takes less effort	
Severity or Benefit: Rating: 1 – Cosmetic Justification (Frequency, Impact, Persistence): Frequency: How often operators would look at a graph for speed on a component is an area that is still unknown and is being tested, so frequency right now is unknown. Impact: The impact is also unknown, since it is not known how necessary such a graph is. Persistence: This will take a bit of learning to be able to just look at a graph and know the speed.	
Possible solution and/or trade-offs: Show actual speed by showing rate of change.	

No. UAR-06-07	**Problem**
Name: Do not look at integrated graph	
Evidence:	
P6.1	Participant does not even look at integrated graph to accomplish task

Explanation:

To figure out speed from a graph, the participant needs to line up time marks with graph values, whereas the participant can figure out speed by watching how fast the PV numbers are changing. This latter method takes less effort

Severity or Benefit:

Rating: 1 – Cosmetic

Justification (Frequency, Impact, Persistence):

Frequency: How often operators would look at a graph for speed on a component is an area that is still unknown and is being tested, so frequency right now is unknown.

Impact: The impact is also unknown, since it is not known how necessary such a graph is.

Persistence: This will take a bit of learning to be able to just look at a graph and know the speed.

Possible solution and/or trade-offs:

Show actual speed by showing rate of change.

No. UAR-06-08	**Problem**
Name: Minimized message symbol and message icon too similar	
Evidence:	
P6.1	Participant finds that the symbol for when a message is minimized looks just look the button that creates a new message. This makes it difficult to know that there is a minimized message and also how to open the minimized message.
Explanation: The minimized message symbol is actually the same as the message button. It is also right next to the message button. The only notable difference is that there is a slight change in background between these two objects. If an operator does not realize there is a minimized message, he may never think to click on the icon and open the message and therefore never read it.	
Severity or Benefit: Rating: 4 - Catastrophic Justification (Frequency, Impact, Persistence): Frequency: Operators leave messages for others very frequently, therefore this problem will be very frequent Impact: The impact is very great, since most messages are very important for the other operators to read Persistence: This is not a persistent problem, for the operator will learn after the first time what the minimized symbol is and that it is different than the message button.	
Possible solution and/or trade-offs: Use a different color for the minimized message.	

No. UAR-06-09	**Problem**
Name: No visibility of new message	
Evidence:	
P6.1	Participant does not know what messages are new and which have already been read when multiple messages are open
Explanation: Currently, all messages appear the same. The problem the participant faces is wanting to know what messages have been read by other operators and which ones are new or newer.	
Severity or Benefit: Rating: 2 – Minor usability problem Justification (Frequency, Impact, Persistence): Frequency: Happens as often as messages are read Impact: It is not that important to know what messages are new, therefore the impact of this problem is minor Persistence: This problem will always exist, therefore it is very persistent	
Possible solution and/or trade-offs: Have unread messages appear in a different color. Have separate areas for read and unread messages. Put a symbol on a message that indicates if it has been read or not.	

No. UAR-06-10	**Problem**
Name: No display of number of hidden messages	
Evidence:	
P6.1	Participant minimizes all messages, but from the minimized symbol, the participant is unable to tell how many messages are minimized

Explanation:

The participant creates many messages and then minimizes them all. The minimize symbol displays three small messages on top of each other. This number does not increase as more messages are created and minimized.

Severity or Benefit:

Rating: 2 – Minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Happens as often as messages are minimized and read, which is an unknown amount at this moment

Impact: The operator may not realize there are multiple messages or believe that minimizing his message actually deleted since there is no notification it has been added to the minimized list

Persistence: This will continue to be a problem, there is no learning that can be done to stop it.

Possible solution and/or trade-offs:

Place a number next to the minimized symbol to shows how many messages are minimized.

No. UAR-06-11	**Problem**
Name: Difficult to know can add messages to components	
Evidence:	
P6.1, 6.2	Participant just creates and leaves messages on screen rather than adding them to components
Explanation: The idea is that messages that are relevant to components can be added to these components. Just placing the message over the component will add it and display an attached message symbol. The participants were unable to figure this out and therefore never added any messages to the components	
Severity or Benefit: Rating: 1 – Cosmetic Justification (Frequency, Impact, Persistence): Frequency: Whenever a message can be associated with a component is created – frequency of this is unknown at this time Impact: The impact is also unknown, since it is not known how necessary it is to attach messages to components Persistence: After the operator's first time of figuring out, this problem will no longer persist	
Possible solution and/or trade-offs: Do not let the operator type into a message unless a component is clicked on or a region labeled "General Messages" is clicked on.	

No. UAR-06-12	**Good Aspect**
Name: Messages prevent information from being forgotten	
Evidence:	
P6.2	Participant finds it helpful to write messages down and attach to screen so that next shift worker will get this information even if the participant forgets to tell him
Explanation: The participant finds that many times he forgets to tell the next shift worker about something that occurred during his shift. The participant finds that this method of leaving a message will help keep the next shift worker informed of things even if he forgets to tell the next shift worker.	
Severity or Benefit: This has the benefit of aiding communication between workers.	
Possible solution and/or trade-offs: N/A	

No. UAR-06-13	**Problem**
Name: Difficulty in minimizing message on component	
Evidence:	
P6.2	Participant cannot minimize a message after having enlarged it on a component
Explanation: The participant attaches a message to a component, which produces an attached message symbol on the component. The participant then clicks on this symbol which enlarges the message. The participant wants to minimize this message, but is unable to figure out how to do so. He moves the enlarged message over the attached message symbol that is still showing. The actual way of minimizing this message is to click on the attached message symbol.	
Severity or Benefit: Rating: 3 – Major usability problem Justification (Frequency, Impact, Persistence): Frequency: Will happen whenever a message attached to a component is enlarged. How often this happens is still unknown Impact: Not being able to minimize the message will cause it to cover up important information and also clutter the screen Persistence: Once the operator figures out how to minimize the message, it will no longer be a problem, so persistence is low	
Possible solution and/or trade-offs: Have a minimize button on the message.	

No. UAR-06-14	**Problem**

Name: Did not use integrated graph

Evidence:

P6.2	Participant did not use the integrated graphs to accomplish the task

Explanation:

The task involved balancing the levels of two tanks so that they would be equal with each other. Since the integrated graphs were not on the same scale nor were they right next to each other, the integrated graphs were not helpful.

Severity or Benefit:

Rating: 2 – Minor usability problem

Justification (Frequency, Impact, Persistence):

Frequency: Determining current state, e.g. level, is a common task for an operator. However, it is unknown how often a need exists to balance two levels.

Impact: The impact is minimal since the numeric readouts can be used.

Persistence: The operator would probably improve slightly with practice at comparing two graphs, but the problem will largely remain.

Possible solution and/or trade-offs:

Provide the ability to combine multiple integrated graphs so that the trends are plotted on the same axis with a common scale.

Appendix IV

Pictures from contextual inquiry site visits.

These pictures show the types of actual screen layouts that were observed, which helped us to understand what operators currently work and deal with on a day-to-day basis.

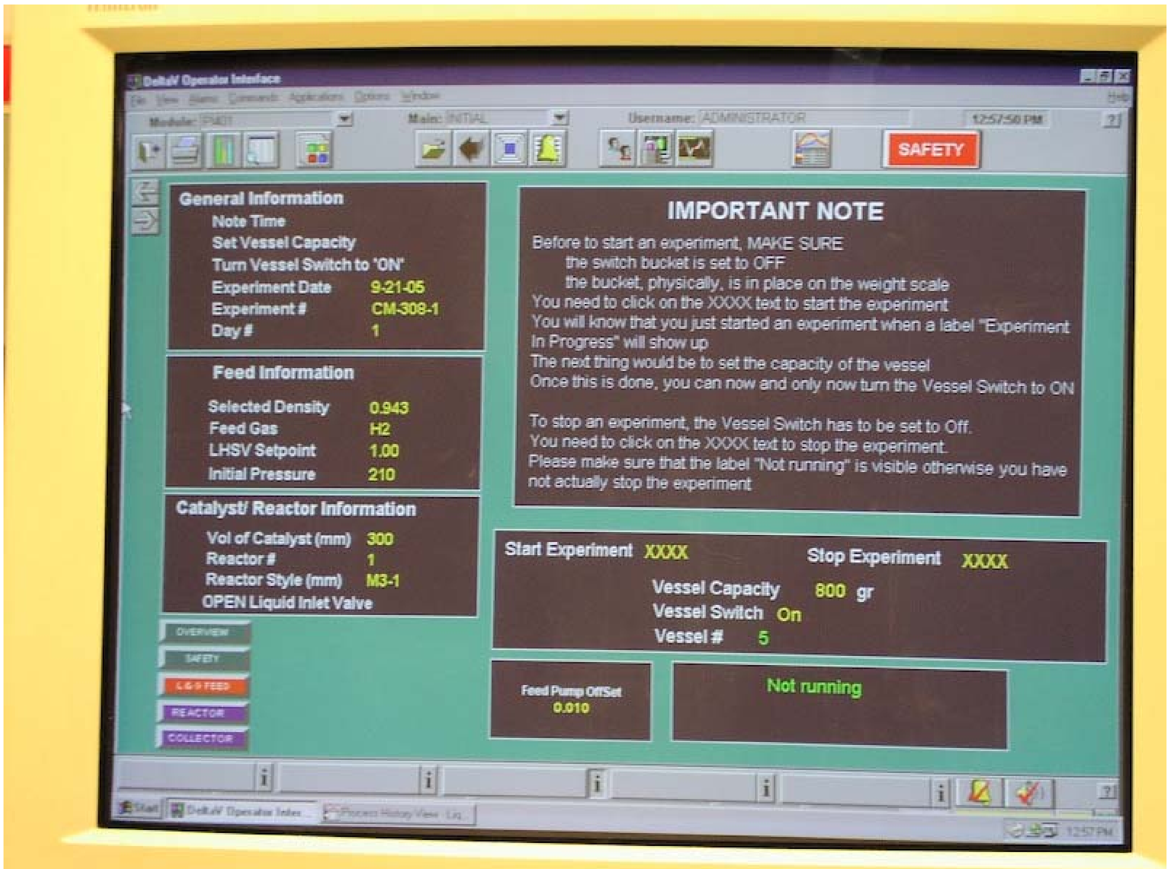


Photo 1. U2 had detailed instructions for starting up the plant as the first screen operators would see. In demonstrating starting the plant to us, he actually failed to follow one of the steps

