VOLUME VII: NUMBER 3 (1997)

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, Ft. Belvoir, VA, technically managed by the Armstrong Laboratory Human Engineering Division, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

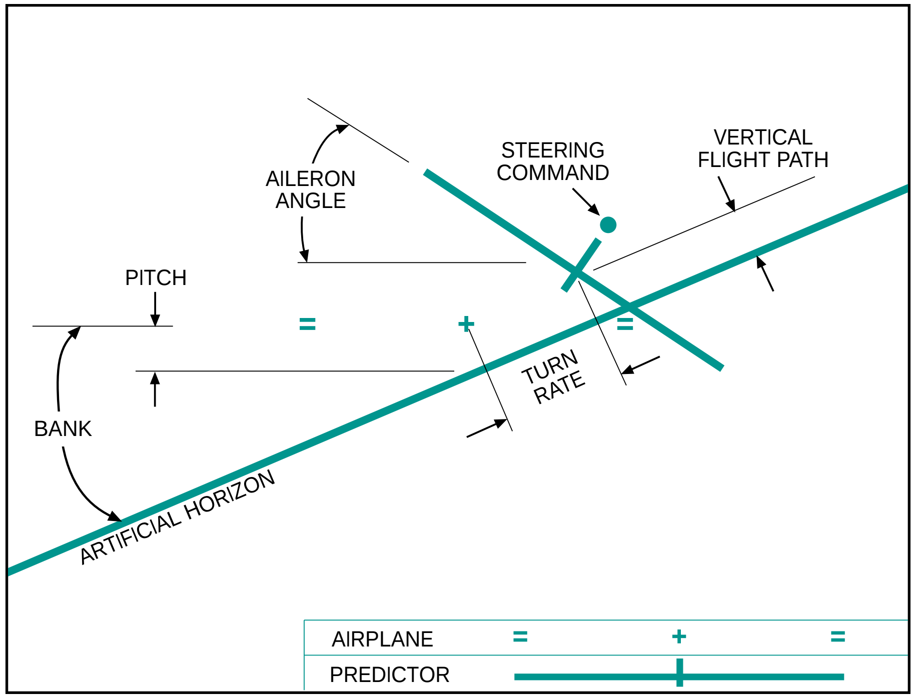

Figure 1. Conventional moving-horizon attitude display with the addition of a flight path predictor and an angles-to-turn-through command symbol for localizer/glideslope and enroute guidance. Illustration by Allison L. Herron.

Horizon Control Reversals and the Graveyard Spiral

Did a Human Control Reversal Cause the 1994 USAir Crash Near Pittsburgh?

Stanley N. Roscoe

A Family of Accidents?

On Thursday, September 8, 1994, a Boeing 737 jetliner owned by USAir departed from Chicago for Pittsburgh on the last leg of a long day's work. Less than ten minutes from touchdown, it crashed into the ground in a screaming, near vertical, spiral dive at a speed of 301 miles per hour. "Graveyard spiral" accidents are common in general aviation, causing on the order of 100 deaths a year in the United States. Such accidents are rare in military aviation, usually less than five a year, and almost never happen in commercial airline operations.

But almost never is still too frequent if such accidents as this USAir Flight 427 crash near Pitts-

Continued on page 2

burgh, the Air India B-747 spiral dive into the Arabian Sea on 1 January, 1978, and the United Airlines B-737 dive out of its final approach to the Colorado Springs airport on 3 March, 1991, could be prevented.

In none of these tragedies was there evidence of mechanical failure in the control system or flight instruments. However, in the Air India and USAir accidents, flight data recorder (FDR) tapes showed the flight controls to be fully deflected, "hard over" in pilot lingo, in the same direction as the rotation of the airplane. Unfortunately the FDR in the United Airlines plane did not record these parameters.

As is frequently the case in spiral dive accidents in general aviation, is it possible that these highly experienced airline pilots had flown their planes into the spiral dives by moving and holding the controls to the very end in the reverse direction to that required for recovery? If so, what could possibly cause such a pilot error?

The most probable answer from my research experience is known as the "horizon control reversal," and I have studied it experimentally over the past 50 years both in airplanes and in flight simulators at Hughes Aircraft Company and at the University of Illinois at Urbana-Champaign.

What Moves, the Airplane or the World?

Though extremely rare among instrument-rated pilots, it is possible—even for airline pilots—to confuse the moving horizon bar of the gyroscopic attitude indicator and the fixed airplane symbol when they find themselves suddenly and unexpectedly in an unusual flight attitude. When this occurs, the initial reaction—to fly the horizon bar back to straight and level flight—will increase rather than reduce the bank angle. The more the horizon bar banks, the harder pilots, now totally disoriented, will twist the control yoke and push the rudder pedals in the direction of the turn and pull back on the yoke to stop the loss of altitude. This tightens the turn into a near-vertical spiral dive, and at this point the pilots have as much control of the airplane as do the rest of the passengers.

Unfortunately the National Transportation Safety Board (NTSB) has never been able to establish the horizon control reversal as the probable cause of a spiral dive accident, because such accidents are invariably fatal to all aboard. Also, because there is never definitive evidence, a human control reversal has never been mentioned as a probable cause, or to my knowledge even as a possible cause, in an NTSB report. However, in the USAir B-737 accident near Pittsburgh, no other probable cause can be found, and the stage-setting conditions for a horizon control reversal were all present—save one.

