Building an HMI that Works: New Best Practices for Operator Interface Design

Introduction

At 6:20 on the evening of Jan 20, 1992, an Airbus A32 took off from Lyon, France on a regularly scheduled domestic flight to Strasbourg. The flight was uneventful until the crew prepared for descent. When the crew programed the angle of descent, -3.3, into the Flight Control Unit, they failed to notice that it was in vertical speed mode rather than in flight path angle mode. Because the FCU was in the wrong mode, the value of -3.3 meant a descent rate of 3300 feet (1006 m) per minute rather than the correct 800 feet (244 m) per minute. Visibility was poor, and the flight crew did not notice the error until it was too late. Eighty-seven of the 96 passengers and crew perished when the plane struck a mountain.

Among several items officially cited as causes for the tragedy was the operator interface, "adequate for normal situations but providing insufficient warning to a crew trapped in an erroneous mental representation….the design tends to increase the probability of certain errors in use, particularly during a heavy workload."[1]

On the afternoon of March 23, 2005, the BP Texas City refinery in Texas was rocked with a series of explosions when a distillation tower in a hydrocarbon isomerization unit flooded and sent a geyser of liquid into the air, producing a cloud of highly flammable vapor that was promptly ignited by an idling pickup truck. Fifteen workers were killed and 180 injured. Windows were shattered in houses within a 3/4-mile (1.2 km) radius.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) spent nearly two years investigating the accident.[2] Their final report cited a number of causes, including inadequate training, failure to follow startup safety procedures, inaccurate instrumentation, poor maintenance, and "a poorly designed computerized control system that hindered the ability of operations personnel to determine if the tower was overfilling."

> *The computerized control system screen that provided the reading of how much liquid raffinate was entering the unit was on a different screen from the one showing how much raffinate product was leaving the unit. Having the two feed readings on separate screen pages diminishes the visibility and importance of monitoring liquid raffinate in versus out, and fails to make the imbalance between the two flow readings obvious.*[3]

Human Error?

These two tragedies have at least one thing in common: the failure of the human beings in control to see the problem as it developed or to anticipate the disaster it would lead to.

Was this simply human error on the part of the operators, or were the operator interfaces partly to blame? Increasingly, ineffective or misleading human-machine interfaces (HMIs) are being cited as causes in industrial accidents.

The Strasbourg Airbus and BP Texas City were disasters that cost lives. If your plant or processes aren't so dangerous, why should you care whether your operator interface is a good one? Why should you spend money

1. Investigation by Bureau d'Enquêtes et d'Analyses (BEA), France: http://aviation-safety.net/database/record.php?id=19920120-0
2. http://www.csb.gov/investigations/detail.aspx?SID=20&Type=2&pg=1&F_City=texas+city&F_State=TX
3. http://www.csb.gov/assets/document/CSBFinalReportBP.pdf, p. 83

to change an HMI that no one complains about, that seems to be working adequately, perhaps has for years?

The Value of Change

The Abnormal Situation Management Consortium, a group of companies and universities concerned with the handling of unexpected events in the process control industry, tracks incidents and accidents globally as they appear in the media. In 2012 alone, they recorded more than 1000 incidents.

While few incidents result in explosions and death, all are costly in terms of delays, reduced product quality, or damage to equipment. Based on their research, the ASM Consortium estimates that unexpected events cost 3-8% of capacity each year.[4] Three to eight percent is a significant cost for any business.

Here's what an improved HMI can do:

- Improve quality during normal system running
- Save time during startup, shutdown, and transitions
- Save money by avoiding downtime and errors
- Reduce training time
- Provide a less stressful work environment and minimize operator fatigue

One study testing an ASM-approved display against a traditional interface in a high-fidelity process simulator found that operators using the approved displays:

- Recognized problems more quickly and consistently
- Responded to problems 35-48% faster
- Successfully solved problems at a 25% higher rate[5]

Back in the Day…

We've been creating HMIs for decades. Why don't existing HMIs work as well as they could?

Let's take a quick look at the history of operator interfaces.

Early process monitoring typically was done using a wall of gauges, indicators, trends, and an enunciator panel that showed all alarms. Operators had fewer instruments to monitor, and instruments were grouped on the wall based on the operator's tasks. By looking at the wall, you could see at a glance the status of the whole system.

Enter Computers

Then processes became more complex, and in the 1980s computers were brought in to help handle them. Early computer interfaces attempted to reproduce the panel instrumentation, but the capability just wasn't there.

