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CSERIAC GATEWAY

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In this issue:

Page

1 HUMAN PERFORMANCE WITH NEW HELMET-MOUNTED DISPLAY DESIGNS

5 CALENDAR

6 COTR SPEAKS

7 A CONVERSATION WITH MARTIN HELANDER

10 HUMAN FACTORS IN PROCESS CONTROL: DEVELOPING CRITERIA FOR THE REVIEW OF ADVANCED HUMAN-SYSTEM INTERFACE DESIGNS

13 FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER: HUMAN FACTORS SUPPORT

16 CSERIAC PRODUCTS AND SERVICES

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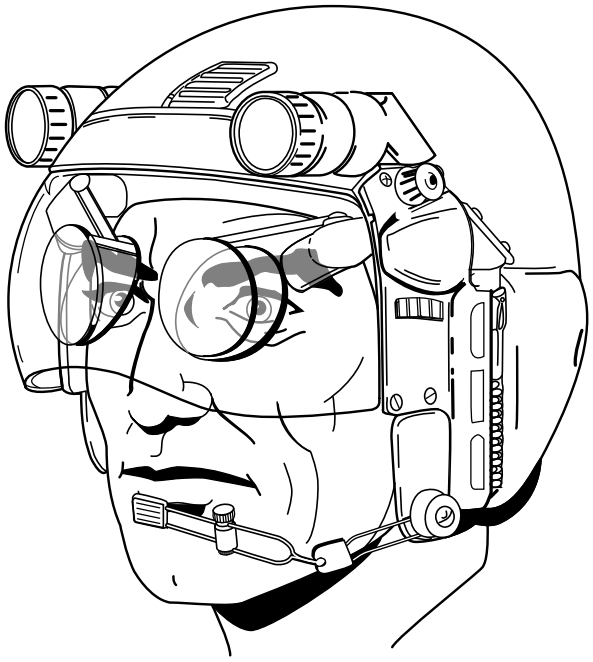

Figure 1. A version of the proposed Comanche helmet-mounted display.

Human Performance with New Helmet-Mounted Display Designs

Victor Klymenko
Clarence E. Rash

The Army's helmet-mounted display (HMD) research effort at the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, incorporates a number of interrelated disciplines. The purpose of the program is to optimize the presentation of visual information by taking into account both the physical hardware and environment on the display side, and the human visual system and cognitive capacity on the observer side. The goal is to optimally match the information display generation capabilities of the hardware technology to the visual information processing capacities of the human observer. The research relies on expertise in optical physics, optometry, electro-optical sensor and display engineering technology, and visual psychophysics and psychology. USAARL's research teams have been

Continued on page 2

psychophysically testing new designs for military HMDs (e.g., Kotulak, Morse, & McLean, 1994; Rabin & Wiley, 1994), as well as physically measuring the image quality of emerging display technologies, such as the new miniature flat panel displays being incorporated into HMDs.

New Helmet-Mounted Display Design

The proposed HMD design for the Army's new helicopter, the RAH-66 Comanche, has been the focus of USAARL's most recent HMD research (Klymenko & Rash, 1995). This new system, referred to as the Helmet Integrated Display Sight System (HIDSS), is a bi-ocular design (see Fig. 1, page 1). This is a binocular subtype in which duplicate images of the scene, derived from a single sensor, are presented individually to each eye (instead of the case where two slightly different images of the outside scene, from two sensors, are presented to the two eyes). In the current plan for the Comanche, a single nose-mounted forward-looking infrared (FLIR), or thermal, sensor provides the view of the outside world in the display images presented to the eyes. This design has the operational and performance advantages of binocular redundancy, but not the advantages of binocular depth perception (from stereoscopic disparity and binocular parallax).

The simplest way in which a bi-ocular display design can be implemented is where the sensor's view of the outside scene is presented fully to each eye. In this case, the display's available field-of-view (FOV) consists solely of a common, or full overlap, region. This would be the optimal approach; however, as sensor design has increased the available FOV, the concomitant optics needed to display the entire FOV have been limited by factors of weight, size, and image quality, so that the entire FOV cannot be presented to each eye. A technique of partial overlap is being employed to make the larger sensor FOV available to the aviator. This involves sharing the sensor FOV between the two eyes, so that each eye will see a part of the total scene. The central portion of the scene is seen by both eyes, and each eye also sees an additional adjacent portion of the visual world not seen by the other eye. As with normal human vision, the visual world is divided into three regions–a common, central binocular overlap region, seen by both eyes, and two flanking monocular regions, one seen only by the right eye and the other only by the left eye (Figs. 2 & 3).

Figure 2. Top view of the normal horizontal FOV.

The three regions of this partial overlap HMD FOV together are smaller than the normal human FOV. Current plans for the Comanche HMD call for a horizontal FOV of approximately 52 degrees of visual angle with 18 degrees of binocular overlap, whereas the normal human FOV is approximately 200 degrees with about 120 degrees of binocular overlap. The visual system sees each of the flanking monocular regions in the HMD's small FOV with two eyes rather than one (Figs. 2 & 3); the flanking regions are seen binocularly rather than monocularly. Now, each of the monocular regions is the binocular combination of the visual scene from one eye and the dark background outside the circular monocular field from the other eye. The HMD's entire FOV is within an area where the visual system expects binocular stimulation.

Partial overlap FOVs can be presented in one of two ways. One might expect the right side of the sensor's FOV (dotted circular region in Fig. 3b) to be presented to the right eye and the left side to the left eye as in normal, unaided vision. This is a divergent design. However, if the right side of the sensor's FOV is presented instead to the left eye, and the left side to the right eye, the display is a convergent design. This latter approach requires electronic processing of the sensor's output to present the correct image to each eye. These HMD-induced FOV changes have been the focus of recent HMD research at USAARL.

