DEFEATING TERRORISM:

What Can Human Factors/Ergonomics Offer?

Principles described here, though focusing on aviation security, apply to *all* aspects of human interaction with technology to facilitate homeland defense.

By P. A. HANCOCK & S. G. HART

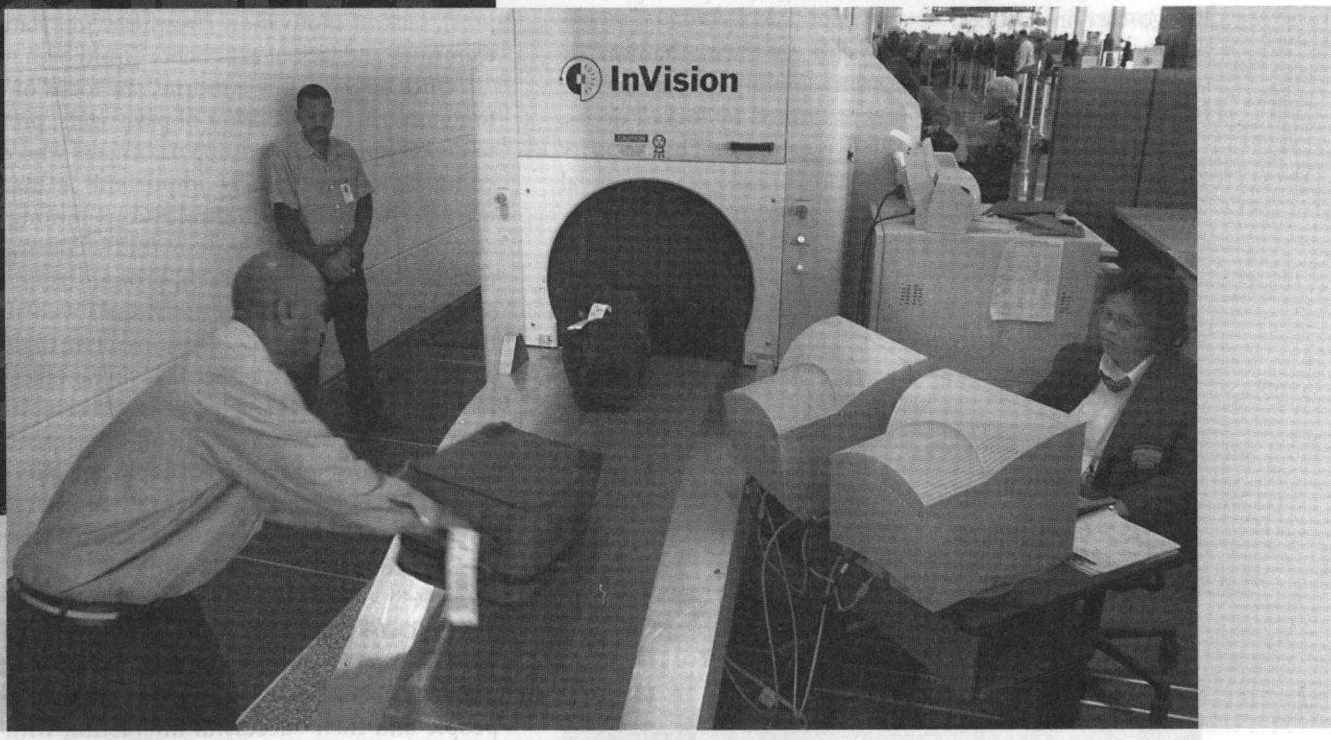
"THE TIMES CHANGE AND WE MUST CHANGE WITH THEM." In light of the events of September 11, 2001, this is indeed true. In response, a panel was convened at the 45th Annual Meeting of the Human Factors and Ergonomics Society in early October 2001 to explore some human factors/ergonomics (HF/E) implications of the attacks and the ways in which future attacks may be avoided through the application of our science. The following article, an extension of that discussion, seeks to communicate ways HF/E can address the vast range of techical challenges that, because of these acts of terrorism, now face society.

First, we describe some of the existing HF/E research that is relevant to the challenges posed by the events of September 11. (After all, HF/E professionals are not newcomers to the concerns that have been identified.) Second, we provide a brief summary of some areas in which we see opportunities for HF/E science to contribute.

We are especially intent on disseminating this information broadly. In the past, HF/E has shown the fallacy of oversimplistic technological fixes in which the human element is either overlooked or neglected completely. Human-centered solutions to problems involving complex human-machine systems are much more liable to be permanent and obey the principle of *primum non nocere* (first, do no harm). Through these strategies, HF/E professionals can provide effective answers to crucial issues of security, emergency response, and military action. Without such input, well-intentioned, immediate technical responses to the identified problems of terrorism may not only fail but even ultimately support terrorists' aims by inadvertently inducing unnecessary disruption.

