Flexible displays: Concept interfaces for Future Force Warrior

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ABSTRACT

The present paper begins with a look at early display concepts to emerge from the soldier-as-a-system program that focused on the future warrior. In these early advanced technology demonstrations the dominant visual display was the head- or helmet-mounted display (HMD). These displays evolved from aviator-like HMDs with CRTs to miniature lighter weight liquid crystal and active matrix electro-luminescent displays. It took some time before alternative display forms were more seriously considered as developers and researchers gained a better understanding of how displays best work for a wide variety of military operators. Considering this history, the challenges faced by flexible display technology include the search for appropriate devices and form factors for application. This paper outlines how developers might more rapidly conceptualize innovative, yet functional, design concepts to address the requirements of the future dismounted soldier.

Keywords: Flexible displays, future concepts, interface design, human factors engineering, evolutionary design, user-centered design, future force warrior

1. INTRODUCTION

In 1989 the US Army began an advanced technology demonstration program to develop the soldier-as-a-system. This first system technology demonstration was referred to as the Soldier Integrated Protective Ensemble (SIPE) and was completed in 1993.[1] It grew, in part, out of a previous Army-wide effort to address the problems of the soldier's load.[2] The conclusion from the Lightening the Soldier Load study was that unless all equipment to be worn and carried by the individual soldier is developed as a system there was no way the developer could influence total load weight of various soldier load configurations. Ironically, this first Soldier System demonstration focused more on advanced technologies and future capabilities than on configuration management and reduction in system weight. Nonetheless, advances in new communications technologies for soldiers have contributed greatly to the development of the soldier-as-a-system.

2. PAST AND CURRENT "FUTURE" DISPLAYS FOR SOLDIERS

The SIPE was conceptualized at a time when there were developments in small displays in general and head- and helmet-mounted displays (HMDs) in particular. HMDs were being developed for aviators and wearable computer enthusiasts, as well as for the world of virtual reality.[3] At the same time science fiction novels and movies were presenting cyborg like soldier systems that incorporated head-mounted displays.

As early as 1966 Ivan Sutherland at MIT had created the first computer-based head-mounted display. It was a tethered HMD using two CRTs mounted on each side of the wearer's head, with mirrors reflecting the images to the user's eyes. The weight of the dual displays was carried by tethers anchored to the ceiling. It was nicknamed "The Sword of Damocles."[4]

In 1987 the movie *Terminator* was released. Of special note are the scenes from the point-of-view of the Terminator, with text and graphics overlaid on the view of the real world.[4] In 1989 the Private Eye, a lightweight head-mounted display sold by Reflection Technology, was marketed as a development device.

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The display was a 720 x 280 pixel monochrome (red) monitor in a 3.5" X 1.5" X 1.25" package. Screen size was 1.25" on the diagonal, but the image appeared to be a 15" display 18" away. This innovative display worked with the standard desk-top IBM PC of the day and allowed presentation of text and graphics.[4] Many researchers began using the Private Eye in exploratory research on HMDs for foot soldiers.[5,6]

In 1991 Henry Girolamo, of the US Army Natick Soldier Center completed a survey of near-term and future technologies for Army notional helmet systems. This was in support of the SIPE program and provided a guide to advanced technologies for helmet systems. It highlighted the advances of various display technologies primarily for HMDs and became a blueprint for many future display programs.[7]

In these early years various other Army labs were initiating studies on a wearable soldier computer that incorporated the HMD as the primary display. These were not directly tied to the SIPE program. Laboratory experiments were conducted to study the impact walking (using treadmills and mobility courses) had on the processing of information from HMDs.[5,6,8] The mindset was on head-worn displays. Early thinking about wearable computers for the soldier considered hands-free as critically important, thus, the HMD appeared to be the logical design form for the rifle carrier. Much of this research was completed prior to the development of the more advanced hand-held devices we see today and before we acquired a better understanding of how soldiers would actually use displays.

In 1992 the SciFi movie *The Universal Soldier* came out showing the soldier of the future with a monocular HMD fitted closely around one eye.[4] Such movies seemed to validate the merit and promise of these display forms. Unfortunately, what movie producers can portray actors and fictional devices doing may not match well with what soldiers and technology can ultimately do.

