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INTEGRATED SYSTEM OF TRANSPORT MANAGEMENT

Summary. Advancing process of transport market deregulation is a phenomenon which can be observed in recent years. At the same time the scope of available abilities of computerized traffic and transport management systems is widening as well as abilities of positioning transport entities and systems of telecommunication connecting transport components and subsystems. The paper presents some elements of SESAR conception and the authors own ideas about future systems of transport entities management (chiefly aircraft) as well as management of the whole transport system (for the most part air transport) in uniform European area in years 2020-2030.

ZINTEGROWANY SYSTEM ZARZĄDZANIA TRANSPORTEM

Streszczenie. W ostatnich latach obserwujemy postępujący proces deregulacji rynku transportowego. Jednocześnie rozszerza się zakres dostępnych możliwości komputerowych systemów zarządzania ruchem i transportem, systemów pozycjonowania jednostek transportowych, systemów teletransmisyjnych łączących elementy i podsystemy transportowe. W niniejszym opracowaniu zawarte są niektóre elementy koncepcji SESAR i własne przemyślenia autorów na temat przyszłych systemów zarządzania ruchem jednostek transportowych (głównie statków powietrznych) i zarządzania całym systemem transportu (głównie transportu lotniczego) w jednolitej europejskiej przestrzeni w latach 2020-2030.

1. FLEXIBLE USE OF AIRSPACE

The principles of air traffic organization in Poland and in the world are recently evolutionally changing. Rapid development of aviation in the middle of the eighties resulted in emerging of worldwide traffic capacity crisis as well as crisis of air traffic control. Because of increased volume of traffic and requirements of air transport economy, it was necessary to undertake task of developing and implementing Flexible Use of Airspace Concept (FUA). In 1990 European Civil Aviation Conference (ECAC) adopted Area Strategy aimed at harmonization of the European systems of air traffic control and subsequently – by the first years of XXI century – their integration. European Air Traffic Control Harmonization and Integration Program (EATCHIP) was developed and accepted for realization of the strategy objectives.

The EATCHIP program had four main objectives:

- increasing air traffic safety,
- better (more effective) use of European airspace and airspace of respective states,
- better quality of air traffic services,

- decreasing costs of service and infrastructure maintenance.

As a result a European version of FUA concept was developed. This concept is based on the following principles:

- airspace should be perceived as a common national asset and allocated according to users needs,
- airspace should never be allocated to only one user,
- any necessary segregation of airspace can only be temporary and based on time of it's actual usage.

Realization of the FUA concept resulted in reorganization of polish airspace, which means introducing new classification and new structures. Airspace classification determines flight regulations and services responsible for air traffic safety. New, flexible structures of airspace make possible it's effective use by all participants.

In accordance with the FUA concept, a three levels system of airspace management (ASM) was implemented in Poland. First level – ASM1 is the level of strategic management aimed at shaping ASM policy. Second level – ASM2 is the level of before-tactic management aimed at developing plans of airspace exploitation. Demands of respective users are collected, analyzed and correlated with parameters of estimated volume of air traffic. Third level – ASM3 is the level of tactic management aimed at realization of a plan of airspace usage.

Recent implementation in Poland of CAT ASM-3 application and planned implementation of respective procedures as well as initiating application CAT ASM-2 (2007/8) would lead to availability of all information about current usage of airspace elements. The process, realized in whole Europe, should result in increasing capacity of air traffic control sectors and elimination of collision situations, thereby increasing air transport safety.

