AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

UDC 656.7.052(045)

Volodymyr Kharchenko[1]
Yuriy Chynchenko[2]

INTEGRATED SAFETY MANAGEMENT SYSTEM IN AIR TRAFFIC SERVICES

National Aviation University
Kosmonavta Komarova avenue 1, 03680, Kyiv, Ukraine
E-mails: [1]kharch@nau.edu.ua; [2]chynchenko@gmail.com

Abstract. *The article deals with the analysis of the researches conducted in the field of safety management systems. Safety management system framework, methods and tools for safety analysis in Air Traffic Control have been reviewed. Principles of development of Integrated safety management system in Air Traffic Services have been proposed.*

Keywords: Air Traffic Flow and Capacity Management; assessment of hazards and risks in Air Traffic Control; Integrated Safety Management System in Air Traffic Services; safety management systems; safety of flights.

1. Introduction

While the elimination of aircraft accidents and/or serious incidents remains the ultimate goal, it is recognized that the aviation system cannot be completely free of hazards and associated risks. Human activities or human-built systems cannot be guaranteed to be absolutely free from operational errors and their consequences [2]. Therefore, safety is a dynamic characteristic of the aviation system, whereby safety risks must be continuously mitigated. As long as safety risks are kept under an appropriate level of control, a system as open and dynamic as aviation can still be managed to maintain the appropriate balance between production and protection.

A safety culture [2] encompasses the commonly held perceptions and beliefs of an organization's members pertaining to the public's safety and can be a determinant of the behaviour of the members. A healthy safety culture relies on a high degree of trust and respect between personnel and management and must therefore be created and supported at the senior management level.

Safety risk management [2] encompasses the assessment and mitigation of safety risks. The objective of safety risk management is to assess the risks associated with identified hazards and develop and implement effective and appropriate mitigations. Safety risk management is therefore a key component of the safety management process at both the State and product/service provider level.

An Safety management system (SMS) [2] is a system to assure the safe operation of aircraft through effective management of safety risk. This system is designed to continuously improve safety by identifying hazards, collecting and analysing data and continuously assessing safety risks. The SMS seeks to proactively contain or mitigate risks before they result in aviation accidents and incidents.

The SMS framework includes four components representing the minimum requirements for SMS implementation [2]:

– safety policy and objectives;
– safety risk management;
– safety assurance;
– safety promotion.

Integrated SMS in Air Traffic Services (ATS) includes above mentioned general requirements to SMS and also deals with such complex tasks as [4, 5, 6]:

– assessment of flight safety level, threats and hazards in different airspace structures (aerodrome traffic, Terminal Control Areas (TMA) and control areas);

– estimation/optimisation of air traffic flows parameters in terminal control areas and control areas;

– improvement of airspace structures/route network based on results of assessment of flight safety level and estimation of air traffic flows parameters.

These tasks are solved by specific modules of Integrated SMS in ATS, which are considered further in this article.

2. Methods and tools for safety analysis in Air Traffic Control

Assessment of flight safety level, threats and hazards is a complex problem and covers a wide spectrum of activities, so large variety of tools is needed. The methods and tools are organized into seven classes.

This classification is based on the function of the tool, but other means of classification could be adopted, and many tools could have been placed in more than one class, as they perform multiple functions [3]:

1. Safety Event Data Systems. These tools are designed to collect, manage and/or analyse data on events that imply a compromise of the margin of safety desired in air traffic management. Such tools might be used to retrieve data on a single event, or on a collection of events.

Examples of these tools/systems are:

– Automatic Safety Monitoring Tool (ASMT, Eurocontrol);

– Tool Kit for ATM Occurrence Investigation (TOKAI, Eurocontrol);

– Civil Aviation Daily Occurrence Reporting System (CADORS, Transport Canada);

– Mandatory Occurrence Reporting Scheme (MORS, UK CAA).

Also shall be mentioned European Co-Ordination Centre for Aviation Incident Reporting Systems (ECCAIRS), is a European Union initiative to harmonize the reporting of aviation occurrences by Member States so that so that the Member States can pool and share data on a peer-to-peer basis.

2. Air Traffic Replay and Non-interactive Simulation. Tools for real-time (or fast-time) replay or static display of recorded aircraft tracks and/or air traffic controller actions for the purpose of helping an analyst determine how an actual or hypothetical event, or series of events, might have occurred. These tools also include under various traffic loads, routings, procedures, etc.

