Design of a Process Model for Unmanned Aerial Systems (UAS) in Emergencies

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ABSTRACT

The electricity network is one of the most important infrastructures in modern industrialized societies. In the case of power outages, the society becomes aware of their dependence on electricity and organizations responsible for recovery work need precise information about the location and the type of the damage, which are usually not available. Unmanned Aerial Systems (UAS), commonly known as drones, are aircrafts without a human pilot on board and may help to collect this information. While many technical approaches for UAS exist, a systematic process model for using UAS in emergencies based on the organizations needs is still missing. Based on the presentation of current types of UAS, approaches of using UAS and workshops with organizations responsible for recovery work (police and fire department, public administration, power supplier) this paper presents a process model for UAS in emergencies, especially power outages, which takes both theoretical findings and human experiences into consideration.

Keywords

Unmanned Aerial Systems (UAS), Drones, Process Model, Collaboration, Emergency, Power Outage

INTRODUCTION

Modern societies depend very much on the availability of electrical power, water, gas and communication infrastructures. In central Europe under normal circumstances, their supply is guaranteed nearly all the time. But in case of natural disasters (e.g. gale-force winds, flooding, strong snowfall) the power lines and other means of supply can be cut for large areas in a very short time. This can have fatal consequences for business as well as private households and can even be hazardous for human beings (Reuter 2013). So, the fast restoration of the supply with electricity, water, gas and telecommunication after an emergency is a very important task for the providing companies and government. Crucial for a fast restoration is the precise information about the location and the type of the damage. Hereby actual aerial photos in a very high spatial resolution are important sources of information for an efficient coordination of the restoration teams. On the one hand the damages themselves can be detected and evaluated; on the other hand the fastest access to the location of the damages can be decided, by choosing a road with the fewest obstacles (e.g. fallen trees). In the past the high resolution remote sensing images where taken my manned airplanes or helicopters. But there are some disadvantages, e.g. under special weather conditions (e.g. low clouds) or when the airstrip is blocked, the airplanes cannot be used. For the last years, due to the immense technical progress, there are small remote controlled Unmanned Aerial Systems (UAS) available which are easy to operate and provide potential for acquiring remote spatial data more rapidly and at lower cost than from piloted aerial vehicles (Everaerts 2008). Those data need to be acquired in situ because the situation assessment needs during complex emergencies cannot be completely covered by routine processes and anticipatable information demands (Ley et al. 2012).

Within this paper the use of UAS for generating needed information to restore supply of electricity, gas and telecommunication in case of an emergency is evaluated. Therefore two workshops had been organised where on the one hand representatives of organizations responsible for recovery work on the other hand manufacturers and operators of UAS had assessed and discussed the demand on spatial information in a very high resolution as well as the possibilities and limitation of the UAS for gathering spatial information in case of emergency. Based on the empirical results from these workshops a process model is developed which illustrates how UAS and its information could be integrated in the emergency management processes and operations.

TYPES OF UNMANNED AERIAL SYSTEMS (UAS)

In this chapter a short overview of the different types of low-cost UAS (price for a system lower than 40.000€) with their characteristics are given. The first remote controlled Unmanned Air Vehicles (UAV) where developed for military use and called “drones”. To make a clear difference, scientists used the term UAV if they are used for non-military purpose. In the last years there is an understanding that the definition "Unmanned Aerial System (UAS) comprises individual system elements consisting of an 'unmanned aircraft', the 'control station' and any other system elements necessary to enable flight" (EASA 2009) is more appropriate. There is a wide range of different UAS types available from small systems with less than 0.8 kg (e.g. type: Sensefly) up to very big systems with a flight weight of more than 900 kg (e.g. type: B-Hunter), Eisenbeiß (2009) gives a good overview over the different systems helicopter and multi-rotor, fixed wing and parachute UAS. There are different options to classify the UAS, regarding the weight, the flight height or the construction.

multi-copter: MULTIROTOR fixed wing UAS: MAVIONICS parachute UAS: SUSI 62

Figure 1: Different types of UAS

There are the small UAS which are able to start and land vertical, the *helicopter*, or *multi-copter types*. Equipped with vertical rotors, no airstrip is needed. Because no dynamic lift is created by wings, the whole lift has to be created actively, which consumes much battery. Therefore the flight time and height is limited (between 10 - 25 minutes) and not much payload can be carried. For multi-copters good autopilots are often available, so that only the start and landing has to be made manually and covering the area is done automatically. In general they have very advanced gyrocompass and sensors which assist the flight. Therefore it is comparatively easy to operate them, which reduces the learning time for operators. Multi-copters can be used in case of emergency to cover areas 1 ha to 100 ha or to monitor damages on buildings (Pratt et al. 2006, Chou et al., 2010, VT Group 2011).

