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EVOLUTION OF UAVS IN THE LIGHT OF RADIOLOGICAL DETECTION

Today, application of aerial vehicles can be considered as a routine task in the field of disaster management, in particular flood prevention, aerial reconnaissance, radiological detection, search and rescue and air rescue have got a significant role. Professionals may receive useful information by applying aerial reconnaissance technologies. Data transmitted by these aerial vehicles can greatly support the work of the personnel involved in prevention, protection and reconstruction tasks. One of the essential parts of the aerial reconnaissance is a tool applied on the UAV/UAS1which is capable to take pictures and to record videos. In this article the author examines the adaptability of unmanned aerial vehicles during the elimination of the consequences of possible disasters, particularly the aerial reconnaissance of damaged sites. The author also introduces the historical development of these appliances, their types, design and performance.

Keywords: aerial photography, remote sensing, aerial radiological detection, disaster, unmanned aerial vehicle.

INTRODUCTION

Data and experience collected in recent years and decades indicates that the number of natural and civilization related catastrophes and also the severity of their consequences have been increasing. In addition, new types of potential threats have also appeared. Professionals of disaster management shall face additional risks of a civilizational disaster due to the emergence of the peaceful use of nuclear energy. We just have to consider the disasters of Chernobyl (26 Apr 1986) and Fukushima (11 Mar 2011) nuclear power plants. In both cases the priority was to determine the dimension of the catastrophe, to estimate the contaminated area and to specify the possible routes of radiological contamination. Moreover, the delivery of essential information about the required defence works to the personnel in charge also took priority. Another significant danger factor of today is terrorism and terrorist acts. We have to take it in account that radical groups may use weapons of mass destruction (hereinafter referred to as WMD) to prove the legitimacy of their ideologies. The above mentioned facts promote the importance of disaster management professionals and organizations; it highlights their need for proper technical end professional preconditions that are essential during the execution of their tasks. One segment of the technical appliances is the group of aerial vehicles that can be used for a wide range of activities in the field of disaster management. Aerial survey/reconnaissance is only one segment of their scope; they also have a significant role during the prevention, defence and reconstruction period. Depending on the parameters of the required reconnaissance activity – distance of the flight, altitude, contamination of the affected area, meteorological conditions- survey can be executed by including but not limited to aircrafts, helicopters, balloons and Unmanned Aerial Vehicles (hereinafter UAV). UAVs have got a longstanding, 150 years old history. Possibilities of their application have been evolving alongside with the technological development. Their application can be divided in three main groups; military, public and commercial [1]. In my study, I introduce the history and present of aerial

[1] Unmanned Aerial Vehicle/Unmanned Aerial System

survey/reconnaissance; I present some types of UAVs and their adaptability to various tasks. I also present the RABV – can be installed on UAVs – radiological reconnaissance system produced by Gamma Műszaki Zrt.

PAST AND PRESENT OF AERIAL RECONNAISSANCE

The history of aerial reconnaissance goes back to the age of Napoleon. Contemporary balloons were used to survey the manoeuvers of enemy forces. The first aerial bombing took place just before the First World War during the Turkish – Italian war. In those days aircrafts were not really useful as a strike force, mainly because of their power and the lack of their appropriate arsenal. On the other hand, they were perfect to execute reconnaissance missions and to control artillery fire.

Figure 1. Fort Douaumont just before the battle [2]

The Figure 1 below was taken in those days in the frontline. After WWI the evolution of aircrafts accelerated and tasks of reconnaissance and bomber aircrafts merged. Priority of their deployment was to cause as great damage as they could to military installations behind the enemy lines. During the First World War a half million photos –similar to Figure 1- were taken, say British data. Due to technical evolution cameras could take pictures from an altitude of 4500 meters in the end of the WWI. During the WWII aerial reconnaissance developed further and radio electric devices also appeared. That was the time when distance and near reconnaissance evolved. The symbol of the Cold War the so called space project gave rise to the existence of spy satellites and reconnaissance aircrafts -with extreme capabilities- were also evolved. Due to the evolution of data transmission technologies it also became solvable to evaluate and analyse the data received from reconnaissance aircrafts in real time. A question may arise. Why do we need photos taken by reconnaissance aircrafts in case we have spy satellites? The answer is really simple. The quality of a photo is much better than the quality of an image taken by the most modern satellite that is affected seriously by the current weather conditions (e.g. clouds). That is also important, that photos taken by an aircraft are much cheaper than those taken by a satellite.

