The orange service van drives slowly down Runway West. There is no hurry, it is the middle of the night and no aircraft are allowed to take off or land. A well-rehearsed process takes place inside the van: two Fraport technicians sit at a hatch in the floor; one dismantles a light and hands it over to a colleague at the workbench and the other replaces the old light with a new one. The technicians do their rounds across the movement area night in night out, inspecting, repairing and replacing the lights. After all, the movement area and external lighting at Frankfurt Airport consist of a sea of 37,000 lights and they all have to be serviced by the technicians from Fraport’s Airfield Engineering department. “Every single light source has to be replaced after a fixed lifetime,” reveals Markus Kröger, head of Airfield Engineering. In the case of the new Runway Northwest and most of the existing systems, faulty lighting is even automatically reported by computers, as many areas of the taxiways have already been equipped with LED technology.

**Ambitious climate protection goals**
“The Future belongs to LED,” says Kröger. “The technology’s lifetime is not only longer in comparison to conventional halogen spotlights or mercury vapor lamps, it also reduces energy consumption by about 70 percent and has a lifetime of up to seven years.” Fraport therefore plans to replace all lighting on the movement area with LED technology in the long run. The airport operator has set
itself ambitious climate protection goals: It plans to lower its climate-damaging CO₂ emissions per passenger or 100 kilos of freight to the level of 2005 by 2020, which would be equivalent to a reduction of 30 percent. Another of its aims is to avoid any additional CO₂ emissions despite its plans to expand Frankfurt Airport.

Fraport is therefore carefully reviewing its existing infrastructure, buildings and vehicle fleet for energy-saving potential. “The largest part of our CO₂ emissions comes from the operation of buildings and equipment,” explains Dr. Stefan Schulte, Chairman of the Executive Board at Fraport AG, “which is all the more reason for us to analyse each and every single area in search of energy-saving potential and to also make sure that it is tapped. That is the only way that we will achieve our environmental goals.”

**Successful Development Project**
Besides those on Runway Northwest or in projects involving new buildings on the south side of the airport, LED lights were, for example, also installed during the Runway Mike repairs this year. “The rest will be equipped step-by-step,” says
Kröger. In some cases, such as the many-meter-high apron floodlights, the corresponding, sufficiently powerful technology is not yet even ready for serial production. “The particular challenge in the case of the movement area lighting is that the floodlights are mounted 36 meters above the ground and sometimes have to light up an area as large as 80 meters,” explains Kröger. As there are only very few LED spotlights suited to these needs that exist to date, last year Kröger and his team set the ball rolling for the necessary developments. “In cooperation with Röder Präzision in Egelsbach, we developed a high-performance LED spotlight that is powerful enough and also reduces energy consumption,” reveals Kröger.

Not Overnight
The test operation on the movement area is only one of the many areas where Fraport is currently testing LED technology. “We’re also taking a close look at where we can save energy in the terminals,” says Andreas Schleider, head of Technical Facility Management for Terminals at Fraport. Although the many thousand lights on the movement area can be seen from a great distance, they are actually only responsible for about two to three percent of the airport’s overall power consumption. The lighting for the terminals and other buildings accounts for a much larger share, with the lighting in the terminals, for example, accounting for about 15 percent of Fraport’s electricity consumption.

However, retrofitting the terminals with energy-efficient lighting also will not happen overnight. “It represents a major investment decision that has to be made on a case-by-case basis,” according to Schleider. The same applies in the terminals; we do not simply replace functioning technology. “If, however, we have to renew the lighting somewhere, we check whether the use of LED technology would be economically viable in that area.” Besides energy efficiency, other factors, such as how often maintenance is required, also play a role in these decisions. In order to ensure that they are not based solely on assumptions, Fraport is currently testing the functionality and profitability of LED lighting in various different areas of the terminals. For example, in Arrivals A and C of Terminal 1, 26 LED panels, which are extremely thin constructions that can be integrated directly into the ceilings, are currently being tested in place of the conventional fluorescent tube lighting. “In this area, we currently have 30 percent more illumination despite the fact that we have reduced the number of lights by 40 percent,” states Schleider.

Alternatives to LED Technology
In addition to all of this, Fraport is also testing other possibilities to reduce its overall energy con-
All light sources on the movement area have to be replaced after a fixed lifetime. Faulty LEDs are automatically reported by the computer system.

Follow-the-Greens: Optimized Taxiing

A look into the future at Frankfurt Airport: An aircraft has just landed. Instead of following instructions radioed by an apron controller, as is the case today, the crew are directed to their parking position by green lights on the taxiways. The lights are automatically deactivated as soon as the aircraft passes them. Any aircraft that follow, being towed or on their way to a runway are directed to their respective positions with their own green lights.

The scenario described above is a computer-assisted system called “Follow-the-Greens” that assists pilots as they navigate their way through complex airports and helps to reduce the workload in the cockpit. In the future, it could lead to automated and therefore safer airports, shorter taxiing times, better traffic flows and lower CO\textsubscript{2} emissions. Another positive effect is that the energy consumption for apron lighting would be reduced, as generally, only a minimal percentage of all “Follow-the-Greens” lighting has to be switched on for taxiway navigation at any given time – even during peak operation. At present, all lighting is switched on during the hours of darkness and poor weather conditions. In July, the system was tested in the simulator at Frankfurt Airport with 20 pilots from all over Europe as part of the EU’s “Single European Sky Air Traffic Management Research” (SESAR) project.

Due to the complexity of the data, the detailed analysis shall take until the fall; however, sources from within the project have revealed that the initial findings are very positive. According to the participating pilots, navigation using the light signals is clearer and more convenient. The new system is particularly effective when it comes to poor weather conditions where it can handle traffic better than the existing system. In addition, it means that less time is required for communication between pilot and controller, which relieves both sides. The findings of the simulation shall be collected and documented in the SESAR project. When exactly the “Follow-the-Greens” system shall be deployed across Europe remains to be seen. Fraport however, is today already equipping all new and renewed taxiways and apron areas with the innovative technology so that they are prepared when the new navigation system is introduced.

