Lt. János Csengeri:

REMOTE TOWERS II.[1]

ABSTRACT: *In the present article the author demonstrates the process of the formulation of remote tower as a concept and technology and interprets the general layout of the system. The advantageous attributes and added values are summarized and compared with the ordinary tower control. The manufacturers and international experiences and instances are shown as well as the utilization and the research and development activity in Hungary regarding the remote tower control.*

KEYWORDS: *remote control, ATC tower, remote tower control, virtual ATC tower.*

INTRODUCTION

It is the air traffic/airport remote controlling that seems to be the main direction in the air traffic controlling sector, which determines the interests of the sector and carries promising innovative possibilities. Air traffic control, as a type of service, and military air traffic control, within the defence public service sector, are facing a wide range spread of technology which represents significant added values concerning the topic. In the present series of articles, consisting of three parts, I examine this type of technology, namely the Remote Towers (r-TWR), and its connections to other areas.

In the first part[2] I presented the development and use of remote control technology, furthermore, I dealt with remote sensing, too. I specifically emphasized the development, spread, capabilities and opportunities of services and technology of remote airport tower control. I also represented the solutions of atipycal air traffic control towers, the mobile air traffic control tower, as well as the remote virtual control tower.

In this, second part of the series, I will demonstrate the process leading to the present technological concept, and I will outline the construction of the system. As a matter of course, the advantageous features and added values of the system will also be presented, compared to the traditional tower control. I will mention the international experience gained so far, the availability of research and developement activity in our country, and the possible places to apply the solutions.

THE FORMATION OF THE TECHNOLOGY[3]

As I have mentioned above, in the first part of the series I presented the appearance of remote controlling in the air traffic control sector in detail. In that certain case, it is a radar-based

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[1] The work was created in commission of the National University of Public Service in the Győző Concha Doctoral Program.

[2] Csengeri, J. "Remote Towers I.". *Hadtudományi Szemle* X/3. 2017. 8–25.

[3] Fürstenau, N. "Introduction and Overview". In Fürstenau, N. (ed), *Virtual and Remote Control Tower: Research, Design, Development and Validation*. Cham: Springer International Publishing, 2016. 5–12.

control we talk about, which means signals on a screen, provided by radars, which result in the abstraction/image of a given airspace. In this case, it is not enough to simply present the working site, but it should be indicated in its reality with motion picture, in close to real-time, with the correspondent Frame Per Second (FPS) rate, and afterwards, supplementary functions enhancing effectiveness may be adjusted to it. All this is going to be dealt with later on.

One very early proposal for a revolutionary new virtual control tower work environment was put forward in 1996. A virtual reality (VR) concept was proposed for air traffic control which was called virtual holography. Nowadays VR projection systems of this type are commercially available but the actual research towards remote tower operation (RTO) took a more conservative course.

Another initial experimental research was the retinal laser scanning display for the support of tower controllers. One motivation for investigation in the so-called optical see-through technology was the perspective to reduce head-down times in the tower so that controllers can read display information without losing visual contact to the traffic situation on the movement areas.

Another example is the transparent head up display in the form of the holographic projection screen which was investigated by means of laboratory experiments and tested under operational conditions at Dresden tower. Here the idea was investigated to augment air traffic controller's direct view out of the control tower windows, for example by weather data, approach radar and flight data information superimposed on the far view without additional head-worn gear.

During that time the DLR team decided to drop the original idea of augmenting the controller's view out of the real-tower windows by means of the optical see-through technology and to follow the video see-through paradigm instead, for example, using the video reconstruction of the environment as a background for superposed additional information. This solution illuminates latency problem, for example, the information delay superimposed by real world. Many discussions among domain experts at that time led to the question if the virtual tower idea could provide solution for a rather urgent requirement: cost reduction in providing aerodrome control service to small, low-traffic airports. Such a requirement for cost reduction and increase of efficiency leads to our main topic: the remote tower as a paradigm change for low-traffic airport surveillance from a distant location and perspective of a single remote tower center (RTC) for aerodrome traffic management of several small airports.

The corresponding high-quality video reconstruction of the far view became the main technical research topic for the next eight years (2005-2013). In 2008 experimental or initial human-in-the-loop simulations started at the remote airport traffic control centre. The above mentioned process had been carried out at DLR (Deutsches Zentrum für Luft- und Raumfahrt – German Aerospace Center) at Braunschweig Research Airport. The first phase of the experiments with virtual reality technology lasted from 1996 until 2002, the second phase has been lasting since 2002 until present. In the meantime, experiments and related research activity had been carried out in several countries like the United States, Sweden and Hungary as well.

