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CSERIAC GATEWAY

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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 intimidating complexity of the F-4 cockpit designed in the late 1950's typifies the single-function mechanical controls and displays. Displays had to be small to get so many on the panel. All the information available is displayed to the pilot all the time. Only a few of these intercommunicate. Photo taken at the U.S. Air Force Museum, Dayton, OH, by Larry Burgess, University of Dayton, Dayton, OH.

Obsolete Accounting Model Hinders Crew System Integration

Joe W. McDaniel

Editor's note: The views presented are those of the author and do not necessarily represent the views of the DOD or its components. JAL

During the last 30 years, the complexity of aircraft-cockpits has evolved beyond the range of traditional management technology. Today, multifunction digital controls/displays, multiple interconnected processors, and the need for a truly integrated crew system create engineering demands that are not being effectively met. To be effective, the modern crew system must be integrated, consistent, and compatible with the capabilities of the operator. Notably, the design and program management environment must also evolve commensurate with the system being developed. In other words, an integrated design process is necessary to develop an effectively integrated system.

Failure of some of the design sup-

Continued on page 2

port processes to evolve to meet the demands of the digital crew system have, in some cases, actually become a hindrance to effective design. One serious impediment to integrating crew system functions may be the aircraft model in Appendix A of MIL-STD-881B Work Breakdown Structure For Defense Materiel Items (WBS). The WBS is prescribed for use on new system acquisitions to aid definition, analysis, tracking, and control of each element of the system throughout development. The WBS is a hierarchical diagram that decomposes the entire system into elements, subelements, sub-sub, etc., down to the level of each element of hardware, software, services, data, training, support equipment, management, and other work tasks.

This is not meant to attack either military standards or the WBS concept, but rather a specific part of one that has become obsolete. The WBS is absolutely necessary for developing a complex system. If we did not already have the WBS process, one would have to be invented. The WBS provides a consistent mechanism for tracking all the subcontracts and suppliers contributing to the system. Its most important function is in tracking the cost, schedule, and progress of each element. The problem is simply that the model WBS for aircraft does not include an element for the crew system. That model was developed in the early 1970s. When this standard was last updated (March 1993), this deficiency remained uncorrected.

A brief review will illustrate the problem. In the WBS hierarchical model for an aircraft, Level 1 has but a single element, the entire Aircraft System. The ten Level-2 elements listed in Table 1 point out that an aircraft system is much more than an aircraft. The system includes training and trainers; it includes hangars and mechanics; it includes everything necessary to own and operate the aircraft. The aircraft is just one element at this second level in the WBS hierarchy.

The problem for the crew system

Table 1.
The model hierarchy for Aircraft Systems in Appendix A of MIL-STD-881B has 10 Level-2 elements under the Level-1 Aircraft System. Notice that the aircraft (Air Vehicle) is just one of the 10 elements.

- **Air Vehicle**
- **Systems Engineering/Program Management**
- **System Test and Evaluation**
- **Training**
- **Data**
- **Peculiar Support Equipment**
- **Common Support Equipment**
- **Operational/Site Activation**
- **Industrial Facilities**
- **Initial Spares and Repair Parts**

Table 2.
Under Air Vehicle, there are 17 Level-3 elements in the model. The crew system of an Air Force aircraft is scattered among the 12 underlined Level-3 elements.

- **<u>Airframe</u>**
- **<u>Propulsion</u>**
- **<u>Air Vehicle Applications Software</u>**
- **<u>Air Vehicle System Software</u>**
- **<u>Communications/Identification</u>**
- **<u>Navigation/Guidance</u>**
- **<u>Central Computer</u>**
- **<u>Fire Control</u>**
- **<u>Data Display and Controls</u>**
- **<u>Survivability</u>**
- **<u>Reconnaissance</u>**
- **<u>Automatic Flight Control</u>**
- **Central Integrated Checkout**
- **Antisubmarine Warfare**
- **Armament**
- **Weapons Delivery**
- **Auxiliary Equipment**

occurs at the third level of the model hierarchy. At the third level, the Air Vehicle itself is subdivided into the 17 elements listed in Table 2. At a glance one can see that none of the 17 is a cockpit, a crew system, or any equivalent terminology. The Air Force aircraft crew system is scattered among at least twelve (underlined) of the seventeen Level-3 elements.