In accordance with the current mission, aircraft involved in the execution of reconnaissance tasks can be equipped with a wide range of technical devices

"Typical devices of reconnaissance aircrafts:

a) high-precision cameras equipped with high-definition objectives;
b) cameras capable to record stereo recordings;
c) flashing lights and thunder-flashes to enlighten great areas;
d) infrared photo cameras;
e) digital video transmitter;
f) TV cameras;
g) radio locator systems to ensure flight irrespective of weather conditions". [3]

Due to the social and civilization evolution – e.g. IT, robotics and avionics- the next milestone in the history of aviation was the appearance of UAVs. With regard to their dimensions, technical equipment and range UAVs are perfectly tailored to accomplish aerial reconnaissance, operational and catastrophe management tasks and duties.

UNMANNED AERIAL VEHICLES

The oldest written document on the existence of UAVs was registered on 22 Aug 1849. It was reporting about the bombing of Venice when unmanned flammable and explosive balloons were dropped on the city. Then several inventors and scientists had concerns on the creation of an unmanned aerial vehicle. Customers mainly came from the Home Defence Commands. During the WWI Charles Kettering received a purchase order from the US Military Command to develop an unmanned torpedo. The first real breakthrough was the UAV called Queen Bee. The Queen Bee was the first unmanned aerial vehicle that could return to its point of departure after accomplishing its duty. The expression drone was used first at this time. The development of Vergeltungswaffe-1 (hereinafter referred to as V1) started in the 1930`s in a research facility of Peenenmünde`s airbase. Its purpose was to deliver a 850 kg weighing warhead to its destination which could be 350 km far from the launch site. During the WWII around 3500 missiles were launched mainly against British targets. In the end of the WWII the interest for unmanned aerial vehicles reduced. With the beginning of the Cold War and the nuclear age the UAV project has been forgotten and the focus turned on intercontinental ballistic missiles. Later on, in the beginning of the 60`s the Soviet Union took the lead in the field of UAV production and development. Tu-143 Rejs was constructed in the USSR to serve as a short-range reconnaissance drone. It was developed to enter enemy territories in the depth of 50–60 km and to accomplish tactical reconnaissance flights. The so called U2 crisis in 1960 greatly accelerated the UAV program of the United States. In that year the Soviet air defence shot down the USAF2 Lockhead U-2 type drone in the airspace of the USSR3. During the next decades UAVs were involved in several military operations such as the Vietnam War, Gulf

[2] United States Air Force

[3] Union of Soviet Socialist Republics

War, Balkan crisis, Iraq War and they were also involved in counter-terrorism operations. Today, a wide range of UAVs are available.

Their classification can be based on several criteria. One of the most common classification criteria is to classify UAVs by their weight, flight duration and range is highlighted in the Figure 2 below.

	Class I UAV	Class II UAV	Class III UAV	Class VI UAV
level	Platoon	Company	Battalion	Brigade
weight	2–5 kg	50–75 kg	150–250 kg	>1500 kg
flight duration	50 min	2 h	6 h	24 h
range	8 km	16 km	40 km	75 km

Figure 2. Classification of UAVs used by the US Army [4]

UAVs can be also distinguished upon the design of the airframe. In this case we categorize the way of buoyancy and the way it is generated. Upon this categorization we can set up three main classes; fixed wing, rotary wing and hybrid. It is really popular nowadays to apply more than two rotors. In such cases rotors do not have to have adjustable cyclic and collective pitches. Control can be achieved by the adjustment of the rpm of one single engine. This solution is one of the simplest mechanical and electronical solutions of all in the field of Vertical Take Off and Landing UAVs (hereinafter referred to as VTOL). Disadvantage of this technology is the high energy consumption therefore long range flights are not feasible with such a UAV [5]. Another important aspect is the field of application. Single use type UAVs can be used as tactical equipment that are capable to recon and destroy their target. Their core duty is to serve as flying targets to support the combat training of anti-aircraft and artillery units. The greatest benefit of multiple use type UAVs is the cost-efficiency. On the other hand, a built-in on-board and in addition a ground navigation system is also needed to ensure their flight and safe landing. UAV control can be accomplished by several techniques. They can be controlled by an operator remotely from departure to landing, or they can be equipped with a pre-programmed on-board computer to control the flight and to control the execution of the task. Combined controlled type UAVs merges the above mentioned types of control.