Another type is the *fixed wing UAS*. The design is similar to classical model aircrafts. Because many percentage of the lift is created by the wings they can reach long flight times, in comparison with multi-copters, this UAS type has a higher payload. For take-off most of them can be thrown or they are started via a catapult so they do not need a runway for take-off. But for landing a kind of an airstrip, fairly flat with no high vegetation or other obstacles, is necessary. They can reach high speed over ground (more than 120 km/h), therefore they can be operated even under strong wind conditions. For fixed wing UAS a range of advanced autopilots are available. The comparatively high speed over ground demands good light conditions for a short shutter speed of the camera. A disadvantage is as well, that the landing speed is quite high (in general greater than 25 km/h up to more than 40 km/h). So an even slight mistake during landing can cause severe damages of the systems. Often there are advanced landing assisting systems available, but in general to operate the fixed wing UAS, a higher expertise is necessary in comparison with multi-copters and in case of a system failure, their high speed can be dangerous. There is a big variety of fixed wing UAS available from a 0.5 kg system up to UAS with more than 150 kg (Klonowski et. al. 2009). Due to their comparatively long flight time and high flight speed they are used in case of emergency to cover larger areas (Adams & Friedland 2011).

An UAS type which has a comparatively high payload, long flight time, and a low flight speed, so that the images have very good quality even under bad light conditions are the *parachute UAS* (e.g. SUSI 62 as described in Thamm 2011). They are very robust, easy to fly and due to the design as with the parachute as wing, very save in case of system failure. As well the 2-stroke engine makes them independent form electrical power. The disadvantage of these parachute UAS is that it cannot be operated under rainy conditions and a safe operation is in general only possible by wind speed less than 6 m/s. Other UAS types like Balloons with engines are not suitable in case of emergency, because they are very sensitive to wind and too slow.

RELATED WORK

UAS have been proven to be very suitable tools to get quick overview about the situation in case of a natural disaster. An example conducting structural damage inspections of several multi-story commercial buildings damaged by Hurricane Katrina was successfully performed by Pratt et al. (2006) with a helicopter type UAS. This encouraged others to perform post emergency documentation with UAS. Successful campaigns to monitor post emergency damages with UAS had been recorded in L'Aquila in 2009 (Quaritsch et al. 2010) and Haiti in 2010 (Huber, 2011). Based on Huber's experiences, he demanded additional functions, which should be implemented at the UAS, e.g. the UAS should return automatically to the last point with good communication to the operator, when the steering signals are not received any more, which is nowadays implemented in many UAS. Murphy et al. (2008) described scenarios where UAS were used to conduct post-disaster inspects of bridges, seawalls, and piers damaged by Hurricane Wilma. Interesting in that study was the simultaneous use of an UAS and an Unmanned Sea-surface Vehicle (USV) and their connection. The UAS provided precise aerial photos, so the USV could be manoeuvred towards the areas of interest. To overcome travel limitations caused by floods, dam failures, landslides, and infrastructure damages following by the 2009 typhoon Morakot in Taiwan, a helicopter UAV was deployed to collect post-disaster imagery to support post-disaster reconnaissance, disaster restoration and reconstruction assessments (Chou et al., 2010). This campaign was a success and inspired other groups all over the world to use UAS for similar applications. The VT Group (2011) documents an example of how the use of UAS can help to coordinate the rescue teams successfully, during the Haiti earthquake. From the high resolution images they could detect that an orphanage's critical infrastructure was intact, so that the rescue teams could concentrate on other areas.

The limitation of the small UAS with limited flight time was the reason for using big UAS with flight times up to 30 h to provide the aerial photographs for larger areas (Adams & Friedland 2011). Small Octocopter (1,2 kg) and Quatrocopter UAS had been used successfully in Cyprus to monitor the stability of an industrial building, which was damaged after an explosion of ammunition at a military base. The gained information is described to be very useful for the rescue teams and service technicians (DLR 2012). Another well-known public scenario was Fukushima where multi-rotor UAS, with a weight of 8.5 kg were used to monitor the damaged nuclear power plant. Within this operation photos have been taken and radioactivity was measured using UAS (Reavis & Hem, 2011). But one UAS had to perform an unplanned emergency landing on the roof of the reactor because it was out of control (Pluta 2011). This documents the risk of using UAS in case of emergencies, and should urge builder and operators of UAS to emerge strategies to handle failures.

