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CSERIAC GATEWAY

PUBLISHED BY THE CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER

In this issue:

CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Alexandria, VA, hosted by the Armstrong Laboratory Human Engineering Division, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

Figure 1. The Anniversary logo for the Fitts Human Engineering Division.

50 Years of Human Engineering

Paul M. Fitts Human Engineering Division May 1945 - May 1995

Walter C. Summers[1]

Fifty years ago this summer, a group of talented and dedicated professionals, led by Paul M. Fitts, founded the Psychology Branch of the Aero Medical Laboratory and, with it, the entire field of human engineering. With the modern title of "Human Engineering Division," the organization now marks 50 years of continuous human engineering research and development for the Air Force. The program Dr. Fitts founded at Wright-Patterson Air Force Base flourishes today, providing the Air Force Materiel Command with a focus for Air Force, DOD, national, and international research and development in the human engineering disciplines. In recognition of this 50-year anniversary, the Human Engineering Division will stage a week-long celebration from June 12-16 to honor its storied past. The Anniversary logo is featured in Figure 1.

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Distinguished History

On May 29, 1945, the Headquarters for U.S. Army Air Forces (HQ USAAF) directed the Air Material Command at Wright Field (near Dayton, Ohio) to establish a psychological research facility to study equipment design problems. As a result, there was established, on July 1, 1945, a Psychology Branch of the Aero Medical Laboratory. Dr. Paul M. Fitts (Lt. Col.) [see the inset on Paul M. Fitts], stationed in the Office of the Air Surgeon, was selected to head the new venture at Wright Field.

Most of the initial staffing of the Psychology Branch was by officers and enlisted men from the wartime Aviation Psychology Program. Initially, space was made available in Building 29. Within a few years, construction of a new building, Building 248, provided two floors specifically for the Psychology Branch. Building 248 is the home of the Human Engineering Division to this day.

With the war drawing to a close, why did the Air Force find it necessary to set up a new and pioneering program of psychological research? The answer lay in the fact that a major weakness in many weapon and support systems during wartime was the human operator. Far too many aircraft and their crews were lost because of pilot or navigator error. Bombing accuracy fell far short of what the systems should have been capable of delivering. Although the human operator proved to be a major weakness, it was realized that much of the fault was in the original design of the equipment, which was often poorly matched to the physical and intellectual capabilities of the men and women who had to use it. Research was needed to find designs which were more compatible with human capabilities.

For the members of the new Psychology Branch, coming to Wright Field was a very stimulating experience. Here they learned about the Air Force of the future; about partial pressure suits, advanced G suits, atomic flash protectors, and liquid oxygen converters; and about jet aircraft, rocket engines, transistors, new concepts of air traffic control, new ideas for aircraft cockpits, and many other new areas of aviation development.

With the war's end, many members of the Psychology Branch staff were replaced. Among the new additions were pilots, navigators, and bombardiers, some with no training in psychology. They were, however, valuable additions to the group because of their personal knowledge of flight operations and flight crew duties. Figure 2 shows the staff in 1948.

About 1958, the Anthropology Section, under Ed Hertzberg, joined the branch. Some years later, the branch's mission was again expanded to include research on training, with special emphasis on design of training devices and equipment. Dr. Gordon Eckstrand headed this new activity.

To give proper direction to their research, members of the Psychology Branch visited nearby laboratories whose end items would be the focus of their research. These laboratories were primarily Communication and Navigation (radios, instrument landing systems, and air traffic control), Equipment (aircraft instruments, instrument and cockpit lighting), Aircraft (crew station design and layout), and Armament (radar and fire control systems). When project engineers in these laboratories understood that the Psychology Branch was not developing competitive end items, they were happy to talk about operator problems. Many valuable research ideas came from these discussions.

A number of landmark research efforts took place in the early days. Dr. Julian Christensen conducted activity analyses of navigators in B-20 aircraft during very long operational-type missions, mostly in the Arctic.

Figure 2. The personnel of the Psychology Branch in 1948. Standing in the back row, from left: Lt. Wise, Mr. Bakalus, Mr. Gardener, Miss Fuerst, Mr. Roettele, Miss Connell, Mr. Warrick, Mrs. Morris, Mr. Christensen, MSgt. Kake, Sgt. Edison, and Mr. White. Seated in the front row, from left: Capt. Jones, Maj. Long, Dr. Fitts, Dr. Grether, Dr. Biel, and Capt. Wilcox.

The experience gave him valuable data on how the navigators conducted their duties and membership in the exclusive Pole Vaulters Club as well. Elsewhere, lack of standardization and differentiation of cockpit controls and displays, in terms of location, shape, and operation, was a major contributor to human error among pilots.

"Many of Lt. Col. Fitts' early experiments dealt with the design of air crew stations....The controls and displays in WWII airplanes were similar in shape, design, and location. If a flight member mistakenly grabbed the wrong control, an aircraft accident or bombing error could result."

