Controller Support for Time-Based Surface Management

First results from a feasibility workshop

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***Abstract*—This paper reports first results from a workshop to assess the feasibility of a new method of tool-supported time-based surface management. Using high-fidelity human-in-the-loop simulations, ground controllers had to manage traffic in adherence to time-based surface trajectories while being supported by a surface management system prototype and a departure management system prototype. Controller feedback was gathered and compared to a baseline with standard operational procedures and without any decision support system. It was found that a considerable amount of comments were favorable to the presented concept of time-based surface management and the surface management system´s prototype human-machine-interface. Especially the presentation of planned routes was appreciated. However, a higher stability and reliability of optimized surface management plans, higher safety margins and less replanning at short notice were requested. Furthermore, possibilities to set additional remarks at the aircraft´s label and a more intuitive display of advisories were desired.**

Keywords-surface management, time-based, controller, prototype, feasibility, workshop, HITL, TRACC, CADEO, SMAN, DMAN, ATS360

I. INTRODUCTION

Aviation has evolved to a vital part of the global transportation system and sustaining a healthy economy depends on a well-functioning air transportation system. Challenging questions arise due to the expectation of a continuous growth of air traffic. Questions regarding efficiency, safety, and sustainability are of growing interest both to the public and to policy-makers as well as the scientific community (cf. [1][2]).

Many research projects in recent years focused on the reduced quality of life through aircraft noise in the vicinity of airports [3]. As a result, new approach procedures such as Continuous Descent Approach (CDA) and curved approach were developed. Using 4D-trajectories, these procedures offer the opportunity to gain noise reduction and fuel efficiency without compromising the airport´s capacity [3][4][5].

However, little work has been done to ensure that the benefit created by 4D-trajectories in the air is not diminished due to inefficient routing on the ground. Therefore, the purpose of this study is to describe and examine a capable new method of tool-supported time-based surface management that transfers the 4D-trajectory concept to the ground. In order to investigate this method, we used human-in-the-loop (HITL) simulations to conduct a first feasibility workshop. During the trials, air traffic controllers (ATCOs) performed their normal operations as ground controllers but had to manage the traffic in adherence to time-based surface trajectories. They were supported by a sophisticated surface management system (SMAN) prototype, called TRACC (Taxi Routing for Aircraft: Creation and Controlling), coupled with a thoroughly tested departure management system (DMAN) prototype called CADEO (Controller Assistance for Departure Optimization). Feedback was gathered during as well as after the runs and compared to a baseline run with standard operational procedures and without any decision support system. The ATCOs gave mixed feedback regarding the concept of time-based surface management and valuable suggestions regarding the human-machine interface (HMI) of the SMAN prototype, which was in the focus of this workshop. Implications for further refinements of the concept and the SMAN prototype are given.

II. TOOL SUPPORTED TIME-BASED SURFACE MANAGEMENT

To achieve time-based surface trajectories, controller support tools are used. For optimal results concerning efficiency, capacity, and flexibility, it is necessary to look at the combination of departure and surface management because surface management itself influences departure management and vice versa. As the introduction of tool supported departure management has already started at some larger airports (e.g. the pre-departure sequencing within Airport Collaborative Decision Making [6]), some words are spend on this topic first.

A. Departure Management System

Departure Management Systems are generally used to control the departure flow and to reduce runway queue times. The specific departure management system CADEO used in this study is a research prototype optimizing the departure runway sequence taking constraints like separations into

account [7][8]. CADEO calculates Target Take-Off Times (TTOTs) and – if not integrated with an SMAN – Target Start Up Approval Times (TSAT) based on variable taxi times and generates advisories. These are represented as time countdowns when to give the next clearance for each departure. CADEO supports local controllers but the concept of runway sequence optimization also assists ground and apron controllers [8].The concept of CADEO is already proven [9][10][11] but planning quality will be increased by more reliable taxi times [8]. In turn, these are outcomes from SMAN.

B. Surface Management System

Surface Management Systems could implement different implementation levels [12] from very basic route planning to time based trajectory planning including automatic conflict detection and resolution. The implemented level depends on the purpose and the availability of technical enablers.

The SMAN research prototype TRACC [13] used in this study aims for an advanced implementation level: Conflict free time-based trajectories are calculated and optimized, using precise taxi speeds both for planning and within generated advisories for the ATCO. Conformance monitoring with automatic conflict detection and resolution is aspired. Clearance advisories containing route and speed instructions are generated to support the ATCO. Initial conflict-free and optimized taxi trajectories are planned at a certain time before starting ground movement (TLDT: Target Landing Time or TSAT) for every aircraft taking into account all already planned trajectories of other aircraft on the airfield. The trajectory creation process starts from a predefined set of default routes. These are adapted to the actual traffic situation by two different algorithms (TOA: Time Optimization Algorithm, ROA: Route Optimization Algorithm) by changes of speed or routing. The resulting trajectories are converted into a set of taxi advisories. Besides the planning and optimization module, TRACC also has a conflict detection and resolution module (CD&R) and a prototypical HMI (see section III.B). The HMI is used to visualize the results of the trajectory optimizations and to enable necessary taxi advisories for the ATCOs. The CD&R works in the background and checks for deviations from the planned route or speed profile and initializes replanning.