These operations of UAS show that they are able to play an important role to gather vital information in case of emergencies. There are much more operations of UAS in case of disaster as documented in literature. A reason is that UAS are operated by companies where writing of scientific papers is not the main focus of their work or the detailed workflows for operating UAS is business secret, so they are not eager to publish it in detail. As mentioned by Bürkle et al. (2012) an open integration framework is needed „*to gain the most use out of the increasing number of available sensors and sensor carriers (e.g. unmanned aerial vehicles) in an emergency response scenario, their use has to be coordinated*". Quaritsch et al. (2011) present a framework how *"*multiple UAVs that are able to fly autonomously over an area of interest and generate an overview image of that area*"*. They found that "*images were intensively used for assessing the situation and planning next steps*". Never the less this paper presents more a technical concept for their concrete "*system of networked, collaborative UAVs*" and is not focusing on process models. Ollero et al. (2006) reviewed different types of UAVs - fixed wing, vertical take-off and landing (VTOL) - for their use and applicability for forest-fire fighting. Before the fire they can be used for forest surveillance and monitoring of the vegetation and the estimation of hydric stress and risk index. Never the less this paper does also not contain the processes necessary in order to use those systems.

With this paper we want to develop a systematic process model for using UAS in emergencies, especially power outages, and give the organizations guidelines and a possible framework how to integrate the use of UAS into their current or future work practices. Because this process model is based and derived from an empirical study with different organizations it is strongly related to existing working practices. In this process model we consider some challenges like (1) the flow of information to the operator from the different UAS groups, (2) fast processing of the images (creation of orthophotos, geo-referencing, deriving the needed information out of the data), (3) fast transfer of information to the control room and the (4) integration of the different sources of information in a decision support system and efficient coordination of the different systems.

RESEARCH FIELD

Within our overall empirical study (Ley et al. 2012, Reuter et al. 2012) the information and communication practices of organizations involved in recovery work after power outages, such as the police force, the fire department, the Red Cross, public administration and a major power supplier were analysed with a special focus on the situation assessment during emergencies. The study puts a focus on the current practices of each organization. The data was acquired in 2011 and 2012, in two different areas in North-Rhine Westphalia, Germany. When choosing them we made sure that they were geographically and structurally different: The first is a more rural area (area A), the second is an urban area (area B). Our methodology was chosen according to the human-centred design approach (ISO 9241-210).

METHODOLOGY

In order to research the possibilities and limitations using spatial information in the planning, response and recovery phase of emergencies we conducted a workshop on 25.02.2011, which should investigate and record the current state of available spatial information in the event of a disaster at the individual institutions. Therefore the 14 participants had to identify existing gaps and collect desirable improvements, in particular on high-resolution remote sensing images in case of disasters. At this workshop, representatives of police and fire department from two counties (A and B), power supplier, university and a company specialized in cartography and mapping were present. As a qualitative information gathering method we used a semi-structured group discussion. With a semi-structured questionnaire, we intended that the relevant questions were discussed (Randall et al. 2007), but interesting aspects of each organization, which were not always obvious beforehand, could also be mentioned. The first section focused on the current use of spatial information including the questions which spatial information is used at present, in which format the information is available, how the information is updated and how the distribution of the information is in case of an emergency. The second section dealt with the discussion of assets and deficits of the current spatial information use. It contained the questions which map and information distribution channels had been useful, what the deficits in the spatial information in each emergency phase are, and which information would be important to have.

No.	County	Organization	Role
1	A	agency for technical relief	local representative
2	A	voluntary fire brigade	deputy head
3	A	fire department	head of control centre
4	A	county administration	district fire chief
5	A	police department	head of control centre
6	-	university	professor
7	-	university	research associate
8	B	police department	head of control centre
9	B	fire department	district fire chief
10	-	geo consulting company	UAS builder and user of UAS
11	-	power supplier	head, high voltage
12	-	power supplier	operation technician, low voltage
13	-	power supplier	operation engineer, high voltage
14	-	power supplier	operation engineer, distribution network office

Table 1: Participants in the workshop

Figure 2: semi-structured group discussion with organizations responsible for recovery work (anonymized)

RESULTS: USE AND NEEDS OF SPATIAL INFORMATION IN EMERGENCIES

The *police* uses currently two kinds of maps for situation assessment based on spatial information. First road maps with special extensions (e.g. sections) and second static satellite maps (e.g. Google Maps). Such maps occur as in paper based form as well as digital form. With respect to these existing map types and forms some criticisms were mentioned: (1) The maps are updated centrally and caused by the long chain of command this procedure is slow, so the maps are often out of date. (2) The maps are tailored to the needs of the police, so some important information (e.g. incline of streets, maximum vehicle weight) are not included. (3) It is not possible to enter information on the maps. Forwarding of recorded spatial information to the head office or other forces is not easy. (4) The maps do not contain object information, e.g. telephone numbers of persons responsible for buildings or inhabitants, stocks hazardous materials. (5) With the existing information system only the first emergency vehicle can be represented in the information system. Other vehicles are not covered. It is unclear how many vehicles are still on-site. (6) Spatial information can only be passed from the on-site units to the control centres verbally through phone. Desirable information to the police is incline and maximum vehicle weight of the streets, turning options, detailed object information (e.g. buildings or factories), areas where hazardous materials are stored and information from other organizations (fire department, power supplier).