Charles Bates, May 1985
Human Engineering, Yesterday and Today, *Civilian Employees Reporter*

Numerous experiments were conducted in this "knobs and dials" research era, especially focusing on the six principal indicators of horizon, altitude, air speed, rate of climb, heading, and rate-of-turn, resulting in lifesaving advances in the design of cockpit controls. From interview and crash data, scientists determined that errors in reading instruments, principally the three-pointer altimeter, were a major problem. A redesigned altimeter with a single pointer and odometer was tested, proven to be superior, and eventually became the standard. Finally, interest in possible benefit from flying in the face down, or prone, position was put to the test by members of the Anthropology Section of the Psychology Branch using controls developed by the University of California at Berkeley and installed in the nose of a B-17. Test flights by branch members highlighted serious disadvantages, including difficulty with forward and upward vision. The idea seems to have been laid to rest as a result of this trial.

The decades have moved by quickly, bringing sweeping political, technical, and programmatic changes to the path of Air Force human engineering. In its second ten years, a major goal became the preparation of man for space exploration. Numerous apparatuses and methods, including zero-G, parabolic flight profiles, were used successfully to simulate weightlessness in order to learn about the ability of humans to function in space. These pioneering accomplishments paved the way for later NASA successes.

Figure 3. The laterally firing gunship, developed by Col. John Simons and Col. Ron Terry at WPAFB, was successfully deployed in Southeast Asia.

"I was lucky enough to be on the selection committee for the original seven Project Mercury astronauts. I had done the anthropometry on all of the candidates, as well as stereo photographs. The photos were to be used to provide accurate body shape information, which would then enable us to make customized pressure suits....It was an interesting time in the lab for a few weeks, having all the astronaut candidates around taking tests, meeting, and discussing the results. All the candidates were very impressive, but John Glenn was in the 99th percentile on everything. He was amazing."

Charles Clauser, Anthropologist
Human Engineering Division

Later, a seemingly small war in a far-off land taught our nation painful lessons about fighting limited wars with limited military objectives and limited success. The Vietnam war years pressured the human engineering community for near-term improvements in weapon systems and procedures. One result was a now-famous laterally firing gunship, sometimes referred to as "Puff the Magic Dragon," (see Fig. 3) which permitted accurate air-to-ground fire from a fixed-wing aircraft engaged in a continuous turn. In another program, first steps were taken in the development of visually coupled systems which would link helmet-mounted sights and helmet-mounted displays into the forerunner of today's virtual reality systems.

Research in the decade following the Vietnam war was driven in large part by an avionics revolution sparked, in turn, by phenomenal advances in computer technology. Efforts to bring additional information into the cockpit and extend Air Force mission areas resulted in the development of controls and displays of enormous complexity. The Human Engineering Division responded with landmark research programs in pilot workload

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and man-machine interface. Anthropometry, among others, also benefited from the computer revolution which made retrieval and manipulation of large databases practical for the first time.

The final decade in the 50-year history of human engineering was dominated by the end of the Cold War. Air Force laboratories were subjected to inevitable downsizing; research programs were recast to emphasize commercialization potential. Nonetheless, pioneering advances were achieved in workload measurement, basic visual performance modeling, space vision, cockpit design integration, access to human performance and perception data, 3-D scanning and CAD modeling in anthropometry, night-vision goggle technology, situation awareness, and, of course, virtual reality componentry and perceptual issues (see Fig. 4).

Modern Human Engineering

Today, the Human Engineering Division, one of three research divisions within the Crew Systems Directorate of Armstrong Laboratory, executes a balanced program of basic research, exploratory development, and advanced development in human engineering organized into the areas of Information Management and Display, Design Integration, and Performance Aiding. "Fire-fighting," i.e., short suspense problem-solving in the field using the best available data, knowledge, and skills, is balanced against "fire-prevention" activities (about 70 percent of the program) which focus on building the technology base, tools, techniques, and media needed to get ahead of today's defense requirements. Research is conducted in over 80,000 square feet of laboratory space in four buildings by an on-site government-contractor team numbering well in excess of 200 people.

tubes, advanced electronics, and sophisticated optics to usher in the age of virtual reality.

50th Year Anniversary Celebration

The commemoration of 50 years of human engineering research will fill the week of June 12-16, 1995 with colloquia, tours, and a climactic banquet. Colloquium speakers include Nobel laureate Dr. Herbert A. Simon of Carnegie-Mellon University, Dr. Grete Myhre of the Norwegian Institute of Aviation Medicine, and Dr. Thomas A. Furness, Director of the Human Interface Technology Laboratory at the University of Washington. Information on times and locations of colloquia is available from Mr. Jeff Landis at (513) 255-4842 or DSN 785-4842. Open houses on Tuesday, June 13 through Thursday, June 15 will showcase twenty Human Engineering Division research laboratories to designated groups of visitors. Specifically, Tuesday morning is set aside for senior active and retired government officials; Wednesday for university faculty and peers from government; and Thursday for members of industry. The week-long celebration culminates in a banquet on Friday evening, June 16, 1995, held amidst the fabled aircraft of the historic Air Force Museum adjacent to Area B, Wright-Patterson AFB, Ohio. The banquet features a buffet dinner with music provided by the Air Force Band of Flight. All members of government, industry, academia, and the community are welcome to participate in these anniversary events. Information on the open house and banquet can be obtained by calling (513) 255-8057 or DSN 785-8057.

