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TRAFFIC MANAGEMENT SYSTEM ON AIRPORT MANOEUVRING AREAS

ABSTRACT

In the last twenty years the number of flights at the busiest airports in the world has doubled, which, in the meantime has led to a situation in which runways and taxiways (manoeuvring areas) cannot follow such substantial increase. As the result, many airports could not use their capacities in the full range in terms of handling passengers and cargo. As a consequence, there were delays and traffic congestion, fuel was unnecessarily wasted, all of which caused negative impact on the environment. Traffic capacity increase on the ground cannot be considered without the development and implementation of the system infrastructure that would optimize traffic flows and its distribution on the airport itself. In these terms, and for positive solution of these problems, a new system for surveillance and control of aircraft on the airport manoeuvring areas is necessary, one which could be implemented fairly quickly, would be complementary with the existing international standards and would be upgraded to the existing and available technology and infrastructure. With the implementation of the Advanced Surface Monitoring and Control System (A-SMGCS) the aircraft taxiing time could be significantly shortened and could be determined more accurately, which would have positive impact on the flight schedule. The unnecessary aircraft braking actions could be also avoided, and this would reduce the fuel consumption, as well as noise and environmental pollution.

KEY WORDS

traffic management, airport manoeuvering areas, A-SMGCS, upgrading control systems

1. INTRODUCTION

In the last twenty years the number of flight operations at the busiest world airports has doubled, which has, among other things, resulted in the overburdening of the capacities of the runways and taxiways that could not follow such a dramatic increase in traffic. The result was that many airports could not fully use their available capacities for passenger and cargo handling. The consequences of such conditions were the delays, traffic congestions, wasted fuel, and all this accompanied by negative impact on the environment.

According to forecasts, in the next ten years an increase in passenger traffic of 5% annually is expected, and since the construction of new runways and airports requires a certain longer period of time, including planning, design and construction, a process of improved and better usage of the available capacities and resources had to be started both in the air and on the ground.

The increase of traffic capacities on the ground cannot be considered without the development and implementation of infrastructure and the system that would optimize the throughput capacity and operation of such traffic, i. e. its distribution at the very airport. Consequently, and in order to solve the mentioned traffic problems, a new system for control and guidance of aircraft on the manoeuvring areas on the ground is necessary, and one which could be implemented relatively fast, that would be complementary with the existing international standards and would be upgraded to the existing, available technology and infrastructure.

The introduction of a unique system for control on the manoeuvring areas such as A-SMGCS (Advanced Surface Monitoring and Control System), would significantly reduce the aircraft taxiing time and provide more accurate forecasts which would to a great extent have positive impact on the flight schedule. Thus, also constant aircraft braking requirements would be avoided, which would reduce fuel consumption, noise and pollution.

2. STRUCTURE OF THE A-SMGCS SYSTEM

The system named A-SMGCS (Advanced Surface Monitoring/Guidance and Control System) has the basic task to increase the possibilities and capacities of the control of movements of vehicles and aircraft on the manoeuvring areas of the airport, and thus to affect positively the increasing intensity of traffic at airports. The system insures surveillance and clear identification of traffic participants on airport surfaces, increases the overall image on weather circumstances and conditions and features a warning and advisory function in possible crisis events (collision, skidding off, etc.). Optimization of the system has been achieved by the compatibility with the other existing systems at the very airport, so that e. g. the functions of the system for guidance and control receive data from the airport systems in order to be able to determine the ground routes and movement paths of inbound and outbound aircraft. The information is used by air traffic controllers in issuing instructions for aircraft taxiing while preparing for take-off or leaving the runway upon landing.

The entire system A-SMGCS consists of three subsystems: the sensor part, the main processing unit and the system for display, monitoring and control of traffic (the system architecture is presented in Figure 2).

a) Sensors: A network of sensors arranged on the airport manoeuvring areas registers the position of aircraft or other vehicles, either moving or stationary. Apart from the compatibility with the transponders used by aircraft and vehicles, using A/C or S mode the respective identification is also displayed (the monitoring system receives and decodes the signal from the transponder mode A/C, S or signal from system ADS-B), which includes the flight number, type of vehicle or aircraft and company it belongs to. In order to determine the position of aircraft that have no possibility of A/C or S mode, other sensors are used such as the ground monitoring radar SMR (Surface Movement Radar). The system and the network of sensors