The one thing that most criticisms of current systems and proposed solutions have in common is the human element. Examples abound of the vulnerability of pilots, flight attendants, passengers, and the inhabitants of targeted locations to a determined foe; the fallibility of security personnel; and the enormous range of choices faced by everyone involved in responding to the events of September 11. Although the examples we provide focus primarily on preventing and mitigating future terrorist attacks against the flying public, *HF/E principles and solutions can and should be applied to the vast majority of all concerns for homeland security.*

We fully realize that many readers will already be familiar with much of the material we have presented. However, our purpose is twofold. First, this article is a "call to arms" to HF/E professionals to continue to conduct research relevant to counterterrorism and to press for the implementation of systems, procedures, and devices that incorporate HF/E research and methods in order to help all countries better prepare for new threats to human well-being. Second, we wish to provide HF/E professionals and HFES members with a manifesto to carry to lawmakers, business leaders, and the general community to illustrate and champion the crucial role of human factors/ergonomics in this "war" on terrorism.



Baggage screening at Washington's Reagan National Airport after passage of a new law requiring airlines to screen baggage for explosives. AP Photo/J. Scott Applewhite. Used with permission.

Considering Current Issues

Nationwide attention has now focused on vulnerabilities in the security surrounding the national airspace system that have been ignored for decades. The events of September 11 simply highlighted the inadequacies of airport security exposed in investigations and reports during the past 20 years. For example, U.S. Department of Transportation investigators were able to breach airport security 117 times out of 173 attempts (68%) in a test of airport security effectiveness performed just a year ago (Dillingham, 2000). Interestingly, many of these reports documenting the deficiencies of airport security systems attributed a number of the problems (and, thus, potential solutions) to "human factors." To some extent, lack of progress in resolving identified deficiencies has reflected an inherent conflict between airline goals of reducing cost and increasing profit and the expense of maintaining effective passenger and baggage screening.

Until very recently, airlines, government agencies, and the flying public focused more on improving flight safety and system capacity than on security. Passengers demanded inexpensive, on-time operations with minimal irritation and worry over the possibility of an accident. Airlines sought to maintain a competitive advantage by focusing on convenience, cost, and comfort and preventing accidents. Those responsible for the aviation infrastructure likewise have sought to increase the capacity and reliability of the system and to prevent aircraft from colliding with each other, or from entering dangerous weather conditions.

Unfortunately, meeting the demands of the flying public left open opportunities for terrorists. Global acts of terrorism in aviation have been on the rise. Between 1995 and 1998, there were an average of 11 hijackings per year, rising to 20 in 2000 (FAA, 2000), but hijackings are only one type of threat. In 2000 alone, 42 criminal acts were performed against aircraft and flight personnel worldwide, nearly double the 1999 total.

One consequence of the events of September 11 is that renewed attention is being devoted to each of the layers of security required to offer a "defense in depth" to threats already known – hijackers, bombs in luggage, suicidal pilots – as well as others only imagined. Although the FAA had ultimate responsibility for airport security, this has been primarily in the form of setting standards and monitoring performance. Air carriers were assigned the *immediate responsibility* for passenger screening and baggage facilities, although this will change under the recently signed Aviation Transportation and Security Act.

Increased security efforts are supported by a variety of technologies provided by the U.S. government (e.g., metal detectors and machines to detect weapons in carry-on luggage or explosives in checked luggage or cargo). Ultimately, however, the effectiveness of the process has and will continue to depend on the performance of the human operators. Thus, people continue to be the key line of defense in preventing threats to the integrity of passenger- and cargo-carrying aircraft.

Just as important, but less visible, are the mechanisms by which access to secured areas surrounding aircraft and air traffic control (ATC) facilities is limited by locked doors, security guards, and surveillance cameras. This security function has been performed by a mix of state or local police, private security forces hired by the airport, and physical barriers such as fences and locked or guarded gates. A variety of suggestions are being considered to limit access to parked aircraft and airway and ATC facilities. It has been estimated that as many as one million people have access to such areas by virtue of an ID card, key, or keypad code, and not all of these retain legitimate rights to such access. Thorough background screening of people who will be given access to secured areas in the future (so-called threat vectors) – such as pilots, flight attendants, maintainers, food service contractors, cabin groomers, baggage handlers, construction workers, and security personnel – will become mandatory. This process requires accessing numerous and disparate databases, a skill possessed by many human factors/ergonomics experts. An additional layer of security might be offered by security cards containing some form of biological marker.

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Many have commented that the 30,000-strong aviation security personnel force in the United States has been an ill-paid, undertrained, and transitory workforce. This situation has persisted despite numerous reports (e.g., U.S. Government Accounting Office, 1987) and public criticism (e.g., Dillingham, 2000). In 1978, screeners failed to detect 13% of test objects, and in 1987, they failed to detect 20% during a similar test (GAO, 2000). The reasons cited for this poor performance in 1978 included high turnover, low pay, and inadequate training. These are the same deficiencies cited in 1987, 1997, and 2000 (GAO, 1987, 2000; White House Commission on Aviation Safety and Security, 1997).

The 2000 report also summarized the results of a study in which U.S. screeners were found to perform substantially more poorly than their European counterparts and suggested lessons to be learned from Europe. Offering security workers a living wage, imposing strict selection and performance standards, and providing a path for advancement might solve a host of human issues, such as the lack of vigilance caused by fatigue (from being forced to work two jobs), lack of motivation (from low job status), and poor teamwork and lack of experience (from high turnover).