Examples of these tools/systems are:

– Future ATM Concepts Evaluation Tool (FACET, NASA);

– Reorganized ATC Mathematical Simulator (RAMS Plus);

– Replay Interface for TCAS Alerts (RITA, Eurocontrol);

– GRaphical Airspace Design Environment (GRADE, USA).

3. Human Interactive Simulation Tools and Facilities are real-time simulation tools for involving one or more humans acting as air traffic control specialists and possibly as aircraft pilots. These are useful in studying human factors relating to actual or hypothetical events. They could also be used to evaluate proposed changes in equipment, operating rules, procedures, etc.

Examples of these tools/systems are:

– Controlled Airspace Synthetic Environment (CASE, Alenia Marconi Systems);

– FAA Center for Aviation Simulation, The NLR Air Traffic Control Research Simulator (NARSIM, Netherlands).

Also shall be mentioned EUROCONTROL Simulation Capability Platform for Experimentation (ESCAPE), which is the biggest ATC real-time simulator in Europe used for R&D, training, and various studies.

4. Risk Analysis. Those tools have a place in getting some sample data. But to estimate risk one would have to resort to a risk analysis tool that could simulate many replications of a risk scenario in order to get an estimate of what the probability of a failure might be. These tools estimate risk associated with a specified event, procedure, or action.

Examples of these tools/systems are:

– Traffic Organization and Perturbation AnalyZer (TOPAZ, Netherlands);

– Quantitative Risk Assessment System (QRAS, The University of Maryland).

5. Human Factors Analysis refers to the study of human performance (e.g., cognitive, perceptual, physiological, motor) and the human-machine interface. This includes tools for investigating, estimating, or predicting human error, capacity, capability, and task loads under various situations.

Examples of these tools/systems are:

– Human Error Reduction in ATM (HERA, Eurocontrol);

– Technique for Human Error Rate Prediction (THERP);

– TRACEr lite (Eurocontrol).

6. Text/Data Mining and Data Visualization. Text mining tools are designed to automatically extract structured information from text. Data mining tools process large volumes of structured data to extract potential cause and effect relationships, patterns, trends, etc. Most of these tools were not developed for aviation safety, but could potentially help analyse air traffic safety event data.

7. General Tools for Data Analysis. Dealing with data often requires the construction of databases. This includes general tools for creating databases, and for retrieving and processing electronic data. They facilitate computerized detection of potential relationships and trends. The only purpose in defined separate categories is that some questions about methods and tools in one group would not apply to those in other classes.

The presented samples of methods and tools provide a wide range of capabilities to support air traffic safety analysis. All of these tools require considerable skill and knowledge of air traffic management procedures to use effectively, as well, of course, as access to suitable data.

3. Description of Integrated Safety Management System in Air Traffic Services

The integrated SMS in ATS operates in environment of the Simulator complex “Control” as a set of external/independent modules (Fig. 1).

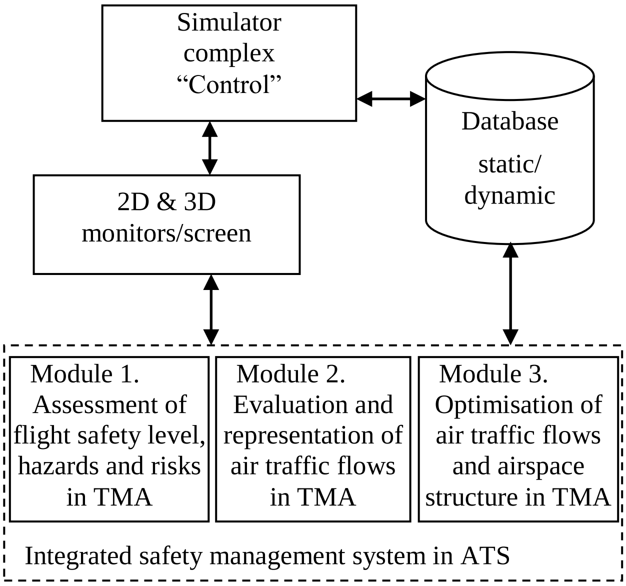

Fig. 1. The Integrated SMS in ATS in environment of the Simulator complex “Control”

The Simulator complex “Control” is designed to provide training of air traffic control students on workplaces of tower, approach and area control centre. The Simulator complex “Control” includes workstations of administrators/researches, set of workplaces of users, central server, network equipment and the display system (projectors and panoramic screen).