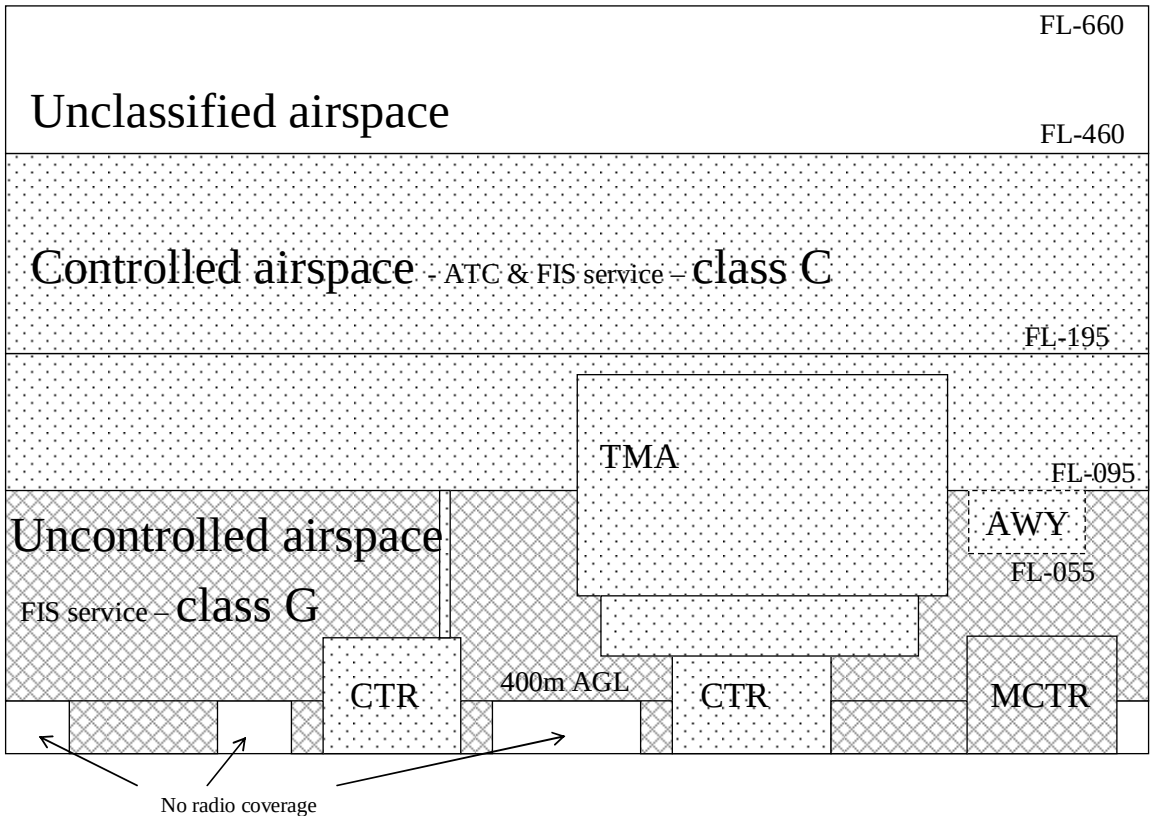

Fig. 1. Previous organization scheme of Polish airspace
Rys. 1. Dotychczasowy schemat organizacji polskiej przestrzeni powietrznej

The flexible use of airspace (FUA) implementation in Poland amounts to principal change in air traffic organization. Flexible airspace structures enable it's exploitation by various users. In consequence new principles of air traffic control were created – without fixed network of air routes. New possibilities of scheduling aircraft stream in time and space emerged. Allocation of flight trajectory outside air route also became possible. Such trajectory must be verified against possibility of collision with active elements in airspace in given time. Of course, verification against possibility of collision between aircraft flight paths is also necessary. It is now the principal problem of implementation of FUA concept.

The flexible use of airspace concept (FUA) is now realized in two versions: American and European. American version is based on concept of Free Flight Program (FFP). The concept assumes free and to-destination flights as well as management of air traffic in airspace controlled jointly by air traffic control services and users of airspace – air carriers.

The European version of FUA envisages implementation of Free Routes Airspace Project (FRAP). The concept assumes that users of airspace can design, without constraints, flight paths from point to point outside air routes network. The task of ensuring separation during flight would be realized by air traffic controlling services. To this end European Civil Aviation Conference (ECAC) adopted in 1990 Area Strategy, aimed mainly at harmonization of the European systems of air traffic control and their subsequent integration. For the sake of realization of this strategy European Air Traffic Control Harmonization and Integration Program (EATCHIP) was developed and approved.