The *fire department* uses currently more detailed maps for situation assessment based on spatial information. They are provided with road maps from the biggest German automobile organization for the promotion of the interests and perceptions of the automotive field. Beside these maps, they use topographic maps in scale 1:50.000 as well as a large scale paper based maps for display in the control centre. These maps have some very detailed information about specific objects, e.g. stored hazardous materials or water conservation districts. Although the fire department has very detailed maps, there are problems, which restrict an appropriated and effective map-based emergency management: (1) Those maps are not as up-to-date as the fire fighters need it during an emergency, because all the information produced in the operation based on paper maps and have to be updated manually at the control centres and in the vehicles. (2) Information is just disseminated verbally through radio or phone. Therefore it is not immediately apparent which car is at which location and information, e.g. road barriers are often stored several times at different places. Desirable information is all that help to answer the questions: How resilient are the ways? What surface do the roads/paths have? Are the roads passable? Where are the collection points for the units? At the moment these deficits could only be overcome by the use of experienced and very knowledgeable local units. However especially in a disaster, forces that are unfamiliar with the area have to support.

The major *power supplier* currently has a sophisticated geo data infrastructure with very detailed digital maps of the operating field. It shows both, the topographic information with a scale of 1:50.000, and the detailed special maps (e.g. location of power lines, with information about each individual electricity pylon). The power supplier has the same road maps provided as the fire department. The vehicles of the on-site units are equipped with bi-directional GPS, so that the location of the vehicles can be transmitted via GSM-network and displayed at any time. Advantageous is the fully independent system, which works also during network congestion or other failures. Desirable information cannot all be mentioned at an early stage. The relevance of information is different from emergency to emergency. For example, when there is a storm with much rain, real-time high spatial resolution aerial images of the current distances from waters to the power supplier's electric stations are very important to optimize the planning for the current situation.

All organizations agreed that nearly real-time aerial images of the current situation could provide an enormous additional value for the situation assessment. These images should have a very high spatial resolution (around 10 cm x 10 cm) and should be always geo-referenced, so they could be integrated into the existing digital maps in the control centres. Therefore it is important, that at first the spatial image data is transmitted to the control centre. There the staff has to interpret, comment and validate this data, so that the emergency services on-site do not have to make much interpretation effort, which could lead to errors due to misinterpretation. An example for the pre-processed maps is information about blocked roads. To capture that high resolution aerial information during an emergency, there are two possible solutions: The first is an airplane/helicopter-based capturing, the second solution could be aerial images from UAVs. The first option was eliminated due to the high costs for the organizations. The use of UAS was agreed to be desirable under the conditions that they are cheap, reliable, can create images with a high quality and transmit nearly real-time information. Based on the second option some requirements for using UAVs in emergencies were raised. (1) Flight routes should be transmitted in real-time to the UAS during emergencies. (2) A high number of different sensors, such as optical, multispectral, thermal, and possibly air quality collectors are necessary to generate special image types with regard to specific environmental factors, such as darkness. (3) Easy handling of the UAS and devices with gloves. (4) The screens should be visible in an appropriated way during strong sunlight or darkness. (5) They should also be very robust, dirt resistant and waterproofed. (6) An essential quality characteristic is a long-lasting battery, because real-time information is needed over the entire operational time of an operation, without changing the UAS or charging them too often.

A PROCESS MODEL FOR THE USE OF UAS IN EMERGENCIES

Based on experiences from related work and human experiences, as collected in the workshop, the process model for the integration of UAS in emergencies, especially power outages, (figure 3) is designed in the two phases prevention (before) and response (during) the emergency.

