DG ECHO LEAPFROG
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Deliverable B.2: Report on RPAS technology

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1 Introduction

Remotely Piloted Aircraft Systems (RPAS) are becoming a very useful tool in emergency response teams because of their extreme capabilities. In the recent past, the use of RPAS has been mainly focused in military and high end aerospace applications requiring enormous economical investments, however, nowadays such a technology is widely available at very low cost. Giving the ability to a first responder management team to constantly monitor and collect aerial data in real-time gives a huge advantage in terms of situational awareness of the team, saving crucial time as well as safety by minimizing the use of manned helicopters. Most RPAS are now equipped with high-end sensing and communication nodes, low-power lightweight on-board embedded processing computers, while they also exhibit increased flight times, excellent maneuverability and extended ranges of operation.

Although RPAS have been proved a valuable asset for emergency response teams it is very important that the RPAS platform used is suitable for the emergency scenario the team is responding to. The RPAS platform characteristics and payload equipment should always been chosen according to the mission needs and requirements. For instance, if the mission requires to monitor a very large area in the sea and locate a missing person during nighttime then a fixed wing equipped with a thermal camera should be suitable. On the other hand, if the mission requires to monitor a collapsed bridge and search for victims, then a rotor craft should be used. The aim of this report is to provide an overview of current state-of-the-art technologies available in RPAS along with platform characteristics and how mission requirements are related to those technologies.

2 General characteristics

RPAS are mainly categorized in respect to their size, weight or structure type. A platform of very large size and weight is much more stable and can withstand severe wind disturbances as opposed to a structure of a tiny lightweight size RPAS. However, a small sized RPAS could operate in very tight and demanding places or even inside buildings. A large heavy weight structure has also the capability to carry heavy payload and hence it could carry more payload equipment and sensors required for specific missions. Another important parameter that directly affects the performance of an operation is flight time. Flight time is affected by the weight of the payloads as well as the type of the aero structure. Most of the time, fixed wing RPAS have the ability to perform long endurance flights due to their aerodynamic efficient frame compared to rotorcraft. Additionally, as payload weight is increased the flight time of a RPAS is drastically decreased and this should be considered at all times not to carry equipment that is not necessary for the specific mission. Another important parameter that is strictly required by some missions is waterproofness. Some missions are much more demanding regarding extreme temperatures while others require fully waterproof structure.

2.1 Structure

The aero-structure of the RPAS is a fundamental parameter that affects its capabilities. RPAS are categorized into two main categories, horizontal take-off and landing and vertical take-off and landing. Both categories of RPAS give advantages to specific capabilities while at the same time limit its performance on others.

2.2 Horizontal Take-Off and Landing (HTOL)

This kind of RPAS structure is also known as fixed wing RPAS. The propulsion of the RPAS is used to push or pull the aircraft towards the horizontal axis and the lift force is generated mainly from the wings. This provides a very high level of efficiency in terms of flight time, long range distances and high velocity. Nevertheless, this type of aircraft requires much more experienced personnel to operate and a more demanding take-off and landing site because it requires larger space to operate compared to vertical take-off and landing structure.

2.3 Vertical Take-Off Landing

This category of RPAS structure is also known as rotorcraft RPAS. The propulsion of this kind of RPAS is used to lift the aircraft and therefore all the lift is performed directly from the rotors. This provides very low level of efficiency in terms of flight time and long range distances, however, this type of aircraft is able to hover in the air and provide flexibility and agility in the flights. This is very useful for variety of applications in disaster management because it can monitor a fixed point of area without complicated manoeuvers.

Figure 1: Fixed wind and Rotorcraft RPAS.

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3 RPAS Platform Equipment

As technology evolves, more advanced navigation equipment is introduced into latest RPAS. For navigation purposes RPAS are using Inertial Measurement Units (IMUs), Global Positioning Systems (GPS) and a central processing platform called flight controller. Currently, latest RPAS use high quality advanced IMUs that provide precise and accurate measurements of the RPAS orientation in the 3-Dimensional space. Some RPAS have also a number of IMUs for redundancy purposes. The main component the RPAS uses for navigation through space is the GPS. More advanced RPAS use multiple GPS receivers to make sure that the signal is not lost in bad environmental conditions or during strong interference. Some high-end RPAS are using a new technology called Real-Time Kinematic (RTK) to give extreme levels of accuracy in terms of position by using a single reference GPS station. Nowadays, RPAS can provide reliable navigation outdoors, however, indoor navigation is a much harder task. Current technologies are using advanced ultra-sonic sensors to detect and avoid obstacles which provide some kind of safety for indoor navigation.