UAVs were initially applied by armed forces to accomplish bombing sorties and to deploy aerial torpedoes and to execute reconnaissance flights. However, nowadays these modern devices are capable to compete with the threats and challenges of the 21st Century like terrorism, guerrilla war and proliferation of WMDs. Today frontlines are faded away. They are usually in the direct vicinity of the civil population and cities and villages. Hostile soldiers do not use any military uniform often and/or fails to comply with the 1000 years old rules of war. Multiple application possibilities of UAVs primarily manifested while they execute long range tasks that are burdensome for a flight crew. Good example is the Kosovo Conflict in 1999 when B-2 bombers and their crew departed from the USA and after the execution of a certain task they arrived back to their place of departure [6].

UAVs can also be applied in airspaces contaminated by radiation and in biologically or chemically contaminated areas. To avoid harm and injuries of the air crew UAVs can be applied. In addition, drones can also be deployed in operational areas where our air traffic control is not proven or assured. The number of UAV deployments have started to increase in such missions as well where -in the past- their presence was not usual and conventional aircrafts were responsible to accomplish all emerging tasks [7]. Such exercises were intelligence gathering, surveillance and reconnaissance, laser target designation, aerial support of troops deployed on the ground, air cargo/transport and aerial communication and data transmission as it is highlighted in Figure 3.

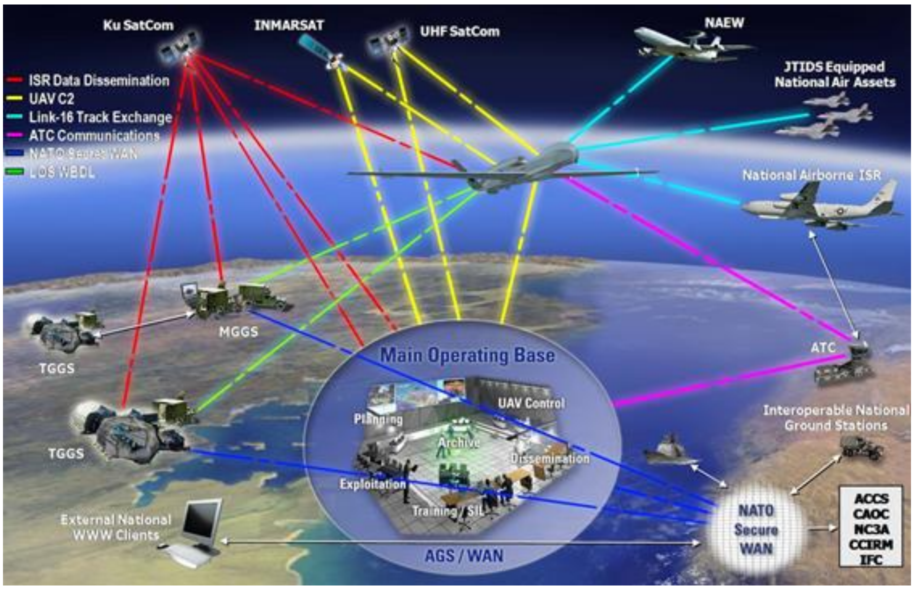

Figure 3. NATO AGS system [8]