The definitions of these elements are too lengthy to be reproduced here, but the following will summarize the dispersed nature of the crew system. The Airframe includes manual flight controls, fuel, navigation, and engine displays, but the Propulsion includes the engine controls (if furnished as an integral part of the engine). The Air Vehicle Applications Software relates to pilot controls and displays. Communications/Identification has the radios for talking, but Navigation/Guidance has the radios for range and bearing, radar, compasses, etc., except for the terrain-following radar, which is under Survivability. Central Computer coordinates and directs some, but not all of the avionics systems, and its software is in a separate element. If the aircraft is a warplane, the Fire Control functions have a separate element. The Data Display and Controls sounds a lot like a cockpit, but is actually a miscellaneous catch-all that includes those multifunction controls/displays that are not specifically defined elsewhere.

The advocates for this modular structure point to the different missions of various aircraft. For example, only combat aircraft need Fire Control functions; trainers and transports do not. System planners are supposed to delete any elements that are not relevant. This modular approach was very appropriate when the WBS process was standardized back in the early 1970s. Then, the pilot's crew station was composed of several independent subsystems, usually supplied by different subcontractors. Then, it was the prime contractor's job to locate each of these subsystems in the aircraft. In the context of the cockpit design, the prime contractor's effort centered on the cockpit layout and installation of controls and displays, which generally did not intercommunicate. Figure 1 (page 1) shows an example of mechanical analog instrumentation having single-purpose controls and displays.

In contrast, Figure 2 depicts a modern digital cockpit having an almost generic physical appearance, clean and uncluttered, consisting of a few multifunction controls and a few multifunction digital displays. Today, the critical design issues in the crew system relate to information management and integration of data. The modern crew system is no longer a mere collection of subsystems, but a highly integrated information and control system in which each data input (sensor, control, communication, etc.) is not just displayed to the pilot, but is fed into a common digital data bus to allow additional information to be computed and shared throughout the system. So much information is now available that only a small portion can be shown to the pilot at any one time. Integration of the entire system is key to modern crew system design.

To understand the problem of the scattered crew system functions, it is necessary to understand the role the WBS has in shaping the management of the system development. In practice, once the WBS has been defined, the management organizations of both the military and the contractor are changed to be consistent with the WBS. Since the WBS Level-3 elements are the major products to be developed and delivered, industry re-organizes into departments that correspond to each of these products, with a separate department head responsible to the program manager for those specific Level-3 products. Since the WBS model has no Level-3 element for crew system, industry has no department head responsible for the crew system. The task of integrating the crew system requires coordination among several departments within the company. This coordination is further

Continued on page 4

Figure 2. The modern F-22 prototype cockpit has multifunction displays. The push buttons around these displays do not have permanent labels, for their functions change to match the information displayed. This uncluttered appearance conceals a mind-boggling amount of information and control options.

hindered because many of the WBS elements are subcontracted to other companies, with the prime contractor serving as the sole coordinating agent. So, a change made in one department may adversely affect the crew system function in another department without the other department's being aware of a problem until it is too late to correct.

So far, requests to modify the WBS standard to consolidate and integrate the crew system into a single Level-3 WBS element have fallen on deaf ears. While most of the engineering community supports this proposal, it is vehemently opposed by the cost accountants who promulgate the standard, because it would ruin their cost traceability and prediction models. This is a major change, for it involves more than adding a new element called "Crew System"; it also involves removing those functions from the other elements. Additionally, this proposal would cause a significant re-organization of industry, removing some of the traditional responsibilities from these department managers.

When the Air Force begins to acquire a new aircraft or make a major modification to an existing aircraft, a System Program Office (SPO) is established by bringing members of various disciplines together as a team. These SPOs are located at Wright-Patterson AFB to be near the research and development expertise centered in the laboratories also located there. This SPO team translates the operational requirements into a contract and later manages that contract. Typically, the Air Force contracts with industry for aircraft design and production. The official involvement of military personnel in the process is monitoring industry's efforts.

To implement the Integrated Product Team (IPT) approach to system development, the Air Force's ongoing F-22 program has made a radical departure from the WBS aircraft model in MIL-STD-881. Using its prerogative to "tailor" the model WBS, the F-22 SPO completely overhauled it into eight level-3 elements, one for each of the IPTs, one of which is the Cockpit System IPT. The Cockpit System Element is subdivided into five level-4 elements: Pilot-Vehicle Interface (PVI), Aircrew Station Accommodations, Escape, Life Support, and Canopy. The F-22 program did not make a total break with tradition, however, for part of the crew system is in another level-3 element, Avionics, which contains the avionics control and display hardware. Notwithstanding this one exception, the F-22 program is the first military program to attempt such a high level of integration of the crew system design activities. The results to date indicate this approach to be far superior to the traditional WBS model, providing high visibility to crew system issues and getting problems resolved in favor of the pilot. The creation of a unified crew system design team to address all crew system issues marks an advance in the design process. The F-22 SPO believes that IPTs are effective, and their use will likely continue and spread to other programs.