A commemorative bibliography was prepared to mark the occasion (see Fig. 5). This 292-page volume is organized around a reference bibliography comprising the cumulative technical reports, journal publications, conference proceedings, books, and book chapters documenting the research and development program of the Fitts Human Engineering Division from August 1945 through December 1994. The bibliography is divided into five sections, or decades, of activity and is organized alphabetically by author within each of these decades. The bibliography is itself generously illustrated with photos, illustrations, data functions, quotes, biographic notes, and period anecdotes which exemplify the people and events which shaped the history and character of the division. A copy of the bibliography can be ordered by calling (513) 225-8057 or DSN 785-8057.

Walter C. Summers is Chief of the Ergonomics Analysis Branch of the Paul M. Fitts Human Engineering Division, Armstrong Laboratory, Wright-Patterson AFB, OH.

Figure 5. 50 Years of Human Engineering: History and Cumulative Bibliography of the Fitts Human Engineering Division, 1945-1995.

Footnotes

[1] Portions of this article were excerpted from *The Genesis of Human Engineering* by Dr. Walter F. Grether, Chief, Psychology Branch (1949-1956).

Lieutenant Colonel Paul M. Fitts, Ph.D.
Chief, Psychology Branch
1945 to 1949

Lt. Col. Paul M. Fitts is generally regarded as the father of human engineering as a technical discipline. He received degrees in psychology from the University of Tennessee (B.S., 1934), Brown University (M.S., 1936), and University of Rochester (Ph.D., 1938) prior to being commissioned in the Army Air Force as a first lieutenant in the Aviation Psychology Program in April 1942. During most of the war years, he served as Assistant Chief of the Psychology Branch in the Office of the Air Surgeon, HQ USAAF.

In 1945, he developed a plan for a psychological research unit that would address man-equipment engineering design problems that underlay aircraft accidents, bombing errors, and other such phenomena that were evidence of human failures attributable to poor engineering design. The Air Staff approved his proposal on May 19, 1945 and he became the Chief of the Psychology Branch of the Aero Medical Laboratory. He served in this position until 1949.

His subsequent career included Professor of Psychology and Directorship of the Aviation Psychology Laboratory at The Ohio State University, Professor of Psychology and Head of the Human Performance Center of the University of Michigan, and membership on several research and development boards.

Paul Fitts died on May 2, 1965. His many contributions to the Air Force are well documented in both the scientific literature and in the methods, techniques, and disciplines applied today in the development of Air Force weapon systems. It was in light of Dr. Fitts' profound influence on the technology and programs of the United States Air Force that Building 248, Area B, Wright-Patterson Air Force Base, was memorialized in his honor as the Paul M. Fitts Human Engineering Laboratory.

The COTR Speaks

Reuben "Lew" Hann

As you may have already noticed from the lead article on the front page of this issue of *Gateway*, the host organization for CSERIAC—the Fitts Human Engineering Division of the Armstrong Laboratory—is celebrating an important milestone in its history during the month of June. Walt Summers, Chief of the Ergonomics Analysis Branch, describes some of the persons and events from the first 50 years in the life of the Division. All of us in the Division are proud of our heritage, and we trust you will find our story interesting and informative. Please note that *you* are invited to join us during the big celebration; Walt gives all the details in his article on how you can be a part of this historic event.

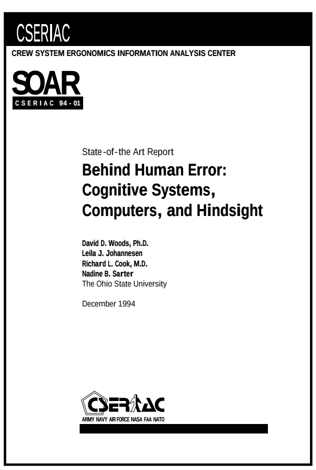
Dr. Hal Henrick from the University of Southern California was the third speaker in the 1994 Armstrong Laboratory Colloquium Series: The Human-Computer Interface. He spoke on "Macroergonomics, VDT Job Design, and Preventing Work-Related Musculoskeletal Disorders." Unfortunately, I was attending the biennial meeting of the Department of Defense Human Factors Engineering Technical Group and missed the opportunity to interview him. However, Steve Harper, a Senior Design Engineer with CSERIAC, has written a synopsis of

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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State-of-the Art Report
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December 1994
CSERIAC
ARMY NAVY AIR FORCE NASA FAA NATO

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.