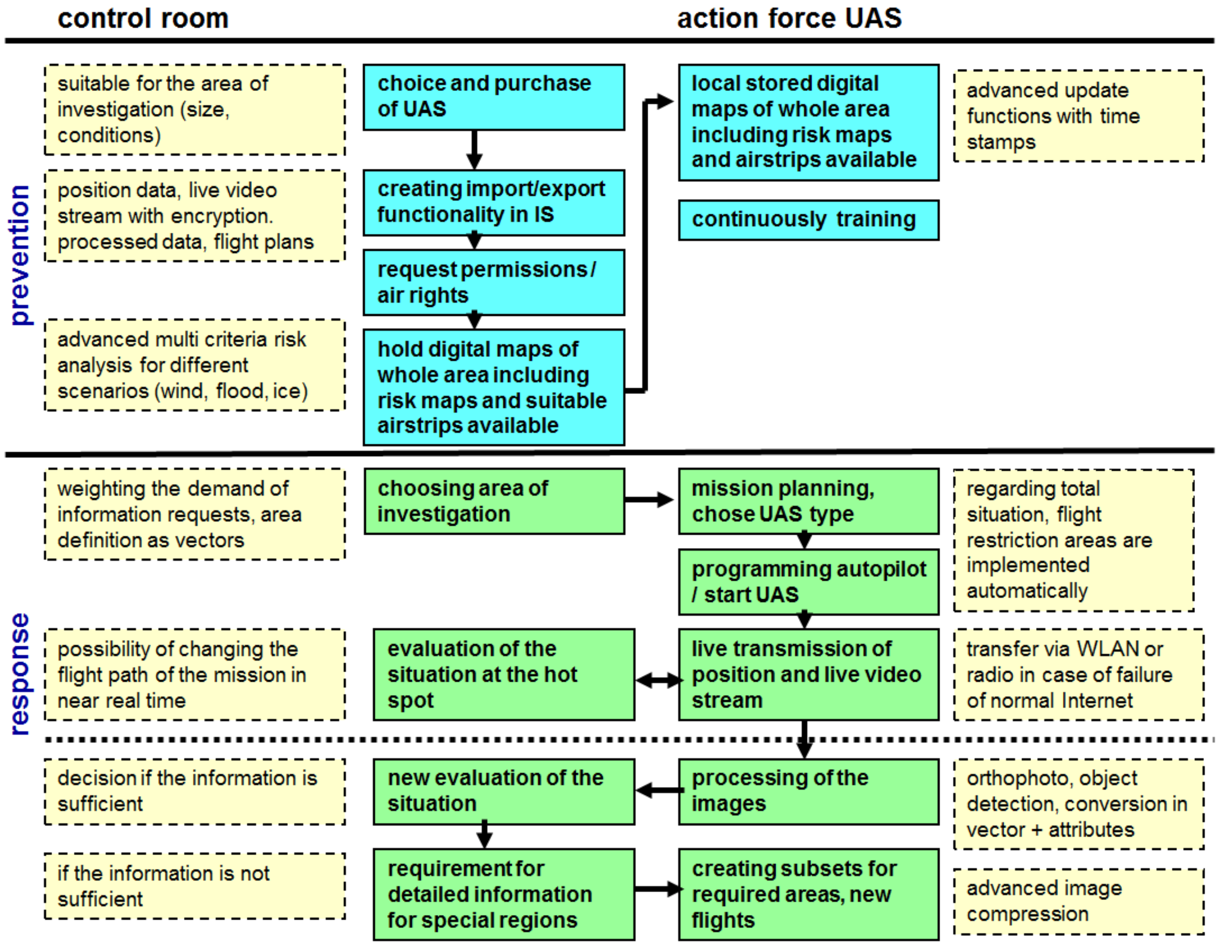

Figure 3: Illustration of the process model for UAS in emergencies, especially power outages

Prevention

In the prevention phase, both technical and organizational aspects have to be considered. A technical aspect is the purchase of an appropriate UAS type. There are several factors, which influence the choice: The budget determines which device of which UAS type with which sensors can be ordered. Besides the budget there are other questions, which should be answered in advance: What flight time does the organization need? Which area size should be covered (per flight)? Which transport options of an UAS does my organization has? Where could the UAS be stored? Based on these issues, the procurement of an UAS type should be discussed. The higher the performance and number of technical options are, the more expensive are the UAS.

It should be ensured that the head of operation can assign dynamically the UAS a location at any time. Such locations should be defined by flight routes that can automatically be flown by an autopilot. Also the organization has to figure out individually, how the later transmitted image data could be integrated in the existing systems. Current techniques are mobile cellular radio (LTE, UMTS) or the digital radio, if telecommunication is disturbed (see: response phase). Therefore the system has to be adapted to offer interfaces for those import and export functionality. To prevent misuse by third parties, all communication with the UAS and the ground station /control room should be encrypted.

UAS type	Multi-copter	Fixed wing systems	parachute UAS
Acquisition costs	25.000 € - 60.000 €	30.000 € - 70.000 €	18.000 € - 40.000 €
Training	Basic: 3 days Individual: 2 weeks Refresh: 1 day quarterly	Basic: 3-5 days Individual: 2 weeks Refresh: 1 day quarterly	Basic: 2-3 days Individual: 1 week Refresh: 1 day quarterly
Area size / hour	0,5 km²	5 km² - 8 km²	3 km² - 5 km²
Flight time	up to 25 min	40 min - 60 min	up to 3 h
Payload	0,3 kg - 2,5 kg according to the size of the UAS	0,3 kg -3 kg according to the size of the UAS	up to 6 kg
Life-Time	Without hard landing around 100 flights.	Estimated around 15 - 60 flights per body.	More than 1.300 hours of flight time
Additional costs	After ca. 200 flights new battery for 400 €	After ca. 200 flights new battery for 400 €	After 500 hours general overhaul

