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The Military Specifications of Remote Control Tower Technology

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Abstract:

Nowadays the Remote Control Tower (hereafter RTWR) appears as a piece of modern ATM (Air Traffic Management) technology in many European countries, including Hungary. After a successful validation process at a medium-sized civilian aerodrome called Liszt Ferenc, co-operation began between HungaroControl[1] and the Hungarian Ministry of Defence concerning the introduction of the RTWR in the military environment. The author makes an attempt to determine the safety and the security aspects of RTWR in the military environment, its specifications for the handling of military air traffic and makes suggestions for further installations at given military airfields.

Keywords:

remote control tower, military aerodrome traffic, air traffic controller procedures, visualization, safety enforcement, enhanced technology

1. Introduction

Since the installation of RTWRs started at civilian aerodromes, their air traffic controllers (hereafter ATCO) have been gaining experience related to the similarities and differences between this new solution and the traditional one.

The traditional control tower is a unit which provides air traffic control service to all aerodrome traffic. Aerodrome traffic involves all traffic in the manoeuvring area and aircraft flying in the vicinity of the aerodrome [1]. ATCOs normally use visual contact for providing the service; eyesight can be aided by binoculars or electronically by radar. ICAO (International Civil Aviation Organization) recommends that the optimum tower site be as close to the centre of the manoeuvring area as possible. The tower cab should be built in such a way that aerodrome controllers be able to perform adequate visual surveillance and to distinguish aircraft from other vehicles, but the structure must not

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[1] *HungaroControl: Air Navigation Service Provider in Hungary http://en.hungarocontrol.hu*

be an obstacle or present a hazard to air traffic [2]. The aerodrome control tower must be equipped with radio sets providing effective two-way air-to-ground and ground-to-ground communication. It may occasionally be substituted by light gun signals to approve or deny any request by pilots or vehicle drivers. The control tower has to meet soundproofing requirements in order not to be hazardous or damaging to air traffic controllers. The layout of workstations provides an ideal human-machine interface, balance between the 'head down' and 'looking out of the window' view of the controller and close contact with the ground controller, flight data or the supervisor. The monitors in the control tower display meteorological data, the picture of the ASR (Aerodrome Surveillance Radar) or the SMR (Surface Movement Radar) and controlling the lighting system, the ILS (Instrument Landing System) and NAVAIDs (Navigational Aid System) installed. The layout also features the consoles for radio and telephone communication and desks for flight progress strips.

The procedures for aerodrome controllers [3] involve issuing information and clearances to ensure the safe and orderly flow of traffic and preventing collisions between aircraft flying within the designated area, including the traffic circuit. Aerodrome controllers are also responsible for ensuring safe clearance between aircraft operating in the manoeuvring area, taking off or landing, between aircraft and other vehicles, as well as between aircraft and ground obstacles. They continuously monitor all flight operations in the air and on the ground and their primary method is visual observation. Evaluating meteorological data allows them to select the runway in use. They must warn all air traffic of any hazards to flight safety. Transmission of information on local traffic can be based on visual observation, pilot reports and displayed information on integrated flight plan and SMR data, called ASMGCS (Advanced Surface Movement Guidance and Control System). During ground operations, it is also important to prevent collisions and runway incursions and to recognize any malfunctions or unsafe operations (fire, smoke, leaks, contamination, or FOD [Foreign Object Damage]) in time. Visual observation, integrated radar-based and flight plan data, and runway incursion warning systems together support controllers in providing prompt assistance in case of danger. Unusual or non-standard situations or conditions in flight (jammed gear, smoke, fire, sparkling breaks) must be recognizable by visual contact from the control tower [4].

The phenomena that can influence aerodrome operations in the short or long term (surface conditions, weather phenomena, maintenance work, bird hazard, etc.) must be continuously monitored. ATCO clearances are based on the known traffic situation, where identification is the product of the position reports of pilots and visual contact

Fig. 1a Real ATC tower [4]

Fig. 1b RTWR LHBP [5]

with aircraft from the control tower. ATCO can provide separation based on pilot position reports and their confirmation of traffic in sight. Separation can be time-based with regards to the different turbulence category of aircraft [3, 5], the track of departure traffic, the speed difference of aircraft [3, 5], the distance from a given point (runway threshold), or the type of operation.