2. NEW GENERATION OF EUROPEAN SYSTEMS OF AIR TRAFFIC AND TRANSPORT MANAGEMENT

The experiences accumulated so far during functioning of the FUA concept in Europe, resulted in starting work on prospective concept of European Airspace management. The first step along this path was adopting Single European Sky (SES) concept, which legal base was approved by the European Commission on 10th of March 2004 (end of legislation process). The next step consisted of undertaking research on Future Air Traffic Management (ATM) in SES airspace – Single European Sky ATM Research (SESAR).

The objective of the SESAR program is modernization of air traffic in Europe by means of **new generation European ATM system**. Future European ATM system must, among others, be able to safely serve increasing number of flights and meet requirements of the airspace users concerning costs and effectiveness. The SESAR program can be described as technological component of SES conception.

The SESAR program is realized in three subsequent phases:

- Defining phase (carried out since November 2005; completion is planned in 2008) – which is realized by the SESAR consortium. This phase encompasses analysis of current situation on air transport market and outlining of modernization plan of the ATM system in Europe (proposal of it's final shape for 2020) as well as conditions which such a system must meet.
- Development phase (2008-2013) – realized by the enterprise SESAR Joint Undertaking. This phase will be devoted to development of existing and creating new technologies, which are the foundations of new generation ATM system.
- Deployment phase (2014-2020) – would be realized probably by the SESAR Joint Undertaking or specific private companies. This phase will be devoted to installing new systems (worked out in development phase), which would ensure functioning of the new generation ATM system. The principles of functioning of this system would also be implemented.

The first phase of the SESAR program is envisaged as theoretical base as well as action plan for modernization of existing and development of the new ATM systems in Europe. Recapitulation of this phase should be so-called "ATM Master Plan", which will present coordinated actions up to 2020 and ways of their practical realization. Defining phase is financed by the European Commission in TEN-T framework program (Trans-European Network-Transport) and Eurocontrol. The **SESAR consortium** was set up for carrying out defining phase. Among it's members are 29 companies and organizations

and over 20 branch partners. For the first time in history of air traffic management in Europe, main participants of European air transport were assembled together for creating common new generation ATM system. Members of the consortium were divided, according to their activity and interests, into following groups:

- Airspace Users – representatives of air carriers, general aviation and organizations representing their interests,
- Air Navigation Service Providers,
- Airports,
- Professional Associations,
- Research Centers,
- Military, represented by EURAMID,
- Supply Industry Group.

Additionally, for the sake of ensuring interoperability with solutions implemented in USA, Supply Industry Group was enlarged by incorporating such firms as: Boeing, Honeywell and Rockwell Collins. Informal member of the group is also Eurocontrol, which performs advisory functions and approves final documents of every stage of defining phase. Unfortunately, there is no Polish representative in the consortium.

The defining phase was divided into six stages (deliverables). Every stage ends with final report prepared by the SESAR consortium (milestone deliverable), which recapitulates work done in given stage. After Eurocontrol approving, a document with opinion of the SESAR consortium is presented on stakeholder forum. On this forum respective firms and organizations present their remarks and propose changes. Open discussion follows.

The names and subjects of respective stages (deliverables) of the SESAR program defining phase are as follows:

D1: Air Transport Framework – The Current Situation – ended 6th of July 2006. Subjects: characteristics of present air transport market and analysis of it's needs.

D2: Air Transport Framework – The Performance Target – ended 22nd of December 2006. The final report presented demands of air transport market concerning new generation ATM system, formulated conditions of program success and outlined vision of air transport after 2020.

D3: ATM Target Concept – ended 27th of September 2007. The final report included description of functioning new generation ATM system in Europe (after 2020) as well as it's architecture and technologies. The document described also crucial solutions and technologies and included analysis of costs and profits of proposed ATM concept.

D4: ATM Deployment sequence - provisional completion date – February 2008. This stage would be devoted to selection of best scenario of new ATM system implementation. Final document would include guidelines of constructing new European system of air transport management (ways of implementing of respective solutions).

D5: ATM Master Plan – provisional completion date - May 2008. Final document would include coordinated action plan until 2020 aimed at creating future ATM system in Europe and ways of it's practical realization. The document would also include tasks, which should be fulfilled by participants in order to achieve planned benefits and conditions designated in D2. ATM Master Plan (final document of this phase) would be a plan of action up to 2020 and would include implementation plans for the near future as well as research and development plans for more distant future.