Visual Effects

The HMD-induced changes in the aviator's visual stimulation have raised performance questions concerning this design. The monocular regions of this HMD's FOV are in the normally bin-

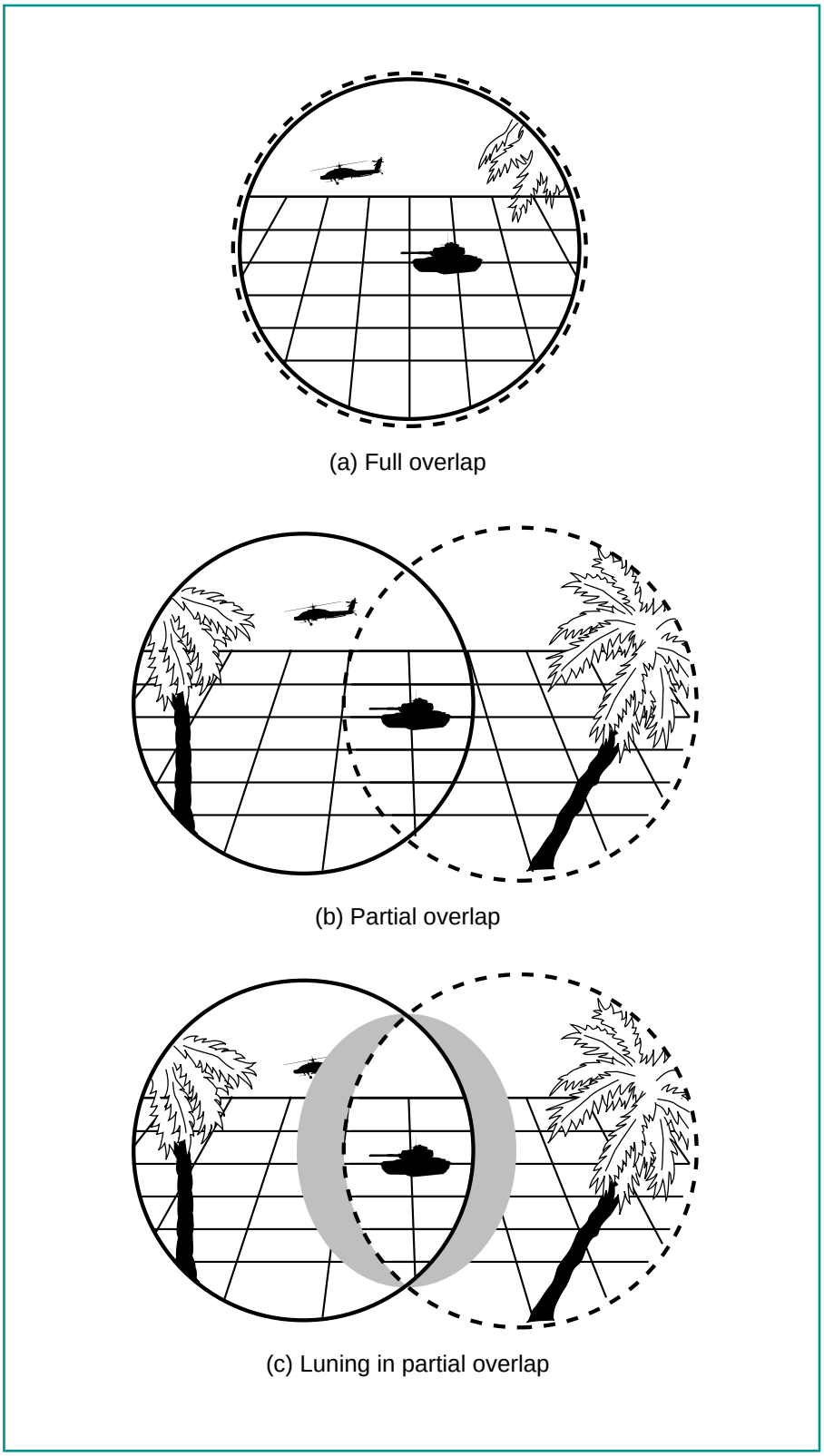

Figure 3. (a) HMD's full overlap FOV consisting of one binocular region. Each eye sees an identical image in a circular monocular field. (b) HMD's partial overlap FOV consisting of central binocular region delineated from two flanking monocular regions by binocular overlap borders. (c) Luning is the subjective darkening which can occur outside the overlap borders.

ocular area of the human FOV. The visual system is primed to receive and interpret binocular information, where the disparity between the images in the two eyes is expected to be small corresponding to the small angular difference in viewing position between the two eyes. Instead, in the HMD monocular regions, one eye sees a portion of the visual scene and the other eye sees the dark background in the corresponding location. The lack of binocular correspondence in the two images presented to the two eyes results in a visual process known as dichoptic competition, which potentially manifests itself as a number of undesirable visual effects. These include binocular rivalry, where visual awareness alternates totally or partially between the images presented to the two eyes, and monocular suppression, where one eye's input dominates awareness at the expense of the other eye. A perceptual effect which occurs when the wrong eye's image tends to dominate the binocular percept is known as "luning," a subjective darkening in the flanking monocular regions near the boundaries of the overlap region (Fig. 3c). Luning is so named because of the moon-like crescent shape of the darkened regions (CAE, 1984). Luning can cause the FOV, as a whole, to lose its visual continuity, resulting in fragmentation–the appearance of the FOV as three distinct regions. Two questions naturally present themselves: one, how to reduce luning, and two, what effect does luning have on objective visual performance, such as target detection?