- Since early computer displays could not easily show analog representations of data, simple number values appeared instead of gauges.
- Trends were difficult, so trending became rare; in its place alarms were used, but the number of alarms rapidly increased until they were overwhelming.[6]
- Colors on early computers were limited to just eight colors with two levels of intensity on a black background. Control room lighting had to be lowered so the black backgrounds weren't too much contrast, but dimly-lit rooms increased operator fatigue.[7]

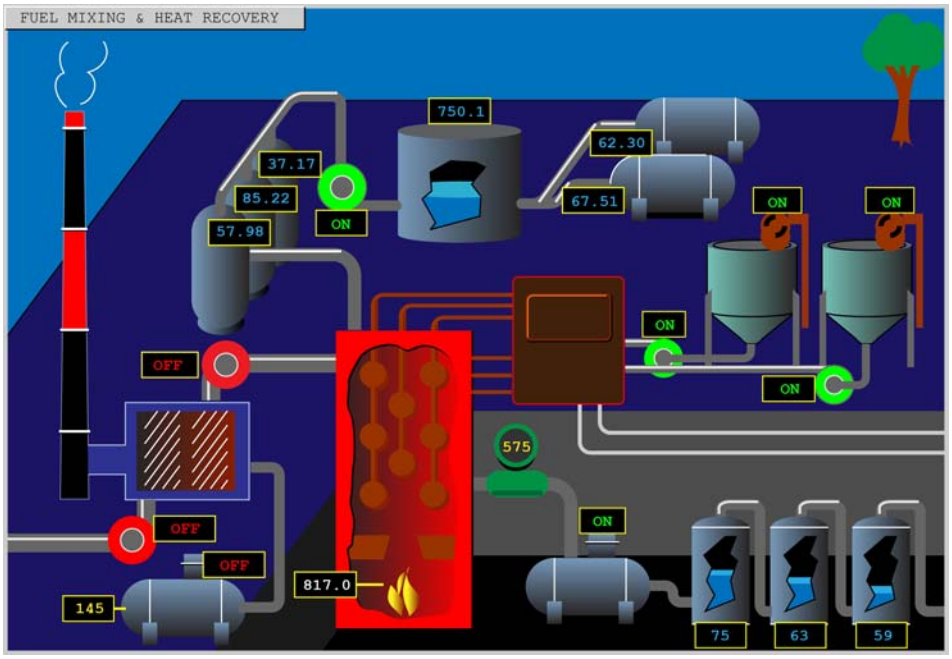
As the computer's ability to display graphics improved, interface designers often turned to piping and instrumentation drawings (P&IDs) for graphics, because they were easy to obtain and seemed like a logical source. After all, that's how the process works. Most HMIs are still based on P&IDs, note Bill Hollifield and Ian Nimmo, authors of *The High Performance HMI Handbook*.

But P&IDs are "tools for designing a process, which is a very different thing than a user interface for controlling a process."[8] Designing an HMI based on P&IDs is like designing an automobile dashboard to show the internal parts of the engine. But driving a car involves a different set of tasks than building an engine. The dashboard needs to present data about the car based on the tasks the driver will do.

4. http://www.asmconsortium.net/defined/impact/Pages/default.aspx
5. ASM Consortium Guidelines, "Effective Operator Display Design," http://www.asmconsortium.net/Documents/ASM_Handout_Display.pdf
6. Ian Nimmo, "The High Performance HMI," p. 3. http://www.lin-andassociates.com/documents/The%20High%20Performance%20HMI%20L&A.pdf
7. Peter Bullemer et al., "Gray Backgrounds for DCS Operating Displays?" *Control Engineering*, February 2011. http://www.controleng.com/index.php?id=483&cHash=081010&tx_ttnews[tt_news]=43233
8. Bill Hollifield et al., *The High Performance HMI Handbook.* (Kalamazoo: 360 Digital Books, 2008), p. 14

Additionally, P&IDs put too much in one place. "They have no hierarchy, and are intentionally a very 'flat' view of every element of the process, rather than supporting 'drill down' for additional information."[9] If too much data is on one screen, it's difficult to find the important data.

An example of a poor HMI



Unfortunately, these early computer-based design limitations set the course for years. When computer graphics became really detailed and thousands of colors were available, they were mostly used to make the same P&ID representations look more realistic, not to change the HMI to better suit the operator's tasks. Furnaces with dancing flames and detailed floors and walls don't provide useful control information; they only serve to distract the operator on the job.

The HMI shown above is an example of graphic capabilities run amok. The actual data on the screen is drowned out by bright colors, textures, and images that don't provide any real information. You can't tell whether the system is running well or not.

> **There is still 'a tremendous focus on the process hardware rather than the operator's mind.'**
>
> - Dave Strobhar, Center for Operational Performance, quoted in *Automation World*, December 2012

Modern Computer Interface Design

Meanwhile, outside the world of automation, computers have shrunk in size and cost to the point where we carry them around in our pockets. They provide a plethora of functions that everyone wants to use, from personal communication to banking to getting directions to accepting credit payments for products and services.

And why are the vast majority of untrained people able to use all these functions? Because as computer capabilities increased, hardware and software interface designers began paying attention to the way people interact with computers and how interfaces need to be designed to make interaction easy.

Years of human factors and ergonomics research have turned up a great deal of information about how to design products so that whatever a human wants or needs to do with them can be done easily.

Why shouldn't automation HMIs reflect this research on computer interfaces, and make monitoring, controlling, and manipulating data from control systems easy?

New Standards for HMIs

With awareness of human factors research and spurred by costly industrial accidents, people in the industry are increasingly paying attention to the quality of HMIs and the value of having a truly usable operator interface.

