Preface

The paradigmatic symbol in air traffic control (ATC), essentially unchanged since the beginning of commercial air traffic early last century, is the characteristic control tower with its large tilted windows, situated at an exposed location, and rising high above the airport. Besides the impressive 360° panoramic far view out of windows, it provides the tower controller an aura of competence and power. It actually hides the fact that tower controllers as employees of the air navigation service provider (ANSP) are members of a larger team of collaborating colleagues at different locations, including the apron, approach, and sector controllers, not all of them enjoying the exciting view out of the tower windows (for more details, see Sect. 1 in chapter "Introduction and Overview"). Only the apron controllers supervising the traffic on the movement area in front of the gates, mostly as employees of the airport operator, enjoy a similar panorama, although usually from a lower tower. The topic of this book, Virtual and Remote Control Tower, questions the necessity of the established direct out-of-windows view for aerodrome traffic control. It describes research toward an alternative work environment for tower and apron controllers, the Virtual Control Tower. It is probably no exaggeration to assert that this book is about a paradigm change in air traffic control, where paradigm in this context means a generally accepted way of thinking and acting in an established field of technology.

As explained already by Steve Ellis in the Foreword to this volume, Virtual and Remote Tower refers to the idea of replacing the traditional aerodrome traffic control tower by a sensor-based control center which eliminates the need for a physical tower building. For small low-traffic airports, the main topic of this book, the out-of-windows view will be reconstructed by a high-resolution videopanorama which may be located anywhere on the airport or even hundreds of kilometers away at a different location. This concept quite naturally leads to a new type of aerodrome control center which allows for remote control of several airports from a single distant location. It is understandable that many tower controllers are not really happy with this revolutionary idea, viewing videos instead of enjoying the reality behind the windows. The detailed research toward the Virtual Tower presented in the following chapters will show that their skepticism is partly justified, and it is the responsibility of us researchers to take their critique serious and understand their requirements in order to maintain and exceed the safety and performance level with the new system which the traditional one has achieved within nearly a hundred years of technical evolution.

After surfacing of the Virtual Tower idea, several requirements for “Future ATM Concepts for the Provision of Aerodrome Control Service” were formulated by the International Federation of Air Traffic Controllers Associations (IFATCA), such as:

The controller shall be provided with at least the same level of surveillance as currently provided by visual observation

Controllers shall be involved in the development of aerodrome control service concepts

While the first condition relates to official regulations of International Civil Aviation Organization (ICAO) concerning visual traffic surveillance on aerodromes, the second one addresses the methods for design, research and development, validation, and implementation of the proposed new human–machine systems for aerodrome traffic controllers. It appears self-evident that the introduction of a revolutionary new work environment in the safety-critical field of aeronautics which attempts to replace an established operationally optimized and validated existing one requires intensive cooperation between developers and domain experts. In Germany, most of them are employees of the Air Navigation Service Provider DFS (Deutsche Flugsicherung), cooperation partner in the recent Remote Tower projects.

While the development of any new human–machine system by definition is an interdisciplinary undertaking, nowadays involving at least experts from engineering, computer science/informatics, and engineering psychology/cognitive engineering, this book is about an especially challenging case. On the one hand, a revolutionary concept based on latest technologies is suggested which promises a significant increase of efficiency and decrease of cost. On the other hand, it attempts to replace a well-established system with a hundred years of operational experience which has to satisfy two often competing goals: safety and efficiency.

One of the problems with this kind of interdisciplinary research and development is that the field of engineering psychology and cognitive ergonomics addressing the human operator side of the system has a much weaker scientific foundation concerning established and usable formal theories as compared to the technical-engineering side. The engineers and scientists on the technical side can usually rely on a well-accepted and established basis of theoretical, mathematically founded knowledge (e.g., applied optics for the realization of a high-resolution videopanorama) and powerful software tools for simulating engineering problems and prediction of the technical system performance. The human factors experts/psychologists on the other side usually have to work with data derived from a huge amount of statistically quantified experimental results, backed up by only a relatively small number of generally accepted formal theories of human perception and behavior (e.g., Weber-Fechner Law/Steven’s Function and the Signal Detection Theory; see Appendices A and B). Moreover, there are only very few if any usable quantitative approaches and simulation tools for addressing concepts like operators "mental model," "situational awareness," or "human performance" and decision-making in a way which would allow for the numerical prediction of, e.g., decision errors. System performance under operationally relevant conditions is typically derived from human-in-the-loop simulations, with participant's responses derived from subjective questionnaires (for cost reasons often only students instead of well-trained domain experts and not seldom with questionable statistical relevance). This situation makes it difficult to obtain reliable quantitative statements about the operators' performance in the new environment. For specific questions regarding requirements and performance, experiments under more laboratory kind of conditions at the cost of reduced operational relevance can be designed which have a better chance to be comparable with theoretical predictions. Within the framework of the Remote Tower work system research, this truly interdisciplinary book contains chapters addressing, on different levels, both the technical system engineering, the human operator and (cognitive) ergonomics, and the human–system interface aspects.