The Simulator complex “Control” provides:

– airspace modelling with defined dimensions and characteristics;

– procedural, modular and complex operational modes;

– radio and speakerphone modes of communication;

– generation of traffic flows with required density/intensity, potential conflict situations and other parameters;

– imitation of defined weather conditions in ATC zone.

The Simulator complex “Control” includes the 3D view of an manoeuvring area of aerodrome (Fig. 2), which is used by the modules of the Integrated SMS in ATS for the initial, visual survey of hazards and risks on aerodrome and in the vicinity of aerodrome.

Fig. 2. 3D view of manoeuvring area of aerodrome

The 3D view of manoeuvring area of aerodrome generated by the Simulator complex “Control” includes aerodrome layout, infrastructure, buildings, facilities, static/dynamic objects, aircraft, vehicles and personnel, meteorological conditions, etc.

This information is highly demanded by the experts investigating the flight safety level on aerodrome and in the vicinity of aerodrome.

As a part of the Simulator complex “Control”, the Integrated SMS in ATS includes following modules:

Module 1 – The module of assessment of flight safety level, hazards and risks in TMA;

Module 2 – The module of evaluation and representation of air traffic flows in TMA;

Module 3 – The module of optimisation of air traffic flows and airspace structure in TMA.

Let’s give the brief description and explanation of principles of work of above mentioned modules of the Integrated SMS in ATS.

The functional tasks of the module of assessment of flight safety level, hazards and risks in TMA are:

– proactive search of latent conditions, problematic areas and origins (triggers) of possible incidents and accidents;

– assessment of revealed hazards and risks according to standardised methodology;

– detailed qualitative evaluation and analysis of indices representing actual flight safety level in defined TMA;

– assessment of interrelations between major safety factors and analysis of direct influence of different categories of factors on integral flight safety level.

The functional tasks of the module of evaluation and representation of air traffic flows in TMA are:

– gathering and pre-processing of statistics of air traffic flows according to standardised methodology;

– generation of summaries (reports) of air traffic flows depending on user request parameters and filters;

– initial analysis of parameters of air traffic flows in TMA, which is necessary for further improvements;

– tactical level tasks including operations with optimisation of trajectories of aircraft in real-time mode (also use of more direct routes, bypass routes, etc.).

In this module used a linear dynamic systems model for the air traffic (Fig. 3). This model can be used for predicting traffic count, which is the number of aircraft in a given area centre.

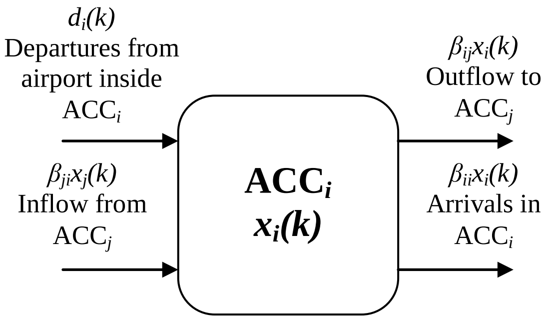

Fig. 3. The components of air traffic flow in a given area centre:
ACC – Area Control Centre

The resulting traffic count forecast, which is a measure of future demand, can then be balanced against the available capacity using traffic flow management:

$$x_i(k+1) = x_i(k) - \sum_{j=1}^{N} \beta_{ij} x_i(k) + \sum_{\substack{j=1 \\ j \neq i}}^{N} \beta_{ji} x_j(k) + d_i(k).$$

The functional tasks of the module of optimisation of air traffic flows and airspace structure in TMA:

− optimisation of airspace structures, network of ATS routes and standard arrival/departure routes according to air traffic flows statistics and qualitative evaluation of flight safety level;

− improvement of airspace structures in order to increase capacity and flight safety level;

– safety management by means of implementation of strategies of risk control/mitigation;

− strategic level tasks including long term planning to improve composition of the route network, capacity of airspace structures and optimise main air traffic flows in region (also civil-military co-ordination, flexible use of airspace, airspace use scenarios, etc).