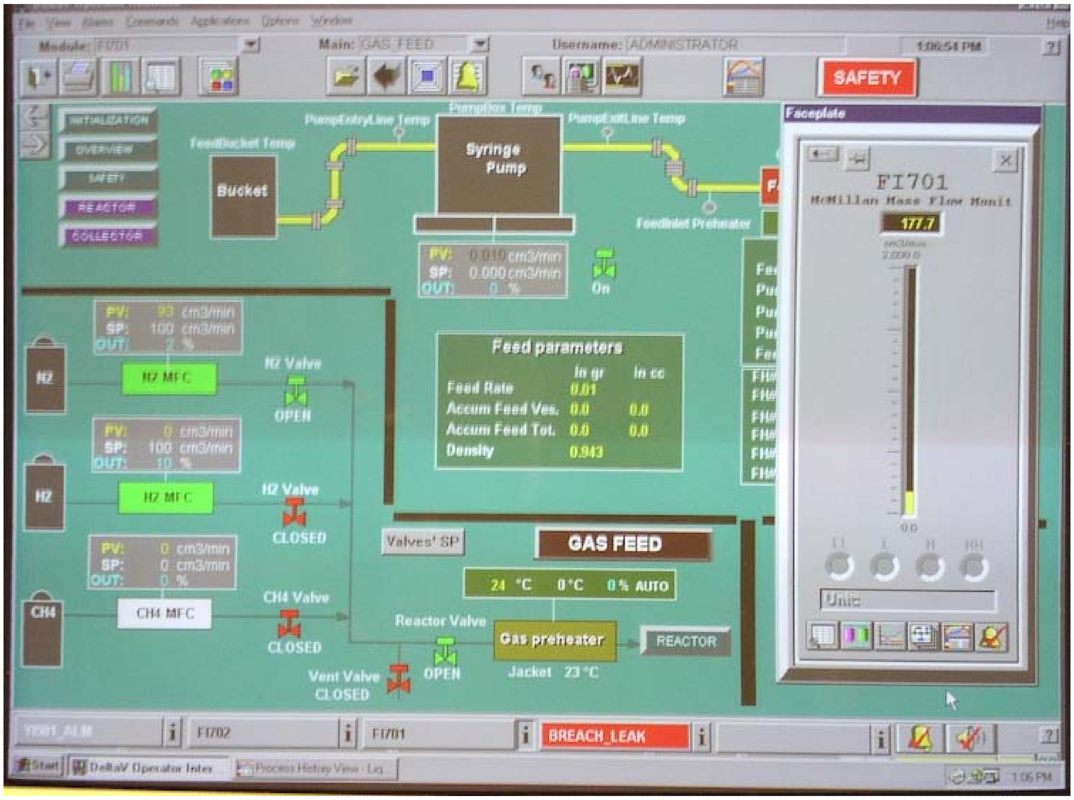


Photo 2. U2's displays were incredibly simple, sometimes sticking with boxes and shapes instead of any pre-made objects. Here one can also see that the Windows taskbar is visible and above the bottom line of DeltaV's Operate Run display so the user can switch to the Process History View.

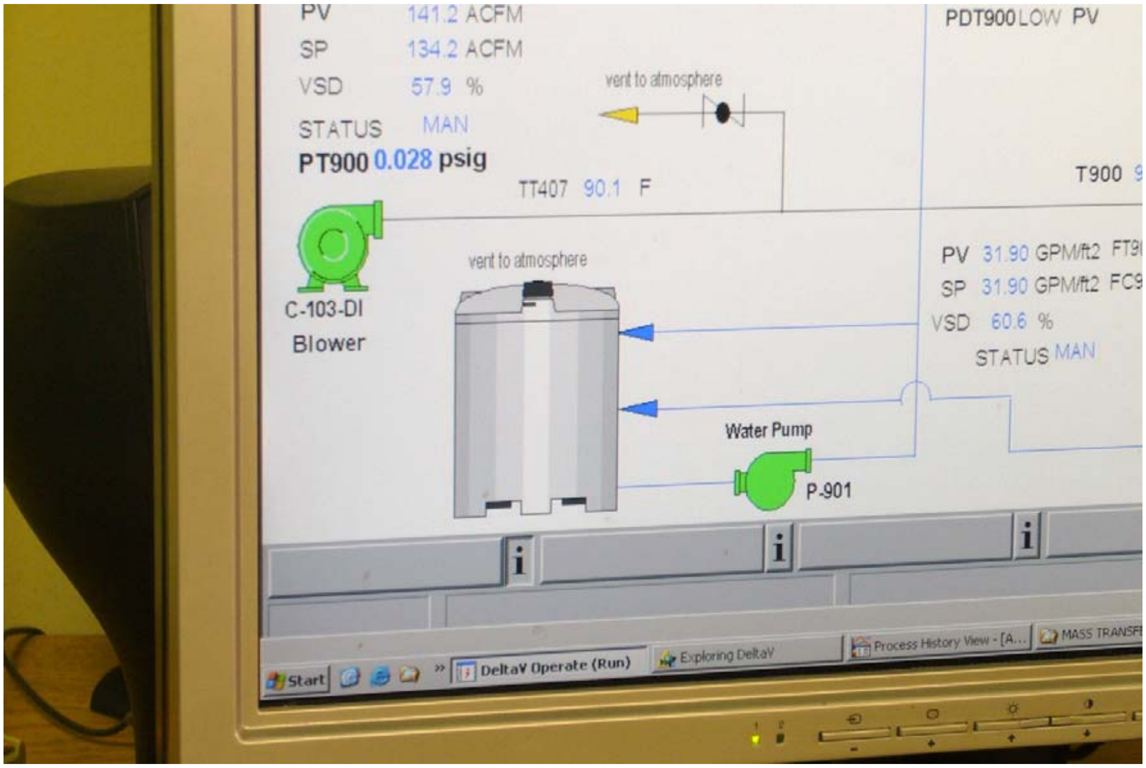


Photo 3. A zoomed in view of U1's display shows limited use of the simple pre-made objects, with colors carefully selected for printing. The Windows taskbar is visible so the user can switch to Process History View.

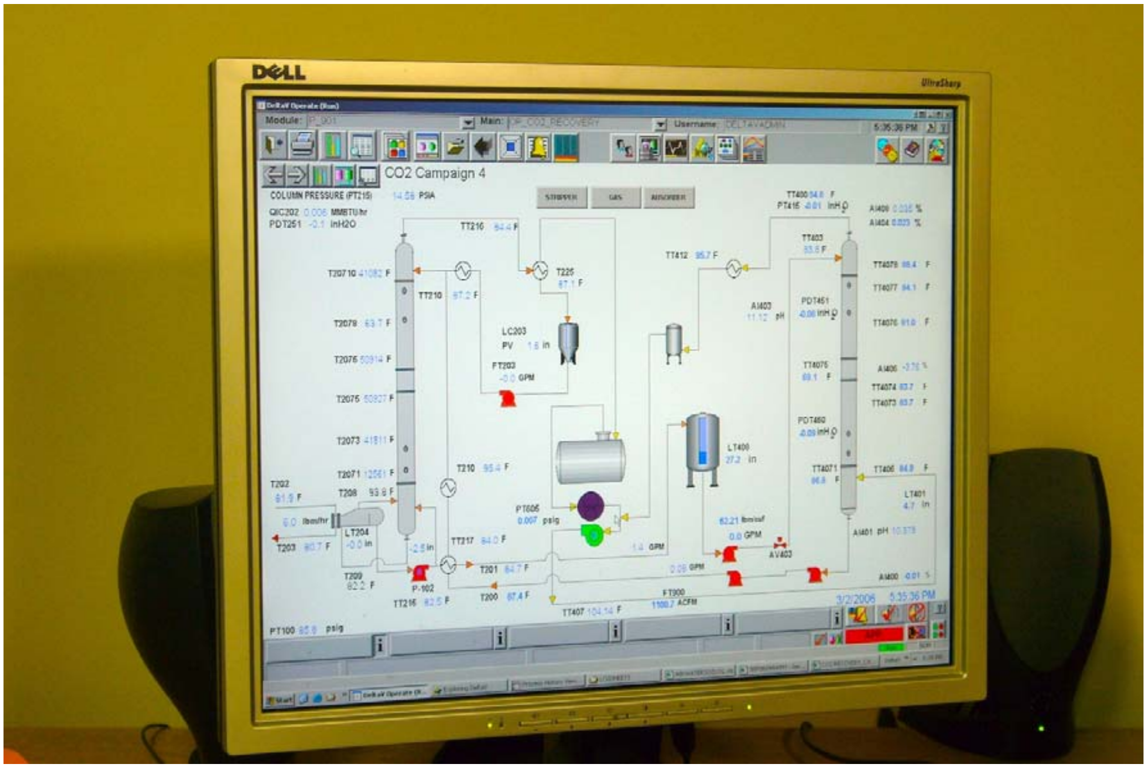


Photo 4. U1's overall view. The tall objects along the side are custom-made out of shapes. The user spent a lot of time attempting to mimic Visio's lines with line hopping.

Photo 5. U2's Process History View. The user was very particular about the arrangement of the windows and spent quite a bit of time arranging them every time he would take over from the previous user.

Photo 6. U2 had two machines set up; one for viewing history and one for controlling.

Photo 7. The notorious missing volume knob. U2 was told by an engineering firm that they should remove the plastic knob so that the volume could not be turned down. He and others at the site still turned down the volume by manipulating the remaining metal knob.

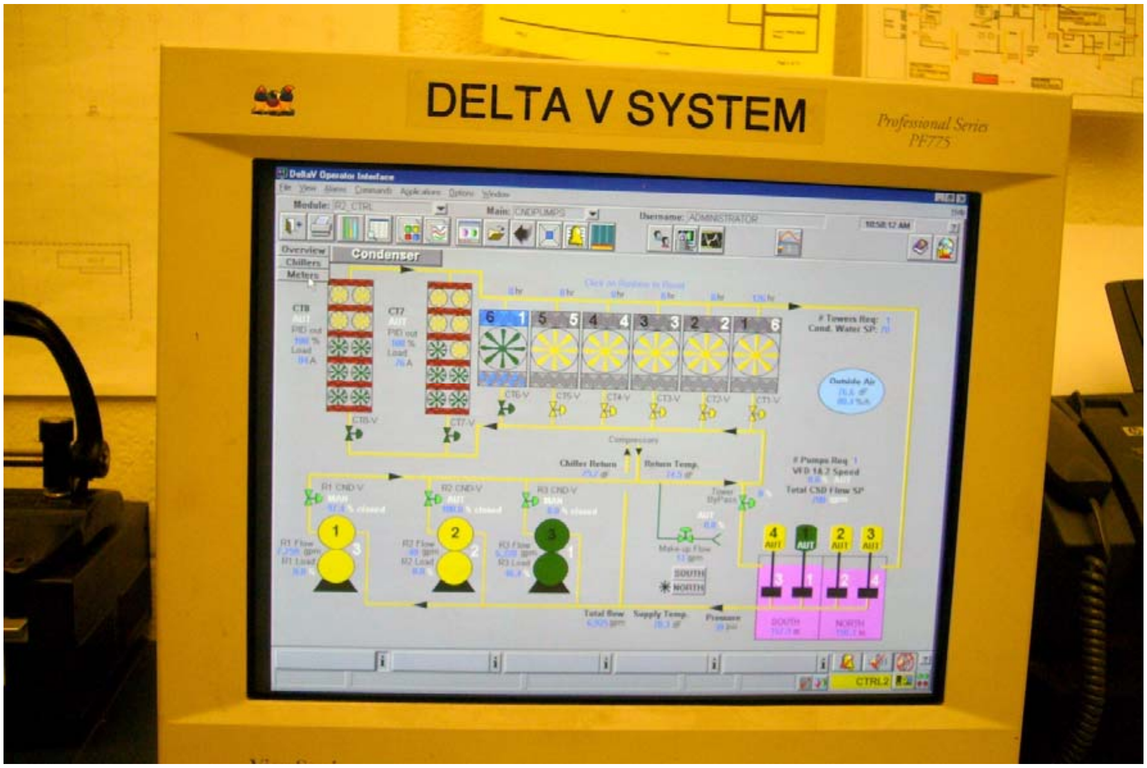


Photo 8. A typical screen from U4. Operators spend all day staring at screens like this.

