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Colin G. Drury Written Testimony for the Subcommittee on Technology and Innovation of the House Committee on Science and Technology, April 2008

Charge to me from the Subcommittee

In your testimony please answer the following questions:

1. What role does human factors engineering play in the design and testing of aviation security technology? How well do current aviation security technologies incorporate human factors engineering and human-technology interface principles?

2. How does human factors engineering impact the effectiveness of these technologies to detect or deter threats? What are the possible detrimental effects of not involving human factors engineers throughout the technology design process?

3. How should the Transportation Security Administration and Transportation Security Laboratory test and evaluate whether human-technology interface principles have been properly applied in the design and manufacturing of aviation security technologies?

Response

1. I am a Human Factors Engineer from University at Buffalo: State University of New York. I have spent much of my life in research and intervention in the area of human performance in inspection systems. This started in manufacturing industry (cars, electronics, glass products) but transitioned to aviation inspection of civil airliners and inspection of people and goods for security threats. My CV provides samples of the technical papers published in inspection for manufacturing, aircraft maintenance and security. This work, as with all Human Factors Engineering (HFE), involved working with people on the front lines (e.g. maintenance technicians, TSA screeners) as well as membership in committees on research and development in this field (e.g. the NRC's *Committee on Assessment of*

Security Technologies in Transportation, and the FAA's *Research, Engineering and Development Advisory Committee*).

2. Human Factors Engineering (HFE) is a discipline dating from World War II that uses data on the performance of humans (in our case security screeners, airline passengers) in complex systems (in our case aviation security) to design better systems that make the best use of the unique capabilities of both humans and automated devices while reducing the impact of their respective limitations. The diagram of the airport security system used by the National research Council (Figure 1) shows the level of complexity and the numerous places where humans can both make errors and act to prevent errors.

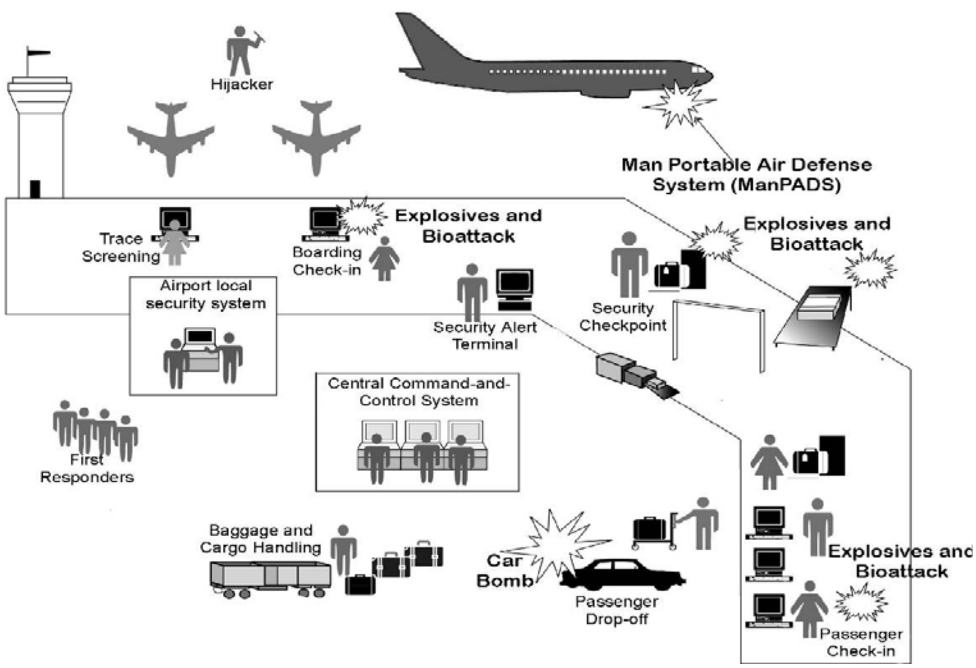

Figure 1: Airport Security System, from National Research Council, 2007, p 14.

Standard texts in this area include Wickens, Lee, Liu and Gordon-Becker (2002). It has a record of designing systems to prevent human error and inefficiency, beginning in the military but subsequently moving into civil aviation and industrial systems. If HFE is not used, then often the system errors only become apparent when the system is put to operational use, for example the control room and training deficiencies at the Three Mile Island nuclear power station.