LAYOUT OF REMOTE TOWER CONTROL SYSTEMS

Camera

Generally fix and PTZ high resolution cameras are deployed at remotely controlled airfields in order to provide adequate visualization of the aerodrome.

PTZ stands for pan, tilt and zoom. The two terms which should be explained are pan and tilt. In cinematography and photography panning means swivelling a still or video camera horizontally from a fixed position. This motion is similar to the motion of a person when they turn their head on their neck from left to right. Tilting is a cinematographic technique in which the camera stays in a fixed position but rotates up/down in a vertical plane. Tilting the camera results in a motion similar to someone raising or lowering their head to look up or down.

Nowadays two layouts of camera deployment are utilized. At small sized airports the visualization (place of the cameras) is realised from one single spot and this is the way how a 360° panorama is provided (Figure no. 1.). At a medium sized airport (like Liszt Ferenc International Airport) cameras have to be deployed differently in order to reduce the distortion and to provide proper visualization opportunities from all over the aerodrome (Figure no. 2.). Furthermore, it is general (and recommended) to deploy cameras at places which are considered as „hotspots", such as main intersections and junctions, thresholds or touchdown zones, heliports, etc.

Figure 1. *Camera system at a small sized airport*

Source: *"Remote Technologies in Air Traffic Management (ATM) RPSA demo". https://www.youtube.com/watch?v=qQy6cXYx43M, Accessed on 15 November 2017.*

Data Link

Properties of data links vary on a quite wide scale. In general we can state that the high resolution and high-dynamic range camera picture and often audio data (the noises at the airport) are put through a wide bandwidth fibre optic ethernet (for example 100 Mbit/sec) connection. It is advisable to split the data flow into two directions: one should feed the data compression and encryption computers for data storage (for the capability of replay) and the other one drives the simultaneous real-time image processing for movement detection.[4]

[4] Fürstenau, N. and Schmidt, M. "Remote Tower Experimental System with Augmented Vision Videopanorama". In Fürstenau, N. (ed), *Virtual and Remote Control Tower: Research, Design, Development and Validation.* Cham: Springer International Publishing, 2016. 172–174.

Figure 2. *Camera spots' layout at a medium sized airport*

Source: *HungaroControl. "Remote Tower video". https://www.youtube.com/watch?v=DWCRpyCi2i8, Accessed on 15 Nov 2017.*

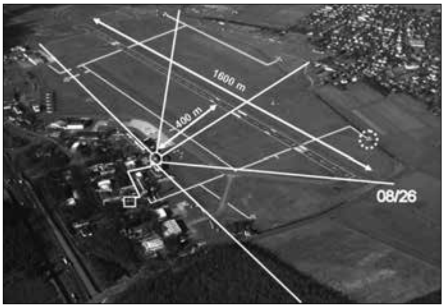

Figure 3.: *Data Link of rTWR System of Braunschweig Research Airport (yellow lines)*

Source: *Fürstenau, N. and Schmidt, M. "Remote Tower Experimental System with Augmented Vision Videopanorama" In Fürstenau, N. (ed), Virtual and Remote Control Tower: Research, Design, Development and Validation. Cham: Springer International Publishing, 2016. 174.*

Control Room

As for the control rooms, they consist of two major parts: the visualization and the controller working positions. There are two solutions regarding the visualization. One utilizes projectors which are mounted onto the ceiling of the room and projects the camera picture onto a white screen. This version of presentation is getting to be discontinued, just to mention one reason: the projected image is disturbed when an object (or human for instance) gets between the projector and the white screen. Furthermore, a projector is much more sensitive and fragile device than a modern LED/LCD (Light-Emitting Diode/Liquid Crystal Display) television.

So the other solution is the creation of a flat video wall like on Figure 3, where an 8x4 55" LCD television has been built in front of the CWPs (Controller Working Position) to provide common visual reference for all ATCOs (Air Traffic COntroller) and SV (SuperVisor).

All the fix and PTZ views are combined into one LCD screen which is presented at every ATCO CWPs. The control of the PTZ camera can be linked to one CWP to control the PTZ and the other CWP can follow the presented picture. A control can be requested and shall be released by the "owner" (controller) of the PTZ. On the top of Figure 3 the allocation and distribution of camera images can be seen.

