CHAPTER

1

Human Factors in Aviation: An Overview

Eduardo Salas
University of Central Florida
Dan Maurino
International Civil Aviation Organization
Michael Curtis
University of Central Florida

In 1988, Earl Wiener and David Nagel's *Human Factors in Aviation* was released. At a time when the stealth bomber, Hubble telescope, and *perestroika* were fresh ideas, this important book signified a symbolic shift in the role of human factors within the aviation industry. "Human factors" was not a new concept, and human factors research, which traces its origins to aviation, had slowly established its place in improving safety in aviation already. At that point in the intertwined history of aviation and human factors, though, human factors researchers were just beginning to find themselves prominently involved in the design of aviation systems. This was in stark contrast to previous decades when human factors was not emphasized in aircraft design and aviation operations, but instead, was generally a corrective science. This evolved role helped the expansion of human factors research in the field. Whereas the origin and early years of study had predominantly been in cockpit and cabin technology design, the industry was beginning to address other important topics like cockpit organization, crew interaction,

crew fitness, judgment, and automation. In all, their book should be considered a seminal contribution to aviation research as a whole. It represents one of the first books to present human factors topics relevant to aviation in a manner accessible not just for human factors professionals but also to pilots, aviation industry personnel, and others casually interested in the topic area.

In March of the same year, Avianca Flight 410 crashed into mountains shortly after taking off from a Colombian airport, killing all passengers and crew aboard (Aviation Safety Network, n.d.). The official cause of the accident was determined as controlled flight into terrain. This was precipitated by poor crew teamwork and cockpit distractions, including nonflying personnel present in the cockpit. Mentioning the tragedy of this accident following praise on the impact of the initial edition of this book serves to illustrate an important point in aviation research: Despite what is accomplished in terms of safety and operational improvements in aviation, the work is never done. Like any other form of transportation, the prospect of having a 100% safety record in aviation is improbable. As humans, our propensity to propel technology design into futuristic states will always drive the need for the research community to address evolving demands of aviation.

At any point in the history of human factors in aviation, one could characterize its current state at that time by the progress that had been made and by the opportunities that presented themselves for the future. Keeping this in mind, in this chapter we aim to provide a brief snapshot of aviation human factors since the first edition of this book. We will first highlight a few brief themes that show the progress that has been made in aviation research since the first edition. Following this, we will talk about the opportunities that we as human factors professionals, pilots, instructors, maintenance personnel, air traffic controllers, and interested parties in general are presented with currently to drive future generations of aviation. To conclude, we will provide a short overview of the chapters that follow in this edition. In all, we hope this chapter orients the reader to the causes and effects that guide the cutting edge of our field now, and whets the appetite of inquisitive minds to explore the subsequent chapters of this edition further.

PROGRESS SINCE THE FIRST EDITION

A little more than two decades has passed since the first edition of this book. Since that time, the industry has continued to change, technology has improved, and demands on crews have shifted. In part, the progress that scientists and developers have made in the topic areas covered in the initial edition have perpetuated the maturation and evolution of aviation. There have been a number of advances to classic human factors topic areas such as cockpit design in addition to the further development of several topics that were just burgeoning at the time of the first edition. The progress that has been made is too far-reaching to sufficiently cover in this chapter—in fact, we really don't do that here; other forums will have to document that. Despite this, we feel that there are several general areas in which progress has helped shape the evolving industry. We next briefly touch on two topic areas and how these have influenced training, technology, and flight procedure in general.

Training Crews Instead of Individuals—the Importance of Teamwork

In the mid-1980s the focus of attention for most pilot training programs still relied heavily on development of technical skill. Little emphasis was placed on developing teamwork skills within the flight crew. Evidence in the form of accident and incident report data suggested that suboptimal crew interactions were contributing to a noticeable number of human errors in the skies. Around this time, a number of important publications began surfacing with a call for increased emphasis on developing crew team behaviors in addition to the already ingrained technical skills required in flight (Foushee, 1984; Foushee & Helmreich, 1988; Orlady & Foushee, 1987).