The Fatal Scenario?

Preceding the spiral dive, the plane was upset by a momentary encounter with the wake vortex from another airliner up ahead. The flight data recorder showed abrupt changes in several flight variables, including a sudden loss of altitude. The encounter was totally unexpected, and the pilots suddenly found themselves in an extremely unusual flight attitude. So the conditions for a horizon control reversal were all present except that this accident occurred in daylight and good visibility; control reversals normally occur at night or in clouds. How could the crew fail to recover from the unusual attitude and actually apply reversed control pressures if they could see the ground and the real horizon?

It is axiomatic that in all aircraft accidents there is never a single cause, and this one is no exception. For passenger comfort, airline pilots never intentionally allow their planes to get into unusual attitudes, and there is no requirement for civilian pilots to be trained in spin and other unusual-attitude recoveries. The first time a person enters a spin in an airplane, the universal reaction is, "It looks like the world is spinning." And, to compound the initial confusion, the design of the "artificial horizon" cockpit display is actually conducive to horizon control reversals.

So How Could *That* Come About?

From the earliest blind flying experiments by Lt Jimmie Doolittle with the original Sperry gyro horizon, there was controversy over whether the airplane symbol or the horizon bar should move relative to the fixed display coordinates. Those with "common sense" argued that the horizon bar should move to maintain "congruency" with the real horizon, and that's the way Sperry built it. But Doolittle and other early-day instrument fliers had trouble seeing it that way and remembering that the fixed "little airplane" was what they were supposed to control and not the moving horizon bar.

All pilots do learn to control flight attitude by reference to the artificial horizon, and by the time they qualify for airline duty they have long since overlearned the correct responses to the display's indications and consider them natural. But they still see the horizon bar as the part of the display that moves and not the little airplane symbol, and in the perceptual and cognitive confusion of a sudden, unanticipated entry into an unusual attitude, there is a strong tendency to control the part of the display that is moving, not the part that is fixed. We naturally expect the moving part to represent the airplane and to move in the same direction as the controls.

Motion-Compatible Flight Path Predictors

The time has passed when it would be reasonable to consider reversing the control/display relationships in flight attitude indicators. In fact, the reversed relationship is not the best. A much easier change results in an even better display, one that would be trivial to implement in modern jetliners with "glass cockpits" in which cathode ray tubes replace mechanical instruments.

A flight path predictor can be added to the conventional moving horizon display by allowing the airplane symbol to move in immediate response to aileron and elevator control inputs and in the same, expected direction. About 35 years ago a mockup board of the North American F-108 long-range interceptor project voted unanimously to adopt a similar display, but a week later the F-108 was cancelled in favor of the Lockheed YF-12. Had that not happened, we would now almost surely have flight path predictors in our head-up displays and in the glass cockpits of modern airliners.

An extremely simple flight path predictor display has been tested in both simulators and airplanes at the University of Illinois starting in the 1970s (see Fig. 1). In addition to responding immediately to control inputs, the flight path prediction has been improved by having the airplane symbol move laterally from the display center in proportion to the rate of turn, thereby creating a superior flight-director presentation as well. This type of flight path predictor has been incorporated in the computer-animated visual system of a primary training simulator at Illinois, resulting in a large improvement in initial performance (see Fig. 2) as well as high transfer of simulator training to flight.

The experiments at the University of Illinois have covered a wide range of operationally realistic contact and instrument flight tasks. Not only do beginning students learn to land airplanes and fly by instruments more quickly, but also their terminal performance of instrument maneuvers is far more precise. The latter is also true for experienced instrument pilots who have no trouble taking advantage of the flight path predictor without having to unlearn their overlearned responses to the moving horizon display. And because airline pilots

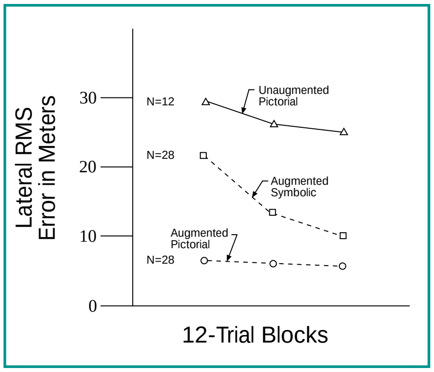

Figure 2. Initial performances of independent groups of pilot trainees learning to land a flight simulator. The nonaugmented pictorial display was a computer-animated view of an airport scene that was dynamically responsive to the changing attitude and flight path of the simulated airplane. The principles applied to the augmented displays included direction of motion compatibility through flight path prediction and a simplified command guidance presentation.

now do little hand flying of their highly automated planes, when they do have to take over manual control, those who have flown a flight path predictor welcome the assistance it provides.

Quo Vadis?

The time is near when the NTSB will issue a final report on the USAir B-737 crash near Pittsburgh. The report will most likely recommend that pilot training be required to include spins and other unusual attitude recoveries and that air transport pilots be required to receive periodic refreshment on these maneuvers in flight simulators. And for the first time, the NTSB may address the horizon control reversal phenomenon, perhaps even finding it a possible, though unprovable, proximate cause. There may even be a discussion of the benefits of incorporating a flight path predictor in glass cockpit attitude indicators, a far less costly change than increasing the training requirements. Our research suggests that this relatively simple improvement could go a long way toward preventing graveyard-spiral accidents in commercial aircraft.