Other energy-saving possibilities for lighting

Last year Fraport and its subsidiary Fraport Cargo Services GmbH (FCS) were able to reduce both the CO\textsubscript{2} emissions and energy and maintenance costs for lighting by implementing the following measures:

- During the hours between midnight and 4:00 a.m. the lighting of all parking rows in car parks at Terminal 1 and the staff car park is reduced by switching off an average of 30 percent of the lighting. As a result about 210,000 kilowatt hours of electricity and 95 metric tons of CO\textsubscript{2} emissions are saved annually.
- In 2012, Fraport Cargo Services GmbH tested LED technology at the truck station reducing CO\textsubscript{2} emissions by 47 metric tons. During the third quarter of 2013, the use of corresponding LED lights in FCS freight hangars will be expanded, resulting in 545 metric tons of CO\textsubscript{2} emissions being saved per year.
- In 2012 a wide range of LED lights and fluorescent tube lamps from various manufacturers were tested in the underground car park of Terminal 2 over a longer period. It is planned to already complete the retrofitting of general lighting in this area with energy-saving fluorescent tube lamps by the end of this year. This shall result in annual savings of roughly 560,000 kilowatt hours and about 230 metric tons in CO\textsubscript{2} emissions.
Throwing a light on automatic guidance

In June 2013 Frankfurt hosted a real-time validation exercise on automatic aircraft guidance via airfield ground lighting, using the SESAR Airfield Ground Lighting Simulator (SASIM) designed and developed by Flightdeck systems and ATRICS.

The initial follow the greens (FTG) trial, in support of the Single European Sky ATM Research (SESAR) programme, was planned and conducted on 24-28 June in CargoCity North at Frankfurt by the SESAR European Airports Consortium (SEAC) and two air navigation service providers.

ENAV of Italy and DFS of Germany. DLR, the German aeronautical research agency, assisted as subcontractor. SEAC includes Fraport and five other operators of European hub airports: Aéroports de Paris, Flughafen München, Flughafen Zürich, Heathrow Airport Holdings, and Schiphol Group.

SEAC is involved in 33 SESAR projects, co-leading Work Package 6 (Airport Operations) with Aena and heading project SWP 6.9 (Collaborative Airport Flanking).

Preliminary results of the FTG trial were announced on 7 August 2013. “The exercise was a great success: 20 pilots from various airlines performed all 50 scheduled missions [taxi movements] on our two cockpit simulators in only five days,” said Björn Daniel Vielen of Fraport's Airside Systems Development Department and SESAR validation manager for the FTG project.

“We can already say that AGL is clearly preferred to pre-SESAR procedures by the pilots and that taxi times and fuel burn are considerably reduced with AGL.”

SASIM delivered a three-dimensional situational ‘out of the window’ view from two A320-family cockpit simulators (provided by Flightdeck systems) and two controller positions using the ATRICS automated tower and apron control operations suite, which incorporates A-SMGCS functions such as routing.

Passenger mobility in the spotlight

Around 31.5 million of the 57.53 million passengers using Frankfurt in 2012 were in transit. In fact, the airport was the busiest transfer hub in Europe.

In this context, Fraport is a leading member of the German project ‘IKF 2020 – Research into II Navigation’, which focuses on technology to help improve the mobility of travellers, especially the elderly.

The project aims to remove all the barriers faced by travellers when moving through an airport.

Fraport obtained development funding from the Federal Ministry of Education and Research for the Personalized Assistance System and Services (PASS) project.

PASS involves all transport providers who are working together towards a common solution to improve mobility on journeys within Germany.

Partners of Fraport include public transport company Rhain-Main Verkehrsverband; DLR Teutonic Reisebuero; OIC (a travel agency belonging to the RVR Group); Hannover-Lingenhagen Airport; and Symbio and Funding & Consulting.

The project is predominantly supported by Lufthansa and rail operator Deutsche Bahn.

PASS envisages a completely unbroken chain of mobility for passengers from home to the final destination and back again.

New services and innovative technologies will create an easy-to-operate guidance system suitable for the elderly.

It should also be possible to adapt the system for disabled travellers.

The system consists of information and communication technologies that supply users with assistance (or wayfinding and timetables, for example) via apps available on a mobile device or a PASS device that elderly passengers would be able to hire prior to travel.

The PASS device also integrates functions for medical assistance or a porter service. It also indicates confirmed or possible delays on various modes of transport, and physical difficulties at specified locations (such as the absence of escalators or lifts).

Fraport's share of the EUR 3 million (USD 3.9 million) project amounts to EUR 1.1 million. The project started in February 2012 and runs for 30 months.
IVT Expert Report performed for Exercise VP-759

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Expert Names

Adriano Covizzi  
Francesco Modafferi  

Abstract

This IVT Report describes the Phase 2 V3 real-time simulation activity regarding Airfield Ground Lighting performed by EDDM Apron Controllers within project 06.03.01 (EXE-06.03.01-VP-759) “Individual guidance with Airfield Ground Lighting”.

This validation exercise highlighted the Apron controllers’ perspective when operating with Follow-the-Greens. In different scenarios the controllers’ workload, situational awareness and other operational benefits were measured.
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### Prepared By - Authors of the document

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<tr>
<th>Name &amp; Company</th>
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<tbody>
<tr>
<td>Adriano COVIZZI – ETF</td>
<td>IVT Expert / ATCO</td>
<td>04/05/2015</td>
</tr>
<tr>
<td>Francesco MODAFFERI - ATCEUC</td>
<td>IVT Expert / ATCO</td>
<td>15/05/2015</td>
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### Reviewed By

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<tr>
<td>Catharina DE DECKER</td>
<td>IVT Coordinator</td>
<td>16/06/2015</td>
</tr>
<tr>
<td>Marcus Rossbach</td>
<td>Validation leader</td>
<td>03/08/2015</td>
</tr>
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### Approved By

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Executive summary

EXE-06.03.01-VP759 is the successor of EXE-06.07.03-VP649 performed in 2013. It is a maturity level V3 real time simulation (RTS) covering the phase 2 concept of the Airfield Ground Lighting (AGL) Service.

AGL automatically provides guidance instructions to mobiles operating on the aerodrome surface. The corresponding procedure is called ‘Follow-the-Greens’ (FtG).

It should be stressed that this validation exercise was restricted to the apron area*. Extending the FtGs to the Manoeuvring area would require extra validation.

The primary focus of the Validation Performance was on the Apron controllers’ point of view and the impact of the availability of AGL on human factors and airport performance indicators.

