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RELEVANT TASKS FOR UAV PROTECTION SYSTEMS IN RELATION TO THE AERIAL SCENARIO OF NUCLEAR FACILITIES

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Abstract: The goal of this paper is to present the risks that Unmanned Aerial Vehicles (also called Drones) pose for nuclear facilities. The technologic advancements of these unmanned aerial vehicles are one of the most dynamically evolving industries currently; which while through the growing widespread and numerical increase represent many advantageous usability, are also starting to pose an ever-increasing threat. An increasing number of cases get reported when UAVs violated the airspace and security of critical infrastructure facilities. The paper includes a technological overview of the UAVs, their use-cases and a discussion of the security risks they represent. In order to present the actuality of the topic, the recent nuclear power plant endangerment incidents committed by drones and the properties of drones that represent a potential source of danger are detailed. Additionally, the physical protection technologies of nuclear power plants are discussed; also, the importance of capabilities for the detection, delay and neutralisation of drones. In the final chapters we present our conclusions and suggestions.

Keywords: Umanned aerial vehicle; Nuclear facility; Anti-drone systems; Risk; Defences tasks.

1 INTRODUCTION

The global threat of terrorism has elevated to new levels after the 9/11 terror attacks on the U.S., and it gave rise to new concerns about the risks of a terror attacks on nuclear facilities. If we take into consideration the significant effect they have on national moral, economy and power safety - these facilities can be a very tempting target for terrorist groups. Though the paramount objective a terrorists group can achieve with an attack on a nuclear facility which makes it even more tempting is global new coverage. Attacks on nuclear power plants (NPP) not only have the potential for nuclear endangerement of the general population, but can also greatly damage the power supply and the economy with it (49,2 % of Hungary's power generation is realized in the NPP of Paks for example) [1]. The fact that there were more then one occassion of airspace violation of airs spaces of NPPs by drones in France in recent years shows us, that the risks are all too real and the threat is serious. Not only does it gives reason for worry that these drones could perform this act, but the fact that the competent authorities could not find an answer on how these incidents could happen or prevent them from happening is even more worrisome. Political leaders around the globe have noticed these problems. In spring 2016 there was an international nuclear security meeting in Washington D.C. where David Cameron british prime minister have said that in his opinion the terrorists will utilise any tools and equipment they can get their hands on to achieve their goals. [2] Trusted sources have confirmed, that two terrorists organizations – the Al-Queda and the AumShinrikyo (Japan) have already attempted to acquire nuclear or radioactive material or weapons. Other sources have confirmed that Chechen terrorists groups have performed reconassiance missions on russian nuclear weapons depots, and as part of the nuclear arms initiative of the Al Queda they have tried to purchase nuclear material and recruit nuclear expertise to their ranks. Amongst the plans for the 9/11 terror attacks was the plan to attack a NPP also. In the databases of the Interpol counter-terrorism unit one could find 167 cases which involved nuclear material in the three decades between 1970 and 1999. Between 1966 and 1977 there was 10 attacks in Europe which were performed against power plants or related infrastructure. Based on reports of the russian intelligence services 50 of such cases were registered in the Russian Federation. In the October of 2005, chechen insurgents have attempted to hijack airplanes and planned on attacking russian targets with them - and amongst the targets was one NPP as well. 240 cases of attacks were registered in the U.S. in the time period of 1967 – 1975. In a report published in 2005 January 40 cases were published of endangerement of the safety of NPPs in the United Kingdom. The sabotage action committed against the Belgian Doel 4 reactor in 2014 was performed by an insider who have – by opening a simple valve – released all the machinery oil from the turbine of a reactor, which lead to it overheating and becoming irreversibly inoperable. Even though there was no risk of radiactive endangering, the losses of the forced downttime and repairs were 100-200 million U.S. dollars. In 2016 both the identity of the saboteur, and possible motivations were still mistery for the authorities.