To answer these questions, we designed and built a binocular vision testing laboratory, illustrated in Figure 4 (page 4), with which we simulated the different display conditions. We tested the effect of a number of display factors on luning (Klymenko, Verona, Martin, Beasley, & McLean, 1994c). The results indicated that the divergent FOV induced more luning than the convergent FOV, and placing black contours on the binocular over-

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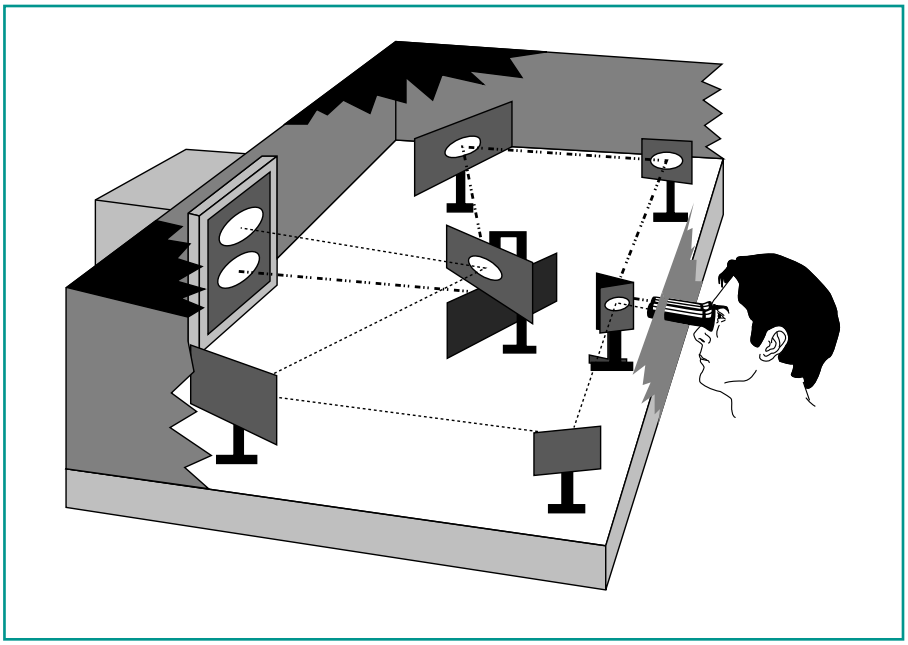

Figure 4. Perspective view of USAARL's binocular vision apparatus consisting of a computer graphics workstation to generate visual stimuli, a custom optical table mirror configuration to optically direct the image from the monitor to the viewing binoculars (lens and filters not shown), and a subject booth, a light-proof enclosure where observers view test-stimuli through the binoculars and respond with a keypad.

lap border reduced luning in both convergent and divergent FOVs, confirming previous studies (Melzer & Moffitt, 1989, 1991). Also, for the conditions with no contours or where a black contour was placed on the binocular overlap border, changing the overall display luminance level had no effect on luning; however, for the conditions with white contours on the overlap border, the magnitude of luning was dependent on display luminance. We also tested the effect of a number of factors on visual fragmentation of the FOV (Klymenko, Verona, Beasley, Martin, & McLean, 1994b).

We found that neither the monocular field size (area seen by an eye), the monocular region size (area seen exclusively by an eye), nor the total FOV size, had any effect on fragmentation. (Definitions of visual areas are given in Fig. 2.) However, the size of the binocular overlap region was a significant factor. Displays with smaller overlap regions fragmented more often. Also, divergent FOVs fragmented more than convergent FOVs. In another study, we found the contrast threshold of small targets in the scene was dependent on both the type of FOV and the position within the FOV (Klymenko, Verona, Beasley, Martin, & McLean, 1994a). Target visibility was particularly poor for divergent FOVs, especially for small targets located in the monocular regions near the binocular overlap border (see Fig. 3c). The divergent FOVs which induced the most luning and fragmentation also reduced target visibility the most.

We have described some results of our research at USAARL on the effect of binocular HMD designs on human performance. Future efforts will focus on the physical and psychophysical evaluation of the incorporation of the new miniature flat panel display technology into the HMD platform. ●

Victor Klymenko, Ph.D., is a Cognitive Psychologist with UES, Inc., working at the U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL. Clarence E. Rash, M.S., is a Research Physicist with the U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL.

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Calendar

November 6-9, 1995
Monterey, CA, USA
35th Biennial Meeting of the Department of Defense Human Factors Engineering Technical Advisory Group (DoD HFE TAG). Contact Sheryl Cosing, TAG Coordinator, 2444 Ridgehampton Court, Reston, VA 22091. (703) 758-2574, fax (703) 758-1493. Email: scosing@arl.mil *The meeting is open to all government personnel and others by specific invitation.*

November 14-16, 1995
Yellow Springs, OH, USA
A Short Course in Anthropometry. This course emphasizes hands-on training in anthropometric measurement and provides background lecture material. Contact Anthropology Research Project, Inc., PO Box 307, Yellow Springs, OH 45387. (513) 767-7226, fax (513) 767-9350.

November 30-December 1, 1995
San Francisco, CA, USA
Ergonomics Programs and Their Impact: A Presentation and Evaluation of Existing Ergonomics Programs. Contact Patricia J. Cottrell, University of Michigan Center for Occupational Health and Safety Engineering, 1205 Beal, 174 IOE Building, Ann Arbor, MI 48109-2117. (313) 936-0148, fax 764-3451.