Appendix V

Non-Implemented Ideas and Thoughts

Operating off of alarm conditions

A comment often made in journals/papers/books is that operators run the process off of the alarm system. Although there was plenty of evidence to support this supposition there was also considerable evidence that expert operators do much more than this.

Background

To increase plant efficiencies the process set point is often adjusted towards its limits - companies are not usually paid for exceeding product quality. Running close to limits can dramatically improve profitability. The run close to its limits the process must be tightly controlled. However, if the process exceeds a critical limit the product may have to be shipped at a lower grade, an environmental constraint could be exceeded, a piece of equipment damaged, etc. As a result operators and engineers tend to design and operate the process with a safety margin.

Changes in the process are often caused by unmeasured disturbances such as variations in feedstock and changing weather conditions. When these process disturbances occur many things may need to be corrected at once. If an operator can anticipate changing process conditions they can maintain tighter control and avoid upset conditions. Operators use a number of indicators to track these unmeasured disturbances.

Expert Operator

We observed expert operators performing a number of functions that suggests that the use of multiple sources of measurements, trends, and in some cases gut feel played an important role in the operation of the plant. For example, the lead operators at GP would take their lab samples (delivered on 4"x4" slip of paper), overlay them, and compare results. They would then go to their historian displays looking for trends. When I asked them what they were doing they proceeded to talk about product quality – their goal was to run the quality indicators as close to specification as possible – exceeding specification resulted in lower costs, missing specifications resulted in shipping lower grade product. There were no alarms, no trends, no managers telling these expert operator what to do – they just understood.

In another case at Flint Hills the operators went to great length describing the importance of not flaring (i.e. minimizing environmental impacts). They also talked about feed stock from different sources, the impact of weather on efficiencies, etc.

The role of the expert operator is not well understood. Some questions that arise:

1- What are the characteristics of an expert operator? Why is the expert so much more effective (GP made the comment that they wish they had several more people just like their lead operator – what makes this person so much more effective?)

2- How should the operator interface software be changed to support the expert?

3- What additional inputs does an expert use?

4- What patterns are experts looking for and what tools can we provide to support these patterns?

Appendix VI

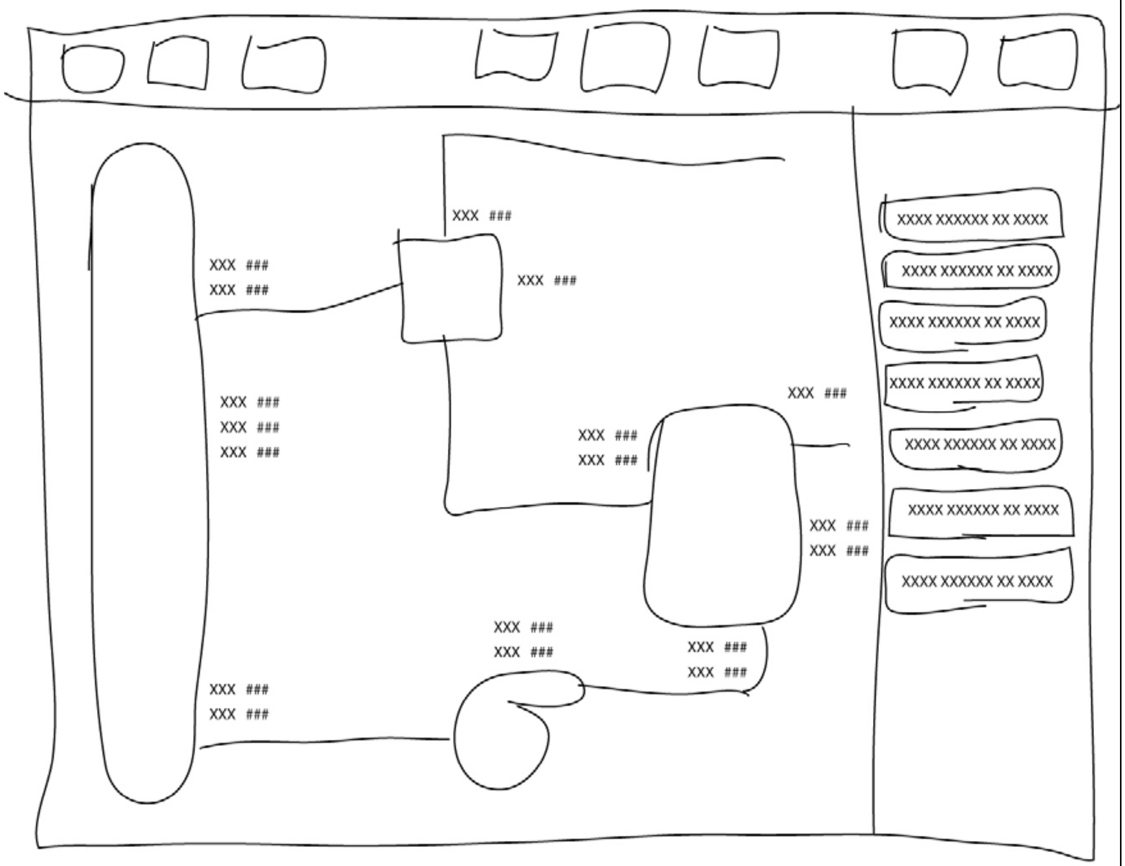
Design Sketchbook

This document includes additional ideas that sourced from the joint effort between Emerson Process Management and the HCI Masters program at CMU, as a part of DeltaV@CMU 2006.

After gathering data from literature and on-site visits to process control sites, the Masters students in this group began an ideation phase and started sketching ideas. We involved our classmates, by using the analogy of a chocolate-chip cookie manufacturing facility and asking them to contribute quick ideas to illustrate concepts such as flow rate, process speed, efficiency, and quality. We also involved our clients, and used web conferencing to share and refine ideas and sketches.

Ultimately, due to the time constraint we had to decide on a design direction, and turned back towards our focus of how to help operators keep better track of processes, make predictions, and investigate past problems. Even with those bounds, we still had to go through another round of cuts in order to better concentrate on prototyping, testing, and iterating on a few select designs within the given timeframe. Our goal in compiling this design sketchbook was to preserve all of these ideas that came from this project, in hopes that it might aid and inspire future work on the DeltaV system.

Design Idea #1

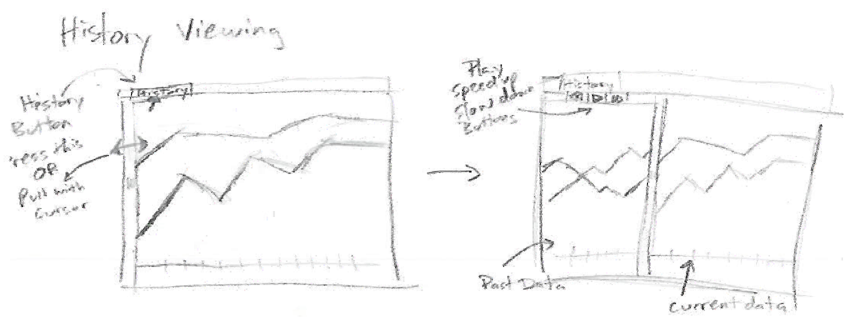


Alarm Task Pane

The alarms have been moved to a Office-style task pane on the right side of the screen. This allows for more alarms or more information for each alarm (e.g. Outlook-style auto preview) to be displayed. The alarm task pane would be resizable. (This would work better if the plant graphic is a vector drawing instead of a bitmap.) There could be intelligent displays for different widths of the task pane, e.g. icon-only for narrow width.

DeltaV@CMU - 5/31/2006

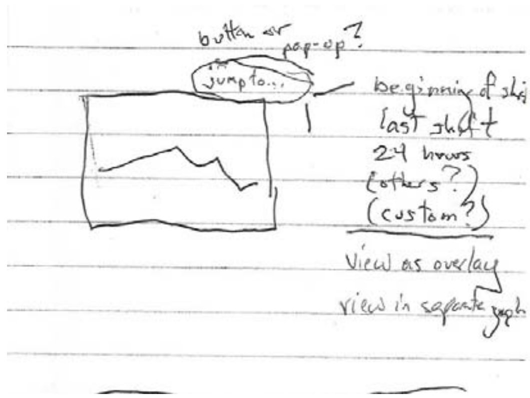
Design Idea #2



History Viewing

The top portion is about viewing history. There is a button labeled “History” that if pressed will pop open history information as seen in the top right picture. One can also pull on the left side of the current data screen to open the history and also to change the amount of space that the history screen takes up.

Design Idea #3



History with Jump Back Points

This is another way of viewing history, by including a menu that provides logical points in time to jump back to. Logical jump points might be the start of your shift, the last shift, the last alarm, etc. Additionally, provide multiple ways of viewing the information - for example, a separate view, or an overlay, or as seen in a different sketch, a split view. For example, if you are comparing one shift to the next, an overlay might be more meaningful - but if you are plotting two very different components, it might be nice to see them on separate graphs.

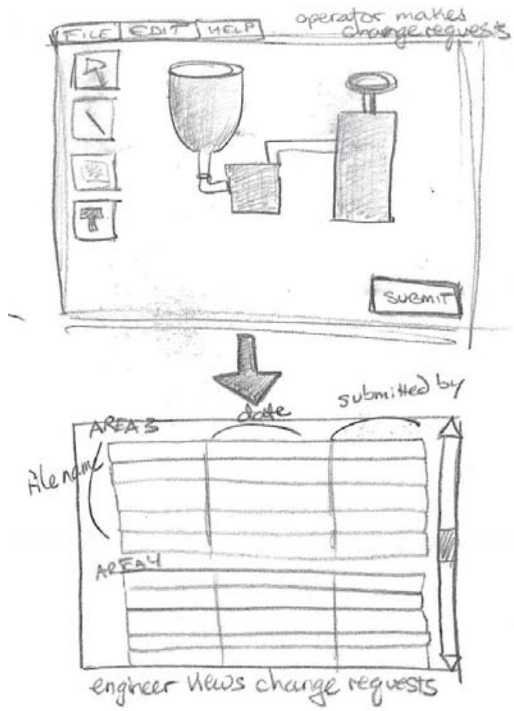
Design Idea #4

Alarm Addressing Options

When a user clicks on an alarm notification, a dialogue pops up that allows the choice of silencing the alarm for 15 minutes, bringing up the faceplate to resolve the problem manually, or automatically fixing the problem by changing the set point to the recommended level. This would require the system to have a bit of a brain, to be able to detect the best adjustment based on the history and current plant status. Being able to silence an annoying alarm for a period of time would appeal to operators who tire of hearing the same alarms sound over and over, frequently just hitting a key to silence them without evaluating the situation. If they didn't have to hear the sound repeatedly, they may be more likely to take a look at the problem before silencing the alarm.