3. There are three aspects of aviation security inspection performance where humans have a large impact: missed threats (failure to stop a

threat), false alarms (stopping a person/item that is not a threat) and time taken to process each passenger or baggage items. All translate into two system performance measures: risk and delay. HFE applied to aviation security inspection can, and has, addressed each of these. A good example is the Threat Image Projection System (TIPS) which presents images of guns, knives and IEDs to screeners performing an X-ray screening task. This counteracts the known human tendency to detect fewer threats when there is a low probability that any single item contains a threat. TIPS has the added benefit of providing embedded training and performance measurement for screeners. TIPS act as a motivator to screeners, as well as reducing monotonly, but it must be technically well-executed to prevent non-threat-related artifacts from cuing the screener that a TIPS image is being displayed. HFE tells us that these three aspects of performance trade off against each other. In any given system, fewer missed threats are accompanied by more false alarms (e.g. National Research Council, 2007, p 25; McCarley et al, 2004). Also there is a Speed-Accuracy Trade-Off in that fewer threats are detected if insufficient time is devoted to the inspection of each person or item (Drury, Ghylin and Holness, 2006). Mathematical relationships can be used to model these trade-offs (Drury, Ghylin and Schwaninger, 2007), so that we can deploy security systems to meet specific needs. The interaction between the screener and the technology is not the only application of HFE to security systems: passengers too interact with the system. Obvious examples are queuing at airports, where the screening delays turn into passenger dissatisfaction (Marin, Drury, Batta & Lin, 2008), and HFE input into helping novice passengers deal with the complexities of required tasks in a timely manner.

4. To integrate HFE into design of future technological systems for aviation security, successful design techniques from other domains can be used. HFE has been successfully applied to the design of most military systems, to civil aircraft cockpits and to chemical and nuclear facility control rooms. The issue in all of these, as in aviation security, is to use data on human behavior to blend the automation and human components of a system so that human and automation each do what they do best. This is known as Allocation of Function (e.g. Hollnagel and Bye, 2000; Lee and Moray, 1992) and has been applied to inspection tasks previously (Hou, Lin and Drury, 1993)

5. The first step is to recognize that humans will be present in all security systems. The traveling public is no more trusting of completely automated security systems than they are of unmanned airliner cockpits. The issue is not whether we can eliminate the human, but how best to use the human who will be there. An example is the in-line checked baggage inspection systems at many airports. The technology is based on 3-D scanning of each bag to build a 3-D image of the bag. Automation is used to locate areas of potential threat (e.g. atomic numbers associated with explosives) within the whole bag, i.e. a search function. The bag image with the potential threat area highlighted is displayed to the operator who then has the decision function of choosing to pass the bag as "no threat" or mark it for further screening, typically hand search (which is itself not error free). This allocation of functions between the automation (search) and the human (decision) capitalizes on known strengths and limitations of humans in inspection (Hou, Lin and Drury, 1993). For humans the search function is consistently quite error-prone, while the decision function (with suitable training and aiding) can be reliable (Drury and Spencer, 1997). Overall, automation provides the ability to take rapid and consistent action within strict rules, while humans provide the flexibility to respond when the rules do not apply (e.g. Parasuraman, Sheridan and Wickens, 2000).

6. Having decided what roles humans and automation should play in each future system, the next steps involve designing specifically for the human. This means working from the human outwards rather than the technology inwards. It means devising the interfaces between the human operator and the technology, identifying the training (and retraining) required for top performance, and designing the interfaces between the front-line operator (e.g. screener) and others in the system (e.g. other front-line personnel, supervisors, law enforcement officers, etc.). Interface design uses standard HFE methods with data and models of human functioning (from sensory and cognitive capabilities to physical size and strength) and applies it to design of the physical interface and computer software (Wickens et al, 2002). Applications range from comfortable seating and sightlines (e.g. for X-ray screeners) to human computer interaction (e.g. display and response logic for body scans or checked baggage inspection) using standard texts, e.g. Helander, Landauer, & Prabhu (1997) . Training design can be based on well-known adult learning

techniques. Design of human – human interaction can use techniques from either Crew Resource Management (CRM) or socio-technical systems design (STS) as found in Helmreich, Merritt & Wilhelm (1999) and Taylor and Felten (1993) respectively. Many comprehensive systems exist for including the human in the design of complex systems, e.g. Cognitive Work Analysis (Vicente, 1999) and even earlier in Systems Analysis (Singleton, 1974). All of these methods will help eliminate errors in the final human-machine system.

