UNIVERSITY OF PUBLIC SERVICE
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REVIEW OF THE DOCTORAL (PhD) DISSERTATION

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INVESTIGATION OF THE DEVELOPMENT AND APPLICATION OF REMOTE AIR NAVIGATION SERVICES IN CIVIL AND STATE AVIATION

the author's description and official reviews of the doctoral dissertation

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ACTUALITY AND REASONS OF THE THEMATIC CONCEPT

Over the past half-century, the Air Navigation Service Providers of the Member States of the United Nations International Civil Aviation Organization have sought to handle the progressive increase of air traffic by individual infrastructure developments in their sovereign airspace and international airports.

At the same time, the military side has continuously developed its own airspace control and air defense capabilities (independently and in the actual geopolitical allied system) and allocated tremendous efforts to early detection, identification and effective interventions of air operations in the sovereign airspace.

As a consequence of the global economic growth, the civil air traffic has exceeded a level which can be handled at individual level (i.e. independent actions by states) in a limited extent (in fact, it is simply impossible to manage some areas). Instead, more system-level problem solving, a network centric approach, and global (pan-European and EU wide) standardization progress can provide solution to the problems.

The multi-stakeholder value chain and the divided European airspace are mentioned as fragmented infrastructure in some criticisms, which is the cause not only of low efficiency but also of the excessive energy consumption. Based on the European Commission ambition the most effective solution would be the airspace optimization and enforced reduction of the number of Air Navigation Service Providers, as well as the reorganization of certain functions under market conditions, thus the aviation, and in particular Air Traffic Management (ATM), can contribute to economic development and carbon-neutrality objectives of the European Union.

However, the abovementioned circumstances admittedly raise the question what are the critical ATM infrastructure elements or functions where, despite any external intention, the Commission’s envisaged economic competition rules cannot be imposed, more precisely which areas could or shall be kept as a public service or being open under market conditions.

Notwithstanding the above, over the last decade NATO and the civil Air Navigation Service Providers have been increasing the emphasis on the R&D of interoperability, physical and cyber security, adaptive modularity, and deployable (remote) air navigation, ATM and airspace control capabilities. The expected intense proliferation of such services in civil aviation and military air traffic control will create new conditions and circumstances in airspace control, air defense and also in civil-military ATM cooperation, which will require detailed scientific researches.

Many questions need to be answered regarding the use of site-independent infrastructure and services, as well as the physical protection and cyber security of remote infrastructures. Nevertheless, the new air traffic services and technologies are probably transforming the civil-military cooperation, also the role of the civilian services in national airspace control duties and NATO Deployable ATM capabilities. Interoperability between the geographically independent air traffic control, communication, navigation and surveillance functions and the ATM system of the Hungarian Armed Forces is unforeseen, and it is also not clear how the new ecosystem will comply with the national airspace control and policing obligations derived from NATINAMDS.

THE SCIENTIFIC PROBLEM

For many decades, the evolution of civil air navigation and air traffic management systems has been driven by the constant growth of air traffic, security and safety needs, and certain technological developments. The European aviation network is based on the self-developed infrastructure of sovereign states, which also strives to meet national defense requirements.

However, the international air navigation ecosystem (that can be interpreted as a network and a public service value chain) is being brought from its dormancy by the demands of airspace users, cost-cutting and capacity-increasing pressures of emerging industry players and planned EU policy reforms.

The natural growth trend and consolidation processes are continuously supported and periodically reinforced by many innovative technologies and solutions. In addition, in the air navigation environment, several international partnerships have already been established for data provision, airspace consolidation and air traffic service delegation cooperation, which are used as a reference in the arguments of those calling for reforms, ignoring the fact that these collaborations are organized on a voluntary basis and serving specified needs. In my view, the consolidation solutions found in the air traffic management environment are purely the result of the normal evolution of the industry environment, but displacement from the "dormant" state and the significant increase of the European network capacity require – sometimes paradigm shifting – new technologies and working methods aiming to improve the efficiency of human workload and to increase the level of safety.

Disruptive technologies emerging in the transport sector, as well as in the ATM (e.g. intensive proliferation of autonomous drone systems, location-independent air traffic services, machine learning and artificial intelligence) are changing the industry environment that has been

operating for decades, transforming the "balance of power" among the participants and improving the provided functions and services to a higher level of performance.

In my view, the expected results of this two-way impact should not be examined and assessed from the same perspective. While the (voluntary) exploitation of technological opportunities can assure a competitive advantage and improved service quality, the forced consolidation can potentially lead to the erosion of national responsibilities, infringement of sovereignty and the loss of competence in certain functions and services.

