HIGHER-LEVEL SERVICES OF AN ADVANCED SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS (A-SMGCS)

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Keywords: *A-SMGCS, TIS-B, CPDLC*

Abstract

The occurrences of runway incursions and weather dependent airport throughput have led to the development of an Advanced Surface Movement Guidance and Control System (A-SMGCS). A-SMGCS in its basic levels 1&2 primarily supports aerodrome air traffic controllers (ATCOs) by a weather independent provision of the complete traffic situation and a basic runway safety net. Instead a higher-level A-SMGCS will support ATCOs <u>as well as</u> pilots and vehicle drivers in the functions of surveillance, control, routing (planning) and guidance in a holistic way.

1 General Introduction

In 2004 ICAO published the A-SMGCS manual as document 9830 [1], describing operational, functional and performance requirements. However, procedures and operational requirements for the higher levels of A-SMGCS were rather immature at this time or did not exist at all. The present paper addresses those higher level services of an A-SMGCS, like routing, departure management (DMAN), data link communication (TAXI-CPDLC) and onboard guidance services. Under the umbrella of EMMA2 (European Airport Management by A-SMGCS, part 2), an Integrated Project of the 6th European Framework Programme, a holistic A-SMGCS concept including procedures and requirements was developed and tested in extensive simulation and field trials at four European airports (Prague Ruzyne, Milan Malpensa, Toulouse Blagnac and Paris Charles de Gaulle), using diverse technical solutions and test platforms. The most important results and recommendations to the Prague trials are presented in this paper. They yield feedback to their operational feasibility in general and feedback to new procedures and requirements in particular. Those results serve as an important milestone to support ongoing research in SESAR and NextGen.

2 A-SMGCS Concept

On the airport surface, pilots usually navigate using paper maps, and air traffic controllers (ATCOs) perform the surveillance task, primarily on the "see and be seen" principle. Radio voice transmission is still used as the primary communication means. Under low visibility conditions, pilots are less capable of following the cleared taxi route and seeing and avoiding each other. In order to ensure safety, special low visibility procedures are applied to help overcoming technological limitations. These procedures compromise airport capacity and increase delays.

A further problem on airports is the occurrence of runway incursions. Runway incursions led to several grave accidents in recent years which resulted in the development of A-SMGCS levels 1&2. Such a basic A-SMGCS focuses on providing a reliable automatic surveillance of the complete aerodrome traffic and a surveillance-based runway-incursion warning. At level 1, A-SMGCS consists of the introduction of an automated system capable of improving airport traffic situational awareness through the provision of identification and position information of aircraft and vehicles. The main benefits from implementation of A-SMGCS

level 1 are associated with maintaining safety and airport throughput in low visibility conditions and at night.

A-SMGCS level 2 aims at complementing the surveillance service (level 1) with a control service. It provides ATCOs with a traffic situation picture associated with an automated control service capable of detecting potential conflicts in order to improve safety of runways and restricted areas.

However, comprehensive planning and guidance of flight movements at the aerodrome is still not provided by support of A-SMGCS level 1&2. Increased support for controllers and pilots through automation is the main characteristic of higher-level A-SMGCS services. New tools like electronic flight strips (EFS) enable faster access to and sharing of relevant information. This again leads to a better planning of airport activities and better monitoring of ground traffic. Overall, communication is made more efficient. Up-to-date information, optimised by planning systems such as a Departure Manager (DMAN), is provided to the controller through EFS. A taxi route which is digitally processed by the system has yet another advantage as it can be electronically transmitted to the cockpit. This type of communication with the cockpit is provided by a data link, 'Controller Pilot Data Link Communication', or 'TAXI-CPDLC' for short. Similarly, other instructions, such as start-up and pushback, can be transmitted by data link and acknowledged by the pilot. This will save valuable time on the radio channel, and help avoid misunderstandings by ensuring unambiguous transmission of information to the cockpit. In the future, more and more pilots will be able to determine their position using navigational graphic displays, so-called EMMs (Electronic Moving Map). Technical solutions such as VHF Data Link Mode 2 and TIS-B (Traffic Information Service - Broadcast) could be an enabler for higher-level A-SMGCS on-board services. Pilots will thus be able to see their taxi route, as cleared by the controller via TAXI-CPDLC, and get information about surrounding traffic on the EMM. Automatic