At this point, we would like to acknowledge several contributions and preconditions without which much of the research work described in the following chapters probably would not have been possible, probably it would not have started at all. Starting point within DLR was the first visionary projects competition launched in 2001 by the DLR board of directors under Walter Kröll. In this novel approach to generate and support innovative ideas, the "Virtual Tower" proposal, submitted by the editor together with Markus Schmidt (one of the coauthors) and Bernd Werther (now with VW-Research), won a first prize. Well equipped with the prize money, the core team was able to start the initial 2-years concept study and engage a software engineer (Michael Rudolph, coauthor of chapter "Remote Tower Prototype System and Automation Perspectives") as fourth team member. In the years to come, he designed and wrote all of DLR's Remote Tower related software code.

We acknowledge the contributions of the growing Remote Tower staff during the following two RTO projects (RApTOR: 2004–2007; RAiCE: 2008–2012): Maik Friedrich, Monika Mittendorf, Christoph Möhlenbrink, Anne Papenfuß, and Tristan Schindler, some of them co- and chapter authors of this book. They increasingly took over workshares of the RTO research, in particular addressing simulation trials and validation. The RTO team furthermore was supported by colleagues from the DLR Institute of Optical Sensor Systems (Winfried Halle, Emanuel Schlüßler, Ines Ernst), who contributed to the image processing, movement, and object detection (see chapters "Remote Tower Experimental System with Augmented Vision Videopanorama," "Remote Tower Prototype System and Automation Perspectives"). RTO validation gained additional momentum with the start of an EC-funded validation project together with DFS within the SESAR ATM research joint undertaking, after finishing the RAiCe shadow-mode validation experiments.

The editor of this volume is particularly indebted to Steve Ellis (NASA-Ames/Moffett Field), author of the Foreword, of Chapter "Visual Features Used by

Airport Tower Controllers: Some Implications for the Design of Remote or Virtual Towers" and coauthor of chapter "Videopanorama Frame Rate Requirements Derived from Visual Discrimination of Deceleration During Simulated Aircraft Landing." As a kind of spiritus rector of the Virtual Tower idea, he demonstrated in his Advanced Displays Lab. the initial concrete realization, based on stereoscopic head-mounted displays, which inspired us for submitting our initial proposal in 2001. Nearly 10 years later, in 2010 he again advanced our research as host for the editor, spending a research semester as a guest scientist in his lab. In turn, during this period also Steve worked for two weeks as a guest researcher in the DLR Remote Tower Simulator where he introduced his profound psychophysics expertise into the methodology repertoire of the RTO research, supervising, performing, and analyzing the video frame-rate experiments described in Chapter "Videopanorama Frame Rate Requirements Derived from Visual Discrimination of Deceleration During Simulated Aircraft Landing."

At the occasion of several international Remote Tower workshops and mutual visits and meetings at DLR's Braunschweig research facilities, with the Swedish air navigation service provider LFV in Malmö, with FAA/Washington, and with companies Searidge/Ottawa and Frequentis/Vienna, we exchanged ideas and discussed problems and perspectives. I am very happy that besides Steve Ellis also several of the other colleagues and experts from external institutions and companies involved in the RTO research and development were able to contribute chapters to this book. Specifically I would like to express my sincere thanks to the following colleagues who invested a considerable amount of work and time to help this book to provide the first overview on the worldwide endeavor toward the Virtual Control Tower: Rodney Leitner and Astrid Oehme from Human Factors Consult/Berlin for Chapter "Planning Remote Multi-Airport Control–Design and Evaluation of a Controller-Friendly Assistance System" on Multiple Airport Control, Dorion Liston from San José State University and NASA-Ames as coauthor to Chapter "Visual Features Used by Airport Tower Controllers: Some Implications for the Design of Remote or Virtual Towers" on the basics of visual cues used by controllers, Jan Joris Roessingh and Frans van Schaik from NLR/Netherlands who together with colleagues from LFV and Saab/Sweden contributed chapters "Detection and Recognition for Remote Tower Operations" and "The Advanced Remote Tower System and Its Validation" on the basics of detection and recognition and on the Swedish RTO system, and Vilas Nene from MITRE/United States who provided an extensive overview on the US activities.

