DESIGNING THE TOWER CONTROL RESEARCH ENVIRONMENT OF THE FUTURE

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Abstract

Facing the challenges of increasing traffic load and strong demands for reduction of noise and fuel consumption, research in air traffic management (abr. ATM) needs to be enforced[1]. Among others, human in the loop simulations are a basic tool to conduct this research[2]. Regarding changes in the main research objectives, technical development and user expectations, human in the loop facilities need to be adapted from time to time.

The German Aerospace Center´s Institute of Flight Guidance is one of the world's leading ATM research facilities. To conduct its projects, it has been utilizing human in the loop simulations[3] since the late 1980s. Constant adaptions on these simulations, for instance the apron and tower simulation, were necessary to meet research requirements. The last extensive update of the Apron- and Tower Simulator (abr. ATS) was completed in the beginning of 2002. Thereafter, more than twenty projects were successfully evaluated until 2010. Since then technical possibilities and research requirements changed. As such, a major reconstruction of the ATS is necessary to validate future ATM systems and procedures.

This paper provides a detailed insight into the requirements analysis, the conceptual design and first applications of the new DLR Apron and Tower Simulator. Within a first step, the European vision for air traffic will be analyzed as well as upcoming project-proposals. Furthermore, project experiences and validation knowledge of the major ATM institutes operating a Tower Simulator will be collected. Based on this data, requirements on the new ATS can be derived. Bringing together budget, technical possibilities and the collected requirements, a design is figured out. In the end, the success of this design is shown on the example of two projects performed in the new ATS.

1. INTRODUCTION

The European ATM research relies on human in the loop simulations in many cases. As such the European Operational Concept Validation Methodology (abr. E-OCVM) describes real-time human in the loop simulations as "important in providing human in the loop experience of a proposed concept" ([1], page 49).

Following the E-OCVM and international research standards, the Institute of Flight Guidance utilizes a broad bandwidth of different human in the loop simulations for research purposes. Since 1992, the ATS has been part of this validation infrastructure (cf. [2]).

As described by Kaltenhäuser in 2003 (cf. [2]), after first tests and technical adaptions, the ATS got operational in 1998, including a 200° and a 300° projection system. In 2001 the last major technical update was performed. The projectors were exchanged as well as the simulation software provided by 5S Computer GmbH (cf. [3]) was updated to the latest version.

From 2001 to 2011, the ATS was successfully used in many broad scoped research projects. Among others, planning systems ([4], [5]) and controller-pilot communication (CPDLC [4], ground lighting based visual guidance [5]) were studied as well as remote tower operations (cf. [6], [7], [8]). Within these ten years, simulation technology evolved while the used projection system got less reliable. Also, the objectives of national and international research projects changed and new

[1] Advisory Council for Aviation Research and Innovation in Europe (ACARE) *European Aeronautics: A Vision For 2020*, Office for Official Publications of the European Communities, Luxembourg, January 2001, ISBN 92-894-0559-7

[2] European Organization for the Safety of Air Navigation (Eurocontrol) *European Operational Concept Validation Methodology (E-OCVM)*, Volume I, Version 3.0, February 2020

[3] Definition „human in the loop simulation" in [19]

software features for ATM simulation became available (cf. chapter 2).

Facing those developments, the Institute of Flight Guidance decided to reconstruct the ATS by beginning of 2011. This paper describes the conception from the requirement analysis to the construction. Furthermore, first applications and their success are described and evaluated.

2. CONCEPT

In general the concept for the ATS as described by Kaltenhäuser in [2] still remains valid. As Figure 1 shows, a simulation engine generates the aircraft data (e.g. position, speed, system status, etc.) via a physical model. The data is then distributed to the projection system as well as to the controller HMIs. Based on this data displays and the outside view can be generated, so that the controller gets a close to reality working place. To offer reasonable interactions between controller and air traffic system, the controller can communicate with so called pseudopilots via radio. These pilots use the ICAO Standard Phraseology (cf. [9]), but have advanced features to control multiple aircrafts.