Dr. Hendrick's lecture.

Of particular importance to the human factors and ergonomics community is the release of the Computer Aided Systems Human Engineering (CASHE) CD-ROM. This hypermedia-based CR-ROM contains electronic versions of the *Engineering Data Compendium: Human Perception and Performance* and the MIL-STD 1472D, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities*. Also included is the Perception and Performance Prototyper, a group of test benches for exploring and experiencing selected perceptual and performance phenomena from the two above-mentioned reference documents. Dr. Janet Lincoln of Hudson Research Associates and co-editor of the *Engineering Data Compendium*, has long been involved in the development of CASHE. In this issue, she provides us with an overview of CASHE and its capabilities.

In several past issues of *Gateway*, we have advertised that CSERIAC has its own home page on the World-Wide Web. This electonic link to CSERIAC can provide the user access to past issues of *Gateway*, CSERIAC products and services information, and general information on CSERIAC, as well as links to all our sister IACs n other technical areas. Ken Klauer, Chris Sharbaugh, and Dave Wourms, all from the CSERIAC staff, have prepared an article which will inform the reader of many other sites on the Web where human factors information can be obtained.

As always, your comments and s uggestions concerning *Gateway* are welcome. Please forward them to Jeff Landis, Editor, at:

CSERIAC Program Office
AL/CFH/CSERIAC Bldg 248
2255 H Street
Wright-Patterson AFB OH
45433-7022

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

Calendar

June 13-18, 1985
Ledyard, CT, USA
12th International Symposium on Night and Shiftwork. Contact Donald I. Tepas, Dept. of Psychology, University of Connecticut, 406 Babbidge Rd., Box U-20, Storrs, CT 06269-1020; fax (203) 486-2760, email: shiftw@uconnvm.uconn.edu.

June 13-16, 1995
Seattle, WA, USA
The 1995 Industrial Ergonomics and Safety Conference. Contact Dr. Alvah Bittner, Battelle, P.O. Box C5395, 4000 N.E. 41st Street, Seattle, WA 98105-5428. Fax (206) 528-3552.

June 19, 1995
Orlando, FL, USA
Safety Technology 2000. Contact American Society of Safety Engineers, 1800 E. Oakton St., Des Plaines, IL 60018-2187; (708) 692-4121 ext. 56 or 707.

June 19-22, 1995
Orlando, FL, USA
American Society of Safety Engineers 34th Professional Development Conference and Exposition. Contact American Society of Safety Engineers, 1800 E. Oakton St., Des Plaines, IL 60018-2187; (708) 692-4121 ext. 223, fax (708) 296-3769.

June 27-29, 1995
Cambridge, MA, USA
The 6th IFAC/IFIPS/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Man-Machine Systems. This meeting, held at the Massachusetts Institute of Technology, will be the first held in the United States. Contact Dr. Thomas Sheridan via fax (617) 258-6575 or email: sheridan@mit.edu. Or contact R. John Hansman, Jr. via fax (617) 253-2271 or email: rjhans@mit.edu.

July 9-14, 1995
Pacifico, Yokohama, Japan
HCI International '95. Contact HCI International '95 Secretariat, c/o Dept. of Industrial Engineering, Musashi Institute of Technology, 1-28-1 Tamazutsumi, Setagayaku, Tokyo 158, Japan; 81-3-5707-9053, fax 81-3-5707-9053, email: hci95@ie.musashi-tech.ac.jp.

September 24-28, 1995
Montréal, Québec, Canada
2nd International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS 95. Organized by the Institut de recherche en santé et en sécurité du travail du Québec (IRSST) under the auspices of the Scientific Committee on Musculoskeletal Disorders of the International Commission on Occupational Health. Contact IRSST, 505, Boulevarde de Maisonneuve Ouest, Montréal, Québec, Canada, H3A 3C2; (514) 288-1551, fax (514) 288-7636.

October 9-13, 1995
San Diego, CA, USA
Human Factors and Ergonomics Society 39th Annual Meeting, "Designing for the Global Village." Hosted by the San Diego Chapter. Contact HFES, P.O. Box 1369, Santa Monica, CA 90406-1369; (310) 394-2410, fax (310) 394-2410, email: 72133.1474@compuserve.com.

October 23-25, 1995
Québec City, Québec, Canada
27th Annual Conference of the Human Factors Association of Canada. Contact Peter Fletcher, HFAC/ACE, 6519 B Mississauga Rd., Mississauga, ON, Canada L5N 1A6; (905) 567-7193, fax (905) 567-7191.

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

Armstrong Laboratory Human Engineering Division Colloquium Series

Macroergonomics, VDT Job Design, and Preventing Work-Related Musculoskeletal Disorders

Hal Hendrick
Synopsis by Steve Harper

Editor's note: Following is a synopsis of a presentation by Dr. Hal Hendrick, University of Southern California, as the third speaker in the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. This synopsis was prepared by Steve Harper, Senior Design Engineer, CSERIAC Program Office. JAL

Dr. Hendrick began his discussion by noting that work-related musculoskeletal disorders (WMSDs) are one of the primary occupational health issues faced by industrialized countries.