onboard conflict recognition, which warns pilots about possible collisions with other aircraft or vehicles, as well as deviations from their cleared taxi route, are very promising new onboard services. A higher-level A-SMGCS was under investigation in the EMMA2 project.
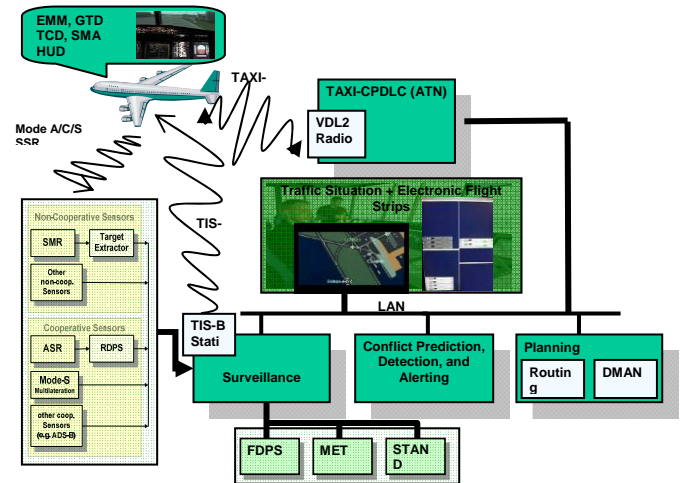

Fig. 1: System Architecture of an A-SMGCS

2.1 Technical A-SMGCS System

The A-SMGCS is a modular concept defined in the ICAO Manual Doc. 9830 on A-SMGCS [1], which systems are aiming to provide adequate capacity and safety in relation to specific weather conditions, traffic density and aerodrome layout. With the complete concept of an A-SMGCS, controllers and flight crews are assisted in terms of surveillance, control, planning and guidance tasks. A-SMGCS will improve capacity, efficiency and safety by maintaining this in different visibility conditions. The environmental impact of fuel consumption and pollution will decrease and the comfort for passengers will increase due to less idle time at the airports.

To follow the ICAO definitions [1] regarding surveillance and control requirements usually more than one type of surveillance sensor is needed to meet the surveillance requirements. In clear words: To ensure the identification and continuous tracking there is the need of a sensor set in dependence of the airport layout. This sensor set must be defined in such a way that redundant information sources - fused by a sensor data fusion (SDF) -

are available to survive short term single sensor faults and to confirm the information validity.

2.2 Surveillance

Each individual aircraft is seamlessly tracked and identified from final approach until it reaches the parking position and vice versa. Towing operations, other car vehicles and obstacles shall be detected as well, at least on the maneuvering area but preferably on the whole movement area, which includes aprons. Therefore three main types of sensors are available:

1. non cooperative sensors:
    These sensors are only able to track an object without a clear identification (e.g. SMR).

2. cooperative sensors type1:
    These sensors are able to track and identify an object. This prerequisites that the object is equipped with a special transponder. The current objects' position will be calculated by multilateration receiver systems on ground (e.g. Mode-S).

3. cooperative sensors type2:
    These sensors are able to track and identify an object. This prerequisites (similar to cooperative sensor type1) that the object is equipped with a special transponder. But in contrast to the sensor type1, the object itself knows its own position and transmits it to the ground sensor (e.g. ADS-B).

2.3 Control

The Control function basically applies some alert algorithm comparing position and speed vectors of converging traffic and issues alerts when a conflict is detected. Those conflicts are related to the severe runway conflicts and infringements into prohibited areas (e.g. construction sites).

In a more advanced implementation with electronic flight strips and planning/routing system support more advanced safety nets come into consideration:

- Deviations from a taxi route
- Clearance monitoring to show conflicting clearances
- Deviations from a pre-planned timing

The clear advantage of this approach is that it is active and not reactive. Preventing conflicts before they appear is obviously better than solving them under time pressure when they become obvious.

2.4 Routing / Planning

A taxi routing function is an essential function of an A-SMGCS. It is less an assistance system to ATCO than a technical enabler to have a valid route available inside the A-SMGCS. This route is needed to calculate the taxi time to detect route deviations or to transmit it to the flight deck via data link. Planning is mainly related to an optimal departure timing and sequence, called departure management. Such a DMAN computes a most efficient departure sequence by providing a target take off time (TTOT), takes the taxi route into account and comes up with a most efficient target start-up approval time (TSAT) to have the flight at the runway entrance at the right time and with minimized "stop and go" during taxiing and with minimized waiting time at the runway entrance.