The influence of the new SESAR systems and procedures on flight crew workload, situational awareness, perceived safety, and further performance indicators still remained in the scope of the exercise.

The validation aimed to embed the AGL Service into a state-of-the-art future hub airport environment. The controller working positions comply with SESAR concepts defined in the projects 06.07.01, 06.07.02, 06.07.03, and 06.09.02.

This validation activity, performed on the SASIM-2 platform located in Frankfurt addressed two separate validation scopes:

1. the first scope (not covered in this exercise because covered in previous trials on October 2014, using a dedicated Frankfurt scenario) addressed the future situation at Frankfurt Airport;
2. the second scope (object of this validation activity) dealt with the expected upcoming situation of Munich Airport.

Airspace users provided flight crew expertise, while the airport of Munich provided apron controllers (apron controllers working for the airport operator or daughter companies, but not holder of any ICAO/EASA Air Traffic Controller licence) in the execution phase of the validation.

The validation aimed to identify possible benefits of the AGL Service in combination with a sophisticated system and procedural environment at complex hub airports in future traffic.

*One of the objectives of ATS is to prevent collisions between aircraft on the manoeuvring area and obstructions on that area – Apron is part of the Movement area but not part of the Manoeuvring area (ICAO doc 4444 – Chapter 1 Definitions)
1 Introduction

1.1 Purpose of the document

This document is an external review of VP759 validation exercise performed in Frankfurt, on Fraport AG’s RTS platform SASIM-2, from the 20th April to the 24th of April, 2015, addressing the so called “MUC scope”. It will briefly describe the concept validated during the trial and exercise conditions.

The interaction of these tools leads to the future way of performing Apron Control operations, with differences from nowadays. Personnel involved in the simulation had received a proper training to cope with the enhanced working methodology.

This report focuses on expected operational benefits, prospective training and foreseen changes for Apron control and pilots especially regarding HMI and interactions between Apron control and flight crew.

1.2 Intended readership

Intended audience of this IVT report are:

- EXE-06.03.01 Project manager/Validation leader
- SJU Management including SJU Validation Manager and SJU Experts

This report is provided to integrate the overall view of the validation trial. The Project Manager in charge of the supervision of the trial should consider integrating the IVT report in the Validation report, considering this document as the independent point of view from the operational side.
2 Concept Overview

The strategic objective of EXE-06.03.01-VP759 is the validation of the Airfield Ground Lighting (AGL) Service in SESAR on maturity level V3. The AGL Service is part of the OFA04.02.01 ‘Integrated Surface Management’. EXE-06.07.03-VP649 was the first step in validating the AGL Service made in 2013 on the SASIM platform in Frankfurt. The exercise was a V2 RTS validation of the phase 1 concept with a focus on the flight crews’ perspective.

EXE-06.03.01-VP759 started from the results of that previous exercise, using the same SASIM platform located in Frankfurt, covering the future layout and forecasted traffic figures of Munich (MUC scope) airport. It is a V3 RTS validating the phase 2 concept with the main focus on the Apron controllers’ perspective with the flight crews’ point of view still in the scope.

The validation embedded AGL into a state-of-the-art controller-working environment, compatible with the SESAR concepts defined in various WP6 projects. It will furthermore integrate the idea of remote apron control. The scope of this exercise was to look at future traffic values and also to use a sophisticated system for controlling the traffic on the apron. The scenarios were performed during daytime and in varying weather conditions (CAVOK and reduced visibility). One objective of the validation was to prove that although traffic is increasing, the Apron controllers are still able to control the movements in acceptable working conditions.

Altogether, the two scopes of the VP-759 exercises, which will be a SESAR solution intend to demonstrate that FtG is beneficial on the whole, reduce controller and flight crew workload, enhances safety, human performance and efficiency, reduces taxi times, fuel burn, and emissions and furthermore that an increased size of AoRs is feasible and easily achievable without increasing the workload of an individual.

EXE-06.03.01-VP759 does not depend on other validation activities. The main constraint influencing the planning of the exercise was the lack of international standardisation concerning AGL parameters and phraseology.

The data obtained comprises objective methods such as measuring of the time taken as well as analysis of questionnaires filled by the Apron controllers and flight crews, mainly according to international standards.
3 Conduct of Validation Exercises

3.1 Overview

The IVT experts involved appreciated the good organization and the collaborative environment found in Frankfurt. They were well accepted in every situation, creating some interesting opportunities for exchange. Before the start of the exercises the IVT experts received a complete set of documents and activity schedules. A complete briefing was held on the first day of each trials activity.

The validation was performed in Frankfurt airport, on Fraport AG’s RTS SASIM-2 simulator using the Munich airport layout (see Picture 1, showing the simulated Apron Control 2 in MUC). Also part of the SASIM-2 was a simulated MUC Apron 3 control tower (Picture 2) and an A320 cockpit simulator located in a nearby building (Picture 3) represented into the aprons’ simulators as different aircraft types in different runs.
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3.2 Layout

The layout of Munich airport is characterized by different Areas of Responsibility for Apron controllers and ATCOs. Both runways and its parallel running taxiways are under the responsibility of the German ANSP DFS.

At the same time the guidance on all apron areas is provided by the airport operator itself. Therefore Munich Airport employs a number of “Apron controllers” for providing guidance in these areas of the airport.

Apron controllers are not in possession of an ICAO ATCO licence. Apron controllers are airport technical staff that received a proper training. On the documents provided by the Project Manager, in particular the “VP-759 Validation Plan” used as a reference for this report, they are improperly described as ATCOs, but they don’t have any “Air” Control qualification. Regardless the absence of an ICAO licence, the competence of the personnel was at a high level; sometimes the phraseology and practice was not properly aligned with the current EASA/ICAO requirements.

Even if this is not the scope of the trial, it was not possible to investigate the thin boundary between the two areas (manoeuvring and movement) and the relative details.

This is particularly noticeable because Munich layout is quite peculiar (the pictures in the next pages could help to better understand). Munich has two big squared aprons (apron 1, not considered for this validation, and apron 2/3) that form the manoeuvring area. There are only 8 entry/exit gates to/from the taxiways (4 for apron 1 and 4 for apron 2, apron 3 not having any gate, so there is a need to taxi trough apron 2 to reach or to exit from the taxiways). For this reason all the ground traffic management and sequencing has to be done on the manoeuvring area before reaching one of the 8 entry/exit gates to the movement area, creating sometimes a heavy workload to the personnel involved.