D6: Work Program for 2008-2013 would be a plan of action for 2008-2013. This stage would be a transition to development phase of SESAR program.

The final six documents of respective stages are defined as milestones because all of them would completely describe all aspects of future European ATM system.

3. REQUIREMENTS OF FUTURE ATM SYSTEM IN EUROPE (2020)

The document **D2: Air Transport Framework – The Performance Target** in the SESAR program presents 11 Key Performance Areas (**KPA**). Their present (2005) as well as final values, which the new generation ATM system must meet, were designated. They are as follows:

- Cost Effectiveness,
- Capacity,
- Efficiency,
- Flexibility,
- Predictability,
- Safety,
- Security,
- Environmental Sustainability,
- Accessibility and Equity,
- Participation,
- Interoperability.

Detailed description of every KPA can be found in D2 SESAR report. The goals of four most important KPA for future ATM system can be described as follows:

- Capacity: in 2020 the ATM system must be able to safely and effectively serve air traffic volume increased by 73 % in comparison to 2005. It must also enable three-fold increase of the volume after 2020.
- Safety: increased three-fold before 2020 and ten-fold in following years.
- Environmental Sustainability: decreasing by 10% negative influence on environment (on flight) because of the ATM.
- Cost Effectiveness: decreasing by 50% per flight direct operational costs of the ATM system.

Evaluating general vision of the new generation ATM system, one can single out it's novelty in terms of:

- introducing efficiency,
- introducing so-called Business Trajectory, which will be one of pivotal elements of the future ATM system.

4. BUSINESS TRAJECTORY

The Business Trajectory is a 4D trajectory (containing position in 3 dimensions plus time) representing a user interests with possibility of occurring certain limitations. Such trajectory can be fixed by ground or air-based operational segment. The business trajectory can appear in following appearances:

- **Business Development Trajectory (BDT) -** implemented by a user of airspace for planning and not intended for exploitation outside user enterprise.
- **Shared Business Trajectory (SBT) –** published business trajectory, which is available for joint planning in the ATM framework. SBT can contain limitations, which user should take into account in business calculations. This trajectory would present a plan of best flight efficiency, assuming that there is no other air traffic in vicinity.
- **Reference Business Trajectory (RBT) –** is a trajectory which the user accepted for flight and which ANSP approved for realization (with separation taken into account). RBT would contain all possible limitations and would be used as reference by all ATM participants during flight. RBT can contain four parts:
  - performed part (RBTX) – corresponding to part of trajectory already covered by an aircraft,
  - current position (CP) – position of aircraft in three dimensions in given time,
  - authorized part (RBTA) – corresponding to segments of trajectory (with ground segments), which were approved by ANSP,
  - planned part (RBTP) – segments from the end of authorized part to the end of trajectory.

5. TARGET CONCEPT OF EUROPEAN ATM SYSTEM (SESAR)

In the SESAR D3 report "The ATM Target Concept" final conception of ATM system in Europe after 2020 was proposed . The report contains structure of the system, outline of used technologies, analysis of costs and defines which projects, presently realized in Europe, can support the final ATM conception. The principal assumptions of ATM Target Concept can be summed up as follows:

- the concept is based on so-called 4D trajectories (positions in 3 dimensions plus time), which will define present and future position of an aircraft,
- the concept is flexible and can be adjusted to local needs, taking into account their evolution during realization of the SESAR program,
- the concept is relevant to all operations performed by users of airspace (air carriers, military, general aviation (GA), business aviation (BA), non-pilot aircraft (UAV/UAS),
- functioning is based on Network-Centric Operations (NCO),
- the system must be inter-operational with international solutions (ICAO doc 9854) as well as local (e.g. NGATS/NextGen in USA).

The ATM Target Concept contains only general outline of future system and guidelines of steps to be taken. Some of actions and solutions presented are only in developing phase (more or less advanced). One can single out some principal elements of proposed functioning concept of the SESAR program.

