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Operational Concept for a complete A-SMGCS
An Output of conceptual work in the European Project EMMA

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The basic idea of this paper is to identify "implementation packages" to support the stepwise implementation of an A-SMGCS. The EMMA "implementation packages" go beyond the EUROCONTROL, EUROCAE and ICAO "implementation levels" definition because they define higher level A-SMGCS services including equipment and procedures considerations.

The new term "packages" was chosen to delimit from the "implementation levels" definition that were identified as insufficient to assist the stakeholders to implement a complete A-SMGCS in a stepwise approach. EUROCONTROL's and EUROCAE's four implementation levels definition focuses on the main four A-SMGCS functions, which is relevant for *surveillance* and *control* because the functions base on each other in a successive way. Further on, these two services are mainly used to assist the users, thus procedures do not have to be changed fundamentally.

However, the implementation of routing (planning) and guidance automated services increase the complexity of the A-SMGCS system as several options exist in terms of automated support to the users and their operational use lacks maturity. Careful consideration shall be made on changing operational procedures, shifting responsibilities from human to equipment (e.g. visual reference vs. electronic display), introducing onboard automated services and equipments, as well as on the interrelations between the A-SMGCS functions. The EUROCONTROL and EUROCAE level 3 and level 4 descriptions do not help here anymore. ICAO goes a step further and considers the responsibility shift between controllers, pilots and equipment for higher levels but does not give sufficient information by which procedures the system is used nor it describes what the technical enablers are and what level of service the users can expect.

Logical Interdependencies between EMMA Service Steps

EMMA aimed to extend EUROCONTROL's level 1&2 definition by a detailed description of higher A-SMGCS services that include guidance, routing, planning, and onboard services, as well an extensions of surveillance and control services. Therefore, the first step was to contour higher A-SMGCS services. A second step was to allocate appropriate technical enablers that are needed to fulfil the service requirements. A third step was to group services and technical enablers in order to establish successive implementation steps that base on:

- Development status of the service (already validated by operational life trials or under investigation through simulation or only at the stage of a concept)
- Development status of the technical enabler (standardised, on the market or to be developed yet)
- Degree of interrelations to other functions (complexity)
- Quality of the enabling equipment (needed reliability)
- Impact on current operational procedures and size of the changes
- Cost/benefit considerations

The individual steps for each A-SMGCS service, which were agreed among EMMA partners[1], can be found in chapter 2 of the EMMA OSED document (D133u_OSED-update). The objective here is to map such individual implementations steps to the proposed implementation packages. Such individual service steps shall not be considered in isolation but their interdependencies as well as the required technical enablers need to be considered. For instance, there is no value to implement a “route deviation conflict alerting” function when the taxi route is not known to the alerting function, that is, a routing function has to be implemented first.

Figure 1 attempts to depict the arrangement of individual steps for each A-SMGCS service in a chronological order. The services are arranged to the main users: ATCOs, Flight Crew, and Vehicles Drivers. Concerning ATCOs the services comply with the main A-SMGCS functions: surveillance, guidance, routing, and control. Flight Crews and Vehicles Drivers receive an onboard service by different characteristics (more details to the services in the EMMA document D133u_OSED-update).