Since the genesis and initial investigations into how crew interaction influences the flight process, the concept of crew resource management (CRM) has been developed into an important aspect of aviation. The complexity of the interacting variables within the concept of CRM have spawned research and subsequent progress

into many aspects of the inputs, processes, and outputs of CRM as a whole. This includes investigation of inputs such as how team composition, cohesiveness, and organizational structure influence crew behavior (Guzzo & Dickson, 1996). In addition, researchers have aimed to improve our understanding of team processes such as communication and leadership, among others (Salas, Burke, Bowers, & Wilson, 2001). This has led to the widespread incorporation of CRM training in the curriculum. This includes focusing on crew behavior in full flight training simulations such as Line Oriented Flight Training (LOFT) and development of evaluation methods to accurately assess the pilot skill not only for technical skill but also in the less concretely observed behaviors that make up CRM. What has resulted is progress from a well-thought-out, yet unproven, concept for improving cockpit performance to a tested, successful method that is widely used and accepted in the aviation community for flight crew training. The development of CRM has resulted in a shift from the individualistic focus of training technical skill to the complexity of teamwork that affects standard flight operations.

Technological Advances—Shifting Performance Requirements

As one would expect, technological advance has served both as a product of progress made in aviation human factors and as a catalyst for new directions of research in the field. Technological advance has influence in all aspects of aviation from operations to training. Although it is difficult to get a snapshot of all advances in this area due to continual and rapid growth, there are some general topics that represent many of the more specific areas of research that are constantly at the cutting edge.

In the 1980s the technological and operational realization of automated systems in aviation was just starting to take shape. There was little question as to whether or not automation would have an increased role in aviation, but the impact of that automation on crew performance was largely unsupported by research (Wiener, 1989; Wiener & Curry 1980). Automated systems became more sophisticated, and research into operational concerns such as mode awareness (Sarter & Woods, 1995) and automation surprise

(Sarter, Woods, & Billings, 1997), as well as theoretical works on utilizing automation (Parasuraman & Riley, 1997; Parasuraman, Sheridan, & Wickens, 2000) tempered the "rush to implement" automation mentality. Instead, these works encouraged thoughtful inclusion of automation and consideration of issues associated with automation in parallel to the obvious benefits. The modern aircraft now features many exclusively automated features not possible in previous generations of aircraft. Although there are still challenges with optimizing human-automation interaction, progress in the last two decades has afforded automated features that are designed with human operational needs in mind.

Similar to these developments in automation, the cockpit instrumentation itself has continually evolved in line with the technological advances in computer and display technology. Display development, one of the more heavily studied areas of aviation human factors, originally focused on optimal display of information in a visually crowded cockpit. In that case, physical location and display size were among the most important features. Now, with increasingly computerized displays, it is possible to house much more information in a single display. Although the principles of display used in classic cockpits such as spatial proximity (Wickens & Carswell, 1995) are still applicable to modern instrumentation, the newer "glass cockpit" has led to a need for investigations into how the organization of information in virtual space can impact flight (Podczerwinski, Wickens, & Alexander, 2002; Woods & Watts, 1997). The glass cockpit has, in effect, decluttered the instrument panel, reducing the potential for visual overload, but heightening the need to address the different yet equally challenging prospect of cognitive overload. Improved display and computing capabilities have even spawned new conceptions for multimodal (Van Erp, 2005) and increasingly integrated displays using enhanced and synthetic imagery (Bailey, Kramer, & Prinzel, 2007). As the evolution of cockpit instrumentation continues toward more computerized display, the amount of information and way in which it is integrated will become increasingly important issues for cockpit design.

Technology has also shaped the development of crew training. Although full motion simulators have been in use for several

decades, the simulated imagery and available functions associated with simulation training have improved. With that, more realistic recreations of actual flight are available for the implementation of simulation-based training methods like LOFT. In addition, findings suggest the use of low-cost, more accessible platforms deployed on personal computers or laptops may provide training benefits (Taylor, Lintern, Hulin, Talleur, Emanuel & Phillips, 1999; Prince & Jentsch, 2001; Salas, Bowers, & Rhodenizer, 1998). These low-cost solutions can help reduce the burden of time and cost that already dictates the availability of full-motion simulations.