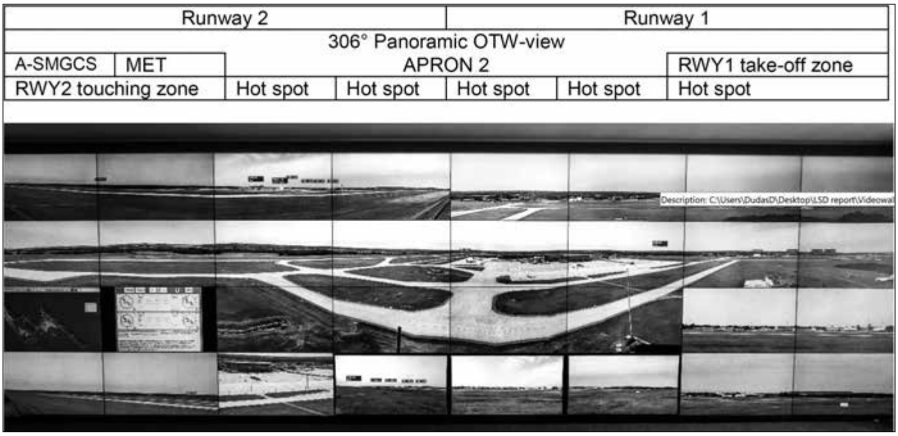

Figure 4: *Combined rTWR video image wall*

Source: *Corte, L. and Füredi, E. Demonstration Report. Project title: Budapest 2.0. Budapest: Pildo Labs, 2017. 81.*

The Controller Working Positions consist of integrated air traffic control systems and other supportive measures as it can be seen on Figure 4. The complexity of such a working position can also be observed. The different elements of the working station are labelled, where:

- MET is the required meteorological information provider display;
- A-SMGCS (Advanced-Surface Movement Guidance and Control System) is the tool for monitoring and controlling ground movements;
- MATIAS (Magyar Automated and Integrated Air Traffic System) is an ATM (Air Traffic Management) system including radar screen, handling flight plans etc. Indicates Mode S data, searches and detects possible traffic conflicts, provides the possibility to exchange data among neighbouring air traffic service providers, etc.;
- EAVD (Enhanced Airport Vision Display) is for individual video processing and presentation in CWP and at video wall;
- AGL (Airfield Ground Lighting) provides information about automated light control system's status;
- ILS (Instrumental Landing System) provides information about the operability and status of the landing system;
- VCS (Voice Communication System) makes both the radio and telephone based communication possible;
- AFTN (Aeronautical Fixed Telecommunication Network) is a worldwide system of aeronautical fixed circuits provided, as part of the Aeronautical Fixed Service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

These working positions are complete and totally suitable to perform a professional air traffic controlling activity. In a single virtual tower control room there might be several working positions which may be differentiated by tower functions, like clearance delivery, ground control, local controller, etc. Up to now there has been no instance for that, but working positions may be equipped with their own video walls and small airfields may be controlled by one single controller as the conceptual footage of SAAB[5] envisions this.

[5] "SAAB Remote Tower". https://www.youtube.com/watch?v=Gqv8EECMXJM, Accessed on 01 March 2018.

Figure 5.: *Controller Working Position in a rTWR*

Source: *Corte, L. and Füredi, E. Demonstration Report. Project title: Budapest 2.0. Budapest: Pildo Labs, 2017. 80.*

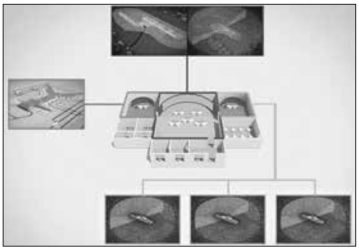

Figure 6. *System of Remote Tower Controlling*

Source: *"Multi-Remote Tower Concept of Operation". Searidge Technologies. https://searidgetech.com/media/Remote-Tower-Centre1.jpg, Accessed on 11 Nov 2017.*

The Overall Result

Thus out of these elements several variations can be worked out concerning the remote, virtual towers, adequately to the actual needs. The basic solution is the one, where air traffic controlling of one airport is carried out from one control room. The next level is when controlling of two or more airports happens from one control room. We may accept it as the same level, when several working positions are installed in one control room, but only one is active, and this single one controls the traffic of several airports. The most complex solution is when several control positions are installed in one control room, many of them are active, and each working station is responsible for controlling the traffic of more than one airport.

As it is seen, very complex systems and control networks can be constructed, but most of them exist on conceptual basis; only the first, the simplest variation has been put into real operation so far. It took a long time's planning to allow carrying this out, and likewise, we will need many years' experience and the sector's trust to be able to apply complex and reliable systems.

