

## **CAR MANAGEMENT ON APRONS (CARMA) – DEVELOPING INTEGRATED SOLUTIONS FOR VEHICLE MANAGEMENT AT MID-SIZE AIRPORTS**

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### **Abstract**

The paper investigates the development of systems for vehicle management on airport aprons, using current A-SMGCS experiences, with a focus on fleet management and turn around processes of mid-size airports. An architecture is proposed that is derived from A-SMGCS, reducing cost by only supporting cooperative targets and off-the-shelf hardware. Available candidate technologies for implementing the architecture's components are discussed, pointing out criteria for selection. Systems for vehicle management on aprons are important, because the continuous reductions of aircraft turn-around times increase the pressure on airports and ground handling companies to optimize infrastructure and resources.

### **1 INTRODUCTION**

After a short period of stagnation air traffic is back at growth rates of 3 to 5% per year – at certain regions even much more [1]. As physical growth of airports e.g. by building new runways is difficult, an optimized usage of available infrastructure resources is a must. In addition the liberalization of ground handling services puts economic pressure on the companies, requiring an optimized usage of resources participating in the turn around processes.

Airports are complex and fragile systems. Deviations at a single airport process propagate easily to the whole airport system and often to the whole air transport network. Those effects can result in immense economic pressure. Such complex and fragile systems can only be efficiently controlled by humans if proper technical support systems are available. After local optimization efforts in the past at individual working positions or for individual stakeholders, now the phase of integrated airport considerations and solutions has started.

Part of a solution for those problems is an A-SMGCS. The concept of Advanced Surface Movement Guidance and Control Systems (A-SMGCS) was invented in the early nineties and through a lot of cooperative research it is meanwhile a worldwide standard – ICAO document 9830 [2] and derived EUROCONTROL material. A-SMGCS comprises technical support systems for controllers, pilots and vehicle drivers, supporting their specific tasks: surveillance, control, planning and guidance. A-SMGCS is a modular concept, already implemented operationally at few European airports in first steps. It has been proven that A-SMGCS is enhancing the safety and efficiency of airport operations as well as maintaining the throughput in bad visibility situations.

In order to prevent accidents like in Tenerife in 1977 or Linate in 2001, in the beginning A-SMGCS development focussed on the runway system. Therefore the ANSP (Air Navigation Service Provider), the tower working positions and the ATC (Air Traffic Control) controllers were firstly involved. But soon it was discovered that the localization and identification of aircraft would as well be beneficial to apron control. Especially at airports like Hamburg where tower and apron control are spatially distributed and operated by different organisations, sharing of A-SMGCS information concerning aircraft position and identification could enhance the coordination between the operators. Equipping cars was as well discovered soon as an operational need, e.g. the follow-me-cars (A-SMGCS project in Prague [3]) or the fire brigade (ETNA-project in Frankfurt [4]). These fleets are relatively small and operate often in the manoeuvring area including taxiway and runway system. In current approaches these cars are equipped like aircrafts with tailored SSR Mode S transponders or ADS-B (Automatic Dependent Surveillance – Broadcast) solutions. The advantage of this is the compatibility to the usual sensor equipment of the airport. The disadvantage is cost as well as radio and processing load of the A-SMGCS multi sensor system.

A clear shortcoming of the current A-SMGCS implementations and research activities is the limiting to the inbound flight phase until on-block and the outbound flight phase after off-block. The turn-around processes must not be ignored in such concepts in the future anymore. The ICAO manual 9830 [2] is clearly indicating that the whole movement area of an airport (including aprons) is covered by A-SMGCS. Turn-around processes and their management can take advantage of A-SMGCS information. E.g. the exact knowledge of aircraft position and identification may help the ground handlers to exactly predict the on-block times of aircraft continuously. Thus, they could more efficiently manage their vehicle fleet, their staff, and their other resources. On the other hand, A-SMGCS could take advantage of vehicle management systems usually starting with the continuous detection and identification of the vehicle fleet. So far, this is very similar to an A-SMGCS, but it can be done by different means than chosen in A-SMGCS, due to the opportunity to equip the fleet with on-board systems not following worldwide standards. This information could be

generated and communicated without occupying further air traffic control frequency bandwidth. If the information of such vehicle management is of sufficient integrity and reliability it can be taken into account by the A-SMGCS system, giving additional services to apron control staff. Of course not all cars of all fleets should be shown on different HMIs, but with an intelligent selection logic, the right cars could be shown at the right moment (or on request) to support apron control.

The paper investigates architecture, development, and integration of technologies for vehicle management on aprons, using current A-SMGCS experiences. This includes needs, potentials and differences in solutions for vehicle control and management. Available candidate technologies targeting parts of the architecture are identified, pointing out criteria for selection.