Between 1984 and 1992, the Paul M. Fitts Human Engineering Division sponsored seven research and development contracts involving five major aircraft companies, several avionics companies, and other specialists. Products of that work were a formal, integrated Crew System Design Process (CSDP) with activities and procedures to highlight the crew system as a distinct design discipline, and a spectrum of computer tools to serve the CSDP. The Crew-Centered Cockpit Design (CCCD) project continues to develop this technology to support the design of new crew systems and upgrades for existing crew systems.

The CSDP currently has about 120 activities, most supported by separate software design tools. It is beyond the scope of this paper to describe all of them. These activities are divided into five categories: Program Planning/ Scheduling, Requirements Analysis and Predesign, Crew System Analysis, Crew System Design, and Crew System Evaluation. The crew system design category accounts for the majority of the activities. The CSDP tool set is directly linked into a generic crew system simulator, which is reconfigurable without sophisticated programmer support. Built with object-oriented software, it allows a journeyman programmer to modify or even create a new display for the system. The simulator is an integral part of the CSDP tool set, allowing the various analyses and evaluations to share data.

CSERIAC has participated in the CCCD project almost from the beginning, is currently helping improve the tools and technology, and will make these tools available to industry when they are completed. This promising technology is beginning validation, with a completion in 1997. Two of five validation applications have been completed and the third is in progress. These include crew systems with different crew sizes and operational missions.

The F-22 program's use of IPTs forced the creation of a new aircraft model for the WBS. Its success proves the efficacy of an integrated crew system as a level-3 element. We hope this momentum can influence another revision of MIL-STD-881 to include an integrated crew system. ●

Joe W. McDaniel, Ph.D., CPE, is an Industrial Engineer with the Design Technology Branch, Fitts Human Engineering Division, Armstrong Laboratory, Wright-Patterson AFB, OH.

Mailing Address

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Please note our mailing address.

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The COTR Speaks

Reuben L. Hann

The design of aircraft has evolved over time, requiring greater integration, consistency, and compatibility between the crew system and the capabilities of the operator. Design and program management must support this changing environment.

Sometimes this has not happened, especially when standards and guidelines developed long ago neglect changing environments. In the feature article of this issue of *Gateway*, Dr. Joe McDaniel of the Armstrong Laboratory discusses this problem with a particular standard and offers a potential solution, one already being used by the F-22 System Program Office.

Also in this issue, we present another summary of a presentation from the Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. This time our guest was Dr. Bonnie John of Carnegie-Mellon University, who spoke on "Applying Psychology to the Design of Computer Systems." A colleague here at the Armstrong Laboratory, Dr. Mike Vidulich, provides a synopsis of Dr. John's presentation, and I follow that with some excerpts from a conversation I had with her.

Related to the topic of integrated crew stations as discussed in Joe McDaniel's feature article, CSERIAC has been supporting the Crew-Centered Cockpit Display (CCCD) program for several years. CSERIAC Project Manager and Senior Design Engineer Mark Detroit explains CCCD's goals and achievements in this issue.

Previously in *Gateway*, the highest level of CSERIACs technical inquiry services, the Technical Area Task (TAT), was defined, with a promise to provide some examples of various TATs managed by CSERIAC. Concluding this issue is an article written by CSERIAC Project Manager and Human Factors Analyst Laurie Quill in which she describes a TAT being conducted to find ways of improving flightline maintenance procedures. This work is

Continued on page 6

being done for the Human Resources Division, another component of the Armstrong Laboratory.

We are planning a new series of *Gateway* articles, which will feature various ergonomics research facilities and programs throughout the world. *Gateway* now has a circulation of over 10,000 and is sent to 36 countries; we think these articles would make interesting reading for this large and diverse audience. If you would like us to consider your organization for inclusion in this series or just want more information, please contact our *Gateway* Editor, Jeff Landis. He can be reached by any of the methods described on the back cover of this newsletter. ●

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

Calendar

September 14-16, 1995
Washington, DC, USA
Work, Stress, and Health '95: Creating Healthier Workplaces. Contact Lynn A. Letourneau, American Psychological Association, 750 First St. NE, Washington, DC 20002-4242; (202) 336-6124, fax (202) 336-6117.