Whether they call their new standards ergonomics, user-centered design, or high-performance HMIs, researchers and automation professionals are establishing new best

9. Nimmo, p. 4.

practices for HMIs that are clear, consistent, give context, and provide real feedback for operator actions.

- **NASA Ames Research Center** maintains research data on color science and usage in complicated information displays.[10]
- The **Center for Operator Performance** publishes research on operator skills, training, and work conditions as well as automation systems and alarms.[11]
- The **ASM Consortium**'s Guideline, *Effective Operator Display Design*, was published in 2008 and includes guidelines for displays, navigation, text & numbers, operator interaction with displays, alarm priorities/ sounds/physical appearance, operator training, and HMI development methodology.[12]
- The International Standards Association (**ISA**) has established a committee on Human Machine Interface standards in manufacturing. The first draft of these standards (ISA101) is currently in review.[13]

Putting New Standards into Practice

All right. So if a good HMI can save time and money, increase quality, and avoid accidents, it sounds like a good thing. But how do you build one?

Let's look at three keys to building an HMI that works:

- **Put data in context** to increase the operator's situation awareness.
- **Make it easy** by reducing the operator's cognitive load.
- **Build an information hierarchy** that's easily navigated.

Put Data in Context

Putting data in context increases the operator's *situation awareness*. Situation awareness is a deceptively simple concept. Of course the operators who run your system should be aware of its current state. But there's much more to it than that.

Dr. Mica Endsley, P.E., writes that an operator must go through three steps to achieve true situation awareness:

- First, he must perceive important data.
- Second, he must comprehend the current situation.
- Third, he must predict future status.[14]

Data ≠ Information
- Dr. Mica Endsley

It's not enough to see current system values; the operator must see them in context to know their meaning, and then see where they are trending in order to predict what is likely to happen next.

Situation awareness does not come from a control system, writes Endsley. "[T]rue situation awareness only exists in the mind of the human operator. Therefore presenting a ton of data will do no good unless it is successfully transmitted, absorbed, and assimilated in a timely manner by the human to form situation awareness."[15]

Situation awareness includes a number of factors, including alarms, trends, and ergonomically designed control rooms to reduce fatigue and distractions.

You can't automate your way out of human error by burying information in the system. If humans are kept out of the loop, they won't understand how the system is progressing and will lose situation awareness. Instead, you need to use the human in the best way possible: by giving him or her the information to develop situation awareness and be able to predict and respond.

Here are some ways to put data into context to increase operators' situation awareness.

Match the operator's mental model.

Good situation awareness demands that the operator's mental model of how the system works matches the way the system is presented in the interface.

Without an accurate mental model, an operator may misinterpret information. She won't know the significance of changes in the system or the probable results of actions she may take.

Before designing the HMI, work closely with operators to understand their mental model and their responsibilities for the system. Beware of changes over time, too: as

10. http://colorusage.arc.nasa.gov/index.php
11. http://operatorperformance.org/research-projects-center-operator-performance.asp#completed_research
12. http://www.amazon.com/Effective-Operator-Display-Design-Consortium/dp/1440431647/
13. http://www.isa.org/MSTemplate.cfm?MicrositeID=1142&CommitteeID=6899
14. Mica R. Endsley, "Designing for Situation Awareness in Complex Systems," Proceedings of the second international workshop on symbiosis of humans, artifact, and environment, Kyoto, Japan, 2001. http://satechnologies.com/Papers/pdf/SA%20design.pdf
15. Endsley, p. 4.

systems change or become more complex, mental models may become out of date and need adjustment.

Make important information stand out.

Attention tunneling, or fixating on one set of information to the exclusion of others, is cited as the most common failure of situation awareness.[16] You can increase situation awareness by making critical information stand out and less important data recede to the background.

The first step is knowing what information is more important and what is less so. Your study of operator tasks should help you determine the relative importance of data in normal and abnormal situations.

When you look at our example of a poor HMI on page 3, the things that stand out are the bright green and red pumps and the flames in the red tank. But these are not important. Even the color of the pumps provides little information, since we don't know whether any particular pump is supposed to be on or off at this time.

In a moment we'll take a closer look at how to use color and movement on the screen to emphasize the important.

Provide information, not just data.

To illustrate the importance of providing information rather than just data, Bill Hollifield, co-author of *The High Performance HMI Handbook*, uses the example of Fluffy the cat.[17]

Can you tell from the following table whether Fluffy is well or ill?

Blood Test	Results
HCT	31.7%
HGB	10.2 g/dl
MCHC	32.2 g/dl
WBC	9.2 x 10^9 /L
GRANS	6.5 x 10^9 /L
L/M	1.3 x 10^9 /L
PLT	310 x 10^9 /L

If you've memorized all the normal ranges for these values and you're a veterinarian, you can probably tell. But it will take you awhile.

It would be easy to turn this data into information, though, by showing normal ranges right next to these values. The ranges would help you understand the current situation without relying on your memory.

Even better, you could add a symbol next to any value outside the range, as in the table below, so you wouldn't have to mentally compare each value to its range to discover whether Fluffy is OK.