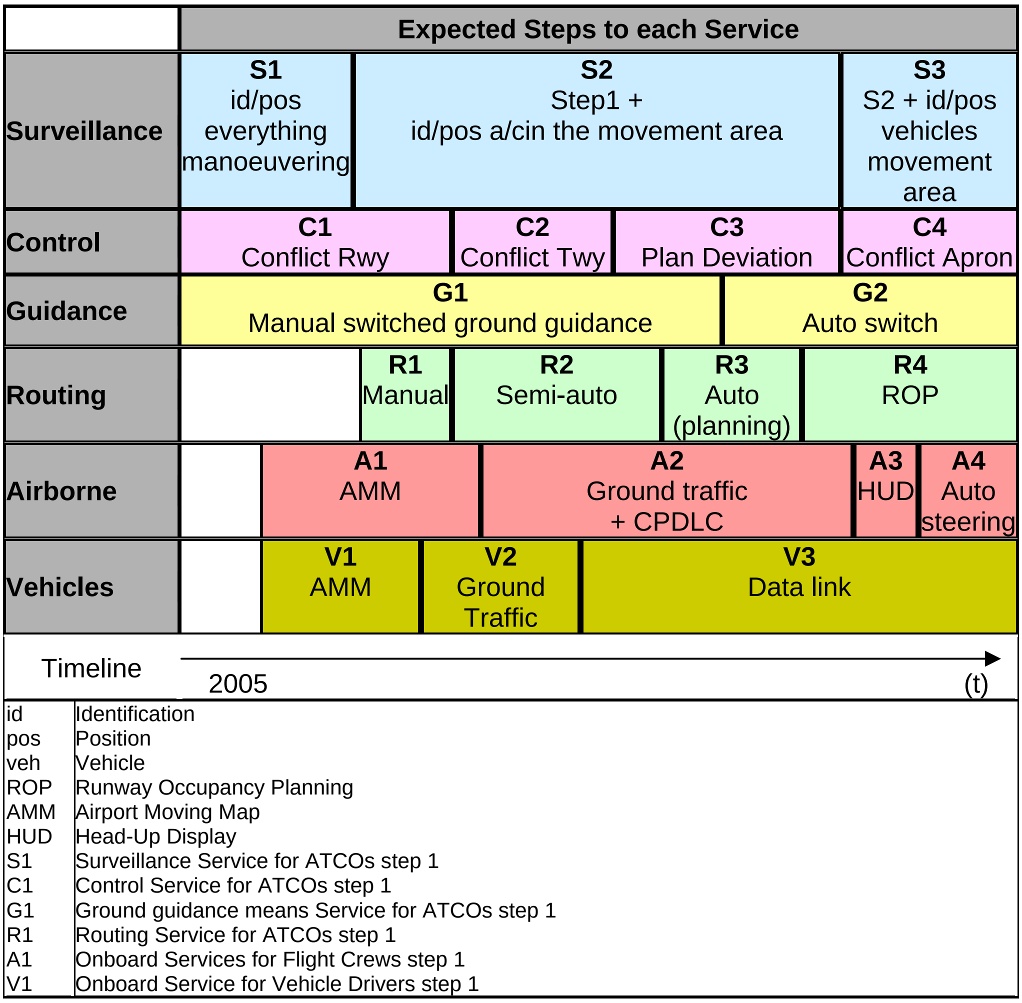

Figure 1: Chronological interdependencies between EMMA Service Steps

Switchable ground guidance means will not further supported with EMMA implementation packages. To install ground guidance means on an airport, which would meet the requirements for such a service, has been estimated as rather expensive without significant relation to its benefit. However, when switchable ground guidance means are already available at an airport (e.g. Heathrow), they should be considered as an additional A-SMGCS service (particularly useful with unequipped aircraft in low visibility).

[1] Beside industry and R&D representatives there were representatives from ANSPs (ANS_CR, ENAV, DSNA, AENA, DSF) and Airlines (CSA and DLH).

Proposed Initial Implementation Packages

Clustering of these different service steps to *packages of implementation* should reflect the operational needs for the considered airport. Such operational needs vary from one airport to another depending on local circumstances such as the complexity of the airport layout, the number of days of low visibility, the amount of traffic, the information flow, the traffic mix, amount of personnel available, etc. The airport-specific characteristics and the current operational procedures are important factors in order to meet the safety objectives while optimising the efficiency of surface movements and will imply significant differences in A-SMGCS implementations. These safety and efficiency operational objectives considered on top of A-SMGCS have been set by ICAO A-SMGCS Manual:

A system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety. (ICAO, doc9830)

Proposed Criteria for A-SMGCS Implementation

It is observed that A-SMGCS is currently deployed for complex airports (more than one runway) and with significant traffic of medium or heavy aircraft. In addition, visibility conditions applicable for A-SMGCS operations represent a further primary criterion. The following table depicts a first decomposition of A-SMGCS in implementation packages according to the proposed criteria:

Layout	Traffic density	Visibility			
		Vis 1	Vis 2	Vis 3	Vis 4
COMPLEX	Medium	Implementation Package (IP) 1	IP2	IP3	IP4
	Heavy	IP5	…	…	…

Table 1: Implementation Package Matrix

For each cell of the matrix implementation packages have to be designed to meet the operational needs. The balance pivot, when clustering services to “implementation packages” to provide *safe* and *efficient* surface movements under specific side conditions (visibility, layout, traffic), are the procedures to be used operationally. For instance, in visibility condition 3 (VIS3) the ATCOs are assisted by A-SMGCS surveillance and alerting services but they are not allowed to use such services as a primary source of information through relevant operational procedures, potential safety benefits will be gained but no change to throughput restrictions (procedural control) will be enabled.

The same applies to planning or onboard guidance. Introduction of these services apart from the right procedures that can influence the behaviour of the traffic would not lead to throughput benefits. The equipment, on the other hand side, is more seen as a catalyst or as a prerequisite to evoke a potential service. But procedures are always the core to enable a service to meet the operational needs.