UAVs can be also utilized in the commercial sector. They can be applied in the agricultural, energy, archaeological, media and geology sectors. UAVs can be employed to monitor crop production and dispersion and also can be applied to remote monitor gas and oil pipelines of the energy sector and to recon their possible malfunctions and to report those to the experts in charge. In addition, they are ideal to support archaeological excavations by taking aerial photos of the designated areas, to record videos and to support the creation of urban management plans. The priority of the commercial sector is the profitability; therefore UAVs always have to perform faster and more cost-efficiently than the substituted technology. Another important aspect is to reach high security level during the execution of the required task and to minimize risk factors that may affect human lives. Remote monitoring of electric cables can be a good example. “In this case, the interval remote monitoring of the grid means monitoring that was earlier executed from a vehicle or was done on foot. During the aerial monitoring we can receive information on the state of pillars, on the state of porcelain insulations and on the connection between that insulation and the electric cable itself. On the contrary, during the execution performed on foot – if some doubts arises on the state of the electric system- the controller has to execute a closer examination of the affected area. It can cause serious physical challenges and can give raise to security difficulties.” [9]

We can find several national and international examples of UAV applications in the field of catastrophe management too. In case of a nuclear catastrophe, the first deployment of a UAV occurred on 21 Apr 2011 right after the accident – 11 Mar 2011 – of the Fukushima nuclear power plant. Back then the Tokyo Electric Power company deployed a T-Hawk type micro air vehicle above the contaminated area to take photos of the damaged nuclear power plant. Regarding its dimensions and control the execution of the task was really simple in the scene of the catastrophe. In this case, we can only talk about the execution of the task performed right after the elemental catastrophe abatement. On the other hand, pre-planned reconnaissance flights were executed above the contaminated area. Additionally, UAVs can be applied preventively to monitor the area of a nuclear power plant and to scan the level of contamination right after the occurrence of a possible catastrophe. During the preventive period, activities like monitoring and radiation measuring can be executed. By applying this scenario higher than normal radiation can be easily observed. Right after the potential catastrophe UAVs can be deployed rapidly and accurately to collect information on the area of the contaminated surface. Drones can provide useful information on the additional risk factors and on the possible routes of the contamination. By receiving these crucial information professionals in charge of the rescue may be able to plan the following task and they can estimate the possible risk factors. It also has to be highlighted that aerial reconnaissance executed by a UAV in the contaminated area may replace those radiation detectors that are controlled by a flight crew and applied on conventional aerial vehicles. Therefore, UAVs can save the life and the health of the participating personnel. HD[4] pictures of the Fukushima power plant shown on Figure 4 were taken by the Japanese Air Photo Service on 24 Mar 2011 just a bit after the occurrence of the catastrophe.

Figure 4. Fukushima nuclear power plant [10]

In case of disasters related to hazardous materials the priority is to determine the routes of the leaking material as soon as possible. This task can be accomplished by the application of UAVs too. "Currently, this task can be partially implemented with a special equipment of the Disaster Management Department (Disaster Management Mobile Laboratory) that is relatively fixed and only capable to create 2D[5] imaging. To take HD and/or 3D[6] imaginations of a large area in a short term it is preferable to apply UAVs. These so called rheological diagrams can support the work of the professionals more efficiently." [11]

Advantages of UAVs in catastrophe situations:

a) high initial costs can be financed by the state;

[4] High Definition
[5] Two-dimensional
[6] Three-dimensional

b) developments in connection with UAV developments and their positive effect on the economic system are obvious for the state as well;
c) state is capable to handle/manage long term investments [12].

AERIAL PHOTOGRAPHY

„Aerial reconnaissance is that part of reconnaissance that collects information and gathers intelligence by applying aerial vehicles on different altitudes with or without human intervention.” [13] The first aerial photo was taken by a photographer called Gaspard-Felix Tournachon in Paris in 1858. A bit more than a half century passed away when the first motion picture, actually a silent film, was taken from the air. It was taken above Rome in 1909. Its title was Wilbur Wright und seine Flugmaschine and it was only three minutes and twenty eight seconds long. Colonel Potte V. F. designed and later created the first semi-automatic camera that was used for aerial photography during the WWI. In the next decades aerial photography went through a great technical evolution. Its scope of use has become even more diverse. Nowadays aerial photography is commonly used in the field of cartography, archaeology and crop land survey and movie shootings. Their common point is to record the surface from above. “In parallel with the evolution of digital systems and networks in the middle of the 20th century remote sensing began to develop rapidly and also started to expand in the civilian sector. The expression remote sensing evolved only during the satellite campaign of the 70’s. This process was accelerated by the increasing power of computers and IT equipments, the evolution of computer apps and the developing efficiency of geodetic and positioning devices. In addition, image processing applications also evolved rapidly and became more and more ideal. The expansion of remote sensing was also assured by other factors. One of these is the fact that expensive optical computers were substituted by adequate PCs equipped with adequate software. On the other hand, adequate raw materials and the required knowledge were still essential.” [14]