In sum, progress in aviation human factors, since the publication of the last edition of this book, has both helped shape the current state of aviation and also uncovered new areas of focus. Fortunately, in line with the progress in research, industry-wide interest and implementation has driven improved safety. Developments like CRM training and collection of safety report data from sources such as Line Operations Safety Audit (LOSA) and Aviation Safety Action Plan (ASAP) have helped guide development of more effective training. Technological advance in the cockpit have produced more improved ways of keeping aircraft in safe operational states. Devices such as the Traffic alert and Collision Avoidance System (TCAS) have improved safety in an increasingly congested airspace. In addition, new theoretical concepts like threat and error management (Klinect, Wilhelm, & Helmreich, 1999) and situation awareness (Endsley, 1995) added to discussions on the factors affecting flight performance.

In all, the examples in this chapter just provide a small sampling of the progress that has been made in aviation through human factors research in the past two decades. Whereas most of the focus previously involved pilot performance and instrument design, today human factors researchers are investigating all aspects of the aviation industry. This includes but is certainly not limited to maintenance, air traffic, and even organizational structure, all with the goal of sending aviation into the future with improved safety, efficiency, and cost savings. Now that we have briefly touched on the progress in aviation human factors since the original edition of this book, we will now look toward the future and the opportunities that await.

A LOOK AHEAD ...

For several decades, aviation slowly evolved. Improvements in technology, operations, and organizational structure came about at a gradual pace, slowly improving safety and the efficiency of operation to levels far beyond previous generations of flight. As each improvement took effect, aviation slowly became more accessible, and thus, began to grow. The proverbial snowball began to roll, picking up additional demands for improvement in a growing field. Growth spawns research, which leads to technological advance, which leads to operational adjustments, which leads to organizational updates, which leads to growth to the point that there is no identifiable trigger for the beginning of this process, but each advance in the industry now has a ripple effect for change throughout. All of this has led to the current state in which change permeates every corner of aviation. The demand for flight is greater than ever before, leading to industry growth at unprecedented rates worldwide. Industry growth leads to an expanding workforce, which puts pressure on the organization to maximize training time and quickly produce capable pilots. Meanwhile, technological advance is facilitating the implementation of increasingly complex, automated systems that alter the way that pilots and personnel interact with aircraft systems. At the same time, a call for industry-wide improvement to the traffic management system is pressing researchers, industry professionals, and airlines to keep up. All of these influences, therefore, have an impact and human factors implications.

The growth and change that is occurring in the industry signifies not just a shift in the structure of the industry but also an opportunity to revolutionize the systems and methods in which all facets of the industry operate on. In this section we will briefly describe the predominant push for change in the aviation industry and the opportunity that is upon us.

Aviation in the NextGen

Although the Next Generation Air Traffic System (NextGen) program is only one of the catalysts for change in aviation currently, it represents the most dramatic call for change in the industry.

NextGen (FAA, 2009), which has a similar European counterpart (Single European Sky ATM Research [SESAR]; European Commission, 2005), is an initiative brought forth by the Federal Aviation Administration (FAA) to change the nature, necessity, and frequency of interaction between pilots and air traffic control. Ultimately, NextGen represents a shift from primarily a ground-based system of air traffic control to one that utilizes satellite-based technology. Current weather, data communication, and positioning technology now provide pilots the fortune of real-time updates in the cockpit. Using this technology, the NextGen program is geared toward shifting some of the flight path and traffic separation burden into the cockpit.