The defining feature of the remote control tower is that the aerodrome controller observes the aerodrome traffic from a remote place and not from the tower cab of the aerodrome whose traffic they are responsible for. The remote control tower is available for providing air traffic control service for aerodrome traffic or for applying aerodrome control procedures. Moreover, it has the additional value of applications that enhance the controller's decision-making and situational awareness capability. The more traffic there is in European airspace, the more overloaded the airspace and aerodromes become. To handle the increased traffic without long delays, it is necessary to turn to innovative technologies, especially at aerodromes, which function as 'bottlenecks' of traffic flow. The technology of the remote control tower brings relief to overloaded airports, while maintaining the same level of service at low-traffic ones. It helps to optimize ATCO's human resource management and to utilize the available national network of airports, including military ones, whose mixed military-civilian utilization is getting more widespread in Europe. Due to the reasons mentioned above, the remote control tower may serve as a good solution to the problems stemming from increasing air traffic. Referring to the question of differences and similarities between traditional and remote control towers, the following answer may be given.

The main differences lie in the location and in the innovative technological solutions which enhance and expand the ATCO's situational awareness and decision-making ability. No deviations or differences in ATCO procedures are authorized because aerodrome control service should be provided with the same procedures regardless of where the controller is [6]. Before looking into the specifics of civilian and military applications, it is worth having a closer look at the components of the enhanced or augmented technology.

2. Enhanced Technology of the Remote Control Tower

Development of the remote (also known as virtual) tower technology started about 10 years ago in order to replace conventional or traditional aerodrome control towers with an advanced sensor technology. Developers combined the available VR (Virtual Reality) technologies, HD (High Definition) cameras and 3D (3 Dimensional) trajectories in order to serve the ATM systems of aerodromes. All developments were tested by controllers in simulated environments and in real-life traffic situations. The main goal of the technological development is to explore how to reproduce the 'out of window' view and to enhance the visual perception of the aerodrome controller. Focusing on the fact that the ATCO's primary tool is visual observation, experimental research started on the augmentation of the vision aspects, which resulted in the so-called optical see-through technology. This technology is known as a kind of HUD (Head Up Display), with an additional laser scanner application that is built in a head mounted device. The device, called HMD (Head Mounted Nomad Retinal Laser Scanning Display), provides information via direct image projection onto the retina by means of a laser scanner [7, p. 3-12]. In order to replace the head mounted device, researchers designed a holographic projection screen [8]. That solution enhanced the controller's view while providing more information without any head movement.

Fig. 3 Vision at low visibility conditions

Fig. 4 RTWR augmented vision [9]

2.1. Visualization

Visual perception and other visual cues are used by the tower controller to provide important support for the traffic under their responsibility and to ensure the required separation. The information necessary for providing ACS (Aerodrome Control Service) can be based on the map view of the aerodrome, the flight plan data, the alternative view of the aerodrome surroundings, and the display of camera system installed. There are many factors that should be taken into account when choosing the ideal visual representation, such as the size of the aerodrome, traffic density, operating flight rules, runway configuration, methods and procedures, and significant points of the aerodrome that influence the selection of different options. The ATCO in the tower uses visual information to ensure and maintain safe separation, to issue a safety warning if necessary, to perform a handover, and to make a decision or control judgement in case of any unsafe situation. It is essential to identify the area within which the controller uses visual information. It includes the runway(s) and the safety area, but it can be expanded to the traffic circuit and the reporting point of the CTR (Aerodrome Control Zone). The altitude in the traffic circuit most traffic fly at, the initial climbing area and the final approach path also influence the camera positioning, the angle of view and the focal length. The analysis of visual features [7, p. 56], which focused on finding out how the controllers use the improved camera technology, yielded the following results. The controllers were able to detect, recognize, and identify objects and judge their importance in the given environment. These included the following: flocks of birds of different sizes, animals (deer, dog, rabbit) in the manoeuvring area, vehicles, different types of aircraft, stationary or temporary obstacles, aircraft on the traffic circuit, condition of aircraft undercarriage, FOD, smoke, water, snow, clouds, types of precipitation, aircraft climbing / descending or going around. Visualization was augmented with thermal imaging technology [7, p. 211], which exhibits a significant sensitivity in the near infrared spectrum. In low visibility conditions and at night, this technology aids object detection and identification. In this way, the situational awareness capability of aerodrome controllers (Fig. 3) improves. It could be much more useful at airfields where there are no other electronic surveillance systems, like ASR, SMR or multilateration.