Based on these cases it can be concluded, that the threat of terrorism targeting nuclear facilities is real and be verifyed. One emerging tool for these attacks are the utilization of drone technology. The evolution of drone technologies gives rise to the need for the evolution of counter-measure technologies. The drones are usually flying equipment, that can either be autonomous or remotely controlled (or combination of these), there is no need for an on board pilot. The reason behind drones becoming a more competent equipment for threat actors can be

traced back to more then one reason. Firstly the price of commercial drones have plummeted in recent years and are easily accessible for any ordinary customer. The drones range and velocity greatly increased, their operating time is ever increasing; furthermore their carry capacity increases as well. The few tens of meters operational range of early commercial drones have increased to 12 km with for example the new Occusync 3 system. [2] Their cameras are capable of taking higher resolution pictures and videos and their navigational precision can reach the cm precision thanks to for example the RTK (real-time kinetic) support. Disguised drones which are only a few grams in weight are available too. Some commercial drones are also capable to carry weapons or equipments for diversion. Their utilisation in case of an attack can be dual therefore; they can both to perform preliminary reconaissance or to take active part in the attack. Hybrid drones that can traverse both in air and water can pose an even more worrying threat. The reason for this concern is that most of the nuclear reactors around the globe are built next to large open waters because of technology reasons (most are either bioling water or pressured water reactors). On the defense side we can see that NPPs are only capable to detect large airborne vehicles.

2 ANTI-DRONE MEASURES OF HUNGARIAN NUCLEAR FACILITIES

The advancements in technological capabilities and the increase in popularity of commercial drones have created a new regulational challenge. The drones don't only pose a security threat for nuclear facilities like nulcear power plants, research reactors and nuclear waste depots but can be also utilised in many industries for great effect. They could also perform many roles in the nuclear field, such as support of operations, security or monitoring and measurement for environmental protection. [3] When discussing the protection of nuclear facilities one must also mention nuclear security, since the protection of the airspace will be considered a part of it. Nuclear security is the whole of activities, equipment and procedures which are utilized for the goal of prevention, detection and repelling of sabotage, deliberate damage or misappropriation of radioactive material. We must point out though, that airspace violation of a nuclear facility could also happen with no intent on causing damage, with motivations to protest or as a „rite of bravery", or simply by accident. Taking the potentional risk into consideration and that the intents of the violation can only be evaluated much later any airspace violation has to be considered an active threat for the facility. Security issues related to UAVs are complex and risk assessments require consideration of wider aspects, such as societal, psychological, political and financial factors. [4] UAV risk assessment therefore is a very important tool for thorough identification and evaluation of active and hidden risks. The evaulation of these risks have to propose possible risk mitigations on how to decrease the likelihood of threat events and their effects. With these results security risks become measurable and can be mitigated systematically. The sub-procedures of a risk assessment are: identification of risks, risk estimation, mitigation, documentation. [5] The phyisical protection system has to provide the functions needed for detection, deterrence, delay and repelling while they have to effectively support physical protection goals. The goal of deterrance is to convince the perpetrator to give up his pursuit of a sabotage or misappropriation early in the planning phase of the attack. During the action of the detection capability the actions of the perpetrator have to be detected, the detection has to be verified, identifying the location of misdemeanor and to alert reaction units. The goal of the delay funcion is to increase the time needed for the perpetrator to successfully reach points in his attack, giving time for the reaction units to intercept in time. As part of the repel function the reaction units prepare for action after they received an alert, reach their destination for interception, and impede and neutralize the perpetrator in accordance with the goals of physical protection. In most European countries most nuclear facilities are classified as critical infrastructures in accordance with the European Union directive on protection of EU critical infrastructure We feel it necessary to clarify the meaning of critical infrastructure at this point. Critical infrastructures provide the necessary continuity for the industry, like power supply, personnel and goods transportation, or the financial sector. After long, domestic critical infrastructures have been identified in Hungary as well, with the 2012. CLXVI. act, though nuclear facitility's nuclear safety, radiological protection, physical protection and safeguards were exempt from the list in the 1st annex. Therefore even though NPP of Paks holds a key role in hungarian industry and the potential consequences of a nuclear catastrophe it is not classified currently as critical infrastructure. [6],[7] It is in the very best interest of the hungarian society and industry that the NPP of Paks can operate safely and continuously. It was realised that it is not enough to evaluate only to the extent of military operations or terror attacks, but the potentional threat to endangerement of power generation have to be taken into consideration as well. It is of importance to protect those objects that, if damaged, though don't pose a threat to nuclear safety, but can lead to loss of production in one or all power units. Since NPP of Paks provides 49,2% of hungarian power production, such loss of production could have significant effect on the economy. Airborne weapons of destruction or attack groups therefore present an elevated threat, since protection strategies provide greater protection for a ground based threat. The primary objective of a theoretic attack doesn't need to be destruction