DARPA HMD programs were part of a miniature flat panel display development for military users who were not riflemen. These included the 1995 Maintenance And Repair Support System (MARSS) Concept, 1997 MARSS Prototype, the 1998 Special Operations Combat Management System (SOCOM) Concept, the 1999-2000 Digital-MP program (aka Micro Wearable PC and Communications System), and the Army 2000 Advanced Helmet Program (AHP) Concepts.[9,10] Most of these programs advanced the supporting technologies, brought prototype systems to soldiers, and obtained user feedback for engineering teams. However, the findings from experiments as well as developments within the wearable computer community eventually moved us away from head displays and towards a variety of alternatives, such as hand-held PDAs, PC tablets, and arm-mounted displays. It took a number of years to move the dismounted operator programs away from the HMD as the dominant display and direct them toward a more careful consideration of other display options. The evolution of commercial display devices has helped accelerate the form factor options for the military. Nevertheless, it is still necessary to look closely at the unique conditions and requirements of the ground soldier relative to the display technology.

3. GOALS OF FLEXIBLE DISPLAY INITIATIVES

In 2004 the Army teamed up with Arizona State University (ASU) to establish the Flexible Display Center (FDC). The Center's goal is to revolutionize small electronic information displays for broad application, including soldier systems.[11]

The FDC brings together academia, industry and government to develop devices that consume very little power and are small, lightweight, and rugged. The Commanding General of the US Army Research, Development and Engineering Command said flexible displays are the next revolution in information technology that will enable lighter-weight, lower-power, more-rugged systems for dismounted and mounted military applications.[12]

The expectation is that displays will develop from monochrome to full-color. They will become more flexible and conform to user equipment and elements of apparel. These displays are being developed with the hope they can be made foldable and roll-able like paper or thin plastic film. The FDC is also developing the associated manufacturing processes that are required to efficiently produce flexible displays for a

variety of devices. Thus, there is a need for FDC engineers and scientists to consider system or device design features that these displays will be a part of, beyond just the display itself.

There will be many technical challenges to making displays fully flexible, high resolution, lightweight, and power efficient. There is also the challenge of designing the systems or devices these displays will go into for specific applications. It will be important not to get locked into a narrow range of form factor options, since generating variations is key to the evolutionary design approach.

4. EVOLUTIONARY DESIGN OF THINGS

Man-made objects evolve over time as the inventors and engineers among us are constantly trying to improve on them and to work out the 'bugs'. Henry Petroski,[13] the popular writer of engineering science, tells us that the design and improvement of 'things' is a result of an evolutionary-like process. "He stresses that for any specific item, the form it has is only an arbitrary choice from many possible solutions that the inventor could have come up with. And the driving force behind invention, according to Petroski, is failure - each change in form that an invention takes is the result of trying to address some failure in what was done previously."[14]

Now almost everyone realizes that objects evolve over time but we frequently ignore the process when trying to develop new technologies. Previous designs have elements of prior evolutionary successes. Too often we throw the baby out with the bath water. When we are critical of legacy systems we tend to reject many, if not most, of their component features as well, only to realize later that these features are a result of some past 'evolutionary' successes.[15]

Sometimes innovators lock onto an idea, fall in love with it, and pursue it without seeking validation, critical analysis, and honest user feedback. In some cases an innovation, unexamined, will succeed in the marketplace. However, too often an idea with superficial appeal and not given critical analysis tends to fade after some extended effort, then reappears repeatedly, but ultimately never seems to take hold. One example has been the promise of a telephone with video for visual-vocal communication. It's an idea long in the coming but today there are very few people, if any, who are actually using the technology as envisioned. Speculation about the video-phone has been around since the 1950's, but it has never caught on as a feature of the telephone.[16] While the excuse has often been that the technology is still not quite ready (bandwidth, costs, etc.), today it is. So even though the capability is here, at little or no additional expense, no one seems to want or use a video-telephone. A variation of this can also be found in the teleconferencing technology.[17,18]