Based on the above reflection, my thesis explored the following questions:

1. *To what extent are the EU airspace and ATM infrastructure consolidation efforts reshaping the conventional national air navigation and airspace control environment and the civil-military cooperation framework?*
2. *What are the ATM critical infrastructure elements and factors need to be taken into consideration when applying remote solutions for ATM infrastructure consolidation?*
3. *What are the benefits of remote technologies and services for civilian and military stakeholders?*

RESEARCH OBJECTIVES

The choice of theme and my research ambition were also driven by personal involvement. As a military air traffic controller (2000-2005), I experienced a significant transformation of military aviation legislation and national airspace structure. Procedures, operational environment and working technologies adopted from the international military environment and harmonised with civil rules anticipated the potential of civil-military cooperation and flexible use of airspace, but the experience gained from day-to-day work also revealed the factors in the civil-military air traffic control environment that slow down and complicate the harmonisation process.

During my studies in the United States of America (2003), I had the opportunity to learn about the specifics of military airport operations and air traffic management of the US Air Force, and I compared them with the standards and procedures applied in the Hungarian civilian and military environment. A deeper understanding of the US Federal and military air traffic and air navigation infrastructure and regulatory system highlighted the advantages and disadvantages of a more integrated operating model that differs from the European and our national environment.

Between 2005-2012, as desk officer of the Ministry of Defence, I was responsible for the coordination of programmes modernising the military air traffic management system of the Hungarian Defence Forces, and for exploring and exploiting opportunities for closer civil-military cooperation. In the European ATM consolidation processes, I had the opportunity to assess the NATO and EU ATM development strategies, which could enable the Hungarian Defence Forces' air traffic organisations to perform peacetime domestic (airbase and offbase) and deployed operational ATM tasks. During the development of the state aviation regulations, I realized the diverse criteria for the civil and military use of airspace and the different priorities of the requirements for air navigation infrastructure, which helped me to objectively assess the opportunities and risks of the consolidation ideas. By monitoring the development of the requirements of NATO deployable ATM component and the military airbase activation concepts, I sought to answer the question of how the national civilian and military technologies and capabilities could be used in multinational engagement, considering them as scarce resources and their prominent nature of aviation security.

Since 2012, as FAB program manager and civil-military cooperation coordinator of HungaroControl Hungarian Air Navigation Service Provider, I have been following the regional cooperation efforts as well as the EU policy and legislative processes aiming for the consolidation of the aviation network (airspace, infrastructure, services), and have been looking

for answers to the fundamental question of how these reform proposals will impact civil-military cooperation and the future operation of critical ATM infrastructures.

During the coordination of the strategic cooperation between the Ministry of Defense and HungaroControl, I was able to compare the harmonization and integration ambition of the parties, while my personal international experience helped me to re-interpret the system of a civil-military cooperative relations.

As a HungaroControl employee, I had the privilege to learn from the innovative national projects (e.g. air traffic control in Kosovo Upper Airspace, remote tower technology at Budapest Liszt Ferenc International Airport, delegated Air Traffic Services airspaces, South East Europe Free Route Airspace), which are real examples of the transformation of the ATM environment and the emergence of geographically independent new services. International research and development trends and solutions (remote design of flight data processing systems in non-adjacent countries, dynamic airspace management, “sectorless” flight management concept, air traffic services by remote tower technology for multiple airports, etc.) have also confirmed my assumption that predicted changes in certain functions of the ATM industry could significantly reshaping the scope of national airspace control and civil-military cooperation.

Based on my professional work, research and analysis, my research objectives for exploring the possible effects of location-independent (remote) ATM infrastructure on civil-military cooperation are grouped to three interdependent topics:

Examination of the current (conventional) air navigation environment, identifying existing harmonized and integrated functions, as well as areas of civil-civil and civil-military cooperation. My analysis identifies the basic similarities between civil and military infrastructures and compares the typical differences.

Investigating the envisaged remote technologies and virtual ATM services. The aim of the research is to analyze the outlined new models and concepts, assess the differences from the conventional ATM environment and their potential impact on civil-military cooperation. I have assessed the links between virtual services and critical ATM infrastructure, as well as the physical and cybersecurity conditions and requirements for remote infrastructures

During the examination of operating remote technologies, my objective was to assess the impact on civil-military cooperation through ATS airspace delegation methods, virtual flight control solutions and technologies. I have also investigated the opportunities of the military applications of remote technologies and services deployed and researched in the civil

environment, in particular to the requirements of NATO deployable ATM capability development capabilities.