Blood Test	Results	Range
HCT	31.7%	24.0 - 45.0%
HGB	10.2 g/dl	8.0 - 15.0 g/dl
MCHC	32.2 g/dl	30.0 - 36.9 g/dl
WBC	9.2 x 10^9 /L	5.0 - 18.9 x 10^9 /L
GRANS	6.5 x 10^9 /L	2.5 - 12.5 x 10^9 /L
L/M	1.3 x 10^9 /L !	1.5 - 7.8 x 10^9 /L
PLT	310 x 10^9 /L	175 - 500 x 10^9 /L

Later we'll see an even better way to present this information.

Show trends.

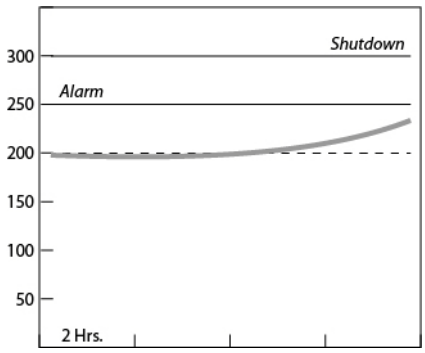
Knowing whether the current situation is all right is just the second step to situation awareness. We also need to know what is likely to happen next. Are there indications the situation may change?

Suppose you're monitoring pressure:

Current Pressure	Alarm Level	Shutdown Level
235.2 psig	250 psig	300 psig

You can see that it's OK right now, but that's all you know.

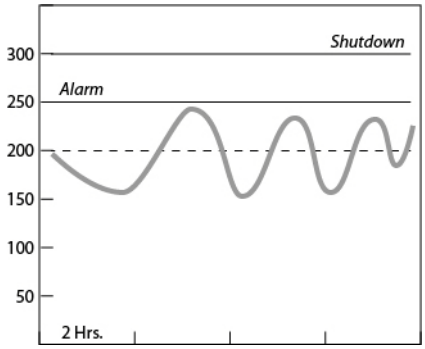
See how much more information a trend provides[18]:



This trend shows that pressure has been steadily increasing over time, and an alarm is likely to go off soon.

16. Paul Gruhn, "Human Machine Interface (HMI) Design: The Good, The Bad, and The Ugly," 66th Annual Instrumentation Symposium for the Process Industries, 2011. http://www.isa.org/~foxri/Gruhn%20HMI%20Design%20%28ISA%20template%29.pdf
17. Hollifield et al., pp. 54–55.
18. Trends from Hollifield et al., pp. 62–63.

Building an HMI that Works



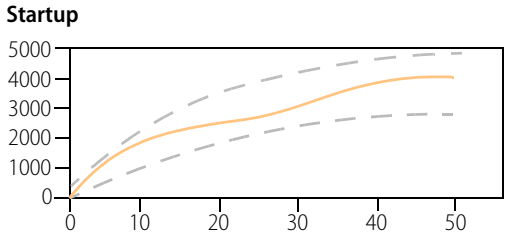
This trend shows the pressure oscillating around a known "good" level. We may want to check on the cause of oscillation, but there appears to be no immediate problem.

Trends like these help operators predict the future. They make it possible to see whether the current state is continuing in the right direction or headed for a problem. Trends can also make it easy to see equipment that needs maintenance, an increase in productivity, or an assortment of other useful directions data may take.

Since trends are so important for taking action before things go wrong, include the trend right there with the data. Don't make the operator waste time finding the trend or building it.

Provide visible boundaries for operator actions.

Another way to put data in context is to show boundaries for the correct path. Startup and transitions are good examples: if you can see the boundaries, you can see where you are in relation to what's good and adjust before there's a problem.



Suppose you were driving your car on a broad highway and there were no indicated lanes, but just an invisible beam on each side of the lane with an alarm that's triggered when you cross the beam. You would veer off slightly to the left and the alarm would go off, so you'd quickly adjust. But then you'd probably overcorrect and trigger the alarm on the right. Bouncing off the sides from alarm to alarm would be stressful. And how much more fuel would you use, weaving from side to side instead of staying in a straight line? How much better it is to have data in the context of lanes, so you know you're in the middle and need to make only small adjustments to stay there.

> **Having an operator waiting for an alarm before engaging in the system is a poor use of a human.**
>
> - Ian Nimmo, "Situation Critical," *Control*, March 2010

Make it easy

Once you've put data into context, focus on making it really easy for the operator to use your HMI.

In the early days of personal computers, you typed commands into the operating system to find or save files or complete any other function. You had to know and remember these commands exactly in order to accomplish any task. Later text-based software presented a list of commands from which you could choose, and then graphical user interfaces and icons made the job easier by reducing your *cognitive load*.

Cognitive load refers to the total amount of mental work you have to do in order to understand something. Having to remember a number of exact commands increases cognitive load; having recognizable commands or icons right in front of you reduces it.

To make it easy for operators to use an HMI, we must reduce the cognitive load required to find pertinent data, understand it, predict the future course of events, and take action. Here are some ways to make it easy.

Put yourself in the operator's shoes.