Once an aircraft is airborne, the focus of security shifts to monitoring the behavior of passengers, preventing access to the cockpit, and subduing passengers who exhibit threatening behavior. Equally important is maintaining the integrity of voice communications among the aircrew, company dispatchers, and air traffic controllers and data transmissions among aircraft, ground-based facilities, and satellites. The presence of individuals who seek to disrupt the normal operations of commercial flight represent a significant concern, whether that threat takes the form of a terrorist group or a single passenger exhibiting "air rage" (Schmid, 1997). Finally, difficult decisions must be faced about the use of military force to prevent aircraft from being used as weapons against citizens by future terrorists. Many layers of security must be upgraded to achieve a system that is as secure as it is safe.

Previous Human Factors Applications

The interdisciplinary science of human factors/ergonomics extends well beyond aviation, being concerned with people and their successful interaction with all forms of technology (see Dempsey, Wogalter, & Hancock, 2000). Through a synthesis of knowledge from the disciplines of psychology, physiology, biomechanics, engineering, and the cognitive sciences, HF/E has applied the benefits of a human-centered philosophy to the design, manufacture, and operation of the vast spectrum of technical systems, demonstrating the theoretical, practical, economic, and even moral advantage that this perspective brings.

With respect to combating the terrorist threat, HF/E professionals have already made significant contributions to issues including areas as diverse as intelligence analysis, security improvements, and emergency egress. The following represents a brief précis of such successes.

Intelligence Analysis

Intelligence about terrorist networks, their associations and locations, and their method of operation is critical to any form of antiterrorism strategy. Intelligence analysis, a critical component, involves developing inferences from collected information through a process of data integration and inductive reasoning – developing "who, what, where, and how" inferences from fragmentary and sometimes inaccurate information. Since 1971, a sustained effort in intelligence analysis has resulted in the development and training of techniques for law enforcement agencies throughout the world (see, for example, Harris, 1978). These courses address a full range of complex criminal activities including terrorism. Courses have been conducted for personnel from more than 1500 agencies worldwide, including the Federal Bureau of Investigation, the London Metropolitan Police (Scotland Yard), and the Royal Canadian Mounted Police. This is only one example of an HF/E success.

The Department of Defense's Joint Vision 2020 acknowledged that information superiority provides the joint forces a competitive advantage only when it is translated into superior knowledge and decisions. Humans make these decisions. To make effective decisions, humans must first have situation awareness. In their review of the critical importance of "substantially investing in the human factors side of situational awareness," Moore and Morris (2001) cited the contribution of Mica Endsley, a participant in the panel that prompted this article.

Just as information technology offers a wealth of opportunities to redefine military superiority and human/technology roles and responsibilities to improve systems safety and efficiency, it also offers similar benefits for systems security. The importance of the link between HF/E and information technology was recognized a decade ago by the Committee on Aeronautical Technologies (1992) convened by the National Research Council to forecast aeronautical technologies in the 21st century. This group predicted that information sciences and human factors would play a different and more fundamental role in development for the next two to three decades, despite the fact that human factors has been applied rarely – even as an afterthought – by developers of computer technology. The simple fact is that many HF/E successes in intelligence are not available for public release, and thus, like the following observations on military response, we have to talk in generalities on these sensitive issues.

Military Response

The military response in an antiterrorism campaign must necessarily rely on the capabilities of highly trained special forces that are physically capable of missions under extreme conditions and environments. Examples of HF/E efforts completed in support of special forces preparation over the past two decades include (a) analysis of the most physically demanding missions and tasks performed by Navy SEALs; (b) analyses of the crew positions of the Swimmer Delivery Vehicle, the submersible transporter used by SEAL team personnel for long-duration covert insertions; (c) support for simulation-based mission rehearsal for the Special Operations Forces of the Air Force; and (d) a behavioral model of the special operations forces mission preparation process (Harris, personal communication, November 6, 2001). Like questions of intelligence, many aspects of military response are enhanced by HF/E, but secrecy is important in maintaining the edge that such applications provide.

Emergency Response

Psychologists working for the FAA as long as 30 years ago developed techniques to train pilots to respond to aircraft hijacking and other threatening events. More recently, these professionals have contributed to the selection and training of the dramatically enlarged cadre of federal air marshals.

In late 2001, the NRC Committee on Human Factors responded to a request from the FAA for input regarding the same program. In addition, there have been clear examples of missed opportunities. For example, one HF/E professional, Jake Pauls, indicated the crucial need for a research effort to evaluate evacuation procedures as he sought to understand the February 26, 1993, evacuation of the World Trade Center (Pauls, 1994). This call for resources was not supported at the time, and an opportunity for understanding was not exploited.

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Now, the call of HF/E must be heeded in order to ameliorate and prevent death and injury from similar events in the future. It is evident that application of HF/E knowledge to emergency response capabilities is liable to be a very fruitful endeavor.