C. CADEO-TRACC Integration

Although the focus of the workshop was the feasibility of time-based surface management implemented by TRACC, integration with CADEO was executed for a first assessment of the expected improvement of the efficiency and stability of CADEOs departure sequence. The workshop was also the first feasibility test for the implemented integration.

The CADEO-TRACC integration used in the workshop is described in the following: The runway holding point was defined as an interface between TRACC and CADEO. TRACC calculated the initial trajectory, ending at the runway holding point. This led to the definition of the Estimated Line-up Time (ELUT). CADEO used this time calculated by TRACC and added the duration necessary for performing lineup. This resulted in the earliest takeoff time for the respective departure. This time was used for runway sequence optimization which came up with TTOTs for each planned departure. The second new definition of a time is the Target Line-up Time (TLUT). This was calculated by CADEO, subtracting the line-up duration from TTOT: As the concept implemented with CADEO aims for queue time reduction and late start of engines, this aim shall also be supported by TRACC. So TRACC used the TLUT as an input to calculate a conflict-free trajectory which allowed the latest possible startup to reach the runway holding point at TLUT.

With each TTOT update calculated by CADEO, the TLUT was communicated to TRACC and each ELUT change calculated by TRACC was communicated to CADEO, so both systems took updates into account for replanning.

During the workshop, the need for improving the used concept of integration was delivered. This concept worked well for initial calculations and when CADEO increased TTOT. But taking ELUT as earliest possible line-up time, CADEO could not decrease TTOT. This shortcoming will be solved by introducing an Earliest Line-up Time (RLUT) calculated by TRACC. A more sophisticated and more general approach for integrating SMAN and DMAN is described in [12]. Continuing research will examine the operational feasibility of this solution.

III. METHOD

A feasibility workshop with high fidelity HITL simulations was conducted as a means of an early validation activity for the concept of tool supported time-based surface management. This procedure is in accordance with the proven method advocated by the European Operational Concept Validation Methodology (E-OCVM [14]). Whereas phase 0 and 1 of the E-OCVM concept lifecycle model define the air traffic management needs and the scope of the concept, phase 2 explicitly addresses feasibility and recommends validating the concept regarding operational user acceptance and operability. A major advantage of the iterative E-OCVM procedure is the early assessment of technical, operational, and human factors feasibility issues. This early assessment provides the opportunity of quick reactions to potential show-stoppers and to develop mitigation means at an early concept stage.

Hence, the purpose of the workshop was to investigate our concept of time-based taxi surface management and the applicability of the coupled DMAN and SMAN prototypes CADEO and TRACC. In addition, the acceptance and fitness for purpose of the TRACC user interface for time-based surface management was assessed via qualitative feedback from subject-matter experts.