2.2. Object and Movement Tracking Technology

In order to improve visualization, mainly in low visibility conditions, and to minimize additional interaction, the aerodrome controller should focus on relevant information, using augmented vision techniques. Augmented vision means that object discrimination happens via 'optical or video see-through' systems. Integrated information on aircraft position can be obtained from the A/C (aircraft) transponder, and displayed in real time in video panorama with the radar label. The label contains the aircraft's discrete code, call sign, speed and altitude, flight track and position, and can be coloured according to the status of the flight. However, this radar-based information can be supplemented with co-ordinates of ADS-B (Automatic Dependent Surveillance and Broadcast), depending on the type of transponder. The high resolution of infrared PTZ (Pan Tilt Zoom) is able to detect moving objects by image processing. Movement detection and automatic object tracking are realized by hardware implementation of algorithms on FPGAs (Field-Programmable Gate Arrays) and software processing with a second processor. Detection relies on the combination of different criteria, like speed, texture, shape and colour. In case of the lack of electronic surveillance system, aircraft position can be determined by triangulation using the high resolution videos [7, p 176-179, p. 207]. The positioning of cameras depends on the path of the traffic circuit, length of legs and the distance which the aircraft should be recognized from. The optical flow analysis that helps to detect the objects by their motion supplements the human peripheral vision. The combination of the above-mentioned solutions results in the augmented vision on the video panorama screen (Fig. 4).

2.3. Screening of Video Panorama

During remote tower research, there were three different versions of video panorama view tested, with 360°, 180° and 200° screens. In the meantime, the 'video wall' solution was introduced only at LHBP remote control centre, which was built based on the aerodrome's characteristics and dimensions, the specifications of parallel runway operations and the layout of aerodrome. An environment and task analysis prevented the screening configuration in order to determine what sources of information were considered crucial from the controller's point of view and filter out the ones which are not relevant for ATCOs. A standard aerodrome control simulator displays a 200° view of the spherical surface, which imitates the out-of-window view, but it could be realized as a 180° panorama view with a reduced vertical perspective angle of 125°. The number of cameras helps to determine the vertical and horizontal FOV (Field Of View). According to the research, 10 cameras are needed to provide a 34°/190° vertical/horizontal video panorama of the airfield. The 360° panorama display contains 6 vertical displays for the 228° view and two horizontal displays covering 136° viewing sector FOV. This solution was tested at Braunschweig airport (Fig. 5). The video wall of LHBP remote control tower (Fig. 1b) focuses on the runways characteristics, the hot spots of the aerodrome and the busiest aprons [7, p. 88, p. 200]. An additional tool of advanced view could be the zoom function of PTZ cameras, which can better substitute for the binocular as a mounted vision of the aerodrome controller. This solution does not distract the controller's attention from the workstation displays and other parts of the panorama view, but zooms in on the selected aircraft or object they want to focus on.

2.4. Working Position Optimization

The optimal ATCO's working positions should meet the requirement of easy adaptability. The more familiar the working environment is, the easier it is to do routine and ordinary tasks and follow aerodrome procedures (Fig. 5). In a tower cab, and even in a remote control tower, the layout of the workstation depends on the level of aerodrome service, and the size and turnover of the airport. According to international standards and recommended practices [3.7.1.1.3], the following working position may be established: aerodrome controller, ground controller, clearance delivery and flight data assistant. Depending on the above mentioned criteria, these positions could be reduced to executive and planning controller. In that case, the executive controller is responsible for direct controlling tasks, and the planning controller, who is also aware of the traffic situation, contributes to coordination, manages the work of executive controller and answers to ground line calls on radio or telephone [7, p. 94-113.]. The ideal workstation is equipped with a generic approach radar application, a weather display, flight progress strips (paper-based or electronic), radio, consoles for indicating and handling NAVAIDs and lighting system and the monitors providing out-of-window view for the controller. The composition of the optimized workstations should meet the requirements of feasibility, acceptance and usability. At the same time, all displayed information appearing in front of the controller should be organized and indicated in a way that allows the controller to reduce the 'head down' time but obtain more information at the same time.