HIPOTHESES OF THE RESERCH

Based on my objectives and statements made so far, I set up the following hypotheses:

1. Remote technologies are necessary but not sufficient means of the envisaged implementation of the EU ATM and CNS infrastructure consolidation processes.
2. Remote technology and services are changing the civil-military relationship.
3. Remote services pose a higher risk in national airspace control obligations.
4. Remote technologies could be part of the national capability package offered for NATO Deployable Airbase Module.

METHODS OF RESEARCH

I used the following research methods in my dissertation:

- research of the national and international literature, which involves the examination of the ICAO and EU standards, EU and national legislation, policy concepts, technical analyses and scientific publications;
- Analysis, study and processing of NATO and Hungarian military standards and regulations;
- reexamination of former analizes;
- conducting empirical research, using and formulating professional experience gained in national and international environment;
- comparative analyses;
- using Graph modelling and Markov processes;
- typification of airspaces and existing service delegation solutions in the European environment, evaluation of their main characteristics;
- network analysis and fault-tree modelling;
- processing research results, presenting them in the form of articles, book chapters and other publications, and interpreting at conferences.

DISCRIPTION OF THE COMPLETED EXAMINATION

In the first chapter, I describe the conventional air navigation infrastructure and air traffic management environment and present the already existing integrated and harmonized functions that can serve as a basis for further consolidation processes. In particular, I describe and analyze the position of the national aviation infrastructure in the defense economy, exploring the roles and responsibilities of the civil air navigation assets and air traffic services in the implementation of national and NATO airspace control obligations.

The second chapter describes the concept of location-independent (remote) air traffic functions and compares them with the conventional services presented in the previous section and also with the national (monolithic) infrastructures in use today. The analysis is based on a study ordered by the European Commission (detailing a 15-year vision of the industry), which defines the new technological opportunities of reconnaissance and data processing indispensable for air traffic management, ATM information infrastructures and the consolidation modes of air traffic services.

In my research of remote services, I have narrowed down the study focus to three methods, which I summarize in the following chapters.

In the third chapter, I examined the cases where responsibility of air traffic control is delegated by designation of a specific airspace portion, where the airspace can be adjacent or remote and the ATS delegation is static or dynamic.

In the fourth chapter, I examined the conditions for the dislocation of air traffic control workstations (in this case the relocation or outsourcing of working positions may be temporary or permanent) while maintaining the original area of responsibility. In this matter, relationship of the controlling unit does not change, thus the study also covers the circumstances of relocation and the requirements for the mobile workstations.

Finally, in the fifth chapter, I analyzed the consolidation of data processing necessary for air traffic control, where local data sources are processed and sent to the data usage site (controller working positions) by decentralized data processing system.

SUMMARY OF THE CONCLUSIONS

In the international context the consolidation of air navigation services is seen as an industrial demand, in particular to optimize performance and to promote technological interoperability and modernization. In order to have a deeper understanding of the envisaged consolidation (opportunities, constraints, risks, etc.), I applied a new approach for investigation of the possibilities of civil-civil-military and civil-military cooperation supported by remote technologies, namely I did not focus on the general capacity, cost-efficiency, safety and environmental objectives derived from the EU performance scheme, but rather on the role of civil air navigation services in the defense economy and in national and NATO airspace control.

In this approach, examination of the current (conventional) environment clearly outlined the overlaps and redundancies deriving from the monolithic structure of air navigation services established by international treaty and statutory obligations, so I could drawn conclusions on the directions for improvement, and opportunities of harmonization and integration opportunities in civil-military cooperation. The conclusions derived from the analysis of theoretical models, concepts and technologies already in use highlighted the links between virtual services and critical ATM infrastructure, as well as the physical and cyber security conditions and requirements for remote infrastructures.

The examination of ATS airspace delegation modes, virtual data processing and air traffic management solutions also enabled the identification of the impact in civil-military cooperation. The remote technologies and services already used, researched and developed in the international civil environment can set directions for the modernization of military air traffic management, especially requirements to the improvement of air traffic control working positions at military airbases and capabilities associated with the development of a deployable ATM contingent of the Hungarian Defense Forces.

By examining the domestic airports, I have concluded that the current infrastructure and the low level or lack of air traffic services significantly limit the relocation capabilities of the armed forces. I have identified correlation between the facts that remote technologies at rural airports and temporary landing sites are not only solutions that improve local air traffic services, but also enhance the defense and disaster management tasks of the defense forces' vitally important dislocation capability.