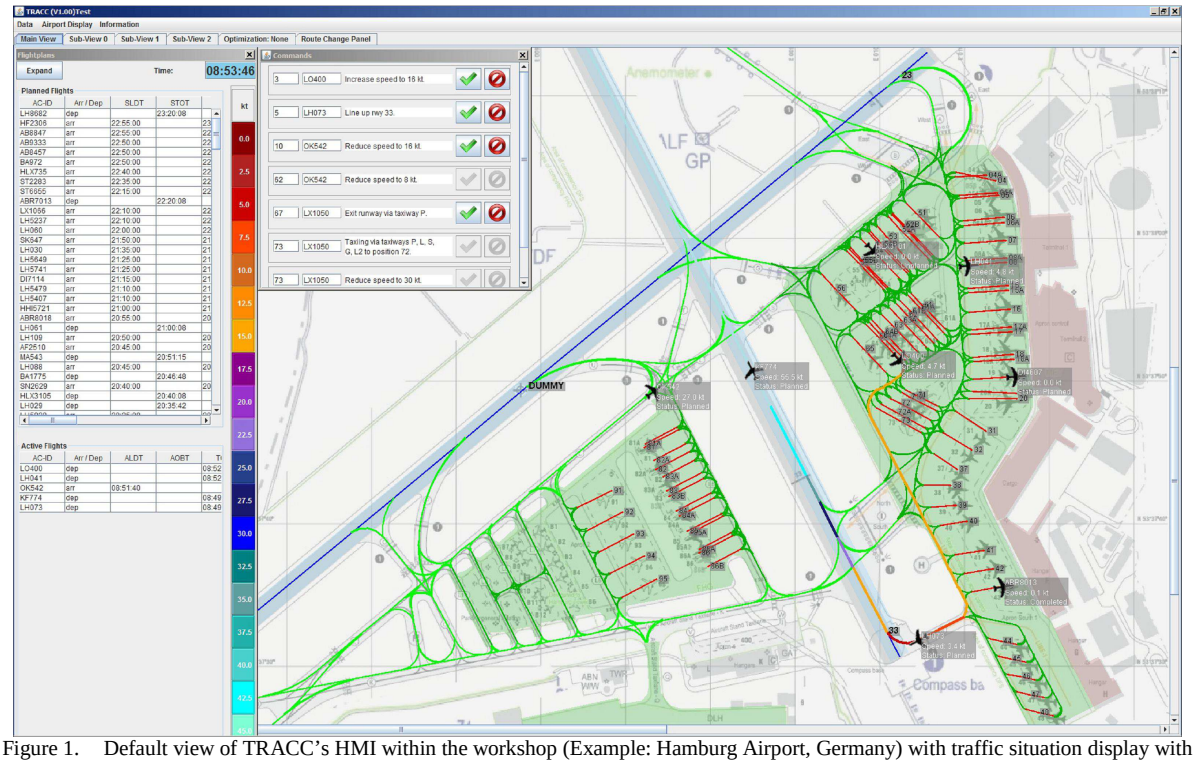

Figure 1. Default view of TRACC's HMI within the workshop (Example: Hamburg Airport, Germany) with traffic situation display with positions as red, taxiways as green, runways as blue lines, flight tables on the left side and the advisory panel next to the tables.

A. *General framework/assumptions*

The following assumptions and restrictions were made to focus on the above mentioned feasibility issues:

- All aircraft are equipped with 4D-Flight Management Systems (FMS) able to predict full 4D-trajectories including ELDTs. The 4D-FMS share this estimate with the Arrival Manager (AMAN), which calculates the ideal arrival sequence, resulting in TLDTs for each arrival. These represent constraints for CADEOs calculation of an optimized departure sequence and are used as an input for TRACC.

- Arriving aircraft precisely comply with TLDTs set by AMAN.

- An advanced surface management guidance and control system (A-SMGCS) provides surveillance information. The positions and speeds of all aircraft are available to TRACC.

- It is possible for pilots to exactly fulfill advised taxi speeds.

B. *HMI TRACC*

The main functionalities of the TRACC-HMI (see Fig. 1) used for the workshop were:

- Depiction of current traffic (traffic situation display).

- Visualization of planned routes and speed profiles.

- Listing of advisories (Fig. 1, next to the tables on the left side).

- Tables with information about expected and active traffic.

All aircraft within a predefined timeframe around their arrival and departure times were shown on the display as black aircraft images together with a label, which indicates at least the aircraft´s callsign. The ATCO had the possibility to display more information such as parking position, actual and planned speed, aircraft type, TLDT/TTOT etc. After an aircraft was selected, the taxi route was shown as colored line, where the colors depended on the planned speeds to fulfill the trajectory. The advisory panel (see Fig. 1) showed the time until a command should be implementation by pilots (between 120 and 180 seconds, depending of the complexity of the command), the callsign, the command, and two buttons for either accepting or rejecting the command. When the time decreases to zero, the advisory was removed and assumed to be rejected.

The tables on the HMI´s left side (see Fig. 1) could be extended to display more flight information and the sequence of the columns could be changed according to the preferences of the ATCO.

As not all parts of TRACC's dynamic deviation monitoring were fully tested in advance of the workshop, it was only activated partially. TRACC used only situations for conformance visualization, where the runway exit or the actual position on the taxi route differed from the planned exit respectively position. No route adaption took place in cases where the taxi route was left, so it was up to the ATCO to catch up the planned trajectory again.

C. Simulation Environment

The Apron- and Tower Simulator is a part of the DLR´s ATM Validation Center. Within its 360° projection system it currently contains three controller working positions with adaptable consoles (ATS360, see Fig. 2, cf. [15]).

This offers the possibility to test TRACC and CADEO in a close to reality setup including ATCOs. Thereby, feedback upon operational usage can be gained without performing complex and expensive field trials (cf. [16]).

The ATCO is provided with the interfaces he/she is familiar with. A projection system generates a (realistic) 360° outside view in order to provide visual feedback. Furthermore, all necessary tools for tower and apron control are offered (e.g. approach radar, flight strips, etc.). Beside visual feedback and tools, the communication with so called pseudopilots is a centerpiece of the ATS. The pseudopilots are well trained simulation participants that can communicate with the ATCO using air traffic phraseology (cf. [17]) and guide the aircraft due to the ATCO's commands.