4. Conclusions

The Integrated SMS in ATS is addressed to Aeronautical services providers to assist in solving complex problems connected with flight safety and air traffic flows in terminal/control areas. Further work will be connected with improvement of the modules and getting feedback from users of the system. Additional researches are necessary to improve the database of air situation scenarios by adding different types of emergency situations on manoeuvring area of aerodrome and terminal/control areas.

References

[1] *Chynchenko, Yu.V.* 2013. Outlines of operational risk assessment with ARMS methodology. Materials of XI International Scientific-Technical Conference "AVIA-2013". 2013. Vol. 2. P. 8.41–8.44.

[2] *Doc 9859.* Safety Management Manual (SMM). Montreal, ICAO. 2013. 251 p.

[3] *Guide to Methods & Tools for Safety Analysis in Air Traffic Management*. USA, GAIN Working Group B. 2003.

[4] *Kharchenko, V.; Chynchenko, Yu.* Concept of air traffic flow and capacity management in European region. Proceedings of the National Aviation University. 2013. N 3. P. 7−12.

[5] *Kharchenko, V.; Chynchenko, Yu.* Integrated risk picture methodology for air traffic management in Europe. Proceedings of the National Aviation University. 2013. N 1. P. 15–19.

[6] *Kharchenko, V.P.; Chynchenko, Yu.V.* Principles of Eurocontrol air navigation system safety assessment methodology. Materials of XI International Scientific-Technical Conference "AVIA-2013". 2013. Vol. 2. P. 8.13−8.16.

Received 2013.

В.П. Харченко[1], Ю.В. Чинченко[2]. Інтегрована система управління безпекою польотів при обслуговуванні повітряного руху
Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680
E-mails: [1]kharch@nau.edu.ua; [2]chynchenko@gmail.com

Проаналізовано дослідження щодо систем управління безпекою польотів. Розглянуто методи та програмне забезпечення аналізу безпеки польотів при обслуговуванні повітряного руху. Запропоновано принципи побудови інтегрованої системи управління безпекою польотів при обслуговуванні повітряного руху.

Ключові слова: безпека польотів; інтегрована система управління безпекою польотів при обслуговуванні повітряного руху; організація потоків повітряного руху та пропускної спроможності; оцінка небезпек та ризиків при управління повітряним рухом; система управління безпекою польотів.

В.П. Харченко[1], Ю.В. Чинченко[2]. Интегрированная система управления безопасностью полетов при обслуживании воздушного движения
Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680
E-mails: [1]kharch@nau.edu.ua; [2]chynchenko@gmail.com

Проанализированы исследования в области систем управления безопасностью полетов. Рассмотрены методы и программное обеспечение анализа безопасности полетов при обслуживании воздушного движения. Предложены принципы построения интегрированной системы управления безопасностью полетов при обслуживании воздушного движения.

Ключевые слова: безопасность полетов; интегрированная система управления безопасностью полетов при обслуживании воздушного движения; организация потоков воздушного движения и пропускной способности; оценка опасностей и рисков при управлении воздушным движением; система управления безопасностью полетов.

Kharchenko Volodymyr (1943). Doctor of Engineering. Professor.
Holder of a State Award in Science and Engineering of Ukraine. Winner of a State Prize of Ukraine in Science and Engineering.
Vice-Rector for Scientific-Research Work, National Aviation University, Kyiv, Ukraine.
Head of the Department of Air Navigation Systems, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Civil Aviation Engineers Institute with a Degree in Radio Engineering, Kyiv, Ukraine (1967).
Research area: management of complex socio-technical systems, air navigation systems and automatic decision-making systems aimed at avoidance conflict situations, space information technology design, air navigation services in Ukraine provided by CNS/ATM systems.
Publications: 402.
E-mail: knarch@nau.edu.ua

Chynchenko Yuriy (1976). Candidate of Engineering. Associate Professor.
Department of Air Navigation Systems, National Aviation University, Kyiv, Ukraine.
Education: Faculty of Air Traffic Services, State Flight Academy of Ukraine, Kirovograd, Ukraine (1998).
Research area: improvement and automation of a professional selection system and development of professional-major skills of civil air traffic controllers.
Publications: 93.
E-mail: chynchenko@gmail.com