Initial procedures developed in EMMA are outlined in the D135 EMMA Operational Requirement Document. These initial procedures for higher A-SMGCS levels are still lacking of maturity but are used as a starting point to form EMMA implementation packages. In the successor project EMMA2 these procedures will be tested in simulation exercises and updated by the gained results.

Implementation Package 1

Concerning Table 1 this IP is aimed a complex airport (> one RWY) with medium traffic density (< 35 movements/h) operating under VIS1. That is, the ATCO can control the traffic by visual reference at all times and everywhere and the traffic is not as heavy as the ATCOs or Pilots reach their mental capacity limits. A-SMGCS shall help here to provide surveillance (position and identification = S1) of aircraft and vehicles on the airport manoeuvring area to enhance ATCO's situation awareness (SA), to complete ATCOs situation assessment (e.g. who is who in a taxi queue far away from the control Tower or to allow them to go without pilot position reports). Further on, a runway safety net (C1) helps to prevent runway incursions. All this would contribute to safety and efficiency.

Optional: Since an Airport Moving Map (AMM) with its basic service (showing the position on the ground) is independent on ground equipage, Airlines and Airports could equip their aircraft and vehicle fleets with an AMM (A1 + V1) to increase the pilot's and driver's situation awareness what would increase safety again. Automatic routing or ROP (R3/R4[2]) could be initiated when the surface movements are identified as too inefficient compared to runway or gate capacity. When the route is known to the system it can be transferred onboard via data link provided that aircraft are equipped with CPDLC service (A2) and provided that an input device for the ATCO and proper procedures are available.

Implementation Package 2[3]

The side conditions with IP2 are the same as with IP1 except that VIS2 is predominating now, i.e. the ATCO cannot see the traffic outside. Therefore, the ATCO[4] should be provided with a surveillance that covers the complete movement area with position and identification information of all aircraft (S2). Since pilots and vehicle drivers can still see and avoid each other, conflict alerting service is concentrated on the runways (C1) where providing separation is the most difficult and safety critical part.

Optional: A Ground Traffic display showing the surrounding traffic by receiving TIS-B information (A2 + V2) would be an option to increase safety. As surveillance covers the whole airport also conflict alerting extended to the taxiway could be implemented (C2). However, detection of conflicts on taxiways by automation is a very complex task because much information has to be known to the control function, e.g. the cleared taxi route. That is why, it is assumed that *see and be seen* seems to be rather efficient with VIS2 [5]. When the route is known to A-SMGCS CPDLC (A2) can be implemented as well to increase safety and efficiency.

Implementation Package 3

Visibility decreases further so that pilots are not able to see and avoid each other anymore (VIS3). Conditional taxi clearances (e.g. "follow CSA123") that base on the pilots ability to see and avoid the other traffic cannot be applied anymore. Currently ATCOs take into account these new limitations and give taxi instruction following procedural control operations (one aircraft only within a specified area). Those procedures for low visibility operations (LVO) (PANS ATM, doc4444, §7.10) maintain safety (as the topmost objective) but on the expense of throughput.

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[2] Manual (R1) and semi-automatic (R2) routing are identified as implementation steps and are certainly needed to evolve automatic routing (R3) at an airport. However, working with R1 and R2 are rated as too inefficient as they would support the ATCOs – therefore these first implementation steps are not considered with A-SMGCS implementation packages.

[3] In general, IP2 complies with EUROCONTROL implementation levels 1&2.

[4] At some airports there is a separate Apron or Ramp Control that are not ANSP. However, within this context the ATCO term is also used for non-ANSP control units.

[5] Has to be proven.

A solution to maintain safety and throughput would be that aircraft are still able to see and avoid each other by providing them a step 2 onboard service (A2). A2 enables them to see the surrounding traffic by receiving surveillance information from ground stations (Ground traffic display enabled by ADS-B in and TIS-B). The main issue with this solution is the transition phase: It would be needed that all movements are equipped with this service because non-equipped movements cannot avoid other ones and they cannot be controlled in a mixed mode environment. Even when A2 would be the best solution it cannot be assumed that all aircraft are equipped from one day to the next. That is why this solution cannot be preferred for the near future.