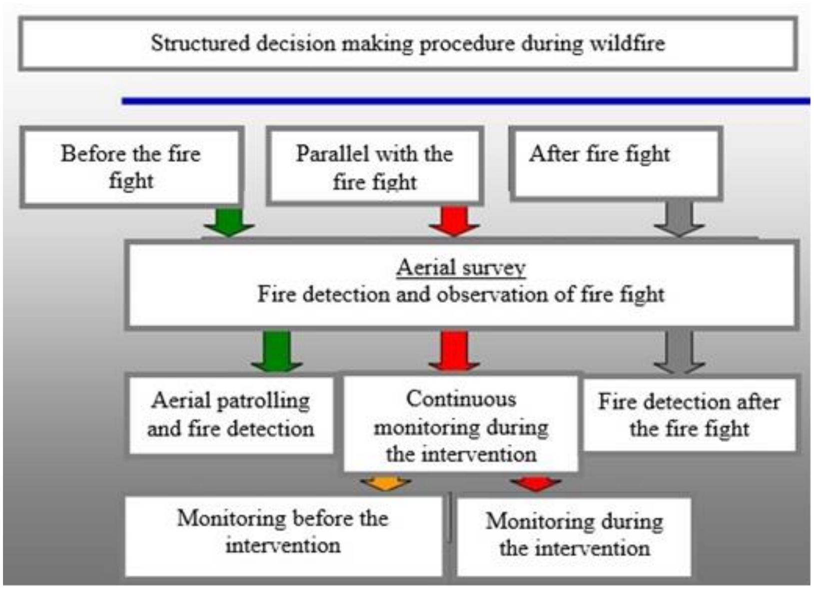

Figure 5. Structured decision making procedure during wildfire [15]

Today aerial images can be taken from several types of aerial vehicles. These can be helicopters, fixed wing aircrafts, balloons, hang-gliders or UAVs. Additional areas of their possible application came up parallel with the technical evolution. Disaster management is greatly influenced by the availability of the information required by the professionals in charge. With the support of aerial photography a relatively large area can be assessed in a short period. That information can be easily utilized by the professionals of disaster management. In the field of UAVs, fixed wing aerial vehicles enjoy advantages against rotary wing devices. The main reason of this fact can be found in the range and flight duration of such UAVs. While electronic rotary wing UAVs are not capable to fly more than 10–12 minutes fixed wing UAVs can accomplish 50-60 minutes long flights. UAVs can be equipped with HD cameras and data transferring systems. With their support the person in charge of the fire fighters and/or elimination units can receive priority information and images. This procedure significantly reduces the duration of the recon executed by the arriving fire fighters. This kind of recon was earlier executed on foot along the perimeter of the fire and it was usually completed by the establishment and manning of a high-ground observation point. The structured decision making system supplemented with aerial photography during a wildfire is highlighted below in Figure 5.

The deployment of UAVs makes it possible to receive HD aerial images within seconds upon their return to base. Recorded images are available to the professionals in a very short period of time. "A micro size UAV was deployed first in Hungary to recon fire in the city of Szendő in 2006. It was also the first time on the globe when such equipment was deployed to execute such task." [16] With the continuous transmission of images taken in the area of the accident further expansion of the fire can be preventable. Aerial images can greatly support the damage assessment work and great time-saving can be also achieved because the affected area does not have to be patrolled on foot.