ADDED VALUES – LESSONS LEARNED FROM A HUNGARIAN EXPERIMENT[6]

Setting up a remote tower needs less capital investment than setting up a new conventional tower.

High level financial analysis shows that the implementation costs of a remote tower facility are considerably lower than those of a conventional tower. The model builds on the assumption that the ATM systems are similar in both cases. Another important assumption is that remote tower can be set up in an already existing (even office like) environment. What makes the difference is the deployment of camera sites, video system, and the necessary network elements on one hand, and the investment needed for building a new tower building and basic infrastructure on the other hand.

In order to make a detailed assessment for specific cases, the basic assumptions need to be validated in the first place. Then, the model should be adjusted with local characteristics like available network, visualization needs, state of the current tower, and other relevant elements of the concept of operation.

There is no significant difference in operational expenditures related to remote tower and conventional tower.

In the case of a single medium traffic airport operation, the basic assumption was that the remote solution does not cause any changes in ATCO staffing. The main elements of the comparison are the maintenance costs of conventional and remote tower infrastructures. In our specific case, these costs elements are at similar level, so the concept does not cause a significant difference.

Actual comparison is dependent on the concept of operation, local environment, and the validity of basic assumptions.

An rTWR working environment can provide the same level of comfort and ease for ATCOs as the CWPs at a conventional tower.

ATCO feedback suggests that the rTWR facility is appropriate for its purpose and it can be a comfortable working environment even for longer durations. ATCOs reported a mild increase in their stress levels that can be attributed to the 'first-time' effect during the demonstration. After a short customization period their behaviour implied the same level of comfort as in the conventional tower.

The importance of this subject should be assessed according to the purpose of the rTWR solution: contingency facility, temporary operation or full-time operation centre.

ATCO workload does not change significantly as a result of the extra controlling needs of the new equipment.

After the mandatory learning period ATCOs were able to control the elements of the visualization in a way that did not effect their workload considerably. ATCO feedback was collected about the necessary adjustments to the video control system that would decrease their workload and frustration, therefore potentially increase capacity.

In a medium size airport environment with several ATCO positions the controlling of the visualization system can be a cause of extra workload. In order to avoid this effect, visualization system should be configured to support work by multiple people (ie. position specific presets, easy PTZ control, effective target tracking).

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[6] Corte, L. and Füredi, E. *Demonstration Report. Project title: Budapest 2.0.* Budapest: Pildo Labs, 2017. 87–89.

Video wall provides reliable visual information to build up a mental image of the traffic situation.

The result of the analysis shows that ATCOs have different patterns in using the elements of the ATM system (MATIAS, ASMGCS, video wall) when it comes to building up a mental image of the traffic. Some of them claim to rely mainly on the radar screens, others say they use the visual representation for that. Both ATCO preferences were represented during the demonstration and none of them reported major issues regarding maintaining the mental picture of the traffic.

If there is adequate radar coverage (air and ground), it might not be necessary to provide a video image of the entire area of responsibility. The area displayed on the video wall should be divided based on the concept of operation, specific traffic characteristics, and local procedures.

ATCOs are able to handle the normal traffic from the rTWR facility during limited visibility conditions.

Live operation was demonstrated during limited visibility conditions (heavy rain and mist) without any issues. Visualization provided adequate support for maintaining the required capacity.

In a further stage of development, IMC and LVP capacity could be revised on the basis of the enhancement potential of the visualization.

A video wall provides enough visual information to build up a mental image of the traffic situation.

As stated above, the video wall together with the other relevant ATM systems provides sufficient information to support the level of situational awareness required by ATCOs. However, ATCOs claimed occasional confusion that can be attributed to the small amount of experience with this specific visual representation.

Adequate time should be allocated to customization with the visualization during ATCO training. This is not equal to the time that it takes to learn the functionalities, it takes longer to gain confidence to handle the system with the necessary routine, and mainly to get used to working with a different image of the movement area.

SWOT ANALYSIS

The chart below (Table 1.) aims to summarize the characteristics of remote tower control technology with the help of a popular methodology, the SWOT analysis (SWOT analysis – Strenghts, Weaknesses, Opportunities and Threats). Applying this method makes it possible to see not only the advantageous perspectives of the given subject, but also the weak ones, and at the same time it gives the opportunity to highlight the occurent threats.