## 2 STATE OF THE ART

During the last decade several technologies and applications have been studied in many different A-SMGCS projects. The series of projects funded by the European Commission in their 4th, 5th and 6th framework program – respectively the projects DEFAMM [5], BETA [6], EMMA [7] and EMMA2 can be considered as the European core activity that led to updated ICAO standards on A-SMGCS as well as operational systems and products. Though the standards specify the concept and the requirements to be met instead of the selection of the technology, in the end the basic A-SMGCS technology – supporting the surveillance and conflict alert – consists usually of the following equipment:

- SSR (Secondary Surveillance Radar) Mode S Multilateration System to localize and positively identify aircraft and vehicles equipped with squitter units
- SMRs (Surface Movement Radars) to localize all aircrafts and vehicles. Vehicles without cooperative equipment can be localized but not identified.
- ASR (Airport Surveillance Radar) interface to ensure seamless tracking of approaching and departing aircraft
- Interface to flight data bases to correlate A-SMGCS data with additional flight information in the identification process
- SDF (Sensor Data Fusion) to merge all data from all sensors into one data set for each individual aircraft or vehicle
- Runway Incursion detection and handling logic
- Displays of the traffic situation for several Controller Working Positions

In support of the A-SMGCS technology some procedures define how to operationally make use of the technical equipment, e.g. transponder operating procedures for the flight crew, A-SMGCS identification procedures for the controllers.

Higher services of A-SMGCS, e.g. making use of digital data communication between controller and pilot (or vehicle driver) or making use of integration of planning systems [2][8] are still more in the research focus, e.g. in EMMA2. Currently the communication between controllers and pilots (or vehicle drivers) is carried out via radio voice communication. Planning is done mentally by the controllers.

Attempts to include vehicles into the A-SMGCS surveillance have been made by equipping some of them – those which use frequently runways and taxiways – by units that transmit Mode S squitter signals. Therefore these vehicles can be localized and positively identified. But this approach is of no help to the driver, it does not support navigation. Further, due to cost (and maybe due to radio load), this solution is not applicable to all vehicles relevant for surveillance for all of the airport stakeholders. Finally it does not support a modern digital data exchange (bidirectional) for fleet management purposes.

Other approaches can be found, e.g. at airport of Frankfurt, where a sophisticated solution of GNSS / INS with driver display has been developed in the ETNA project and has been applied to the fire brigade [4]. This seems to be a high end solution that would be much too expensive for a broad application at mid size airports.

In the EMMA2 project trials have been carried out at the test site Malpensa to check how far standard consumer electronics (WLAN) could be used to support airport apron services. This approach is still not completed but seems to be a promising direction that should further be explored [7]. A similar approach has been followed in the AIRNET project which tries to embed an innovative EGNOS low-cost modular platform and wireless communication networks like TETRA (Terrestrial Trunked Radio), WLAN, or VDL4 (VHF Datalink Mode 4) [9].

### **3 USAGE SCENARIOS AND REQUIREMENTS**

New developments with a short to medium implementation focus have to be based on clear requirements from the operations. Operational people generally help to specify the applications that could give operational improvements and benefits. Derived from operational requirements, technical requirements and potential solutions can be found. Therefore this paper firstly considers important usage scenarios.

#### **3.1 Fleet Management and Turn-Around Process**

Economic benefits from systems for vehicle management on aprons are mainly achieved by optimizing turn-around processes. Ground Handling Companies (GHS) suffer under a steady growth of economic pressure due to the liberalization of the Ground Handling Services at European Airports. Additionally the rivalry between the traditional and the low cost airlines result in a more efficient use of the expensive aircrafts and therefore in shorter turn-around times. As a result, the GHS have to do the same work with fewer resources in less time. This can only be done by optimized processes, but optimized processes get more sensitive against disturbances.

The different fleet operators have their own systems for vehicle planning and operation. Its processes can be optimized by increasing situation awareness enabled by an airport system providing the current position and identity of all vehicles belonging to the fleet.

Planning operators need to see the past, current and coming involvement of individual vehicles in the turn-around-processes they are responsible for. In addition

they need status information and predicted schedules of the turn-around-processes in order to plan the resource usage, including the vehicle fleet. Finally for the steering of vehicles, they need appropriate means for sending tasks to the individual vehicle drivers and to get acknowledgements from them.