January 7, 1996
Washington, DC, USA
29th Annual Human Factors in Transportation Workshop in conjunction with the 75th Annual Meeting of the Transportation Research Board. Contact Richard F. Pain at (202) 334-2964, fax (202) 334-2003. Email: rpain@nas.edu Or write Transportation Research Board, 2101 Constitution Ave, NW, Washington, DC 20418.

February 5-7, 1996
Madison, WI, USA
Using Ergonomic Fundamentals to Analyze and Design Jobs, Work Methods, and Workstations Workshop. Contact Engineering Registration, The Wisconsin Center, 702 Langdon Street, Madison, WI 53706. (800) 442-4214 or (608) 265-3448, fax (800) 462-0876 or (608) 262-1299.

February 7-9, 1996
Madison, WI, USA
Advanced Ergonomics Application Workshop offered by the College of Engineering, University of Wisconsin. Contact Engineering Registration, The Wisconsin Center, 702 Langdon Street, Madison, WI 53706. (800) 442-4214 or (608) 265-3448, fax (800) 462-0876 or (608) 262-1299.

February 11-16, 1996
Fremantle, Western Australia
2nd International Conference on Fatigue and Transportation: Education, Engineering, and Enforcement Solutions. Contact Laurence R. Hartley, Dept. of Psychology, Murdoch University, Western Australia 6150. +61 9 360 2398, fax +61 9 310 9611. Email: hartley@socs.murdoch.edu.au.

March 12-15, 1996
Ann Arbor, MI, USA
Industrial Hygiene Comprehensive Review. Contact Patricia J. Cottrell, University of Michigan Center for Occupational Health and Safety Engineering, 1205 Beal, 174 IOE Building, Ann Arbor, MI 48109-2117. (313) 936-0148, fax 764-3451.

April 10-12, 1996
Leicester, United Kingdom
1996 Annual Conference of the Ergonomics Society to be held at the University of Leicester. Contact the Conference Manager, The Ergonomics Society, Devonshire House, Devonshire Square, Loughborough, Leicestershire LE11 3DW, UK. Telephone and fax +44 509 234904.

April 14-18, 1996
Vancouver, British Columbia, Canada
CHI 96. Conference on Human Factors in Computing Systems. Contact Deborah Compere, CHI 96 Conference Administrator, Conference and Logistics Consultants, 703 Giddings Ave., Suite U-3, Annapolis, MD 21401. (410) 263-5382, fax (410) 267-0332. Email: chi96-office@sigchi.acm.org

May 12-15, 1996
Palo Alto, CA, USA
ErgoCon '96. Silicon Valley Ergonomics Conference & Exposition. Contact Abbas Moallem, ErgoCon '96 Conference Chair, Silicon Valley Ergonomics Institute, San Jose State University, One Washington Square, San Jose, CA 95192-0180. (408) 924-4132, fax (408) 924-4153. Email: amoallem@isc.sjsu.edu. World Wide Web: http://www-engr.sjsu.edu/ergocon96/ *Proposals for papers, posters, workshops, and panel discussions due November 6, 1995.*

May 12-17, 1996
San Diego, CA, USA
SID '96. Society for Information Display International Symposium, Seminar, and Exhibition. Contact Terence J. Nelson, SID '96 Conference Chair, Bellcore, 445 South Street, M/S 2L241, Morristown, NJ 07962. (201) 829-4865, fax (201) 829-5885. Email: tnelson@faline.bellcore.com *Abstracts and technical summaries due December 1, 1995.*

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022

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Rabin, J., & Wiley, R. W. (1994). *Switching from forward-looking infrared to night vision goggles: transitory effects on visual resolution* (Tech. Rep. USAARL 94-28). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory.

The COTR Speaks

Reuben L. Hann

The U.S. Army Aeromedical Research Laboratory (AARL) has been developing a new helmet-mounted display (HMD) for use with its RAH-66 Comanche helicopter. The challenge facing AARL is to match the capabilities of hardware technology with the unique characteristics of the human visual system. Dr. Victor Klymenko of UES, Inc., and Clarence E. Rash of AARL have joined forces to provide us with our feature article that shows us how AARL is tackling this challenge.

In 1993, Dr. Martin Helander, then at the State University of New York, Buffalo, and now at the Linköping Institute of Technology, Linköping, Sweden, was our sixth distinguished speaker in the Armstrong Laboratory Colloquium Series: The Human-Computer Interface. He spoke on "Models of Assembly, Task Allocation, and Computer-Integrated Manufacturing" which he later rewrote as a feature article for *Gateway* (Vol. IV, No. 4, 1993) entitled "Automation and Human-Computer Interaction in Manufacturing." Although I had the opportunity to speak with him during his visit, unfortunately, we were unable to publish the interview in that issue of *Gateway*. However, we finally have the opportunity to share excerpts of my conversation with Dr. Helander in this issue.

Designing control rooms has never been an easy task. But for an organization which has oversight responsibility for nuclear power plant control rooms, the task of setting standards for control rooms must be daunting. In this issue, Jerry Wachtel of the Nuclear Regulatory Commission (NRC) has given us some insight into how the NRC is developing guidelines that will ensure the safe operation of nuclear power plants.

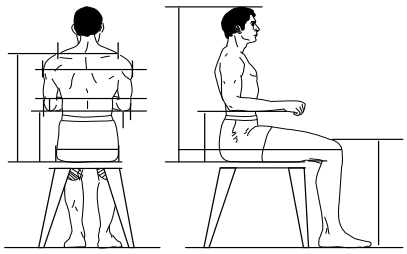
The third installment in our series on CSERIAC Technical Area Tasks (TATs), our most comprehensive level of service, focuses on CSERIAC's work with the Federal Aviation Administration (FAA). Mike Reynolds, Senior Human Factors Engineer with CSERIAC, has written about his team's work with the FAA Technical Center to help evaluate flight simulator-based systems. In addition, he provides information about some upcoming projects where CSERIAC will continue to assist the FAA Technical Center in their human factors research.