The high incidence of WMSDs is not new. Manual materials handling-related injuries have been recognized as an ergonomics concern since the late 1940's. Dr. Hendrick suggested that the major contributor to the widespread increase in the 1980's and 1990's is due primarily to the ever increasing use of video display terminals (VDTs) in the workplace.

Traditional ergonomics methods (microergonomics) of work station design do not appear to be able to prevent VDT-related WMSDs. He cited analysis results (Bammer, 1990) indicating that while ergonomic efforts are important and should be encouraged, by themselves, they often are insufficient to reduce work-related musculoskeletal disorders. According to this research, improvements in work organization to reduce pressure, increase task variety and personal control, and encourage employees to work together should be the main focus of prevention and intervention.

The results of Bammer's research support what psychologists identify as the dehumanizing characteristics of jobs and work systems. Dehumanizing work is characterized by a lack of psychological meaning, responsibility, and knowledge of results. These characteristics often lead to high stress, unmotivated employees, job dissatisfaction, high absenteeism, and reduced productivity (Organ & Bateman, 1991).

Dr. Hendrick cited a NIOSH study documenting that one company spent thousands of dollars implementing ergonomic improvements to VDT work stations and found, a year later, that no significant reduction in WMSDs had occurred. As a result, NIOSH conducted a more in-depth follow-up study that included a macroergonomic emphasis. This study revealed several psychosocial variables significantly related to the incidence of WMSDs, emphasizing the role of the psychosocial work environment in the onset of musculokeletal disorders.

A major cause of WMSDs related with dehumanizing work lies in three interrelated work system design practices, according to Dr. Hendrick. He categorized these design practices as *Technology-centered ergonomics*, the *"Leftover" approach to function and task allocation*, and the *Failure to integrate socio-technical characteristics with organizational and work system design*.

Technology-centered ergonomics is driven by the availability of new technology. If ergonomic factors are considered with this approach, they typically focus on the determination of skills, knowledge, and training necessary to use the new technology. This results in the design of human interfaces for an already designed system that attempt to minimize human error and improve comfort. This approach does not facilitate consideration of the factors found to be an integral part of the solution to WMSDs in the literature cited by Dr. Hendrick. This approach fails to adequately consider the relevant sociotechnical system variables. The resulting work systems are often sub-optimal in their performance, not only in terms of productivity, but also in their effects on employee self-worth, stress, satisfaction, and related health and safety. Dr. Hendrick has personally validated this conclusion by assessing more than one hundred high-technology organizations employing the technology-centered approach to work design.

The "Leftover" approach to function and task allocation is related to the Technology-centered approach to ergonomics. Often the machine is assigned all the tasks its technology will enable it to accomplish. The humans are then allocated the "leftover" tasks. Unfortunately, this has all too often been the approach to function allocation (Bailey, 1989). This approach results in systems that are less than optimal in performance due to the lack of consideration of work force characteristics. To optimize system effectiveness, the capabilities and limitations of the human and machine must be considered together. Bailey (1989) refers to this method of function and task allocation as a "humanized task approach." This approach seeks to justify using a human rather than merely creating a job that can be performed by a human. It takes advantage of the human's capabilities and results in work that is intrinsically more rewarding.

The failure to integrate sociotechnical characteristics with organizational and work system design aspects was identified in the classic longwall coal mining studies by the Tavistock Institute in the United Kingdom over four decades ago (Trist & Bamforth, 1951; Trist, Higgin, Murray, & Pollock, 1963). This literature identified four major sociotechnical system attributes: the personnel subsystems, technological subsystems, organizational structure, and the external environment. These elements all interact with each other. A change to any one of the elements affects the other three. Since the time of the Tavistock studies, the critical dimensions of these sociotechnical elements have been identified and empirical relationships with respect to organizational and work system structures have been developed. Dr. Hendrick stated that the empirical models could be applied to any complex human-machine-environment system to both evaluate and more optimally design its organization and work system structure.

A macroergonomic approach was proposed by Dr. Hendrick for organizational and work system design to reduce the dehumanizing nature of work and the associated WMSDs. This method should be human-centered, use a humanized approach to function and task allocation, and consider relevant sociotechnical system variables. This macroergonomic approach greatly benefits the synergistic nature of systems, in other words, the resulting ergonomically harmonized work system should result in performance that is more than a simple sum of its parts. He stated that instead of the typical 10% - 25% improvements in organizational effectiveness associated with microergonomic efforts, this approach could result in improvements of 60% or more (Hendrick, 1991). Dr. Hendrick cited evidence from a series of recent macroergonomic interventions in the U.S. and Japan to support this hypothesis (e.g., see Rooney, Morency, & Herrick, 1993; Nagamachi & Imada, 1992).

