PROFESSIONAL NOTES

Design Info Displays for Operators

By Lieutenant Commander Chapman Godbey, U.S. Navy

Three years ago, I was weapons officer on a submarine that was practicing to shoot torpedoes on a range. As usual for a weapon shoot, we manned battle stations and the close-quarters situation became even more intense. Sailors moved as smoothly as they could in the tight control room, stacking dots, plotting bearings called out from sonar, and trying to get a solution on the problem of where the other guy was and what he was doing.

This exercise came after an exhausting period of drills and tracking. I was pushing myself and the weapons control party to stay alert and focused. Operators alternated between sheer boredom and frantic action as they tracked and prepared to fire. The tactical situation changed rapidly when we got to a good firing position. Quietly but quickly, our seething mass of submariners finished the last-second details for the launch. I had my list of final checks for the torpedo, including ensuring that one of many torpedo presets was properly set at "in" or "out," depending on what we guessed our adversary would do.

At that point, it hit me: here we were at battle stations for hours, with dozens of people trying to get one weapon out of the tube. Everyone was stressed, tired, and thinking fuzzily—but I had to set something in or out. Did "in" mean to turn on the preset or turn it off? Controls and displays can become more complex in rapidly moving situations, and some of the displays are misleading. In such instances, I should not have to calculate raw bearings. I want to know where the enemy is and what he is doing. What if we have to do this in the middle of the night on a war patrol? Who else on the team would remember what "in" versus "out" means, and why I should have to care about it at the last second before firing?

When we finally got in position, the captain ordered the weapon launched. The shot was successful and our unwary target did not know what hit it. Although we performed well, the experience made me think more about why we did things the way we did. That day I started studying how we sense our environment. Eventually, I came to harangue anyone within earshot about my theory of a big red button on the console marked **SHOOT** that was easy for one person to manage and did all necessary tasks in just the right way.

I want to explain here why Navy personnel should care about information design and why display and control systems look the way they do. I hope that designers of systems for sensing, pointing, and shooting will find my observations useful as well.

Bad Displays Can Kill People

Information can be displayed or controlled in a way that prevents users from understanding actual events. We easily could have missed our torpedo shot by a quick misplot of data or because how we formatted the data prevented us from properly understanding the situation.

Data that people scan or control quickly can cause confusion. In the short time you have to fire, you have less time to integrate information and errors can be multiplied. Similar track numbers and confusion about an aircraft's altitude on a system display designed to accommodate small bandwidths and reduced computing power contributed to the accidental downing of an Iranian Airbus by the USS *Vincennes* (CG-49).

Sometimes, improper presentation of information can cause disasters. A confusing array of simultaneous alarms and misleading displays contributed to the mistakes at the Three Mile Island nuclear power facility. A power-off reset of Global Positioning System data might have caused a forward air controller to bring an air strike on his own position in Afghanistan. How many buttons have to be pressed in *exactly* the right way to get the new contact entered into your fire control system? A person uses more information to change a decision than to make that decision in the first place. Does the system you build or use take that into account?

Good design can help, too—a new way to present data can reveal new information.[1] When the surface-ship active sonar SQS-53 AN/SQQ-89 (V)14 upgrades were developed, a team of senior Navy sonar chief petty officers took advantage of a rapid prototyping system for displays that had not been used for surface sonar systems. The chiefs took advantage of the prototype designers' human factors knowledge, acquired the necessary engineering expertise, and used their experience and extensive at-sea testing to make incremental improvements. Because the data were shown in more effective ways, ships with the upgrade could sense what formerly had been invisible to them as new contacts appeared.

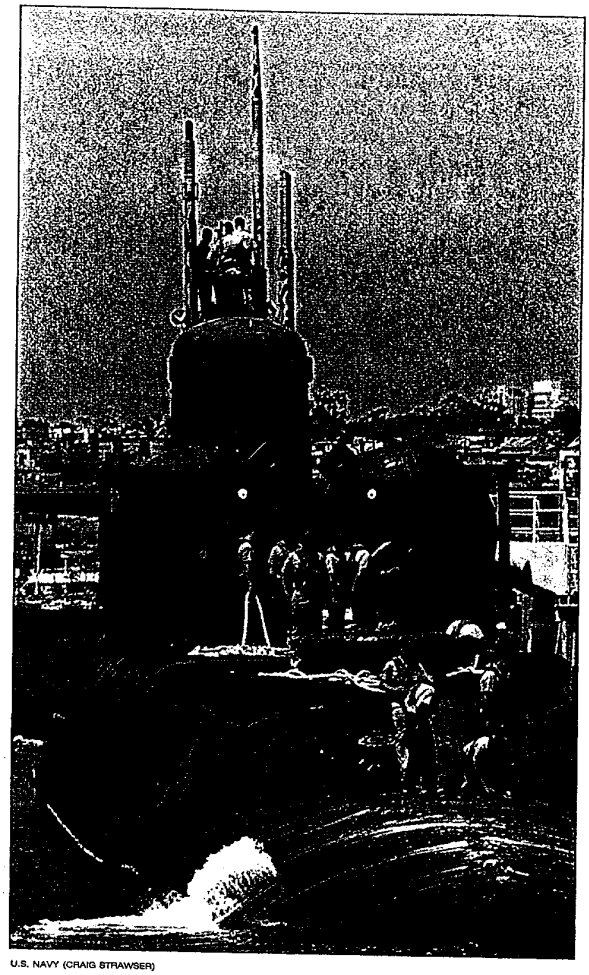
Displays and Controls Are Not Perfect

Most of the shipboard systems we work with were cutting-edge engineering at the time the system was designed and installed. Engineers fought through technical challenges to get a product mature enough to put on a ship. They consulted operators to see if the design made sense and revised the design accordingly. So, with all the good people working hard on good equipment, why do we get displays that take years of experience to interpret? The way we build and integrate ship systems can provide clues—and indicate possible improvements.