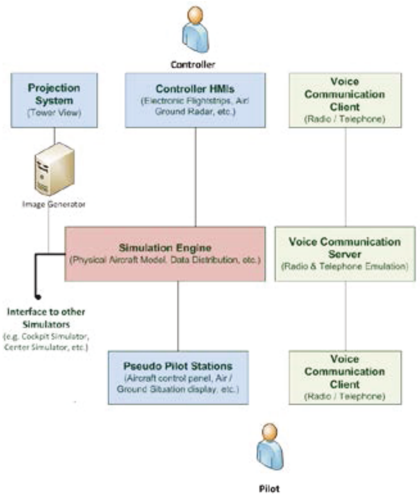

Figure 1: Schematic concept of a tower simulation

As this basic simulation concept is not touched by any changing research objectives or new technical possibilities, it will not be discussed further within this paper. In contrast to that, changing objectives and technique do deeply influence the technical concept how to setup the above described schema. It will be derived throughout a detailed requirements analysis and a structured design process.

2.1. Requirements Analysis

Analysing the requirements offers some challenges as the needs of future research cannot be exactly determined today. Nevertheless, several sources can be taken into account to anticipate possible requirements:

- **Past projects**: Analyzing projects which have been evaluated within tower simulators in the past years offer the possibility to determine how the focus of ATM research changes.
- **Future projects**: Current proposals for research projects give an insight to upcoming requirements in the near future (scope: one to five years). For the far future, vision document can be analyzed (scope: five to twenty years).
- **ATM researchers**: ATM experts have a deep knowledge about the ongoing discussions and the main streams of research. Analyzing their point of view on future research offers a long-term perspective.
- **State of technology**: Analyzing the current state of simulation technology offers a view on the possibilities to layout the technical infrastructure.

The following subchapters describe, how information from the sources above was collected and to what conclusions this led.

2.1.1. Past projects

The analysis of past tower simulation projects is not limited to the Institute of Flight Guidance´s facility. As the institute participates in European as well as in international projects, these projects need to be encountered as well. Nevertheless, these sensitive project data is not always available in public. As a consequence project objectives and short project descriptions were requested from EUROCONTROL and NASA as the biggest ATM research institutes in Europe and Northern America. While NASA Ames offered the needed data, EUROCONTROL´s data could not be acquired. As an alternative to EUROCONTROL, information about projects, of the National Aerospace Laboratory of the Netherlands (NLR) could be collected. NASA and NLR's data was completed by project data of DLR.

The study covers a period of the last ten years back from 2010. This scope is estimated as a life cycle of a tower simulator from one reconstruction to the next based on the experience of the DLR. Furthermore, an evaluation scheme for the data was defined - each simulation project was assigned to one or more topics. Due to this aggregation main research objectives could be determined. The following list shows the chosen definition scheme of research objectives:

- Procedures (ground, arrival/departure, enroute, weather, noise abatement)
- Airport-Layout (taxiways, runway configuration, tower sight)
- Assistance systems (arrival, departure, surface, enroute, datalink, Visual assistance, system ergonomics)
- Simulation cluster (tower-cockpit, tower-radar, tower-tower)
- Work organization
- Training
- Others

As a result it was figured out that a strong research focus is put on assistance systems (cf. Figure 2). Currently about 30 projects of DLR, NLR and NASA within the last ten years dealt with assistance systems.

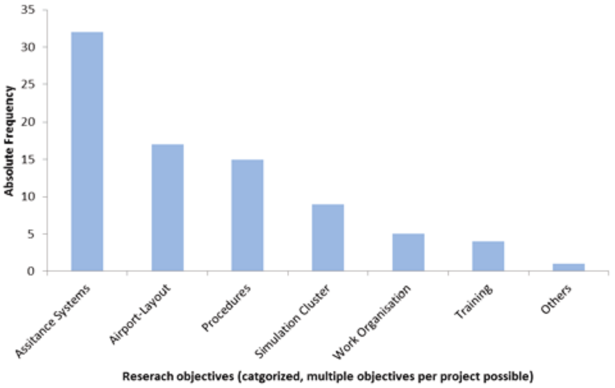

Figure 2: Projects aggregated by research objectives

The second most common research objective were evaluations of airport-layouts (17 projects), closely followed by procedure design (15 projects). This statement needs to be qualified as each research topic was mainly driven by one institute (airport layout: nine NASA projects, procedures: 14 NLR projects) while assistance systems were evaluated by all three institutes.