Figure 6. Northrop Grumman MQ-8B Navy Fire Scout. [17]

In Hungary UAVs have been collecting data and information on floods since 2010. Actually the aerial images were taken in the Bodrogköz in 2010 [18]. During the period of flood prevention it is significantly important to remove all present natural barriers from river beds and river meadows and to keep the appropriate condition of dams. UAVs are perfectly convenient to accomplish such monitoring missions. They are capable to fly along the affected area and can take and transmit images to supply appropriate information. In the period of flood control it is also a priority to monitor the effected sections of dams and flooded areas. It is also important to monitor all ongoing defence activities from the air. Personnel in charge of defence and prevention activities can plan all needed further actions in accordance with the information received from UAVs. They can establish decisions on evacuation and on the redeployment of human resources. It is only a matter of budgeting if UAVs are available or not for the professionals of disaster management. Such UAVs can be capable to accomplish rescue missions, to rescue wounded or to deploy sand bags or any other equipment that is needed to support the ongoing defence activity. The main and primary advantage of aerial reconnaissance executed by UAVs is cost-efficiency. By the application of UAVs decision makers can gather as good quality information as those provided by conventional aerial vehicles. The MQ-8B Navy Fire Scout highlighted on Figure 6 weighs 1430 kg, its maximum speed is 213 km/h, its range is 275 km and its maximum flight duration is 8 hours [19]. Regarding its flight capabilities it is perfectly applicable to accomplish flood control, radiation recon and fire fight missions. Due to its possible service duration time efficient prevention and defence is achievable.

AERIAL CHEMICAL, BIOLOGICAL AND RADIATION SURVEY

Aerial chemical recon, aerial radiation recon also belongs to the group of aerial reconnaissance tasks and duties. Aerial radiation recon is primarily exercised in case of wartime or in case of an industrial catastrophe to detect the contaminated area after the unexpected nuclear explosion/disaster. A radiation measuring instrument, an aerial vehicle and a navigation system is required to accomplish the task. On the other hand, aerial radiation reconnaissance can be perfectly applied to track down and locate stolen or lost radiation sources like sticky bombs. Regarding the flight capabilities and possibilities of UAVs they are perfectly adaptable to execute aerial chemical and radiation reconnaissance tasks. In accordance with the above international example –Fukushima- main aspects of deploying UAVs in a contaminated area –imaging and radiation survey- are the cost-efficiency and the protection of human manpower. We just have to think about the contamination affecting the UAV itself. For example, helicopters deployed during the protection work of the earlier Chernobyl nuclear accident were left behind in the greatly contaminated area because of the large contamination they suffered. The question would then arise. Is it worth to deploy and decontaminate such recurring equipment after its chemical or radiation recon flights?

Decontamination is basically influenced by the following factors:

a) quantitative and qualitative level of the contamination;
b) the value of the UAV with its amortization and its return productivity and its substitutability;
c) cost of decontamination and other required resources.

Focusing on the value of the UAV it can be presumed that higher value strategic equipment in case of higher level of contamination suffered is being decontaminated. They are decontaminated even in case the level of contamination occurred is high and costs of decontamination are outstanding. On the other hand, tactical equipment may be subtracted permanently only after the accomplishment of a single mission [20].

Aerial biological threats can evolve as a secondary consequence of natural or civilizational catastrophes. Mass fallen stock or human remains may start rotting, biological laboratories may break down or intended terror acts may occur. An unmanned aerial vehicle to recon biological threats was developed in the USA in 1997. It weighs 19 kg while its wingspan is 4 meter. It is capable to take air samples in the altitude of 10–30 meter and transfers the data within 5–20 minutes. A sampling chamber is established in the airframe of the UAV. The infected air flows through and precipitates. A built-in optical sensor system is responsible to collect and analyse these bacterial spores. Each and every optical sensor is responsible to detect a specific bacterium. Then these optical fibres are getting turned in a special liquid that contains fluorescent antibodies which are associated with a single type of bacterium. During this process a light impulse is generated. This impulse is induced further and transferred to an electronic signal. That electronic signal can be simply transmitted. Bacteria can be identified upon the collective results of the light impulse of the concerning optical fibre and the electric signal [21].