Airport Security

HF/E professionals have been addressing issues of commercial aviation security for the past decade at the FAA and on committees and panels of the NRC. They have discussed threats and physical security for much longer. HF/E issues were central to many of the findings of these multidisciplinary committees and panels. A past HFES president, Douglas Harris, served on the NRC Committee on Commercial Aviation Security; he and another former president, Kenneth Laughery, also served on the NRC Panel on Passenger Screening. These efforts resulted in a better understanding of human factors in security and provided many recommendations (which have not yet been implemented) for security enhancement (NRC, 1996, 1999; and see Harris, this issue).

The FAA's Aviation Security Human Factors Program (AAR-510) has been in place for several years, instituting programs to improve the performance of security personnel. The redesign of equipment to conform to human needs and the development of personnel policies have been the subject of research initiatives. In recent years, new tests have been developed for screener selection and training, and the requirements for on-the-job training have been changed to include much human factors knowledge.

For example, the Threat Image Projection (TIP) system was developed by HF/E researchers in the FAA and industry partners to maintain the alertness of checkpoint screeners and to monitor their performance. This system, which received the prestigious Aviation Week Technology Innovation Award in 2000, randomly projects computer-generated images of virtual bags containing guns, knives, and bombs or images of weapons onto the screen images of real bags going through security checkpoint X-ray machines. FAA Administrator Jane F. Garvey said about this system, "We've deployed hundreds of advanced technology devices to detect explosives in passengers' bags, but this is the first system we've designed to improve the performance of the human operators – our first line of defense in aviation security" (FAA, 2000).

Unfortunately, deployment of the 1200 systems necessary to equip all checkpoints has been slower than projected. Establishing a program to certify security companies that staff such checkpoints, recommended by the White House Commission on Aviation Safety and Security (1997), was delayed as well because TIP systems were not in place to set standards and evaluate compliance.

Let us move from past examples to what HF/E can contribute to future efforts.

Potential Human Factors Contributions

Many layers of security must be upgraded to achieve an aviation system that is as secure as it is safe. Similarly, there are many subdivisions in the field of HF/E with the relevant knowledge and tools to accomplish this. Potential avenues for improving security have been detailed in previous reports (GAO, 2000; White House Commission on Aviation Safety and Security, 1997). A number involve issues encompassed in the field of HF/E. Human factors professionals must "think in a more creative way about how our research might be useful – we know a great deal that is not being used," as the executive director for Science of the American Psychological Association asserted (Carpenter, 2001), even though complete or immediate answers might be lacking. As recent events promise to replace previous inaction with a desire for rapid implementation, HF/E professionals must be ready to offer information and assistance. The following represent a few examples of topics that are certain to be addressed.

Federalizing the security workforce might go a long way toward reducing the high turnover of airport security personnel (more than 100% per year at all major U.S. airports, and as great as 400% at one major airport last year; GAO, 2000). Associated with turnover are matters concerning personnel experience (which remains limited), performance (which is inadequate both absolutely and relative to that in other nations), and training (which is inadequate at 12 hours). The requirements for shiftwork and the stressful conditions under which many security workers labor affect job satisfaction, retention, and performance unless steps are taken to remediate the situation.

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The Aviation Transportation and Security Act, signed into law on November 19, 2001, requires that all baggage carried aboard commercial jets be screened. This will require not only the expenditure of billions of dollars to purchase sufficient machines to screen the baggage of nearly two million passengers each day in a timely way but also a cadre of human monitors to differentiate false alarms, which are frequent, from true threats, which are extremely ill-defined and infrequent. The human factors/ergonomics field might contribute to the development of technologies to perform the elements of airport security that humans tend to perform poorly.

Procedural, structural, technological, and regulatory changes envisioned for the flight deck or cabin of commercial aircraft and the host of people and facilities with whom they interact might prompt the HF/E community to ready relevant research to support or caution against specific proposals. These professionals might lend their expertise in task analysis, modeling and simulation, interface design, human-centered automation, performance measurement, procedure development, and selection and training to this segment of aviation security.

Overreaction is of great concern as HF/E professionals seek to improve safety and deny the terrorist aim of social disruption. Woods (personal communication, October 16, 2001) noted that although many well-meaning procedures are being considered for implementation to enhance homeland security, a new risk for "friendly fire" accidents is possible perhaps by a breakdown in ground-to-air communication leading to military response. The depth of the risk and the effectiveness of the new processes going into effect would benefit significantly from careful scrutiny, a task at which the HF/E field excels. Identification of friend-or-foe-type technologies does not work in the case of hijacking, in which intent must be inferred by actions. The decision to bring down an off-course commercial airliner poses a terrible problem, and people are all too ready to apportion blame when a mistake is made in such a situation.

One potential solution offered by Gilson (personal communication, October 10, 2001), among others, is to provide envelope protection such that aircraft are preprogrammed (and cannot be deprogrammed) to exclude flying into specific prohibited areas, such as those involved in the September 11 attack. Even more extreme are proposals suggesting that pilots of threatened aircraft give over control to remote pilots, who would somehow guide the aircraft through a safe landing. Aside from issues of technical feasibility (which are not as trivial as implied by the proponents), the implications for the humans in the system (the system as a whole) must be addressed by dispassionate, thorough, and systematic analyses. The field of human factors/ergonomics offers the tools and rigor to evaluate alternative proposals in a dispassionate, controlled, and systematic way.