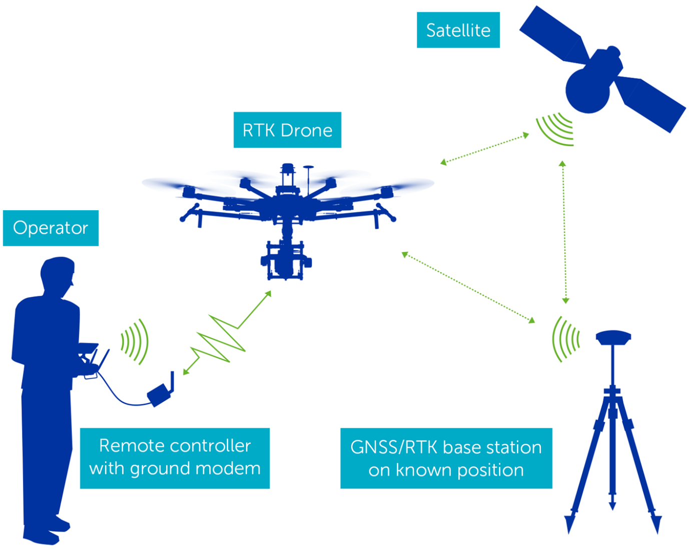

Figure 2: Real-Time Kinematic (RTK) equipment diagram.

3.1 Communication

Communication of RPAS is referring to communication between the actual aircraft and the ground station. This includes telemetry data and video link. The communication may be

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digital or analog and encrypted or unencrypted. Depending on the mission requirements communications links may require high level of security and therefore digital encrypted data link is preferred or it may just require some simple communication protocol to get the job done.

3.2 Telemetry

Telemetry is the communication process by which measurements and other flight related data are collected and transmitted between the aircraft and the control station. This includes flight parameters such as aircraft position, velocity, angle of attack, altitude, temperature, distance from take-off point etc. These data are usually transmitted in the following frequency bands: 433 MHz, 868MHz, 915 MHz and 2.4 GHz. Generally signal penetration is much better at lower frequencies and the signal will propagate further giving extremely high distances of flight. However, it is not possible to send large packets of data in lower frequencies meaning that for a given period of time, higher frequencies will transmit a larger amount of data.

3.3 Video Link

A dedicated communication channel used to transmit live imagery is called the video link between ground station and aircraft. This channel is usually on the bandwidth of 1.2GHz, 2.4GHz or 5.8GHz. Usually in commercial RPAS this channel is not encrypted and this should be considered at all times. Latest technology available uses very resolution cameras giving ultra-high definition imagery. However, usually the video link channel used is 5.8GHz and lacks penetration and signal propagation meaning that the video link its vulnerable to noise if line of sight is intercepted. Older video link communication technologies available may be used for redundancy purposes, such as an analog video link which will provide a very low quality of imagery but will maintain video link even if line of sight is interrupted.

4 Payloads

4.1 Cameras

In any disastrous event, aerial imagery is the vital payload a first responder will need to evaluate and assess the situation. It will also provide a high level of situational awareness to the command center and will vastly help in decision making. Camera sensors are categorized depending on their spectrum.

4.2 Visual Spectrum Cameras

This type of cameras is able to capture imagery in the visual spectrum, similarly to human eye. This is extremely useful in circumstances where a visual inspection and/or monitoring of

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buildings, structures or even people is required. These cameras are able to capture ultra-high definition imagery and some state of the art cameras can even do very high level of optical zoom, providing the advantage to inspect in high detail a very tiny object from a long distance. Although this kind of cameras are really handy to an emergency response scenario; are mainly restricted for daylight operation only.

4.3 Thermal Camera

Thermographic cameras are able to capture the infrared spectrum. Basically these sensors are able to capture the infrared light emitted by any object and convert this information to a color scale imagery at which each color represents a specific temperature value. This gives to the end user the ability to have an RGB image representing a scene into temperature spectrum discriminating hot objects from colder ones and vice versa. The advantage of these camera sensors is that are not vulnerable to light conditions, meaning that daytime imagery is represented exactly the same during nighttime. Currently, some thermal cameras on the market are also radiometric meaning that they provide the end user with actual temperature values and can even accept an input temperature range from the user. This can be very helpful in a search and rescue situation where a human body is known to emit a temperature between 35-38 °C.