7. Currently TSA has HFE professional expertise at the Transportation Security Laboratory, although none of these professionals are currently listed as members of the *Human Factors and Ergonomics Society*. They have worked with researchers and manufacturers on short-term improvements to the interfaces as well as on longer term research studies such as developing selection procedures, socio-technical systems design of the whole security checkpoint and human problems in container security. They have also funded some more fundamental studies applying cognitive science to security modeling, including a one-year grant to me at UB:SUNY as listed in my disclosure letter to the committee. Could more be done? Most certainly. There are new ideas where HFE expertise can be incorporated early in the design process. A recent example is data fusion, that involves humans as one of the many sensors whose data is fused to enhance decision making, (e.g. NRC, 2007). Most manufacturers and researchers still see the physics and chemistry of detection as central, with design for the human in the system limited to training design and design of the computer screens and response keys. The last time I visited a manufacturer (for the NRC Committee) was several years ago but there was no evidence of using HFE professional expertise in systems design. Without early involvement of HFE, the human in the system may not make optimum decisions, and by then only small changes can be made to the system at evaluation time. This does not ensure that risk and passenger delays have been minimized.

8. How can we measure the effectiveness of HFE design in security equipment? This is important to ensure that we are indeed designing the systems optimally. Two alternatives are possible: examining the equipment for evidence that HFE has been used in its design, and/or evaluating the complete system (equipment plus human) and analyzing its performance and errors. Both have been used successfully. A design

checklist can be rather simplistic for complex equipment embedded in operational systems, but the design procedures can also be reviewed to see how the deasign team took HFE into account. The TSL has used such a checklist to assist machinery designers in applying HFE to their products. The current, and recommended, method is to evaluate the performance of the complete system in as close as possible to real use conditions. Here we can measure the errors and performance times and also observe and interview users. This evaluation gives a figure of merit for the system (misses, false alarms, delays) and uses behavioral observation and structured interviews to examine the locus of any performance deficits.

9. Overall, there is no down-side to using HFE in design of security systems. Without it, predictable performance lapses occur, leading to increased risk and passenger delays. The additional cost of incorporating HFE has been found in aviation and military domains to be low.

References

Drury, C. G., 1994, Function allocation in manufacturing. In S. A. Robertson (ed), *Contemporary Ergonomics 1994* (London: Taylor & Francis, Ltd), 2-16

Drury, C. G., Spencer, F. W. (1997). Measuring human reliability in aircraft inspection. *Proceedings of the 13th Triennial Congress of the International Ergonomics Association'97,* Tampere, Finland, Vol. **3**, 34-35.

Drury, C.G., Ghylin, K.M. & Holness, K. (2006) Error analysis and threat magnitude for carry-on bag inspection. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting —2006, 1189-1193*

Drury, C.G., Ghylin, K.M. & Schwaninger, A. (2007) Large-Scale Validation of a Security Inspection Model, *Contemporary Ergonomics 2007*, Taylor & Francis, London

Helander, M., Landauer, T. & Prabhu P. (1997) *Handbook of Human-Computer Interaction* (2nd Edition) Amsterdam, North Holland

Helmreich, R.L., Merritt, A.C., & Wilhelm, J.A. (1999). The evolution of Crew Resource Management training in commercial aviation. International Journal of Aviation Psychology, 9(1), 19-32.

Hollnagel, E., and Bye, A. (2000). Principles for Modeling Function Allocation. *Int. J. Human-Computer Studies*. Vol. 52, pp. 253-265

Hou, T.-S., Lin, L. and Drury, C.G. (1993). An Empirical Study of Hybrid Inspection Systems and Allocation of Inspection Function. International Journal of Human Factors in Manufacturing, 3, 351-367

Lee, J. and Moray, N. (1992). Trust, control strategies and allocation of function in human machine systems. Ergonomics 35(10), 1234-1270

Marin, C. C. Drury, C. G., Batta, R. and Lin, L. (2007) Server Adaptation in an

Airport security System Queue. *OR Insight,* 20.4 22-31.
McCarley, J.S., Kramer, A.F., Wickens,C.D., Vidoni, E.D. & Boot, W.R. (2004) Visual Skills in Airport Security Screening. *Psychological Science, 15(5)*, 302-306.
National Research Council (2007) *Fusion Of Security System Data To Improve Airport Security*, The National Academies Press, DC
Parasuraman, R., Sheridan, T. B. and Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man and Cybernetics-Part A: Systems and Humans,* Vol. **30 (3),** May 2000
Singleton, W. T. (1974) *Man-Machine Systems* (Penguin, UK)
Taylor, J. C. and Felten, D. F. (1992) *Performance by Design*, Prentice Hall
Wickens, Lee, Liu and Gordon-Becker (2002) Introduction to Human Factors Engineering (2nd Edition), Prentice-Hall, NJ.