DeltaV@CMU - 5/31/2006

Design Idea #5

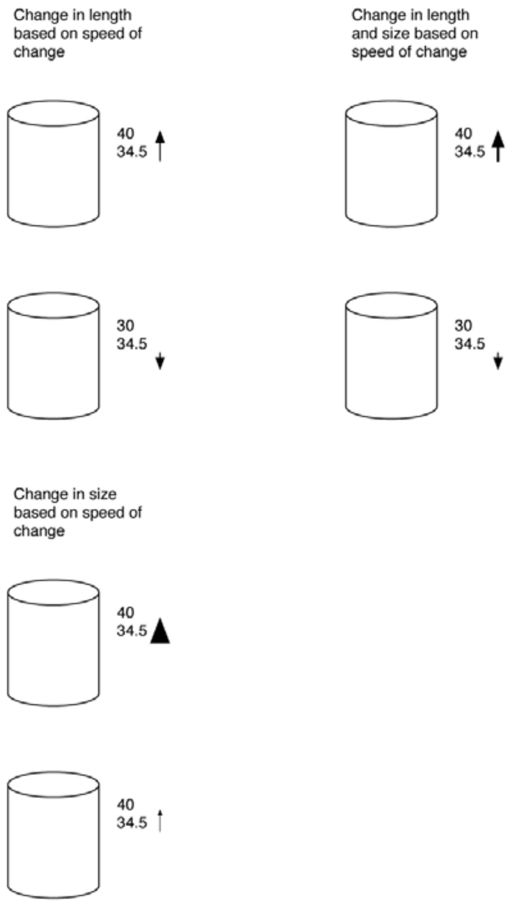


Operator and Engineer Communication

Operators use a basic shapes and line application to recommend layout changes and submit them to an engineer with the click of a button. Prevents extra print-outs and verbal communication that may be forgotten. Engineers have a database of requests to allow quick priority sorting and change tracking.

DeltaV@CMU - 5/31/2006

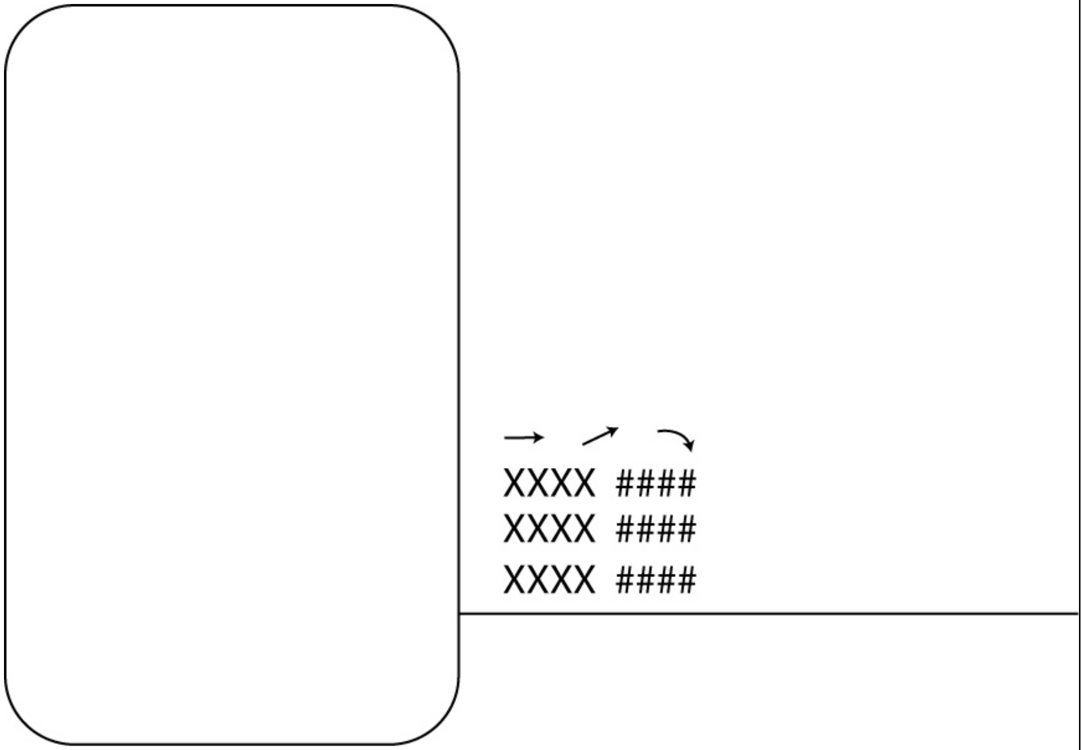
Design Idea #6



Rate of Change Arrows

This sketch explores the various ways one can alter the arrows based upon rate of change: simply line length, line length and thickness, or just thickness.

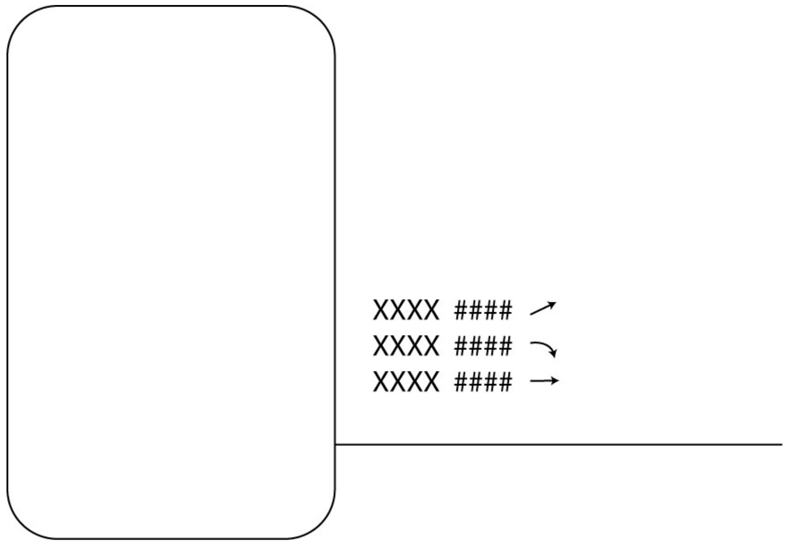
Design Idea #7



Value Slopes – Version 1

The current and recent “instantaneous” slopes are shown for select monitored values. Instead of showing one slope per value, a different use of screen space would be to show several slopes from the recent past for a few values. The engineer should be able to configure how many and for what points in time they are shown.

Design Idea #8

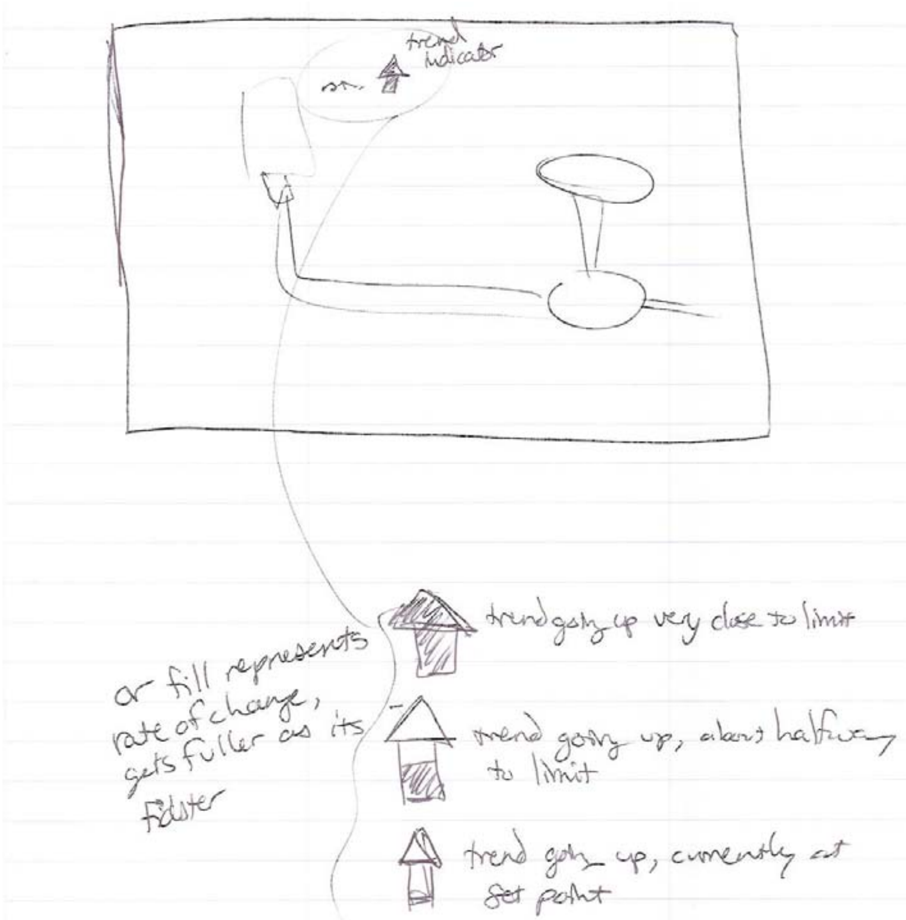


Value Slopes – Version 2

An “instantaneous” slope is shown for each monitored value. The window used to determine the slope should be engineer-configurable, though it would be helpful to provide recommendations. The vast majority of slopes should probably be shown with straight lines. (The angle of the line would vary.) A curved line could be used to indicate extreme change or other noteworthy events such as startup, shutdown, or leaving stable. The amount of curvature probably should not be variable, as it is probably to difficult to discriminate. That would leave 4 different curves: whether the curve is up or down and whether the arrow is up or down.