Table 2: UAS types

Not only technical aspects, but organizational issues, have to be considered. To save time in case of an emergency the potential areas of risk, e.g. zones where trees or waters are located close to power lines in cases of storms or heavy rains or past flooding and landslides areas should be detected beforehand in multi-sensorial approaches and stored in the respective IS system. As well suitable start and landing places for UAS must be assessed in advance. Thereby the different UAS take-offs as well as the operation radius has to be considered. Another issue, which should be taken into account, is the sensitive nature reserves, where flight restrictions might occur and often the network coverage for telecommunication is weak. As well alternative areas, if a airstrip is not accessible, have to be stored in the IS system. The fact that different emergencies (strong wind, flooding, heavy snow) demand different locations must be considered in the IS that in can offer the optimal options for the different scenarios. It is desirable that the IS system of the operation units can be updated quickly, even in case of emergency by the control room, so that it represents the real situation in the area of investigation as precise as possible. To meet the legal requirements, it is necessary to apply for the permission to operate the UAS in forehand. The well-known no-fly zones must be regarded and have to be enforced in the planning software of the UAS, this ensures that the UAS cannot violate the no fly areas.

Response

In the control room the operators indicate the areas, where detailed information of the recent situation are demanded and can mark them with vectors (points, lines or polygons) in the IS system. The so identified areas are communicated to the operation units, which overlay the areas on their maps to make decisions about a place for set up their operation base. Thereby the accessibility of the areas and flight restrictions must be checked automatically. After reaching the operation base, they have to set up the UAS, transfer the predefined areas of interest to the autopilots and establish telecommunication connection with the UAS and the control room. The time between reaching the area of interest to UAS take-off can be less than 30 min. After the start, the video camera of the UAS sends images to the operator's ground station and can be be transferred as well to the central control room. This enables the responsible operators in the control room, to have a near real time video stream of the situation and can, adapt immediately the flight path of the UAS if needed. Due to the often limited bandwidth of the telecommunication, the resolution of the video camera is today normally HD, which is often not sufficient or it demands a low flight height of the UAS. The main cameras of the UAS have in general a much higher resolution and store their images on a memory card. After landing of the UAS the memory card will be replaced and the UAS will be recharged / re-fuelled for the next flight. Meanwhile the images of the memory card are downloaded and processed. So an ortho-photo in a very high spatial resolution will be computed from the numerous single images. This ortho-photo must be geo-referenced and information could be extracted (e.g. indication of fallen trees blocking the roads) either manually or with object based algorithm. If this is done on-site, the amount of information which must be transferred to the control room can be reduced dramatically. Transferring only the information about the detected hot spots instead of the whole area can reduce the data size by the factor 1000. But therefore the on-site units must be equipped with powerful computers which is expensive. The processing demands between 10 minutes and some hours, depending on the amount of photos and the computers' processing power. The exact position where every photo was taken is stored within the photos and in a separate file, so if urgent detailed information for a spot is needed, the respective photo or a subset showing the area of interest can easily be selected on demand and transferred to the control room. To optimise an IS system which serves the above mentioned demands, is a challenge.

Recovery

After an emergency the damages must be recorded. The advantage of using UAS is on the one hand the information gaining in a very high temporal resolution, on the other hand the quick establishment and flexibility So processes, like swelling of flood, the resistance or damages of dykes in case of flood, cracks in power lines, as well as the progress of cleanup work, can be observed. These images can be taken when the illumination is not suitable and they can fly under deep clouds, when manned airplanes cannot take images. Following the whole operation should be discussed very carefully to optimize the work flow, to figure out advantages and disadvantages of some field operation bases and to detect short comes. It must be taken care that the UAS with all its components will be refueled/charged and maintained carefully.

EVALUATION OF THE PROCESS MODEL

The aim of the second workshop, which was conducted on 11.05.2012 at an airfield in area B, was to evaluate the process model of UAS in power outages based on a presentation and practical use of three different types of UAS, their advantages and disadvantages in order to review if current UAS fulfil the requirements and special cases mentioned in the first workshop for an appropriate work capability in emergencies. At the workshop representatives of police, power supplier, university, a company specialized in cartography and mapping, a pilot and three UAS companies were present.