THE RABV RADIATION DETECTION SYSTEM

The Gamma Műszaki Zrt has invented the RABV –in NATO terminology called CBRN Chemical, Biological, Radiological and Nuclear- system to determine the radiation level of a given section of the surface from the air. However, this device is capable to locate and identify point radiation sources too and also capable to collect data and to simultaneously transmit them. Other benefits of the equipment are the built in USB data port, the easily exchangeable data memory and the topographic visualisation ability. In case the device is applied on a UAV the navigation occurs with the support of a barometric altitude meter and a GPS positioning tool. It determines the accurate geographic coordinates of radiation sources by indicating spots that have significantly different background radiation. The fundamental part of the system is the BNS-98L type doses performance data collector. The measurement range of the gamma radiation from consists of seven magnitudes. The special built-in algorithm changes time constant in case the measured radiation significantly differs from the normal background radiation [22]. Technical specifications of the system are highlighted in Figure 7.

operating range	50 nGy/h-500 mGy/h (15%)
indication range	500 mGy/h-10 Gy/h (30%)
energy range	60 keV-1,5 MeV
alarm levels	2 adjustable / 1 automatic
time set	4 s-120 s
communication	RS-232, 9600 Bps
temperature range	(–25)–(+50) C°
device chassis	hermetic and environmental resistance

Figure 7. Technical specifications of the RABV radiation detection system [23]

To increase the measuring range of the RABV system and other similar systems all required technologies are available. However, the application of an RABV system on a UAV depends on several factors. Barriers of application can be the flight capability, the refuelling and feeding of the UAV and its maximum payload. The expansion of the range of the reconnaissance and the size enlargement of the UAV is not directly proportional. Therefore, in case the requirement is to achieve double reconnaissance range than a double size UAV is not be enough because the weight and the energy consumption of the UAV will significantly increase.

CONCLUSION

Civilizational and technological evolution occurred in the past century, the peaceful utilisation of nuclear energy, industrial factories dealing with hazardous materials and the increase of natural disasters have been presenting new challenges to the professionals of the disaster management sector. These challenges require special procedures and technologies because the detection of a contaminated area cannot be accomplished without the appropriate defence of the assisting personnel. But not only the risk factors evolved in the past century. Due to the technological development such preventive and protection/control equipment and tools appeared like the UAV. In the early years of their existence they were used only by defence forces but later on they have been greatly involved in commercial and disaster management tasks too. It became possible to accomplish disaster prevention and control tasks on a higher level and on the other hand professionals and decision makers could receive appropriate information on time. Today aerial reconnaissance became the essential part of the disaster management system and the continuously developing UAV also contributed to this achievement. Nowadays we are capable to fly above a radiologically, biologically or chemically contaminated area and we can collect and transmit the required data in time. Due to this possibility all dangerous tasks can be performed without risking the life and health of the professional personnel. Several national and international examples can be mentioned to prove this statement. In Hungary –first on Earth- we deployed a micro size UAV in 2006 to support fire fight. In Japan, the aerial reconnaissance of the injured Fukushima nuclear reactor and the surrounding contaminated area was also executed by drones in 2011. Cost-efficiency also has got high priority. Cost-efficiency is feasible because the operational cost of a UAV is far lower than the operational cost of a conventional aerial vehicle. In addition we also receive the similar quality of reconnaissance information from a UAV than from a normal aircraft. However UAVs also have weaknesses like limitations of their maximum payload, limitations of their flight capabilities and limitations of their energy sources.

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AZ UAV-K ALKALMAZÁSÁNAK FEJLŐDÉSE A SUGÁRFELDERÍTÉS TÜKRÉBEN

Napjainkban a légi járművek alkalmazása a katasztrófavédelmi feladatokban rutinszerűnek mondható, különös tekintettel az árvízvédelmi, légi felderítési, sugár felderítési, kutató-mentő és légi mentő feladatokra. A légi felderítés segítségével hasznos információkhoz juttathatjuk a szakembereket, és ezen adatok kiértékelve és elemezve nagyban segíthetik a megelőzési, védekezési és helyreállítási munkálatokban részvevők tevékenységét. A légi felderítés egyik nélkülözhetetlen eszköze a légi járműre szerelt fényképet vagy mozgóképet rögzíteni képes technika. A cikkben a szerző vizsgálja a pilóta nélküli repülőgépek alkalmazhatóságát a katasztrófák következményeinek felszámolása során, különös tekintettel a kárterület légi felderítésére. Bemutatja ezeknek az eszközöknek a fejlődési történetét, tipizálását, kialakításukat és működésüket.

Kulcsszavak: *légi fotózás, távfelderítés, légi sugárfelderítés, katasztrófa, pilóta nélküli repülőgép*

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