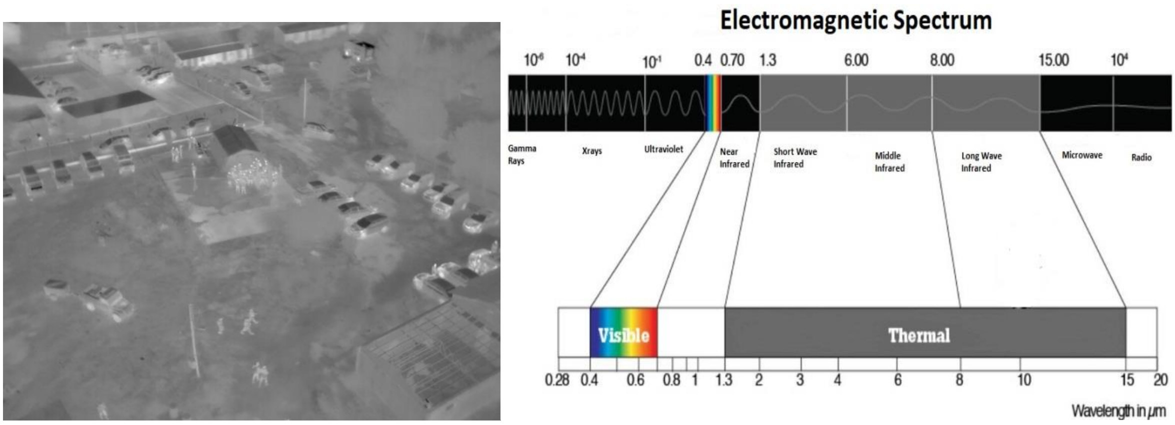

Figure 3: Electromagnetic Spectrum used by a Thermal Camera and a visual representation of a scene in this spectrum.

4.4 Combined Visual and Thermal Cameras

A new technology available combines a visual and thermal sensor into the same equipment giving the ability to monitor from a visual and thermal perspective at the same time. This

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state of the art equipment is extremely useful attached to a RPAS because it gives advantages from both sensors into one equipment at the same time.

4.5 Multispectral Camera

Multispectral are able to obtain images in several frequency ranges. They are frequently used in precision agriculture to detect if the crop is healthy or not. This information can be used to evaluate the damages of a crop or forest in a disaster. Moreover, as they also have near-infrared sensors, they can also be used to detect fires

4.6 Lidar sensor

Laser Imaging Detection and Ranging (LIDAR) is a distance measurement sensor that uses laser technology to calculate the distance of a specific target. These sensors can be either used to measure the distance of a single point or by using an area of lasers to scan a 3-Dimensional area. In the case of emergency response applications this technology could be proved beneficiary if a 3-Dimensional digital reconstruction of a scene is required, for instance in the event of collapsed buildings.

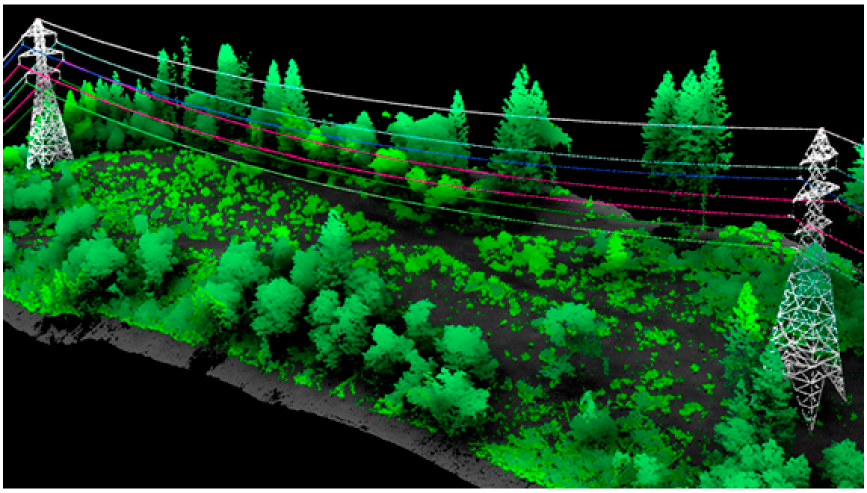

Figure 4: 3-Dimensional reconstruction of a scene used Lidar Sensor.

4.7 Releasing Mechanisms

Releasing mechanisms, could be used to attach important supplies to a RPAS and release them in a certain location. These supplies may include med kits, tools, food, blood, defibrillator, a bottle of water etc. that may be vital in an event of emergency response. The releasing mechanisms may be operated completely manual by the operator or it may be controlled from a sophisticated artificial intelligence algorithm.

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Figure 5: Releasing mechanism for RPAS.