No.	Organization	Role
1	university	research associate
2	police department	head of control centre
3	power supplier	engineer
4	power supplier	head, high voltage
5	power supplier	operation engineer, distribution network
6	geo consulting company	UAS builder and user of UAS
7	self-employed	local pilot
8	UAS company I	engineer and UAS designer
9	UAS company II	pilot and UAS builder
10	UAS company III	engineer and operator of UAS

Table 3: Participants in the workshop

The three UAS types were (1) small multi-copters, (2) fixed-wings and (3) parachute systems, because these systems cover, beside the unsuitable balloon types, all low-cost UAS. A major producer of each UAS type was invited. For the multi-rotor systems, an agent of MULTIROTOR was present, because their systems have the reputation to fly stable even under stronger wind conditions. As well it can be equipped with optical and thermal sensors at the same time. For the fixed wing UAS Mavionics had a demonstration. It was chosen because their UAS flies even under very strong wind conditions (more than 20 m/s wind speed) and has references to work successfully under different climate conditions. The long flight time, a very sophisticated autopilot with mature mission planning software and the possibility of flying it manually in case of an autopilot failure were strong arguments to invite them. The parachute UAS were represented with SUSI 62 manufactured by Geo-Technic. This system is very robust, has a long flight time (>2 h), big payload (ca. 6 kg), high security in case of technical failures and it is proofed to work satisfyingly under harsh conditions in numerous projects in all over the world having a flight time of more than 900 hours without major problems. After the practical, interactive live-demonstration, the different organizations discussed these three UAS types with regard to fitting in the designed process model and the conformance to the previous mentioned requirements.

The major *power supplier* stated that at present none of the systems is total meeting their needs. The major issues comprised of legal and technical issues: Due to legislation the UAS have to fly in sight of the operator. So the covered areas are not very large. The process to obtain the permits for the use of UAS is too long and complex. The big advantages of UAS, the fast mobilisation, cannot be used if the permit procedure is complex and takes a long time. From the technical point of view even if the laws allow autonomous flights out of sight, the rage of the available systems is be too short. From the point of view of the power supplier it the flight range must be at least 200 km in order to control a power line with a length of 100 km could be in one flight. Another criticism is that the systems are not able to fly under all weather conditions (rain, wind, snow), so a helicopter is more appropriate. Further on it is not practicable to train the groups to operate the systems. In case of emergency they need their full workforce for reconstruction of the damages. This could be overcome by employing firms to operate UAS. But it would be much more appropriate if the UAS could operate complete autonomously without any operator in the field. For the scenario of detailed investigation of power lines in a sub-centimetre resolution the multi-copter UAS could be of interest, especially when it is equipped additionally with a thermal camera. Furthermore the electronic of the UAS should not be disturbed by the magnetic fields of the power lines.

The representative of the *police* summarised that this process model including UAS can be a valuable tool for some operations, e.g. using a multi-rotor UAS for a precise situation assessment after a traffic accident or during preservation of evidence at crime scenes. Equipped with thermal cameras UAS are meaningful to search and observe hidden persons even at night. Further battery-powered UAS enable the noiseless observation of areas where criminals are, without tightening the situation by the noise of man carrying helicopter. Also it is possible to track criminals without endanger the police units. For the police the major advantage in comparison with helicopter is the quick mobilisation and the small size, so they could be stored in some police cars by default. Concerning the use during power outages no specific use cases were mentioned.

CONCLUSION

This paper presents a process model for UAS in emergencies, which takes both theoretical findings and organizations needs and experiences into consideration. We first presented current types of UAS, approaches of using UAS in emergencies and conducted workshops with organizations responsible for recovery work, in order to gather requirements from real working practices. Recent UAS have potentials to provide important information in case of emergencies. Many technical modules of the UAS are already mature enough for application under difficult conditions: The autopilots and their mission planning software as well as the radio communication between the UAS and the ground station are working well. These data streams can easily be integrated in the individual information systems. Further the current available sensors (optical, multi-spectral and thermal cameras) are applicable in the case of an emergency.

Anyway before UAV can replace manned helicopters and airplanes in emergencies some major challenges must be solved: (1) The operation time of the UAS must be enlarged up to 2-3 h of flight time and they should be able to fly 200 km in one flight in order to be usable for power supplier. (2) UAS must have all-weather capability (rain, mist, strong wind). (3) The interference of magnetic fields and transformers on the control of the UAS has to be tested sufficiently. (4) The autopilots of the UAS must have intelligent strategies in case of failure of the systems (e.g. autonomous emergency landing on suitable airstrips, emergency parachutes, or other systems). (5) To integrate autonomous flying UAS in the normal air traffic, reliable detection systems, to avoid accidents must be developed. (6) Installation of radio communication with bigger bandwidth should enable the near real-time transmission of HD-videos or faster image processing after the flight (generation of orthophotos, geo-referencing and information extraction) should be supported. (7) Important application fields may also be to establish telecommunication when the normal channels of telecommunication are broken. Last but not least currently the safe use of UAS requires particular knowledge, which is not always available.

In current use the need to approve each flight separately and the ban out of sight of operators to fly prohibit the inclusion of large areas limits their application fields. Anyway, advantages of the UAS are the fast mobilisation, the possibilities to take photos in extreme high spatial and temporal resolution by their ability to fly very low over ground, ability to fly below clouds and lower costs in comparison with helicopters, especially if the area of investigation is not too large. This urges the creation of intelligent designed process models which take the possibilities and limitations of the different systems into account. The described approach of a vital participation of all actors proved to be appropriate.