For more information, visit the following World-Wide Web site: www.aero.ca

Stanley N. Roscoe, Ph.D., is Professor Emeritus of Aviation, Engineering Psychology, and Aeronautical and Astronautical Engineering at the University of Illinois, Urbana-Champaign; Professor Emeritus of Psychology at New Mexico State University; former Head of the Display Systems Department of Hughes Aircraft Company; President of ILLIANA Aviation Sciences Limited, McKinleyville, CA and Las Cruces, NM; and Senior Vice President of Aero Innovation, Inc., Montreal, Ontario, Canada.

Suggested Reading

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Seeking Chief Scientist

The University of Dayton Research Institute is one of the leading not-for-profit R&D organizations in the nation providing basic and applied research for government and industry. We are currently seeking a qualified candidate for the position of Chief Scientist for the Crew System Ergonomics Information Analysis Center (**CSERIAC**), which is a department of Defense Information Analysis Center sponsored by the Defense Technical Information Center. It is technically managed by the Armstrong Laboratory Human Engineering Division and operated by the University of Dayton Research Institute. **CSERIAC**, a DoD human factors information analysis center, is looking for a dynamic, technically credentialed individual to fill the position of *Chief Scientist*. The *Chief Scientist* position is responsible for technical leadership of **CSERIAC** including technical guidance of a staff of 30 human factors analysts and engineers. Specific responsibilities include identification, assessment, and exploitation of current and emerging technological areas in which human factors information analysis plays a key role; defining, advocating, and sustaining **CSERIAC's** role and clarity of vision within the scope and intent of Department of Defense directives; designing and delivering advocacy presentations and maintaining proactive technical liaison with DoD, industry, and university laboratories and organizations; and serving as the senior technical advisor in providing direction to all internal technical operations, including the quality production of technical manuscripts, documents, and ongoing technical projects. Work location Wright-Patterson AFB, Dayton, Ohio.

Qualifications

- Ph.D. in Human Factors Engineering or Human Factors Psychology.
- Minimum of 10 years experience as a Ph.D.
- Experience with human-system interfaces (e.g. interaction with complex systems, information display and aiding).
- In-depth knowledge of DoD Science and Technology programs and planning processes.
- Experienced and persuasive communicator.
- Extensive experience in DoD laboratory, program office, and senior staff positions.
- Ability to travel to contact DoD, military services, and science and technology community.

Resumes must be received at the following address by May 31, 1997.

University of Dayton Research Institute
Human Resources Office Room 565 D
Dayton, Ohio 45469-0105
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Attn: Chief Scientist Opening

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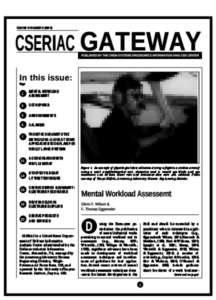
CSERIAC GATEWAY

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Mental Workload Assessment

CSERIAC Gateway (Vol. V No. 2, 1994)

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Calendar

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May 4-7, 1997
Palo Alto, CA, USA
ErgoCon '97. 3rd Annual Silicon Valley Ergonomics Conference & Exposition. Contact Abbas Moallem, Ph.D., ErgoCon '97 Conference Chair, Silicon Valley Ergonomics Institute, San Jose State University, One Washington Square, San Jose, CA 95192-0180. Tel: 408-924-4132, FAX: 408-924-4153, Email: amoallem@isc.sjsu.edu

May 11-16, 1997
Boston, MA, USA
SID '97. Society for Information Display International Symposium, Seminar, and Exhibition. Contact Hugo Steemers, SID '97 Symposium Chair, dpiX, A Xerox Company, 3406 Hillview Avenue, Palo Alto, CA 94304-1345. Tel: 415-812-4513, Fax: 415-812-4502, Email: steemers@parc.xerox.com

June 1-4, 1997
Washington, DC, USA
12th Annual International Occupational Ergonomics and Safety Conference. Contact Biman Das, Technical University of Nova Scotia B3J 2X4, Canada. Tel: 902-420-7606, Fax: 902-420-7858, Email: dasb@tuns.ca

June 3-4, 1997
Patuxent River, MD, USA
2nd Annual Symposium and Exhibition on Situational Awareness in the Tactical Air Environment. Sponsored by the Electronic Warfare Advanced Technology Program and the Naval Air Systems Command, and hosted by the Naval Air Warfare Center Aircraft Division. Contact Karen Garner, NAWC-AC, Crew Systems Dept, Bldg 2187, Suite 2280, 48110 Shaw Road, Unit 5, Patuxent River, MD 20670-5034. Tel: 301-342-9285, Fax: 301-342-9305

June 8-12, 1997
Orlando, FL, USA
IEEE 6th Conference on Human Factors and Power Plants. Contact Stephen A. Fleger, SAIC, 11251 Roger Bacon Drive, Reston, VA 20190. Fax: 703-709-1039, Email: stephen.a.fleger@cpmx.saic.com