September 18-22, 1995
Boston, MA, USA
Industrial Ergonomics: Human Factors in Occupational Health and Safety short course. Contact Nicole Costa, Harvard School of Public Health, Office of Continuing Education, 677 Huntington Ave., LL-23, Boston, MA 02115-6023; (617) 432-1171, fax (617) 432-1969. Email: contedu@sph.harvard.edu

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.

September 28-29, 1995
Atlanta, GA, USA
Human-Computer Interaction short course. Contact Dept. of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385; (404) 894-2547. Email: conted@gatech.edu

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, PO Box 1369, Santa Monica, CA 90406-1369; (310) 394-2410, fax (310) 394-2410. Email: 72133.1474@compuserve.com

October 16-20, 1995
Rio de Janeiro, Brazil
Ergonomics Design: Interfaces, Products, Information. Contact Stephan Konz, Dept. of Industrial Engineering, Kansas State University, Manhattan, KS 66502; fax (913) 532-7810. Email: sh@ksuvm.ksu.edu

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.

October 30-November 2, 1995
Arlington, VA, USA
Defense Technical Information Center (DTIC) Annual Users' Meeting and Training Conference. This conference will address the numerous types of information available to the Department of Defense community through the Internet as well as from DTIC and other government agencies. Contact Julia Foscue, Conference Coordinator, Directorate of User Services, Special Programs Branch, Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. (703) 274-3848.

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.

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.

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. *Abstracts due September 22, 1995.*

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

Notices for the calendar should be sent at least four months in advance to:
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Armstrong Laboratory Human Engineering Division Colloquium Series

Applying Psychology to the Design of Computer Systems

Bonnie John
Synopsis by Michael A. Vidulich

Editor's note: Following is a synopsis of a presentation by Dr. Bonnie John, Carnegie-Mellon University, as the fourth speaker in the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. This synopsis was prepared by Michael A. Vidulich, Human Interface Technology Branch, Fitts Human Engineering Division, Armstrong Laboratory. JAL

Dr. John addressed the issue of how psychology and human factors could contribute to the interface design process. One especially desirable way to contribute to the design process would be through the development of engineering models of human performance. These models would ideally make quantitative estimates of the time to learn tasks, the time to perform tasks, and the number and type of errors that could be expected from a given interface design in a specified task domain. These models would then be tools that could be used by system designers to identify promising interface concepts at the earliest possible stage of a system design. If such tools were valid, considerable time and expense could be saved in the design process.

To illustrate the potential of such tools, Dr. John reviewed her involvement in Project Ernestine, which was an evaluation of a proposed redesign of the Toll and Assistance Operators (TAO) interface conducted by NYNEX (the parent company of New England Telephone). The TAOs are highly skilled workers who handle many calls in the course of a work shift. Given the number of TAOs employed by NYNEX and the number of calls handled by each, it was estimated that saving just 1 second of the average call-handling time would save NYNEX about $3 million a year. Not surprisingly, NYNEX was considering employing modern computer interface technology to speed up the TAO's average call-handling time by redesigning the information presentation and the keyboard layout. Based on the expected improvement in the time taken to display a complete screen-full of information and the reduced number of keystrokes required for most calls, NYNEX estimated a 20% reduction in the average time per call. NYNEX decided to test the proposed new system in an extensive field evaluation.

Independent of the field evaluation, Dr. John and her colleagues conducted an analytical evaluation of the new and old interface designs using Card, Moran, and Newell's (1983) Goals, Operators, Methods, and Selection (GOMS) modeling methodology. Contrary to the intuitions of everyone involved in the redesign of the TAO interface, the GOMS analysis predicted that performance with the new interface would be somewhat worse than with the old interface. This was because the new interface benefits generally appeared in sub-components of the TAOs task that were not on the critical time-line. Meanwhile, there was a predicted slowing of some critical time-line events.