Pseudopilots and all ATCO HMIs get their data from the simulation engine. For the TRACC / CADEO tests Narsim, a software system from the National Aerospace Laboratory of the Netherlands, was used [18]. The Narsim models the physical behavior of the aircraft and distributes the data. As such, TRACC and CADEO needed to be coupled with Narsim to get position and speed data. Therefore, the implementation of the High Level Architecture standard for real time simulation systems [19] was used. At the end of the integration work, TRACC and CADEO were fully integrated into the 360° projection system of the ATS being connected to all flight information.

D. Semi-Structured Interviews

Assessing the feasibility of new concepts and tools can be realized using various approaches. We decided to use a workshop with high-fidelity HITL simulations. During the simulation runs, observers recorded the behavior and comments. This data were complemented by elaborate semi-structured guided interviews with mainly open-ended questions in the debriefings after each simulation run.

Figure 2. ATS 360° projection system.

A semi-structured interview is a well-established method, which has an incomplete script comprising a predetermined order for most of the questions but offers some flexibility as well [20][21]. Intensive cooperation with the system engineers of TRACC and CADEO took place throughout the design and developmental process of these tailor-made semi-structured guided interviews. During the workshop, it was taken care that every comment and every response to the questions were written down by at least two investigators.

Despite the given structure of the interview, both the investigator and the ATCOs had – within certain limits – the chance to control the interview. The participating ATCOs were provided the opportunity to clarify their position and to talk freely about their experience as a ground controller using the new concept assisted by TRACC. Accordingly, each ATCO gave special attention to slightly different questions. It follows from this explanation that semi-structured interviews are by design only partially comparable between interviewees. Nevertheless, the chosen approach was appropriate for an initial feasibility assessment, because open interviews offer even less comparability and a questionnaire comprising only closed questions permits more comparability, but potentially valuable input from ATCOs would not have been included.

IV. Feasibility Workshop

A. Participants

Each participant needed to have - or at least to have had - an apron or ground controller license to give a substantiated feedback on the experimental setup. Based on this requirement, an invitation was spread via the ATCO union. Using the union, not only ATCOs of the German Air Navigation Service Provider, Deutsche Flugsicherung GmbH (DFS), but also ATCOs from apron controls could be reached.

Out of 25 returns, five ATCOs were selected. A cross section was chosen to enable feedback from different points of view. Thereby, the factors ATCO at Munich airport, age and background in system development and certification were considered.

For the experimental setup, the German airport of Munich (EDDM, cf. [22]) with its real layout was chosen. As a consequence, ATCOs from Munich airport were supposed to give detailed feedback on issues concerning characteristics of their airport. Nevertheless, the defined concepts should also be generally applicable, so participants from other airports needed to be chosen as well. The age of an ATCO can influence his or her handling of a new system. While older ATCOs are estimated to have more often tested and evaluated new systems, younger ATCOs might have more experiences in new technologies. Furthermore, the support in ATC system design and certification enables a very much diverting view from the pure operational point of usage. Having those three criteria in mind, five ATCOs were selected, two coming from Munich apron control, two from Berlin apron control and one being a former tower controller in Düsseldorf.

B. Scenario design

The experimental design of the workshop consisted of two levels of controller support for time-based surface management and a baseline. After a training-run, the first simulation run was the baseline without decision support systems and with normal operational procedures as a ground controller. The second simulation run was used to gather feedback about the TRACC HMI and the concept of time based surface guidance but without support of CADEO. In the third run, TRACC was coupled with CADEO in order to see benefits of integration. Each run was meant to last for one hour.

The airport of Munich is characterized by two parallel independent runways separated by the terminal buildings and the airports aprons [22]. During simulation, the southern runway 26L was operated in mixed mode while runway 26R was used for arriving aircraft only. In contrast to the procedures used in Munich, two adaptions were taken: The ATCO was exclusively responsible for arriving and departing traffic on one of the main aprons (apron 1) and the taxiways. To simplify the apron´s layout, only the yellow lines were available for taxiing aircraft.

The chosen traffic load was 30 arriving and 20 departing aircraft per hour. In order to allow the ATCOs an eased familiarization with the airport and simulation environment, the number of aircraft was reduced to a total of 30 in the training run. To avoid ATCO´s habituation towards the traffic scenario, each simulation run differed concerning aircraft types, callsigns, and the chronological order of gate occupancy. As a special case, two scenes with a potential conflict between taxiing aircraft were added to one of the scenarios in order to gain insight into the ATCO´s level of trust towards the TRACC system.