We are pleased to announce that we have received our first commercial advertisements for *Gateway*. The first, announcing a short course on anthropometry, appears on this page while the second, announcing the availability of an ergonomics manual, appears on page 15. For those readers interested in placing commercial ads in *Gateway*, please contact our Editor, Jeff Landis, at (513) 255-4842 or fax (513) 255-4823.

Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Manager for the CSERIAC Program.

A Short Course in

ANTHROPOMETRY



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Armstrong Laboratory Human Engineering Division Colloquium Series

A Conversation with Martin Helander

Reuben L. Hann

Editor's note: Following is an edited transcript of a conversation with Dr. Martin Helander, then at the State University of New York, Buffalo, and now at the Linköping Institute of Technology, Linköping, Sweden. He is also the current President of the International Ergonomics Association (IEA). Furthermore, he is involved with starting an Institute on Human Factors in Aviation in Linköping. He spoke on "Models of Assembly, Task Allocation, and Computer-Integrated Manufacturing" during the 1993 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL

CSERIAC: First, a bit about your background. I see you were trained in Sweden as an engineer.

Dr. Helander: Yes—as a civil engineer at Chalmers University of Technology in Göteborg, Sweden. I did traffic safety research and took an interest in road design and the effect of design parameters on driver behavior. I studied physiological activation as a function of road design features, and the continuous adaptation of the driver to the road environment, and how this could be measured using physiological measures such as galvanic skin response.

CSERIAC: It is amazing that you were able to pursue these kinds of studies while in a civil engineering program.

Dr. Helander: I was fortunate to have a very liberal professor. He was interested in a broad range of issues, and encouraged me to do unusual things. I think I was the first person who used the term "hypothesis testing" in the Department of Civil Engineering.

CSERIAC: I notice you made a distinction between cognitive engineering and human factors during your presentation. Could you say a bit more about that?

Dr. Helander: The way I see it, in cognitive engineering you may use analytical methods for designing a system. These methods work *top-down*; you can devise a broad methodology for designing a system. In human factors and experimental psychology it is the other way around—it is a *bottom-up* approach. If you need to design a cockpit, for example, you would work with a very specific set of restrictions in technology and tasks. Here the bottom-up approach is appropriate, since you would investigate things like anthropometry or control/display design—working with the system components of a task and trying to build a system.

Now, if you are designing a system for manufacturing, you cannot afford to analyze subsytems in such great detail as you would in cockpit design. It really needs a different approach. I don't think this has been recognized enough in the scientific community. Even among my colleagues in operations research, most of the studies are bottom-up. They are developing algorithms for optimizing this or that, but not really looking at the "big picture." So, we need a broad approach to problem solving.

CSERIAC: Some persons claim the applicability of artificial intelligence was "oversold." Do you believe that automation has also been—to some extent—a victim of overly enthusiastic proponents?

Dr. Helander: I think *design* automation is extremely important. I believe that spending research resources on comprehensive methods for concurrent design is appropriate and significant, but, when it comes to manufacturing and assembly of products, the use of automation is less important. Of course, manufacturing engineers are accustomed to exercising their engineering skills; they are not trained to look into the human factors aspects of the system. In the 1980s, they were hit by many surprises when they realized that the automation schemes they had come up with didn't pay off. The government has

"If you are designing a system for manufacturing, you cannot afford the analyses in such great detail as you have in a cockpit design. It really needs a different approach."

Continued on page 8

also had a number of similar experiences, where the human factors aspects of automation were overlooked. I think this is what is now hitting industry.

CSERIAC: I was struck by your description of how you "tailored" some jobs to make the automation work better, with the result—in a few cases—that the human could actually do the task more cost-effectively.

Dr. Helander: Yes, this came as a surprise. If you truly design a system with the human in mind, you will usually come up with a very different system. The reason we looked into these issues was because of the restrictions in product design encountered using automation to assemble new products. People can always adapt to any peculiar demands you make of them, but a robot does not have that kind of adaptability; you have to design products very carefully so that robots can put them together. What we observed was that people profit from the same principles. A product designed for automatic assembly can be assembled so fast by human operators that automation may not be cost-effective.

So this is the irony: In industrial engineering we are experts at modeling the time aspects of a task, using time-motions studies, for example. But time-motion is not a good methodology for questioning the method of *how* the task is being done or the product designed. This is our great weakness.

CSERIAC: Have you every looked at the notion of "trust" with regard to the human operator's attitude about the automated portions of his or her task?

Dr. Helander: It is a complex problem. In the area of automated decision making, for instance, the notion of trust is often discussed. The computer frequently comes up with different decisions than a human would

Scenes from the Armstrong Laboratory Human Engineering Division Colloquium Series:

Dr. Martin Helander speaking on automation and human-computer interaction to a crowded auditorium at Wright-Patterson Air Force Base, OH.

Dr. Helander speaking with several visitors following his lecture.

make in the same situation—due mostly to the biases we bring to the task. Computers are much better than humans at taking into consideration probabilities and calculating which decisions are made under uncertainty. Because of their human biases, people are going to find that their decisions differ from those of the computer. This leads to a distrust of the machine. So I think people using these systems need to be made aware of the computer's "working methodology." This could improve operator trust.

CSERIAC: I once heard a presentation about the use of "explanation" in computer-aided decision making. That is, the system, when asked, was able to tell the human operator *how* it arrived at its decision or recommendation for action. This sounds very much like the "working methodology" you are referring to.