Strengths	Weaknesses
It is not necessary to build a remote tower building at the aeroport at high costs; Application of advanced sensors in various periods of the day and all weather conditions; Solutions helping the work of the air traffic controller.	Errors are not acceptable; Distrust of the sector; Early stage of the technology and the methodology.
Opportunities	Threats
Cost-effectiveness; Neglecting the lack of building site; Controlling several airports from one spot; Traffic can be controlled from a safe center on operating site; Limits of human sight/attention may be exceeded; Application of virtual reality; More effective investigation in flight disaster cases.	Dependence on technology; Vulnerability; Virtual threats; Loss of capabilities concerning the acquired controlling capabilities.

Table 1: *SWOT Analysis of Remote Tower Control Technology*
Source: *collected and edited by the author.*

Strengths

- *It is not necessary to build a remote tower building at the aeroport at high costs:* as I have already mentioned above, among the added values, the significant advantage of rTWR technology is its low cost of implementation. The new control tower at MH Pápa Bázisrepülőtér (military airfield at the town of Pápa, Hungary) was inaugurated a short time ago, the positioning and height of which caused a lot of troubles, because a new hangar serving the C17 airplanes was built close to the end of the runway, which disturbed the view of the imaginery extension of the runway (which is extremely important in air traffic controlling, furthermore the standards also cover this area). This aspect influenced the size and the location of the tower to a great extent. It is a well-known fact in the Hungarian Defence Forces that the building (and not exclusively the devices) of the tower control at Szolnok military airfield should be restored. Certainly, with the utilization of the remote tower control, the tower building in use is being amortized, and in the course of time its renovation will be needed, but with the use of this possible solution, the (nearly) same expenditures are not to be paid after each operated airport. The tower control facility of Liszt Ferenc International Airport is also facing a renovation, which means far higher investment than it is in the case of military airports. It is not surprising that rTWR technology is being introduced at the airport at full blast, reducing the high costs.
- *Application of advanced sensors in various periods of the day and all weather conditions:* we all know the limits of human eyesight; at night, or under rainy, foggy weather conditions eyesight sensing abilities significantly reduce. As a resolution, night vision cameras can be installed, furthermore, the ability of these cameras to see through the fog is also much better than that of the human eye.
- *Solutions helping the work of the air traffic controller:* referring to the previous point, several functions simplifying the air controller's work can be added to the represented

camera image. The borders of the runways and taxiways can be marked with coloured lines (these borders are very difficult to define from a big distance even in the case of good visibility). The data of the radar can be assigned to the camera images, where the basic information is indicated (e.g.: call sign, code number of S-mode, height, speed, etc.) in a label box, furthermore these labels would appear at the time when the airplane is not visible, nor displayed by the camera image, but the radar data are already available. Over the working sites, the certain zones out of use could be indicated, therefore the controller is not likely to direct an airplane there. Binocular function is also available, which simplifies the examination of the particular terrain compared to the traditional telescope function. The following one is just an idea, but with the help of virtual reality glasses (that was the starting point of technological research) and proper cameras installed at the important spots of the airport, the controller may reach an even better view on the situation, as if being in the position of the perspectives of the scene. Trying to save the space, I am not going to present pictures depicting these solutions, but in the quoted videos the mentioned functions are well observable.

Weaknesses

- *Errors are not acceptable:* this statement is certainly true for the whole of the air traffic sector, however, here I am referring to the fact, that the camera-datalink-display triplet should operate with a very low error-level to make the technology reliable for the experts, for the profession itself, and for the public opinion. It is, after all, not likely to happen that the human eye loses its contact with the human brain all of a sudden; something similar would happen in the case of losing visualization, consequently, this is that certain minimum level that must continuously work. This can be achieved with the proper defence of the airport[7], with data encryption, with the installation of spare components, with multiplying etc.
- *Distrust of the sector:* I have already mentioned the matter of trust/reliability before, now I am going into details. Fortunately, reliability is not denied because of any kind of accident or harmful event that would have happened earlier in the course of applying the technology. Simply, there are few people having close experiences with rTWR technology or spending enough time in the meantime of operation. It is a general human feature to be afraid of the unknown, or at least keeping distance with it. In time, however, with increasing application, and growing experience with the operation in the controller working position without hazards or accidents, reliability will also grow.
- *Early stage of the technology and the methodology:* at present we are talking about a young and constantly developing technology, the errors of which should be under constant repair. As I have already mentioned, for the time being, this technology has been applied in simple forms. Its operation under difficult circumstances, such as controlling several airports from one center, or controlling several airports from one controlling working position, has not been tested yet. I consider this the most significant weakness of the technology at the moment, compared to the traditional air traffic controlling. Visualization (out of conflict situation) seems to be stable, trust is growing, and human curiousness