Ultimately, the NextGen program is intended to help address issues associated with the enormous burden of growth that air traffic controllers are already feeling worldwide. Before this goal can truly be realized, the industry has to prepare itself for the technological, operational, and organizational impact that NextGen will have. In the past, human factors was largely an afterthought in the design process of aviation systems. The job of the human factors professional would be to assess the state of a currently existing system and make recommendations for improvement. For NextGen, this may no longer be the case. In fact, at a recent panel discussion at an international aviation conference, Dino Piccione, a representative for the FAA on the panel, suggested that instead of being an afterthought, NextGen presents the opportunity for human factors to guide the design of systems that will comprise the future of aviation (Boehm-Davis, 2009). The balance of optimism and skepticism from the audience suggested that the entire aviation community may not be ready to accept this challenge, but Piccione drove home an important point. The dramatic change called for, and the timeframe in which it is proposed to take effect, will make it necessary for us collectively to take what we know about human factors and project that onto the future state of the industry. To design not just for the present but for the future of aviation.

The challenge of redesigning the air traffic management system, as we know it, is no small task. NextGen requires input from all phases of the aviation system. It will require new technology, role

responsibility, crew interactions, training, organizational structure, and a host of other changes to fully transition to the new system. Whereas previous introduction of technology caused a spike in incident while everyone adjusted, perhaps we can use our knowledge of human factors to reduce the adjustment period for NextGen and related programs.

HUMAN FACTORS IN AVIATION: THIS EDITION

Although the message of this book is to discuss where we are, the sweeping changes briefly described earlier promise to alter the face of the industry in coming years. In addition to knowing where we have come from, and where we are in aviation, looking to and preparing for what the future holds is more important than ever before. With that in mind, we look to the following chapters to orient readers to human factors aviation and arm them with a base of information to guide progress into the changing future of this complex industry.

Overview of the Book

This book is intended to provide a current state of human factors in the aviation industry. Simply reviewing the current state of affairs in this field, however, does not adequately represent what industry personnel, researchers, and the aviation community at large are experiencing. In fact, if a one-word summary were required to describe human factors within the aviation industry at this moment in time, there is really only one relevant response: change.

The chapters in this book are organized into five sections. Following this introductory chapter, the next section focuses on the organizational perspective. At the organizational level, these chapters address human factors issues that occur at a macro level. As an industry composed of High Reliability Organizations (HROs), this section delves into the quantitative and qualitative conceptions of safety, and addresses the organization's responsibility for promoting a climate of safety.

In Chapter 2, Tom Sheridan discusses the origin and fundamental ideas of systems from a quantitative perspective. Using this

perspective, he describes a number of relevant system models of control, decision making, information, and reliability. By providing history, definition, and normative modeling examples, he makes a case for how developing "systems thinking" encourages engineers to design with the human in mind.

Amy Pritchett (Chapter 3) follows this by emphasizing the consideration of safety as a function of risk mitigation distributed across technology, operational concepts and procedures, and effective human performance. Using the design of a collision avoidance system, she outlines how system "negatives" such as risk, error, and failures as well as positive human contributions such as shared representations, situation awareness, adaptation, and preemptive construction of the operation environment can help guide design using the system safety perspective.

In Chapter 4, Manoj Patankar and Edward Sabin address safety culture. By focusing on previously unaddressed issues like cultural evolution and the emergent role of leadership, they provide descriptions of safety culture measures and how these measures reflect safety culture. The resulting framework emphasizes the importance of change in values, leadership strategy, attitudes, and behaviors to the improvement of safety culture.

In Chapter 5, Sidney Dekker and David Woods provide a discussion on the importance of reliability in HRO. They address previous engineering conceptions of reliability, and how these may not fully encompass the concept of organizational reliability. The concept of Resilience Engineering is proposed as a way to address safety oversight such as overconfidence and performance demands that can interfere with recognition of organizational safety concerns.

Pilot and Crew Performance Issues

After providing a basis for a macro understanding of human factors in aviation, the third section narrows the focus to individual pilot and crew performance issues. A common thread in these chapters is in their agreement that changes that have and are occurring in the cockpit have altered the pilot and crew roles in the aviation

system. The first four chapters of this section are heavily focused on specific concepts that influence performance.

In the first chapter in this section (Chapter 6), Kathleen Mosier suggests the idea that pilot tasking has evolved from a primarily kinesthetic task to a much more cognitive task as a result of technological advances. She discusses the hybrid ecology that results from the combination of naturalistic and electronic elements in the cockpit. Given the increased importance of NextGen in the aviation evolutionary process, she describes how facilitation of both correspondence and coherence are critical to foster cognitive sensibility in the modern cockpit.