Dr. Helander: Yes, this additional information would greatly enhance the operator's "trust" in the automated decision process.

CSERIAC: Sweden seems to have taken the lead internationally in the area of establishing strict ergonomics standards for video display terminals. Why do you think that it has been the country to take such a strong stand in this field?

Dr. Helander: This has to do with the strength of the labor unions in Sweden. Not only the blue-collar, but also the white-collar unions have expressed much interest in VDTs [video display terminals]. They have taken very seriously the strains—or supposed strains—of working with VDTs. Some of the controversial issues have not yet been cleared up in research. For example, is it possible to identify one keyboard–from a set of keyboards–that will reduce the rate of biomechanical injuries? To what extent do psychosomatic factors affect reported injuries? And should such factors affect how we work as ergonomists?

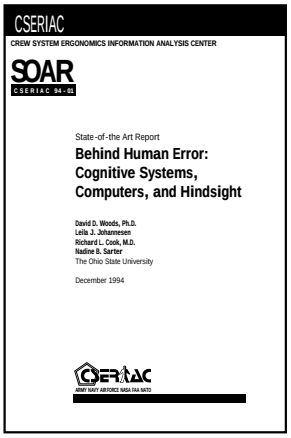
Nonetheless, the Swedes were among the first to write a standard for VDTs. They came right after the Germans, who had introduced their own standards through DIN [Deutsches Institut fuer Normung] about 1977. I saw the potential for the US to write its own standards for VDT terminal design. So about ten years ago I organized the group which developed the ANSI/HFS 100-1988, *American National Standard for Human Factors Engineering of Video Display Terminal Workstations*. This effort was inspired in large part by the work going on in Europe. It has become HFES's [Human Factors and Ergonomics Society] most successful publication. ●

Behind Human Error

Cognitive Systems, Computers, and Hindsight

David D. Woods, Leila J. Johannesen, Richard I. Cook, & Nadine B. Sarter

The Ohio State University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Behind Human Error: Cognitive Systems, Computers, and Hindsight
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Richard L. Cook, M.D.
Nadine B. Sarter
The Ohio State University
December 1994

Behind Human Error: Cognitive Systems, Computers, and Hindsight (Woods, Johannesen, Cook, and Sarter, 1994).

Accident investigations have often found operators of complex systems to be points of failure, and hence the perception exists that there is a human error problem. This view turns out to be too simplified to allow us to learn from incidents and failures. To learn about the nature of system failure, one must go behind human error by seeing error not as an end point, but as the starting point for investigation. A new state-of-the-art report (SOAR) from CSERIAC investigates what lies behind human error. It explains how outcome knowledge biases our attribution of error. It shows how cognitive system factors play a role in accidents and illustrates the importance of strategic tradeoffs and conflicting goals faced by system operators. It focuses especially on how the design of computers, automation, and other new technology affects the potential for system failure.

Price: $39 plus shipping. To order, contact the CSERIAC Program Office at (513) 255-4842 or DSN 785-4842.

Human Factors in Process Control: Developing Criteria for the Review of Advanced Human-System Interface Designs

Jerry Wachtel

What does a nuclear power plant control room (see Fig. 1), have in common with a Federal Aviation Administration in-route air traffic control center, a railroad routing center (see Fig. 2), or a freeway incident management center? Each of these facilities, despite major differences in purpose, scope, safety impact, and the regulatory environment in which they function, exhibits an increasingly common approach from a human factors perspective (i.e., a complex process controlled by several operations personnel and their supervisors from a centralized control center). Such process control centers have, of course, existed for many years (except, perhaps, in freeway incident management) but have only recently begun to exhibit dramatic change as a result of the availability of new, more powerful, human-system interface (HSI) technologies.

The U.S. Nuclear Regulatory Commission (NRC) reviews the human factors characteristics of commercial nuclear power plant control rooms and "local" control stations (those located proximal to specific equipment throughout the plant) to determine if they are designed and built to standards sufficient to ensure that the nuclear power generation process can be conducted safely. Although the NRC staff does not design facilities, it has learned much about the design process and the designs which result from it to support the mandate for regulatory review. During a four-year effort that recently culminated with the publication for public comment of the NRC's HSI review criteria, we have learned many valuable lessons from work undertaken in other industries and in other countries. The lessons learned have, in turn, proven useful to those responsible for the design, operation, and review of process control centers in diverse industries worldwide.

Background

In the past, NRC reviews of control room HSI were directed toward the individual nuclear power plant facilities already in existence. In contrast, future plants will employ control rooms which will use increased automation and computer-based technologies that will affect the operators' overall roles and their means of interacting with the plants. A key issue to emerge from our initial advanced control room reviews was that detailed HSI design information was not available because the vendors were early in the design process. Accordingly, we developed criteria for the review of a human factors engineering (HFE) design process and guidelines for the review of the resultant design. The *Human Factors Engineering Program Review Model* (U.S. Nuclear Regulatory Commission, 1994) and *Human-System Interface Design Review Guideline–Draft Report for Comment* (*Guideline*) (O'Hara, Brown, Stubler, Wachtel, & Persensky, 1995), were developed to meet these objectives. This article will focus on the latter.