solely, it can also be reconaissance, to cause panic, to provoke political and societal effects through news coverage which could greatly deteroirate the safety perception and trust in the government and state authorities of the general population. [8]

The parameters of the required protection against airborne threats are defined in more than one domestic legislative document. The basic requirements for the physical protection systems are defined in the 1996. CXVI. act on Atomic Energy. In the 4/A. § c) it declares that the primary responsibility for the safety of a nuclear facility belongs to the organization which is the licensee of the nuclear facility or activity. The detailed regulations, containing requirements for the DBT and the Physical Protection Plan can be found in the government decree 190/2011 (XI.19.) on physical protection requirements for various applications of atomic energy and the corresponding system of licensing, reporting and inspection. The requirements for the operation of armed security guards that protect the facility requirements are set in the 1997 CLIX. act on armed security guard services, nature and field guard services and in 27/1998. (VI. 10.) Ministry of Interior decree on Operations and Service Code of armed security guards. Neither of the aforementioned legislations deals with the ways how the personnel performing the protection of the facility could act against airborne vehicles and equipment, nor by the possibility to distrupt their flight nor to open armed fire on them.

During evaluation of the possibilities of airborne terrorist attacks it is important to take into consideration both the level of control of the affected airspace and the set regulations for the use of that airspace. Airspace of the Hungarian Republic can be divided between „controlled" and „un-controlled" areas. In the controlled airspaces an authority is responsible for it and for authorizing passage in it if someone wishes to use that airspace. Armed protection of the hungarian airspace is the sovereign right and obligation of the Hungarian Defense Forces in accordance with the 36. § (1) a) of the 2011. CXIII. Act on Hungarian Defense Forces and on applicable actions in case of special legal order. Amongst the nuclear facilities of Hungary, the NPP of Paks has a 3 km radius and up to 5950 meters in elevation to ground level airspace, named LHP1 which is a no-fly zone deisgnated in the 26/2007 (III. 1). GKM-HM-KvVM joint decree on designation of airspace for airtravel. This decree has been modified in 2018, which allowes flight in this zone during peacetime with special authorization by the ministry. This no-fly zone is very important for both nuclear security and for the avoidance of a nuclear accidents caused by accidental airplane crashes. The HAEA have suggested earlier to extend the radius to 15 km around the facility. The authority reasons this would result in the increase of the timeframe available for detection and to repel an attack. The fact that if you consider the current 3 km radius zone, if an object with 180-200 km/h velocity enters the no-fly zone it reaches the facility within 1 minute proves the viability of such suggestion. This velocity can be reached with current drone technology and this has to be a consideration when calculating required reaction times. On the other hand, such measure could prove to be a difficulty for the surrounding settlements and could cause a significant financial burden.