Fig. 5. 180° and 360° panorama view of RTWR CWP [10]

3. Introduction of a Couple of Aerodromes with Remote Control Tower

3.1. Örnsköldsvik Airport, Sweden

This airport known as the first place where traffic was controlled from a remote place is in the northeast of Sweden. Remote aerodrome controlling is conducted from Sundsvall ATM centre, 150 kilometres away. After successful validation, more than 4 000 aircraft have been managed by remote technology since 21st of April 2015. This airport, as expected, is small because the daily traffic count is under 30 [11]. It has only one 2 016-metre-long runway, one taxiway and 3 aprons [12]. The camera system provides a 360° panorama view, and makes it possible to cope with difficult light conditions much better than before. The system adjusts the images automatically when there is direct sunlight or snow reflections [13]. At Sundsvall ATM centre, the ATCOs can monitor the aerodrome manoeuvring area and its vicinity on 55-inch displays. The idea of handling multiple airport traffic came up after the success of Örnsköldsvik; that is why, from the beginning of last year, additional airport views have been integrated into the Sundsvall ATM centre. All of them are small with low traffic density, so the LFV's[2] next goal is to achieve that one ATCO be responsible for traffic at more than one aerodrome at the same time, with safe and innovative technological support [14].

[2] LFV: Swedish Air Navigation Service Provider http://www.lfv.se/en

3.2. Liszt Ferenc International Airport, Budapest

The air traffic control tower of the airport was built in 1983 and it is obsolete, which has caused aerodrome control service suspension twice recently [15]. In the beginning, the concept was to establish a contingency tower solution, as it works in London Heathrow, which would be able to take over all responsibilities in case of unsafe operations at the aerodrome control tower. According to the first objectives, the RTWR should work with 70 % traffic capacity, with regards to the restrictions of LVP (Low Visibility Procedures) operations. At that time, the airport is able to work only on the base of ASMGCS and without visual displays and window views. Moving on to creating an optimised aerodrome view, the main challenge was to find the best solution for the parallel runway configuration airport, ideal hot spots pictures and an optimised view. The airport handles 100 000 movements a year, which corresponds to medium-sized airports. It has two terminals with two separate aprons at different locations. The traffic consisted almost exclusively of IFR departures and arrivals and the local aerodrome traffic of vehicles. The pictures of the distributed camera system were displayed in a matrix structured video wall (Fig. 1b). The CWPs (Controller Working Positions) were modelled on an ordinary aerodrome controller environment that the ATCOs were already used to. They were equipped with additional functions of hot spot view, integrated labels of ASMGCS to video wall, better visual surveillance in LVP and night conditions, enhanced runway edge lighting and zoom function. Although the remote control tower is not as far from the airport as in the Swedish example, it requires the same solution. Moreover, due to the airport layout and traffic complexity, the establishment required new ideas of the available technology. On 14th November 2017, the remote control tower of Budapest was introduced after successful validation and was ready for operational use in case of a contingency situation [16]. The remote tower project has not finished yet, because additional plans are underway thanks to the SESAR[3] 2020. The project is targeting the implementation of modern ATM technologies even in the area of remote tower solutions. The aim of HungaroControl is to extend the one-airport remote control tower to a multi remote control centre, from which two more civilian airports (Sármellék, Debrecen) would be controlled and one military airfield would be monitored [16-17]. Both civilian airports handle seasonal traffic, have a corresponding size and are located more than 100 km from Budapest, where the centre is. Both of them have a single operational runway, four taxiways, use two or three aprons, are equipped with ILS and have experienced 2-3 % growing trends [18]. We will now turn to the military airfield and examine why it was selected and what kind of challenges remote controlling technology may face in the military environment.