Guideline Development and Description

Based upon an evaluation of research and industry experience re-

Table 1. High-Level Design Review Principles

Category	Principle
General	Safety, Cognitive Compatibility, Physiological Compatibility, Design Simplicity, Consistency
Primary Task	Situation Awareness, Task Compatibility, User-Model Compatibility, Design Organization of HSI Elements, Logical/Explicit Structure, Timeliness, Controls/ Displays Compatibility, Feedback
Secondary Task Control	Cognitive Workload, Response Workload
Task Support	Flexibility, User Guidance & Support, Error Tolerance & Control

Figure 1. A nuclear power plant control room simulator. Reprinted with permission of the Electricité de France.

lated to the integration of personnel and advanced systems, we developed a set of High-Level Design Review Principles (see Table 1). These principles provide the generic HSI characteristics necessary to support operator performance and make systems more tolerant of human error. Since these principles were general in nature, they were further developed to a level of detail sufficient to support HSI review and evaluation. They were then translated into terms that could be applied to specific applications by developing guidelines for the review of the specific types of technology (e.g., graphic displays and expert systems).

Due to the commonality of HSIs across industries, we determined that it was unnecessary for us to reinvent guidelines developed elsewhere, particularly given our criterion for including only individual guidelines that had demonstrated validity. Thus, the effort to develop detailed guidelines began with an identification of existing human factors guidance documents for advanced HSIs. (Note that an existing NRC document [U.S. Nuclear Regulatory Commission, 1981] contained guidance for the review of conventional technology). Through a critical review of the literature, some 50 previous efforts were identified and evaluated based on validity. "Internal" validity was evaluated by the degree to which the individual guidelines within a document were based upon empirical research and provided an audit trail to that research. "External" validity was evaluated as a function of the degree to which independent peer reviewers determined the guidelines conformed to accepted human engineering practice. Our rigorous weighting process yielded a compendium of documents which we designated as "primary sources."

These primary source guidelines were edited to eliminate duplication and to produce a common format. Compound guidelines were simplified, and conflicts between guidelines were resolved. The editing process resulted in a reduction from several thousand guidelines originally identified to about 1,600 which have survived in the draft recently published for comment.

Figure 2. A railroad traffic control center, Stockholm , Sweden.

The *Guideline* was organized into eight major sections, each containing both general and more detailed guidelines addressing specific HSI imple-

mentations, techniques, and formats. "Information Display" deals with the formatting of text and graphic visual displays. "User-System Interaction" addresses the modes of interaction between the operator and the HSI. "Process Control and Input Devices" addresses information entry, operator dialog, display control, information manipulation, and system response time. "Alarms" is currently a place holder for the results of another NRC research project to develop review guidance in the area of advanced alarm systems. "Analysis and Decision Aids" addresses the use of knowledge-based systems. "Inter-Personnel Communication" contains guidelines for activities related to speech and computer-mediated communication between plant personnel. "Workplace Design" addresses the organization of displays and controls within individual workstations and control room configuration and environment. A final section addresses the special considerations associated with "Local Control Stations."

In addition to a hard-copy document, the *Guideline* has been developed as an interactive, computer-based review aid. The interactive document will facilitate review planning, guideline access and evaluation, data analysis, and report preparation. *Guideline* maintenance, such as editing and the incorporation of new guidelines as they become available, is also supported. Availability of the *Guideline* on a portable computer will also facilitate in-field reviews, report preparation, and debriefings.

Because of our reliance upon existing, validated guidance developed both within and outside the nuclear industry and the rapidly changing technology being developed for and incorporated into advanced control rooms, we knew that our initial *Guideline* would be incomplete–that it would reflect "gaps" in those technological areas for which existing, adequate guidance was not yet available or had not yet undergone thorough validation testing. In those areas, we plan to develop and test new guidelines as part of other ongoing and future research projects.

Limitations in the Applicability of Guidelines

Nuclear power plant control rooms, despite calm appearances during normal operations, can be very dynamic, demanding, and stressful environments during rare abnormal or emergency events. However comprehensive, static HSI guidelines cannot possibly support the evaluation of those time-sensitive operator responses necessary to determine if the crew can meet system performance requirements. Although a guideline-based review is a necessary part of a comprehensive HSI review process, it is not sufficient as the only design review methodology. It is essential that an HSI review strategy acknowledge and accommodate both the strengths and limitations of HFE guidelines. These limitations can be minimized by using a review methodology that addresses the requirements of tasks operators must perform. This methodology is intended to improve the reviewer's ability to make the guidelines more sensitive to the task context and to overcome some of the unique issues associated with the review of advanced systems. However, since the limitations cannot be completely eliminated, a complete review must use multiple evaluation methods (including, for example, a dynamic simulation evaluation) to complement the use of HFE guidelines. NUREG-0700, Revision 1 provides guidance and review procedures for conducting such a comprehensive design review.

Conclusions

A framework for the review of HSIs in advanced nuclear power plants has been developed. Safety evaluations are based upon the information from both the design process and its products. The *Program Review Model* provides criteria for the review of the design process and the *Guideline* provides guidance for the review of the HSI resulting from the process. This framework is being used to support the NRC reviews of the HFE programs for the current advanced control room designs being evaluated for design certification, and it will be applied, as appropriate, to the review of advanced HSI being backfit into conventional control rooms. We have learned a great deal from work in other industries, and we hope that the results of our efforts will prove useful to those who must design HSI and those who must review such designs in other complex human-machine systems. ●

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CSERIAC Technical Area Tasks

Federal Aviation Administration Technical Center: Human Factors Support

Michael C. Reynolds

This is the third in a series of articles on CSERIAC's technical area tasks (TATs), a vehicle which gives customers the ability to tailor CSERIAC's services to meet their unique human factors needs. CSERIAC has supported the Federal Aviation Administration (FAA) Technical Center's Airborne Data Link Branch for the last two years. The valuable support provided by CSERIAC resulted in a new, five-year interagency agreement between the FAA and the Defense Technical Information Center (CSERIAC's sponsor). This agreement will continue CSERIAC's support to the FAA on flight deck human factors research activities.