Performance Assessment

HF/E rests on a foundation of expertise in assessing the performance of humans and systems in simulated and operational environments. These skills can be useful for estimating the impact of proposed antiterrorist solutions to aviation. In the near term, such expertise might be devoted to mitigating the negative consequences of the current proliferation of unilateral and ad hoc responses to perceived threats and to avoiding unintended consequences associated with the hasty introduction of new technologies, procedures, or regulations.

Tools such as the Crew Activity Tracking System (Callantine, 2001) enable existing and proposed technologies and procedures to be specified, analyzed, and assessed. Multiple models can be interleaved to discover procedural gaps that might pose future security threats. HF/E performance assessment skills might contribute to improved selection and training criteria and methods to ensure that the new cadre of security personnel have the requisite aptitudes and attitudes.

Signal Detection, Vigilance, and Monitoring

The strong scientific foundation of knowledge about sustained attention and visual search can contribute to requirements for monitoring multiple channels simultaneously, seeking unspecified threats, and detecting low-probability, infrequent targets – approximately one knife or gun per month per airport that has been the norm. In most situations, the problem comes down to distinguishing the harmful from the harmless, as, for example, in the security issue of weapon-spotting or in the realm of potential biological attack (that is, in distinguishing specific events against a fluctuating background of normal disease). In HF/E terms, this requires the detection of signal among noise and is served by *signal detection theory*, or SDT (see Swets, 1996). This mathematical formulation allows us to identify the capability of the observers, their sensitivity to targets, and their change in decision criterion over time.

In the real world of airport security, as newer and more sensitive technical systems (such as TIPS) are brought on line, screeners are required to make ever more sophisticated distinctions between what is a potential threat and what is not. HF/E experts know, for example, that an observer's capability diminishes over time, although a number of ways to sustain higher levels of attention in the face of this *vigilance decrement* have been developed (Davies & Parasuraman, 1982; Warm, 1984).

A recent extension of SDT in which the inherent uncertainty of observations and responses is explicitly included may improve human-machine detection significantly. For example, what happens when a weapon is divided into pieces and each component part may be thought harmless but their assemblage would certainly be dangerous? Fuzzy signal detection theory (Parasuraman, Masalonis, & Hancock, 2000) can address this situation and is also applicable to other military counterterrorist responses. HF/E has the theoretical foundation to address the new situations now being experienced.

Often the goal of safety or security is to ensure something does *not* happen. But people are not good at understanding nonevents, and there is little reinforcement. Thus, each of these small victories goes by unnoticed and unremembered, whereas the one spectacular failure is the topic of endless scrutiny. Individuals responsible for security are thus faced with the ongoing problem of vigilance or sustained attention with little reward. The ability of people to detect signals in conjunction with advanced technologies is one aspect of study by HF/E professionals. Existing knowledge can specify how a person's detection capacities

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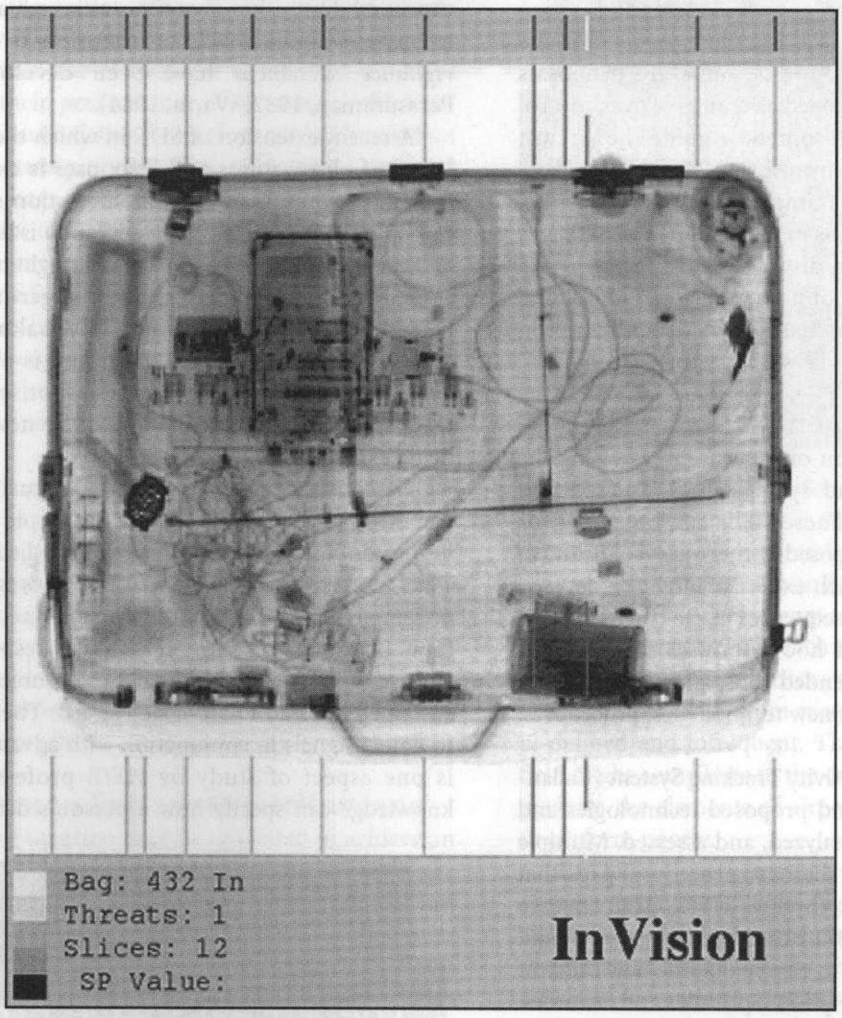
are influenced by target probability, previous success and failure rates, and the payoffs or incentives for avoiding errors and performing correctly. For example, it is widely accepted in the psychological literature that feedback on the correctness of each response fosters optimal performance. Feedback is effective even if it cannot be provided in every instance.