The model predicted that overall performance would be about 3% slower with the new interface, and this was exactly what was found in the field evaluation (see Fig. 1). Dr. John contended that the model's analysis was essential for providing an explanation of the counter-intuitive results of the field study. Taken together, the

Continued on page 8

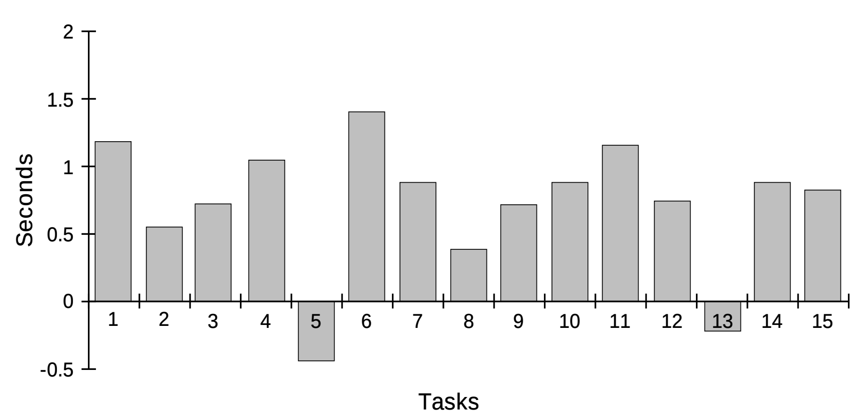

Figure 1. The GOMS Model predicted that with the new interface design, some tasks would be performed more slowly while others would be performed more quickly. Out of 15 tasks analyzed, only two were predicted to result in improved performance.

field study results and the GOMS modeling analysis convinced NYNEX to reject the new interface design.

Dr. John concluded that such engineering models of human performance are useful design and evaluation tools. The proper use of such tools should, in the future, help designers avoid the production of sub-optimal interface designs. ●

References

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum.

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. We are also looking for sponsors of future SOARs. CSERIAC is a contractually convenient, cost-effective means to produce rapid authoritative reports.

Send your suggestions and other replies to:

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Scenes from the Armstrong Laboratory Human Engineering Division Colloquium Series:

Dr. Bonnie John, Carnegie-Mellon University, discussing the evaluation of interface designs. Photo by Larry Burgess, University of Dayton.

Dr. John ponders a question from the audience. Photo by Larry Burgess, University of Dayton.

Armstrong Laboratory Human Engineering Division Colloquium Series

A Conversation with Bonnie John

Reuben L. Hann

Editor's note: Following is an edited transcipt of a conversation with Dr. Bonnie John, Carnegie-Mellon University, as the fourth speaker in the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL

CSERIAC: I see your educational background is in engineering. How did you eventually end up in "human factors?"

Dr. John: Actually, I got into engineering while in high school. This was in New York, where the schools were "zoned." My zoned high school had a bad reputation for drugs and other serious problems. The only way to escape was for me to go into "pre-engineering" or four years of Latin. I chose the former because I thought it would be more fun. I continued on through graduate school with a major in Mechanical Engineering. I worked as a mechanical engineer at Bell Labs, where I designed boxes around other people's circuits, taking into consideration such things as heat transfer, power, and so forth. Then I found myself on a committee looking at the problem of teleconferencing using a single telephone line, where you wanted to use not only voice, but also FAX, electronic blackboard, and slow-scan TV. The question was how to decide which of these had control of that single line at any moment. The committee was struggling with determining the communication protocols suitable for this situation. It was really an enjoyable project. Then my department head yanked me off the committee, telling me that mechanical engineers don't do that sort of work. I asked him who does. He told me that was the work of system engineers. So I decided that's what I wanted to do. I transferred into a Systems Engineering department, where I wrote specifications for the Merlin telephone system. I am very proud of that work; it was the only thing which sold well for a while after the breakup [of the Bell Telephone Company]. It is *still* popular after ten years.

CSERIAC: This was a Systems Engineering department; how did you get involved with more traditional human factors issues?

Dr. John: Well, I became interested in understanding whether what I was designing was going to be easy for people to use. I took a lot of courses in Human Factors at Stevens Tech—almost enough for a Master's degree, in fact. In my work, it seemed that at every turn, the most important question was always whether the system was going to be usable by people. My mechanical engineering training was not helping me to answer that question. But I also found that the traditional experimental psychology and human factors training was not helping as much as I wanted it to when dealing with the cognitive aspects of the problem. So I went to get a degree in Cognitive Psychology at Carnegie-Mellon University (CMU).