The following figure represents current Munich Airport layout.
The area which was used for the validation exercise (apron 2 & 3) is represented in Picture 5.
3.3 Scenario

The MUC Scope of EXE-06.03.01-VP759 consisted of five different scenarios, one reference scenario and four solution scenarios.

The reference scenario presents the pre-SESAR technologies and procedures according to A-SMGCS level 2. That means that in the reference scenarios the guidance of the controller will be provided by the guidance tools which are already in use today (pre-SESAR technology). Consequently the FtG guidance concept will not be applied in the reference scenarios and guidance will be limited to guidance instructions via R/T and manual activation/deactivation of the relevant AGL.

In addition to this SESAR reference scenario, a specifically designed third reference scenario will be performed. This Munich reference scenario will represent the today’s operations at Munich Airport under LVC. In this scenario guidance will be provided by a semi-automatic Follow-the-Greens guidance.

The reference scenario (especially the LVC/day run) is specifically designed for also representing the today’s guidance procedures at Munich Airport under low visibility conditions. The difference between the Munich and the SESAR Reference is that the Munich Apron Control is already today operating with a semiautomatic guidance system. This system, which is based on A-SMGCS level 3, allows the Apron controller to use movement specific AGL guidance under LVC. In order to reflect also this operating method, this third reference scenario has been added to the validation scope.

Within this scenario the AGL will be activated / deactivated in segments. That means that a variable number of lights (3 to 16) depending on the length of a segment will be switched on and off. When guidance is provided by these segments only one a/c per segment is allowed. Consequently the separation between two a/c increases compared to situations under CAVOK without Follow-the-Greens operations.

In contrast to the reference scenario all solution scenarios will have a new allocation of Apron controller responsibilities. That means that in all FtG scenarios the position of the apron assistant will not be re-staffed again. Therefore one controller per apron will take over all tasks including those of the former assistant position.
Among the different scenarios tested, the solution scenario basic was characterized by a basic configuration of the FtG guidance concept. These configurations are explained in detail in the following two run descriptions:

- **SCN-06.03.01-VP759-0014 – Solution Scenario Basic, CAVOK (CAVOK/Day, FtG)**
  This scenario was used for providing guidance instructions by the use of FtG. That means that the controller gave the flight crew an initial taxi clearance and afterwards all taxi instructions were given by the AGL. Consequently the instruction of the controller will be “Lufthansa 123, follow the greens to S8”.
  Moreover, swing-overs were only allowed at the beginning of a taxi movement in order to avoid a disruption of the green AGL guidance indication. Consequently the Apron controller instruction for this procedure would be: “Lufthansa 123, swing-over C2, and then follow the greens to S8”.
  The clearance limits were indicated in all areas of apron 2 and 3 by the use of red stopbars. These stopbars were located in the areas of intersections or on taxiways as in the current Munich Airport environment.
  The configuration of the AGL allowed the controller to switch the AGL in segments. Thus multiple lights of the AGL can be switched at one time.

- **SCN-06.03.01-VP759-0015 – Solution Scenario LVC (LVC/Day, FtG)**
  In comparison to SCN-06.03.01-VP759-0014 this run was performed under low visibility and day-time conditions. Another major difference is that in this run the Apron controller was responsible for establishing a safe separation between different taxi movements. Consequently the surface manager automatically creates a protective gap behind a taxi movement by switching the AGL accordingly (floating separation).
  During each scenario run there were observers and human factors experts.
3.4 Data collection

In fact observation and questionnaires are the two main data collection methods that were used in the validation exercise for SASIM validations. In addition, radar tracks and R/T communication were logged for further analysis.

Observation
Observation was carried out during the simulation session and supported by an observation grid built on the basis of expected Apron controllers’ and pilots’ behaviour throughout the scenarios and on success criteria related to objectives.

Questionnaires
A number of different questionnaires were used throughout the evaluation to gain the necessary feedback from the participants regarding validation objectives.

- **Pre-simulation questionnaire**
  The aim of the pre-simulation questionnaire was to gain information about the Apron controllers and pilots participating in the validation exercise in terms of their operational experience to date and previous simulation experience.

- **Post scenario questionnaire**
  The post exercise questionnaire also contains an additional open question for Apron controllers and pilots to note down any additional comments relevant to the exercise just completed. Where possible data gained from questionnaires were supported by observations made during the exercise and the post exercise interviews.

- **Post simulation day questionnaire**
  A bespoke post simulation questionnaire was used to gather all the relevant information regarding the validation exercise. The final questionnaire was distributed to participants at the beginning of the evaluation, to enable them to understand the feedback required from the evaluation in terms of utility and usability. However, the participants were requested to fill it out at the end of the simulation day.
Debriefings

- **Post scenario debriefing**
  After the Apron controllers and pilots had completed the questionnaires, a short post-exercise debriefing led by the operational experts took place. The debriefing will give Apron controllers and pilots the opportunity to discuss any issues that may have arisen during the previous exercise.

- **Post-simulation day debriefing**
  A post evaluation debriefing was held at the very end of the evaluation session after the final questionnaires had been completed and collected. This debriefing was led by the operational experts to gain group feedback from all the participants on the 06.03.01 validation exercise.

Data Logging

Objective data, i.e. all mobile positions over time (tracks), all R/T communication per speaker/recipient, were recorded automatically by the simulation system.
4 Conclusions and recommendations

From the point of view of the IVT Experts the benefit of the “Follow the Greens” concept and technology are evident and quickly available for deployment. These new systems can also be easily tailored to the needs of any airport.

The following validation objectives were properly addressed without any major issue:

- **Capacity**: increase the movement capacity by an increased availability of RWY and TWY resources over time based on reduced total taxi time, improved traffic flow, reduced clearance delay, and improved re-route delay.
- **Environment / Fuel efficiency**: reduce the environmental impacts and the fuel consumption during the taxi procedure.
- **Human Performance**: reduce the apron controllers’ and the flight crews’ workload and improve their situational awareness at the same time.
- **Safety**: increase the safety during the taxi procedure (e.g. less route deviations) by improving the situational awareness and reducing the workload of flight crews and apron controllers.
- **Predictability**: improve ground trajectory management capabilities.
- **Efficiency**: improve the taxi flow by using Follow-the-Greens.