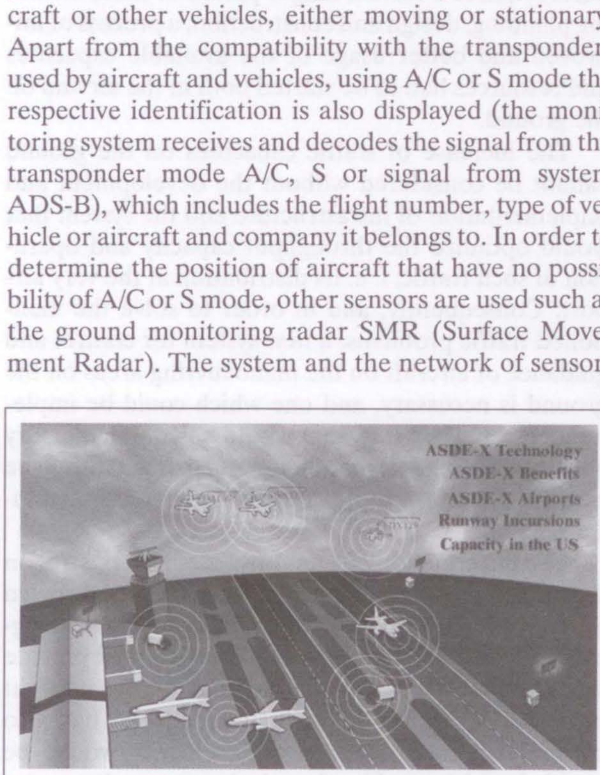

Figure 1 - Global presentation of system operation

allow optimal monitoring of the targets on the ground as well as in the phase of final approach, and insure positive identification thereof. The system includes cooperative sensors that receive data when the vehicles or aircraft use the transponders (Mode A/C or S), and non-cooperative sensors which register the data from the targets that have no respective equipment (SMR and additional sensors that cover the SMR radar shades). Such a concept of the sensor system allows reliable usage of A-SMGCS system in identifying and monitoring of all the targets (with and without the necessary equipment) on the entire area of the airport.

The primary and secondary surveillance radar (ASR, SSR) insure monitoring of the targets and their identification for all aircraft that are within the terminal zone (20 to 200 NM from the airport). Here all aircraft are singled out that are in overflight, i. e. those that are not on approach or departure paths. Within the final approach zone (0 to 20NM), the target monitoring is done also by means of ASR, SSR and the ADS-B system, and the identification of targets is done by means of SSR code which is assigned to each aircraft (squak), flight number or aircraft register code. The system also compares whether it is the same identification code that has been assigned to the adequate aircraft flight number. The control and identification of targets within the airport zone is done by means of a combination of SMR and other cooperative sensors that are arranged at the airport.

Multilateral Surveillance System (MSS) for cooperative targets receives signals emitted by the onboard transponder (mode A/C, S or ADS-B), and determines the position of the source of signals using the triangulation method.

Vehicle identification system consists of the vehicle equipped with ADS-B system which emits at 1090 MHz (the same as in case of aircraft), which reduces the required quantity of ground equipment. Alternative solutions are based on the DGPS and/or on UHF radio-stations.

b) Main processing unit: The main processing unit enables precise location and identification of aircraft or vehicles. The most important part of this unit is the multi-sensor component which stores and processes the collected data, and which has been developed for the military requirements and modified for ground traffic control. Finding of the unique traffic solution has been facilitated because the data on the movement of a single aircraft or vehicle are collected at the same time from several types of different sensors that cover the entire airport area. Also, a possible conflict situation is detected and the warning is automatically activated for the ground traffic controller as well as the function which provides advice on how to proceed in that moment in order to avoid an accident.

The most important functions of central multi-sensor components include:

- combination of data collected via a network of sensors,
- identification of targets,
- guidance and control,
- safety,
- display and HMI
- system management and control.

The combination of data from sensors represents the processing of the input data from the accompanying targets on the ground, and the data processed in this way represent and generate an accurate, precise, unambiguous and updated image of the current situation of traffic on the ground. Not only do the auxiliary sensors reduce the possibility of the system failure, but they also improve the accuracy and precision of path calculation which is of crucial importance for the safe functioning of the system.