When I was trying to determine what credentials I would need as a professional to try to solve these kinds of problems, it seemed to me that the human factors field was made up of engineers who cared about psychology and psychologists who cared about engineering. It looked to me at the time that nobody listened to you unless you had a Ph. D. in psychology, so I chose that as the credential to get. I chose CMU because it was immediately apparent that there was excellent communication and cooperation between the various departments—Psychology and Computer Science, for instance. And, the facilities were impressive; at the time—this was 1982—the psychology department had *six* VAX computers—more than most university computer departments. I decided this was the place to pursue a degree in Cognitive Psychology, where my goal was the study of human-computer interaction.

"When I was trying to determine what credentials I would need as a professional…it seemed to me that the human factors field was made up of engineers who cared about psychology and psychologists who cared about engineering. It looked to me at the time that nobody listened to you unless you had a Ph.D. in psychology, so I chose that as the credential to get."

CSERIAC: I see that CMU has established a new institute in the area of

Continued on page 10

Human-Computer Interaction.

Dr. John: Yes, there are faculty from 8 or 10 different organizations around campus who all work on different aspects of human-computer interaction. So there are computer scientists, psychologists, people from social and decision sciences, from the School of Industrial Administration, from the Industrial Design Department, people from the Software Engineering Institute, from robotics, and others I may have forgotten. There are probably about 30 or so faculty who have been meeting periodically for the past year to bring together a research institute that will facilitate our working together and having joint projects.

CSERIAC: How do these projects come about? Do they come in from the outside?

Dr. John: Yes, right now the Institute is a loose amalgamation of independent researchers who cooperate when the science is "right." We don't force anything. As they get to know each other better, they will know when they should be making a joint proposal to outside agencies, such as government or industries involved in areas like software and telecommunications.

CSERIAC: I have asked many of my guests what kind of research they would undertake if the problem of financial resources were removed. What kind of problems would you tackle if you had no restriction?

Dr. John: I would study the issue of —how do people learn something new? How do they use what they already know to go into a new computer system and learn it? By "learn it" I mean—how do they use prior knowledge to guide their problem solving? How do they formulate problems in the first place? How do they explore the problem to find out how this knowledge can help to reach the goal? How do they retain that information? How do they react with it if there is time pressure? So I am interested in what happens when you walk up to a new system and have something you want to accomplish with it. How do you explore it, problem-solve with it? How does it help guide you, and how do you learn the information needed to perform satisfactorily?

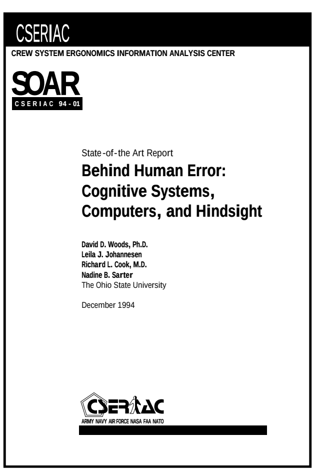
There is a rule-of-thumb in the industrial software business that, in any complex system, any one person only knows about 10% of the functionality of the system. And it's a different 10% for each person. So how does that happen? How do people get into a particular "corner" regarding what they know, and how can you help break them out, so they can learn more. All these issues of learning and problem-solving—that's where I would put my effort. ●

Behind Human Error

Cognitive Systems, Computers, and Hindsight

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

The Ohio State University



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.

Crew-Centered Cockpit Design Program

Mark Detroit
Cindy Martin
Capt Steve Beyer

With current acquisition reform initiatives and decreasing military budgets, it has become increasingly important to ensure cost-effective development of weapon systems. In response to this need, the Crew-Centered Cockpit Design (CCCD) Project is developing a structured process and tool set to improve the design, analysis, and testing of cockpits (see Fig. 1). The CCCD Project is an advanced technology development project at the Armstrong Laboratory Fitts Human Engineering Division. Under the CCCD Field Demonstration Contract, Veda Incorporated is working with the CCCD Project Office to enhance and validate a new Crew-Centered System Design Process (CSDP) and a Cockpit Design System (CDS) tool set to meet this need. In parallel with developing the process and tools, CSERIAC has been working with the CCCD Project Office to evaluate the tools and to provide ancillary support.