A significant change from one research objective to another throughout the observed ten years could not be concluded.

Beside the research objectives the workload of the simulators were analyzed. Thereby it was figured out that the workload of NASA AMES and DLR is at about one project per year, while the NLR performs two projects a year in average. As a maximum, the NLR had seven projects within one year (2005).

Further results of this study are summarized in [10].

2.1.2. Future projects

The near future (one to five years scope) can be estimated by analysis of project proposals. No matter whether accepted or not, these proposals describe challenges which are going to be faced within the next years.

In 2010 the DLR did submit a total of eight project proposals on different national and international research programs concerning tower and apron issues. Out of these, main trends can be figured out:

- **Remote Tower Research**: Three proposals concerning remote tower issues are currently under assessment. One addresses the SESAR research program (SESAR 6.8.4). The other one is a validation project initiated by the German air traffic control (DFS, Deutsche Flugsicherung GmbH) regarding issues of a remote tower center (cf. [12]) and the third project is the continuation of the internal DLR project RAiCe (cf. [6]).
- **Time Based Taxi:** Three proposals on time based surface movement planning or time based taxi have been submitted. 4DTaxi concentrates on onboard systems to automatically guide aircraft on ground. In contrast to that, OptiFlow and flexiGuide (cf. [11]) concentrate on surface management software to assist the controller.

Beside those two main trends, one project is in negotiation to validate the apron layout of an airport, also including the usage of a surface manager. Furthermore, an idea about predicting extreme events is in discussion for the internal DLR competition “Wettbewerb der Visionen”.

While project proposals only offer the near future perspective, vision documents of central councils and institutions give insight into the far future perspective. Among others, the Advisory Council for Aviation Research and Innovation in Europe (abr. ACARE) is a potential source. As ACARE brings together stakeholders all over Europe (e.g. Airbus, KLM, DLR, SESAR Joint Undertaking, EASA, etc.) and is also input for the decisions of the European Commission the development objectives of this community are a reliable basis for future research.

Summarizing the Vision 2020 of ACARE (cf. [13]) it becomes clear that future ATM research projects are facing great challenges including quality and affordability, environment, safety, air transport system efficiency and security. The ATS mainly deals with the matters environment and efficiency. Therefore ACARE states (cf. [14]) for example that until 2020:

- Traffic flow will increase by the factor of three
- 50% cut in CO^2 Emissions is necessary
- Reduction of accident rate by 80% is necessary

These goals are of course imprecise in the terms of this requirement analysis. Nevertheless they show, in which direction research needs to focus. Moreover, ACARE gets precise in terms of apron and tower control within the following goal: “Eliminate noise nuisance outside the airport boundary by day and night by quieter aircraft, better land planning and use around airports and systematic use of noise reduction procedures” (cf. [13]).

To summarize, the long-term perspective of ACARE tower control research must expect a significant increase of traffic and a special focus on emissions and noise reduction. As stated above a better planned landing process can be an instrument to handle those aspects especially.

2.1.3. ATM Expert interviews

Project proposals and vision documents can give a good overview about already structured ideas for future research. Nevertheless there exist many ideas not yet recorded and therefore not covered by those sources. To gather those undocumented ideas and to involve later users on an early stage of development, interviews with ATM experts from the Institute of Flight Guidance have been conducted.

As a method, the focus group interview design was chosen (cf. [15]). This method enables a creative process within the expert group as well as an early assessment of the generated ideas. The chosen 25 participants represented a cross section of the institutes' departments. Thereby opinions of controller and pilot assistance specialists were gathered as well as the ideas of human factor and ATM systems experts.

As a first step the experts should generate possible usage scenarios for the tower simulator. Furthermore they were asked to sort these scenarios due to their priority. This led to seven major research areas in the following order:

1. **Efficiency Increase**: Simulations to adapt operational procedures for higher capacity, less fuel consumption, less noise and lower CO_2 / NO_x emissions.