The important part of the multi-sensor concept of the A-SMGCS system is the flexibility related to the selection of sensors, which is first of all owing to the software for the combination of sensor data that can be used in different sensor systems. The software packages are used as part of the subsystem of the main

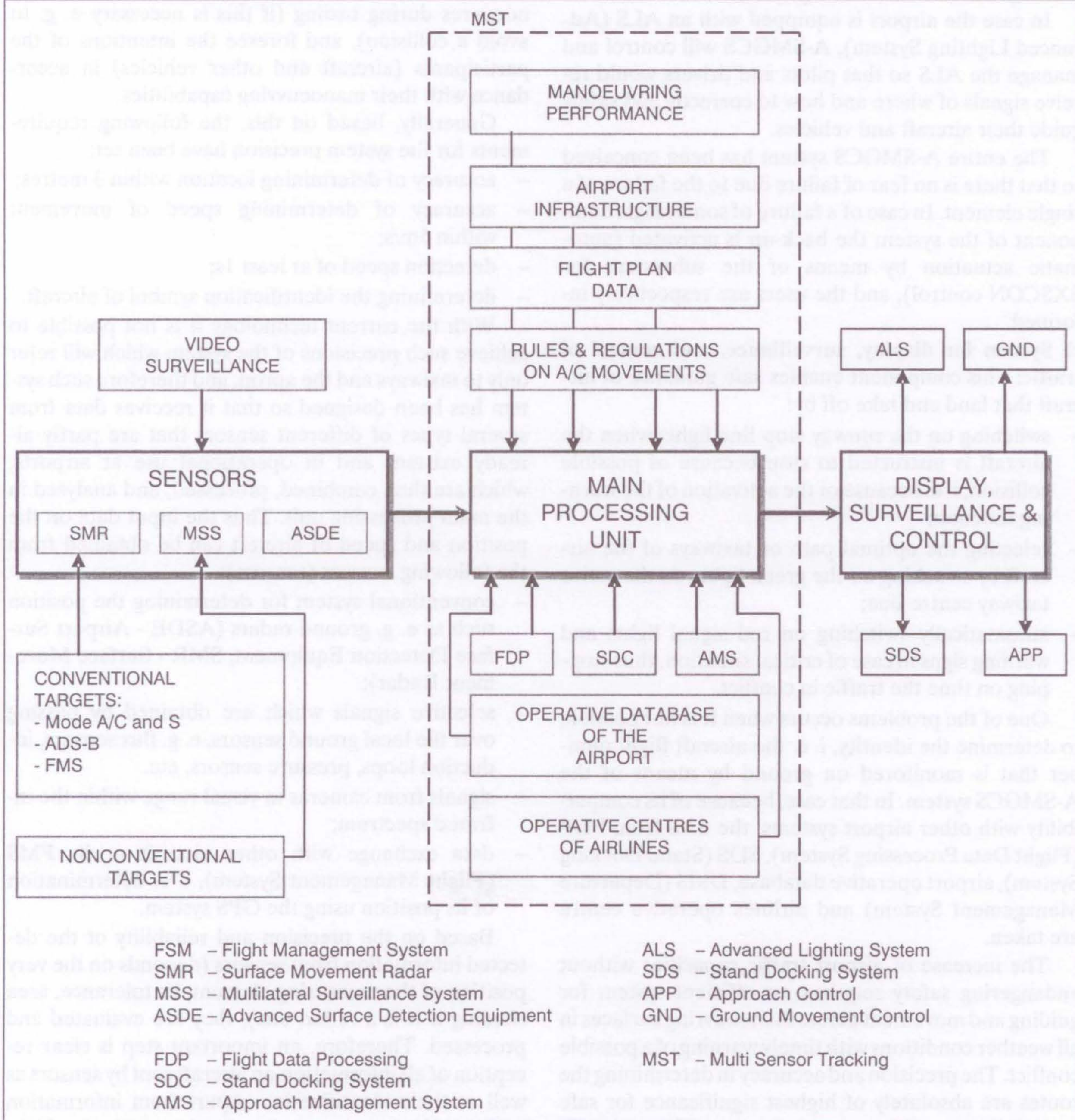

Figure 2 - Architecture of the system

processing unit called AMASS (Airport Movement Area Safety System) and RIMCAS (Runway Incursion Monitoring/Conflict Alert System). The task of these subsystems is to provide pilots, controllers, and airport staff with timely information, overview and real-time evaluation of the situation and guidelines for possible reactions. Both systems monitor the traffic situation on the airport manoeuvring surfaces, which includes aircraft and vehicle movements. The task of the RIMCAS system is the evaluation of the situation on the entire area of the manoeuvring surfaces, whereas the AMASS system estimates the relation between individual traffic participants on a certain segment of manoeuvring surfaces.