C. Experimental setting

Out of the capacities which the ATS360 offers, the experimental setting needed to be designed. For the comparison of TRACC and the baseline, two different ATCO working positions setups were implemented into ATS360. One working place was dedicated to give a baseline with standard tools such as electronic flightstrip display, weather monitor, and ground radar display. The other working place included the HMI for TRACC. To provide the same view on the airport during the simulations, the outside view was rotated depending on the working position currently in use.

Furthermore, a technical supervisor, the TRACC system engineer, and an experimental observer needed to be placed in close contact to the ATCO. They were in charge to detect technical problems as well as to answer questions and record data during the simulation runs.

D. Instructions and Training

Prior to the simulation runs, the ATCOs were provided with information about the concept of time-based surface management, the functionalities of CADEO and TRACC, and the operational procedures at the simulated airport. Subsequently, the ATCOs completed a training session to familiarize with the simulation environment and to become acquainted with their role in the simulation and the adapted layout and procedures of the simulated Munich airport. In this training run, the ATCOs had to work half an hour using the baseline setup with normal operational procedures. Following the baseline simulation run, the ATCOs completed another training of 30 to 50 minutes according to the new concept of time-based surface management. Appropriate care was taken that the controllers configured the layout of the TRACC HMI to their needs and used the most relevant TRACC features and tables at least once during the training run. At the end of this training session, a first short debriefing was conducted.

E. Measures

To evaluate the concept´s feasibility, two types of feasibility questions were distinguished within the tailor-made semi-structured guided interview described in the Method section:

1) Questions regarding the concept and implemantation of time-based surface management

Main aspects within this group of questions were concerned with the advisories containing precise taxi speed commands. Furthermore, questions regarding the stability and reliability of optimized surface management plans were another major part of the guided interviews. These questions were important as a higher stability of optimized plans requires less replanning at short notice and thus, a high degree of transparency with respect to the TRACC optimization is supposed to result. On the other hand, a very accurately timed planning and optimization is needed for holistic air and ground 4D-trajectories at airports operating at their capacity limits. There is certainly a trade-off between high adaption to minor plan deviations and a higher stability of committed plans, but with less time precision. Hence, these questions were discussed with the ATCOs.

Furthermore, questions regarding the safety margin of the conflict-free routes planned by TRACC were discussed. Again, small safety margins for each flight would – in case of minor plan deviations – result in controller reactions at short notice and less stability. As a result, the ATCOs could have concerns regarding the transparency, dependability, and reliability of the system and, thus, trust issues could arise. Therefore, questions regarding optimization algorithms and parameters form a further part of the guided interviews.

Questions regarding acceptability, general feasibility (including situation awareness and workload), satisfaction (including a rating of changes in operational procedures), efficiency and ideas for improvement constituted the last part of the concept-related questions.

2) Questions regarding the usability of the TRACC HMI

The second type of feasibility questions was concerned with the clear arrangement of the displayed information, commands, and advisories. The questions addressed the

timeliness, quantity, type, and variety of information, whether the right information was displayed in an appropriate manner and whether the color and position of the information was reasonable.

Further questions dealt with the transparency, traceability, and plausibility of route adaptations due to replanning. In addition, questions regarding conflict detection and the notification as well as perception of safety and critical events were asked.

V. RESULTS

It was suggested in the Introduction that time-based surface management is important to ensure efficient trajectories both in the air and on the ground. We reasoned that an optimal method for this may be a tool-supported time-based surface management which gives advices about speed and route changes. This fundamentally new approach was investigated with a feasibility workshop. As one ATCO had to cancel his attendance, the remaining four ATCOs from three different German airports (Berlin, Munich, and Düsseldorf) gave qualitative feedback.

As outlined in the Method section, the advantage of an involvement of subject-matter experts at an early concept stage is to timely counteract critical feasibility issues. Therefore, the remainder of the results section will focus mainly on ideas for improvement and critical feedback, which is most valuable for the further improvement of the concept and TRACC, rather than on favorable feedback from the participating ATCOs.

Overall, we obtained plenty of valuable feedback. As can be seen from Table I, more than 500 comments covering favorable, critical and neutral/nonspecific feedback and ideas for improvement were gathered, transcribed, and clustered.

As can be seen in Table I, a considerable amount of comments were favorable to our concept of time-based surface management and the TRACC HMI. The ATCOs especially appreciated the presentation of the planned trajectory in the traffic situation display and indicated a positive impact on their situation awareness.