2. **Planning Systems**: Simulations to validate new planning systems (namely departure and surface manager)

3. **Remote Tower**: Simulations to define operational procedures and workplace design for remote tower operations.

4. **Presentation**: Using the tower simulator to show demonstrations of DLR developments or research results.

5. **Technical Test Platform**: Evaluating new technologies (e.g. 3D-Displays, voice recognition, etc.) for application within the field of airport control.

6. **Additional Tower**: Tower working position to complete a simulation cluster (e.g. cockpit simulation that needs communication to the tower controller).

7. **Airport Control Center**: Using the technical infrastructure to create a new working position for the total airport management (e.g. vehicle coordinator, airport security, etc.)

As a second step, the experts were asked to determine requirements out of these research areas. Over 30 requirements were defined. Later on, the requirements were categorized in "must have" (absolutely necessary for the tower simulator), "should have" (recommended for a valid research environment) and "nice to have" (could improve research).

The last step was a brainstorming about possible technical solutions for the tower simulator. Concepts such as 3D view usage, future working positions and post-trial analysis stations were discussed.

2.1.4. Conclusion of requirements

At the end of the data collection a broad bandwidth of possible research objectives, usage scenarios and first requirements for the ATS have been derived. To get an overview and main points to focus on, the data was aggregated by the reconstruction team. This lead to the following main objectives the ATS needs to support:

- **Validation of operational procedures** to increase capacity and lower fuel consumption, noise and emissions.

- **Validation of assistance systems** to decrease controllers' workload and increase the efficiency of the ATM system.

- **Design of remote tower operation** procedures and of working places.

- **Validation of time based taxi guidance** and taxi planning systems.

- **Platform for new technical systems** development (3D displays, voice recognition, etc.)

Beside those aggregated five main aspects, a number of additional research objectives and detailed usage possibilities were collected. With a documentation length of about 30 pages those scenarios exceed the limit of this paper.

From the above perspective technical requirements were derived. Those requirements reach from basic needs for a projection system to advanced requests for eye tracking systems and post-analysis tools. Eventually a list of about 150 requirements was summarized and ordered in the three categories MUST HAVE, SHOULD, NICE-TO-HAVE. This final list was used as an input for the design.

2.2. Design

Analyzing the list of requirements, the Institute of Flight guidance quickly came to the opinion, that it is not possible to fulfill all collected requirements within one facility. In general, two basic ideas could be extracted: On one hand, a most realistic working place with a 360° visual system and close to reality tools (state of the art flight strips, radio emulation, etc.) was demanded. With these elements a possibility to validate the benefit of new procedures and systems should be generated.

On the other hand, a highly flexible structure to design innovative working places, test new technologies and develop new systems was requested. Herein features like a free arrangeable display system, flexible working situations (e.g. order of controllers' working positions) and elementary interfaces need to be considered. Both trends – a most realistic and a most flexible ATS - are in certain requirements contradictory.

As a result the institute decided to build up two facilities. One facility should offer a most realistic tower environment while the second facility should be used for design and development processes in early stages. Hence the facilities ATS360 and TowerLab were defined.

2.2.1. ATS360

The ATS360 is dedicated to make tower controller's working processes as realistic as possible. Therefore a 360° projection system as well as a close to reality working position is necessary. These needs faced the challenge of the available space (at the institute). The room for the ATS360 was assigned fixed and offered space of 8m to 10m. In a consequence, a diameter of about 8m could be used for the projection system. As measured upon a visit to the tower of Frankfurt airport, the standard tower console of the DFS has a depth of about 2.5m. Taking chair distance, distance to the projection screen and surrounding equipment into account, a space of about two square meters for three controllers would have been left. As this is not an acceptable value for close to reality working conditions, a new workplace had to be designed.

The DLR developers therefore designed a console with a minimum depth and a high level of flexibility. As shown in Figure 3 the depth is only about 30 per cent of the DFS console. To achieve the flexibility, a modular design was chosen. As the console is based on a standard building kit system, a broad bandwidth of construction possibilities is available. To ensure small setup times, the technological infrastructure was integrated into the console and is easily accessible. For example, the desk can be changed from a version that includes a touch screen to a standard desk within five minutes. The DLR designers named this console "Modulare Tower Konsole" (eng.: modular tower console, abr. MoToKo).