Nuclear catastrophe could occur as a consequence of an accident and a terrorist attack as well. Reactor accident are usually caused by the deprivation or decrease of coolant material in the reactor. In this case the criticality of the fissive material reaches levels that could result in uncontrolled chain reaction. This can lead to radiological exposure of the environment which exceeds the safe levels multiple times. The consequences in case of stolen or lost radiation sources which don't have control by the authority depend on the activity, condition and position of the source and the time of exposure. [9] As we mentioned earlier, most of the commercially available drones are 800-1500 grams in weight, therefore they don't pose a kinetic threat to the facility. Greenpeace have ordered a paper on the risks drones represent to NPPs from a consultant company, which have found that even these low-kinetic, lightweight drones could damage small, vital parts of a facility that could result in nuclear accidents of the magnitude Fukushima represented. For this, during an attack the first wave has to target the coolant supporting systems which are usually outside of the main structure, while a second wave should target the diesel generators which provide auxuliary power supply for the continous cooling of the reactor. An attack like this could lead to cooling distruption or could make cooling impossible. According to the paper lower grade explosives used as a payload attached to the drones could be enough to reach this effect. [10],[11] Malicious intent attacks can be also supported by drones. There are disguised commercial drones available, which are harder to identify. These usually represent some kind of a bird, not only in their looks, but also in the method they fly, mimicing and utilizing wing stroke. The lack of rotors lead to a much lower noise and also provides longer flight time with more efficient power usage. [12]

The potential dangers are the reconaissance performed by drones; the live intelligence support of ongoing terrorist attacks; the transportation of forbidden objects into the protected zones; and the utilization durcommercial of drones as weapons platforms and as explosives delivery method. Weather and environmental resilience of drones also greatly improved, with water resistant drones availabe which aren't held back by rain or high levels of humidity. Some hybrid drones are capable of traversing both in water, under-water and in the air. One example of such hybrid is the Spry drone which became available in 2019. [13] This could prove to be

of greater importance because of the usual proximity of open waters and NPPs. The NPP of Paks has direct connection to the river Danube for example. The Danube provides the coolant required for the NPP and it is situated about 2000 meters from the middle of the river. Because of this, violation of the territory of the NPP by an aquatic or submerging drone is a highly realistic possibility. Drones equiped with heat sensors can navigate and reach their targets in bad visual conditions, but simple GPS based navigation can also reach accuracy measured in centimeters. Furthermore some drones are capable of autonmous operations. The operator has to set the flight plan and it performs the flight individually without the need for any interaction by the operator. The industry leading DJI manufactures drones that have the so-called „no-fly zone" protocol which prevents them from entering or taking off in no-fly zones (currently this usually means areas around airports). However, this measure can be circumvented by illegal modification, hacking and some manufacturers don't use these measures. The news about the results of the joint research of Eötvös Lóránd University department of biological physics and MTA-ELTE Biological and Statistical Physical research group on drone swarms have been published in 2014. The research group lead by Tamás Vicsek have created worlds first self-organizing quadrocopter drone swarm consisting of ten drones. The researchers have managed to achieve successful, collision-free cooperation between thousands of high-speed drones in more then 30 cases which have simulated highly difficult environment. These so-called intelligent drone swarms give rise to the need for completely new methods of defense, which challenge is yet to be answered by an accepted protocol. [14] Drones or smaller drone swarms can be equipped by explosives and can be directed to critical structures. They can be also equipped with weapons, small explosives, or with graphite bombs, which can distrupt electric networks. The live monitoring of the defensive forces during attack is also possible and could greatly support an ongoing attack.

3 SUGGESTIONS

Protection against drones has to become high priority in domestic nuclear facilities, because the properties presented prove that they are capable to distrupt operations, can obtain information (pictures, videos) which can support preparation and execution of a terrorist and sabotage actions against the facilities. Below we have summarized the suggestions for measures against drones.