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REFERENCES

Adam, M.A & C.J. Friedland (2011). A survey of unmanned aerial vehicle (UAV) usage for imagery collection in disaster research and management, Stuart M. Adams and Carol J. Friedland, 9th International Workshop on Remote Sensing for Disaster Response. Stanford University, September 14-16.

Chou, T.-Y., M.-L. Yeh, Y.-C. Chen, Y.-H. Chen (2010). Disaster Monitoring and Management by the Unmanned Aerial Vehicle Technology. ISPRS Technical Commission VII Symposium. W. Wagner and B. Szekely. Vienna, Austria, IAPRS. XXXVIII: 6.

DLR, (2012). Ziviler Octocopter-Katastropheneinsatz auf Zypern. http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10660/1147_read-4512/, Accessed 26.11.2012

European Aviation Safety Agency (2009): Rulemaking Directorate, Policy Statement Airworthiness Certification of Unmanned Aircraft Systems (UAS), Document. E.Y01301

Eisenbeiß, H. (2009). UAV Photogrammetry, PhD Thesis, Institut für Geodäsie und Photogrammetrie, Eidgenössische Technische Hochschule Zürich, Zurich.

Everaerts, J. (2008). The Use of Unmanned Aerial Vehicles (UAVS) for Remote Sensing and Mapping, In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Congress, Beijing, China, XXXVII. Part B1, 1187-1192.

Huber, M. (2010). Evergreen supports UAV team mapping Haitian Relief. Aviation International News. March 2010.

Klonowski, J.; Neitzel, F. & S. Siebert (2009). Unmanned Aerial Vehicles (UAV) – Historische Entwicklung, rechtliche Rahmenbedingungen und Betriebskonzepte. -- Photogrammetrie - Laserscanning Optische 3D-Messtechnik - Beiträge der Oldenburger 3D-Tage, Berlin.

Ley, B., Pipek, V., Reuter, C., & Wiedenhoefer, T. (2012). Supporting Inter-organizational Situation Assessment in Crisis Management. In: Proc. ISCRAM. Vancouver, Canada.

Pluta, W. (2011). Drohne musste auf Reaktorgebäude notlanden. http://www.golem.de/1106/84478.html, accessed 26.11.2012

Pratt, K.; Murphy, R.; Stover, S. and Griffin, C. (2006). Requirements for Semi-Autonomous Flight in Miniature UAVs for Structural Inspection. AUVSI's Unmanned Systems North America. Orlando, Florida, Association for Unmanned Vehicle Systems International.

Quaritsch, M., Kuschnig, R., Hellwagner, H., Rinner, B., Adria, A., & Klagenfurt, U. (2011). Fast Aerial Image Acquisition and Mosaicking for Emergency Response Operations by Collaborative UAVs. Proceedings for the International ISCRAM Conference (pp. 1–5).

Quaritsch, M., K. Kruggl, et al. (2010). Networked UAVs as aerial sensor network applications. Elektrotechnik und Informationstechnik 127(3): 56-63.

Randall, D. W., Harper, R. H. R., & Rouncefield, M. (2007). Fieldwork for Design: Theory and Practice. London: Springer.

Reavis, B., B. Hem (2011). Honeywell T-Hawk Aids Fukushima Daiichi Disaster Recovery: Unmanned Micro Air Vehicle Provides Video Feed to Remote Monitors. Honeywell Aerospace Media Center. Honeywell International Inc., 19 Apr. 2011. http://honeywell.com/News/Pages/Honeywell-T-Hawk-Aids-Fukushima-Daiichi-Disaster-Recovery.aspx, accessed 27.11.2012

Reuter, C. (2013): Power Outage Communications: Survey of Needs, Infrastructures and Concepts. In: Proc. ISCRAM 2013, Baden-Baden, Germany.

Reuter, C.; Pipek, V.; Wiedenhoefer, T.; Ley, B. (2012): Dealing with terminologies in collaborative systems for crisis management. Proc. ISCRAM 2012, Vancouver, Canada.

Thamm, H.-P. (2011). SUSI 62 A robust and safe parachute UAV with long flight time and good payload. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII-1/C22, UAV-g 2011, Conference on Unmanned Aerial Vehicle in Geomatics, Zurich, Switzerland

Ollero, A., Martínez-de-Dios, J. R., and Merino, L. (2006). Unmanned Aerial Vehicles as tools for forestfire fighting. Forest Ecology and Management. V International Conference on Forest Fire Research, D. X. Viegas (Ed.).

VT Group (2011). Devastating Earthquake in Haiti: Pioneering Technology Application Saves Time & Resources. VT Group Portland, Oregon, USA. http://www.vt-group.com/media/11406/haitiearthquakecasestudy.pdf, accessed: 22.11.2012