Communication with drivers can be fulfilled with on-board devices installed in vehicles. For instance, the device may show the next task to be conducted by the vehicle (e.g. the fuelling of an aircraft  $x$  at stand  $y$ ). After completing the task the driver confirms it directly on the device. The device should be part of the airport system for vehicle management on aprons, because it provides general services to that system (e.g. communication with apron controller). Thus fleet specific functionality for optimizing turn-around processes, need to be implemented generically for all fleet management systems or as a plug-in.

The large number of vehicles for ground handling to be equipped requires inexpensive on-board devices (in the order of magnitude of a car radio) also allowing ad-hoc installations for vehicles rarely accessing the airport. The low price can be achieved by applying off-the-shelf hardware. An obvious choice is PDAs such as Pocket PCs commercially available with GPS for positioning and communication equipment like WLAN and GSM.

### **3.2 Workplaces**

Working positions in the tower, apron control and fleet control centers have different requirements, which vehicles they are interested in and want to see on their screens, in which situation, when, and by what data. The tower is interested in all vehicles that move on the runways and taxiways, no matter if it is a cooperative or non-cooperative target. The tower is not interested to see the vehicles on the apron, if it is not under responsibility of the ANSP. Apron control is primarily interested in a safe and effective control of the aircrafts on the apron. It needs to be able to determine, if apron taxi lanes are free of any obstacles. Therefore they are interested in surveying ground vehicles as well. Ground Handling Companies are interested in the vehicles belonging to their fleet. More then the other work places, they are looking for detailed information about the vehicles, their actual status, and assigned tasks.

### **3.3 Driver Navigation and Alert**

In addition to supporting fleet management on-board devices can be applied to support drivers with airport navigation functionality and for alerting in case of danger, to increase safety particularly in low visibility conditions. Therefore, on-board devices need to display a moving airport map indicating current position, speed, and direction – similar to car navigation systems – and also other traffic participants. Protected areas or areas that are temporarily closed (e.g. due to road works) have to be clearly marked. If the vehicle is only allowed on specific roads or corridors this has to be visible too. An acoustical and visual alert needs to notify the driver if the vehicle violates restricted areas.

## 4 ARCHITECTURE

The use cases for vehicle management on aprons can be implemented with the initial architecture used by the CARMA project shown in Figure 1 in comparison with the current A-SMGCS architecture. Both follow a similar architectural approach. The unidirectional connections are mainly used to provide surveillance information, the bidirectional connections are used for information exchange between the vehicle drivers/pilots and the Controller/Operator, standing for higher services like guidance, control and planning. While the basic functions (surveillance and control) are very mature for the A-SMGCS system, the car management ground system has to measure up. The higher functionalities are under research in both systems.