3.3. Pápa Military Airfield[4]

The military airfield in Pápa was offered to have the RTWR installed for the purposes of the multi-RTWR project of HungaroControl. Located in western Hungary, it was reconstructed and reactivated to serve air operations in 2005, following a four-year-long shutdown. According to the law, the airfield is available for military traffic, but thanks to the different letters of agreements with aviation companies, periodically civilian traffic is allowed to land, depart or complete training flights there. The layout of the manoeuvring area is much like a typical “Warsaw-treaty” military home base of fighter

[3] SESAR 2020 http://ec.europa.eu/research/press/jti/factsheet_sesar-web.pdf

[4] Airfield: military counterpart of airport

aircraft. It is a single-runway airfield with narrow track line taxiways, which are perpendicular to the runway. There are five taxiways and eight aprons, and a separated helipad for the SAR (Search and Rescue) service. There is ACS (Aerodrome Control Service) provided for aerodrome traffic in published MCTR (Military Aerodrome Control Zone). The airfield is opened for IFR (Instrument Flight Rules) traffic owing to the different established equipment like ASR, ILS with a CAT I. lighting system and VOR (Very High Frequency Omnidirectional Radio Range) [19]. But most air operations are completed by VFR (Visual Flight Rules). Aerodrome controllers basically use visual observation for the provision of service. According to movement numbers, which is about 7-8 000, it is considered a small airfield. The traffic peaks usually coincide with the time of international military exercises, when a number of different types of aircraft are located temporarily at the base and hundreds of movements happen within a few days. Domestic traffic involves several C17 heavy aircraft and SAR helicopters [20]. The airfield occasionally has handled civilian traffic, like medium jet and turboprop air transport aircraft, light business jets and light training aircraft that complete training flights by the agreements with civilian operators. The airfield is continuously under development, the runway is going to be extended to 3 000 m, which enables the airfield to accommodate heavier-than-C17 aircraft. The airfield is located in a mountainous area, close to the connection of the Alps and the plain called Kisalföld, and its geographical location influences the weather phenomena of the airfield. Among them it is worth emphasizing the orographic effect, which influences the air flow and the moderately cool and wet climate, whose combined presence is responsible for the cloud formation and the huge amount of annual precipitation [21]. There is no large water surface near the airfield which could affect the weather. The prevailing wind is from the northwest, but southerly wind may also gust, even at low speed. Marginal crosswind component frequently exceeds the limits, which causes problems for different types of aircraft at the airfield. Low level ceiling and reduced visibility conditions mainly occur in winter, which seriously restricts flying at the airfield. While reduced visibility occurs in winter the odd morning starts with haze and the best conditions with more than 5 000 m visibility usually are usually obtained in June and July. The above-mentioned weather characteristics could also be important for the installation of the camera system and the view sight [22].

4. Specifications of the Military Traffic

The features of the above-mentioned airports have many similarities in ATCO procedures and the layout of the manoeuvring area, but they also have some differences, mainly in the nature of traffic. It includes its density and distribution, different types of aircraft whose V_{AT} (Speed above threshold) ranges from A to E[5], and their landing configurations may also vary. During the RTWR installation, it is worth considering the landing procedures that include tactical elements, the features of the formation and splitting procedures, parachute dropping procedures, NVD (Night Vison Device) operations, flare engagement and RPAS (Remotely Piloted Aircraft System) flights. In the following chapters, these procedures, as well as factors which can influence installation of a RTWR system, will be examined [20-23].

[5] ICAO Doc 8168 PANS OPS Aircraft operations, Volume I. Flight Procedures;

4.1. Traffic Density and Distribution

This military airfield is small according to the system-based approach of SESAR [11], but its annual 7-8 000 movements are distributed unevenly. Therefore, it makes sense to consider the busy hours of the airfield according to Annex 14[6]. This approach of aerodrome traffic density could yield that the heaviest traffic occurs at least twice a day, with 26-aircraft peaks per runway and 35 or more aerodrome movements within an hour. The busy hours of the aerodrome usually fall in the early hours of the day, when the traffic diverts to ROZs (Restricted Operation Zone), and late hours, when they return to the base. While fixed wing operations are counted as runway occupation, rotary wing aircraft are able to land and depart from taxiways and stands, and often do so in formation [22].