In case the airport is equipped with an ALS (Advanced Lighting System), A-SMGCS will control and manage the ALS so that pilots and drivers would receive signals of where and how to correctly and safely guide their aircraft and vehicles.

The entire A-SMGCS system has been conceived so that there is no fear of failure due to the failure of a single element. In case of a failure of some single component of the system the back-up is activated (automatic actuation by means of the subsystem for SXSCON control), and the users are respectively informed.

c) System for display, surveillance, and control of traffic: This component enables safe guidance of aircraft that land and take off by:

- switching on the runway stop line lights when the aircraft is instructed to stop because of possible collision, i. e. because of the activation of the warning function;
- selecting the optimal path or taxiways of the aircraft by switching on the green lights on the active taxiway centre-line;
- automatically switching on red signal lights and warning signs in case of critical situation, thus stopping on time the traffic in conflict.

One of the problems occurs when it is not possible to determine the identity, i. e. the aircraft flight number that is monitored on ground by means of the A-SMGCS system. In that case, because of its compatibility with other airport systems, the data from FDP (Flight Data Processing System), SDS (Stand Docking System), airport operative database, DMS (Departure Management System) and airlines operative centre are taken.

The increase of airport traffic capacities without endangering safety requires an efficient system for guiding and movement across manoeuvring surfaces in all weather conditions with timely warning of a possible conflict. The precision and accuracy in determining the routes are absolutely of highest significance for safe and reliable operation of such a system. The most efficient control of ground traffic can be established only if an integral and precise surveillance and positive identification of the entire ground traffic is established. This is also necessary for the timely alarm and signalization by means of lights on the taxiways and runways.

2. DETERMINING OF THE CURRENT POSITION

Surveillance and monitoring of ground traffic on the airport manoeuvring surfaces requires unambiguous location of aircraft or vehicle moving across them, but this is, however, not sufficient. It is necessary also to estimate the possibility for performing the manoeuvres during taxiing (if this is necessary e. g. to avoid a collision), and foresee the intentions of the participants (aircraft and other vehicles) in accordance with their manoeuvring capabilities.

Generally, based on this, the following requirements for the system precision have been set:

- accuracy of determining location within 3 metres;
- accuracy of determining speed of movement within 5m/s;
- detection speed of at least 1s;
- determining the identification symbol of aircraft.

With the current technology it is not possible to achieve such precisions of the system which will refer only to taxiways and the apron, and therefore such system has been designed so that it receives data from several types of different sensors that are partly already existent and in operational use at airports, which are then combined, processed, and analysed in the main processing unit. Thus the input data on the position and speed of aircraft can be obtained from the following sources (sensors):

- conventional system for determining the position such as e. g. ground radars (ASDE - Airport Surface Detection Equipment, SMR - Surface Movement Radar);
- selective signals which are obtained by passing over the local ground sensors, e. g. flux sensors, induction loops, pressure sensors, etc.
- signals from cameras in visual range within the infrared spectrum;
- data exchange with other aircraft or its FMS (Flight Management System), i. e. determination of its position using the GPS system.

Based on the precision and reliability of the detected information from sensors (depends on the very position of the measuring element, its tolerance, area shading if it is a radar, etc.), they are evaluated and processed. Therefore, an important step is clear reception of all information on aircraft sent by sensors as well as their identification. Apart from information and data from sensors, also the data from the flight plan are processed and analyzed, that is all the other available data on aircraft (so-called Multi Sensor Tracking). In order to locate the position of aircraft on ground, the following data are used:

- in-advance processed and, if necessary, corrected data from the sensors from various sources;
- valid data from the flight plan;
- data on manoeuvring performances of single types of aircraft (e. g. range of permitted speeds in taxiing, data on braking performance, etc.);
- models of airport infrastructure related to manoeuvring capabilities of aircraft;
- restrictions and rules of aircraft movement on manoeuvring surfaces (in general and for a specific airport).