The FAA Technical Center conducts flight deck human factors research to support the certification and flight standards functions of the FAA. In this role, the Technical Center conducts both large-scale and small-scale flight simulator-based systems evaluations. The FAA requires significant amounts of information to plan, coordinate, conduct, and document these evaluations. CSERIAC's role has been to provide this information in a number of ways. For example, CSERIAC has gathered and assimilated information on perceived problems within the National Airspace System that are related to the technologies employed by pilots and air traffic controllers.

CSERIAC's initial involvement under the new agreement will provide support in three areas. CSERIAC will survey several major airlines on fleet composition and review existing avionics equipment. This information will assist the FAA in the critical area of retrofitting older aircraft with data link avionics. CSERIAC will look at integrating data link communications with controls and displays on existing flight decks from a human factors perspective. CSERIAC will also gather information on aircraft operating procedures, airline training methods, and flight dispatch methods. Data link procedures must be incorporated into existing procedures and training must conform with existing training and flight deck operations.

Another area of CSERIAC support involves gathering and assimilating information on various topics of interest to FAA researchers, for example, crew alerting, automation effects, and display design and placement. CSERIAC will also survey the primary data link research organizations on a regular basis and provide the FAA with a continuous awareness of ongoing flight deck data link research (see Fig. 1). In addition, CSERIAC will review available literature for information related to the flight deck research at the FAA Technical Center.

CSERIAC will provide human factors support (planning, execution, and documentation) for actual flight deck evaluations conducted by the FAA Technical Center. The FAA has several evaluations planned for the next five years with a retrofit avionics evaluation planned for

Continued on page 14

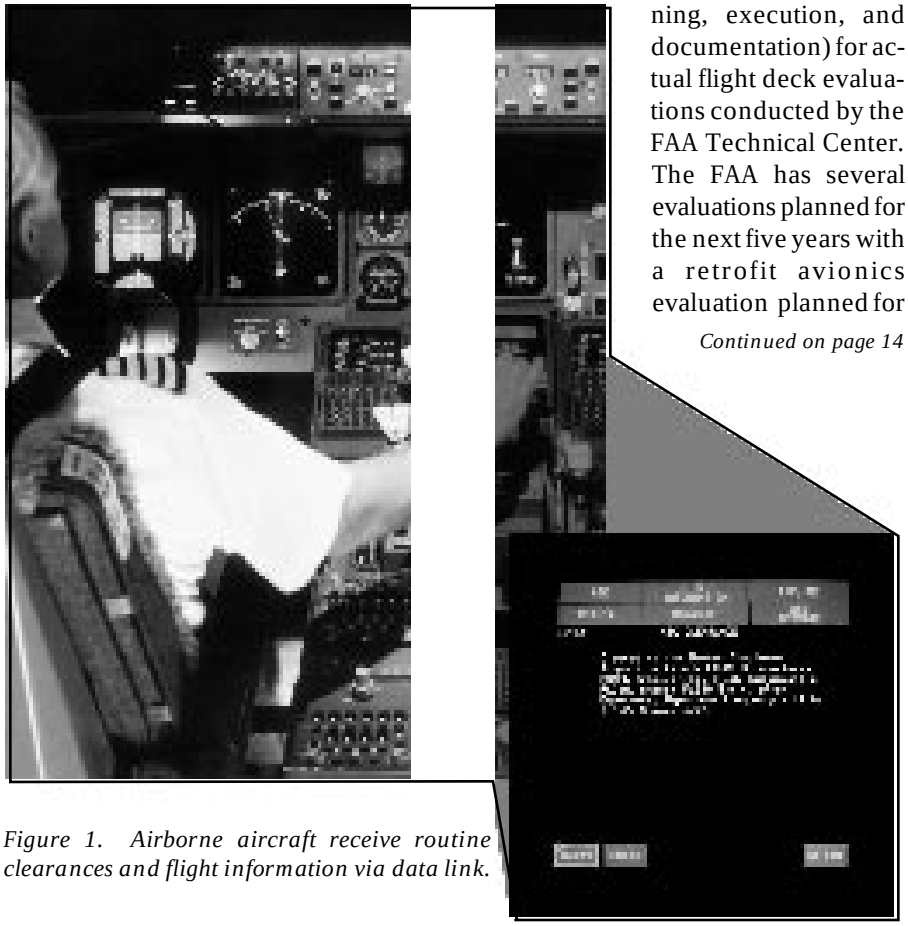

Figure 1. Airborne aircraft receive routine clearances and flight information via data link.

the Fall of 1995. This evaluation will assess pilot reactions to an early 1960s commercial airplane retrofit which involves the installation of a data link capable flight management system and a navigation map display.

CSERIAC has access to a vast amount of information that the FAA needs to conduct this important research. This includes an in-house library, direct access to numerous databases (e.g., on-line and CD-ROM sources), and an extensive expert network. Furthermore, the CSERIAC staff has several years of direct experience in the area of data link human factors research. Previous support to the FAA has allowed CSERIAC to build significant experience is this area. This expertise has proven invaluable to the FAA. ●

Michael C. Reynolds is a Senior Human Factors Engineer with CSERIAC.

Request for Topics For State-of-the-Art Reports (SOARS)

CSERIAC makes every effort to be sensitive to the needs of its users. Therefore, we are asking you to suggest possible topics for future SOARS that would be of value to the Human Factors/Ergonomics community. Previous SOARs have included *Hypertext: Prospects and Problems for Crew System Design* by Robert J. Glushko, and *Three Dimensional Displays: Perception, Implication, Applications* by Christopher D. Wickens, Steven Todd, & Karen Seidler. Your input would be greatly appreciated.

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