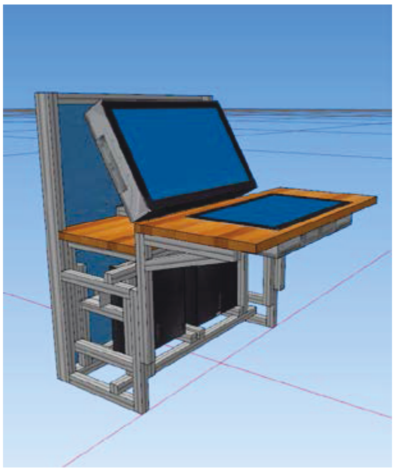

Figure 3: Modular Tower Console

The MoToKo solves a lot of problems concerning the space inside the simulator. Nevertheless, the demand was to get as close as possible to a real workplace. In specific cases, this might make the usage of a real tower console indispensable. For these cases, the projection system was set up with a unique design, as shown in Figure 4.

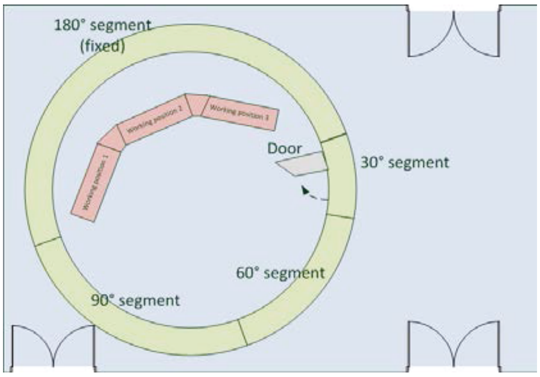

Figure 4: ATS360 segmentation and working positions

The projection system can be segmented and is partly moveable (cf. Figure 4). A 180° screen segment is fixed to the ground and assures the stability of the construction. The 90°, the 60° and the 30° segment are moveable, so that systems (e.g. working positions or measurement equipment) with a certain demand on space can be integrated into the simulator.

The projections screen was shaped cylindrical with a diameter of 8m and a height of 3.5m. 13 projectors in a front projection order generate the image in a WUXGA solution (cf. Figure 5).

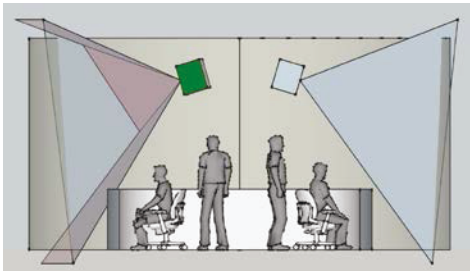

Figure 5: Order of the Projection system

Within the most simulations, the DLR did not use more than three working positions. So this number was integrated into the ATS360. This should cover the three positions Clearance Delivery, Ground and Tower at an airport. The integration of additional working positions is possible.

2.2.2. TowerLab

The general specification for the TowerLab foresees a most flexible setup. Single working places needed to be designed as well as operational procedures for a remote tower center. At least a whole crew of supervisors, flight data revisers and multiple tower and apron controllers need to find space in the tower lab during projects.

The Institute of Flight Guidance provided as a basis a room with about 95m² (8m to 12m). Furthermore it was decided to use the MoToKo as platform for controller working positions. Originally designed to fit into the limited space of the ATS360, the MoToKo can easily be adapted to the needs of each project. Furthermore its standard components enable simple ways for extension.

The visual system should then be designed as flexible and variable as the console. A projection system is not qualified for this purpose, as projectors need to be synchronized and aligned to the screen. Therefore, displays were chosen. They can easily be moved and adapted to the setup of the working place. The type of display was chosen in several technical evaluations including prototype setups. Moreover, possibilities to utilize 3D-displays were discussed. As a conclusion, each working place was planned with five 46 inch displays. In a basic configuration this setup was planned to cover about 180° of the controllers view. Each display is held by a freely moveable pedestal constructed out of a standard building kit system (cf. Figure 6).