In particular, the use of the “floating separation” method permits to reduce separations, to increase the apron throughput and to maintain a high grade of safety both in VMC and LVC. The integration of the FtG system with the data gathered from the A-SMGCS permits to follow in real-time the evolution of the traffic and to easily manage the congestion of a busy apron.

IVT experts had the possibility to observe some of the exercises from the cockpit simulator. Also from this opposite point of view the workload of the flight crew was highly reduced using the FtG system, especially in LVC, and the use of taxi charts was almost unnecessary, especially for crews not familiar with the airport layout.

Minor issues could be considered: the touchscreen of the HMI (some operators reported it was too sensible, some other preferred an electronic pen to input orders), but these can also be easily fixed.

A point to be deeply investigated is the rule-layer and its application to both sides: ground operators and flight crews. A coherent environment (at a global level) will produce real improved outcome, while a jungle of different implementation and rules could cause confusion and misunderstandings that could reduce the real benefits.
Edition 00.00.00
IVT Expert Report performed for Exercise VP-759

It should also be stressed that this validation exercise was restricted to the apron area*. Extending the FtGs to the Manoeuvring area would require extra validation.

*One of the objectives of ATS is to prevent collisions between aircraft on the manoeuvring area and obstructions on that area – Apron is part of the Movement area but not part of the Manoeuvring area (ICAO doc 4444 – Chapter 1 Definitions)
Appendix A  Comment /Answer from the validation project leader on items mentioned in the report

Please fill in the section down below if you would like to comment or develop some aspects of the report from the IVT. Should you have none, please leave out the mention "No Comment"

Validation Scope – Movement Area:
There were several reasons why SEAC decided to validate the Follow-the-Greens concepts only on Apron 2 and 3 of Munich Airport. On the one hand, these two apron areas contain all challenges of ground movement guidance you can find at the airport (e.g. Apron alternative parallel taxi routing, triple lane movements, swing overs etc.). On the other hand, too many controllers would have been required for integrating also the Manoeuvering area into the validation scope.

Finally, SEAC is convinced that the validation showed that Follow-the-Greens guidance as it was used in the validation for Apron 2 & 3, is also applicable for an airport’s Manoeuvering area.

Validation Controllers
As described in this report the controllers involved in this validation exercise belong to the airport operator itself and not to an Air Navigation Service Provider (ANSP). Nevertheless the qualification of the Apron Control Staff is adequate to thus of the German ANSP DFS. To become an Apron Controller you have to undergo an intense 3 days recruiting test (same than DFS does) done by the DLR (German Institute for Aerospace). Afterwards at least 18 months of training, theoretical and on-the-job training followed by checkouts and covered by various tests during this phase. Operational Manuals are based on ICAO/EASA requirements and are certified by the airport regulator responsible for the overall airport operation.

Validation Scenarios
Each of the two controllers groups participating in VP-759 performed twice the following 10 scenarios:
<table>
<thead>
<tr>
<th>Number of controllers per Apron</th>
<th>Reference VMC</th>
<th>Reference LVC</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
<th>Solution 5</th>
<th>Solution 6</th>
<th>Solution 7 Apron Merge 1</th>
<th>Solution 8 Apron Merge 2</th>
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<td>LVC</td>
<td>VMC</td>
<td>LVC</td>
<td>VMC</td>
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<td>VMC</td>
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<tr>
<td>LAT NAV Support</td>
<td>No</td>
<td>Today's MUCops with manual FtG</td>
<td>FtG (auto) Single Lamp Switching</td>
<td>FtG (auto) kleinstes schaltbare TCL unit (Stand heute)</td>
<td>FtG (auto) Single Lamp Switching</td>
<td>FtG (auto) Single Lamp Switching</td>
<td>FtG (auto) kleinstes schaltbare TCL unit (Stand heute)</td>
<td>FtG (auto) Single Lamp Switching</td>
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<td>Manual Block</td>
<td>No</td>
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<td>Auto Block</td>
<td>Floating</td>
<td>No (Flight Crew)</td>
<td></td>
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<td>Peak</td>
<td>Peak</td>
<td>Peak</td>
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<td>Peak</td>
<td>Peak</td>
<td>Off Peak</td>
<td>Off Peak</td>
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<td>Swing Overs</td>
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<td>Not possible</td>
<td>Possible</td>
<td>Not possible</td>
<td>Not possible</td>
<td>Possible</td>
<td>Not possible</td>
<td>Not possible</td>
<td>Possible</td>
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</tr>
<tr>
<td>Visual stop indication</td>
<td>None</td>
<td>Stop bar</td>
<td>End of greens</td>
<td>Stop bars</td>
<td>End of greens</td>
<td>Stop bars</td>
<td>End of greens</td>
<td>Stop bars</td>
<td>End of greens</td>
<td>End of greens</td>
</tr>
</tbody>
</table>
Appendix B  List of recipients

This report will be sent to the following persons:

- Validation leader
- IVT Coordinator
Appendix C References

[1] The Airport in the ATM environment, VP-759 Validation Plan, 00.01.00, 14/11/2014
Advances in Intelligent Systems and Computing

Volume 484

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Advances in Human Aspects of Transportation


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#### 7th International Conference on Applied Human Factors and Ergonomics


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Part X
Aviation—Human Factors in Aviation
Follow-the-Greens: The Controllers’ Point of View Results from a SESAR Real Time Simulation with Controllers

Karsten Straube, Marcus Roßbach, Björn D. Vietten and Kerstin Hahn

Abstract Although pilots are often supported by signage, markings and lighting when taxiing on the airport surface, navigation and monitoring remain workload intense tasks even in good weather conditions. Radio communication is near capacity limits on many airports today resulting in waiting times and delay. Apart from well-known safety issues this also constitutes a negative impact on the environment. The European aviation research program SESAR addressed this problem and came up with a solution: A new surface traffic management concept proposes the automated use of Airfield Ground Lighting with individually switched green taxiway centerline lights indicating the path to be followed. This paper presents official validation results indicating that SESAR developed a safer, quicker and greener surface traffic management concept.