4.2. Speed Difference above the Threshold (V_{AT}) *and Tactical Procedures*

The different V_{AT}'s of aircraft are closely related to the applied procedure of air operation, approaching altitude and type of landing. Aircraft categorization by V_{AT} is relevant for planning the runway in use, longitudinal distance between aircraft in case of reduced runway separation. It is also relevant for preventing runway incursions with keeping safe distance from the approaching and departing traffic of the runway. It has an important role mainly in case of reduced visibility when the weather minima drop under VMC (Visual Meteorological Conditions). The other point we should take into account is the features of tactical flight manoeuvres. The first one is the low level flight of helicopters. It may be completed in formation or solo at the height of the trees, and the appearance of aircraft can be expected from any direction, thanks to low approach speed easily manoeuvring within limited airspace. These flights are sensitive to turbulence in the air and on the ground. Another tactical procedure which has markedly different characteristics is called high key procedure. It usually starts with a high speed approach from the threshold. After approaching to overhead, the aircraft still remains high above the ground, then cutting the thrust completes a key turn back to the base leg and turning to the short final for the landing runway. This procedure is completed in short time, in extended vertical and reduced horizontal space in the vicinity of the runway. This tactical procedure has other configurations, which are named as the low key, the beam approach and the teardrop (270°/90°). The difference between them is in the direction of approach and the level above the ground. In order to observe and monitor the tactical procedures, panorama view with expanded horizontal view angle for overhead manoeuvres would be the ideal solution. At the same time, it is important to monitor each approaching direction from the reference point of the runway at low and high level. The significance of formation flights from a MATCO's (Military Air Traffic Controller) point of view lies in the timely observation and identification of the group of aircraft, the position of the leader, and the expected splitting procedure. The splitting procedure requires timely ATC clearance, its compliance based on strict instructions and reports of the pilots on radio. For observing this procedure, it is also important to focus on the horizontal area of the runway [23, 24].

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[6] ICAO Annex 14 Aerodromes Volume I Aerodrome Design and Operations Seventh Edition, July 2016, definitions

4.3. Parachute Dropping and Aerobatic Flight Procedures

This procedure is characterised by the horizontal flight path of the parachute-jumpers or cargo, with restricted manoeuvring capability and normally low speed. Compliance with and observation of this procedure also involves safety factors. The first one is the aircraft transporting the cargo or paratroopers, the time of dropping (day or night), from different levels, usually not lower than 2 000' but could be completed even from FL145 (14 500 feet). Dropping starts with the approval of MATCO, who is responsible for keeping the airspace and the runway area clear of aircraft, until the paratroopers have safely landed. The MATCO works in close cooperation with the jumpmaster in checking the paratroopers, and this procedure requires continuous observation of the runway, the landing zone and the overhead area. The MCTR of the airfield is authorized for parachute dropping with safety restrictions, and also for other unusual flight operations, like aerobatic flight. The similarity of this operation lies in the observation and required MATCO approval, but continuous monitoring is influenced by sharp turns, dynamic climbing and diving manoeuvres [25].

4.4. NVD Procedures

Training flights with NVD are for practicing hidden approach and landing at airfields or in unprepared areas, where runway lighting system is not installed, or camouflaged due to security reasons. During this practice, the aircraft itself remains hidden, because it flies with navigational and anti-collision lights switched off. However, in peacetime it is allowed to switch the transponder on, which indicates the position of the aircraft, but it does not provide reliable information at low level, so the aerodrome controller can't use it for issuing ATC clearances. During NVD practice, the tower building should remain dark, or with only the security lighting system in operation. On the one hand, from the MATCO's point of view, the ATC procedures could be the same as applied in LVP because the aircraft and even the runway are not in sight. This procedure requires extended separation and cautious methods for checking the positon of aircraft in the air or on the ground. On the other hand, the MATCO has to be prepared for any disturbance, and take actions to keep unauthorized aircraft away from the airfield and keep unauthorized vehicles out of the manoeuvring area. In case of NVD formations**,** the MATCO should keep them in sight for safety reasons and it is also important to check the runway because in the dark wild animals could appear randomly within the RESA (runway and safety area). During NVD operations, MATCO can take advantage of the infrared view of RTWR, which makes aircraft and airfield obstacles visible, and thanks to target tracking, each movement at the airfield becomes traceable. The lights in CWPs of remote centre may remain in normal operation, because they are not disturbing the pilots directly.

