AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

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Yuriy Chynchenko[1]
Volodymyr Kharchenko[2]

THE FREE ROUTE AIRSPACE UKRAINE IMPLEMENTATION CORNERSTONES

[1,2]National Aviation University, 1, Lubomyr Husar ave., Kyiv, 03058, Ukraine
E-mails: [1]chynchenko@gmail.com; [2]kharch@nau.edu.ua

Abstract

The article describes the scope of problematic issues (cornerstones) arising from fragmental processes of Free Route Airspace implementation on regional level in European airspace. Complex processes of step-by-step integration of national Free Route Airspace areas into greater regional Free Route Airspace areas, principles of gradual improvement of air traffic flow and capacity management on tactical level and optimisation of European fixed air traffic services route network are analysed and possible solutions are proposed.

Keywords: free route airspace, air traffic flows optimisation, implementation cornerstones, network strategic modelling tools, implementation milestones.

1. Introduction

The Free Route Airspace (FRA) is considered as a specified airspace, where users may freely plan a route between a defined entry/exit points, with the possibility to route via intermediate significant points, without reference to the fixed Air Traffic Services (ATS) route network [1]. The flights still remain a subject to air traffic control services.

The development of FRA in the Central European Functional Airspace Blocks was initiated/launched by the **European Organization for the Safety of Air Navigation (EUROCONTROL)** in 2008 [2] and supported by many international aviation agencies, such as International Air Transport Association (IATA) and multiple national Air Navigation Service Providers (ANSPs), including Ukraine.

The FRA represents one of up-to-date airspace design solutions and operational concepts, that covers the pan-European network perspective (avoiding segregated national approach, local “patch-up” solutions) [3]. The FRA Projects, mostly new regional cross-border initiatives, are planned for implementation in European airspace till 2024, according to the **EUROCONTROL Network Manager Action Plan** [3], as shown on Figure 1.

The main criteria and assumptions for the coordinated Pan-European FRA Projects implementation are following [3]:

- capacity and flight efficiency performance (together with environment protection);
- European airspace as a single airspace continuum;
- military and other specific requirements.

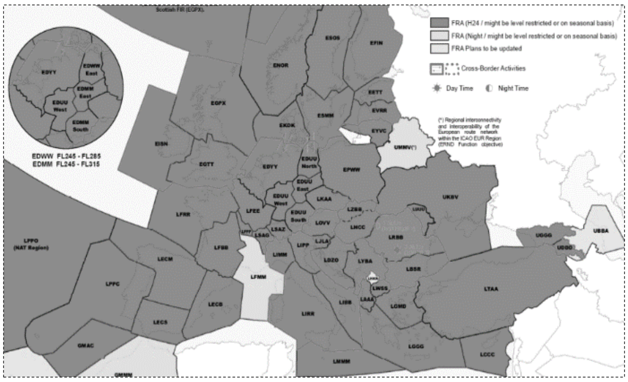

Fig. 1. The FRA Projects implementation in Europe

FRA builds up as an integral part of the overall European ATM system, interfacing vertically or laterally with the fixed ATS route operations airspace (not FRA).

To maximise efficiency of FRA and ensure safe and smooth transfer of flights, all efforts need to be made to ensure any required realignment of the fixed ATS route network in adjacent airspace not applying FRA.

The FRA project that is currently under implementation in Ukrainian airspace, should be based on the safety case, enabling requirements for optimum use of airspace, taking into account existing and future air traffic flows, ensure compatibility with the regional ATS route network, guarantee optimal use of technical and human resources on the basis of cost-benefit analyses, ensure smooth and flexible transfer of responsibility for air traffic control between air traffic service units and, finally, comply with conditions stemming from the regional agreements concluded within the ICAO.

2. Analysis of research and publications

The most of publications regarding FRA implementation and publication, air traffic flow and capacity management and airspace management are contained in EUROCONTROL regulations, partially duplicated and adopted on national level.

The basic FRA concepts, the conceptual European approach towards FRA, the typical FRA airspace structures and templates for the European FRA deployment plans are provided in [4].

The scope of plans regarding the European Route Network Improvement, covering specific questions of FRA implementation, procedures for airspace management, the Route Availability Document (RAD) and the official European Airspace Design Methodology are available in [1, 5-7].

The detailed description of FRA methodologies, including rules for establishing significant points, fixed ATS route network connectivity with FRA and FRA connecting routes theory are provided in [8]. Specific Network Manager issues regarding flight planning and aspects of FRA Application in Network Manager Operations Centre are stated in [9,10].