One great problem in vigilance for security is the very low frequency of signals. In addition, increasing the number of different targets being sought degrades performance. To increase sensitivity, it may be necessary, for instance, to have each item scanned by different observers assigned to detect



A can bomb is detected with the FAA-certified CTX 500 explosives detection system. AP Photo/InVision File. Used with permission.

different weapons or classes of weapons. But often screeners may work many shifts without observing anything approaching a signal. The less likely the target, the higher the observer tends to set the criterion for detection; thus, the radar operators who first detected the Japanese attack on Pearl Harbor, and the officer in charge, found the evidence displayed on their screen hard to believe.

Occasional detection can increase sensitivity by refreshing the image of the target and by contributing to heightened alertness. (This notion prompted the development of the TIP system.) Through the deliberate introduction of artificial targets, the perceived probability of target occurrence and the criterion for detection can be manipulated to foster additional benefits. As a consequence, HF/E professionals can help with long-term vigilance and target detection well after the initial gains associated with the heightened awareness dissipates.

Since the late 1940s, the conception of vigilance or monitoring tasks was that they were boring and poorly performed because of the low level of cognitive and sensory demand that they placed on the individual (see Buckner & McGrath, 1963). This conception changed when a new view of vigilance proposed that enforced, prolonged monitoring is in fact a highly stressful situation. HF/E can help significantly in this realm by contributing to the understanding of the nature of cognitive deterioration and how this reduction in performance capacity can be addressed by machine assistance. Such apparently sedentary tasks are much more difficult to perform over a prolonged period than might be suspected from a cursory glance at what the individual appears to be doing. Specifically, HF/E science can improve the detection efficiency of existing systems and show how much-improved systems can be designed. Again, this includes security screening and extends to pattern recognition applications in which links to vision research and cognitive sciences demonstrate how the design of human-machine detection and decision systems can be enormously improved.

Operator Perception

As the spectrum of targets sought by human and machine screeners becomes clearer, means of enhancing the signals they provide can be devised. Initially, simply increasing the contrast of displayed images is likely to enhance performance. Knowledge of the human visual system might eventually form the basis for machine vision algorithms to offer automated pattern recognition systems to support the efforts of human monitors of a variety of video displays used for security. Similarly, the effective remote surveillance of digital streams of video images transmitted from passenger boarding areas, the cabins and cockpits of transport aircraft, and restricted areas surrounding aircraft and sensitive ground facilities could be enabled by video compression techniques that retain key perceptual information (Watson, Yang, Solomon, & Villasenor, 1997).

The human visual system follows a set of principled rules to achieve pattern recognition (Biederman, 1987). With knowledge of these rules, HF/E professionals know how to improve significantly the effectiveness of people engaged in such tasks. For example, using current technology to render three-dimensional representations of objects on screens, as compared with the current 2D representations, will clearly benefit those engaged in screening baggage for suspicious objects. To supplement visual displays, auditory alerts from multiple sources that have been spatially separated might enable a single operator to monitor multiple channels (Begault, 1994). HF/E knowledge of the human visual system offers support for the development of very efficient iris-scanning or face-matching procedures.

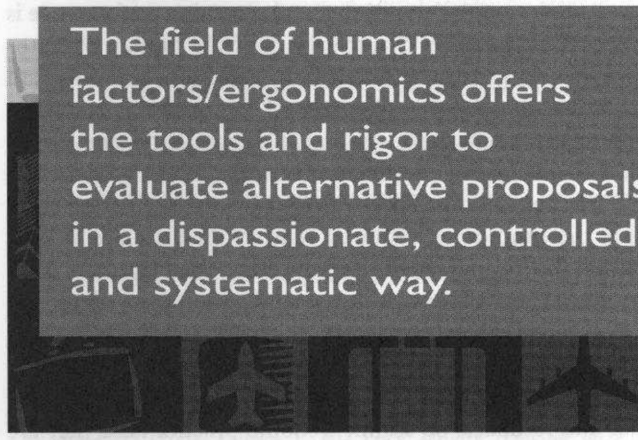
Operator Alertness

HF/E research on fatigue, shiftwork, and circadian effects suggests that tired workers are more likely to respond more slowly to or even overlook obvious threats. Fatigue is a risk factor for any extended, repetitive task, especially a task performed at night or at the end of a shift, and is exacerbated by preexisting sleep debts. New technologies have been developed that can monitor alertness levels unobtrusively in real time, identify periods of reduced vigilance, and alert operators (or their supervisors) when a threshold reduction in vigilance is detected (Dinges, Mallis, Maislin, & Powell, 1998).