June 16-19, 1997
New Orleans, LA, USA
36th Amercian Society of Safety Engineers Professional Development Conference. Contact ASSE, 1800 Oakton Street, Des Plaines, IL 60018-2187, USA. Tel: 847-699-2929, Fax: 847-699-2929, Email: 73244.562@compuserve.com

June 29-July 4, 1997
Tampere, Finland
13th Triennial Congress of the International Ergonomics Association, "From Experience to Innovation." Contact Prof. Markku Mattila, Tampere University of Technology, Occupational Safety Engineering, PO Box 589, FIN-33101 Tampere, Finland. Tel: +358-31-3162-621, Fax +358-31-3162-671, Email: mattila@cc.tut.fi

July 14-18, 1997
Sydney, Australia
INTERACT97. 6th IFIP TC13 Conference on Human-Computer Interaction. Contact INTERACT97 Conference Office, Australian Convention and Travel Services, Unit 4, 24-26 Mort Street, Braddon, GPO Box 2200, Canberra ACT2601, Australia. Tel: +61-6-257-3299, Fax: +61-6-257-3256, Email: interact97@acs.org.au, WWW: http://www.acs.org.au/interact97

July 31-August 3, 1997
Breckenridge, CO, USA
5th International Symposium on Organizational Design and Management (ODAM'96). Contact Ted Brown, 2 Belle Aire Road, Colorado Springs, CO 80906-4204, USA. Tel & Fax: 791-635-8881, Email: jbrown@databahn.net

August 24-29, 1997
San Francisco, CA, USA
HCI International '97. 7th International Conference on Human-Computer Interaction jointly with 13th Symposium on Human Interface (Japan). Contact Dr. Gavriel Salvendy, General Chair, or Kim Gilbert, Conference Administrator, School of Industrial Engineering, Purdue University, 1287 Grissom Hall, West Lafayette, IN 47907-1287. Tel: 317-494-5426, Fax: 317-494-0874, Email: salvendy@ecn.purdue.edu, WWW: http://palette.ecn.purdue.edu/~salvendy hci97/

September 15-20, 1997
Stockholm, Sweden
25th International Congress on Occupational Health (ICOH). Contact ICOH-Congress, National Institute of Occupational Health, S-171 84 Solna, Sweden. Fax: +46-882-05-56.

September 22-26, 1997
Albuquerque, NM, USA
41st Annual Meeting of the Human Factors and Ergonomics Society, "Ancient Wisdom–Future Technology." Contact the Human Factors and Ergonomics Society, PO Box 1369, Santa Monica, CA 90406-1369, USA. Tel: 310-394-1811, Fax: 310-394-2410, Email: hfeshq@aol.com, WWW: http://hfes.org

October 1-3, 1997
Galway, Ireland
International Conference on Revisiting the "Allocation of Function" Issue: New Perspectives. The Irish Ergonomics Society, International Ergonomics Society (IEA), & Institute of Industrial Engineers of Ireland. Contact: Edna F. Fallon, Centre for Occupational Health & Safety Studies, Dept. of IE, University College, Galway, Ireland. Tel: +353-91-52524411, Ext 2770 or 2754; Fax: +353-91-750524; Email: enda.fallon@ucg.ie; WWW: http://indeng.ucg.ie/allfn97

November 6-8, 1997
Kuala Lumpur, Malaysia
Association of Southeast Asian Nations (ASEAN) Ergonomics 1997 - 5th Southeast Asian Ergonomics Society (SEAES) Conference. Contact Dr. Halimahtun Mohd Khalid, Centre for Applied Learning and Multimedia, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Tel: +6082-672311, Fax: +6082-672312, Email: hali@calm.unimas.my, WWW: http://www.unimas.my

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

The CSERIAC Interface

Aaron "Ron" Schopper

What's in a name? HELP!

I was near the coffee pot the other day and I overheard the following conversation between two of our clerical assistants:

Mary: Hi Joanne. I'm headed back to my desk, Jim wants some help finding something. What are you up to?

Joanne: Well, I'm trying to help Harold. He wanted me to get a bunch of video screen design articles for him. And because he was going to be out of town for a week, he asked me to assist him by sorting them out according to the way the tasks were approached and how the end products differed.

Mary: Well, that should be a snap for you; you always seem to get involved pretty deeply with these things. The guys are always asking you to help them.

Joanne: Yeah, I know. That Introduction to Human Factors class I took was very interesting. And now that everyone has their own word processor, my job doesn't involve that much typing anymore. Most of the time I really enjoy trying to assist them; I like the opportunity to learn more.

Mary: But right now you seem a little frustrated.

Joanne: Well, Mary, I started reading the reports, and truthfully, they seem pretty confusing.

Mary: Say, I've helped on a couple of projects related to that–you know, what colors to use, how big to make the letters and such. That can't be too bad.

Joanne: Well, maybe its just me, but I've read a bunch of them this week, and I can't seem to understand how they differ all that much. They all appear to be talking about the same things, yet they refer to them by different names. A couple of them describe screens with "emergent" properties that were supposed to improve performance. Others wrote about "object displays" and . . .

Mary (interrupting)**:** Well, I'd be interested in looking at them.