The job characteristics identified by Bammer as related to WMSDs are the same as those identified by industrial and organizational psychologists as critical to job motivation, employee self worth, stress reduction, and satisfaction. These characteristics are task variety, sense of job wholeness, perceived significance of the job, autonomy to control one's own work, and feedback on results (see Table 1).

The approach suggested by Dr. Hendrick would incorporate task variety into VDT jobs to vary the types of computer work and structure of the work system, allowing VDT operators to perform other administrative and clerical tasks. It should also improve the meaningfulness of the job. Job autonomy could be enhanced by allowing VDT operators to pace their own work, devise their own schedules, and by ensuring that managers do not over-supervise. In addition, feedback mechanisms, for the use of the individual (not management), should be designed into the system. The final consideration Dr. Hendrick discussed from Bammer's work was the importance of allowing VDT operators the opportunity for social interaction. This can be facilitated by physical workplace arrangements and by structuring tasks to at least permit social interaction.

Conclusion

Dr. Hendrick concluded his discussion of macroergonomics by emphasizing its potential for developing or improving work systems over historical design practices. According to Dr. Hendrick, macroergonomics may have a particular benefit with total quality programs and in meeting the occupational health and safety requirements of ISO 9000 (a series of international quality standards and guidelines established by the International Standards Organization. The U.S. version is known as ANSI/ASQC Q90 series) . The macroergonomic approach proposed will facilitate cre-

Continued on page 10

Table 1.
Key Characteristics of VDT Positions Which Prevent WMSDs

- **Task Variety**
- **Identity (sense of wholeness of job)**
- **Autonomy (control over work)**
- **Feedback (timely knowledge of results)**
- **Opportunity to meet social needs on job**

ation of work systems characterized by job designs known to enhance both employee health and other quality of work life aspects associated with VDT tasks. This approach has the potential for designing work systems and jobs that reduce WMSDs, humanize VDT work, enhance productivity, and reduce costs. ●

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Scenes from the Armstrong Laboratory Human Engineering Division Colloquium Series:

Dr. Hendricks addressing the audience on the topic of musculoskeletal disorders and their prevention.

Dr. Hendricks speaking with Lt. Col. William Marshak, now retired, but then Deputy Chief of the Human Engineering Division.

The CASHE:PVS

Hypermedia Ergonomics Database for System Designers

Janet E. Lincoln

Research data on human perceptual and performance capabilities often do not receive adequate consideration in the system design process because of the difficulties designers encounter in locating, interpreting, and applying these data.

The Computer Aided Systems Human Engineering (CASHE) program at Armstrong Laboratory has been exploring ways to integrate ergonomics data into a computer-assisted design environment to support engineers in applying this information in the design of complex human-operated systems.

CASHE's first product release, the Performance Visualization System (CASHE:PVS), Version 1.0, is a hypermedia ergonomics database with specialized visualization tools to aid in the interpretation of human perceptual and performance data.

CASHE:PVS contains complete and interlinked electronic versions of two ergonomics data sources:

- *Engineering Data Compendium: Human Perception and Performance* (EDC) (edited by Boff & Lincoln, 1988), a comprehensive ergonomics reference for system designers that presents human behavioral data in a standardized,user-friendly format;

Continued on page 12

Figure 1. Typical screen display showing open text, figure, and table windows for an EDC reference entry. Pull-down menus under icons on the entry palette (upper left) allow users to identify and rapidly access all available figure and table components or test benches associated with the entry. The animation window (lower right) offers a demonstration of the audio effects described in the displayed table.

- MIL-STD 1472D, *Human engineering design criteria for military systems, equipment, and facilities* (Notice 3, 10 February 1994), a legal military standard of design criteria, principles, and practices for human-operated systems.

CASHE:PVS also includes the Perception and Performance Prototyper (P^3), a collection of interactive simulations, or test benches, that allows users to explore and experience selected perceptual and performance phenomena covered in the two reference documents.

Information Access

CASHE:PVS provides three primary means of accessing information in the database: browsable outlines, text search, and hyperlinks.

Because designers may come to CASHE:PVS with different backgrounds and information needs, several different browsable outlines are included. Each outline provides a hierarchical listing of topics covered in the database but approaches the subject matter from a slightly different organizational perspective so users can match the way they have structured their queries.

Users who have already defined their object of search in terms of a specific word or phrase can rapidly access the information they need by performing an electronic full-text search on the reference documents in the database.

CASHE:PVS also provides electronic connections, or hyperlinks, between related database items to support a non-linear mode of information search.

Both documents in the database contain embedded cross-references that point users to related information items. All these cross-references are hyperlinks that navigate the user directly to the referenced data.

Figure and table references in the running text are also hot links that, when clicked, immediately display the corresponding figure or table in a new window.

Figure 2. Control panel for the Custom Options topic of the Display Vibration Test Bench.

To help users interpret specialized material, technical terms in the text are also hyperlinked to their Glossary definitions.