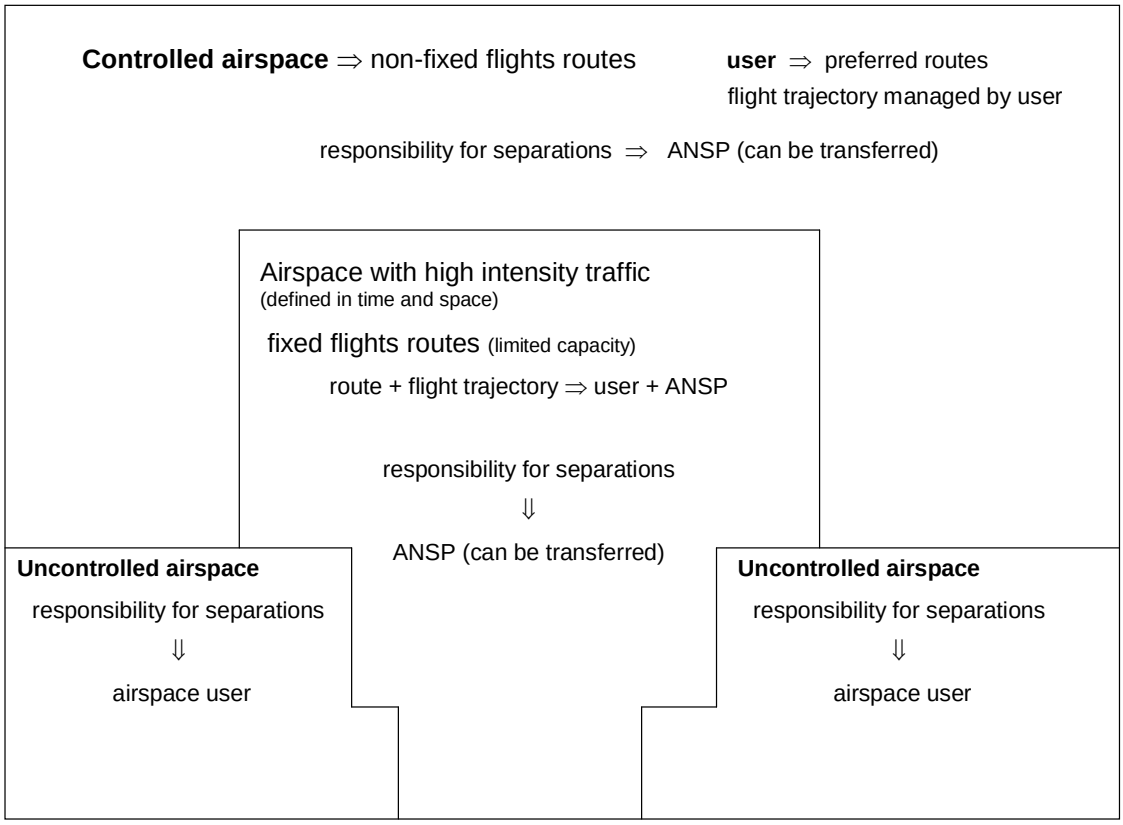

Fig. 2. Target concept of European airspace (according to the SESAR and the authors own deliberations), ANSP – Air Navigation Service Provider

Rys. 2. Docelowa struktura europejskiej przestrzeni powietrznej (według SESAR i własnych przemyśleń autorów) ANSP – dostawca usług żeglugi powietrznej

Business trajectories – the concept envisages business trajectories as one of foundations of the whole system with assumption that every flight is to the highest degree conform with intention of it's executor (organizer):

- the ATM services should ensure that flight is carried out safely and economically, taking into account infrastructure limitations and weather conditions,
- modifications in business trajectories are as insignificant as possible thanks to Collaborative Decision Making (CDM) mechanism with exception of urgent situations,
- business trajectories would be designated in 4 dimensions (position and time) and flight along them would be carried out with greater precision than today.