Joanne: Well, if you have the time, I'd appreciate it. But it's even worse than I've indicated, Mary. There were "integrated" displays, "augmented" displays, and "configural" displays as well. When you tried to understand what they were really doing, it seemed there was an awful lot of overlap. You'd think that people whose entire careers are devoted to making things "user friendly" and "simpler" to understand could make the distinctions clearer. They should devote some time to "human-factoring" their own jargon!

Mary: Well, if it's that confusing for you, I'm certainly glad that it's your project and not mine.

Joanne: Yeah, you're lucky.

Mary: Say, I've got to run now. Jim's about to return, and I know he'll want me to get right on his project. I think he said he wanted me to help him get some information together to help him answer a software designer's question. Like always, Jim was in a hurry, and I didn't catch all that he said, but I think it had to do with designing an "ecological" something-or-another. Its amazing what computers can do–we'll probably be helping to save some endangered species.

So much for side-bar conversations at the coffee pot. But maybe Joanne has a point. It strikes a mildly sensitive nerve–that comment about "*human factoring* their own jargon." Well how about it? Are there any of you out there who are willing to accept her implicit challenge? How do they differ (integrated, object, emergent, configural, augmented, and ecological screen displays)? Are they intended to address different classes of display-related design issues? How do their approaches differ (i.e., what does the practitioner do differently in his or her efforts to design a video screen using each of these approaches)? If the same screen-design problem were to be given to an advocate of each approach, how would the final products differ? (I'll provide kudos to–and quotes from–those who provide the best responses. And you don't have to address all types; partial assistance welcomed!)

Any "takers?"

Aaron "Ron" Schopper, Ph.D., is Chief Technical Advisor to the CSERIAC Program.

41st Annual Meeting of the Human Factors and Ergonomics Society

"Ancient Wisdom–Future Technology"

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CSERIAC Techology Teams

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Dear CSERIAC...

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts. These questions have been compiled by David F. Wourms, Senior Technical Analyst. If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway* or email Dave Wourms at wourms@cpo.al.wpafb.af.mil.

- An industrial design student from Delhi, India, requested information about ergonomic considerations for designing city buses. Of particular interest were issues related to driver comfort, passenger ingress and egress, and safety.

- An engineer from a prominent technology center requested information on the latest design guidelines for graphic user interfaces for personal digital assistants.

- A professor from the Air Force was interested in literature related to head and eye movements associated with the onset of sleep in drivers.

- Navy personnel contacted CSERIAC to obtain information on modeling and simulation products to provide time-to-repair estimations for the maintainer.

- An Air Force researcher requested information on the benefits of simulators as training aids.

- An engineer from a major airframe manufacturer requested information on landing displays appropriate for vertical take-off and landing aircraft.

- Research scientists from Singapore contacted CSERIAC to obtain subject-matter expert points of contact in the areas of crew resource management, visual performance, safety, human error, anthropometry, and telemedicine.

- Air Force officials requested information regarding metrics that could be used to assess "quality of life" issues.

- A human factors specialist with a prominent research organization contacted CSERIAC regarding anthropometry and strength characteristics of the index finger.

Armstrong Laboratory Human Engineering Division Colloquium Series

When Human Errors Serve Safety Goals

René Amalberti

Editor's note: Following is a synopsis of a presentation by Dr. René Amalberti (see Fig. 1), IMASSA Laboratory, Cognitive Science & Human Engineering Department, French Airforce Aerospace Medical Research Laboratory, Paris, as the second speaker in the 1996 Armstrong Laboratory Human Engineering Division Colloquium Series: Human-Technology Integration. This synopsis was prepared by Barbara Palmer of the CSERIAC Program Office. JAL

Human reliability research in the 1960s and 1970s showed that humans were "intelligent, but fragile" machines. Belief in limited resource capacities led designers to oversimplify the end-user model. Human performance was seen as the result of a single-channel processor, which was workload-sensitive and highly unreliable. These concepts led safety and design engineers to conclude that in future systems, human error should be suppressed or at least considerably reduced, in the same way that system failures rates had to be reduced. The intensive development of automation and support systems in the last two decades was a pragmatic attempt to bypass these expected human reliability limitations. Only recently have these conclusions been questioned by a set of convergent research findings conducted in the field of operator cognitive modeling.

The newer thought is that human error cannot be suppressed, but negative consequences can be controlled. Therefore, a better safety goal should not target the suppression of human error production, but rather should suppress the propagation of human error toward error chain and incident/accident occurrence. Individuals develop protections and defenses against their own cognitive deficiencies. They have great abilities to recover their errors. Long-unrecognized detection and correction capabilities are now considered good indices of the operator's skills, and as key factors in the learning process and regulation of cognitive processes. Individuals also control risk-taking by means of a sophisticated contextual control model of cognition. The core of this control model is based on metaknowledge and confidence. Most of the results expressed here come from two programs: one, an eight-year effort called the Co-Pilot Electronic of the Rafale (French Pilot's Assistant program) and another, a four-year program for designing specific assistance regarding human error detection and prevention in military and civil aviation.

Figure 1. René Amalberti, IMASSA Laboratory, Paris.

A general ecological safety model which maps the limitations of performance (see Fig. 2) emerged from these studies, and relies on four characteristics:

- An analogy between dynamics cognition and a bet-making system. A dynamics model of cognition could be seen as consisting of a tool set, a bottleneck in available resources, and several solutions to bypass resource limitations.