TABLE I. OVERVIEW OF FREQUENCY AND TYPE OF FEEDBACK REGARDING THE FEASIBILITY OF THE CONCEPT AND THE USABILITY OF THE TRACC-HMI

Frequency of concept and HMI related comments		
Type of feedback	***Feasibility of Concept*** [a]	***Usability of HMI*** [a]
Favorable	114	76
Crictical	96	64
Neutral/nonspecific	48	27
Ideas for improvement	43	77

a. Some comments were considered to belong to both categories and therefore are counted for concept and HMI respectively.

More general comments were assigned to constructs (e.g. situation awareness, acceptance). In a further step, possible improvements were deducted from the comments.

It is the exception rather than the rule that a suggested improvement is based on only a single comment. In the following, the possible improvements deducted this way are reported regarding the 1) concept and implementation and the 2) usability of the TRACC HMI.

1) Feedback on the concept and implementation of time-based surface management

Some critical feedback concerned the compromise between stability and accuracy of generated plans. The participating ATCOs requested a higher stability which should lead to less frequent changes of the advisories. To avoid advisories that require quick reactions, both long-term and fallback solutions should be integrated.

Furthermore, some recommendations regarding the optimization parameters were derived from the comments and the gathered ideas for improvement. First, the generation of new trajectories should be less frequent and faster. In addition, the safety buffer should be increased, as small deviations currently require quick reactions of the ATCOs. In addition, the standard routes of the observed airport should be used as default routes for TRACC if possible to increase the predictability and trust. Moreover, aircraft ahead of schedule should wait at their final position rather than on taxiways if possible. The speed profiles should comprise less de- and acceleration and consider restrictions of airlines regarding the maximal taxi speed. The route planning should reduce the amount of curves to avoid additional decelerations and accelerations.

To deliver a large amount of necessary speed advisories to the pilots without overloading the ATCO, it was suggested to transmit these advisories automatically to the aircraft (e.g. with datalink).

2) Feedback on the usability of the TRACC HMI

Several comments about the HMI concerned the clarity of the presented information. Some comments complained that too much information was displayed. Especially the tables with information about the active and expected traffic and the speed profile coded as colors in the planned route were seldom used by the ATCOs. The standard configuration of the HMI should be changed to show this information only optional. In contrast, some information was missing, for example the clearance status of an aircraft. Additionally, the labels on the traffic situation display could overlap. This and the possibility to set additionally remarks should be integrated. Furthermore, the last speed advisory and the stand (for arrivals only) could be displayed in the aircraft labels.

Asides from the question of which information should be displayed, some comments were given about how the information should be displayed. It was noted by the ATCOs that they often needed to search necessary information. As a recommendation, more information should be shown at the

labels in the traffic situation display if possible and the different sources should be better connected, for example by highlighting the relevant information in the tables, when an aircraft is selected in the traffic display, or by using the same colors for arrivals in the table and the advisory panel (and another color for departures).

A lot of comments about the presentation of information regarded the advisory panel in particular. Some advisories were missed by the ATCOs or were removed while the ATCOs worked on them. To avoid such situations, an additional button to prevent an advisory from being removed from the panel could be integrated. Numerical countdowns for several advisories at the same time can overwhelm the ATC. The countdowns should be given more intuitively.

A further point regarded situations requiring increased attention of the ATCOs. For example, it was suggested not only to show the difference between the planned and actual position, but to show an arrow next to each aircraft indicating necessary speed changes. Additionally, the traffic situation display should highlight small areas of the airfield, where aircraft are getting close and small deviations of the planned route can cause conflicts.

Finally, it was noted that the HMI should be improved to increase the system's traceability and transparency by informing the ATCO about the reasons for changes.

VI. Discussion, Conclusions, and Future Work

Some of the improvements suggested by the ATCOs and derived from their comments are already implemented within TRACC. Most of them are related to the HMI (see Fig. 3). For example, a color-coding (yellow for arrivals, green for departures) was introduced for both, tables and the advisory panel. Furthermore, all elements of the traffic situation display are connected: Clicking on a table row or an advisory now highlights the related aircraft on the traffic situation display for an increase in situation awareness. For the same reason, the information shown on the display for each aircraft was reduced: Now, non-active aircraft have no label and are colored in gray.

Because the ATCOs requested a possibility to mark aircraft with information, a status panel was added where the ATCOs manually - or later on the system automatically - set the actual clearance status of the aircraft (pushback requested, pushback given, etc.).

Furthermore, the advisory panel was completely revised. As the ATCOs complained about the necessary effort to read the numbers indicating the time left to execute a command, the decrement of time is now shown as a colored bar below the command. The length of the bar indicates the remaining time and the color the urgency of the advisory.