Figure 6: Working place for the TowerLab

Out of these three basic components – available space (90m²), MoToKo and outside view displays – a room design for the TowerLab was made. Here, the aspect of ongoing internal work on a technical remote tower system (cf. [8] and [16]) had to be taken into account. This system was setup in Erfurt Airport and should be transferred to the DLR in Brunswick. Here technical tests of the cameras, the data transition and the working place should be performed. The TowerLab offered an ideal platform for this system under development. Furthermore a test and development station for assistance systems as well as remote tower operations and innovative workplace concepts should be offered in the TowerLab. Considering this and some additional space for the supervision, interviews and debriefing, the room concept displayed in Figure 7 was concluded.

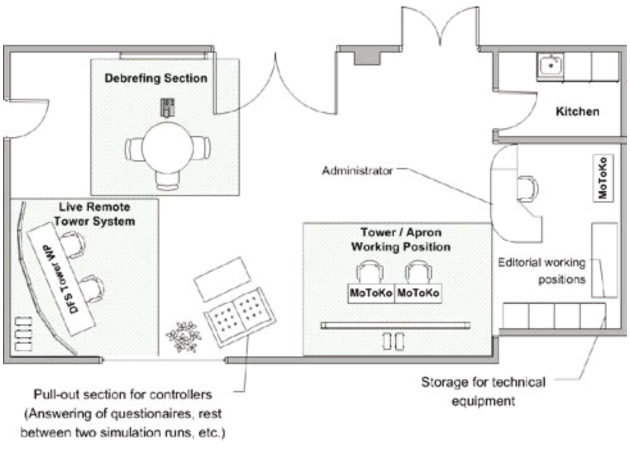

Figure 7: Room design of the TowerLab

Soon after the design- and before the implementation phase, an urgent remote tower project showed up. To provide a proper research infrastructure for this project in a timely manner, the room was directly adapted to the needs of this project. More about this project and the resulting room design will be described in chapter 3.1.

3. APPLICATION

Soon after completing design and construction, the first projects took place in the ATS360 and the TowerLab. To give a first impression of the facilities'' application two projects will be described and later considered within the evaluation.

3.1. Ground Traffic Factors

After calibration tests and first system tests with students (performing air traffic control at Frankfurt airport), the ATS360 got into real operation within the project Ground Traffic Factors that took place in the beginning of 2013.

In most former projects, the Institute of Flight Guidance did not consider ground vehicles while simulating airports. This seems reasonable, as the main research focus usually lies on air traffic and the detailed implementation of ground vehicles is an elaborate and therefore costly process. Nevertheless, multiple controllers gave the feedback that ground vehicles increase their workload significantly. For instance the radio communication traffic rises and preplanning needs to encounter more factors. Concerning this information, Ground Traffic Factors was initiated to determine the influence of ground traffic vehicles on apron controllers. Besides, teaming aspects of apron controllers were evaluated during the simulations.

Within ATS360, the environment of Hamburg-Fuhlsbüttel Apron control was set up. The validation setup consisted of a baseline with small amount of air traffic and no ground vehicles. All following scenarios included a comparable amount of air traffic and different scenes with ground vehicles (e.g. fire brigade training, foreign object debris, construction site, etc.). The Institute of Flight Guidance recorded the workload as well as other key performance indicators to confirm the hypothesis that the controller´s workload is increased by dealing with ground vehicles.

Until now the data of Ground Traffic Factors is not fully analyzed. As such, a summary of the results cannot be given. Nevertheless, as the demanded data was fully collected and no simulation run needed to be repeated the simulations already are assessed as a success.

3.2. Remote Tower Research

In 2011 and the beginning of 2012, a cooperation project with the DFS was performed using the TowerLab for the first time. The objective of this project was to determine the workload a controller can handle on a remote tower working position. Furthermore, it should be evaluated how transfer from one remote tower working position to another affects the controller (cf. [12]).

The project´s requirements lead to a different initial setup of the TowerLab than planned in the design phase, as the project came up before the construction phase (cf. chapter 2.2.2) with a narrow timetable. Nevertheless, the full setup was completed within two months. In the first phase of the simulations, one remote tower working position was simulated. As shown in Figure 8 this working position was designed in close contact to the controllers of the DFS using the standard TowerLab components (e.g. MoToKo, Displays, etc.). Following the design process, a validation phase of one week took place. Herein, the limits of the controller's workload on the remote tower working place were determined.