Current position and direction of aircraft movement on manoeuvring surfaces are calculated precisely by using the MST method (Multi Sensor Tracking), whereas the accuracy of these calculations is increased with higher frequency and quality of the received signals from the sensors.

This method not only represents the best possible planned position, but also has high precision and possibility of automatic identification and warning, and information forwarding in case of any deviations from the planned values or the possibility of conflict situation. Since this procedure is not based on a certain type of sensor, the detection done with the already existing sensors may be gradually expanded by the integration of other sensors or locating systems.

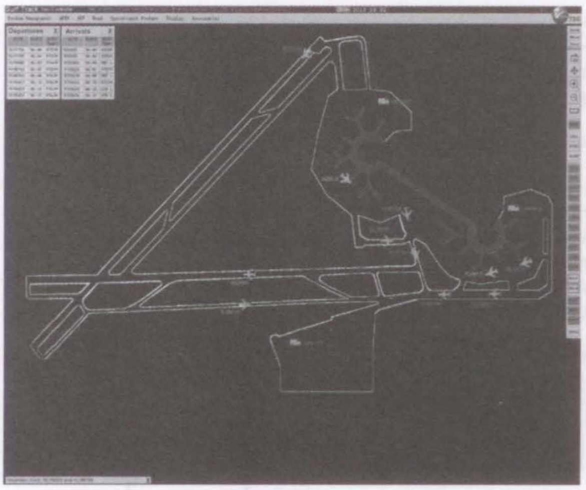

Figure 3 - Display of the entire situation on the runway and airport manoeuvring surfaces

3. RECOGNITION AND MONITORING OF TARGETS

Identification, i. e. recognition of targets that are equipped with adequate equipment (so-called cooperative targets), is achieved by inter-correlation of data from the secondary surveillance radar (SSR) with the data from the aircraft flight plan (obtained via FDP system).

Identification of aircraft that do not have adequate equipment (so-called non-cooperative targets) is done in the following way:

- aircraft in the landing phase are identified during approach to land via data from the flight plan and AMS (Approach Management System);
- aircraft in the take-off phase are identified via a unique aircraft flight number and number of parking positions from which the aircraft has departed (gate).

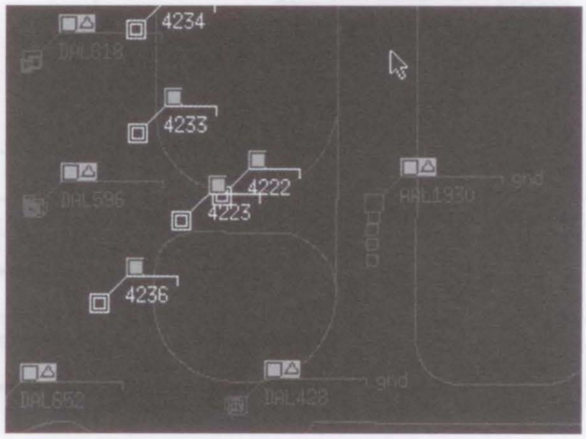

Figure 4 - Display on ground using the A-SMGCS system

While taxiing on the manoeuvring surfaces, the A-SMGCS system forecasts the routes that an aircraft must follow. These routes can be determined in advance or can be dynamically calculated and agreed upon during the very process of taxiing. During the process of determining the best aircraft taxiing route, the system provides constantly information that are an important part of the decision-making process done by the controller who manages the ground traffic. The most suitable route of an aircraft that lands and has the intention of taxiing to the parking place is determined on the basis of several data: current traffic and situation on the ground, position of other aircraft and routes, active runway and final parking place. The system can also assign independently the number of the parking position to the aircraft, depending on its size and number of available places at the terminal.

The safety part of the system provides alerting in case of conflict situations (unauthorized entry onto the runway, crossing of the runway done by aircraft or other vehicle, etc.) which is done via ALS system and the controller's warning (Figure 5). Conflict situation on the taxiway/runway is defined as any situation at the airport which includes an aircraft, vehicle or some other object, and where there is the possible danger of collision or loss of spacing between the aircraft that take off, land or have intention to land. The routing defined by latitude, longitude, altitude and time insures high-quality and reliable information on the position and planned position of aircraft at every moment. In case of diverting from this route, the controller and the aircraft crew have to be informed immediately.