The use of remote technologies and delegated air traffic services in an international ATM environment will increase the complexity of the civil-military cooperation, which will result a

certain exposure to the air traffic services in their defense-related obligations in normal (peacetime) and all of the crisis situations.

NEW SCIENTIFIC RESULTS

1. Thesis

I have demonstrated through analyses that remote technologies are a necessary but not sufficient means to achieve the envisaged consolidation processes of EU ATM and Communication, Navigation and Surveillance (CNS) infrastructure. By examining international cooperation, I have shown that, in the absence of an EU legal obligation, proliferation of remote services can only supervene by independent initiative of Member States and air navigation service providers in order to achieve the capacity and cost-efficiency objectives outlined above, but there is a fundamental pre-requisite that the national defense obligations of civil air navigation services continue to be fully met. I concluded that the European civil air navigation and air traffic management ecosystem is a constellation of sovereign national ATM and CNS infrastructures (also subordinated to national defense interests), in which the development of consolidated services (remote functions and technologies) is not necessary yet, but I identified a sufficient condition if the concerned parties make their own decision to develop services and functions independent of national borders but limited in space or time, in order to meet safety and performance efficiency criteria.

2. Thesis

As a result of a more detailed examination of ATS delegations in international and national environment, by using induction I found that remote technology and services are changing civil-military relations, however the identified impacts occur differently in national and international dimension.

During scrutiny of the Hungarian ATM environment, I concluded that virtual technologies can strengthen national civil-military cooperation and provide an infrastructural basis for the integration of some functions. I found that new technologies support the flexible adaptability and modularity of the deployable ATM component built up by national (civil and military) resources.

Nevertheless, based on the investigation of international remote technologies and air traffic services, I concluded that the transformation of conventional infrastructure is leading to a more complex system with cooperative relations whose effectiveness (both in relation to the results of the national environment study and to the current international civil-civil and civil-military relations) is questionable, especially in cases when state aviation must get supreme priority in in normal (peacetime) and all of the crisis situations.

3. Thesis

Through a comparison of conventional and virtual systems, a combination of graph-theoretic modelling of the Kosovo upper airspace environment and network analysis and fault-tree analysis of virtual ATM data centers in a specific theoretical model, I have shown that remote services pose a higher risk to the fulfilment of national airspace control obligations. However, the studies of international examples were not sufficient to explicitly define the exposure arising from the use of remote technologies and services, because some states determine the degree of integrability (outsourcing) of certain infrastructures and services, as well as the ways of risk management identified in the context of business continuity on the basis of aviation safety risk assessments and subjective transport and defense policy criteria.

4. Thesis

By examining the delegability of air traffic services and the deployability of ATM data processing systems and controller working positions, I concluded that the deployability of infrastructures in civil and state aviation is a claim with the same objectives, but with different aspects and ambitions. I have found that certain remote and virtual solutions can be implemented into the conventional military environment and mixed with military mobility procedures and basic infrastructure, resulting a deployable national ATM capability with advanced technologies that can enhance the effectiveness of military, disaster management and humanitarian air operations executed not only in Hungary but also beyond national borders (multi-national tasks and NATO deployable airbase module activation).

APPLICABILITY OF THE RESEARCH RESULTS

The basic objective of my research was to explore the potential impact of remote ATM infrastructure in civil-military cooperation and to summarize my research results in an essential document supporting decisions concerning future planning and development of civil and military air navigation services.

1. *The conclusions and findings of my thesis can be used for more complex (transport and defense) decision-preparatory analyses of the remote technologies and services to be used in the national air navigation and air traffic management ecosystem.*

2. *I propose to use the conclusions and findings of my thesis to define the basic requirements of the civil infrastructure elements of a national deployable ATM capability package.*

3. *Based on the findings of my thesis, I suggest to review the national legislation of aerodrome flight information services (AFIS) and the development of a capacity-based development concept for rural airports.*
4. *I also recommend the use of graph-theoretic models and network analysis in the designing process of remote infrastructures in order to substantially pre-assess the exposures.*
5. *I propose to investigate the deployment feasibility of the outlined virtual technologies in the military air traffic services, both in terms of the implementation in a conventional environment and the possible integration of certain services.*