Fatigue countermeasures developed for and implemented in a variety of other environments can be adapted readily to improve the performance of security personnel (Caldwell, 1997; Rosekind et al., 1994). Efficient methods of calculating optimal schedules and timing rest periods are being developed that could be adapted to reduce the impact of fatigue and shiftwork on the tedious yet crucial jobs of monitoring security cameras and baggage-scanning displays.

Team Performance

HF/E expertise in establishing and maintaining effective team performance might be brought to bear on teams of security personnel at individual checkpoints as well as the many people who are responsible for other aspects of airport security. Similarly, this subdiscipline offers approaches for reestablishing flight deck crew, cabin crew, and air-ground interactions that will be affected by recent events and potential introductions of new regulations, procedures, and technologies (see Weiner, Kanki, & Helmreich, 1993). Experts in organizational psychology offer techniques for improving the performance of the larger entities within which these transitory teams of security personnel, aircrew, and air traffic managers must fit. Audio, video, and digital technologies might be employed to facilitate the development and archiving of response plans across organizations, supporting the need for collaborative teamwork under time-critical conditions (Kanki, Seamster, Lopez, & LeRoy, in press).



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Public awareness programs could educate and reassure the flying public. Just as the effective creation of a safety culture within a company requires the involvement and buy-in of its employees, so will the evolving security climate in the national airspace system require buy-in of its customers (the flying public). Johnson (personal communication, September 26, 2001) advocated the notion that cabin crewmembers can coordinate their efforts with able-bodied passengers specifically recruited to lend support to thwart such threats. Thus, in addition to an awareness of potential sources of threat, cabin staff should also be trained to identify passengers who might help defuse a disturbance. This is, after all, only an extension of a current procedure to identify those ready to assist in evacuations through emergency exits. HF/E professionals can help by applying already developed techniques for identifying both potential supporters as well threats among passengers.

Selection and Training

HF/E expertise in training can be brought to bear to improve personnel job satisfaction, retention, and performance; to support new procedures and technologies; and to incorporate security into airline safety cultures. The field has a long and successful record concerning the use of training to compensate for poor design, although this is not a preferred strategy.

A particularly relevant application of human factors to aviation has been the institutionalization of crew resource management (CRM) in all major airlines (see Salas, Bowers, & Edens, 2001). Applying these techniques to ensure that the humans in the system are ready for changes in regulations, procedures, and technologies will be a valuable contribution to counterterrorism efforts. As is also true with respect to safety, it is unreasonable to expect that aviation will ever be completely free of risk as a result of increased security. However, it must be the goal of everyone in the system to eliminate as many known deficiencies as possible, to take advantage of available databases and airspace-system-monitoring capabilities to identify additional risks and vulnerabilities, and to track the impact of solutions as they are implemented.

As an example, monitoring and screening performance is affected as much by characteristics of the human operator (which are, in turn, influenced by selection, training, and experience) as by characteristics of the work environment, job requirements, and equipment design. Until one knows how to distinguish effective scanners from those who are less effective, one may be limited to the obvious, such as ensuring that the candidates' required sensory qualities are at least within the normal range (as many targets displayed on video monitors are of low contrast and automated alerts are color-coded). Thus, applicants might be tested for contrast sensitivity and color vision. Perhaps the most robust finding in all of psychology is that performance improves with practice and feedback. So scanners should practice tasks they are to perform until their performance approaches an asymptote.

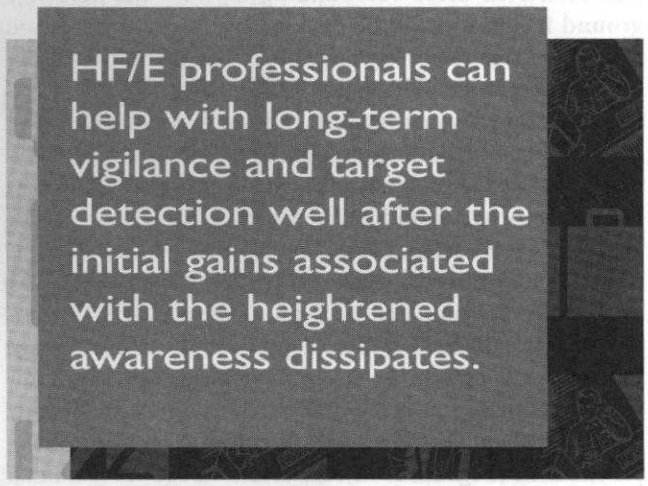
Computational Modeling and Simulation

Exploration of the impact of counterterrorism philosophies and technologies among aircrews, controllers, and others using computational human performance models offers the possibility of performing early trade-off analyses in software rather than waiting until regulations have been implemented or hardware installed. HF/E expertise in task analysis can provide an approach for systematically looking at requirements (see Laughery & Corker, 1997). From this might flow specifications of required aptitudes, definition of training content and approach, procedures, tasks that would benefit from automation or aiding, appropriate performance evaluation techniques, and support for the development of new policies. By incorporating HF/E into the design, development, and insertion of new technologies, issues of usability, ease of implementation, procedures, scheduling, training, roles and responsibilities, and more can be resolved quickly while hardware capabilities are engineered and new regulations are crafted and approved.