The tool set is made up of the capacities of perception, action, memory, and reasoning. The solutions for overcoming resource limitations are threefold: (a) schematics of mental representation, and the ability to use the representation, allow humans to oversimplify the world with limited risks; (b) planning and anticipation allow humans to reduce uncertainty and to direct the world (proactive position) instead of being directed by the world (reactive position); (c) skill development and behavioral automation are natural outcomes of training and a remarkable way to save resources. These three solutions have two dominant characteristics. They are goal-oriented and based on a relationship to betting or establishing probabilities. The subject cannot reduce his universe to simplify it without betting on the rightness of his comprehension; the operator cannot be proactive without betting on a certain evolution of the situation; and the operator cannot drive the

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system using skill-based behavior without betting on the risk of routine error.

■ A regulation of cognition by several mechanisms dominated by meta-knowledge, margins, and confidence. Meta-knowledge allows the subject to keep the plan and the situation within supposed known areas, and therefore to bet on reasonable outcomes. The central cue for control mode reversion is the emerging feeling of difficulty triggered by contextual unexpected cues or change in the rhythms of action, which turn on several heuristics to update the mental representation and to keep situation awareness (comprehension) under (subjective) satisfactory control.

■ A model of error detection and error recovery. Controlling risk is not enough. Errors will occur regardless of the level of control and the subject knows that. She develops a series of strategies and heuristics to detect and recover errors. But the most interesting and recent result coming from field studies is that error rate is higher when the subject is extremely relaxed, then converges toward a plateau, and decreases significantly only when the subject approaches her maximum performance level. The detection rate is very high during the plateau, and decreases when the subject approaches her maximum performance precisely at the moment she is making very few errors.

■ Self-regulation of performance based on series of mechanisms when approaching maximum performance. The approach to maximum performance leads the subject to unstable boundaries with specific cues appearing in his behavior. This area of unstable boundaries is characterized by multiple and unstable changes in cognitive mode control, extreme attention, total resource involvement, reduction of error rate but an increase in undetected error rate, and the emerging feeling that the situation could soon be out of control.

For all these reasons, suppressing human error is seen as a naïve goal. A better approach would be to correct system ergonomics, but keep the human in the loop. Second, human error will come, regardless of the quality of design and training. The solution should never result in an extreme reduction of human-system interaction, since extreme reduction of human-interaction impairs human faculties to control the level of performance. The operator, deprived of any feedback of his own performance, is therefore deprived of the basic cognitive tools which ensure his ecological safety. In this case, the rare error he makes will have the double drawback of occurring at a strategic level of control (for which the system is unable to assist him because it asks for too much intelligence), and will have a greater chance of remaining undetected (because of the impairment of safety ecological mechanisms). Third, we need to develop systems defenses which respect ecological safety mechanisms, the individual and collective alerting cues which activate when approaching unstable boundaries (maximum performance). These mechanisms permit operators and systems to self-limit their performance to remain under the system and themselves under control. A good safety model should develop techniques and training to preserve and reinforce these ecological mechanisms instead of trying to hide them. ●

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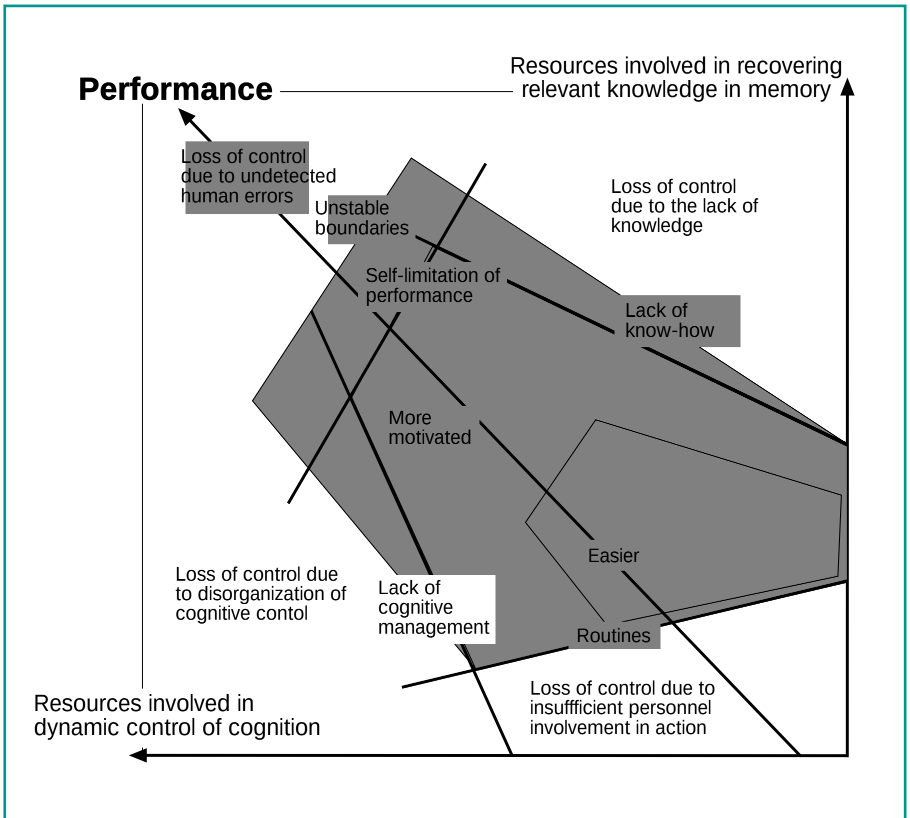

Figure 2. Mapping the limitation of performance. Illustration by Allison L. Herron.