The primary aim of such a system is to provide sufficient time for the required reaction of the pilot (directly or indirectly through the controller on the ground), and to give better overview of the entire situation and the environment. This is precisely what occurs in the main processing unit of the system (subsystems AMASS and RIMCAS) so that every second the obtained data are processed and analyzed and then simulate the situations on the ground so that the potentially hazardous situations could be identified. The data collected and processed by the mentioned subsys-

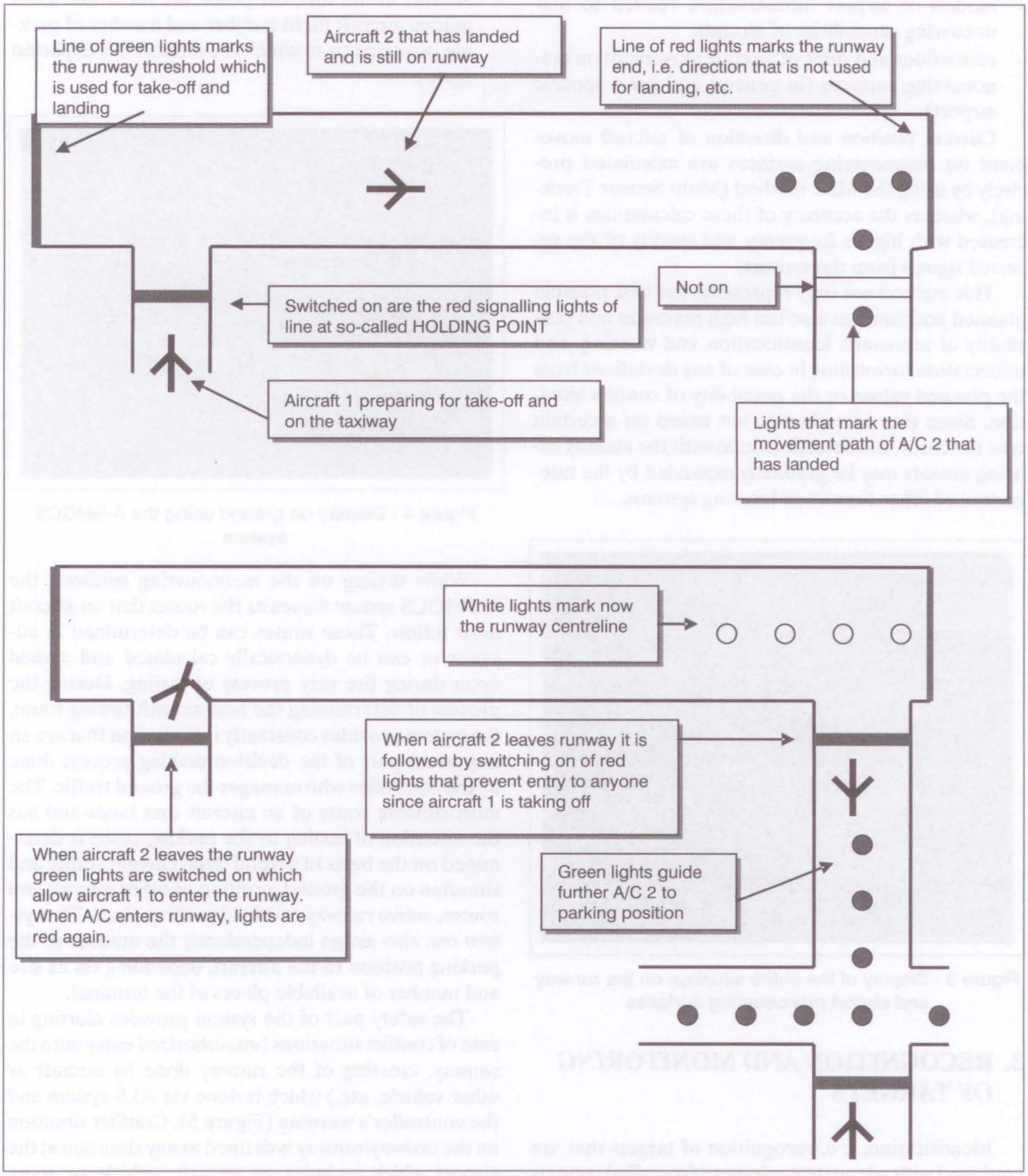

Figure 5 - The operation of A-SMGCS via ALS system

tems contain various information from the geometry of the taxiways and runways to current configuration and the condition at the airport.