Keywords Human factors · Airfield ground lighting · Follow-the-Greens · Safety · Air traffic control · Airport operations
1 Introduction

On 22nd December 2013, a British Airways Boeing 747 from Johannesburg to London Heathrow was taxiing for departure and had been cleared to taxi to holding point runway 03L via taxiway Bravo but missed the turn towards the holding point runway 03L and continued on the smaller general aviation taxiway Mike until the right hand wing collided with and sliced through the walls of an office building. [1].

This example reveals that taxiing at major airports with a complex aprons and taxiway system constitutes a workload intense navigation and monitoring task for the flight crew which can ultimately result in safety critical situations. In order to mitigate these risks, pilots should be supported by concepts and procedures that increase their situational awareness. One of these concepts and procedures is the Airfield Ground Lighting (AGL) service with the Follow-the-Greens (FtG) procedure. The first step in validating the Airfield Ground Lighting (AGL) service as a cornerstone of a holistic Advanced Surface Movement Guidance and Control System (A-SMGCS) was made between 2007 and 2010 in the German Aviation Research Programme IV. A report in German language on the scope and the outcome of the project can be retrieved from [2]. After transferring parts of the concept to the European SESAR Programme from 2010 on, a first large-scale validation exercise on the FtG concept with the focus on the flight crews’ point of view was performed on the Frankfurt Airport’s SASIM (SESAR AGL Simulator) platform in 2013. The exercise was very successful and results can be found in [3].

This paper focuses on a second validation trial performed in 2015 on SASIM-2, the successor of SASIM, with a clear emphasis on the controllers’ point of view, also performed in the premises of Fraport AG in Frankfurt. Key objective of the second validation was to find out, whether partial or full implementation of FtG change controller workload, efficiency, safety and airport performance. Furthermore, the validation was conducted to prove that FtG allows for acceptable working conditions for controllers despite increasing traffic loads.

The FtG concept used for the validation exercise were developed in the context of the SESAR Programme and co-financed by the SESAR Joint Undertaking (SJU). The responsibility for this paper lies exclusively with the authors. The SJU and its founding members are not responsible for any use that may be made of the information contained herein.

2 Follow-the-Greens: The Concept

FtG is an innovative, self-explanatory and performance enhancing guidance method for aircraft and ground vehicles operating on airport taxiways. The objective of FtG is to make the process in all more efficient and more eco-friendly by improving the traffic flow on the aerodrome surface and consequently by reducing taxi times and fuel burn.
FtG provides visual navigation support to flight crews and vehicle drivers along the cleared route by activating a defined stretch of taxiway center line lights in front of the aircraft. All center line lights not needed for the visualization of a cleared path are deactivated. By moving forward, the aircraft literally pushes the lit segment forward, while all lights below and behind the aircraft are switched-off again. Furthermore, the logic within the fully automatic system safeguards longitudinal separations and wingtip clearances in all kinds of converging traffic situations and assists the controller by acting as a holistic safety net.

The operational procedures related to FtG are a simplification of the current way of working, especially when it comes to radio communication: After the initial instruction to “Follow-the-Greens” followed by and information on the destination of the movement, e.g. “Lufthansa 123, Follow-the-Greens to Stand A28”, all further instructions will be provided via AGL and without an accompanying voice instruction.

The regulatory basis for FtG was already laid in ICAO Doc 9830 [4]. The authors of the document state that visual aid instructions can be provided by using taxiway center line lights. In addition, the document clearly defines the general meaning of different colors of AGL: Green lights in front of the mobile represent the instruction to follow. The absence of activated green lights; or the presence of activated red lights; indicate the instruction to stop the mobile. Yellow or flashing lights mean caution.

The first local implementations of FtG, in those days manually or semi-automatically switched, date back to even before ICAO Doc 9830 was written. The pioneers were airports such as Munich Airport and London-Heathrow that can look back at histories of more than two decades or more than ten years of using FtG respectively. The system comprises an integrated Controller Working Position (CWP) and a fully-fledged Surface Management System (SMAN) covering several SESAR solutions related to Routing, Planning and Guidance, and Safety Nets.

Technically speaking, AGL can provide individual guidance information to any cooperative (transponder equipped) or non-cooperative target, e.g. an aircraft, a vehicle, or a combination thereof. While many other guidance services are partly or fully depending on on-board installations, guidance via AGL is a purely ground based service. If the AGL service is implemented at an airport, it will need to be available 24/7 and under all operating conditions, including traffic peaks and low visibility conditions. Automated guidance via AGL has the following features at the current stage in SESAR:

1. Segments of lights: Taxiway centerline lights are switched in segments of lights each containing a minimum of two and a maximum of six lights. Each segment can only be entirely on or entirely off. These segments should be as short as possible close to intersections, turns, or slopes in order to make the visual indication for the flight crew as clear and precise as possible. All segments activated for one individual mobile at a defined point in time are called the individual route indication. The individual route indication comprises a locally configurable number of taxiway centerline lights in the field.
2. Single Lamp Control: Each individual lamp at the taxiway centerline can be controlled by the ground service. This feature is intended to deliver a smoother flow of the activated route indication in the field of vision of the flight crew and the vehicle driver. Furthermore, Single Lamp Control allows for a more efficient sequencing of ground movements.

Each ground controller monitors the traffic in his or her area of responsibility via the CWP Human Machine Interface (CWP HMI). Ground controllers are responsible for assuring that all mobiles comply with the guidance provided from the controller via the AGL. This means that either all guidance decisions are taken by the system, e.g. who crosses an intersection first, or all decisions taken by the controller have to be entered into the CWP HMI.

The SMAN automatically translates all guidance instructions into individual switching commands for the AGL. Ground Controllers are always in the position to modify previous decisions via the CWP HMI whenever necessary. In case of non-compliance by the flight crew, specific procedures will be established such as revert to radio telephony (R/T) instructions. In general, R/T will remain available at any time and e.g. as a backup in case of AGL malfunction or for the clarification of the intent behind an instruction, etc.