DeltaV@CMU - 5/31/2006

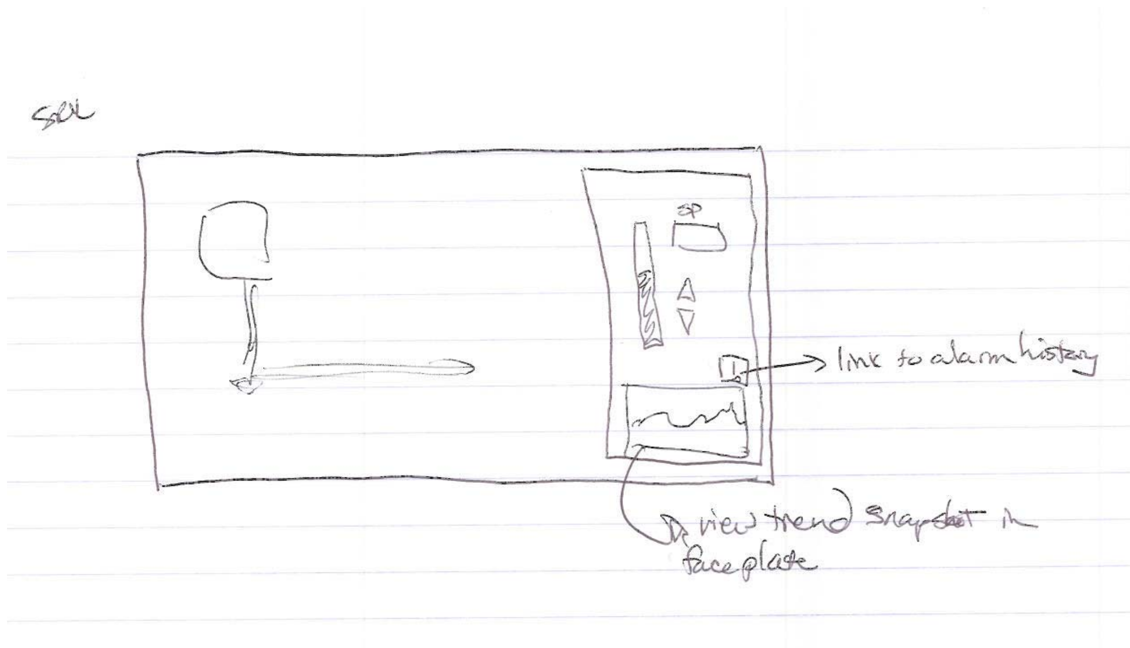
Design Idea #9



Trend Indication

An arrow indicates the trend direction near values being watched. In addition to the trend direction, the fill level indicates either the rate of change, getting more full as the rate gets faster, or as the trend reaches the recommended limits, gets more full, letting the operator know before an alarm will go off. Operators frequently use PI to create their own “pre-alarms” to alert them before an engineer-set alarm goes off.

Design Idea #10

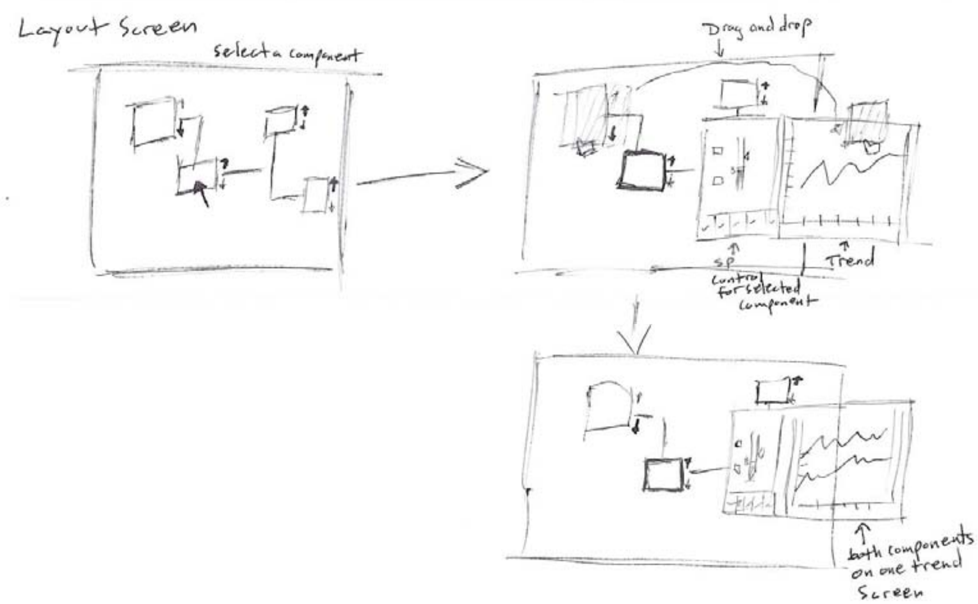


Faceplate Enhancement – Version 1

In the faceplate, an operator can view a mini-trend of the history of that component, clicking on it to link to the full view, and can link to the alarm history as well.

DeltaV@CMU - 5/31/2006

Design Idea #11



Layout Screen

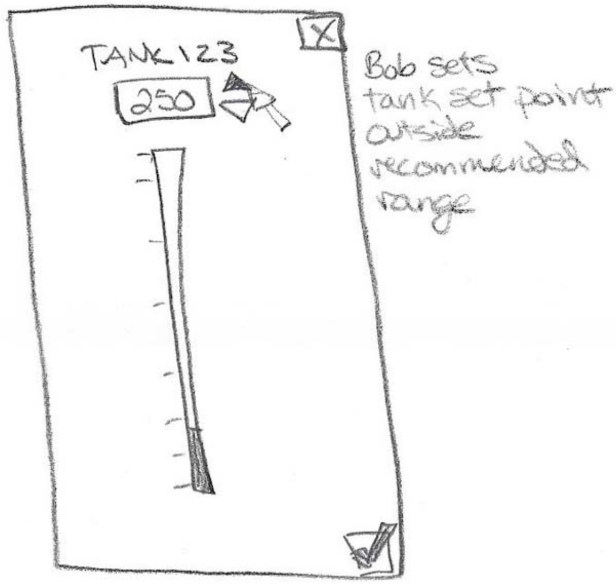
The first graphic at the top right of the screen displays a typical layout, but with arrow icons added. There is an arrow that points up and one that points down next to each component. When the component is increasing in temperature, flow, or whatever is associated with that component, then the arrow pointing up will be highlighted and the arrow pointed down will be faded. On the other hand, when the component is decreasing, then the arrow pointing up will be faded and the arrow pointing down will be highlighted.

If a user clicks on one of the components, the typical faceplate will show up but now a trend screen will also show up and be attached to this faceplate. The user can open and close this trend screen by moving the right side of it and increasing or decreasing its size. Not pictured in this graphic, but there is also the idea of having a trend button in the faceplate that would open and close the trend screen.

With this trend screen open, the user can then click on other components and drag and drop them into the trend screen. This will then display this component's data trend along with the original component's trend, allowing for comparison of these two component's data.

DeltaV@CMU - 5/31/2006

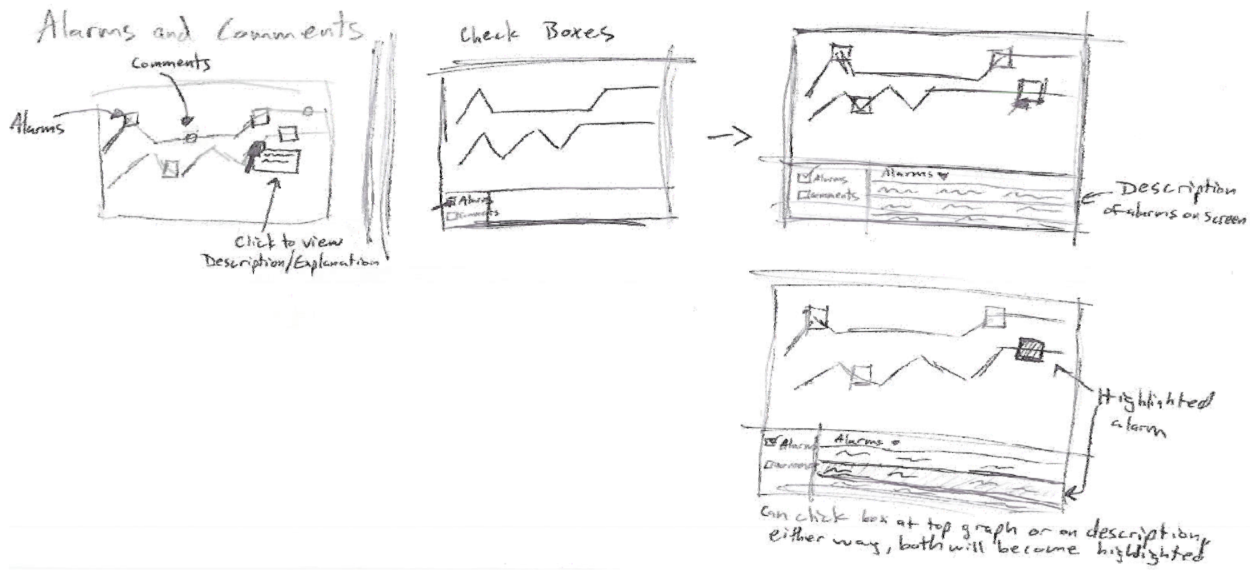
Design Idea #12



Set Point Change Warning

When the operator changes the set point a percentage greater than recommended change, a warning pops up before the change goes through. As often operators use a keyboard and mouse to make the change, the problem of entering a value too high accidentally can cause disastrous results. A warning system may help address this issue.

Design Idea #13



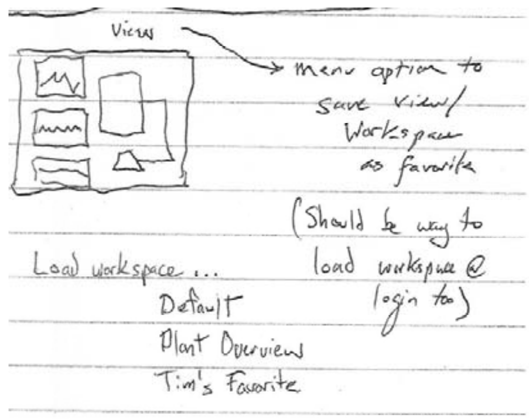
Alarms and Comments

The lower portion is about alarms and comments. The first graphic on the left displays a trend with alarms shown as square and comments as circles. My thoughts here is that these objects would not be that large and would have colors that slightly stick out so as not to annoy or attack the user. If the user clicks on an alarm or comment, information about it comes up where the mouse clicked.

This following graphics or about the concept of using a check box to display desired information. The user can either click to display Alarms or Comments or both using the checkboxes. When one of these is selected, the associated symbols (circles or squares) will appear on the trend and the associated information will appear in the bottom portion of the screen. If the user clicks on a symbol, the associated information below will be highlighted. If the user clicks on information below, the associated symbol will be highlighted.