Figure 8: Working position for the first simulation campaign

The second part of the project regarded a so called remote tower center. Thereby, three airports were remotely controlled. This included three tower working positions and one additional working position for an extended Clearance Delivery (cf. Figure 9). Within the trials, controllers changed their working place after a “shift” of 45 minutes. After each change, so called transfer costs (cf. [17]) were measured.

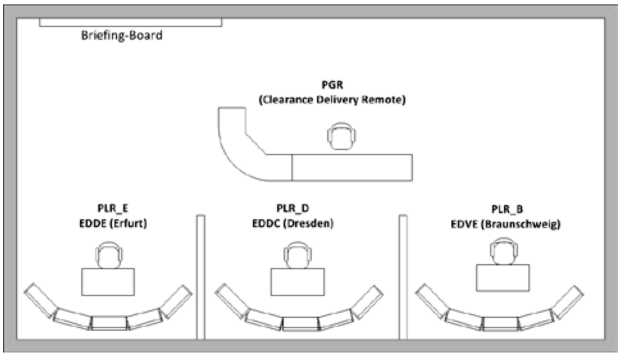

Figure 9: TowerLab room design for the second part of remote tower center simulations

Measured by the number of airports displayed in parallel, this project turned out to contain the most extensive remote tower simulation ever performed in DLR. Furthermore, this simulation was the first to ever display full remote tower center operations. In four months, it was successfully completed.

4. EVALUATION

4.1. Controller's Feedback

The Institute of Flight Guidance is certified according to the DIN EN ISO 9001:2008 standard (cf. [18]). Among other regulations, this standard and the Institute´s quality management manual prescribe several processes to check the quality of work, including human in the loop simulations. In general, controllers participating in simulations are asked several research-specific questions within debriefings. Additionally, the Institute of Flight Guidance asks the controllers to assess the simulation quality. Thereof the quality regulations are met.

These quality questions offer a basis for the evaluation of the new tower simulation facilities. As being standard, those questions were asked in both described projects. Within the Remote Tower project, the twelve air traffic controllers were asked to assess the following phrase on a scale from one to five: “The quality of the simulation enabled a realistic working process”. A rating of one would mean total dismissal and a rating of five total approval. As an average value, the controllers answered with 3.83 with a standard deviation of 0.58. Thereby, the controller stated in general that a realistic working process is possible.

As Ground Traffic Factors still is in an early project phase, only two controllers took part until submission of this paper. Both stated with a value of five (on the same scale as in the Remote Tower project) that they were “satisfied with the quality of the simulation”. Furthermore they stated with a value of three and five that the offered systems enabled them to work close to reality. Questioned in which situations they could not work close to reality, none of them gave an answer.

As these questions are very general and do not give an insight in possibilities to improve the simulation, additional questions in the debriefings and comments recorded from simulation observers were analyzed for this paper. Hence it came clear that some of the lower ratings according to closeness to reality were not dedicated to the technical design of the facilities, but to the behavior of the pilots and the displayed procedures. Some statements are shown as an example in the following list:

- "Every command (N.B.: of the air traffic controller) was executed correctly, no pilot requested a repetition of a command."
- "No display of ground vehicles (N.B.: Stated for Remote Tower project)"
- "Taxi and pushback procedures proceeded too fast"

Further comments addressed the displayed systems such as electronic flight strips and approach radar. But as these are configurable and not fixed part of the simulation facility set up, they are not encountered within this paper.

The only controller talking about technical improvements for the simulation suggested a sound system to get not only a realistic visual but also a realistic acoustic environment during simulation. For instance, the controller named the spooling up of the engines after takeoff clearance that is audible in his tower.

4.2. Technical Assessment

Beside controllers' feedback, the technical point of view needs to be analyzed. To evaluate this technical point of view, different criteria were selected upon experiences with the old tower simulator. One general criterion is the number of days, on which the simulator has been out of order because of maintenance. Those days need to be documented within the DLR facility cost calculation. Anyhow this source needs to be considered carefully. Often, maintenance only takes an hour or two (e.g. rearrangement of displays), but is documented as a day. On the other hand, a lot of maintenance is done in parallel to project work and not logged as a maintenance day.