The local technological manuals for applied instructions on FRA implementation include the Free Route Airspace Ukraine (FRAU) Operational Concept (Step 1, Scenario 1b) [2] and FRA UKRAINE Airspace Design – Working Plan [11], which explain in details the principles of gradual implementation of FRAU, changes in ATS and description of measures on every development phase including ATS/ATM procedures.

Practical recommendations and explanation of air traffic controllers' procedures in FRAU are provided in current edition of The UkSATSE Air Traffic Services Manual [12], accordingly updated after every phase of FRAU development.

Some practical aspects applicable to FRA projects in Ukraine, such as air traffic flows and capacity management under uncertainty conditions and estimation of air traffic flows in terminal control areas are explained in [13-15].

3. Gradual approach to FRA implementation in Ukraine

One of the main objectives of FRAU is offering opportunities for airspace users to improve efficiency of plannable direct trajectories (DCT's) within available FRA (including cross-border FRA), as well as increased coordination between FRAU and adjacent ATS Units of neighbouring states [2].

The other objectives are – enabling the direct flight plannable routes for airspace users, tactical direct routing from actual available route options, optimising trajectories and improving air traffic flows predictability.

The FRA Concept implementation in Ukraine is based on following conceptual requirements [11]:

- meeting the safety objectives;
- compatibility with existing procedures (national and regional levels);
- scalability to adjacent FRA areas.

Developments of the FRAU are guided by such principles:

- FRAU should follow the operational approaches and deliver significant benefits for all airspace users;
- military users' requirements should be taken into consideration on all phases of FRAU;
- European airspace design concept, general principals and technical specifications regarding airspace design should be strictly adhered;
- general practices and concepts used by EUROCONTROL for providing FRA implementation initiatives should be applied for the majority of airspace design structures.

The current state of FRAU implementation (Step 1, Scenario 1b, Phase 3) is represented on Figure 2.

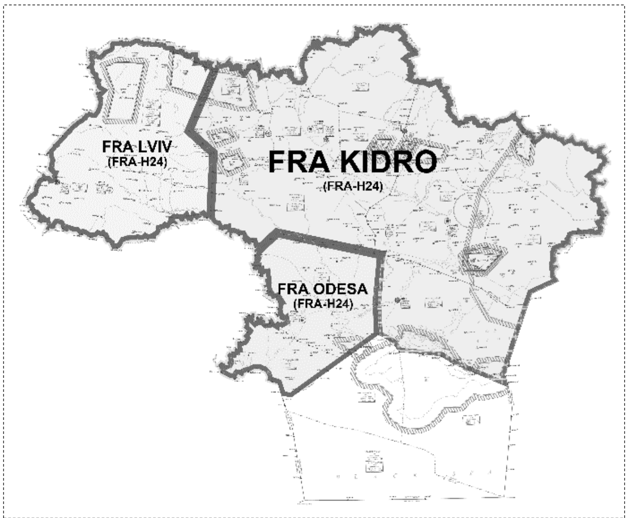

Fig. 2. The current state of FRAU implementation

According to [2,3,5,11] the FRA operations in Ukraine are being implemented in following sequence:

a) **Step 1**: FRAU implementation within individual FRA areas.

- **Scenario 1.a**. FRAU within individual FRA areas, which are published in AIP Ukraine ENR 1.3.7. Horizontal limits – within individual FRA areas. Vertical limits – FL275 – FL660. Operating hours – Night time 20.00-05.00 (21.00-04.00) UTC. Implemented in 2015;

- **Scenario 1.b**. FRAU within individual FRA areas, which are published in AIP UKRAINE ENR 1.3.7. Horizontal limits – within individual FRA areas. Vertical limits: FL275 – FL660. Operating hours – H24. Implementation – in 2019-2021.

b) **Step 2**: FRAU implementation within Ukrainian UIR.

- **Scenario 2.a**. FRAU within Ukrainian UIR. Horizontal limits – within Ukrainian UIR. Vertical limits – FL275 – FL660. Operating hours – H24. Implementation – in 2021-2022;

- **Scenario 2.b**. FRAU within Ukrainian FIRs and UIR. Horizontal limits – within Ukrainian FIRs and UIR. Vertical limits – controlled ATS airspace class "C", excluding TMA and CTR. Operating hours – H24. Implementation – in 2023.