Text, figures, and tables are displayed in separate windows that support functions and features tailored to the specific data class (see Fig. 1). Multiple windows of each type can be opened, and windows can be resized and repositioned as desired so information can be compared easily across entries or data types.

Users can personalize the database information by attaching electronic notes to text, figures, or tables, placing electronic bookmarks, and creating customized hyperlinks that allow rapid navigation from one component to another.

A current work session can be saved to preserve user annotations, a history list of recently visited entries, and window contents and layout, so that unfinished work can be continued later or an especially useful work context can be reinstated.

Special Tools and Enhancements

Special enhancements and visualization tools help users interpret the information in the reference database and understand its implications for a current design problem.

Many figures and tables are supplemented with visual animations or audio demonstrations that illustrate underlying concepts and illuminate the meaning of the data presented.

To help users understand and visualize behavioral data in a more analytical way, all figures provide direct access to a DataDigitizer that allows users to digitize any data graph in the reference database. The digitized data can then be exported to a spreadsheet or other data-analysis application for further quantitative and graphic manipulation.

The Perception and Performance Prototyper (P^3) is another visualization tool that is one of the most innovative features of CASHE:PVS. The test benches comprising P^3 are interactive multimedia simulations that link to and amplify the information in an individual entry or group of entries in the reference database.

Test benches help illustrate and further explain a perceptual or performance effect described in the database by reproducing the effect so users can experience it firsthand.

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Human Factors Information on the World-Wide Web

Ken M. Klauer
Christopher J. Sharbaugh
& David W. Wourms

The World-Wide Web (WWW) or the "Web" is the creation of a group of physicists at the European Laboratory for Particle Physics (CERN) who needed an improved method of sharing information with their colleagues. When the Web was first accessible to the public early in 1990, there were less than 50 servers worldwide. After the release of the NCSA MOSAIC™ Web browser in the spring of 1993, a freely distributed program which offered user-friendly access to the Web, the number of available Web sites almost tripled within four months (Gray, 1995). Presently, the Web continues to expand at a rate of approximately 300 new sites per week!

With the early influence of CERN, the Web has remained a powerful tool for the dissemination of scientific and technical information. Fortunately, many sources of human factors and ergonomics (HFE) information have appeared on the Web as well, and their numbers are increasing at a rate approximating the growth of the Web itself. A survey conducted in December of 1994 located over 60 individual HFE Web sites. Over 200 additional sites were then revealed in a survey conducted in February of 1995. In addition to the many sites directly related to HFE, there are hundreds of other sites devoted to allied sciences such as physiology, mechanical engineering, software engineering, and systems engineering.

In a previous issue of *Gateway* (Volume V, Number 3, 1994) it was announced that a CSERIAC home page is now available on the Web. Upon accessing **http://www.dtic.dla.mil/iac/cseriac/iac.html**, the user is directed to information about contacting CSERIAC via "snail mail," a calendar listing of important HFE events around the world, the latest issues of the *Gateway* newsletter, and the CSERIAC Products and Services Catalogue, detailing products and services of use to the human factors professional. In the near future, CSERIAC will also offer free downloading of select software products. Return links to the Defense Technical Information Center (DTIC) on the CSERIAC home page are also available to guide the user to other Information Analysis Centers in the Department of Defense IAC System.

In addition to the CSERIAC home page, samples of other HFE-related sites on the Web include:

- **Human-Computer Interaction (HCI) Resources**. This home page is a major index node for many other HCI resources on the Internet. In addition to HCI news groups, on-line HCI bibliographies, and conference listings, the Human-Computer Interaction Resources home page also points to a listing of employment opportunities. Go to **http://www.ida.liu.se/labs/aslab/groups/um/hci/#assoc** to browse this comprehensive site.

- **ErgoWeb**. ErgoWeb is an excellent home page sponsored by the University of Utah and funded by the American Automobile Manufacturers' Association (AAMA). ErgoWeb offers a large collection of ergonomic information and a unique on-line database of case studies where ergonomics issues have been successfully addressed in the workplace. Visitors to this site may also download the complete working draft of OSHA's Proposed Ergonomics Protection Standard and make comments on-line. The ErgoWeb home page can be found at **http://ergoweb.mech.utah.edu:80/**

- **The Encyclopedia of Virtual Environments (EVE)**. Dr. Ben Shneiderman's students maintain EVE at the University of Maryland. EVE describes the technologies and techniques being used to produce Virtual Reality (VR) applications. EVE reviews several areas within the realm of VR, such as system components, applications areas, the human factors of VR, and concept and terminology definitions. Those interested in EVE can jump to **http://www.cs.umd.edu/projects/eve/eve-articles/TOC.html**.

- **The wOrlds Project**. As stated, "wOrlds is focused on the development of a next-generation computer-supported collaborative work (CSCW) framework." The wOrlds CSCW environment will facilitate a seamless integration of existing CSCW tools and a wide range of collaborative activities. For more information and a tour of the wOrlds environment, jump to **http://acsl.cs.uiuc.edu/kaplan/worlds.html**.