2.5 Guidance

The Guidance function supports the implementation of the A-SMGCS plans - either computed by the technical system and approved by the controller or directly created by the controllers. The function supports pilots as well as vehicle drivers in following the correct route and the associated time constraints. Two fundamentally different technical approaches have to be considered:

1. Ground Bases Guidance Means, as e.g. switch-able centerline lights, stop-bars or as well runway status lights. Those are often available and could be used and integrated. Enhancements to 'follow the greens' are technically feasible today.

2. Onboard Guidance Means as a "Moving Map Display" (MMD), presenting the current own-ship-position on a graphical map are the promising future solution. This solution can be extended in modular steps, e.g. to handle clearances and plans transmitted via data-link (CPDLC) or to show other traffic via TIS-B to the pilot. Further this onboard system could integrate warning functions as a safety net, like detection of route deviations, certain timely plan deviations or collision conflict detection.

3 EMMA2 Technical Systems

3.1 Surveillance

The installed surveillance systems at Prague Ruzyne Airport, extended by the necessary components for TAXI-CPDLC and on TIS-B, are described in the following table:

ASR stations	1
SMR stations with EXTR-	1
MLAT stations	15
Data Fusion & ATCO HMI (TSD)	3
- Conflict Detection	✓
Gap Filler	Camera
Vehicles equipped	80
Ground based Guidance (Stop bars)	✓
Onboard MMD tested with TCD & SMA	✓
ADS-B (*)	✓
CPDLC by ATN over VDL2	✓
TIS-B	✓
DMAN	✓
EFS with DMAN interface	✓

Tab. 1: EMMA2 Equipment used in Prague

(*) The results of ADS-B trials have shown that due to a poor implementation status in aircraft it is not useful for ground applications (less accuracy, missing time stamp for calculating the latency). In case of vehicles ADS-B can be used because there the ADS-B position data based on GPS navigation data which can be improved by differential GPS stations for increasing the accuracy significantly.

3.2 Taxi-CPDLC

Within EMMA2 the TAXI-CPDLC based on VDL-2 and the ATN stack for the data link communication system. At the onboard side the TAXI-CPDLC end application was the Cockpit Display of Traffic Information (CDTI), which

served for displaying the traffic situation as well for data link communication. At the ground side the TAXI-CPDLC end application was integrated with the Electronic Flight Strip System (EFS), which provided HMIs for the Tower/Runway Controller (TEC), the Ground Controller (GEC) and the Clearance Delivery Controller (CDD). [The abbreviations TEC, GEC and CDD are Prague-specific.]

3.3 TIS-B

TIS-B is a service to pilots and vehicle drivers, not to air traffic controllers. The TIS-B System provided for the EMMA2 test-bed at Prague airport operated in accordance with RTCA MOPS document DO-260A. The TIS-B Server operated in full surveillance mode whereby all targets within the Traffic Information Volume (TIV) were broadcast, including those that were sending 1090ES ADS-B reports. The general requirements for TIS-B transmission interoperability with on-board systems were fully met, with the exception of the radio frequency (RF) coverage volume and message latency requirements, which were deliberately degraded for safety reasons.

The RF coverage volume was determined by RF field simulation analysis. The analysis showed that, due to the antenna characteristic and the antenna location, not all areas of the TIV could be covered. Coverage was only provided for the northern half of the Prague airport movement area, which was the main area used for the EMMA2 on-site trials. This was done deliberately in order to avoid any possible interference with the MSSR in the southern part of the aerodrome.

The theoretical mean transit delay (latency) of TIS-B messages passing through the SDF, the TIS-B Server and the TIS-B Ground Station (including the local area network) is well below 0.25 sec. However, the TIS-B update period was set to 2 seconds in order to reduce the RF field load and avoid possible interference with other systems. This led to a mean transit delay of

0.5 sec in relation to the track reports generated by the MLAT/ADS-B system.

The preliminary safety assessment of the TIS-B ground system at Prague identified a hazard that could result in malfunction of the operational A-SMGCS. In its current version, the operational MLAT system is not able to distinguish between ADS-B and TIS-B messages (i.e. DF18, CF0-1: ADS-B and DF18, CF2-5: TIS-B). This is because the MLAT system was designed to meet the requirements of DO-260, which does not include TIS-B requirements; it was procured before DO-260A was published.