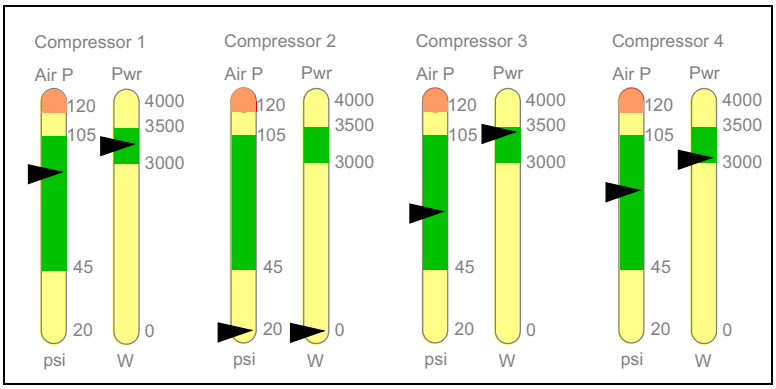
Design from the operator's point of view. Talk with operators directly. Don't ask how to improve the HMI; most won't know, and some comments may lead you down the wrong path. Instead, ask operators what tasks they have to do, and find out what information they need in order to do those tasks easily and successfully. Watch them as they work.

Lay out a process in a way that's generally consistent with the operator's mental model of the process and the direction from which she looks at it. Make gases flow up and liquids flow down, as they do in real life. In regions where people read from left to right, show a process flowing in that direction.

Group data that belongs together.

Again from the operator's point of view, what information should logically be grouped together?

Suppose that part of the job is to monitor four compressors, three of which are running at any given time, with one held ready to swap in when one of the three is running poorly. You wouldn't want to check four screens to see the status of each, and try to keep those values in your head as you switch screens. Instead, they should be grouped together on one screen, for example as shown at right, so you can easily scan them all at once.



Grouping can be done in a variety of ways. Physical location is one of the most effective ways. Humans naturally perceive objects as belonging together when they are in proximity. But there are other ways, too: by making objects the same shape, size, or color; by connecting them with a line; by enclosing them in a box or putting a subtle shaded background behind them.[19]

Grouping information that belongs together helps the operator perceive important connections. It also cleans up the screen visually, making it easier for operators to absorb information.

In the case of our four compressors, putting a shaded box behind their data indicates that they should be looked at as a group and separates them from unrelated information on the same screen.

Keep it simple.

An HMI that's optimal for running a process and handling abnormal conditions should look boring![20]

Simplicity is not a matter of increasing white space on the screen, but of what is shown and how it's presented.

Take a good look at the screen and try to eliminate anything that doesn't add information: unchanging internal parts of equipment, floors and walls, 3D depictions of equipment or data, unnecessary lines or movement, color gradients. As you saw in our example on page 3, all these things add clutter and make it harder to see what's important. Instead, try these ideas:

- Change 3D to 2D.
- Use simple line drawings.
- Make sure elements on the screen have enough contrast to be clearly seen, but avoid stark contrasts.
- Choose subdued backgrounds and elements. For equipment, process flow, or descriptive text, dark gray elements on a light gray background reduce glare.
- To make important information stand out, use thicker lines, color, shape, or added indicators.
- Show values with the minimum number of decimal places for the operator's purpose.

Then try the squint test: stand back, look at the screen, and squint. Does the most important information stand out? Make it dead easy to see abnormal conditions.

Use color, motion, and sound sparingly.

If too much is vying for the operator's attention at any given time, he won't be able to focus on what's important. Increase the signal to noise ratio, so the important things aren't drowned out by the trivial.

> **It took 25% longer to find alarms when red was also used to indicate motor/valve status as when it was used for alarming alone.**
>
> - Center for Operator Performance

Use color carefully, because it makes the screen more complex. It's impractical for operators to memorize several colors and what they mean. Also, about 10% of men and 1% of women are colorblind.[21]

19. Stephen Few, *Information Dashboard Design*. (Sebastopol: O'Reilly, 2006), pp.90–95.
20. Hollifield et al., p. 50.
21. An online source for checking colors in your HMI is from Etre Limited in the UK. See how your HMI would look to a color-blind person: http://www.etre.com/tools/colourblindsimulator/

Building an HMI that Works

Because peripheral vision and color blindness can be problems, make sure you distinguish the most important elements, like alarms, by more than just color. For example, give alarm level indicators different shapes as well as different colors:

Be even more careful with motion than you are with color. Humans are immediately attracted to movement: we're wired to do that because we spent thousands of years as hunters, where anything that moved was either potential prey or a potential danger.

Reduce the cognitive load by saving motion for important things. A bad way to use motion is to show spinning pumps. A good way to use motion is to blink an unacknowledged alarm. (Better to blink the alarm indicator than the value; the operator will need to read the value.)

Sound is distracting as well, so limit its use and let the operator turn it down or off when acknowledging.

Be consistent.

A consistent interface makes it easy for the operator to understand the system and know how to take actions or respond to problems. Familiarity breeds confidence.

When Apple introduced the iPhone, they required that developers building apps for the new device follow strict standards for elements and actions in their apps. The standards provided controls with specific functions, prescribed where to place buttons, what a finger pinch should do, and much more.[22] Because all iPhone apps were consistent, users could confidently use any app on their phones.