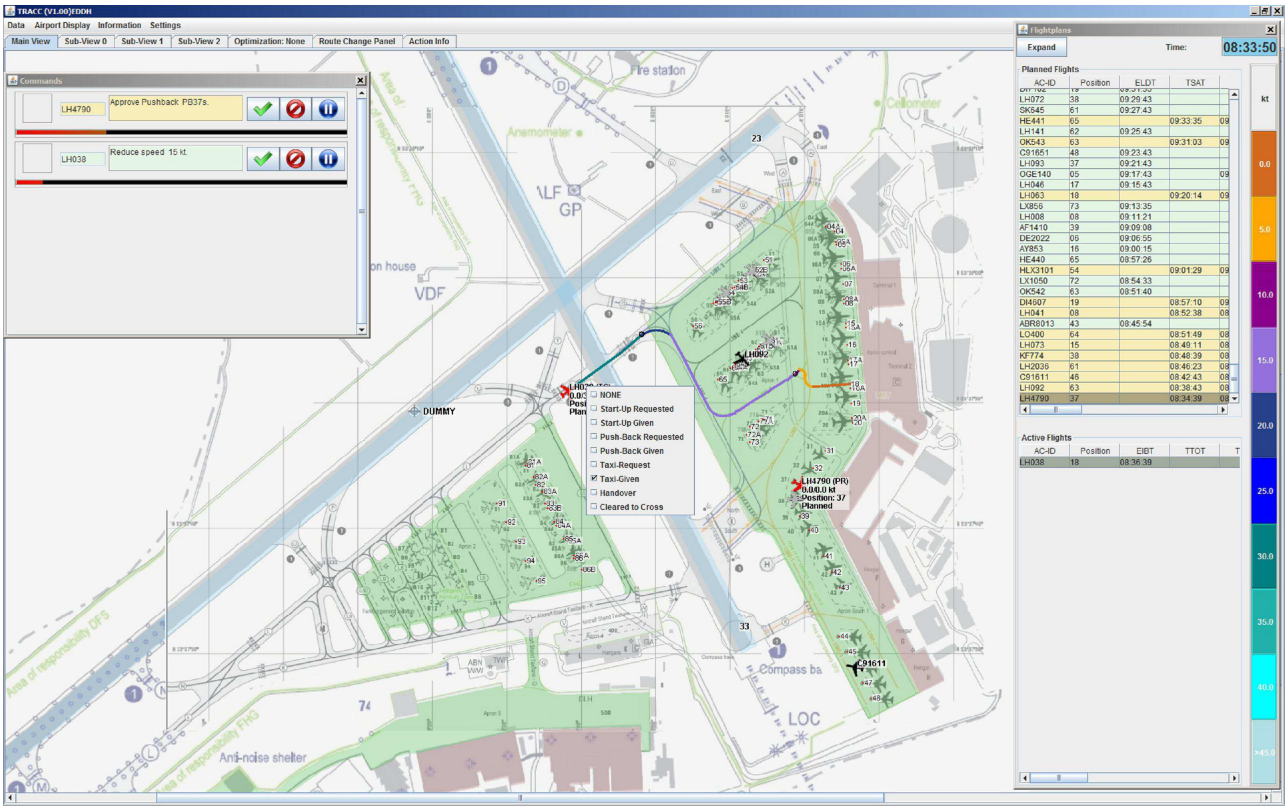

Figure 3. Revised TRACC HMI.

Another point was the disappearance of advisories before they were given by the ATCO. To prevent this, a button was introduced to “lock” a command when working on it or to store it for later. Also, information icons like “Warning” or “Locked” were added for easier situation assessment.

For an increase of trust in the background work of TRACC, a new tab was added with information about the optimizations carried out, a review of advisory handling, and reasons for special actions like delaying pushback due to other traffic.

The future work will focus on the improvement of the connection between CADEO and TRACC for increasing the efficiency of runway usage and the planning stability. Nevertheless, the routes resulting from the optimization part of TRACC should become more realistic regarding the number of applied curves and the way they are used. This will lead to the necessity to adapt the evaluation function of the optimization to these parameters.

Another important point is the CD&R module. Actually, deviations from the expected runway exit or from the planned position caused by speed deviations are included. Therefore, CD&R should be extended to situations where an observed aircraft deviates from advised trajectory and a new trajectory from the actual position of the aircraft has to be planned. Because of the aircraft’s current lack of ability to follow speed advisories very closely, especially the CD&R-part of TRACC is of high importance for the mid-term future.

ACKNOWLEDGMENT

We would like to thank Felix Timmermann and Tim Rambau for significantly contributing to the successful realization of the workshop. As well, we appreciate the many hours the pseudopilots spent for training and the workshop itself. Last but not least, we would like to thank Dr. Marco Temme for supporting the workshop on behalf of the project management.