The Cognitive Engineering Laboratory University of Toronto

Kim Vicente

Cognitive Engineering Laboratory

The Cognitive Engineering Laboratory (CEL) at the University of Toronto (U of T) is part of the Department of Mechanical & Industrial Engineering, and is one of three laboratories that comprise the U of T Human Factors Research Group. CEL was founded in 1992 and is primarily concerned with conducting basic and applied research on how to introduce information technology into complex work environments that require people to adapt to unanticipated and changing task demands. CEL's areas of expertise include advanced interface design principles, the study of expertise, and cognitive work analysis. The general mission of CEL is to conduct principled investigations of the impact of information technology on human work, so as to develop research findings that are both relevant and useful to industries in which such issues arise. CEL's long-term vision is to design and guide the principled implementation of a sociotechnical system that effectively supports adaptive behaviour, leading to demonstrably improved productivity, reliability, and health. Six plans have been identified to make progress towards this vision:

- Develop conceptual and analytical tools to systematically analyze, design, and evaluate adaptation in sociotechnical systems.
- Use these tools to identify and understand factors that influence adaptation within the context of (a) field studies of operational settings and practices, and (b) experimentation with representative micro-worlds and prototypes.
- Study and understand the engineering design process to identify methods and opportunities that could be used to influence that process so as to implement an adaptive sociotechnical system.
- Apply conceptual and analytical tools to design novel industrial applications in diverse domains, thereby assessing the generalizability of the findings obtained from field studies and experiments.
- Exploit opportunities to improve the fluency of work by removing technological barriers to functional adaptive behavior.
- Make novel and significant contributions to the component disciplines of cognitive engineering to bridge the existing gap between basic research and the applied problems motivated by the plans above.

Current CEL projects include:

- Studying the interaction between interface design and adaptation in process control systems.
- Understanding control strategy differences between people of various levels of expertise within the context of process control systems.
- Developing a better understanding of the engineering design process so that human factors guidance can be presented in a way that will be effectively used by human factors engineers.
- Designing novel computer interfaces to display the status of aircraft engineering systems.
- Developing and evaluating semi-transparent user interfaces for 3-D modeling, animation, and painting systems.
- Improving the interfaces to computer-based anaesthesiology equipment.

CEL's research has been funded by the following companies and agencies: Atomic Energy Control Board of Canada, AECL Research, Alias|Wavefront, Asea Brown Boveri Corporate Research-Heidelberg, Defense and Civil Institute for Environmental Medicine, Japan Atomic Energy Research Institute, Natural Sciences and Engineering Research Council of Canada, Rotoflex International, and Westinghouse Science & Technology Center. CEL also has close contacts with Westinghouse Electric Corporation, Honeywell Technology Center, Mitsubishi Heavy Industries, and Toshiba Nuclear Energy Laboratory.

As a direct result of the funding obtained to date, CEL has started to develop an infrastructure for conducting research. The following research equipment is currently available: two Iris Indigo workstations which are complemented by seven personal computers (five Macintoshes and two IBMs). In addition, the laboratory houses a wide range of audio-video devices including several Sony "8" and "High-8" video cameras and a super-VHS Sony editing VCR. CEL also has a variety of powerful software packages, including FIX (by Intellution) and VAPS (by Virtual Prototypes, Inc.) for rapid prototyping and SAS for statistical analysis. All this equipment is housed in a new laboratory facility which has been specifically designed to conduct research with human subjects in a comfortable, controlled environment.

Currently, the staff of CEL is composed of eight graduate students with backgrounds in a variety of disciplines, including industrial engineering, nuclear engineering, systems design engineering, biology, anthropology, geophysics, mathematics, and

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The Second Annual Symposium and Exhibition

Situational Awareness in the Tactical Air Environment

Karen Garner

The nature of the battle scene of the 1990s and beyond makes the lack of adequate situational awareness the paramount mission concern of many warfighters. Even third world opponents use highly mobile and lethal forces against airborne targets. To counter the threat, the tactical aircraft weapon system must rapidly identify, avoid, or defeat various surface and air-to-air threats. Improved situational awareness is the key to providing accurate and effective weapon delivery on today's targets (see Fig. 1).

The 1997 Situational Awareness in the Tactical Air Environment Symposium will be held June 3-4 at the Naval Air Warfare Center Aircraft Division, Patuxent River, Maryland. The symposium is sponsored by the Navy's Electronic Warfare Advanced Technology (EWAT) Program and will focus on adaptive automation, decision aiding, and sensor fusion. These advanced technology concepts and programs are vital due to the critical nature of situational awareness.