Fig. 2: TIS-B Ground Station

3.4 Controller HMI

The controller HMI (CWP: Controller Working Position) consists of a Traffic Situation Display (TSD), the Electronic Flight Strips (EFS) feed by A-SMGCS functions like planning, routing, guidance and alerting.

3.5 Pilot HMI

The Cockpit Display for Traffic Information (CDTI) consist of the Electronic Moving Map Display (EMM) with the own ship position and the surrounding traffic transmitted by TIS-B.
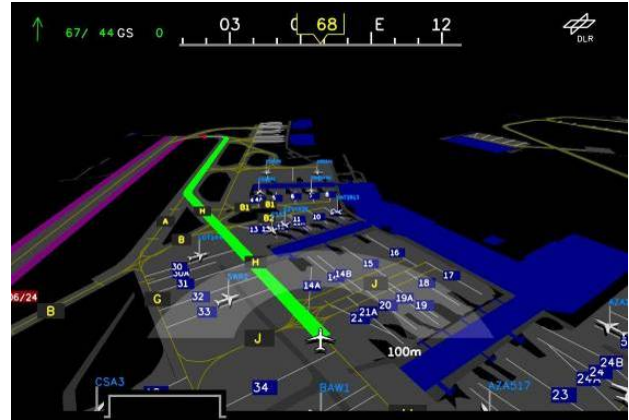

Fig. 3: TAXI-CPDLC on the MMD

4 Benefits on an A-SMGCS

Knowing about the benefits that can be expected from A-SMGCS is a key factor in decisions on A-SMGCS implementation. Only if the technological and operational feasibility is sufficiently demonstrated and if operational improvements are identified and quantified, the relevant decision makers will include ASMGCS in their investment plans. A-SMGCS will mainly provide benefits in terms of safety, increased throughput and efficiency. The airport operator and passengers will benefit from a reduction in diversions and cancellations. There may also be some benefits to the airspace user and the airport operator in terms of increased safety, including reduction in loss of life and damage to ground infrastructure, aircraft and vehicles.

4.1 Verification and Validation

Although many tests can be performed in field– mainly needed to test the system in real environment in terms of its technical performance and its operational feasibility – some essential benefit criteria can only be validated in simulation runs. Real Time Simulations (RTS) usually offer a good opportunity to measure operational improvements in terms of objective traffic data (e.g. taxi times, R/T load, etc.). They were also used to investigate safety critical situations like low visibility conditions or conflict situations without any danger. A sufficient quality of validation can only be reached if adequate tools and experts are used who are well trained on the

new systems / procedures. The real time simulators deserve special attention in this context. They should provide the required performance and flexibility for the envisaged validation. In addition shadow mode trials will support the evaluation: Within shadow mode trials controllers are acting as system observers while the traffic gets controlled in parallel by active operational controllers not involved in system observation. After assuring an adequate performance in the verification phase of the ATM system, validation completes the cycle by including the user's judgement about the right operation of the system. [6]

4.2 Validation Approach [5]

The Prague Ruzyne Airport consists of two crossing runways, the short one in the south is used for parking positions only:
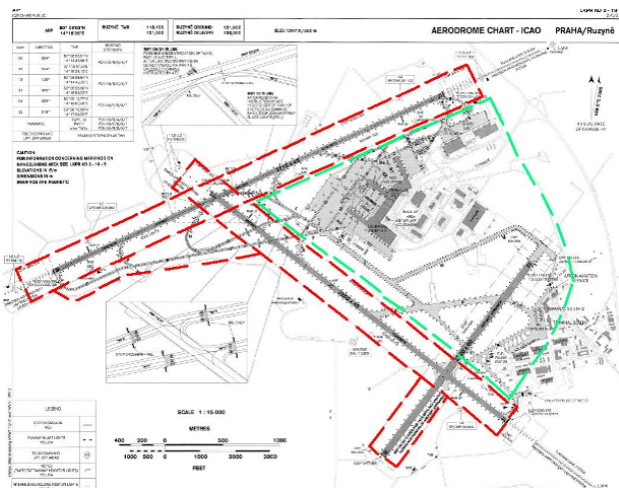