At this point one remark should be included concerning possible missing information and errors which may have been overlooked during the iteration of the manuscript to its final state. Most chapters are extended versions derived from previous publications, e.g., in conference proceedings volumes that underwent a selection process, usually including modest reviews, which typically, however, are less strict than journal contributions. All chapters were reviewed by the editor and all of them underwent at least one revision, some of them more. Nevertheless, we cannot exclude that the critical reader and in particular the domain experts may detect unclear, maybe even false statements or missing information. Of course, the editor and all Chapter authors will be happy about any feedback concerning errors and suggestions for improvements that may be included in a follow-up edition of this volume.

Mentioning the domain experts we certainly have to express our greatest appreciation for long years of support and cooperation by active controllers and expert managers from Deutsche Flugsicherung (DFS), the German Air Navigation Service Provider. In particular in the early phase basic domain knowledge was provided during numerous discussions and meetings with Detlef Schulz-Rückert, Holger Uhlmann, Dieter Bensch, and others which was used for a systematic work and task analysis. Later on, a formal Remote Airport Cooperation (RAiCon) was started and many more experts and managers (we would like to mention Thorsten Heeb and Nina Becker) helped in defining requirements and setting up the experimental system at Erfurt airport for performing the initial validation experiment under quasi-operational conditions.

Special thanks are due to Dirk Kügler, director of the DLR Institute of Flight Guidance since 2008. One of his first tasks was a signature under the just finished RAiCe project plan. Since that time he showed continuous interest in the RTO activities and supported the project by intensifying the cooperation with DFS, resulting in the formal RAiCon cooperation. Due to his engagement, the Virtual Tower patent was successfully licensed to company Frequentis/Austria and a cooperation agreement signed in 5/2015. A month later Frequentis won the DFS contract for realizing the first commercial RTO system in Germany to be installed and validated on the airport of Saarbrücken. After successful validation, DFS plans to set up two more RTO systems at airports Erfurt (location of the DLR-DFS validation trials of 2012; see chapters "Remote Tower Prototype System and Automation Perspectives," "Which Metrics Provide the Insight Needed? A Selection of Remote Tower Evaluation Metrics to Support a Remote Tower Operation Concept Validation," "Model-Based Analysis of Two-Alternative Decision Errors in a Videopanorama-Based Remote Tower Work Position") and Dresden (location of DLR's initial live Augmented Vision test; see Chapter "Introduction and Overview") and start with a first Remote Tower Center operation from airport Halle/Leipzig for the three remote airports.

Last but not least, we would like to express our thanks to Dr. Brigitte Brunner as the responsible science officer of the DLR program directorate. In an always supportive way, she accompanied both DLR Remote Tower projects from the beginning. She provided extra resources when there was urgent need, e.g., when the necessity of tower controller recruitment for human-in-the-loop simulations surfaced and it turned out that we had been kind of naïve with regard to the cost involved. She was tolerant and supportive also when things did not run as planned (as every active scientist and engineer knows, this is of course characteristic of any "real" research project) and when toward the planned project end it turned out that an extra half year was required for the shadow-mode trials, for initial data evaluation, and for finishing the undertaking with an international final workshop. The proceedings booklet of this event, containing the extended abstracts of the presentations, was the starting point for this book.

Finally, I would like to thank the team of Springer Publishers for their professional support, specifically Mrs. Silvia Schilgerius, Senior Editor Applied Sciences, who encouraged me to start this endeavor more than 2 years ago, Mrs. Kay Stoll, Project Coordinator, and Mrs. S. Gayathri from the technical service, who in a competent and helpful way and patiently accompanied the gradual evolution from abstract collection through repeated manuscript iterations into the present 13 chapters volume: thank you, it was fun!

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