The EWAT Program considers situational awareness an onboard commodity: the processing and presentation of information from radar warning, missile warning, laser warning and countermeasures systems to the operator. Primary attention is given to the human operator as sensor and processor. Operator situational awareness comprises detecting information in the environment, processing the information with relevant knowledge to create a mental picture of the current situation, and acting on this picture to make a decision or explore further.

Figure 1. Use of cockpit simulation to enhance situational awareness.

By taking a closer look at data provided by the sensors and investigating advanced technology techniques, a more comprehensive, focused picture of the environment can be presented to the aircrew.

Situational awareness is complex and requires integrating inputs from multiple sensors which include offboard and onboard aircraft systems as well as human physiological systems. Sensor systems provide data to aircraft computers; computers process data using algorithms and then present the processed data as information to the aircrew who possess diversified capabilities and preferences. Operator psychophysiological capabilities (sensation and perception, cognitive processing capability, training, experi-

Figure 2. One of many advanced technology displays from last year.

ence, etc.) and environmental stressors (temperature, noise, vibration, acceleration, fatigue, etc.) also affect situational awareness.

The objective of the Symposium is to provide a heightened appreciation of situational awareness in tactical aviation. It provides a forum for information exchange between academia, aircrew, industry, and tactical aircraft platform and program managers. The intent of this information exchange is to heighten individual perception and appreciation of situational awareness in the tactical environment, eventually leading to efficient avionics system design and employment.

A nominal $50 (US) registration fee to cover the cost of the symposium notebook, proceedings, and lunches will be charged. A technology exhibition (Fig. 2) and keynote address (see Fig. 3) will be held in conjunction with the symposium.

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Figure 3. Rear Admiral Steven R. Briggs, USN, delivers keynote speech at last year's symposium.

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. Your input would be greatly appreciated.

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computer science. This diverse mix of students promotes a multi-disciplinary approach to research, which is essential in tackling the research challenges imposed by complex systems.

For more information about CEL, its publications, or graduate school opportunities, please contact:

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Paul M. Fitts Human Engineering Division

Synthesized Immersion Research Environment (SIRE)

Editor's note: To inform our readers of the many unique facilities in the Human Engineering Division of the Armstrong Laboratory, we will periodically focus on one. In this issue, we examine the Synthesized Immersion Research Environment (SIRE). JAL

The Synthesized Immersion Research Environment (SIRE) is a state-of-the-art virtual environment research facility whose mission is to develop and evaluate advanced, multi-sensory virtual interfaces for future United States Air Force crewstations. The facility consists of several autonomous research stations which can support individual research efforts or be combined to form a multi-participant virtual environment.

One striking research station within SIRE is a 40-foot diameter dome with a high-resolution, large field-of-view (70 degrees vertical by 150 degrees horizontal) interactive visual display driven by a Silicon Graphics Onyx computer image generator. It also includes auditory displays capable of presenting simulated three-dimensional, externalized sound information, and an electro-hydraulic control loader system to provide augmented haptic cueing information.

A general purpose research environment, SIRE can be configured to support applied research regarding the design of advanced human-vehicle interfaces, including aircraft and ground vehicles. SIRE also incorporates tactical all-aspect helmet-mounted displays, wide field-of-view binocular helmet-mounted displays, virtual manual controls, and brain-activated controls. It can also be configured to support fundamental research on multi-sensory perception and human performance in virtual environments.

Another research station within SIRE is the Fusion Interfaces for Tactical Environments (FITE). FITE provides wide field-of-view, out-the-window visuals and a crewstation incorporating three-dimensional auditory cueing, haptic cueing provided by an electro-hydraulic control loader system. The FITE crewstation includes standard F-16 controls and an array of liquid crystal head-down displays.

SIRE supports a broad range of human factors engineering research efforts toward the development of future-generation, multi-sensory crewstations. The program includes:

- joint development of advanced crew-station concepts with French and British scientists and engineers,
- development of pilot-vehicle interface concepts which adapt in real-time to the pilot's state of workload and situation awareness,
- integration of physiological measures of workload to optimize information display in real time,
- integration of alternative control technologies including brain-actuated control and eye line-of-sight control,
- development of haptic feedback information to facilitate vehicular control, and
- evaluation of advanced crew-station interface concepts by means of multi-participant simulated air combat scenarios.

One primary function of SIRE is to integrate human engineering technologies being developed at the Armstrong Laboratory into future crewstations. SIRE researchers often collaborate with other laboratories in the Human Engineering Division (including the Brain-Actuated Control, Flight Psychophysiological, and Computerized Anthropometric Research and Design laboratories), and researchers from academia and private industry.

SIRE's visual display capability is unique in its large field-of-view, high-resolution characteristics, and is capable of displaying any scene generated by a general-purpose graphics system. Because of this versatility, the facility's applications extend beyond advanced crewstation interface design. For example, SIRE can support research in defense and industry-related areas including advanced data visualization techniques and computer-aided manufacturing design techniques. SIRE currently supports an international, cooperative research and development program with the French government. This work is geared toward the development of an advanced multi-sensory suite of fighter cockpit displays and controls using technology developed by United States and French manufacturers. SIRE now contains the only joint US-French fighter cockpit in the United States. SIRE is also supporting Vista Warrior, a collaboration effort with the United Kingdom which is developing operator interface concepts which adapt to operator state. ●

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CSERIAC's principal products and services include:

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- 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;
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