[7] Csengeri, J. “Repülőterek távoli környezetének megfigyelési lehetőségei”. *Honvédségi Szemle* 143/6. 2015. 63–74.

is even increasing it. However, risks deriving from the young age of the technology are considerably higher than those of a conventional system, and, from this aspect, the Hungarian Defence Forces are not compelled to take any risks. It is acceptable to wait a few years until the technology is introduced, and in case the expectations are met, and further steps are taken successfully, the introduction of the technology will be highly advisable.

Opportunities

- *Cost-effectiveness:* this aspect has been referred to several times before. It is a very important factor from the point of view of an enterprise or an organization but it should not result in a lower level of general security in this case: the security of the airplane, what is more, the level should desirably be higher. Cost effectiveness, compared to the traditional tower controlling, is mentioned at several places[8] as the advantage of the system, but in the lack of tested multiple systems, it cannot be accepted clearly as strength, so for the time being, it remains an opportunity.
- *Neglecting the lack of building site:* compared to the traditional tower controlling, this aspect is considered also to be an important advantage, but there has been no case where it could mean a real advantage. That is, introduction of remote controlling instead of building a new tower on the territory of an operating airport, or applying rTWR instead of a tower facility at a new airport has not been the case so far. Still, the possibility is at hand.[9]
- *Controlling several airports from one spot:* as it has also been mentioned before, it remains merely an opportunity, too, as there has been no realization yet, but the tests and experiments are taking the technology to this direction continously. To reach a real high cost-effectiveness, this feature should be applicable in practice. This is the point where the Hungarian Defence Forces and the HungaroControl Hungarian Air Navigation Services Pte. Ltd. Co. are striving, that is to control the airports of Budapest, Debrecen, and Pápa from one spot.[10]
- *Traffic can be controlled from a safe centre on operating site:* personal safety in a conflict, on operating site is a factor of high importance[11], and it can be significantly increased with the technology in focus. Airports during conflicts, from technical point of view or because of the number of people present, are accepted as highly endangered facilities in

[8] Corte, L. and Füredi, E. *Demonstration Report. Project title: Budapest 2.0*. Budapest: Pildo Labs, 2017. 87.; Avinor. "Air Navigation Services-Remote Towers". Avinor. https://avinor.no/en/avinor-air-navigations-services/services/remote-towers/, Accessed on 01 April 2018.

[9] Vas, T. "The Remote and Mobile Air Traffic Control Tower and its Possible Application to the Operational Area". J*ournal of Defence Resources Management* 5/2. 2014. 147–152.

[10] "Stratégiai partnerségi megállapodás a korszerű polgári-katonai léginavigációs szolgáltatásért". Honvédelmi Minisztérium, Hungarocontrol Magyar Légiforgalmi Szolgálat Zrt. Budapest, 22 March 2016.; Paulov, A. "Feljegyzés-A Hungarocontrol Magyar Légiforgalmi Szolgálat Zrt. kutatás-fejlesztési projekttel összefüggő megkeresésről". Honvédelmi Minisztérium Hatósági Hivatal. 19-34/2016. 21 April 2016.

[11] Horváth, T. "Az IED hálózat, mint korunk egyik aszimmetrikus kihívása". In Csengeri, J. and Krajnc, Z. (eds), *Humánvédelem: békeműveleti és veszélyhelyzet-kezelési eljárások fejlesztése*. Budapest: Nemzeti Közszolgálati Egyetem, 2016. 275–298.; Horváth, T. and Padányi, J. "Műszaki eszközök a béketámogató műveletekben és a fejlesztés lehetőségei I.". *Katonai Logisztika* 14/4. 2006. 96–130.; Horváth, T. and Padányi, J. "Műszaki eszközök a béketámogató műveletekben és a fejlesztés lehetőségei II.". *Katonai Logisztika* 15/1. 2007. 68–86.

the case of asymmetric warfare (e.g.: in Afghanistan[12]) and even for powers at war possessing considerable air power. In order to be more effective in defending the "nerve center", the controlling staff should be placed in a safer facility[13], applying such a technology. To execute this solution, there are several possible options:

- air traffic controlling is carried out from the traditional tower, until some kind of air raid warning comes into action; as a result, the personnel are placed in the safe, possibly faraway facility;
- the controlling personnel ensure the control services continuously from the safe, and possibly faraway building (on the operating area);
- air traffic controlling is ensured from the traditional tower until air raid warning comes into action, and from then on, another controlling personnel ensure the services from a faraway safe facility (settled in the hinterland, as far as the operating land and the hinterland are not the same);
- without reference to the level of threat, certain personnel carry out the air traffic controlling, settled continuously in the hinterland, or maybe in a safe object.