DeltaV@CMU - 5/31/2006

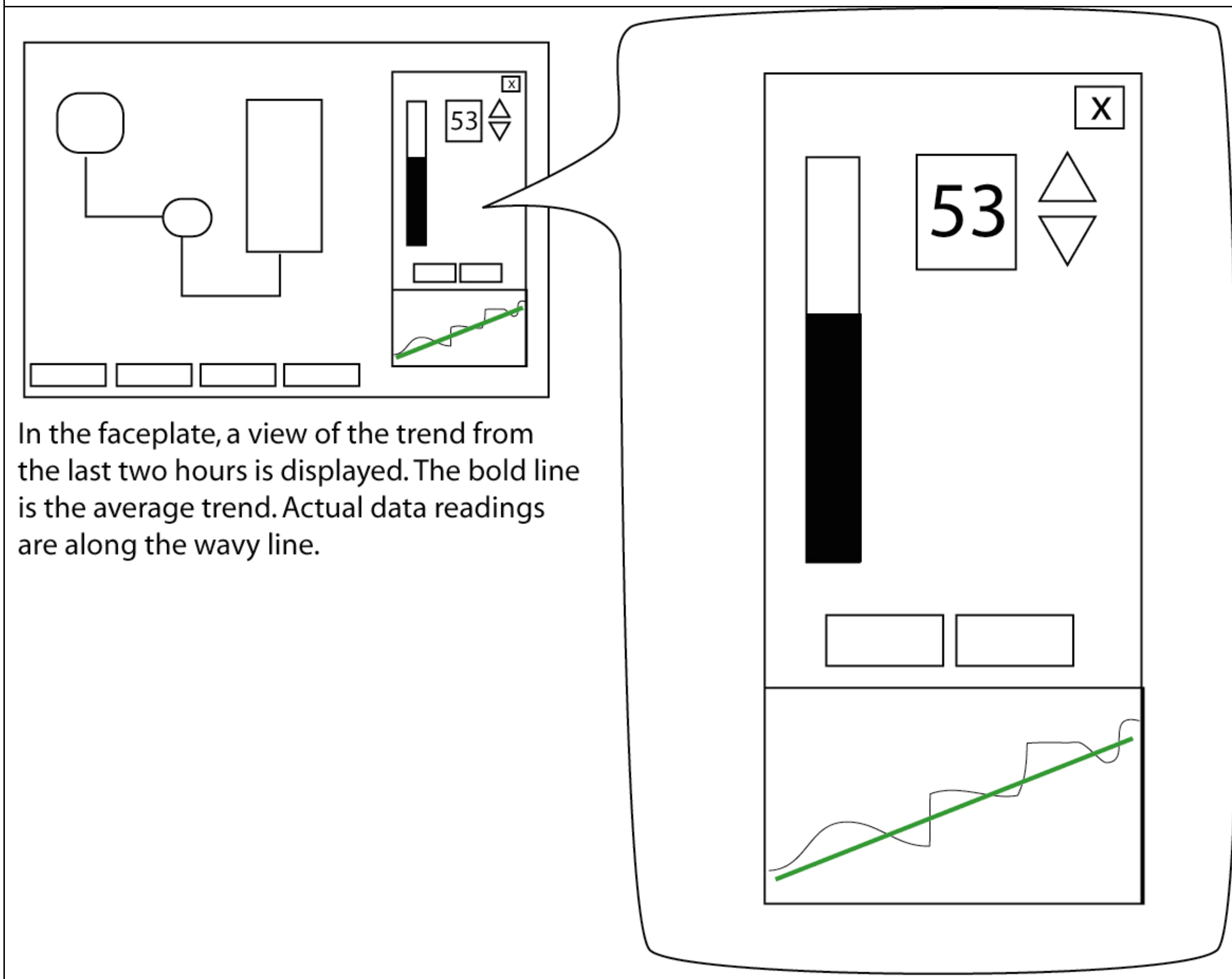
Design Idea #14



Preserve Workspace
This is a way of preserving a workspace, or desktop. Because operators have specific screens they find most useful, and may also open and resize additional windows in order to fit all the information they want to see - it'd be great to save them an extra step by providing some shortcut mechanism to 'Save' their configuration, and give them the ability to load it at a later time. There is certainly room here to have workspaces that are plant-defined that anyone can access, as well as being able to define one's own preferred settings.

DeltaV@CMU - 5/31/2006

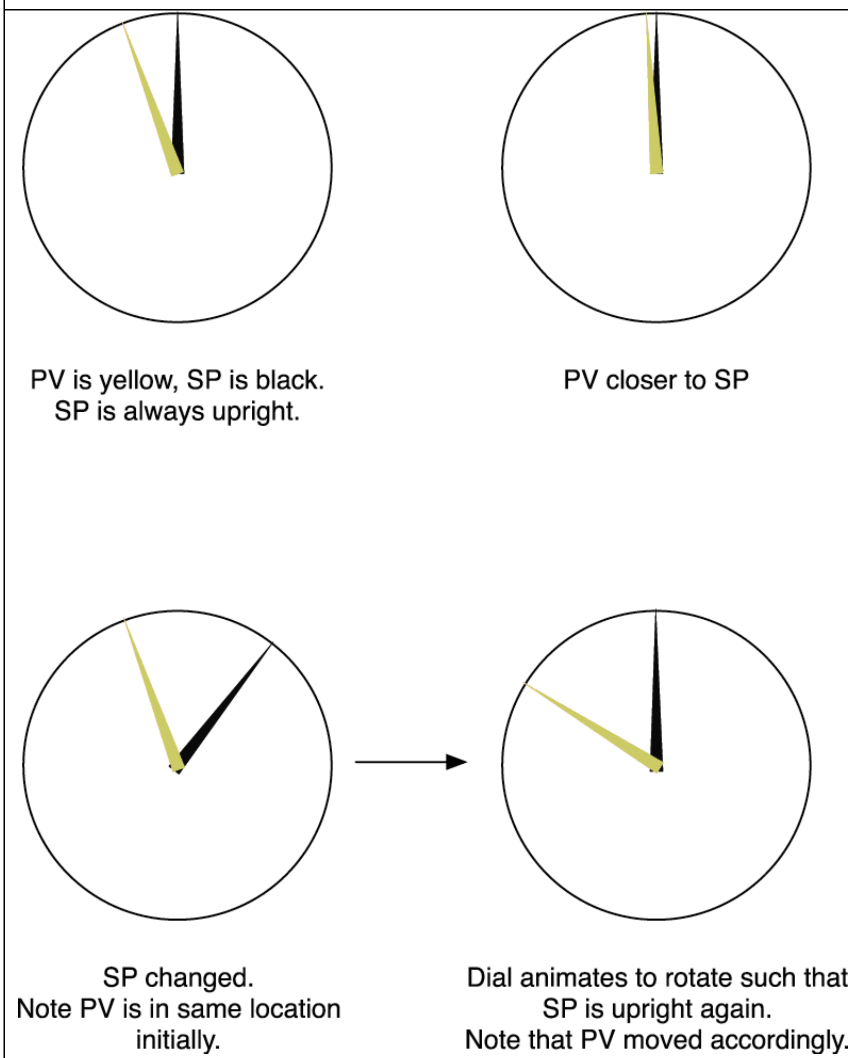
Design Idea #15



Faceplate Enhancement – Version 2
For a quick view of the trend of a component, a small graph would display in the faceplate showing not just the actual captured data, but also an average trend line to help operators identify the trend at a glance.

DeltaV@CMU – 6/3/06

Design Idea #16

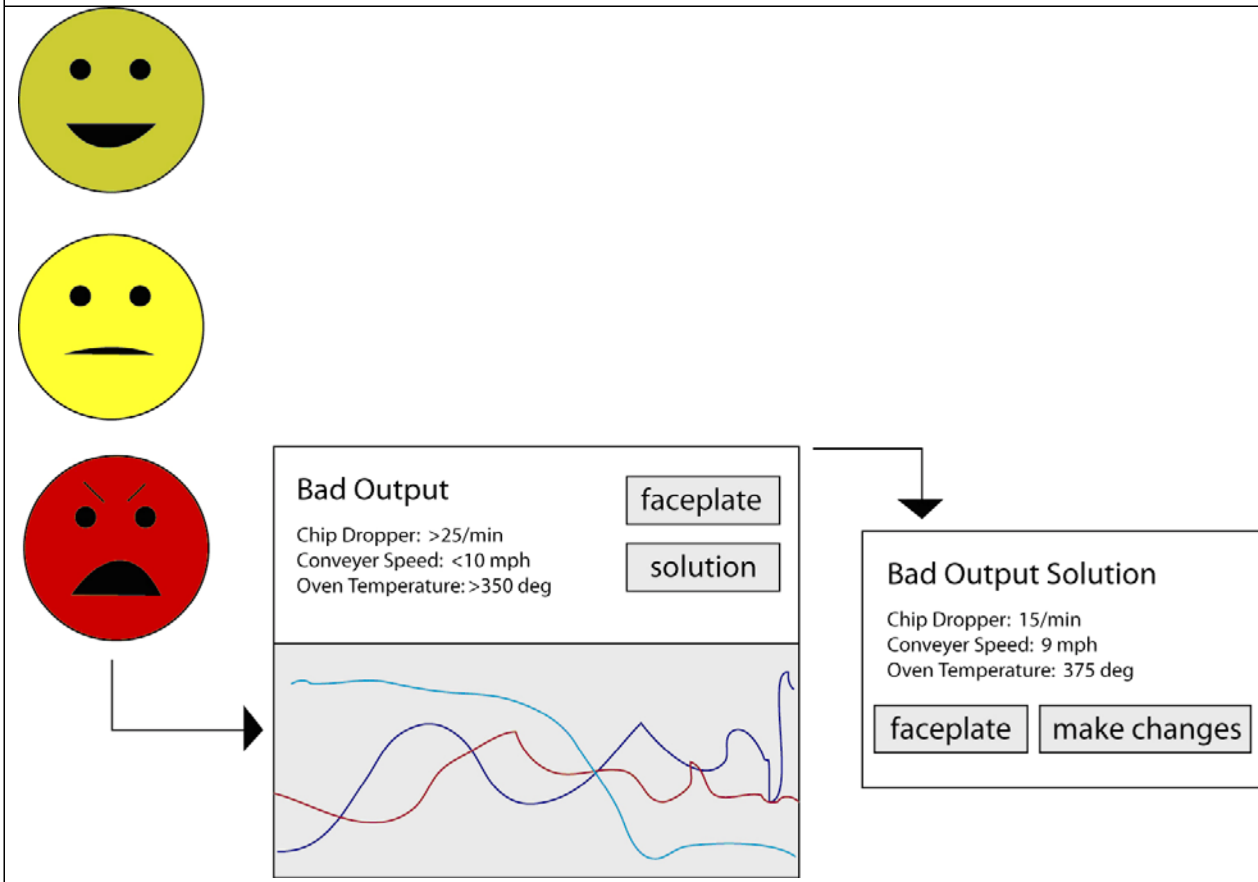


Gauges Displaying SP and PV
Gauges could be displayed which convey the SP and PV. The SP is always upright so the PV's deviation from SP is more immediately apparent.

When the SP is changed, the black needle moves to the appropriate location, then the entire gauge rotates such that the SP is now upright again. Note that the PV will also be rotated so it maintains the appropriate distance from SP.