- **Occupational Safety and Health Resources Page**. This home page is a compilation of occupational safety and health resources on Internet. It is maintained by Teuvo Uusitalo at the Tampere University of Technology Department of Occupational Safety Engineering in Tampere, Finland. This resource includes an international listing of information services, universities, research institutes, government agencies, United Nations organizations, HFE groups, news groups, and conferences. This page can be found at **http://turva.me.tut.fi/~tuusital/oshlinks.html**.

- **Human Interface Technology (HIT) Lab**. This home page is sponsored by the University of Washington and the Virtual Worlds Consortium. It provides descriptions of current and past research projects at the HIT Lab, and an extensive listing of bibliographies by subject. Jump to **http://www.hitl.washington.edu/** to review what Dr. Thomas Furness, Dr. Maxwell Wells, and others are working on.

- **Joint Advanced Strike Technology (JAST) Program Information System**. If you're interested in the research and development of advanced technologies for military aviation, the JAST home page at **http://www.jast.mil/** is a well maintained site to consider browsing. The JAST program was initiated to investigate, develop, and validate technologies applicable for implementation in the next generation of strike weapons systems for the Navy, Marine Corps, Air Force, and U.S. Allies. As such, this site incorporates an extensive Science & Technology database devoted to such areas as avionics, crew systems, supportability & training, and survivability, and is available via FTP as a zipped, tab-delimited text file. Access to a calendar of upcoming events and JAST briefings is also available on the JAST "Information and Announcements" page.

After browsing the CSERIAC home page and other HFE information sites, it is clear that the Web is a valuable source of information for the HFE community. Because information on the Web can be updated quickly, one can access research reports as they are being written, or obtain the latest information from laboratories around the world.

As the Web's bandwidth increases and electronic protocols for information exchange become more sophisticated, users will be able to interact in near real time with various Web sites. It is hoped that in this dynamic cyberspace environment, concepts will be opened up to a new level of discourse and accelerate the growth of HFE.

For further information, contact a CSERIAC Human Factors Analyst at (513) 255-4842, DSN 785-4842, or email: CSERIAC@falcon.al.wpafb.af.mil.

The authors work for CSERIAC. Ken M. Klauer is a Human Factors Analyst, Christopher J. Sharbaugh is Product Manager, and David W. Wourms is a Human Factors Analyst.

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CSERIAC Program Office
AL/CFH/CSERIAC Bldg 248
ATTN: Jeffrey A. Landis, Gateway Editor
2255 H Street
Wright-Patterson AFB OH 45433-7022
USA
(513) 255-4842 DSN 785-4842

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Users can manipulate various stimulus and presentation conditions almost as if they were in a laboratory environment and explore the combinations of variables most closely related to their current design needs and interests.

For example, the Display Vibration Test Bench simulates the effect of display or whole-body vibration on the legibility of a visual display (see Fig. 2). Users can adjust vibration frequency and magnitude, vibration axis, type of display, and other variables, then observe how image quality is affected.

In summary, CASHE:PVS, Version 1.0, provides a comprehensive, integrated, and easy-to-use system that makes ergonomics data more accessible to design engineers and allows designers to analyze, explore, and manipulate these data in a unique way that enriches understanding of their applicability to system design.

Support

CASHE:PVS was developed by the Human Engineering Division at Armstrong Laboratory with the support of the Department of Defense, the Federal Aviation Administration, and NATO AGARD.

Availability

CASHE:PVS Version 1.0 is implemented for the Macintosh computer and is supplied with a 250-page Users Guide. CASHE:PVS is available from CSERIAC for a price of $400. For more information, contact the CSERIAC Program Office at (513) 255-4842 or DSN 785-4842.

Janet E. Lincoln, Ph.D., is Director of Hudson Research Associates, an ergonomics consulting firm. She is co-editor of the Engineering Data Compendium *and has participated in the CASHE program since its inception.*

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CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

- technical advice and assistance;
- customized responses to bibliographic inquiries;
- written reviews and analyses in the form of state-of-the-art reports and technology assessments;
- reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

- organizes and conducts workshops, conferences, symposia, and short courses;
- manages the transfer of technological products between developers and users;
- performs special studies or tasks.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Government Technical Manager.

To obtain further information or request services, contact:

CSERIAC Program Office
AL/CFH/CSERIAC Bldg 248
2255 H Street
Wright-Patterson AFB OH 45433-7022

Telephone .... (513) 255-4842
DSN 785-4842
Facsimile .... (513) 255-4823
Government
Technical Manager .... (513) 255-8821

Director: Mr. Don A. Dreesbach; *Government Technical Manager:* Dr. Reuben L. Hann; *Associate Government Technical Manager:* Ms. Tanya Ellifritt; *Government Technical Director:* Dr. Kenneth R. Boff.

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