The Crew-Centered System Design Process (CSDP) is a detailed description of the activities that are necessary for cockpit design. It is patterned after time-honored practices within the aircraft industry, but adds computer support and a stronger focus on human-centered design. These CSDP activities are electronically accessible through a software interface tool known as the Design Traceability Manager (DTM). The DTM software represents a technology advance, because previous design practices were neither implemented through software nor did they have a means to capture the progression of cockpit design decisions (useful for managing crew system change). For each of the classical weapon system acquisition phases (such as Concept Exploration, Demonstration & Validation, and Engineering & Manufacturing Development) the DTM user can access and invoke CSDP activities which are organized into four major design categories:

- Program Planning
- Requirements Analysis and Predesign
- Design
- Evaluation

Version 4 of the CSDP, scheduled for completion in January 1996, is being developed as part of the Field Demonstration contract. This version will (1) reflect current acquisition reform initiatives, (2) incorporate government standards established in MIL-STD-1776, including the Crew System SEMS (System Engineering Master Schedule), and (3) consolidate work done under predecessors to the current contract.

The CDS toolset comprises an assemblage of customized software, commercial off-the-shelf software, software products created by other Air Force projects, and a real-time engineering cockpit simulator. Customized software includes the Design Traceability Manager and the Timeline Management Tool. Both tools are being reengineered to run on an IBM-compatible PC to enhance their accessibility to the users. Air Force tools include the Tool for Automated Knowledge Engineering (TAKE) and the CSERIAC-developed Requirements Translator Tool (RTT).

An adjunct to the CDS is a new tool that supports crew system Test & Evaluation functions. The Test Planning, Analysis, and Evaluation System (Test PAES) is an interactive tool that helps to plan and perform cockpit evaluation in a flight test. Test PAES includes a structured test and evaluation process (analogous to the Crew-Centered System Design Process), structured test procedures, a visualization system to play back time-synchronized multi-media data (collected in a flight test) for analysis and debriefing, and an array of other software tools which have proved useful to the test community.

Applications

The Crew-Centered Cockpit Design Project is validating its computer tools and design process by applying them to typical Air Force cockpit projects. Two of five planned applications have been completed. The first application examined the effects of redesigning the single-place F-16 cockpit for a new operational mission, tactical reconnaissance. The second application examined an upgrade of the Fire Control Operator's crew station in the multi-place AC-130H Gunship. Both applications successfully showed that use of the process and tool set can lead to measurably improved crew station designs (i.e., improved crew performance, mission performance, and reduced workload in critical mission segments). Better performance was first predicted analytically and then verified through piloted simulation.

In contrast, Test PAES has completed developmental testing and been furnished to flight test users for evaluation in their own operational environments. Beta test sites have been established at the Combined Test Forces (for F-15, F-16, F-22, F-117, B-1, B-2, C-17, AC-130, and U-2 aircraft, among others), at various Air Force, Navy, Army, and other test agencies.

Continued on page 12

Facilities/Resources

The equipment and software that comprise the CDS tool set reside in a research laboratory within the Human Engineering Division. The CDS is located in room 109 of Building 248. It consists of 86 hardware components and 137 computer software programs, all linked via computer network. The computing environment includes Silicon Graphics workstations and IBM-compatible personal computers. The Test-PAES resides on a single personal computer. The CCCD lab also includes a real-time cockpit simulator that can be reconfigured both in hardware and software, for testing the effects of the cockpit design changes relative to the baseline cockpit. In this manner, the performance predictions from the CCCD analysis tools can be confirmed by measured performance from real-time, manned simulator testing.

Both the CDS and Test-PAES will be extended in follow-on work for crew-centered applications to exploit the emerging capabilities offered by Advanced Distributed Simulation and Battle Management Command and Control, building on the proven successes of this CCCD technology, already demonstrated for aircraft cockpit design.

Products

The Crew-Centered Cockpit Design Project, its development progress, and products have been described in numerous technical reports, journal articles, conference proceedings, and informational briefings, both nationally and internationally. The Project has been performed through more than ten research and development contracts, involving over 20 companies, including the direct involvement of five aircraft manufacturers. ●

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Figure 1. A conceptual representation of the CCCD process.

CSERIAC Technical Area Tasks

Integrating Aircraft Maintenance Systems: A Case Study

David Kancler
Laurie Quill
Joy Fasnacht

In earlier issue of *Gateway* (Vol. VI, No. 1) provided an overview of the CSERIAC Technical Area Task (TAT) as a vehicle which gives customers the ability to tailor CSERIAC's services to meet their unique human factors needs. This article will describe a TAT currently under contract with the Logistics Research Division of Armstrong Laboratory (AL/HRG). For the past five years, CSERIAC has supported the Division with a series of TATs dealing primarily with human-computer interface issues. For example, several flightline field tests have been conducted, including the Integrated Maintenance Information System field test at Luke Air Force Base in the summer of 1994.