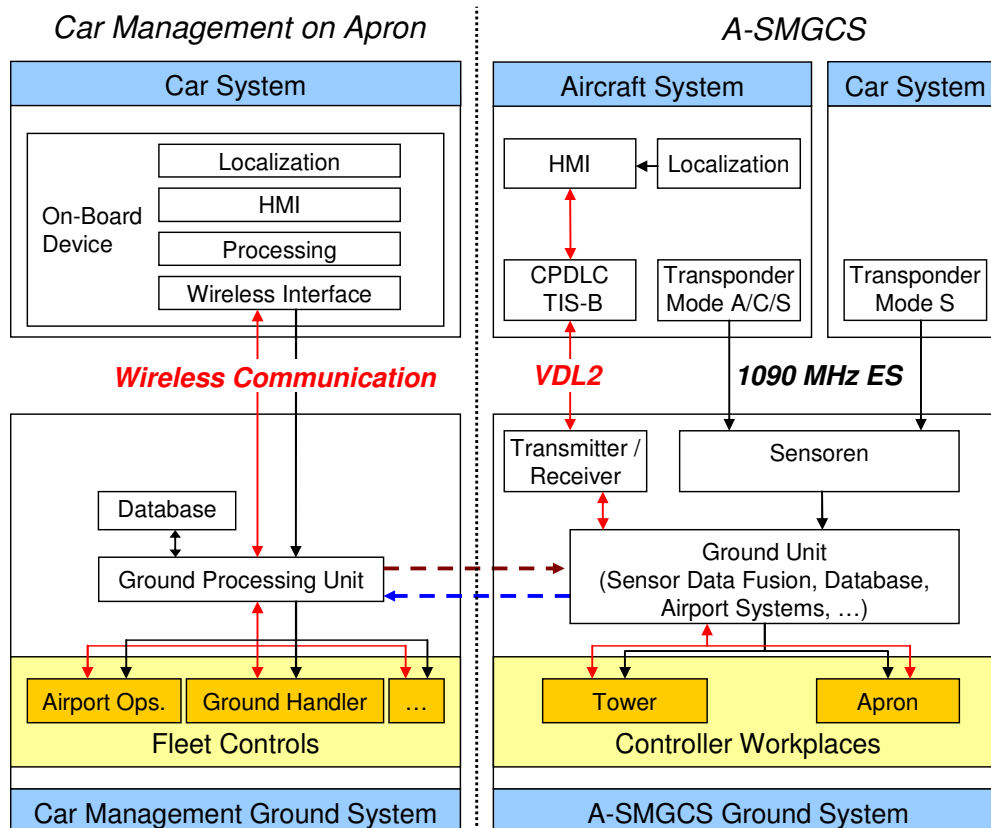


Figure 1: Architecture of CARMA Ground System and A-SMGCS

For the A-SMGCS the position of the aircraft/vehicle is calculated by the multi sensor system. The on board calculated position by GPS, INS, or Radio Navigation is only used for the on-board HMI but often not for the A-SMGCS. Typical aircraft equipment like transponders, are also used for cars and provide identification information via the 1090Mhz ES (extended squitter) functionality. The ground unit combines all available resources and delivers the complete traffic situation to the controller work places. The higher services like data link applications will be realised by the VHF Datalink Mode 2.

Within the architecture for car management there is an integrated on-board solution with localization, position display and data transfer to the ground unit. The position is calculated, displayed on the vehicle HMI and send to the ground together

with identification and status information. The ground unit collects the information and correlates it with additional data of registered cars stored in a database. It uses the information for displaying the situation to the fleet control centre.

Connecting car management and the A-SMGCS system provides additional benefits for both sides, even though both can operate as stand alone systems. For instance, the connection (indicated by the dashed arrows) provides information about vehicles supervised by the other system increasing situation awareness.

## **5 TECHNOLOGIES**

There are alternatives for technologies to implement components of the architecture shown in section 4. Available technologies and off-the-shelf hard- and software should be used whenever possible to reduce cost, especially in case of the on-board devices required in higher quantities.

### **5.1 Wireless Communication**

Several technologies are candidates for the wireless communication between on-board devices and ground system. Selection criteria are safety, costs, reliability, quality of service, and avoidance of interference with other systems.

Candidates for wireless communication technologies belong to the field of cellular phones and mobile LANs. Common technologies for cellular phones in Europe are GSM [10] (including GPRS) and UMTS [10]. A further option is TETRA [10], a similar, digital technology for closed groups such as police and fire brigade. Major candidates from the area of mobile LANs are WLAN [10] (IEEE 802.11) and the more recent WiMAX [11] (Worldwide Interoperability for Microwave Access, IEEE 802.16) with higher bandwidth and transmission range.

Estimation of costs requires considering expenses for purchase, installation, and operation of mobile equipment and infrastructure. Low purchase costs can only be achieved if off-the-shelf hardware is available, even for the mobile on-board devices. Assuming PDAs as on-board devices the selected communication technology needs to be build-in or provided by an extension unit, e.g. a CompactFlash card. Further cost reductions can be achieved by applying available airport infrastructure. For instance, at Hamburg Airport a WLAN is already used for ground handling, spanning the entire airport area including aprons, runways, and taxiways. Infrastructures of public GSM and UMTS networks are also available, but involve basic charges per on-board device and costs for network usage.

Requirements for reliability and quality of service also need to be fulfilled at unfavourable weather conditions, for instance if there is ice (frosted antennas) or snow flurry. Radio coverage – relevant for reliability – needs to span the entire airport premises including indoor areas with vehicle traffic. Requirements for quality of service include limits of latency, and failure rates and durations (e.g. in case of hand-over between radio cells).

The selected communication technology must not interfere with other systems. In particular, air traffic systems must not be affected. On the other hand the communication technology must be robust against radiation emitted by airport systems and devices used by passengers (e.g. mobile phones, Bluetooth, and WLAN devices).

## 5.2 Localization and Identification

Navigation and Control of apron vehicles is essentially based on identifying and localizing each vehicle in the apron area. Basically two general approaches exist: An airport infrastructure can identify and localise all vehicles (e.g. using multilateration and Mode S Transponders) or an on-board device in each vehicle determines its position and forwards it to the ground processing unit. Several technologies can be combined to increase reliability, accuracy and coverage area.

Possible technologies for the two approaches are different. Candidate technologies of airport infrastructures localising vehicles on aprons are ground radar, sensors installed on the apron (e.g. induction loops), and RFID bases solutions. Vehicles can be identified using 2D bar codes, RFID, or active transponders. The self-localization of on-board devices can be enabled with GPS or its recent European counterpart Galileo [12], or the technology used for communication (GSM, UMTS, WLAN, or WIMAX) can be applied. In the latter case the position is estimated by evaluating the signal strength of several base stations [13]. For identification, the vehicle ID can be stored on the on-board device and transmitted to the airport ground processing unit with its current position.