To make air traffic controlling service safe and continuous with rTWR technology on operating site, it should be ensured that it is intensely protected and resistant against external impacts. It should be multiplied and protected not exclusively against the impacts of weather conditions or animals, but mainly against hostile actions[14]. To make the discussed technology applyable under such circumstances, we need even longer time than in case of civilian application opportunities.

- *Limits of human eyesight/attention may be exceeded:* the necessary solutions making the controller's work easier were discussed above at the strength section, but its effects should be mentioned here as opportunities. So, in case the conditions are given and they can be accepted as capabilities of the system, their effects should be interpreted merely as opportunities. As far as it is known, there was no case when an accident or an emergency had been prevented specifically by these devices. As long as such an event takes place, we may talk about this aspect just as an opportunity. However, it is a fact that the human eye cannot perceive aircraft in a distance, where radar data are already available and the system is able to display the arriving airplane (with the help of a label containing its data) on the screen, furthermore, with the help of advanced computer programs conflict survey can be carried out, calling the attention to situations or intersections, where aircraft may cross each other's courses.
- *Application of virtual reality:* rTWR technology started its way with these head-mounted devices, but later the direction of development changed because of the difficulties and restrictions appearing. However, it would be useful in the application of rTWR technology if the cameras installed at the important spots of the airport could create even better situational awareness for the controller, virtually simulating the perspectives of the given space.

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[12] Horváth, T. "Az ISAF Északi Regionális Parancsnokság felépítése, törzse és működése". In Boldizsár, G. and Wagner, P. (eds), *A Magyar Honvédség befejezett szárazföldi műveletei Afganisztánban: tapasztalatgyűjtemény.* Budapest: Nemzeti Közszolgálati Egyetem, 2014. 67–72.

[13] Csengeri, J. „Operation Allied Force – A NATO légi háborúja a dél-szláv válság megoldása érdekében 1.". *Repüléstudományi Közlemények* XXV/1. 2013. 114–125.

[14] Krajnc, Z., Ruttai, L. and Tóth, S. *A légi szembenállás alapjai*. Budapest: Zrínyi Miklós Nemzetvédelmi Egyetem, 1999.; Krajnc, Z., Ruttai, L. and Dudás, Z. "A légtér feletti ellenőrzés képességének szintjei". *Repüléstudományi Közlemények* XIV/2. 2002. 125–131.

- *More effective investigation in flight disaster cases:* while in case of traditional tower control it is merely the control and navigating stuff and the witnesses that can be interrogated regarding air emergencies or accidents, or some data (radio transmission, radar detection of movement, radar data on air space observation, meteorlogical circumstances, etc.) can be analized, in the case of a remote tower control motion picture is also available for analysis, which makes an investigation much easier.

Threats

- *Dependence on technology:* we can even refer to this point as dependence on maintenance, or defencelessness, because, as I have already stated a little jovially, visualization has been overcomplicated, thus it is not the human eye that gets the priority in the perception of the airport events but the cameras, and later on the visual data displayed on the screens arriving through the data link help the controller to get information about the events. This system, and also the supplementary servicing subsystems need continuous maintenance. Furthermore, we all know the everlasting commonplace saying: "If anything can go wrong, it will." All this creates a continuous real source of risk on air traffic controlling, as a service, and as a consequence, on air transport[15], too.
- *Vulnerability:* here, first of all, I refer to the physical vulnerability. This is quite an extended area with numerous directions of threat, which is too difficult to define exactly in detail for the time being. What is more, it is not necessary to damage the cameras to disable air traffic control; it is enough to cover the lenses. Cameras can be damaged by kinetic impacts, by bomb hits (direct or indirect), or by projectiles[16], even by direct abuse with manual tools, etc. Data cables can be cut, computers, and devices can be damaged after someone getting into the control centre. This sensitive system requires a very carefully developed, effective defence mechanism, to be reliably protected.
- *Virtual threats:* as we are talking about computer networks, it is inevitable to mention the dangers of cyber attacks, too. An rTWR system creates a closed network, and the connected services are also closed and encrypted, which is reassuring to a certain extent. But many proven IT devices (last time millions of Intel processors[17]) turned out to be carrying defence hazards, so the operators and users should be aware of the problems, must carry out continuous test and carry out progressive expansion.
- *Loss of capabilities concerning the acquired controlling capabilities:* this threat concerns the controlling staff. What I mean here is that the use of new solutions helping the controllers in their work makes previously evident professional skills incomplete[18]. I can share my personal experince concerning the topic: during the simulations of air traffic