As a second value for technical performance for projection systems, the projector failures can be encountered. They give a reliable indication how reliable the projection system is.

As a third value the general calibration duration is compared. With the old ATS the Institute of Flight Guidance needed to plan realignments carefully as this work took a great effort upon maintenance.

	Old ATS (year: 2008)	New ATS (year 2011)
maintenance days	12	16
projector failures	4 of 6 projectors	0 of 13 projectors
calibration duration	1 week	½ day

Table 1: Comparison of old and new ATS concerning technical issues

As Table 1 shows, the old ATS had four maintenance days less in its last year of operation than the new ATS in the first year of its operation. As stated above, this figure is not totally reliable and needs to be considered carefully. In fact, the 12 maintenance days of the old ATS mainly refer to the calibration of the projection system and some minor technical issues. The maintenance days of the new ATS refer to some revision of the projection screen. This can be considered as a singular work in contrast to the calibration of the projection system. This calibration needs to be performed regularly to guarantee a high quality picture. While this took about a week of work in the old ATS, the automatic calibration system of the new ATS is now able to perform a calibration including all checks within half a day. Furthermore, the new projection system is much more reliable, although this must be considered under the circumstances of the projectors lifetime.

5. SUMMARY AND OUTLOOK

The Institute of Flight Guidance operates an ATS since 1998. The last technological update has been performed in 2001. Since then, simulation technique enhanced and the focus of research projects changed. Concerning these circumstances the Institute of Flight guidance considered a reconstruction of the ATS in 2010.

To provide a reliable and suitable research platform, a detailed requirement analysis was performed. Moreover, research objectives were analyzed and considered as well as technical possibilities and lessons learned within more than ten years of tower simulation operations.

Within the design process, two contradictory requirement trends have been discovered. On the one hand a demand for a most realistic working place exists. On the other hand a most flexible simulation environment is required to evaluate innovative working procedures. Two facilities shall handle these demands since 2011. The ATS360 (cf. Figure 10) offers a high quality projection system and thereby a close to reality working place. The TowerLab (cf. Figure 11) has a most flexible infrastructure which can be rearranged within hours.

Figure 10: ATS360 in operations

First projects, the evaluation of controllers' feedback and an evaluation of the technical issues proved the success of this concept. Recurring maintenance efforts have decreased, while technical reliability has increased. The controllers were totally satisfied with the system. In particular they specially addressed the high quality of the ATS360 projection in a project performed shortly before the submission of this paper.

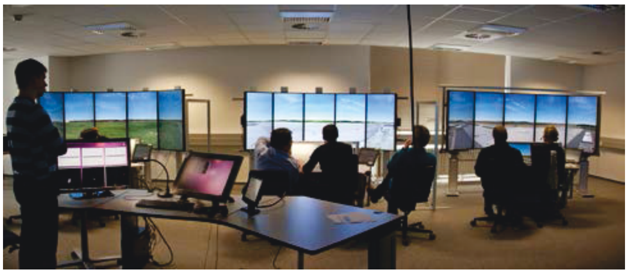

Figure 11: TowerLab in operations

As an outlook to the future, project requests for the ATS as a simulation platform can be considered. While the former average was about one project per year, in 2012 already three projects have been performed within the ATS. In 2013 this number will even increase. Two parts of Ground Traffic Factor, flexiGuide, a broad remote tower campaign and a doctor thesis will use ATS360 and TowerLab. As such, the new design can be considered as a total success.

Nevertheless, a continuous development of the simulator will be necessary to meet future research requirements. Thereby, it is suggested to continuously analyze the project requirements and integrate new features into the tower simulator. In fact, this work has already begun. As suggested by a controller (cf. chapter 4.1), an integration of environmental sound is planned and a master thesis is going to address the simulation of helicopters, as this was a demand of an upcoming project. Thereby, the Institute of Flight Guidance offers one of the most realistic evaluation platforms for apron- and tower research.

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