Simulation research might explore the impact on crew coordination of changes in aircraft cockpit/cabin configuration or that denies access to the flight deck crew in the event of a hijacking. Proposals include assuming remote control from the ground, placing the aircraft in a holding pattern until an authorized pilot enters a code, and landing the aircraft at a nearby facility on autopilot. Further, if in commercial airliners, video images of the cabin were available to the flight crew (and, by extension, to ground facilities), crucial decisions could be informed by real-time evidence of activity in the cabin itself.

Data Mining and Visualization

Data mining and visualization tools offer effective methods of detecting and depicting patterns, trends, projections, alternative courses of action, and secondary conflicts in ways that are quickly and accurately interpreted by all of the people who might be required to collaborate in developing a response to a potential or ongoing threat. Such capabilities already exist, developed for the purpose of detecting patterns in aviation incident reports that differ with respect to surface characteristics but share diagnostic underlying similarities (e.g., McGreevy, 2001). Other tools capture the characteristics of routine operational performance of commercial transports as well as transitory fluctuations (e.g., the Aviation Performance Measurement System; Statler, 2001).



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Incident reporting systems (e.g., the Aviation Safety Reporting System; Connell, 2000) and industry surveys are already in place to gather new information about security issues from the perspectives of those closely involved. Information technology offers the capability for monitoring an incredible wealth of information in real time as well as seeking baselines, patterns, and trends in archived data. However, the quality of the human interface will establish the ultimate utility of the information.

For example, a human-centered decision support system might be developed to alert ticket agents and checkpoint personnel about passengers who might pose a security threat based on elaborations of current profiling techniques. Information about threatening situations in the air, viewed from the perspective of human controllers or automated detection systems, can be accumulated over time under dynamically changing conditions. Determining how to support an evaluation of the potential threat posed by a specific deviation from the planned flight path (Johnson, Battiste, & Holland, 1999), for example, and link such an evaluation to action will be difficult but crucial.

Emergency Egress and Emergency Response

One final area in which human factors/ergonomics can contribute more of its knowledge is emergency response. There are many current examples in which HF/E recommendations have been made as a result of studies concerning emergency response (see Allen, Bowen, Hitt, Guest, Zavod, & Mouloua, 1998; Allen, Guest, Bowen, Hitt, Zavod, & Mouloua, 1998). Such work is backed by more than five decades of foundational HF/E research on human performance in high-stress circumstances. Indeed, one spin-off human factors/ergonomics area is covered in the journal *Human Performance in Extreme Environments.* The Society for Human Performance in Extreme Environments, which publishes this journal, is concerned with the limits of physiological and psychological functioning in the most arduous of performance conditions. It is thus possible to indicate the optimal ways in which humans and technology can react to the spectrum of emergency conditions that can be anticipated with further incidents and different forms of attack.

Terrorists seek to induce disorder, an aim that was expressed in the New York and Washington attacks through the use of a putative fuse (the fully fueled aircraft) and a vastly greater energy reserve (represented by the height and mass combination of the World Trade Center towers). But this situation took time to develop at the World Trade Center; hence a crucial area for current HF/E research concerns people's egress from confined spaces and the behavior of individuals in crowds.

Summary, Conclusions, and Practical Recommendations

The foregoing represents only a brief outline of the areas in which HF/E can contribute to defeating terrorism. As we have noted, the principles of HF/E apply well beyond merely the aviation realm. We have not presented information on HF/E contributions to ongoing military response because we are sensitive to the security issues associated with such activities. Nevertheless, we can confirm that such efforts have been and are in progress and use the fundamental findings of this science to provide a crucial advantage.

Society is engaged in an information war, albeit one that does not preclude the use of conventional weapons. Those who hold the "information high ground" are those most likely to win this war. Human factors/ergonomics professionals mediate between human beings and technological systems. As such, they have a crucial knowledge base in promoting opportunities for the attainment of the goals of safety and deterrence while possessing the antithetical knowledge of how to deny our opponents access and opportunity in this information conflict.

Events such as those we have recently witnessed find their genesis not only in conflicting cultural differences but also in the radical disparity of resources distribution throughout the world. Thus, although human factors professionals stand ready to assist with the immediate problems, we must not forget the larger issues that underlie the events we have seen.

Promotion of the value of the human factors/ergonomics field is an ongoing effort of the Human Factors and Ergonomics Society and similar groups. Readers are encouraged to use this article to further the knowledge and awareness of business and government leaders about what HF/E can contribute not only to counterterrorism efforts but also to the general improvement of human-machine systems of all kinds.

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