4.5. Engaging Flares and RPAS Operations

The flare or decoy flare is an aerial infrared countermeasure used by a plane or helicopter to counter an infrared homing ("heat-seeking") surface-to-air or air-to-air missile. Landing aircraft are more exposed to the risk of missile attacks. The flares can be engaged automatically by the effect of any electronic radiation; even the ASR may activate it, but it can also be engaged manually. That is why it is important to switch the flare engagement into manual position when the aircraft is approaching the airbase. The engaged flares may cause fire, burnt pieces of flares are considered FOD on the runway that could endanger the safety of aircraft. From the MATCO‘s point of view, it is important to call the pilots’ attention to safety procedures, register flare activation and check the runway surface so that the airfield can remain operational.

RPAS operation in the vicinity of the airfield is a sensitive question of aerodrome safety. According to Eurocontrol[7], the RPAS is the system within which the pilot is able to negotiate with the MATCO, and the only one among UASs (Unmanned Aircraft Systems) which could be integrated in the conventional ATM system and ATS (Air Traffic Service) airspace[8]. On the one hand, RPAS may seem like aerodrome traffic; on the other hand, if we are talking about unauthorised UAS (commonly known as drone or model aircraft) activity in the vicinity of the aerodrome, it threatens the safety and security of aerodrome traffic [22]. According to Hungarian state aviation regulations, military UAS flights are allowed to operate in MCTR, but due to the absence of detailed rules of operation and MATCO procedures, the rules for simultaneous manned and unmanned flight operations have not been established yet. Theoretically, if we view the RPAS as part of aerodrome traffic, the same MATCO procedures should be applied. If it is considered a threat to air operations, its detection through the RTWR would be preferable, and through alerting responsible services, countermeasures could be taken [25].

5. Questionnaire Research

The installation of the RTWR at the above-mentioned military aerodrome has raised the interest of the researchers and cadets of the Institute of Military Aviation of NUPS in the new technology [26, 27].

A questionnaire was designed to analyse the experience gained by civilian ATCOs in Budapest and to articulate the expectations and opinions of military ATCOs regarding RTWR.

There are two questions that we expected to be answered by the questionnaire research:

- Whether the application of the RTWR will enhance ATCO’s situational awareness and decision making.
- Whether the RTWR can be fitted into the existing military ATM system.

The questions were focused on three main topics: enhancing safety, human aspects and system security. The questionnaire was filled in by 27 ATCOs two of whom serve at a military airbase. The civilian respondents are part of the aerodrome controller team at Budapest Ferihegy, while the two military respondents who had been selected for the pre-installation simulation experiment are among the nine controllers serving at Pápa Airbase.

Questions related to enhancing safety aimed at finding out which is the preferable view version of the aerodrome manoeuvring area for MATCOs and what is the reason for their preference. Answers to Question 1 regarding visual representation justified our assumption that the “layout”, the traffic and the special procedures of the military aerodrome require a different visual rendering to the one which is applied in the civilian working environment. 80 % of the respondents marked the video wall and only 7 % opted for the 360° panorama view, and the rest marked other options. As most of the

[7] European Organization for the Safety of Air Navigation; https://www.eurocontrol.int/

[8] ICAO Circular 328 Unmanned Aircraft Systems (UAS)

civilian respondents decided to use the video wall option, we can conclude that their choice was justified by the factors mentioned above.

Question 2 was: “What factors justify the choice of the preferred view version?” The answers to this question were the following: runway configuration, traffic density and volume, a large number of VFR traffic, a large number of IFRs, the number of airport hot spots, the number of taxiways and the visibility of the aerodrome manoeuvring area. Most civilian respondents indicated the visibility of the aerodrome manoeuvring area (13-50 %), runway configuration (6-23.1 %) and the number of “hot spots”(5-19.2 %) in their response. The fact that at Budapest airport there are parallel runways, which should be displayed together with the visibility of the aerodrome manoeuvring area, explains the selected answers. Among the areas mentioned in the answers, those ones have to be placed in the controller’s focus that are important from an aviation safety point of view, like “hot spots”, this way reducing the journey of the controller’s view between the presented information, like arrivals, departures, meteorological data, and strips. The military respondents put their vote for the 360-degree display and answers to Question 2 included the option of large numbers of VFR traffic (2-7.7 %). As Pápa Airbase is a single-runway aerodrome with taxiways and aprons located east of the runway, but most traffic is VFR and their special procedures can be carried out only in VFR, the controller’s gaze travels a greater distance in the aerodrome airspace than in the manoeuvring area, which can be a reason for the choice of 360° visualization.