[15] Csengeri, J. "Material Management and Transportation Procedures in Air Force Logistic Operations". Paper presented at Manažment – teória, výučba a prax, Liptovski Mikulas, 24–26. 09. 2014.

[16] Zentai, K. "Beszámoló 'A mesterlövész képességek új alapokra helyezése a Magyar Honvédségben' című kutatási téma keretében választott és kidolgozásra tervezett értekezésről". *Hadtudományi Szemle* X/2. 2017. 71.; Zentai, K. "Az információs műveleti képességek vizsgálata mesterlövészek alkalmazása során". *Honvédségi Szemle* 144/4. 2016. 80.

[17] "Súlyos sebezhetőség az Intel újabb processzoraiban". Origo. 22 November 2017. http://www.origo.hu/techbazis/20171122-intel-processzor-sebezhetoseg-frissites.html, Accessed on 01 April 2018.

[18] Csengeri, J. "A légierő specifikus vezetői kompetenciái, kialakításuk lehetséges metodikái, fejlesztésének javasolt módszerei a vezetői képzésben". In Krajnc, Z. (ed), *A katonai vezetői-parancsnoki (harcászati vezetői) kompetenciák fejlesztésének lehetséges stratégiája*. Budapest: Nemzeti Közszolgálati Egyetem, 2014. 83–94.

controller training, on the plotting board representing the Kaboul airport in Afghanistan, over the maquettes of aircrafts small flags showed the call signs, this way it was needless to remember them each, we just had to read them. After completing the training, when I started to work at Szolnok airport, first it was difficult for me to remember the call signs and associating them with the proper helicopter.

Similar casees may happen unless the controller candidate is "forced" to aquire this skill; watching continuously labelled aircrafts on the screens may reduce or abort the skills even of those who work with many years' experience in the profession, as well. Controllers should know the spatial restrictions in force on the working area of the airport without their being displayed on the screen and the same is true for the dimensions of runways and taxiways, their networks (their names, their junctions, how the aircraft can approach them onland, etc.) as well. Also, the controller should be able to perceive the irregular movement of vehicles on the working site, and the movement of animals, etc, as well,. During the training and work, these aspects should be dealt with in detail, enough attention must be paid to them, and we should remember to elaborate and maintain the traditional skills with the proper methods, too.[19]

SUMMARY

In the present article I shortly outlined the history of remote tower control technology. I demonstrated in detail the construction of remote tower control systems, the characteristics of certain elements, and I used several pictures as visual aids. I also introduced the conclusions of HungaroControl Hungarian Air Navigation Services, concerning rTWR, which allowed to review the main advantageous attributes and added values. Finally, with the help of SWOT analysis, I summarized the strengths, weaknesses, opportunities and threats of the technology in a chart, and I explained all the aspects, underpinning the written concepts with examples and with my own experiences.

The basic conclusion of the remote tower demonstration exercises is that the current level of technology is generally capable of providing the background for safe ATC service provision. However, to secure the continuous and safe operation from a remote tower facility, the visualization needs to be carefully fine-tuned to the local environment and the well-defined concept of operations.

As a medium size airport environment is considerably different from small airports where the benefits of the remote tower solution were first validated, the implementation has its special challenges. It should also be kept in consideration that the implementation at medium size airports has other motivations than that of small airports which shifts the emphasis from pure cost-efficiency motives to capacity considerations. Naturally, as the size and complexity of the airport environment grows, the implemented solution needs more customization to local characteristics. The implementation is highly dependent on local procedures and safety barriers and the deployed visualization should not be expected to make up for the weaknesses of those. The adaptation process is the key to the acceptance and success of the remote tower solution at such a scale.

[19] Szelei, I. "Hogyan motiváljuk beosztottjainkat?". *Humánpolitikai Szemle* 14/4. 2003. 34–45.; Szelei, I. "Motiváció, tudatosság, vezetés". *Hadtudományi Szemle* VIII/3. 2015. 204–211.

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