The data on targets (aircraft and vehicles on the manoeuvring surfaces) are received every second from a wide spectrum of various sensors so that constant monitoring and insight into the situation may be maintained. The data and information about every aircraft or vehicle are compared to the manoeuvring surfaces chart in order to determine their position and direction of movement.

The critical elements in the estimate of the situation safety on the manoeuvring surfaces is the state of movement of the aircraft (taking off, taxiing, standing, landing, coming from the parking place, interrupted take-off, etc.). Knowing thus the position of targets, their operative condition and airport configuration, it is possible to constantly interactively check each target individually and in relation to other targets in order to insure that the safety protocols are not being violated. Violation of safety protocols may be the cause of various parameters such as e. g. stopping time, maintaining the spacing (physical or time-related). These parameters may be different at different airports and on different runways or taxiways, and they change depending on the operational status, which the system naturally takes into consideration in the calculation.

CONCLUSION

The increased number of delays, restrictions in traffic capacity, workload of air traffic controller and pilot, high costs and indicators of unstoppable growth of air traffic represent clear signs of the need for change. Various improvements and additional upgrading of the existing air traffic control system will not substantially increase the capacities i. e. reduce the current costs of air traffic control system.

The existing problems require revolutionary solutions that will lead to more efficient and more independent air traffic management system, which is precisely the vision of ICAO CNS/ATM system. Certainly the transition to such new concept cannot be realized overnight but must rather be based on the development and gradual operationalization of new technologies and technical solutions that fulfil all the conditions of the future CNS/ATM. The implementation and standardization of the system of aircraft guidance on ground on the manoeuvring surfaces will reduce the time necessary for this process which results in great losses both in time (delay, congestion), and in fuel (increase in costs, losses, environmental pollution, noise). Also, such system would facilitate the managing and orientation of pilots during taxiing, even in case of reduced visibility under category CAT II/III. Very important benefit of such a system lies in its possibility, apart from improving the safety on taxiways to distribute in a better and more efficient way the loads and capacities of the taxiways, and to identify and warn on time of the possibility of collision or some other conflict situation.

Apart from all mentioned, the system recognizes the possibilities and performances of aircraft, so that it can forecast on time, with high accuracy, whether an aircraft would be able to stop on time or not, which additionally increases the reliability of the system and raises the safety to a higher level.

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SAŽETAK

SUSTAV REGULACIJE PROMETA NA MANEVARSKIM POVRŠINAMA AERODROMA

U posljednjih dvadesetak godina broj letova na najprometnijim svjetskim aerodromima se udvostručio što je, između ostalog, dovelo do toga da uzletno-sletne staze i staze za voženje svojim kapacitetima nisu mogle pratiti takav dramatičan porast prometa. Rezultat toga bio je da mnogi aerodromi nisu mogli u potpunosti iskoristiti svoje raspoložive kapacitete u prihvatu i otpremi putnika i roba. Kao posljedica takvog stanja javila su se kašnjenja, stvarale gužve na terminalima, nepotrebno trošilo gorivo, a sve to imalo je i negativan odraz na okoliš. Povećanje prometnih kapaciteta na zemlji ne može biti razmatrano bez razvoja i implementacije infrastrukture i sustava koji bi optimizirali protok i odvijanje takvog prometa, odnosno njegovu distribuciju na samom aerodromu. Na tragu toga, a za rješavanje navedenih prometnih problema, potreban je novi sustav za nadzor i vođene zrakoplova na manevarskim površinama na zemlji, a čija bi se implementacija mogla provesti relativno brzo, koji bi bio komplementaran sa postojećim međunarodnim standardima, te bi se nadograđivao na postojeću raspoloživu tehnologiju i infrastrukturu. S uvođenjem jedinstvenog sustava za vođenje po manevarskim površinama poput A-SMGCS (Advanced Surface Monitoring and Control System), vrijeme taksiranja zrakoplova bi se značajno smanjilo i moglo bi se točnije predvidjeti što bi u velikoj mjeri pozitivno utjecalo na red letenja. Također bi se izbjegla potreba za neprestanom nepotrebnim kočenjem zrakoplova, što bi smanjilo potrošnju goriva, buku i zagađenje.

KLJUČNE RIJEČI

upravljanje prometom, aerodromske manevarske površine, A-SMGCS, unaprjeđenje sustava kontrole

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