Suggestions for protection against unmanned aerial vehicles:

1. Extension of the no-fly zone around NPP of Paks.
2. Tracking of air vehicles when approaching the facility's 30 km radius airspace for better early warning capability.
3. Unified protection for Paks I, Paks II and Interim Storage of Spent Fuel.
4. Fielding of a complex anti-drone system for the NPP of Paks.
5. Evaluation of aquatic entry point, utilization of preventive measures if necessary.
6. Introduction of obligatory unique identification for drones and their owners, similarly to license plates of cars.
7. Obligatory drone piloting training for every non-leisure category drone owner. (To minimize number of accidents and to assure legislative knowledgeability).
8. Regulations for drone classifications should not only consider the weight of the UAV but also it's effective range, equipment (for example heat vision, suspension for other equipments, etc.), operation time, carrying capacity, and maximal velocity.
9. Obligatory registration and authorization for home-made drones.
10. The use of serious punishments for the violation of no-fly zones which provide deterring power.
11. Active communication of the nuclear facilities defensive capabilities and of the consequences of airspace violation for deterrence.
12. Re-classification of NPP of Paks as EU critical infrastructure while keeping nuclear safety and security requirements.
13. Obligatory reporting to NPP of Paks for owners planning flights in the vicinity of NPP (but outside no-fly zone).
14. Evaluation of possible liability insurance for drone owners.
15. Mandatory periodic technical inspection for drones.

Regarding nuclear facilities, Hungary has one research reactor, the Interim Storage for Spent Fuel, National Radioactive Waste Repository, the Radioactive Waste Treatment and Disposal Facility, and the 4 reactor units of the NPP of Paks. Of the aforementioned facilities the protection of NPP of Paks I, the planned NPP of Paks II and the Interim Storage of Spent Fuel should be unified – with their close proximity and interlapping airspace taken into consideration – for the most effective results. According to the results of a 2018 paper on nuclear safety and security culture effective installment and operation of physical protection and nuclear safety is a joint responsibility of the state and the lincesees. State participation is not only a technological, but also a strategic neccessity, which can be justified by the following. If drone detection measures are not procured and fielded in a unified measure, it can lead to them being uncompatible with each other, making cooperation difficult, which leads to less effective detection capabilities all around. Time becomes a more important factor in case of spearate protection, because communication, coordination between the independent organizations and personnel leads

to loss of time that could have been spent on reaction, while can also lead to information distortion. Practical examples show that the optimal actor for procurement of these sometimes military grade equipments is the state, because obligations for the protection of the general population allow much higher budget riskwise compared to a company. The technical/technological personnel responsible for the detection, support and operation of these equipment has to have uniform competencies, which leads to the neccessity of uniform, centrally controlled training and organization. In case an agressor state would perform a drone attack, only the state has the required authority and tools to counter such international atrocity or threat.

4 CONCLUSION

It is key to create nuclear facilities anti-drone systems for a modern protection. In today's world every strategically important facility has to take this new kind of threat into consideration and provide counter-measures for it. In the future we can expect that the numbers of residential, commercial and military drones will increase, while becoming more and more available. Because of the constant technological advancements, these drones will be even faster and more quiet, and could spend more and more time operating. The number and variety of equippable tools and carrying capacity of them will increase, while operation will become easier. Another challenge is most parts can be manufactured by privately owned, hobby-grade 3D printers (a Singapoure based company already produces drones with 3D printers, which have the weight of less then 2 kilos, operation time is 2 hours, and maximal speed is 60 km/h. Every part of it can be 3D printed except for the electronics. With 3D printing utilized design time deceased by 40%, weight decreased by 20 %.) Rapid development of drones justifies the neccessity for greater emphasis on the threat they could pose. It is neccessary to declare the professional basis for drone piloting, the paraphrasing of neccessary regulations, the creation of a framework for drone usage. [15], [16] Drone technolgies is one the most rapidly evolving industries, which provides a waste aray for possible use in many fields from hobby, to agricultural and professional). These positive changes are hand in hand with the development of security threats they give rise to, which has to be handled adequatly by security professionals and industry in a timely manner.

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