Since 1982, AL/HRG efforts have focused on the transfer of flightline maintenance procedures from paper-based media to integrated, computerized systems. Traditionally, paper-based procedure systems have required the use of a large quantity of manuals, which maintenance personnel must sift through to complete a particular job. The goal of integrated, computer-based systems has been to present the same maintenance information on a less cumbersome, portable device.

Among the portable devices tested, the laboratory has investigated the use of monocular, occluding eye-pieces to enhance the mobility of maintenance flightline personnel as depicted in Figure 1. As a follow-on to eye-piece research conducted at AL/HRG, voice recognition was identified for study in conjunction with eye-piece technology. Maintenance environments often require the use of both hands; therefore, the laboratory hypothesized that the combination of voice-recognition and eye-piece technologies would allow the user to operate the computer system while performing aircraft maintenance actions.

To accomplish the proposed study, a cooperative effort was required among disciplines and organizations. Disciplines required for the study

Figure 1. A monocular occluding eye-piece with voice recognition as tested on an F-16C airplane at the Air National Guard Base, Springfield, Ohio.

included human factors specialists, software engineers, hardware engineers, and maintenance personnel. The participating organizations included AL/HRG; Air Force Institute of Technology (AFIT); CSERIAC; RJO Enterprises, Inc.; Computer Sciences Corporation; and RCF Information Systems, Inc. With such diverse disciplines required for this project, collaboration was necessary among various government and numerous contracting organizations.

In the voice recognition study, CSERIAC provided literature searches, analyses of cognitively based theories, and recommendations for methods of testing the integrated system. CSERIAC also designed and developed the graphical user interface (GUI) software module required for the presentation application. The key, however, to CSERIAC's support in this project was the capability to use and customize existing resources. For example, reports created by CSERIAC for AL/HRG were used to support literature reviews and provide theoretical bases for the study. In addition, existing software applications were customized to fit the requirements of the voice recognition study. CSERIAC also provided guidance in experimental design for the study of voice recognition as a potential means of input in the computerized flightline maintenance environment. CSERIAC's human factors expertise, plus familiarity with existing resources (inherent in TAT contracts), provided the unique experience required to support this project. Table 1 summarizes CSERIAC tasks on the AL/HRG TAT.

Table 1.
CSERIAC Tasks on the AL/HRG TAT

- **Information Gathering and Analysis**
- **Cognition Theory Analysis and Application**
- **Test and Evaluation Planning**
- **Guidance in Software Design**
- **Graphical User Interface Design**

Essential contributions to the project were provided by other contractors and government personnel as well. RJO Enterprises, Inc. developed and integrated the additional modules required for the presentation application. One of these modules was an expert system for aiding in the decision-making processes (i.e., selection of appropriate troubleshooting procedures) required on the flightline. RJO also integrated the Computer-Off-The-Shelf (COTS) voice recognition software with the presentation software application. Hardware development was provided by Computer Sciences Corporation and RCF Information Systems, Inc. AL/HRG enlisted the use of AFIT graduate students to conduct the study in completion of their masters' theses.

Data collection was conducted in the spring of 1995 at the Air National Guard Base in Springfield, Ohio. Data analysis is underway. The key to the success of this research program has been the collaboration of personnel within the various disciplines and organizations represented in this effort.

Within the scope of a long-term project, CSERIAC TATs provide the flexibility to address specific customer needs while adapting to technological advances. In addition, the TAT structure allowed CSERIAC personnel to provide human factors expertise not only to the customer, but also to other support contractors, including software and hardware developers. Consequently, human factors expertise was available to the entire development team, thereby improving the quality of the final product. ●

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Correction & New Product

In the last issue of *Gateway*, the feature article on the 50th Anniversary of the Paul M. Fitts Human Engineering Division mentioned the availability of *50 Years of Human Engineering: History and Cumulative Bibliography of the Fitts Human Engineeering Division, 1945-1995*. Unfortunately, the wrong telephone number was provided for those interested in obtaining a copy. We apologize for this mistake and ask interested readers to contact CSERIAC directly at (513) 255-4842 or DSN 785-4842 to obtain a copy.

Meanwhile, we are pleased to announce that this same work is available on a CD-ROM, as well. Again, please make your inquiries directly to CSERIAC at one of the aforementioned telephone numbers.

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

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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:

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