### 2.1 Follow-the-Greens: Expected Results

The purpose of this specific real time simulation within SESAR was to gain reliable figures on the operational feasibility and benefits of the new system. Consequently, the operational feasibility had to be validated according to controllers’ and pilots’ feedback in terms of a complex airport environment as a first step. Then, secondly, operational benefits in terms of increased safety, increased situational awareness, decreased workload, increased capacity and reduced fuel burn and CO₂ emissions were in the focus of the exercise [5]. The expected results per Key Performance Area were:

**Safety:** The visual guidance via AGL will lead to a reduction of route deviations and holding position overruns during taxi procedures [5].

**Human Performance:** FtG will increase the controllers’ and flight crews’ situational awareness in Low Visibility Conditions operations and to reduce their workload while using FtG [5].

### 3 Method

The SESAR European Airports Consortium “SEAC” validated the new concept under the leadership of Munich Airport GmbH with its partners Fraport AG, DFS (with DLR acting as sub-contractor), Flugsimulator Frankfurt and ATRiCS between
the 20th and 24th April 2015. The validation was executed on the basis of the layout and traffic characteristics of Munich Airport. Scenarios included runs in good weather as well as low visibility conditions, different traffic loads and remote apron control, i.e. the control of aerodrome surface areas without a direct line of sight.

### 3.1 Participants

Seven controllers (one female, six males, average age = 34.4 years; \( SD = 10.6 \) years) from Munich Airport and five pilots (all males; average age = 40.6 years; \( SD = 5.4 \) years) from different countries and airlines participated in the exercise. While all controllers were highly experienced in Munich Airport’s apron control, the majority of pilots had no experience with the validated airport layout. The selected Munich Airport Controllers who participated in this validation had several training sessions on the ATRiCS CWP prior to the execution in order to get them familiarized with the system. Each controller received about eight hours of training some weeks before the exercise and one hour of refresh immediately before the exercise.

### 3.2 Test Environment

The validation was performed by means of real-time simulations on SASIM-2 at Frankfurt Airport with configurable traffic and different weather conditions (good visibility/low visibility) available. The validation platform was configured to simulate Apron 2 and Apron 3 of Munich Airport and was linked to an Airbus A320 cockpit simulator. SASIM-2 comprises four highly integrated CWPs from ATRiCS, acting as the map-based HMI for a Surface Management System. All inputs to the system were done by means of multi-finger-touch. The view out of the window onto the aprons was simulated with professional 3D software from ATRiCS. The traffic simulation software was also provided by ATRiCS. The cockpit simulator was provided by Flugsimulator Frankfurt with an external 3D view and a very realistic look and feel. Digital voice communication systems provided the radio telecommunication channels and data storage applications saved all relevant information for future analysis including the voice communication.

### 3.3 Scenarios

The term scenario means a cased-based, timely limited and contextually defined experiment during the validation exercise with a specific technical/operational
feature. Each scenario consisted of two runs—one for each controller group. A run is a combination of missions during a pre-defined timeframe. A mission describes a single movement conducted by one flight crew during a run.

Within this validation, ten different validation scenarios were performed by two different validations groups of different controllers and pilots. In the validation week, 20 runs were performed in total. In contrast, two individuals acted as controller assistants for the entire validation week. The validation consisted of ten different scenarios, two of them designed as reference scenarios and eight as solution scenarios. The flight plan used in this validation was based on a stored traffic sample reflecting 40 min of traffic on an average day in Munich airport. This peak consisted of 46 movements (arrivals and departures) and was used for all validation scenarios except for Solution 7 and Solution 8. In these two scenarios an off-peak traffic sample was used in order to represent early morning operations at Munich airport. In all scenarios, two movements were performed by the Airspace Users sitting in the cockpit simulator. All other movements were performed by pseudo pilots.

In both reference scenarios the runs were performed by two controllers per apron. One of them was the controller and the other one was the controller assistant. The first reference scenario presented the pre-SESAR technologies and procedures according to A-SMGCS level 2. In this reference scenario the guidance of the controller was provided by the guidance means which are already in use today. That means the FtG guidance concept was not applied and guidance was limited to guidance instructions via radio telephony (R/T). The second reference scenario was a specifically designed scenario representing today’s guidance procedures at Munich Airport under low visibility conditions (LVC). The difference to the first reference scenario was that Munich Apron Control is already today operating with a semi-automatic AGL guidance system in LVC. Within this scenario the AGL was activated/deactivated in segments. Depending on the length of a segment a variable number of lights (3–16) could be switch on or off. Only one aircraft per segment was allowed. Consequently, the separation between two aircraft increased compared to situations under good visibility conditions (CAVOK) without FtG operations.

Eight solution scenarios were developed in order to allow for evaluation whether the SESAR FtG concept, including new ground controller equipment and AGL guidance, are beneficial compared to the systems and procedures used today. For most of the solution scenarios the staff situation remained identical compared to the reference scenarios with one controller and one assistant per apron. Nevertheless, in some specific scenarios the controller was the only person responsible for an entire apron and in two solution scenarios (7 and 8), Aprons 2 and 3 were merged into one area of responsibility. Table 1 shows all the major scenario characteristics as they were finally used for this validation.
Table 1 Scenario characteristics

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<th>Follow-the-Greens World (solution)</th>
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<td>Reference LVC</td>
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<tr>
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</table>

Follow-the-Greens: The Controllers' Point of View Results...
3.4 Measurements

In order to obtain the metrics and indicators, four types of measurements were applied during the validation exercise.

Observations were performed during the simulation session and were supported by an observation grid built on the basis of expected controller and pilot behavior throughout the scenarios and on success criteria related to the objectives.

Different tailor-made questionnaires were used throughout the validation to gain the necessary feedback from the participants regarding validation objectives and personal experiences. Before the start of the validation, the flight crew, the apron controllers and the assistants completed a demographic questionnaire.

In order to assess possible operational improvements concerning Human Factors, mainly in terms of Situational Awareness and Workload, the apron controllers and assistants were presented an Inter Run Questionnaire consisting of the standardized NASA TLX and 3D SART approaches. In addition, all validation observers filled in an observer sheet after each run. After each cockpit mission a NASA TLX and a 3D SART were presented to the flight crew.

A data logging function focused on several aspects like average and maximum taxi times and taxi speeds and the number of stops and re-starts during taxi of all aircraft movements in the validated airport area. After the completion of the validation week, all recorded data was analyzed with the TRAZER analysis tool provided by ATRiCS. This software tool is able to visualize and analyze surveillance data of airport ground movements.