There are differences in skill sets between the people who build systems and the people who operate them. Most of the time, those skills are not in information design. For instance, an operator can tell you the pink and green screen gives him a headache, but usually he does not know that adding a flywheel effect to the knob makes the knob more natural and improves data control. An engineer can find

an innovative solution to shave six millivolts from the current draw of a portable widget, but sometimes does not realize the widget makes your hand hurt after six hours. Human factors experts, who spend their time working on how to better integrate people with systems, may not know that operators have for years updated procedures for an uncomfortable system so they can work more efficiently. And the human factors experts lose credibility when they propose a new idea that does not take into account systems and procedures that have been tried in the fleet.

Rigorous requirements for human factors standards in new and upgraded systems could more efficiently integrate these skill sets to provide a better product. Iterative designs plans, such as the advanced processing build (APB) for submarine sonar systems, allow a closer coupling between system programmer and system user. Periodic updates of the APB system provide for significant and rapid improvements.



U.S. NAVY (CRAIG STRAWSER)

Well-designed information displays help prevent disasters and better serve the operators. When technicians followed the crew's commonsense suggestion to position the aft-looking sonar display *behind* the officer of the deck, decision making was improved on board the USS *Kamehameha* (SSN-642)—here leaving Naval Air Station North Island, California.

Building a cutting-edge, unique widget also presents challenges because of the immaturity of the technology. The baseline stance that "it is good enough to work reliably, so put it on the ship" often forgets that the user has to figure it out. The best widget you can make is useless to someone who has not learned it, who thinks it is cumbersome, and who must spend time integrating the system to an existing routine.

Unfortunately, the burden of ensuring operators can best use the widget falls to the people who make the widget—an inherent conflict of interest. The difficult part here is the delicate balance between usability and the need to get equipment on ships quickly. If you spend too much time evaluating alternatives and tweaking, you never get anything on the ship. At the same time, you cannot stop innovating once a gadget is installed, or make innovations so hard or expensive that you are stuck with the original product. Program managers are working with the difficult problem of how to get continuous improvement wherever it makes operational and financial sense to do so.

One vital part of the human factors problem is the length of time it takes for people to become proficient with equipment. In the late 1990s, a multinational corporation with decades of experience in providing solutions for retail problems proposed a new cash register system for a high-volume department store chain. The new system solved many problems and added capabilities to the stores' accounting system, but the chain managers rejected the proposal. Although the experts who made the proposal met all requirements, they did not know one important piece of design information: 80% of the clerks turned over in 90 days. Thus, there simply was not enough time to train the clerks on the new system and still get sufficient return on training and capital investments. The retailers intuitively understood the turnover problem; however, they did not explain it successfully to the system designers.

Many Navy watch standers are at their stations for less than three months and few are there for more than two years. How long does it take to recoup the investment of time and training to be proficient on a new gadget? Sometimes the speed of technology outpaces the speed of learning and the natural conservatism of the operator. Who counts that opportunity cost whenever a new system is proposed?

Gaps between design and engineering projects sometimes create interesting problems in controlling and operating ship sensors and fire-control systems. This is more of a systems integration problem than an information-design problem. Nonetheless, a good human factors design requirement should consider the seams between development teams in the same way that data architecture requires standard electrical interface. For example, the teams working on the separate problems of weapon design and control in the latest heavyweight torpedo program are integrated.

More Data Can Be Better

The massive numbers of new computer screens and limited-function tactical decision aids on ships are keeping commanders from quickly assessing what is going on. Some people see this as getting too much information. Others, noting the massive amount of data a human can process just walking into a room and looking around, conclude that we get too little information. The difference between the two positions boils down to how much attention you have to pay to everything at one time. As one expert puts it, we can look at a forest and pick out an individual tree with lots of detail if we want to; but every tree does not try to focus our attention with maximum intensity all the time. Part of the integration inside a control center must be an integration of all the alarms and knobs and screens so that

important information *looks* important and makes sense to people.

On the USS *Kamehameha* (SSN-642), we had a passive sonar system that looked forward and an additional, nearly identical system that looked aft. The backward-looking "hindsight" system was an important part of our ability to stay out of harm's way in complex littoral environments involving many contacts to comprehend and SEALs to insert ashore. During an upkeep, we were scheduled to get a display that allowed us to see the hindsight sonar on the conn (part of the control room); the Naval Undersea Warfare Center technicians initially proposed putting it next to the forward display.

Our chiefs thought that something did not make sense—until we looked behind us and asked the technicians to put the display for the backward-looking sensor behind the officer of the deck. Then, every time we looked at the hindsight screen, our entire bodies reminded us where we were looking. This improved decision making and made ascents to periscope depth safer. Because we could see the other control panels, it also allowed us to better understand what was going on in the rest of the control room.

Conclusions

The way we display information can make all the difference in operational effectiveness. Design and construction of equipment can impede human factors design because the technology usually is new, different experts have different skills, and the experts are not always able to work together. The Navy's acquisition and technology transition process needs a mandated system for combining the requirements for information design and human factors. Improving the display and control of information will help prevent disasters, uncover useful data that was not apparent previously, and make better use of the people who fight ships.

Professor Edward Tufte's books on information design are classics and they have wonderful examples. See *The Visual Display of Quantitative Information* (Graphics Press, 1992) and his web site at *www.edwardtufte.com.*

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