Chapter 7, by Michael Vidulich, Christopher Wickens, Pamela Tsang, and John Flach, examines how the demands of information processing, like attention, are shifting with new aviation technology. They discuss how the balance between essential skill and human bias influences performance in aviation, as well as how information-processing limitations drive development of concepts like mental workload and situation awareness to help facilitate design and system assessment for current and future aviation systems.

In Chapter 8, Frank Durso and Amy Alexander further discuss the relationship between workload and situation awareness in relation to performance. They provide a framework made up of a situation understanding, a workload, and a critical management subsystem to describe the relationship of these concepts to each other and to performance. They address the dissociative nature of these concepts and make recommendations for how these might help predict performance.

In Chapter 9, Eduardo Salas, Marissa Shuffler, and Deborah DiazGranados provide an update to Foushee and Helmreich's chapter (1988) on team interaction and flight crew performance. The chapter addresses the advancement of crew performance research and outlines teamwork behaviors that impact crew performance. Through this, they describe ways currently utilized to help improve crew performance, most notably with CRM.

The next three chapters in this section delve into the measurement, training, and analysis of individual and crew performance.

John Bent and Kwok Chan (Chapter 10) address the importance of improving training to keep up with unprecedented growth in the aviation industry. They combine discussion on how growth is affecting industry safety standards with how it threatens training and safety. Based on this, they provide a detailed list of both hardware and software implications for the myriad of simulation-based training objectives in aviation.

In Chapter 11, Key Dismukes focuses his discussion on human error. More specifically, he discusses the measurement and analysis of human error in the cockpit as it applies to highly skilled pilots as opposed to novices. By addressing these various sources of error information, Dismukes contends that development of countermeasures are contingent on pursuing a more comprehensive understanding of error in this context.

Chapter 12, by Kevin Gluck, serves as an introduction to the concept of cognitive architectures and its utility in the aviation industry. Gluck provides a definition of cognitive architecture and a guide for deeper investigation into important works on cognitive architecture. He describes current computational simulation and mathematical modeling techniques for developing cognitive architectures and identifies a number of challenges to be addressed for improving cognitive architecture in aviation.

The final chapter in this section (Chapter 13) by Melissa Mallis, Siobhan Banks, and David Dinges, talks about the effects of fatigue in aviation. The biological influence of the circadian system and the homeostatic sleep drive are discussed in terms of how they influence fatigue in terms of work factors. Based on this, the authors discuss the challenges that fatigue offers and present several innovative approaches to address fatigue management.

Human Factors in Aircraft Design

In any human factors discussion on complex systems, the conversation would be incomplete without mention of the technology that flight crews interact with. The fourth section of this book focuses on the design of aircraft. In the first chapter in this section,

Chapter 14, Michael Curtis, Florian Jentsch, and John Wise concentrate on how technological advance has changed the nature in which information is displayed in the cockpit. They discuss how source, type, function, and environmental integration of displayed information influences pilot processing. Their discussion mirrors Mosier's discussion about the transition to higher cognitive demand with new displays and discusses how several near-future changes in aviation will influence display design.

Thomas Ferris, Nadine Sarter, and Christopher Wickens (Chapter 15) follow this with a concentration on the impact of cockpit automation on the aviation system. After discussing the current theoretical background on using automation, the authors mention how automation leads to pilot automation interaction breakdowns. Additionally, they outline a number of unintended consequences of automation implementation like workload imbalance, deskilling, and trust issues. Using what is currently known about automation, they include a discussion on how automation will influence future systems that result from NextGen and other near-future aviation industry objectives.

In Chapter 16, Alan Hobbs discusses the importance of the increasingly relevant topic of unmanned aircraft systems (UAS) into the present and future of the aviation industry. He posits that poor human-system integration design, not technological hindrance, are the main concern for UAS development. He organizes his discussion around UAS-relevant operation issues, including teleoperation, design of ground control stations, transfer of control, airspace issues, and maintenance challenges.