REFERENCES

[1] B. Daley “Is air transport an effective tool for sustainable development?,” Sust. Dev., vol. 17, pp. 210-219, 2009. doi:10.1002/sd.383

[2] J. Åkerman “Sustainable air transport—on track in 2050,” Transport Res D-TR E, vol. 10, pp. 111-126, 2005. doi:10.1016/j.trd.2004.11.001

[3] H.J. Davidson Reynolds, T.G. Reynolds and R.J. Hansman, “Human factors implications of continuous descent approach procedures for noise abatement”, 6th ATM Seminar, Baltimore, MD, USA, 2005.

[4] P. Manzi, “RNP-AR approach procedures in Sweden”, International Conference on Active Noise Abatement, Frankfurt, Germany, 2010, http://www.forum-flughafen-region.de/fileadmin/files/Internationale_Konferenz_AS/Manzi_Airport_Conference_2010_LFV_RNP-AR_01R_Presentation_v07.pdf [cited 02.09.2013] .

[5] A. Kuenz and C. Edinger, “Green approaches without trade-off: final results from the FAGI-project” 29th Digital Avionics Systems Conference, 2010.

[6] EUROCONTROL, “Airport CDM operational concept document”, edition number 4, 2012.

[7] D. Böhme, “Tactical departure management with the EUROCONTROL/DLR DMAN,” 6th ATM Seminar, Baltimore, MD, USA, 2005.

[8] M. Schaper, “Operational improvements in the context of DMAN, A-SMGCS and A-CDM”, European Air and Space Conference, Manchester, UK, 2009.

[9] Eurocontrol, “Airport CDM DMAN evaluation at Brussels airport Zavantem”, 2008, http://www.euro-cdm.org/library/evaluation_cdm_dman_bru.pdf [cited 10.09.2013]

[10] J. Jakobi, “Prague – A-SMGCS test report. EMMA2 project”, Document No: 2-D6.3.1, 2009, http://www.dlr.de/emma2/maindoc/2-D631_PRG-TR_V1.0.pdf, [cited 10.09.2013]

[11] M. Schaper, G. Tsoukala, R. Stavrati and N. Papadopoulos, “Departure flow control through takeoff sequence optimisation: Setup and results of trials at Athens airport,” 30th Digital Avionics Systems Conference, Seattle, WA, USA, October 16-20, 2011.

[12] M. Schaper and I. Gerdes, “Trajectory based ground movements and their coordination with departure management,” 32nd Digital Avionics Systems Conference, Syracuse, NY, USA, 2013, in press.

[13] I. Gerdes and A. Temme, “Taxi routing for aircraft: Creation and controlling – ground movements with time constraints,” in Dirk Schaefer (Editor) Proceedings of the 2nd SESAR Innovation Days (2012) EUROCONTROL, Braunschweig, Germany, 2012. ISBN 978-2-87497-068-9

[14] European Organization for the Safety of Air Navigation (EUROCONTROL) “European Operational Concept Validation Methodology (E-OCVM)”, Volume I, Version 3.0, February 2010.

[15] S. Schier, T. Rambau, F. Timmermann, I. Metz and T. Stelkens-Kobsch, “Designing the future tower control research environment“, Deutscher Luft- und Raumfahrtkongress, Stuttgart, Germany, 2013.

[16] Kaltenhäuser, Sven “Tower and airport simulation: flexibility as a premise for successful research”, Simulation Modeling Practice and Theory 11, p.187-196, 2003.

[17] Deutsche Flugsicherung GmbH: „NfL I 7/12 Bekanntmachung über die Sprechfunkverfahren“, Nachrichten für Luftfahrer Teil I, Langen, 2012.

[18] J.M. ten Have, “The development of the NLR ATC research simulator (Narsim): Design philosophy and potential for ATM research”, Simulation Practice and Theory, vol 1, pp 31-39, 1993. ISSN 0928-4869, DOI: 10.1016/0928-4869(93)90009-F

[19] F. Kuhl, R. Weatherly and J. Dahmann, “Creating computer simulation systems: an introduction to the high level architecture”, Prentice Hall, 1st ed., 1999. ISBN 978-0130225115

[20] N. A. Stanton, P. M. Salmon, G. H. Walker, C. Baber and D. P. Jenkins, “Human factors methods: A practical guide for engineering and design”. Aldershot, England: Ashgate Publishing, 2005.

[21] M. D. Myers and M. Newman, “The qualitative interview in IS research: Examining the craft,” Information and Organization, vol. 17, pp. 2-26, 2007. doi:10.1016/j.infoandorg.2006.11.001

[22] Deutsche Flugsicherung GmbH, “Aeronautical Information Publication (AIP) Germany AD 2 – 7 EDDM München”, 3rd Mai 2012.