Fig. 4: Prague Ruzyne Airport Layout

The DLR test aircraft ATTAS (Advanced Technology Testing Aircraft System) was used for TAXI-CPDLC data link applications:

Fig. 5: Test Aircraft ATTAS

In EMMA (A-SMGCS level 1&2) as well as in EMMA2 (higher-level A-SMGCS) eleven respectively six ANS CR ATCOs from Prague Tower worked as test subjects in the DLR Tower simulator. With EMMA 33 test runs and with EMMA2 18 test runs were performed, usually lasted 60 minutes each with a realistic mix of Prague arrival and departure traffic in a high density traffic scenario. Aircraft were operated by pseudo-pilots. Clearance delivery, ground controller, as well as runway controller positions were always manned by ANS-CR ATCOs. Base line scenarios (today status of work) were compared against the different/full A-SMGCS services.

Fig. 6: Tower Simulator

4.3 Analysis of Results [2][3][4][7]

In the upcoming sections, each of the A-SMGCS functions tested in EMMA2 will be analysed by presenting the results of the verification or validation activity carried out.

4.3.1 Testing of technical Enablers (ADS-B and TIS-B)

Although ADS-B Out transmissions from aircraft and vehicles were successfully received and all A-SMGCS interoperability requirements were met, performance requirements for accuracy and timeliness of the information could not be met. The reason for this was that the current 1090 MHz ADS-B standards do not consider A-SMGCS requirements. One of the A-SMGCS requirements is that the Navigation Accuracy Category of position (NACp) should be 10, which is the highest value and only

achievable when the onboard measurement is made using differentially corrected satellite navigation information. A more serious drawback is that the time of the position measurement is not transmitted with the 1090 MHz Extended Squitter and, moreover, the end-to-end latency is variable and can be as much as three seconds, which is not acceptable for rapidly manoeuvring objects like aircraft and vehicles on the aerodrome surface.

In summary, the Prague test site concluded that ADS-B could only be used for A-SMGCS when the respective standards and requirements for transponders consider the A-SMGCS requirements and when they are strictly followed. For vehicles, the situation Prague as they were fitted with low-latency was somewhat better at technology so that the timeliness issue was less grave.

TIS-B technical tests were performed as well. In Prague the TIS-B Server operated in full surveillance mode broadcasting all targets within the Traffic Information Volume and interoperability requirements were fully met. However, RF coverage volume and latency were deliberately degraded for safety reasons. The Prague tests further revealed a hazard that might occur when the MLAT system is not able to distinguish between ADS-B and TIS-B messages. Cause of the hazard and mitigation of the risk were discussed (use of Mode-S Transponder MOPS in RTCA DO-260A). Finally, it was stated that the TIS-B ground system technology had reached a high level of maturity. Technical tests with the ATTAS confirmed this and additionally showed that TIS-B could also work in gap-filler mode (only ADS-B non-equipped traffic is shown).

From a technical point of view, the service worked well and a reliable traffic picture was available in the onboard Ground Traffic Display Function. From an operational point of view, the main benefits are expected to be provided particularly in reduced visibility conditions. TIS-B and ADS-B systems together with the Ground Traffic Display Function provide pilots with the complete surrounding traffic scenario.

This could significantly enhance pilot situational awareness and support pilots in the ground movements.

However, currently pilots would not rely on TIS-B alone for separation. Nevertheless, ATCOs and pilots thought that throughput would be increased due to a better confidence of pilots and workload might even be reduced under low visibility conditions.

4.3.2 Electronic Flight Strips

In the simulations that took place the Electronic Flight Strip (EFS) Systems were used as enabler for a number of different A-SMGCS services. The EFS was very advanced regarding HMI design and functionality, so that both systems were well accepted by controllers. Prague controllers, however, were questioned about their opinion on the EFS and rated the system as useful and ready for operational implementation. Prague controllers indicated that the design fitted their needs, was able to carry the implemented services for departure management, TAXI-CPDLC, routing and alerting, and was reliable, intuitive and interactive. Operationally, it did not impair a comfortable workload level and had a positive effect on situational awareness.

4.3.3 Taxi CPDLC (Ground and On-board)

Extensive TAXI-CPDLC trials, including both simulations and field trials, were performed. Feedback was mainly received on TAXI-CPDLC operations with start-up, push-back, taxi-in and taxi-out clearances, and handover operations, which were well accepted by all the ATCOs. Runway related clearances, granted by the TEC, were always given by voice.

