Preface

Air traffic management has been a highly reliable system for some decades now. However, modern systems are continuously seeking new challenges and are rarely content with the current state of affairs. The initiatives of NextGen and SESAR may indicate that the new aviation environment will become more complex and tightly coupled in order to cope with increased traffic, minimize delays, operate in adverse weather, smooth out aircraft trajectories, and so on. As the air traffic system is being stretched to its capacity limits, safety challenges may increase in the near future.

As the complexity of the operating environment becomes higher, so should the capabilities of organizations expand. This would require the introduction of new technologies, safety nets, and supporting tools, which may affect the operating practices of controllers, their team coordination, and the organizational procedures and regulation rules. In this sense, people, organizations, and artifacts should learn how to adapt to the challenges and demands posed by new situations and new technologies. This view of a joint cognitive system has been the focus of cognitive engineering, a discipline of human factors where practitioners' activities are understandable in relation to the properties of the environment in which they work; for instance, conflict resolution strategies are affected by traffic constraints, availability of job aids, team composition, collaboration with flight crews,

and regulations. In turn, a work environment can be understood in terms of what it demands and affords to the people at the sharp end.

There are several reasons why we have chosen to focus on cognitive engineering rather than on human factors in general. Cognitive engineering looks beyond the performance of individuals in laboratory experiments and tests theories in the context of real work environments or task simulations that reproduce the environment in which work is performed, the tools that are used to support people, and the organizational policies and rules that guide human control. In this sense, the first part of this book presents an overview of the work environment of ATM to provide a basis for understanding how practitioners interact with others, how they use their tools, and how the organizational processes shape human performance.

Until recently, many human factors studies focused on human performance problems while fewer studies looked into how practitioners succeed despite the weaknesses in the system they control. Cognitive engineering has accepted new paradigms of human performance in which people are seen as assets in their organizations as their variability enables them to compensate for inadequate organizational practices and rules. It is now increasingly recognized that expertise and errors are two sides of the same coin and that human variability may lead to success in most situations but it could lead to failures in certain circumstances. For this reason, the second part of this book focuses on decision-making and sensemaking strategies of air traffic controllers (ATCOs) as well as on their strategies in monitoring work, detecting errors, and developing new practices to cope with complex events.

Cognitive engineering has been driven largely by the requirements derived from the regulatory demands and from a need to operate effectively and safely. In this sense, theory is elaborated after the operational problem has been addressed in a real or simulated environment. As human factors and safety practitioners in the aviation domain are users of theory, we have become aware that the principles of cognitive engineering should be cast in practical terms (e.g., behavioral markers of poor and good performance) and should be illustrated in the context of ATM applications. In this respect, the third part of the book examines the relationship between the complexity and the workload of controllers in managing the modern ATM environment as well as

possible ways to match people and technology through training and system design.

Recent developments in cognitive engineering have tried to look at the opportunities and constraints set by the wider organization on the performance of people at the sharp end. Particular emphasis has been on the safety requirements and constraints set by organizations and regulation authorities that affect the way people organize their cognitive resources and strategies. For instance, decision trade-offs regarding production and protection at higher levels may shape the work of practitioners who have to do their best to reconcile different goals simultaneously. Hence, in the fourth part of the book, an effort has been made to look at new ways of combining cognitive engineering with new systems thinking and resilience approaches that would enhance human and organizational performance.

There have been several excellent books on human factors in air traffic management but the majority are edited volumes. Also several studies of cognitive engineering have been published in scientific journals that have enhanced our understanding of how ATCOs organize their performance. The challenge we faced in this book was to try and see how different models fit together in order to provide a comprehensible and practical overview of human performance in modern ATM systems. In this sense, the results represent our personal knowledge of the subject and experience with the ATM domain. The first author has been in the academia for 25 years while the second author has been an active ATCO for 18 years. Both of us have spent a lot of time observing the work of ATCOs and talking to them to understand the way they develop and adapt their practices in the context of work pressures and complex scenarios.

To increase the credibility of the book chapters, we have also attended some refresher training courses where ATCOs had to cope with several familiar and novel scenarios under time pressure. Furthermore, we have used an ATM training simulator on many occasions in order to test theory and propose a model of human performance that would be relatively easy to put into practice. Our work with the training simulator has been very helpful in building a model of Taskwork/Teamwork for effective and adaptive management. In this regard, the proposed T^2EAM model

has built on existing approaches of cognitive engineering and experimental work on a training simulator. The book reflects our continuous efforts, since 2005, to understand the work of ATCOs and develop practical models of human performance that could support the design and safe operation of the joint cognitive system. In the fourth part of the book, T²EAM has been elaborated in order to provide a framework of performance for both humans and organizations.

Our target readership would include not only researchers and practitioners in human factors, but also people who manage or carry out everyday activities in air traffic management. We hope that the book will be of interest to human factors specialists, safety practitioners, incident investigators, ATM regulators, system designers, and, in general, the wider aviation community.

Our main aim has been to develop a model of human and organizational performance that would integrate several principles that can be adapted to the needs of individual organizations. We discuss a variety of applications in training, system design, and safety, but this book is not intended to provide a comprehensive list of off-the-shelf tools. Emphasis has been given to elaborating theoretical principles that could be tailored to particular organizations by paying attention to a range of workplace and organizational factors. Practitioners in the ATM domain are ingenious and adaptable people who can adapt principles to their own work and devise their own solutions.

In summary, the wealth of ideas and approaches presented throughout this book reflects the advances in human factors, cognitive engineering, and system safety that have been achieved over the last three decades. Our main challenge in this book has been to take a scientific approach to the architectures of cognition and organization but also bind theory to the application tasks of ATCOs. Part I of the book aims at describing the ATC system from the perspective of joint cognitive systems of people, organizations and artifacts that are adapted to the different demands posed by unfamiliar situations and new technologies. Part II focuses on the cognitive functions of decision-making, sense-making, problem detection, error recovery, and work adaptation derived from the literature in cognitive engineering and tested in the context of the ATC domain. Part III presents domain applications in the analysis of complexity and workload, the use of cognitive task analysis

in training design, and the implications for new operational designs (e.g., SESAR and NextGen). In a joint cognitive system (JCS), cognitive functions and strategies operate within a larger organizational context that shapes both the cognitive strategies of controllers and the way that they use their technologies and artifacts. Although organizations work at a different level of abstraction and time frame from operating teams, an effort was made in Part IV to present the organization of safety structures in terms of similar functions to the ones utilized in the taskwork and teamwork activities.

Because the book addresses a wide audience of researchers and practitioners, different readers may dip into different chapters to find answers to specific questions they have. In this sense, Part I may be useful for people who are not very familiar with the complexities of the operating environment of ATCOs. Part II presents the backbone of cognitive engineering and it could be of interest to practitioners to see how their everyday strategies fit or differ with those of other colleagues. Researchers may be interested to see how the T²EAM model has "twisted" existing models of human performance to fit the work of practitioners in the ATM domain. Part III is of general interest as it presents applications of the T²EAM model in the areas of controller training, complexity and workload, and system design of the new operating environment. Finally, Part IV reflects our effort to adapt T²EAM to organizational performance with emphasis on safety organization. The final chapter looks into the particular area of "safety risk management" to show how improvements can be made in system safety.

Our thanks in the production of the book go out to Cindy Carelli and Renee Nakash who supported this publication. Finally, we would like to acknowledge our gratitude to all the ATCOs who gave their valuable time and expertise to participate in the simulator sessions and explain the complexities of their work. Without them this book would have not been possible.