Integration and crew station design are the focus of the final chapter of this section, Chapter 17, by Alan Jacobsen, David Graeber, and John Wiedemann. After providing an evolutionary history of both military and commercial crew station design, they describe the competing flight crew station requirements that must be considered in the design process. In light of the increasing complexity of the system and information that needs to be integrated, the authors discuss a number of methods and tools to aid in crew station design.

Vehicles and Systems

To support the notion that there are no limits to the impact of human factors in all of aviation, the final section of this book addresses several specific perspectives that are underrepresented in the aviation human factors discussion. The first two chapters continue the discussion on the air operations perspective, but they are taken from slightly different viewpoints.

The opening chapter in this section, by William Hamman (Chapter 18), provides an airline pilot's perspective on the human factors challenges in the modern cockpit. The chapter raises concern over the effect that changes in the industry are having on the pilot population. Hamman discusses how reduced support for safety reporting programs like Aviation Safety Reporting System (ASRS), Flight Operational Quality Assurance (FOQA) and ASAP in combination with a growing demand for capable pilots is especially concerning. Increased cockpit complexity and limited training resources are leading to reliance on an increasingly inexperienced and overworked pilot fleet.

Chapter 19, by Stephen Casner, addresses the human factors issues associated with general aviation. More specifically, the chapter focuses on personal flying, flight training, and business flying. The chapter discusses several human factors issues similar to those faced in commercial and military flight as well as unique challenges that one would not likely encounter in the other two fields of research.

The next two chapters address human factors in ground operations. In Chapter 20, Ann-Elise Lindeis presents a discussion about the critical issues associated with air traffic management. After providing an effective overview of the air traffic controller–pilot relationship, she discusses the relevant human factors issues associated with effectively maintaining communication, navigation, and surveillance in this relationship. She describes how identifying operational issues through error reporting, air traffic control (ATS) investigations, and observation of normal operations can guide the improvement of ATS.

In Chapter 21, Barbara Kanki closes out the discussion on vehicles and systems with a commentary on aviation maintenance human

factors. The chapter breaks the timeline of human factors in aviation maintenance into two eras, from 1988 to 1999 and from 2000 to the present. Using numerous accident report examples, Kanki effectively outlines the important progress made in this area of aviation human factors and points out the important of sustaining maintenance error management and maintenance error in safety of flight to improve aviation maintenance output.

To complete this edition, Chapter 22, by Dino Piccione, Paul Croise, and Tom McCloy, provides a more detailed commentary on what NextGen and its worldwide counterparts hold for the future of aviation. The aviation industry is on the cusp of major changes in how flight crews and ground personnel interact to maintain separation in the skies.

A FINAL COMMENT

Ultimately, the aim of this book is to orient readers to the current state of human factors in aviation, and, with this, to prepare them for the challenges that are forthcoming in future generations of aviation. We hope that this new edition inspires scientists and those in practice to reach new heights in the application of human factors principles to aviation. We hope that this edition shows the progress, evolution, and maturation of the field. We hope that this edition educates, challenges, and guides those who believe that the science of human factors has much to say about our aviation system. Time will tell. We look forward to the third edition.

References

Aviation Safety Network. (n.d.) *Accident description: Avianca flight 410*. Retrieved July 1, 2009, from <http://aviation-safety.net/database/record.php?id=19880317-0/>

Bailey, R. E., Kramer, L. J., & Prinzel, L. J. (2007). Fusion of Synthetic and Enhanced Vision for All-Weather Commercial Aviation Operations. *NATO-OTAN*, 11.11–11.26.

Boehm-Davis, D. (Chair). (2009). Perspectives on human factors issues in NextGen. Panel discussion presented at the April 2009 International Symposium on Aviation Psychology, Dayton, OH. [panelists: Boehm-Davis, D., Carr, K., Lyall, B., & Piccione, D.]

Endsley, M. (1995). Measurement of situation awareness in dynamic systems. *Human Factors*, *37*(1), 65–84.