Trajectory management – new approach to designing and managing airspace was defined – the emphasis was changed from airspace to aircraft flight trajectory:

- users of airspace would fly along preferred routes without necessity of using pre-defined routes,
- fixed (multi segments) flight routes would be activated only in situations demanding sustaining of given capacity (e.g. in crowded TMA),
- interests of the military would be ensured, for example by Advanced Flexible Use of Airspace (AFUA),
- it was agreed that segregation (division) of airspace is not necessary,
- introducing only 2 categories of airspace: supervised space (separation ensured by ANSP, but in certain situations can be transferred to aircraft crew) and unsupervised space (aircraft crew is responsible for ensuring separation) – fig. 2.

Joint planning systematically reflected in Network Operation Plan (NOP):

- Joint multi-layered planning undertaken on inter-regional and European level would be included in NOP and will ensure that capacity would conform to demand with limitations taken into account,
- would enable efficient management of queues ensuring best possible access to limited resources,
- would diminish number of flights in attendance zone and queues on the ground,
- would enable defining priorities by airspace users in case of insufficient capacity.

Integrating of airport operations – would facilitate obtaining additional capacity and decreasing of harmful influence on environment:

- full integration of an airport operations with process of managing flight trajectory (airports would be integral part of ATM),
- improvement of planning process of airports assets (would increase coordination between various subjects interested),
- increased capacity and reduction of environmental impact (for example by "turnaround management", decreasing impact of limited visibility conditions etc.).

Making available new methods of separation for the sake of increasing capacity:

- new methods of separation (gradually implemented) would use trajectory control and airborne systems of separation for minimizing potential conflicts and controllers intervention,
- supporting controllers and crew by means of suitable tools.

System Wide Information Management (SWIM) – extensive system of information management enabling integration of all ATM data:

- SWIM environment, taking into account all aspects of the ATM (for example aircraft and on ground facilities), would enclose the whole future ATM system into one identity,
- would support the CDM process using effective applications for end users, which would enable taking advantage of joint, updated information.

People would be in the center of the future European ATM system, managing and taking decisions:

- for servicing expected volume of air traffic, an advanced supporting automation would be needed,
- people's role and assignments would inevitably change.

Summing up concepts proposed in the SESAR program, one can say that:

- principal purpose of proposed organization is to support working concept of the new generation ATM system,
- the concept should be flexible and adaptable according to changing air traffic, requirements regarding efficiency and various local conditions,

- the concept should take advantage of existing development and research projects,
- proposed solutions should enable the SWIM implementation, which would be one of crucial elements of the future European ATM system,
- the concept would be modular in character and would take advantage of new approach to system development.