Here it is argued that the engineering and development of new technologies can advance more rapidly if there is active use of evolutionary design principles as well as a validating process of feedback. In the early development of the soldier system this would have meant paying more attention to a broader set of display options (again, variation being the driving engine of biological and object evolution) and letting soldiers explore the pros and cons of each. It also means more attention should have been given to what was happening in the commercial market in terms of portable communication technology. Although there were some attempts to commercialize HMDs (e.g., eye-glass displays), the consumer (other than the wearable computer research community) hasn't gone there. Communication displays have taken the form of PDAs, cell phones, and multipurpose MP3 devices. Thus, becoming more aware of the needs and propensities of certain target people also means observing and talking to them. We need to ask prospective users to speculate imaginatively with various proposed concepts or prototypes in the context of their work or daily lives. Such data are needed by research and design teams as they explore effective interfaces tailored to specific users and their tasks.

5. ON CONCEPTUALIZING FLEXIBLE DISPLAYS FOR FUTURE WARRIORS

In a previous SPIE paper the present author recommended that engineers more actively use mental imagery (visual thinking) of themselves or specific target users using a prototype or mockup of the device on some work-like tasks.[19] Using this approach one can facilitate the generation of design options at little cost. This, in turn, may reduce the time spent on developing designs not likely to work.

To illustrate how this might be done in consideration of FFW displays, we will consider the case of the FFW Platoon Leader executing an urban assault mission (for those not familiar with structure of an infantry platoon see appendix A). The following is a sampling of activities and actions of the Platoon Leader (PL) that can help determine interface features of information displays and devices for this operator. We can then speculate about different types of displays at different points of a mission and identify pros and cons of various design features. The following are some of the initial activities and responsibilities of a PL where he may use digital devices with visual-auditory displays (each soldier or function in this unit would need to be considered separately for their display requirements.):

This scenario starts with the Platoon Leader (PL) obtaining Fragmentary Orders (FRAGO) from his Company Commander (CO). The descriptions throughout assumes face-to-face communications but speculation for FFW suggests that most of the leader-to-leader and leader-to-subordinate communications will involve communications using radio and video teleconferencing technology. Also, in place of maps, notebooks, etc. soldiers might use PDAs, PC-tablets, etc. Selections from a sample scenario go as follows.[20]

Platoon Leader, along with other PLs, meets with the CO at company HQ to obtain his platoon's mission orders. The PL returns to his platoon area. He meets with his Platoon Sergeant (PSGT), Robotics Non-Commissioned Officer (RNCO), and Squad Leaders (SLs) to give the warning orders and guidance for the mission. Using maps, overlays and notepads these leaders and their men begin to outline plan of action, select equipment needed, make assignments, clarify rules of engagement, etc. PL, with help of subordinate leaders, develops and lays out specific aspects of the plan of the mission and determines individual squad responsibilities.

In the assembly area before deployment, PL, PSGT, and RNCO, continue working on mission plans, while SLs meet with fire teams and workout responsibilities. Everyone is involved in selecting and preparing equipment and they begin mission rehearsals (talking through and memorizing the tactical movements or actually practicing physical actions). The leaders use maps and notebooks in working out mission plans, mission rehearsals, listing equipment needed, summarizing orders, and rules of engagement. All soldiers have at least a pocket notepad for making notes, listing equipment, etc.

PL moves platoon (by foot, ground vehicle or aircraft) to the initial objective rally point (ORP), the last stop before movement to the objective, where unit continues mission planning and rehearsals. From ORP PL may initiate a reconnaissance party to observe approach and objective areas, to gather intelligence, identify cover-and-concealment positions, and placements for squads to provide support-by-fire (take pictures, mark on maps, draw, and write down notes). On return from reconnaissance, PL briefs leaders on refinements to plans and assignments. PL continues to review mission plans as he receives up-dated information. He continually reconsiders the plan as required, communicates with his leaders both above and below and gives the order, when instructed from his CO to move his unit out.