European Commission. (2005). The SESAR program: Making air travel safer, cheaper and more efficient. Electronic memo retrieved May 10, 2009, from <http://ec.europa.eu/transport/air_portal/sesame/doc/2005_11_memo_sesar_en.pdf>

Federal Aviation Administration. (2009). What is NextGen? Retrieved March 16, 2009,from <http://www.faa.gov/about/initiatives/nextgen/defined/what/>

Foushee, H. C. (1984). Dyads and triads at 35,000 feet: Factors affecting group process and aircrew performance. *American Psychologist*, *39*(8), 885–893.

Foushee, H. C., & Helmreich, R. L. (1988). Group interaction and flight crew performance. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 189–228). London: Academic Press.

Guzzo, R. A., & Dickson, M. W. (1996). Teams in organizations: Recent research on performance and effectiveness. *Annual Review of Psychology*, *47*, 307–338.

Klinect, J. R., Wilhelm, J. A., & Helmreich, R. L. (1999). Threat and error management: Data from line operations safety audits. In *Proceedings of the Tenth International Symposium on Aviation Psychology* (pp. 683–688). Columbus, OH: The Ohio State University.

Orlady, H. W., & Foushee, H. C. (1987). *Cockpit Resource Management Training, (NASA CP-2455)*. Moffett Field, CA: NASA Ames Research Center.

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors*, *39*(2), 230–253.

Parasuraman, R., Sheridan, T. B., & 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*, *30*(3), 286–297.

Podczerwinski, E., Wickens, C. D., & Alexander, A. L. (2001). *Exploring the "Out of Sight, Out of Mind." Phenomenon in Dynamic Settings across Electronic Map Displays* (Tech. Rep. ARL-01-8/NASA-01-4). Savoy, IL: University of Illinois at Urbana-Champaign, Aviation Research Lab.

Prince, C., & Jentsch, F.. (2001). In E. Salas, C.A. Bowers, & E. Edens (Eds.), *Aviation crew resource management in training with low fidelity devices.* (pp. 147–164). Mahwah, NJ: Lawrence Erlbaum.

Salas E., Bowers, C. A., & Edens, E. (Eds.), (2001). *Improving Teamwork in Organizations.* Mahwah, NJ: Lawrence Erlbaum (pp. 147–164).

Salas, E., Bowers, C. A., & Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *International Journal of Aviation Psychology*, *8*(3), 197–208.

Salas, E., Burke, C. S., Bowers, C. A., & Wilson, K. A. (2001). Team training in the skies: Does crew resource management (CRM) training work? *Human Factors*, *43*(4), 641–674.

Sarter, N., & Woods, D. (1995). How in the world did we ever get into that mode? Mode error and awareness in supervisory control: Situation awareness. *Human Factors*, *37*(1), 5–19.

Sarter, N., Woods, D., & Billings, C. (1997). Automation surprises. In G. Salvendy (Ed.), *Handbook of human factors/ergonomics* (2nd ed.) (pp. 1926–1943). New York: Wiley.

Taylor, H. L., Lintern, G., Hulin, C. L., Talleur, D. A., Emanuel, T. W., & Phillips, S. I. (1999). Transfer of training effectiveness of a personal computer aviation training device. *International Journal of Aviation Psychology*, *9*(4), 319–335.

Van Erp, J. (2005). Presenting directions with a vibro-tactile torso display. *Ergonomics*, *48*, 302–313.

Wiener, E. L. (1989). *Human factors of advanced technology ("glass cockpit") transport aircraft (NASA Contractor Rep. No. 177528)*. Moffett Field, CA: NASA Ames Research Center.

Wiener, E. L., & Curry, R. E. (1980). Flight deck automation: Promises and problems. *Ergonomics*, *23*, 995–1011.

Wickens, C., & Carswell, C. (1995). The proximity compatibility principle: Its psychological foundation and relevance to display design. *Human Factors*, *37*(3), 473–494.

Woods, D., & Watts, J. (1997). How not to have to navigate through too many displays. In M. Helander, T. Landauer, & P. Prabhu (Eds.), *Handbook of human-computer cooperation* (2nd ed.) (pp. 617–650). New York: Elsevier.