Here are some ways to be consistent in your HMI:

- Use the same type of graphic for similar information.
- Use specific colors for specific things. Never use an alarm color for anything other than an alarm.
- Always call the same thing by the same name.
- Organize elements on screens consistently. For example, always place navigation buttons in the lower right corner.

22. Apple, Inc. Developer Library, http://developer.apple.com/library/ios/navigation/

Anything that means the same thing or functions in the same way ought to look the same wherever it appears.

- Stephen Few, *Information Dashboard Design*, p. 168

- Show live values differently to distinguish them from descriptive text. For example, use bold blue text for live values. (Units are considered descriptive text and in this example would not be blue).
- Show similar values in consistent ways. Show the same number of decimal places, for example, and line up columns of figures on the decimal point so they're easy to scan. In the table below, notice how much easier it is to understand the relative values in the right column compared to those in the left, simply because the decimal points in the right column are aligned.

234.56	234.56
1236.91	1236.91
67.68	67.68
6789.02	6789.02
345.11	345.11

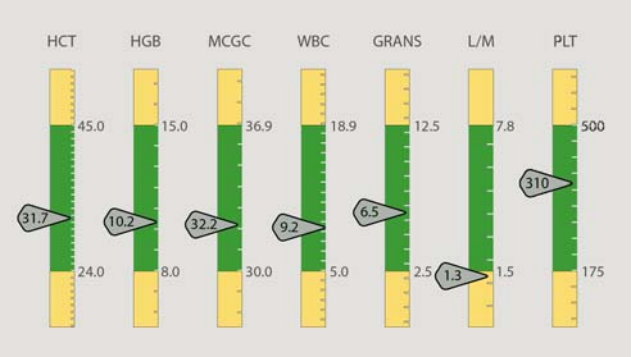
Use analog representations.

Human beings respond to data presented in an analog format because it reduces our cognitive load.

When you ask, "What time is it?" you usually aren't interested in the time itself. Instead, you want to know how long you've been in a meeting, or you're feeling hungry and want to know how soon that 12:00 lunch break will come. An analog clock shows us the context; with a digital clock, we have to do the math.

Remember Fluffy the cat? Even presenting Fluffy's stats as values with normal ranges is not as effective as an analog presentation.

Contrast the numeric table of Fluffy's blood tests on page 5 with the analog graphic below.



With the table, you must calculate each value against its range to see where it lies in the range or how far outside it is. But with the analog version, you can see at a glance that there's only one abnormal value, just outside the normal range. Analog presentations of data reduce cognitive load.

Existing HMIs based on diagrams with numeric values scattered around the screen—like our example of a poor HMI on page 3—are even worse than a table of values. Yet we somehow expect operators to have memorized all the values and their correct ranges.

People are capable of memorizing a great deal with effort and time, but why make it hard when you can make it easy? What if something goes wrong—say it's near the end of a 10-hour shift, the operator is hungry, and suddenly 50 alarms are blaring and the supervisor is yelling over the phone—do we really want to make it hard for that operator to respond?

Provide feedback.

When an operator interacts with the system, he needs to know that what he's doing is correct and effective.

You can make his job easier by building in checks, so it's hard to make mistakes, and by making it obvious what's happening.

- If he selects something on the screen, indicate that it's selected (for example, outline it in white).
- If he initiates an action, indicate that the action is being carried out.
- Design graphics and controls so they behave consistently in all screens and don't offer surprises.
- Require security checks and validate actions as needed, especially actions that are seldom performed and actions with significant consequences, such as a shutdown.
- Question typed values that are outside the expected range. For example, if an operator types 388 when the expected value would be 3.88, verify that it's correct. Mistyping can easily happen, especially on soft keyboards or membrane keyboards.

Build an Information Hierarchy

One of the problems with HMIs based on P&IDs is that they tend to show a series of flat views of the control system. What's missing are often overview screens that show the status of the whole system, or the major part of the system that an operator is responsible for.

Create Levels

Best practices suggest a four-level hierarchy, or three levels for a less complex system. Each lower level provides more detail for a portion of the higher level.[23]

Level 1: Overview—The Level 1 screen gives an at-a-glance overview of the complete system. (See the example on the next page from Bill Hollifield.[24]) This overview should include:

- Key performance indicators (safety, environmental, production, efficiency, quality)
- Top priority alarms & acknowledgment status
- Major equipment status
- Trends for important process parameters
- Abnormal situations and their severity.

The level 1 display often appears on a large screen visible to the operator, supervisors or managers, other employees within the area, and maybe operators in adjacent process areas. It should also be available on the operator's console.