4. The problematic aspects during Free Route Airspace Ukraine implementation

All flight plans containing some portion of flight in FRA are subject of thorough automatic/manual check and further approval (validation) by the Integrated Initial Flight Plan Processing System (IFPS) of EUROCONTROL. Airline operators might encounter following issues at planning flights in FRA (might result in flight plans rejection by the IFPS):

- Issue 1. Not adherence to availability (operation) time of FRA areas (in case of Night-FRA areas). Special tolerance periods of time (up to 30 minutes) used to be provided to mitigate such issues.

- Issue 2. The flight planned route crosses the FRA/state boundary (or 5 NM tolerance), represented on Figure 3.

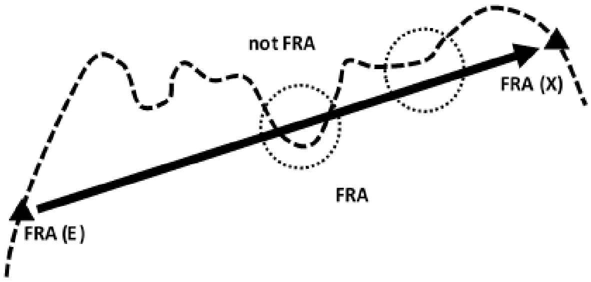

Fig. 3. Issue 2 example

- Issue 3. The flight planned route crosses adjacent FRA area (or NM tolerance), represented on Figure 4.

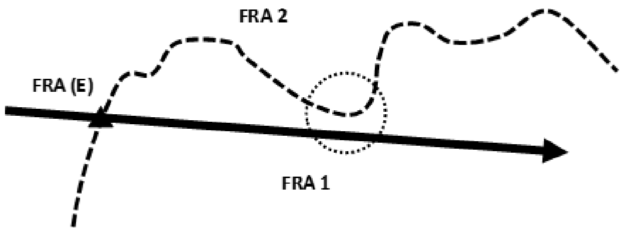

Fig. 4. Issue 3 example

- Issue 4. Aircraft passes FRA area by minimal time (less than 5 minutes), as shown on Figure 5.

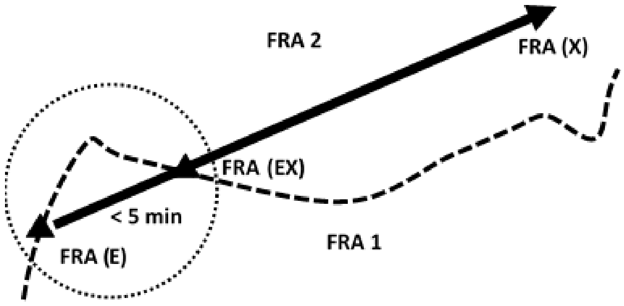

Fig. 5. Issue 4 example

- Issue 5. Aircraft passes ATS sector by minimal time (less than 5 minutes), graphical explanation provided on Figure 6.

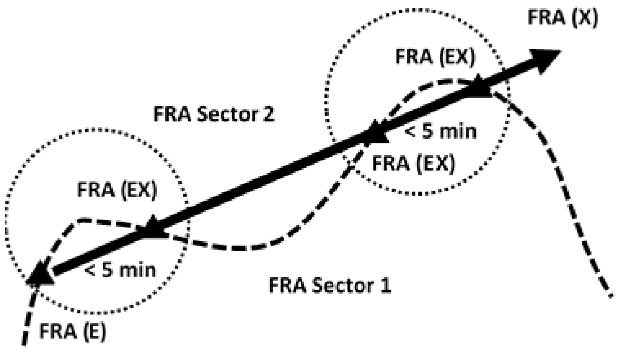

Fig. 6. Issue 5 example

- Issue 6. The flight planned route crosses restricted/reserved areas (P, R, D or TSA/TRA) and appropriate FPL buffer zones, illustrated on Figure 7.

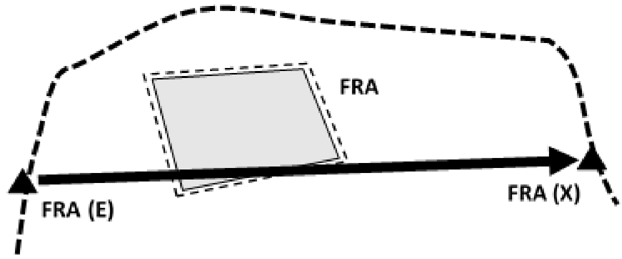

Fig. 7. Issue 6 example

The special algorithms, designed to significantly improve efficiency of flight planning processes and prevent abovementioned issues (see Fig. 3-7), should be composed and accordingly integrated into flight planning tools of airline operators and specific software of air traffic controllers.