A first interims solution would be to assist the ATCO[6] to provide the control service for all movements on the movement area. The runway safety net (C1) would be extended to the taxiways and aprons (C2 + C4) including a route deviation alerting service (C3). To make the route known to the system, automatic routing should be available (R3). Surveillance would have been extended to step 3 (S3), what would enable the ATCO to provide traffic information to aircraft and vehicles for the apron area as well. But as control of the whole apron area would be hard to achieve on the basis of its surveillance display, the ATCO would only be responsible for designated areas of the apron area (taxi lanes, active stands, passive stands). Only authorised movements (vehicles must be equipped and must ask for permission to enter) would be permitted to use such areas. Other movements would be restricted to parts of those areas (ICAO doc 9830, §3.5.16.3).

A second and perhaps more likely interims solution would be to equip vehicles, which have to move on these designated areas, with a ground traffic display (V2). This would enable them to avoid conflicts with moving aircraft and they could move without regard of the ATCO.

Which solution will be applied finally is much dependent on the airport layout, local procedures, and decisions met by the local stakeholders.

Optional: Since S2 is available (includes TIS-B) a ground traffic display (A2) could be used by the airlines to increase situation awareness and efficiency of taxi movements. Routing can be extended to a ROP (R4) when cost/benefit data support this implementation.

Implementation Package 4

Visibility is now insufficient to taxi by visual reference. Onboard service has to be extended to step 3 (A3) that includes a head-up display (HUD) that enhances the pilot's local situation awareness by a HUD scene linked enhanced outside view. Step 2 surveillance (S2) and step 2 control (C2) assist the ATCOs and provide them the required situation awareness. Vehicles are equipped with ground traffic displays (V2) whereby they can move without additional traffic information from ATCO.

Optional:

Service to flight crews can be extended by an auto steering function (A4), which keeps the aircraft on the yellow taxi line automatically. Additionally, alerting can be extended to the apron area (C4) and automatic routing (R3) and ROP (R4) can be implemented if shortages with safety or efficiency are found.

Implementation Package 5 through 8

IP5 through IP8 are designed for the operational needs of complex airports with heavy traffic density, greater than 35 movements per hour. Since the traffic density is very high and thus the human operators often reach their capacity limits, surveillance should always be step 2 (S2) and control should always be step 3 (C3). S2 and C3 provide the ATCO with a complete surveillance and safety net of the overall movement area. This increases mainly safety. To increase or maintain throughput automatic routing including runway occupancy planning (ROP) (R4) should

[6] At some airports there is a separate Apron or Ramp Control that are not ANSP. However, within this context the ATCO term is also used for non-ANSP control units.

be implemented to support the users by optimised and negotiated times and taxi routes (on a CDM basis).
With VIS3 (IP7) it is insufficient for pilots to avoid collisions with other traffic by visual reference. As mentioned above with IP3 the ATCO should be provided with an additional safety net that detects conflicts not only on the runways and on the taxiways but also on the apron areas (C4). Vehicles moving on the designated apron areas (where they can conflict with aircraft) should be equipped with a ground traffic display (V2) to see the surrounding traffic and to avoid it.
With VIS4 (IP8) it is insufficient for pilots to taxi by visual guidance only. As with IP4, the onboard service has to be extended to step 3 (A3) that includes a head-up display (HUD) that enhances the pilot's local situation awareness by a HUD scene linked enhanced outside view.

Optional:
Optional but very beneficial with all IPs with heavy traffic would be step 2 service to flight crew and vehicle drivers (A2 and V2). With this service pilots and vehicle drivers are always able to see where they are, where they have to go, and where the surrounding traffic is. Particularly with dense traffic, this would contribute to safety, but also to faster taxiing what is an efficiency aspect. Vehicles can be equipped further on with vehicles service step 3 (V3) what would allow them to receive a taxi route, or the exact location of an accident, or other information via data link. This would particularly beneficial with VIS3 and VIS4 when they cannot see the destination by looking outside their windows. Table 2 gives an overlook to all eight implementation packages:

Layout	Traffic density		Visibility			
			Vis 1	Vis 2	Vis 3	Vis 4
COMPLEX	Medium	Recommended	IP1 S1 + C1	IP2 S2 + C1	IP3 S2+C3/4+ V2+R3	IP4 S2 + C2 + A3 + V2
		optional	A1 + V1 R3/R4+A2+ V1	A2 + V2 C2+R3/R4 +A2 +V1	R4 + A2	C4 + A4 + R3/R4
	Heavy	Recommended	IP5 S2 + C3 + R4	IP6 S2 + C3 + R4	IP7 S2 + C4 + V2 + R4	IP8 S2+C3+A3+V2+R4
		optional	A2 + V2	A2 + V2	A2 + V3	A4 + V3

Table 2: Implementation Packages