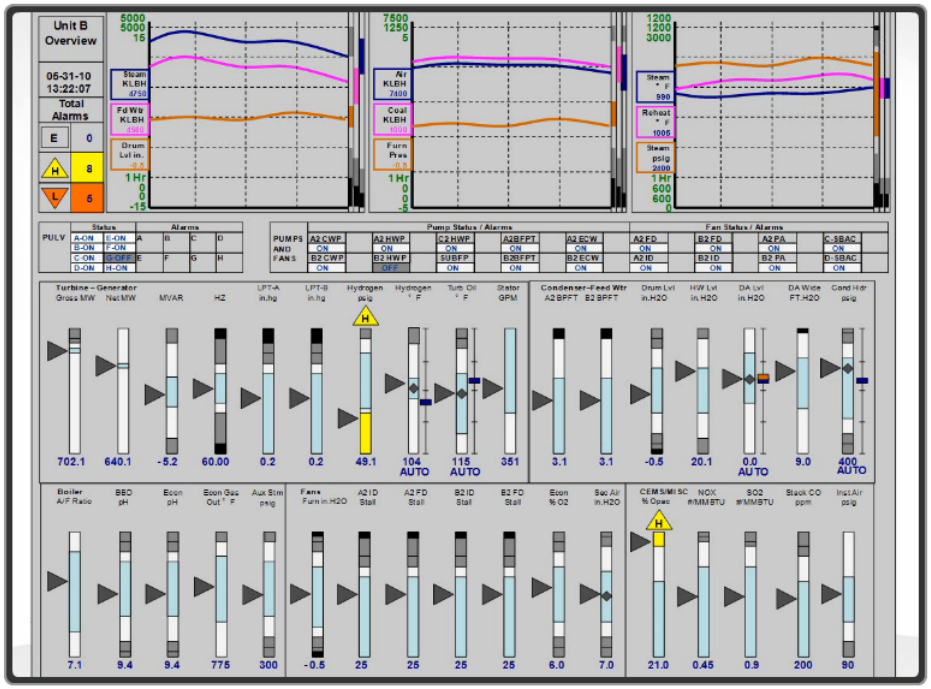
Control panel graphics did not provide necessary process overviews.

- Health and Safety Executive (HSE) analysis of explosion and fires at the Texaco Refinery, Milford Haven (UK), 24th July 1994.

23. Hollifield et al., chapter 8.
24. Bill Hollifield, "High Performance HMI: Concepts and Examples," December 2012. http://www.pas.com/News-and-Events/Webinars/Recordings/HMI-Webinar-Dec2012.aspx

Building an HMI that Works

Example of Level 1 Display Screen



An example of a level 1 overview screen is shown above.

Level 2: Unit Control—Level 2 screens are the primary screens for monitoring and control. This is where operators take almost all of their actions.

Create one level 2 screen for each logical subsystem covered by a level 1 overview. Level 2 screens should include:

- Controllers
- Values
- Alarms
- Trends
- Status

Think about how to provide information for specific situations like startup or transitions: you may need a different version of the level 2 screen. For abnormal situations, you can pop up information and controls and provide checklists to guide the operator.

TIP: When designing your HMI, focus on the operator's tasks for each subsystem and design the level 2 screens first; then go back and design the level 1 overview.

Level 3: Unit Details—Level 3 screens show more detail for an item on a level 2 screen. Level 3 screens may include:

- Control loops
- Individual pieces of equipment
- Troubleshooting displays for problems that are not time-critical
- If useful, some P&ID drawings.

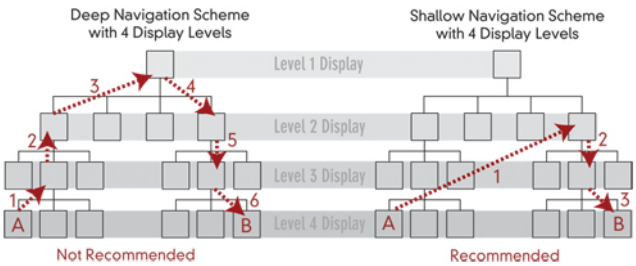
If you're revising an existing HMI, level 3 screens are a good place to use any P&ID-based screens you already have.

Level 4: Unit Support—For a complex system, you may need to separate support documents and information in a fourth level. Here you would include operating procedures, alarm documentation and guidance, and so on.

Provide Quick Navigation

During an abnormal situation, operators often need to switch quickly between screens. If they must click up through the levels and then down again to the next screen they need, essential time is wasted.

In the following graphic from the ASM Consortium, take a look at the difference between deep navigation (at left) and shallow navigation (at right).



ASM's "Guidelines for Effective Operator Display Design" recommends shallow navigation so that all level 2 displays are accessible from anyhere in the HMI. With shallow navigation, it takes only three mouse clicks to get from point A to point B.[25]

25. Jim Montague, "Simple, Strong, and Easy to Use," *Control*, March 2010. http://www.controlglobal.com/articles/2010/UserCenteredDesign1003.html

A common way to provide shallow navigation is to locate a column of buttons in the same place on each screen. One button goes directly to the overview screen; others go directly to each level 2 screen.

Let's Get Started

Whether you're considering changes to your existing HMI or are building a new one, take a good look at the new best practices in operator interface design. We've touched on several of them here, but there's a lot more information available.

Good places to start are with *The High Performance HMI Handbook* and the ASM Guidelines, *Effective Operator Display Design*. Another book less specific to automation but full of excellent examples of effective data presentation is *Information Dashboard Design*.

Remember that a lack of complaints doesn't necessarily mean your current HMI is good. People know what they're familiar with and usually can't tell you how to improve it. They don't know what they're missing until they work with something better.