DeltaV@CMU – 6/5/06

Design Idea #17

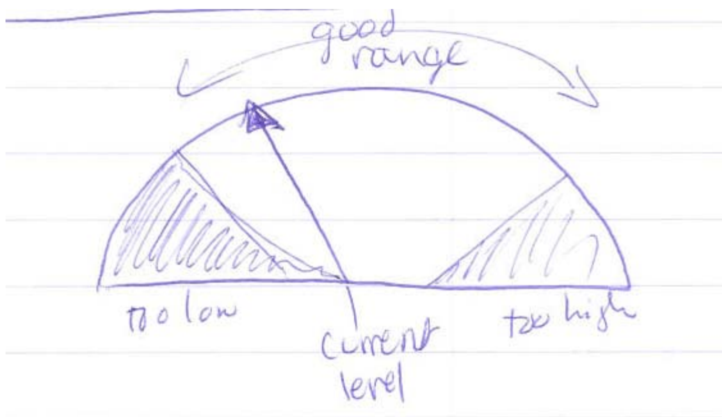


Output Quality Faces

A prominent face icon represents the product output quality. When it is on target, the face is happy, when the product is okay, within limits but not on target, the face is neutral, and when the product is bad, the face is angry. Clicking on the face brings up a window that explains what is making the product good, okay, or bad. If the product is not on target quality, a solution can be reviewed by clicking the solution button. This recommends specific changes to adjust. The operator can either make those changes automatically, or bring up the faceplates of the problem components to manually adjust things.

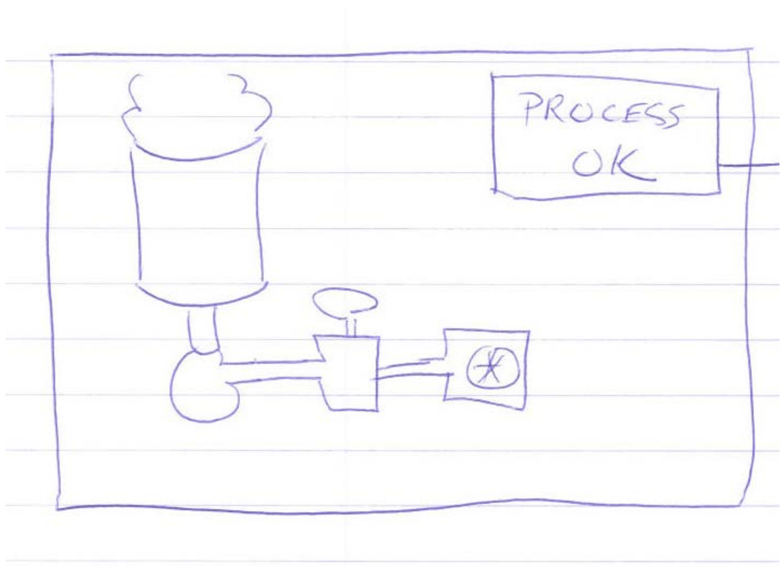
DeltaV@CMU – 6/5/06

Design Idea #18



More Gauges
A half-circle gauge showing when level or temperature is within a good range or below or above this. Not recommended ranges are shaded in red.

Design Idea #19

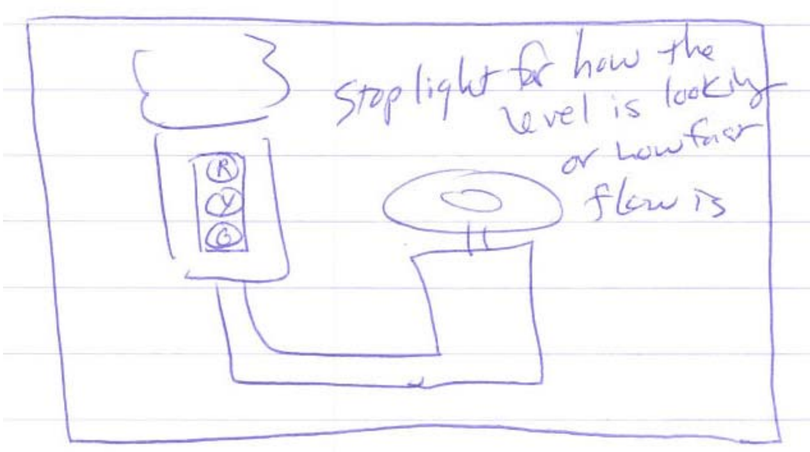


Process Ok Display

When the process is running smoothly and no significant problems are happening (as determined by the engineer), a “process ok” label appears prominently in the top right corner of the display. This allows operators to see at a glance that there is nothing requiring their immediate attention.

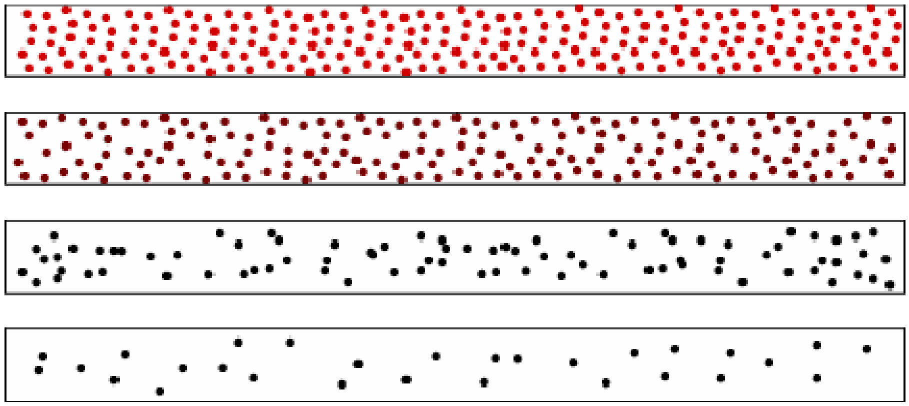
DeltaV@CMU – 6/6/06

Design Idea #20



Stop Light
To show the level or speed of a component, use a stop light icon. Red means there is a problem, yellow means a problem is starting, and green means ok. Trade-off is that there may be confusion with red meaning there is no flow and green meaning there is flow… then what would mean when there is too much flow?

Design Idea #21

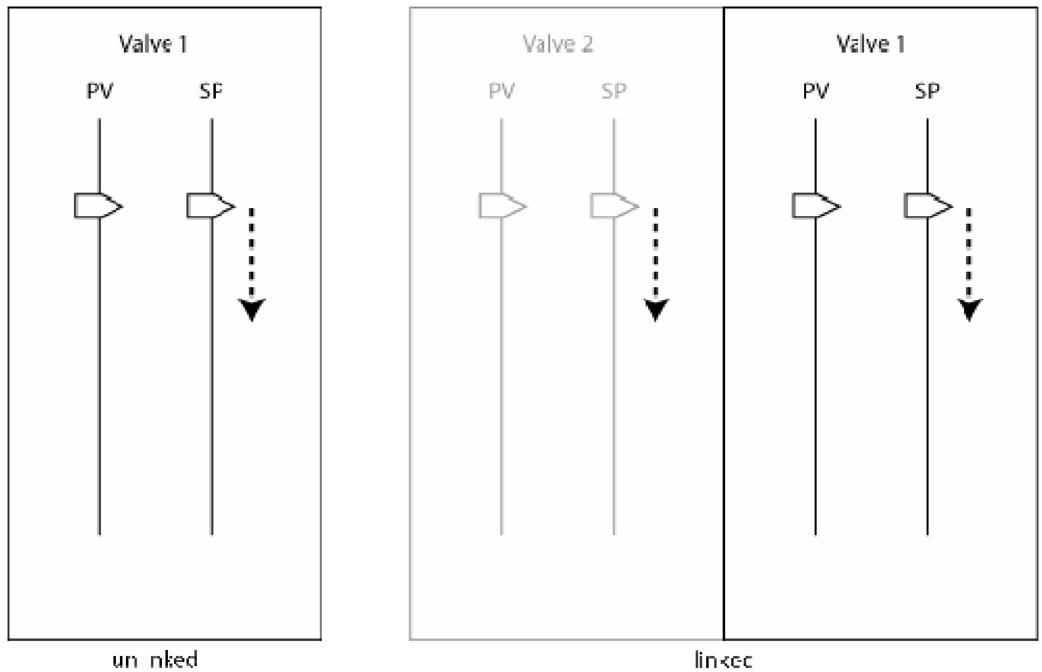


Particle Pipes

Pipes can show volume and flow by animating particles in the pipes.

Quantity of particles would indicate volume. Speed of animation would indicate flow. A color change could be used to indicate that a HI or HIHI alarm has been reached, for example.

Design Idea #22

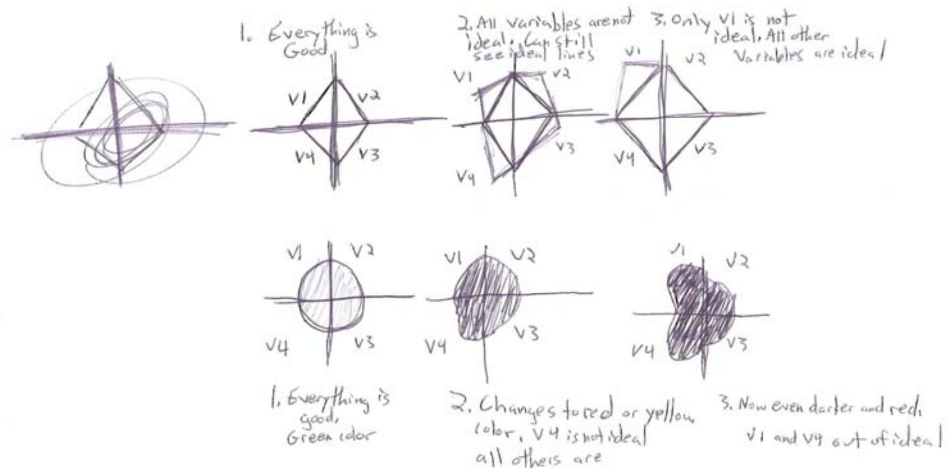


Linked Controls
Controls that are changed together can be linked so that they do not have to be manipulated individually.

The linked items would appear automatically as dimmed. There are probably different ways that they can be linked: maintain absolute ratio across items; maintain percentage of zero-level across items; etc. There needs to be a quick way to unlink items temporarily.