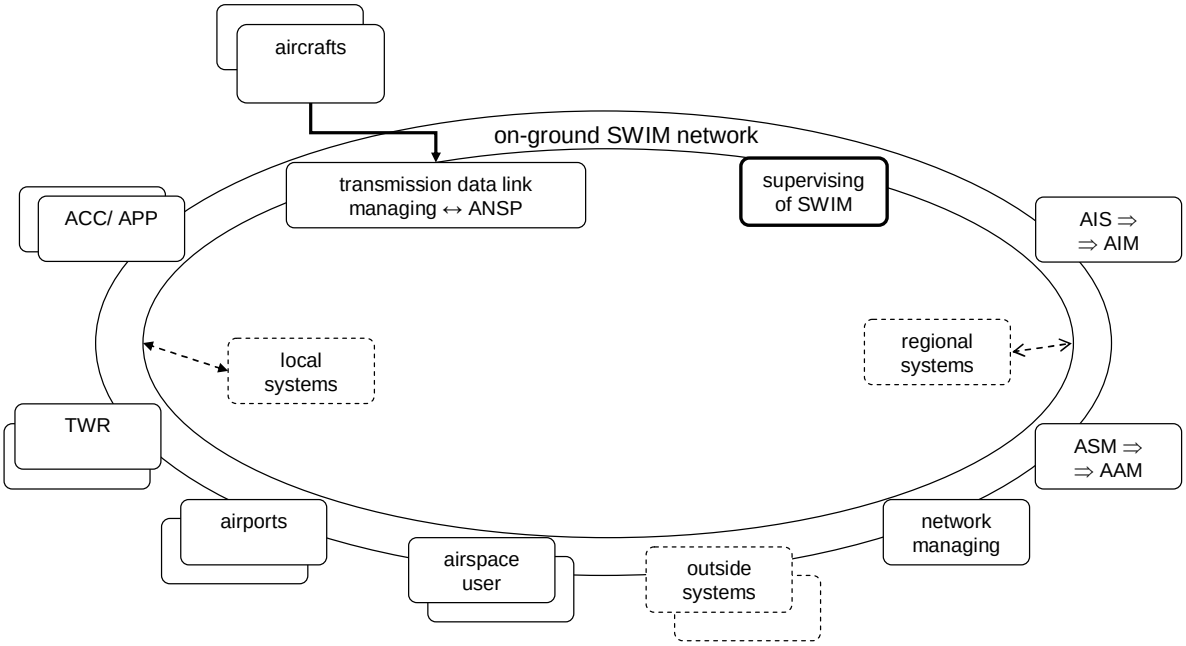

Fig. 3. Functional view on structure of the new generation ATM system concept
Rys. 3. Funkcjonalne spojrzenie na architekturę koncepcji systemu ATM nowej generacji

6. TECHNOLOGIES OF FUTURE SYSTEMS OF AIR TRANSPORT MANAGEMENT

Communication systems would be based on integrated network services for all ATM subsystems. Data transmission, supported by new on-ground and satellite transmission links, would be of crucial importance.

Navigation systems – would be based on satellite technology (GNSS with inertial navigation systems IRS) connected with on-ground systems (DME/DME, TACAN, ILS/MLS) as a reserve.

Supervising air traffic systems – introducing new solutions (for example ADS-B, WAM) would enable transmitting better information about 4-dimentional flight trajectory (position and time) and implementation new methods of aircraft separation. Removal of primary radar systems (PRS) is not envisaged. In the future multi state primary radar systems (MPRS) composed of at least 3 elements (for example 2 receivers and transmitter deployed in different locations) will be used.

The impact of now realized programs on target concept of ATM system is considerable. One cannot ignore now realized in Europe ECAC ATM2000+ strategy. Full interoperability of all initiatives, actually realized in Europe, is indispensable if they are to be reliable foundation of the ATM target concept.

7. SUMMARY

New concepts of final system of air transport management are generally approved by professionals. The target concept of ATM system presented in the SESAR D3 report was met with strong emotions, specially among professional controllers associations (ATC EUC, IFATCA) and some ANSP. Most important subjects of controversies were: people's position in new generation ATM system, methods of relaying responsibility for separation on an aircraft and generally the whole new concept of ATM. It was also underscored that the concept was too generally presented, function of the meteorological services was outlined not clear enough and that the users of airspace are not equally treated.

One of the main assumptions of the ATM target concept should be flexibility and possibility of adapting to local demands, taking into account their evolution during realization of the SESAR program. So far there are no ideas of solving this problem. One can have impression that target concept deals mainly with subjects in the area of greatest intensity of air traffic in Europe (so-called "Core Area"). The lack of direct Polish representative in the SESAR consortium is also worrying (now this role performs German DFS).

Introducing new interoperable ATM system for Europe is in longer perspective necessary. Despite fairly efficient realization of respective phases of creating the target conception of an air transport management in Europe, realization of all phases of the SESAR program by 2020 is doubtful. The process of implementing new solutions and technologies and pure political decisions of respective European states could be main obstacles.

Bibliography

1. *ASM-FUA Flexible Use of Airspace*. Luxembourg, Eurocontrol IANS, 2007.
2. *ASM-ASM Airspace Management*. Luxembourg, Eurocontrol IANS, 2007.
3. *CFMU Handbook*. Brussels, CFMU Eurocontrol, 2006.
4. Malarski M. *Engineering of air traffic*. OWPW, Warszawa, 2006.
5. Malarski M., Sadowski P.: *Zarządzanie przestrzenią powietrzną – poziomy ASM1 and ASM2*. X International Conference "Computerized systems aiding science, industry and transport". Zakopane, 2006, p. 251-256.
6. *SESAR – Reports D1,D2,D3,D4*. Eurocontrol 2008.

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