Need Some Help?

Check with your automation manufacturer to see if they offer HMI software or assistance to help you incorporate good principles of user-centered design. Among large distributed control system (DCS) manufacturers, you might check Honeywell's Experion PKS or Emerson's Delta V. Both have been instrumental in improving the operator interfaces for some very extensive industrial systems.[26]

For less complex systems, automation manufacturer Opto 22 offers *groov* for building simple operator interfaces that run on a wide variety of platforms, from smartphones to web-enabled large-screen TVs. Designed to follow principles of high-performance HMIs, *groov* deliberately limits colors and graphics on operator screens.

System integrators may be able to help, too. Now that you know some of the basics of building an HMI that works, you'll be better able to talk with them about what you want—and don't want. Several of the people referenced in this white paper are well versed in good HMI design and offer services to help you design or redesign an interface.

And remember, any improvements you make in operator interfaces will save you time and money—faster training time, better quality products and services, less stress on operators, less downtime. And fewer accidents.

About Opto 22

Opto 22 was started in 1974 by one of the co-inventors of the solid-state relay (SSR), who discovered a way to make SSRs more reliable.

Opto 22 has consistently built products on open standards rather than on proprietary technologies. The company developed the red-white-yellow-black color-coding system for input/output (I/O) modules and the open Optomux® protocol, and pioneered Ethernet-based I/O.

In addition to SSRs, Opto 22 is probably best known for its high-quality SNAP PAC programmable automation controllers, I/O, and OptoEMU Sensor energy monitoring units, all of which are manufactured and supported in the U.S.A. Because the company builds and tests its own products, Opto 22 guarantees all solid-state SSRs and I/O modules for life.

The company is especially attractive for its continuing policy of providing free product support, free training, free documentation, and free pre-sales engineering assistance.

About *groov*

Designed specifically to follow principles of high-performance HMIs, *groov* offers a remarkably easy way to put system information into the hands of the people who need it.

Simple to build and simple to use, *groov* operator interfaces supplement your current HMI by providing key data to authorized engineers, technicians, and managers.

You build your *groov* interface using a web browser and you view the interface using a web browser. No additional software or plugins are needed.

To build, simply drag and drop a gadget (such as a gauge or button) onto the screen and choose the data tag from your Opto 22 SNAP PAC control system or OptoEMU energy monitoring unit.

26. Ian Nimmo, "Best Practices in High-Performance HMI Design," *Control*, October 2012. http://www.controlglobal.com/articles/2012/nimmo-best-practices-high-performance-hmi-design.html

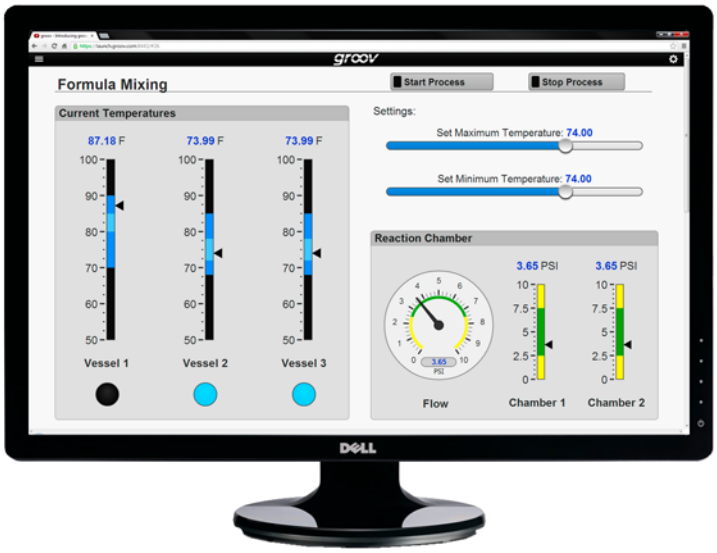
Because it is designed on open standards (HTML5, CSS3, SVG), the *groov* interface you build runs on *any* device that can use a modern web browser: smartphones and tablets from any manufacturer, computers from any manufacturer, even large-screen TVs that are web-enabled.

All software and data are stored on the *groov* Box, an industrially hardened, small-footprint device that plugs into your network. The *groov* Box uses separate network interfaces for your control system and your computer network. All communications from web browsers to the *groov* Box use secure sockets layer (SSL) for security.

For more information, visit *groov*.com or contact Opto 22 Pre-Sales Engineering:

Phone: 800-321-6786 or 951-695-3000
Email: systemseng@opto22.com.

OPTO 22
Automation made simple.



***groov* View on computer (above) and on smartphone (at left)**

***groov* Box**

Opto 22 • 43044 Business Park Drive • Temecula, CA 92590-3614 • **www.opto22.com**
SALES 800-321-6786 • 951-695-3000 • FAX 951-695-3095 • sales@opto22.com • **SUPPORT** 800-835-6786 • 951-695-3080 • FAX 951-695-3017 • support@opto22.com
© 2013 Opto 22. All rights reserved. Dimensions and specifications are subject to change. Brand or product names used herein are trademarks or registered trademarks of their respective companies or organizations.