DeltaV@CMU - 6/6/06

Design Idea #23



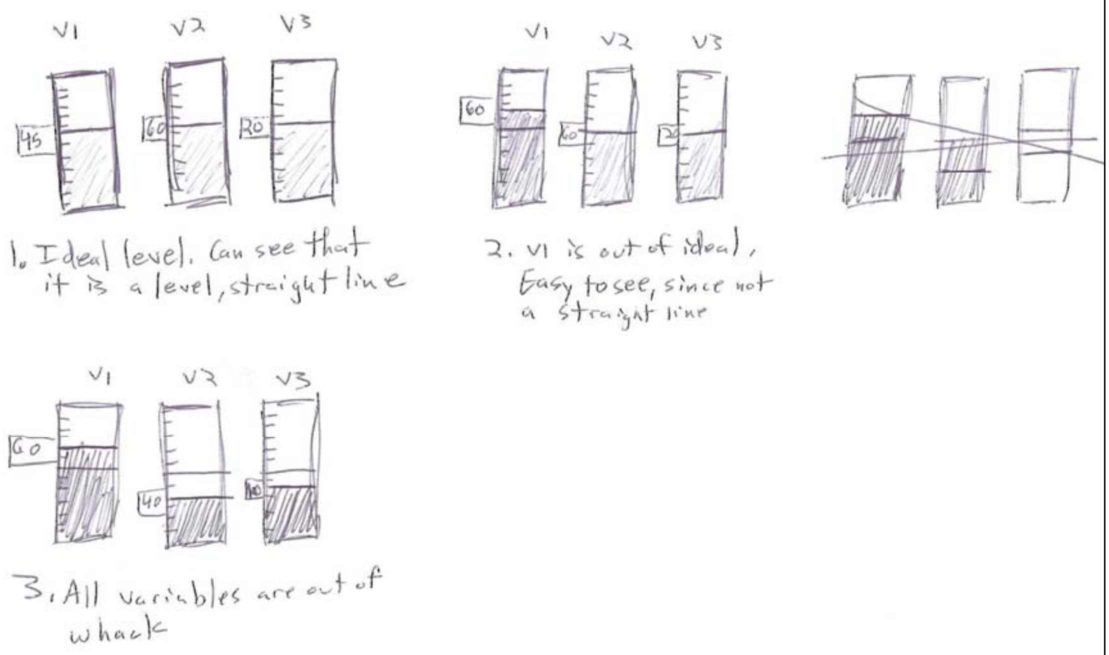
Shape Changing

A shape is used to reveal the interaction between multiple variables. At the top picture, a diamond is used to show the ideal state for all four variables. When one of the variables is out of ideal, it is easy to see, since the diamond will no longer be in the shape of a diamond. The diamond shape will also be visible to see the amount of deviation from the ideal state.

The lower picture is the same idea but with a circle shape. Another difference is the addition of color. For ideal state, the circle is green; as it goes more away from ideal it goes closer to red.

DeltaV@CMU – 6/6/06

Design Idea #24

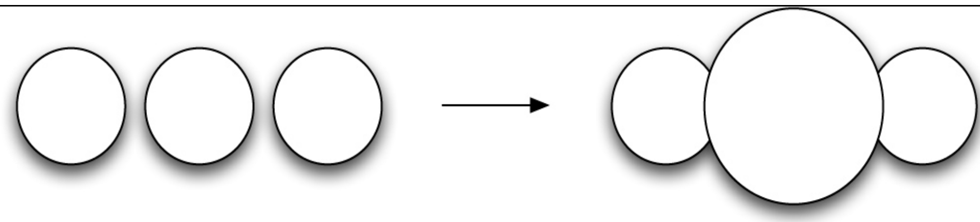


Bar Comparison

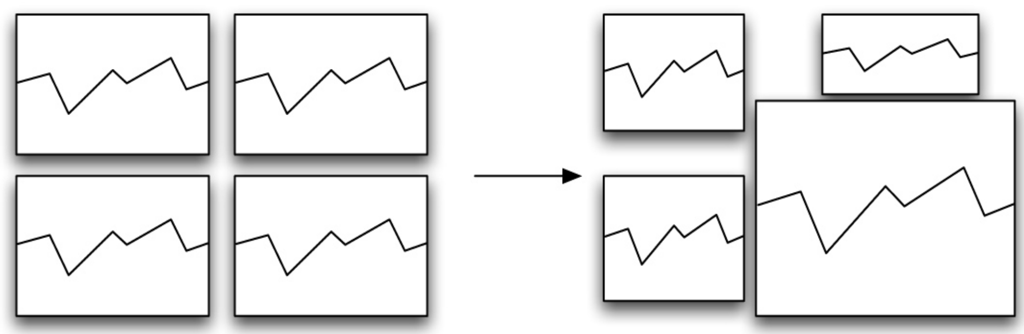
Placement of related variables next to each other. The ideal state for each variable is shown with a line and the line is at the same height for all variable bars. These lines may represent different numbers, but they are in line with each other to make it easy to see if a variable is out of the ideal state.

DeltaV@CMU – 6/6/06

Design Idea #25



The three circles represent three data points, alarm banks, and/or graphs.
If the information contained by the circle starts changing at a rate or to a
point where it would be useful to look at it, the circle grows in size to get your attention.
The same concept is shown below with graphs.

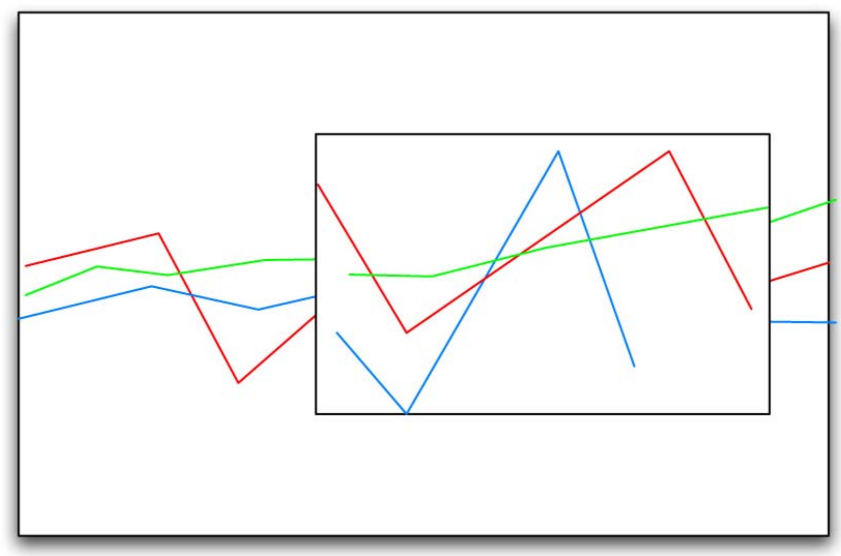


Data Point Circles

The three circles represent three data points, alarm banks, and/or graphs. If the information contained by the circle starts changing at a rate or to a point where it would be useful to look at it the circle grows in size to get your attention. The same concept can be done with graphs.

DeltaV@CMU – 6/6/06

Design Idea #26



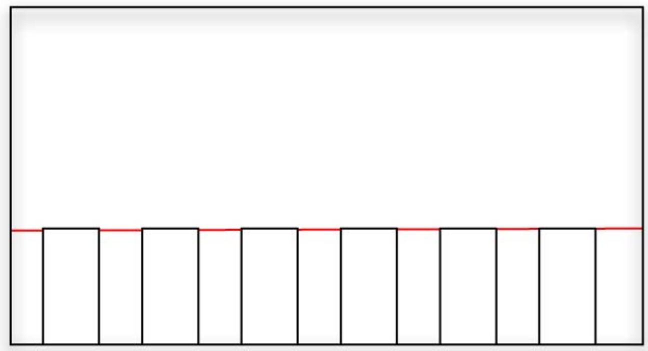
Magnification
Provide a Magnifier, or 'Hotlight' to allow users to focus in on certain parts of the graph. This could be manual only - e.g. user pushes a key to bring up magnifier. It could also be semi-automatic, in that when things need attention, the magnifier window appears at the appropriate place.

It could also be used as a 'Window-in-Window' to examine a single trend line. If a user wants to look at just the blue line, for example, they would now need to create a separate graph or remove all the other lines from this graph. If the magnifier can be called to zoom in on just the clicked line vs. the entire graph, it becomes a temporary way to view single trends.

It also has potential for showing a different scale. For example, if the entire graph is logarithmic in order to make the trends more relative to one another, the magnifier for the blue line only, could be linear - and in the right units/range specific to that trend, so that the data might be more easily discernable.

DeltaV@CMU – 6/6/06

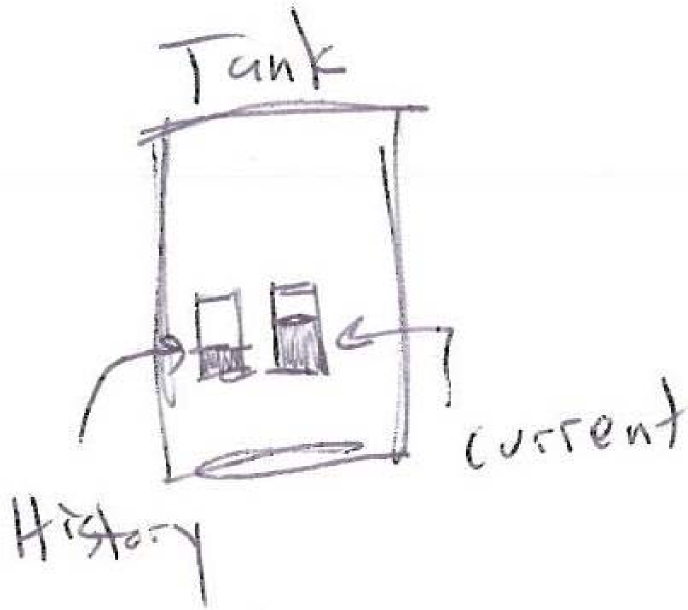
Design Idea #27



Bar Graph Variation
Similar to a bar graph, each bar represents one component, variable, or relationship. These are all shown on a scale relative to one another such that when all bars are at the redline, the system is in 'balance'. If one bar starts moving above or below the line, it is a quick visual indication that something is operating either above or below its acceptable range for the current conditions, and should be checked.

DeltaV@CMU – 6/6/06

Design Idea #28

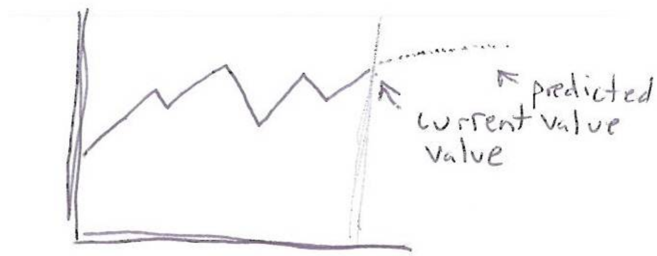


History on Component

The bar on the left shows the past level of the component and the bar on the right shows the current level.

DeltaV@CMU – 6/6/06

Design Idea #29

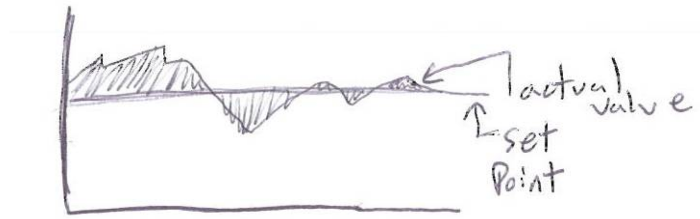


Predictive Trend

Basically, the graph just displays a prediction of where the trend will be heading. The past and current values are solid colors and the predicted value is dotted. A line is used to separate the current and predicted to make it easy to quickly note where these two meet.

DeltaV@CMU – 6/6/06

Design Idea #30



SP Comparison

The Set Point value set by the operator is a horizontal line. The difference between the actual value and the Set Point is colored in so it is easy to see the difference. It also puts the attention on the Set Point.

DeltaV@CMU – 6/6/06