The controllers liked the procedure that handover instructions were given by TAXI-CPDLC, but that the pilot's initial call with the next position was done by voice to assure that R/T contact is established. Thus, in conclusion, it can be stated that voice communication remains a very important factor in controlling ground traffic, even when data link is available.

This is especially true in time-critical situations that require fast and immediate action, and in safety-critical areas close to the runway.

4.3.4 Routing

In EMMA2, the route planning or routing function was seen as an enabler for other services such as TAXI-CPDLC, DMAN, and route conformance monitoring rather than a service of its own. It turned out that not all possible taxi routes were available in the system and could not operate that flexible and efficient as the ATCOs wished to be. In a fully operational system this has to be improved, ideally by support of local operational people.

4.3.5 Departure Management

In general, it could be shown that even though the integrated A-SMGCS departure management process is very complex and needs to be adapted to the local peculiarities of the airport concerned, benefits in reduced taxi times and departure queues can be achieved (waiting time reduced by 26%). More benefits in terms of more reliable and stable planning information are expected as soon as DMAN is integrated into a CDM environment that receives input from the relevant stakeholders (ATC, airline, airport, and ground operators).

4.3.6 Onboard Electronic Moving Map

In EMMA2, the EMM functionality incorporated own-ship position, surrounding traffic information, and route and clearance information for navigation purposes. Pilots agreed that the described functionality would increase situational awareness, thereby reducing navigation errors and increasing the safety of taxi operations. Some pilots also assumed that the efficiency of taxiing operations would increase, which would lead to a decrease in taxiing time (less intermediate stops) and a reduction in emissions. Pilots did not complain about the required workload for handling the EMM and suggested that it was more comfortable than the workload for handling a paper map.

4.3.7 Onboard Surface Movement Alerting

The alerting concept that consisted of visual indications on the EMM, textual information on the PFD and an audible alert was well received and accepted by the pilots. Pilots considered the generated alerts as operationally relevant and added that they were necessary in spite of an already increased situational awareness provided by the EMM enhanced with the display of electronic Pre-flight Information Bulletin through the Ground-Air Database Upload function. The SMA function uses the speed, heading and acceleration information of own-ship to detect the right moment to alert the pilot. The timing of the alert must be early enough to enable the pilot to correct the course, but should also prevent nuisance alerts. In both the real-time simulations and the on-site trials, the timing of the alerts was accepted by the pilots.

4.3.8 Onboard Ground Traffic Display

Generally, the HMI design was well accepted by the participating pilots. They stated that the HMI worked reliably and in an intuitive way, and that it was easy to use without inconsistencies. An update rate of 5 Hz was considered sufficient for presenting surveillance information. Head-down times for using the system (located in the navigation display) were acceptable to pilots. It came to positive results regarding the improvement of pilot situational awareness and efficiency of carrying out the tasks. Pilots stated that displaying other traffic on the map would help in anticipating potential conflict situations.

4.3.9 Onboard Traffic Conflict Detection

Pilots agreed that the presented function could be used appropriately in the surface movement area. Both the Traffic Conflict Detection alerts on the taxiways and on the runways were accepted by the pilots, though the operational relevance of the alerting on the taxiways was deemed lower than the alerting on runways. The pilots accepted the warning concept, which is similar to the one for Surface Movement Alerting, i.e. with three different

colour codes on the EMM and PFD, depending on the urgency of the detected conflict, and with an audible alert. The HMI was considered intuitive and easy to use. As for the Surface Movement Alerting function, the right timing of the alerts is essential for the acceptance of the pilots. Concerning reactive runway incursion alerts, the timing was generally accepted by the crews. For the traffic alerts on the taxiway, a fine-tuning of the function is still needed to prevent some nuisance alerts.