The typical threats and hazards, that require further researches and appropriate mitigation measures in aeronautical system of Ukraine, associated with FRAU implementation/operation are following [16] (according to the ESARR 4 Severity Classification Scheme (SCS) of events [17]):

- incorrectly specified ATS route in the flight plan (application of points of fixed routes, entry points are confused with exit points and vice versa, etc.), the SCS class – Significant Incidents;
- not receiving of system flight plan by the air traffic controller, the SCS class– Significant Incidents;
- an incorrect system flight plan, which was received by the air traffic controller, the SCS class – Major Incidents;
- loss or misinterpretation of planner information regarding the ATS route, the SCS class – Major Incidents;
- the aircraft horizontal and/or vertical position that does not meet the FRA entering conditions, the SCS class – Significant Incidents;
- not transferred responsibility for aircraft control from one ATC unit to another, the SCS class – Significant Incidents;
- the responsibility for aircraft control was erroneously transferred from one ATS unit to another, the SCS class – Significant Incidents;
- the aircraft is at flight level/position that differs from the entry requirements, the SCS class – Significant Incidents;
- the aircraft did not established communication at entering FRA, the SCS class – Significant Incidents;
- the aircraft established communication with wrong ATS unit, the SCS class – Significant Incidents;
- **coordination not performed**, the SCS class – Serious Incidents;
- **coordination is performed incorrectly**, the SCS class – Serious Incidents;
- loss of situational awareness by air traffic controller, the SCS class – Major Incidents;
- partial loss of ability of air traffic controller to detect potential conflicts situations, the SCS class – Major Incidents;
- deviation of aircraft from the planned/agreed trajectory due to adverse weather conditions in the entry/exit FRA points or in areas, where the airspace prohibition/restriction is activated, the SCS class – Major Incidents;
- two-way communication loss with the aircraft in the FRA, the SCS class – Major Incidents;
- **unplanned shutdown of radar information monitor at the workplace of air traffic controller**, the SCS class – Serious Incidents;
- **radar information monitor readings are not changing (freezing) for a long period of time**, the SCS class – Serious Incidents;
- **loss of identification by the surveillance systems**, the SCS class – Serious Incidents;
- **on-board transponder failure**, the SCS class – Serious Incidents;
- **misinterpretation of surveillance data in respect of one aircraft**, the SCS class – Serious Incidents;
- **loss of surveillance data for all aircraft in the area of responsibility of air traffic controller**, the SCS class – Serious Incidents;
- entrance of unknown aircraft to ATS sector, the SCS class – Major Incidents;
- **intrusion of aircraft into activated prohibition/restriction airspace**, the SCS class – Serious Incidents;
- **not cleared GAT flights out of limits of TSA/TRA (or other airspace restrictions) during specific tasks inside this airspace**, the SCS class – Serious Incidents;
- overloading of ATS sectors in FRA, the SCS class – Significant Incidents;
- wrong Medium-Term Conflict Detection (MTCD function) triggering, resulting in additional estimation of dynamic air situation by air traffic controller, the SCS class – Significant Incidents;
- attention distraction of air traffic controller at MTCD triggering in order to reveal/solve conflict pair/group of aircraft, the SCS class – Major Incidents;
- new potential conflict situation in ATS unit as a result of conflict resolution (by MTCD) in adjacent ATS unit, the SCS class – Major Incidents;
- wrong Short-Term Conflict Alert (STCA function) triggering, resulting in additional estimation of dynamic air situation by air traffic controller, the SCS class – Significant Incidents;
- attention distraction of air traffic controller at STCA triggering to estimate relevancy of function triggering, the SCS class – Significant Incidents.

In order to mitigate abovementioned threats and hazards arising on different phases on FRA implementation and achieve target safety level in aeronautical system of Ukraine, the following **safety requirements** should be implemented:

- secure the phased/gradual approach to FRA implementation;
- introduce appropriate changes to regulations and manuals regarding flight planning and ATS procedures in FRA;
- provide appropriate training of air traffic controllers;
- develop different information materials (leaflets) in order to increase situational awareness of airspace users about conditions of flight planning and flight operations in FRA;
- elaborate the valid design of FRA, based on EUROCONTROL regulations, manuals and guidance documentation [1,4,8,10];
- strictly adhere safety requirements for flight planning and ATS procedures in FRA [16];
- adhere safety requirements and functional system requirements for automated systems of air traffic control.