PUBLICATIONS OF THE AUTHOR

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S1 SOMOSI, Vilmos: Kutató jelentés az UAV közelkörzeti légiforgalmi környezetben történő működésének repülésirányítókra gyakorolt humán terhelése vizsgálatáról (alapkutatás az UAV_LAW Kiemelt Kutatási Területhez) Könyvtári nytsz.: E8502

S2 PALIK, Mátyás; SOMOSI, Vilmos: A léginavigációs infrastruktúra-fejlesztés kockázatelemzési sajátosságai (Repüléstudományi Szemelvények 2017 93-111. oldal) ISBN 978-615-5764-80-6

Publications in Hungarian language in domestic academic journals

S3 SOMOSI, Vilmos: az európai légtérszerkezet racionalizációja – a FAB CE program és a magyar állami célú légiközlekedés kapcsolata Repüléstudományi közlemények 2009

S4 VAS, Tímea; SOMOSI, Vilmos A Magyar Honvédség mobil ATM komponens lehetőségei a NATO hadműveleti repülőterein Repüléstudományi közlemények 2010: 2 pp. 2-13, 12 p. (2010)

S5 VAS, Tímea; SOMOSI, Vilmos: A Magyar Honvédség légiforgalom-szervezési rendszere korszerűsítésének fő irányai Repüléstudományi közlemények 2011: különszám pp. 1-11, 11 p. (2011);

S6 HALÁSZNÉ dr. TÓTH, Alexandra; SOMOSI, Vilmos: Az európai uniós és a hazai légiforgalmi irányítói szakszolgálati engedélyezési szabályozás összehasonlítása az állami célú légiközlekedésben (Repüléstudományi Közlemények XXV. Évfolyam 2012/2 szám 685-694. oldal) HU ISSN 1789-770X

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S8 SOMOSI, Vilmos: Kényszerhelyzeti eljárások kezelése delegált légiforgalmi irányítói környezetben (Repüléstudományi Közlemények XVIII. Évfolyam 2016/3 szám 37-48. oldal) HU ISSN 1789-770X

S9 SOMOSI, Vilmos: Légiforgalmi irányítói szolgáltatás delegálása lehetőségeinek és feltételeinek általános vizsgálata (Hadmérnök XI. Évfolyam 2016/4 szám 34-45. oldal) HU ISSN 1788-1919

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S13 KLING, Fanni; SOMOSI, Vilmos; POKORÁDI, László; ROHÁCS, Dániel: Budapest Liszt Ferenc nemzetközi repülőtér légijármű forgalmának elemzése Markov-folyamatokkal (Repüléstudományi Közlemények XXIX. Évfolyam 2017/3 szám 115-126. oldal) HU ISSN 1789-770X

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S15 SOMOSI, Vilmos: Information infrastructures in Air Traffic Management (Repüléstudományi Közlemények XXX. Évfolyam 2018/2 szám 205-216. oldal) HU ISSN 1417-0604

S16 POKORÁDI, László; SOMOSI, Vilmos: Graph-Theoretical Investigation into Vehicle and Transportation Systems (XVI. Mini Conference on Vehicle System Dynamics, Identification and Anomalies, Budapesti Műszaki és Gazdaságtudományi Egyetem 2018. november 5-7.) ISBN 978-963-421-804-3

Publications in international academic journals

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Publications in international journals

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Studies

- 1996-2000 Zrínyi Miklós National Defence University - Aviation Faculty Szolnok, Airspace Controller Department (BSc)
- 2007-2009 National University of Public Service - Military Leader (MsC)
- 2015- National University of Public Service - Doctoral School of Military Engineering

Language proficiency

- English STANAG 3333
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- Russian basic „C”

Academic activities

- Publications: 25
- Participation is research of university, projects:
  - TÁMOP-4.2.1.B-11/2/KMR-2011-0001 „Critical infrastructure defence research” „Data integration” sub program „Safety aspects of unmanned aerial vehicles” researcher
  - GINOP-2.3.2-15 “*Increasing and integrating interdisciplinary scientific potential related to aviation security into the international research and development network”* researcher
- Conferences:
  - Budapest, ZMNE Scientific Students' Associations Conference 1999;
  - Szolnok, Conference on Aviation Science 2009, 2010, 2011, 2012, 2017;
  - Kaunas, XVII. International Scientific Conference Transport Means 2013;
  - INAR Conference 2015 Amsterdam, 2016 Vienna;
  - Budapest, Aeronautical Science Days 2015, 2019;
  - Budapest, InterFAB Research Workshop Fragmentation in Air Traffic and its Impact on ATM Performance 2019