5 Conclusions

The present paper summarises A-SMGCS research activities in EMMA and EMMA2. It shows the technical benefits of A-SMGCS and according to its concept of operations, an A-SMGCS mainly contributes to safety and efficiency.
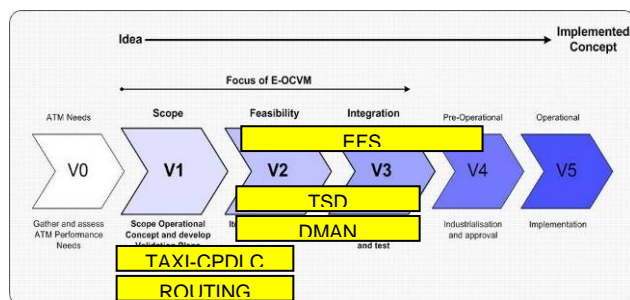

Fig. 7: Today A-SMGCS Status of higher Services mapped on E-OCVM

It was shown again that the quality of the discussed services, especially the higher services, which include several planning, guidance and alerting tools, depends on the quality of the available surveillance information. It was found that ADS-B Out currently is not suitable for A-SMGCS purposes so far, as A-SMGCS requirements have not been considered in specifying transponder standards. Additionally, the varying latency of the information is detrimental to the use of ADS-B in surveillance data fusion and therefore for the use in any A-SMGCS component. Filtering out ADS-B in the data fusion led to more reliable results.

Furthermore, it could be shown that it is difficult to look at the benefits of different A-SMGCS components in isolation, in particular on the ground side. EFS, for example, were seen as an enabler for other services as they allowed the controller to get up-to-date planning information and can input relevant data (e.g. clearances) into the system without increasing workload. This information was useful for anticipation of critical situations, and detection of inconsistencies in clearances.

The integration of a route planning system into the flight strip HMI was seen as enabler for Route Conformance Monitoring and a controller support for transmitting taxi route clearances via TAXI-CPDLC. Thus, apart from reducing R/T load the tool was also meant to reduce time for preparation of clearances. As shown in the trials, the automatic delivery of planning information did not always lead to controller acceptance, simply due to the fact that used flight plan data like ETD are less reliable without a linked CDM process. Without CDM the DMAN is not aware of planned off-block times and can only react on the currently used "First come – first served" procedure. Result is that planning is updated so frequently that the advantage of such a service cannot be exploited by its full extent. However, in simulation when the flights were not delayed by a turn-around process, waiting times at the runway entrances could be reduced by 26%.

In EMMA2, different test sites with different system implementations looked at that series of tasks which led to results that are either very much dependent on a certain implementation of a tool, integration issues between different A-SMGCS components, or fine tuning activities for airport peculiarities. In order to bring the services further and obtain more objective results, future projects should build on these results and further validate the EMMA2 operational concept focusing on the role of air traffic controllers and their working environment and further elaborating task distribution between pilots and controllers. This being said, innovative concepts could be developed that go a step further in integrating

A-SMGCS components and purely look at the different tasks considering new technologies for data input, display, and interaction, potentially resulting in new controller roles and responsibilities. Such innovative approaches are suggested to become part of SESAR activities.

Looking at the airborne side, the situation regarding tools and interoperability heavily depends on the capabilities of the ground systems. Given the results of EMMA2, it seems that the EMM - which integrates different functionalities in a single interface - is rather advanced in development. It combines valuable tools for guidance and control, even to the extent that delegation of certain tasks from the controller to the cockpit might be considered a possible topic for further research. Therefore, it was interesting to learn that the pilots assessing EMM and GTD in EMMA2 did not accept a possible change of responsibilities, such as the delegation of the task for separation on taxiways. Instead, they considered the proposed tools as helpful additions to get a better situational awareness of the overall traffic picture, which would help them in understanding certain controller actions. The pilots were of the opinion that controllers should retain complete responsibility of the separation task, since under low visibility conditions the display tools would not be sufficient to estimate safe separations on taxiways, e.g. when following a predecessor, which frequently happens under good visibility.

The TAXI-CPDLC service, which must be an integral part of both ground and airborne working environments, was tested in EMMA2 with promising results. While refinements are still necessary in the proposed solutions for data input on both the controller and pilot positions, the result regarding workload and situational awareness on both the airborne and the ground side were encouraging, at least for start-up, push-back, and taxi clearances. As regards the more demanding and dangerous operations close to runways, such as runway crossings, line-ups and take-off, a solution of parallel data link and voice exchanges could lead to improvements in situational awareness (with on-board displays being kept up to date) and would not impair workload (read-back would be done by voice only). Additional work will have to be done in this area, though. The results point into the direction of human factors and safety studies. Such studies should indeed be performed on the complete system rather than individual components of an A-SMGCS.

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