The automated systems of air traffic control, that are currently used in Ukrainian FRA areas, meet the most of FRA requirements. The following **functional system requirements** shall be fulfilled in FRAU [2]:

- the system is capable of receiving/transmitting OLDI Basic Procedure from/to external partners;
- the system is able to process route;
- the system is able to reflect flight route in appropriate Lists (Sector List, Inbound List, etc.);
- the system is able to manually/automatically assume/handover a flight;
- the system is able to detect, where the aircraft trajectory is projected to intrude the active restricted airspace;
- the system is capable to operate in two different environments – FRA and existed fixed ATS route network;
- the controller tools to assist ATCO in conflict detection and resolution.

To calculate Safety Targets (*ST*) for FRAU implementation, considering abovementioned typical threats and hazards, might be used such equation:

$$ST_{j(ATSU)} = ST_{j(ATMSP)} \cdot flight\ hrs\ in\ ATSU,$$

where:

- $ST_{j(ATMSP)}$ – safety target of ANSP, connected with Severity Class *j (SCj)*;
- *flight-hours in ATSU* – number of flight hours provided with service by appropriate ATS Unit.

In order to determine Safety Objectives (*SO*), the following equation is applied:

$$SO_{ATSUCxSCj} = \frac{ST_{j(ATMSP)}}{N_{ATSUCxSCj} \cdot Pe_{ATSUCxSCj}},$$

where:

- $SO_{ATSUCxSCj}$ – safety objective for hazard with the worst Severity Class *j (SCj)* in area of responsibility of ATS Unit (*ATSUCx*);
- $ST_{j(ATMSP)}$ – safety target of ANSP, connected with Severity Class *j (SCj)*;
- $N_{ATSUCxSCj}$ – number of hazards with the worst Severity Class *j (SCj)* in area of responsibility of ATS Unit (*ATSUCx*);
- $Pe_{ATSUCxSCj}$ – conditional probability that hazard with the worst Severity Class *j (SCj)* in area of responsibility of ATS Unit (*ATSUCx*) might happen;
- *Cx* – complexity of ATS Unit (*ATSU*), where *x* – complexity category.

5. Application of EUROCONTROL network strategic tool for research of Free Route Airspace Ukraine

The Network Strategic Tool (NEST) is a stand-alone desktop application used by the EUROCONTROL Network Manager and Air Navigation Service Providers (ANSPs) for airspace structure design and development, capacity planning and post operations analysis, strategic traffic flow organization, scenario preparation for fast and real-time simulations and ad-hoc studies at the local and network level.

The NEST offers an intuitive, planner-orientated interface with a functionality that useful for different FRAU researches, such as search of optimal flight trajectory, flight cost efficiency, traffic flows optimisation under restrictions and others (Fig. 8).

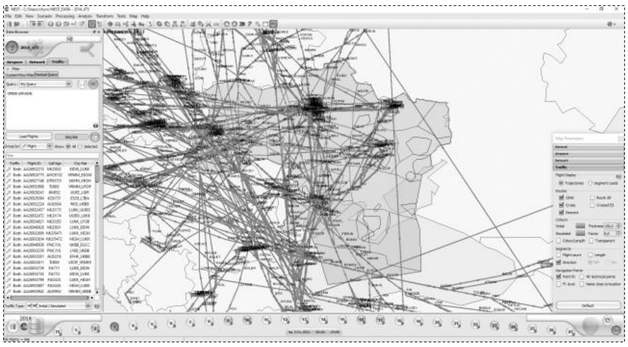

Fig. 8. The use of NEST for FRAU researches

The NEST is scenario based, users can make changes to the original dataset or reference scenario to model an unlimited number of operational planning options in FRAU:

- traffic demand can be based on historical data, or increased according to the selected traffic forecast;

- 4D trajectories can reflect actual flight trajectories, or be regenerated on customised route networks according to shortest or cheapest routings taking the route charges into account;
- impact of airspace changes on sector capacities can be estimated using built-in workload calculations.

To sum up, the NEST is a powerful scenario-based modelling engine, capable of running a broad range of complex, FRAU-relevant analysis and optimization functionalities.