Criteria for selecting a technology are reliability, accuracy, time for providing position, coverage of apron (including roofed and indoor areas), and costs. As with the communication technology, localization and identification need to be fulfilled reliably even at unfavourable weather conditions. Costs for purchase, installation, and operation have to be considered. To reduce purchase costs of the large amount of on-board devices off-the-shelf hardware needs to be available. Applying the communication technology raises the advantage that no additional hardware is needed for localization. Applying available airport infrastructures can also reduce costs.

## 5.3 Databases

Databases for vehicle management on aprons contain the positions of all vehicles and electronic airport maps including the attributes of all objects. The representation of airport maps is similar to those used for aircraft ground navigation. For instance, the Airport Mapping Databases (AMDB) of the Jeppesen Sanderson, Inc, provides maps representing the airport geography as objects based on points, lines, and closed polygons, adding required meta-data as attributes [14].

Databases are as well used in the context of the ground processing unit and provide information about current position of vehicles on apron, because they provide information for terrain, obstacles, etc.

Innovative database concepts show a well founded workflow based data processing of raw as well as pre-processed data that provide the foundation for defining and executing business processes of fleet management. Hence a combined workflow process has to be embedded into the database to overcome the individual influences on data. At present there are no standardized methods for workflow-based database systems that include integration of data and documents, interpretation, execution of work and computer assisted work such as statistics.

## 5.4 Ground Processing Unit

The Ground Processing Unit has a similar task as the SDF (Sensor Data Fusion) of the A-SMGCS. It is collecting time-stamped data from the on-board devices of the cars concerning position, speed, heading and identification. It correlates the collected data with the output of the A-SMGCS data fusion, i.e. the tracks generated by SMR or SMR/Mode-S – if cars are equipped with SSR Mode S Squitter beacons.

The cars are identified by correlating the found tracks with a stored set of pre-registered cars of the airport. By this, additional information becomes available on the individual cars. This additional data can consist of type, colour etc., helping the operator in visual correlation. Further data could be found in the data base that give information on the current mission and future plans for that car, supporting decision support systems in further stages of car management to optimize the resource usage. Cars not found in the database can be extracted for completing the database or for checking their area permission.

The Ground Processing Unit will further act as the car data server for the entire airport. All usage scenarios described in this paper get car data from this server. The A-SMGCS will get the relevant car tracks to process car data in its data fusion. A-SMGCS related applications get their data from the A-SMGCS data fusion, in order to ensure optimal (real time) consistency with aircraft data.

Building such a ground processing unit can at least be based on experiences and principles of A-SMGCS data fusion. Similarities have already been pointed out. Differences are the much higher number of targets compared to A-SMGCS, the lower variety of sensors – especially lack of non-cooperative sensors. Potentially existing A-SMGCS data fusion systems could be tailored to be used for this purpose. Interfaces could use either A-SMGCS standards (Asterix CAT10 / 11 Radar Data Exchange format) or standard non-aviation formats and protocols.

## 6 THE CARMA PROJECT

The CARMA project investigates the possibility to implement a system for car management on aprons for the Hamburg airport based on ideas discussed in this paper. It was started in December 2006 by a consortium that includes the airport (FHG), the German air navigation service provider (DFS), industry (Airbus, Airsys), and research (DLR, University of Hamburg, Hamburg University of Technology, Braunschweig University of Technology).

Main goal is the development of functional models and prototypes, and an on-site evaluation in a real operating environment. For that purpose, technologies for wireless communication, identification, localization, databases, and maps are analysed, selected, and combined into a prototype. The prototype will be demonstrated at Hamburg airport and support fleet management, control workplaces, and driver navigation and alert. The project will be the first that is benefiting from a level 2 A-SMGCS which is installed in parallel and an A-SMGCS test bench also planned in near future. This enables closing the gap from stand alone surveillance and management systems, to systems integrated in a complete airport environment.

## 7 CONCLUSION

In addition to A-SMGCS for ground management of aircrafts and safety critical vehicles, systems for managing ground handling vehicles on the aprons are significant for optimizing fleet management and turn-around processes. Its architecture, proposed by the CARMA project, resembles the architecture of an A-SMGCS only supporting cooperative targets. Cost can be decreased to a level making its installation reasonable by applying suitable, common technologies and off-the-shelf hardware for the large amount of on-board devices and connecting to available A-SMGCS systems.

## 8 ACKNOWLEDGEMENT

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