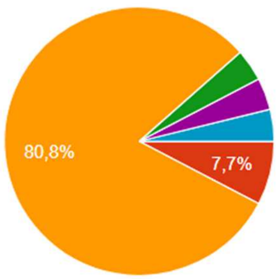

Fig. 6a Answers for Question 1

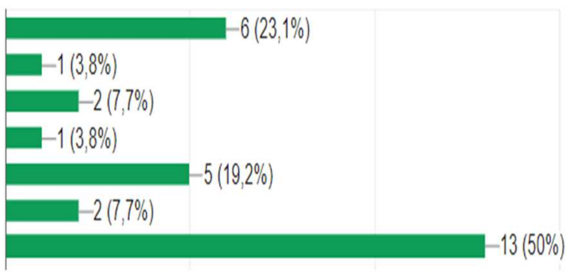

Fig. 6b Answers for Question 2 [27]

Highlighting Question 5 (Which application provides the most useful presentation of the hot spots), the majority of respondents, both civilian and military controllers, selected the zoom function and the separate visual representation.

In the second part of the questionnaire, which deals with the human aspects of RTWR, we sought to find out how the changed working environment influences the workload of controllers. This part of the questionnaire contained statements where the extent of agreement with the statement is displayed on a scale of 1 (smallest) to 5 (greatest). Answers from the military participants are based on experience gained exclusively from the simulation environment. From this section of the questionnaire**,** the following two statements are worth highlighting. To the first one (“It is hard for me to get rid of my old habits like automatically looking up or standing up and checking the part of the aerodrome from where the call came”), 51.9 % of the respondents agreed, including the military participants The other statement related to the importance of perception to the controller habits. Remote control can be exercised from a noise-free room far away from the effects of the airport environment. 55.6 % of the respondents agreed with the statement: “Engine noise, kerosene odour, rain knocks and other environmental influences are important to me because I "live together" with airport traffic". The evaluation of the results showed that most of the respondents adhere to their habits, drilled movements and reactions. The answers related to the human aspects of RTWR application also show that the ATCOs mostly share the same opinion. The human factor is always considered (to be) the most sensitive area because most people have doubts and feel discomfort about changes.

The third area of the research aimed at the weak points of the RTWR system and sought to find out how secure ATCOs think it is. Question 1 was, "Which part of the RTWR do you think is the most sensitive from a system security point of view?" Most of the people marked camera and workroom connection (48.1 %), camera and flight data integration (22.2 %), camera and radar integration (18.5 %), radio connection (11.1 %); two marked the transmission of meteorological data and the transmission of electronic strips.

Taking into account the fact that the release of RTWR technology can be a new target for aviation security offences, the following question was formulated**:** "What type of unlawful interference do you think represents a greater risk of being committed against RTWR at your aerodrome?" Most respondents indicated a risk of intentional damage to the data link cable (51.9 %), blinding the camera with visible light (14.8 %), interfering with laser (18.5 %), phishing, encrypted connection decoding (11.1 %).

Most respondents stated that the security of the data link is the most significant issue in the application of remote controlling technology.

6. Conclusion

The aim of the author was to present the advantages of RTWR and its future applications in a new environment at a military airfield. The literature reviewed on remote control towers helped the researchers get acquainted with the advantages of the new technology and provided useful resources for formulating our expectations concerning military installation. The most important lesson learnt is that the main pros of the RTWR is its adaptability to ATCOs needs. The questionnaire served as a useful guide to further research which will focus on military controllers and the system installation at Pápa airbase. The answers to the questionnaire confirmed that the 360° display would be preferable, mainly due to the special procedures of military traffic and the equipment and devices that have been installed at Pápa military airbase. Results also could be useful for choosing the best option for the observation of the hot spots and significant areas of the airfield in the air and on the ground. It helped to emphasize the importance of the perceptions of each controller. Finally, it helped to realize what risks could threaten the security of the system and, consequently, flight safety.

The aim of further research is to identify the best options for the special military environment, which consider the location of the airfield, its particular weather phenomena and climate, and the specifications of handling military traffic. The paper contains those factors that should be focused on during the system installation, like the area of surveillance, the hot spots of the aerodrome and the significant points of the vicinity of the airfield.

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