6. Conclusions

In this research were considered conceptual principles the Pan-European FRA Projects implementation (coordinated by the EUROCONTROL) and features of gradual approach of FRA development in Ukraine with detailed description of project phases. The possible cornerstones and operational aspects of FRA Concept implementation in Ukraine were studied.

Analysis of typical issues originating at airline operators flight planning processes in FRAU environment was performed. As a conclusion, to improve flight plan composing and submission to IFPS, there is a vital necessity to develop special algorithms and software modules tailored to optimise flight planning process in FRAU.

The typical threats and hazards, which associated with implementation and operation of FRAU were provided and analysed. They require further researches and implementation of appropriate mitigation measures in aeronautical system of Ukraine.

The most dangerous threats and hazards, associated with FRAU implementation/operation are following – coordination not performed or performed incorrectly, unplanned shutdown of radar information monitor at the workplace of air traffic controller, radar information monitor readings are not changing (freezing) for a long period of time, loss of identification by the surveillance systems, on-board transponder failure, misinterpretation of surveillance data in respect of one aircraft, loss of surveillance data for all aircraft in the area of responsibility of air traffic controller, intrusion of aircraft into activated prohibition/restriction airspace and not cleared GAT flights out of limits of TSA/TRA.

The NEST provides functionality for air traffic flows researches under different restrictions, European and national ATS route network harmonisation, search of optimal flight trajectory and flight cost efficiency optimisation.

As a result, the NEST is an optimal solution for airspace structure design and development, for capacity planning and post operations analysis, for strategic traffic flow organization, for scenario preparation for fast and real-time simulations in FRAU.

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Ю.В. Чинченко[1], В.П. Харченко[1]

Проблемні питання впровадження повітряного простору вільних маршрутів України

Національний авіаційний університет, просп. Любомира Гузара, 1, Київ, Україна, 03058
E-mails: [1]chynchenko@gmail.com, [2]kharch@nau.edu.ua

У даній статті описано сукупність проблемних питань, що виникають при відокремлених процесах впровадження повітряного простору вільних маршрутів на регіональному рівні у Європейському повітряному просторі. Проаналізовані комплексні процеси поетапної інтеграції національних районів повітряного простору вільних маршрутів у більші регіональні райони повітряного простору вільних маршрутів, принципи поетапного вдосконалення процесів управління потоками повітряного руху та пропускною здатністю на тактичному рівні та оптимізація Європейської фіксованої мережі маршрутів обслуговування повітряного руху, запропоновані можливі рішення.

Ключові слова: повітряний простір вільних маршрутів, оптимізація потоків повітряного руху, проблемні питання при впровадженні, програмні засоби стратегічного моделювання мережі, етапи впровадження.

Ю.В. Чинченко[1], В.П. Харченко[1]

Проблемные вопросы внедрения воздушного пространства свободных маршрутов Украины

Национальный авиационный университет, просп. Любомира Гузара, 1, Киев, Украина, 03058
E-mails: [1]chynchenko@gmail.com, [2]kharch@nau.edu.ua

В данной статье описано совокупность проблемных вопросов, возникающих при фрагментированных процессах внедрения воздушного пространства свободных маршрутов на региональном уровне в Европейском воздушном пространстве. Проанализированы комплексные процессы поэтапной интеграции национальных районов воздушного пространства свободных маршрутов в большие региональные районы воздушного пространства свободных маршрутов, принципы поэтапного совершенствования процессов управления потоками воздушного движения и пропускной способностью на тактическом уровне и оптимизация Европейской фиксированной сети маршрутов обслуживания воздушного движения, предложены возможные решения.

Ключевые слова: воздушное пространство свободных маршрутов, оптимизация потоков воздушного движения, проблемные вопросы при внедрении, программные средства стратегического моделирования сети, этапы внедрения.

Yuriy Chynchenko (1976). Candidate of Engineering. Associate Professor.
Doctoral candidacy, National Aviation University, Kyiv, Ukraine.
Education: The State Flight Academy of Ukraine, Kirovograd, Ukraine (1998).
Research area: free route airspace implementation, air traffic flow and capacity management, safety of flights.
Publications: 142.
E-mail: chynchenko@gmail.com

Volodymyr Kharchenko (1943). Doctor of Technical Sciences, Professor.
National Aviation University, Kyiv, Ukraine.
Education: National Aviation University.
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: 540.
E-mail: kharch@nau.edu.ua