In the urban battlefield the threat can come from any direction, so formations are such that squads maintain a 360 degrees (plus high and low) watch and weapon positions (sectors of fire). Individual soldier attention is necessarily toward his assigned sector of fire. Under high threat and fast moving circumstances attention of individual soldiers cannot be easily directed towards information displays.[21] Their hands are busy with their weapons and other equipment. The PL may also be in constant radio or text-graphical contact with CO, support elements, and other PLs sending and receiving updated status reports, changes in orders, and adjusting planned action accordingly. PL is often trying to keep track of his men and the environment by scanning their locations and looking ahead (literally eyes-on look-ahead at ground-truth), judging and anticipating the situation and giving direction to the SLs (usually by radio or hand signals or face-to-face voice). While communications can be done by radio while looking out at the environment for threats and judging ground for mobility, the use of visual displays require the eyes to be on the display. Thus, when using a visual display the PL needs to be behind cover and/or concealment and pretty much stationary. It should be noted that the PL also carries a weapon and may be required to engage targets along with his men.

When using a weapon it is unlikely either radio or visual display can be used. There is little advantage to an HMD in most cases unless it can provide simple navigation cues or weapon aiming capabilities on targets on the move. However, movement itself may require eyes-on the ground. Most visual display use will be done under stationary and more secure or protective conditions (the way they now use maps). During mission execution visual displays on CDAs or arm-mounted displays must be quickly uncovered or pulled-out of pocket, probably with one hand, looked at quickly, manipulated, perhaps, with one hand, and put away again or covered quickly using one hand. Information on the display must be understood at a glance. Interaction with the display device must be quick and easy. The device should be constantly on or capable of being turned-on in an instant. Response time of the device's operating system must be in the milliseconds range. Under conditions where threats are not immediate and security is good and time available (like mission planning and rehearsals), the larger interactive display forms like PC-Ts could be used as long as they are non-encumbering and easily stored in load-bearing equipment. Map and planning are best on larger displays and viewable by several soldiers at one time. There are many other requirements like these that must be considered before full evaluation of alternate display devices can be completed.

6. CONCLUSIONS AND DISCUSSION

This paper outlined how the Army's initial advanced technology demonstrations of the soldier-as-a-system employed the head- or helmet-mounted display (HMD). Because of the prevailing mind-set it took time before alternative display forms were more seriously considered. Eventually, developers and researchers gained a better understanding of how displays best work for a variety of military operators. Mention was made of the expected challenges facing the flexible display technology initiatives including the search for appropriate devices and form factors for application to the Future Force Warrior. It was pointed out how developers might more rapidly conceptualize innovative, yet functional, design concepts to address the needs of the future dismounted soldier by generating more alternatives in design. Finally, a sample mission scenario of a small unit of action was sketched to demonstrate how through specific descriptions of specific users and tasks can facilitate development of design concepts for FFW or other applications.

The scenario described above was a sampling of soldier tasks for a platoon level mission. The focus was on the platoon leader but other members of the unit and team interactions need to be considered as well. As prototypes are developed the new concepts should be presented to soldiers and they should be asked to simulate missions, imagining they are using the features of the prototype devices for particular tasks. Such soldier-interactions with new design concepts should be done on a routine basis as design concepts and options evolve.

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Appendix A:
Infantry Platoon Structure

Each Dismounted Element (rifle platoon) has two rifle squads (seven to nine men each) and a weapons squad (six to nine men) that can operate either split, in support of each rifle squad, or can mass to support the entire platoon. Each squad has a squad leader (SL) and two fire team leaders (TL) and each fire team is made up of a TL and three men.

Dismounted Element (Platoon) (example)	count
Platoon Leader (PL) & **Platoon Sergeant** (PSGT) (PL HQ)	2
1st squad Rifle Squad: SL-1	1
Fire TL A and 3 men	4
Fire TL B and 3 men	4
2nd squad Rifle Squad: SL-2	1
Fire TL A and 3 men	4
Fire TL B and 3 men	4
3rd squad Weapons Squad: SL-3	1
Fire TL A and 3 men	4
Fire TL B and 3 men	4
Total:	29