Debriefings were fulfilled with the controller and flight crew after a specific number of runs and at the end of the entire validation. The debriefing gave controller and pilots the opportunity to jointly discuss any issues which may have surfaced during any of the scenarios.

4 Results

4.1 Operational Improvements in Terms of Safety

The following Fig. 1 taken from the Validation Report [6] illustrates the controllers’ perceived safety. In all, each and every controller and pilot indicated in several debriefings that they always fully trusted the FtG system and procedures. Furthermore, neither controller nor flight crew identified any safety critical issues at any time. The rating scale for the following figures is a Likert Scale ranging from one (unlikely/disagree) to 7 (likely/fully agree).

Further safety relevant results are that the total number of ground movement stops as well as the aggregated duration of ground movement stops is reduced by providing guidance with FtG. By using FtG procedures the total amount of communication can be reduced by more than 20 % compared to the pre-SESAR
scenarios. Consequently the controller has more time to focus on other safety relevant aspects. When operating FtG, no route deviation has been recorded in all validation scenarios [6].

4.2 Operational Improvements in Terms of Human Performance

Due to the reduced amount of R/T communication in FtG operations, the controllers’ R/T frequency is less often occupied. Consequently, the controller might be in a better position to give a clearance earlier compared to operations without FtG. Controllers and flight crews had the impression that their mental, physical and temporal demand as well as their effort and frustration level was reduced when using FtG [6].

Situational Awareness. The controllers and flight crews were asked about their perceived situational awareness in the different scenarios by the use of a standard 3D SART. The rating scale for the 3D SART was as follows: Demand on Attentional Resources (−3 minimally demanding/+3 excessively demanding), Supply of Attentional Resources (−3 greatest possible effort/+3 excessively demanding), Understanding of Situation (−3 virtually nothing/+3 almost everything). The following Table 2 from the validation report [6] shows that according
the analysis of the 3D SART the situational awareness of the controllers’ and flight crews’ is improved compared to the reference scenario values.

**Perceived Workload.** The controllers and flight crews were asked about their perceived workload in the different scenarios by the use of a standard NASA TLX questionnaire. The following Figs. 2 and 3 illustrate the answers by the controllers and flight crews about their perceived workload when using FtG guidance.

It is obvious that controllers and flight crews had the impression that their mental, physical, temporal demand and their effort and frustration level were reduced by using FtG. However, according to the answers their performance highly declined. This unexpected behavior has been analyzed in a post-validation study. It is now assumed that the rating scale caused this unexpected performance result. The rating scale evaluating the performance category was the only one reversed in the questionnaires compared to the other categories. In some post-validation debriefings with the controllers who participated in the validation they confirmed that they rather felt an improvement of their performance when using FtG instead of the documented declination. Hence, it is highly probable that the unexpected result was caused by misunderstanding.

**Usability.** Figure 4 gives an impression of the controllers’ rating of the usability of FtG. The feedback during the validation of all controllers and all pilots was that

<table>
<thead>
<tr>
<th></th>
<th>Controller</th>
<th>Flight crew</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRE-SESAR</td>
<td>POST SESAR</td>
</tr>
<tr>
<td>Demand on attentional resources</td>
<td>0.2</td>
<td>−0.3</td>
</tr>
<tr>
<td>Supply of attentional resources</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Understanding of situation</td>
<td>2.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Table 2** Controllers’ and flight crews’ perceived situational awareness

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Fig. 2 Controllers’ workload
they appreciated to work with the FtG system and that it would improve their daily operations. The rating scale for Fig. 4 is a Likert Scale from one (unlikely/disagree) to 7 (likely/agree).

The observations made by a special observer team were also very positive. They revealed that the controller made almost no use of the direct line of sight onto the aerodrome surface and that they were focused on the HMI of the system. A very interesting result is that due to the reduced workload with the FtG concept the controller had the feeling that there was less traffic in the scenarios compared to the reference scenarios. The validation team then clarified that the traffic sample was identical for all scenarios, only the call signs and some types of aircraft were changed in order to avoid learning effects.
A further observation regarding the pilots was that the FtG concept reduced the pilots’ head-down times. Detailed information can be found in [6].

5 Discussion/Conclusions

The results of the real-time simulation allow for declaring FtG as successfully validated on a large, complex and congested hub airport. In all, FtG is a clear improvement compared to today’s procedures from the controllers’ and the flight crew’s point of view. It was demonstrated that FtG qualifies for the guidance of future traffic on complex airports with very high traffic loads and also for very bad visibility conditions during fog and darkness. The simulation proved operational feasibility and demonstrated the scale of the operational improvements inherent in the concept. In terms of safety, responses as given by the controllers and pilots clearly indicate that FtG will lead to safer airport operations. These results are supported by increased Situational Awareness and reduced Workload of controllers and flight crews. The validation showed that the merge of aprons 2 and 3 during off-peak situations would be possible.

5.1 Recommendations

The validation showed that the FtG concept and its system environment have successfully reached V3 maturity and that this solution is ready for industrial applications. Furthermore, a significant number of airports are highly interested in implementing the concept. On a European and global scale, an adequate standardization covering all aspects from technical requirements and parameters to procedural standards up to issues like the phraseology is still missing. The lack of standardization is currently seen as a major roadblock in Europe and an advantage in competition for other regions of the world. Therefore, it is recommended to put additional pressure on the initiatives aiming at developing of standards for “Follow-the-Greens” such as the EUROCONTROL A-SMGCS Task Force.

5.2 Outlook

Further research activities should focus on special operational procedures, e.g. in case a part of a taxiway (temporarily) cannot be equipped with centerline lights. In this case the wording “Follow-the-Greens to xyz” seems inappropriate. Furthermore, future research should clarify the latest possible point in time for a route change in front of a mobile. In addition, the visualization of warnings and
alerts via AGL should be elaborated as well as instructions to not pass traffic on parallel taxiways in case of wingspan restrictions.

A further topic for future validations should be the question on how to hand over the traffic during shift changes. Nowadays, the decisions and guidance instructions given by the previous controllers can be reproduced by the use of the pre-SESAR technologies. Using the FtG procedures, it might be impossible to reproduce the instructions given by the previous controllers.

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