4.8 Software-Defined Radio (SDR)

By definition, software-defined radio is a communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on a personal computer or embedded system. Such device can easily get installed to a RPAS and could be used for a lot of applications. For instance, it could be used to simulate a telecommunication network, providing a temporary solution for cell phone communication in the case that the actual network on the ground has been collapsed or malfunctioning. It could also be used to broadcast a specific SMS message to all the cell phones in the area, providing to the victims of a disaster some useful information that may be proved vital in such an event. Another application of software-defined radios is to track and locate a missing person. By scanning an area using a RPAS equipped with SDR, it could be possible to force the victim's cell phone connect to the SDR and locate him accurately.

Figure 6: Software Defined Radio equipment.

4.9 Other sensors (Flashlight, Gas sensor, CBRN sensor, Loudspeaker, Microphone)

External payloads and sensors that could be attached to a RPAS are not limited to the above. For example, a powerful flashlight could be used to light an area helping first responders perform their duties in total darkness. A loudspeaker or a microphone could also be attached to a RPAS and listen or speak to a victim on the ground while at the same time maintain a live

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image from the camera sensor. Additionally, sensors for evaluating the air quality could be used such as chemical, biological, radiological and nuclear substances.

5 Intelligence in RPAS

RPAS have already been proved beneficial to thousands of applications just because of their extreme capabilities as platforms in respected to manned aircraft. By adding some degree of intelligence to these platforms; their capabilities are further extended. The intelligence may include some degree of autonomy to perform a number of tasks or it could mean that the RPAS is able to fully perform a mission by its own or even in cooperation with other intelligent RPAS.

5.1 Artificial Intelligence in RPAS

Artificial intelligence is a hot field of research in academia and industry nowadays. AI describes the capability of machines to perform sophisticated tasks which have characteristics of human intelligence and include things like reasoning, problem-solving, planning, learning and understanding a situation, scene or a human behavior. Although, there is much more to follow in this field in the following decades, it has already impacted the RPAS industry. Current artificial intelligence algorithms that have been introduced into RPAS are used for object detection, navigation and path planning.

5.2 Computer Vision

Computer vision is an area that could be found almost everywhere, from basic function like face detection in smart phone's cameras to more sophisticated military applications. Introducing computer vision and specifically object detection in UAS can be beneficial in a broad range of applications, especially in emergency response. These may include complex algorithms that are used to analyze aerial imagery and automatically detect objects of interest such as vehicles, human beings, collapsed buildings, flooded areas or spot of fires. Furthermore, computer vision is already introduced into RPAS for navigation purposes. Camera's imagery is used for detection and avoidance of obstacles and hence it enhances the navigational ability of a RPAS to navigate in complex environment without relying only into GPS signal, for example indoors.

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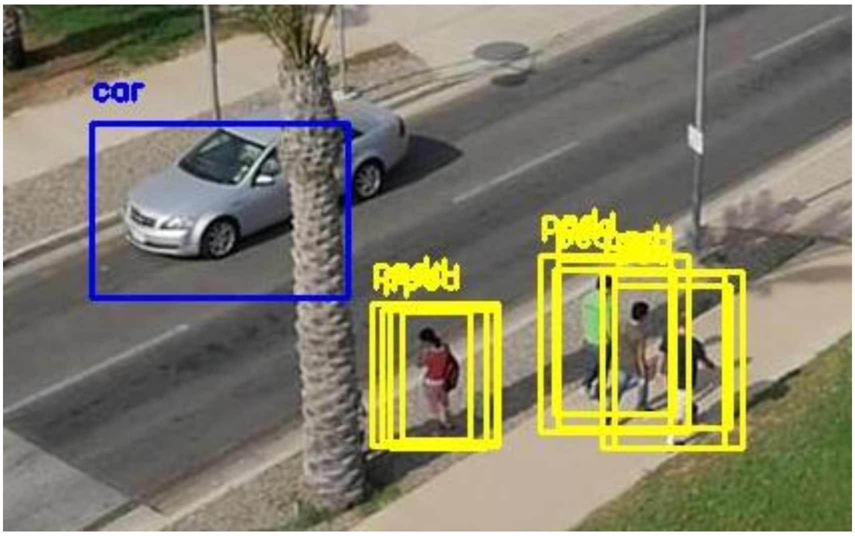

Figure 7: Vehicle and human detection using computer vision and machine learning algorithms.

5.3 On-board Computer

On board computer is usually a low power processing platform that is used to perform calculations or process various data received by sensors to help a RPAS to perform autonomous tasks and missions. This tiny computer is used to integrate all sensors and payloads readings and data acquired from a RPAS and execute algorithms to perform sophisticated tasks in very challenging environments.

Figure 8: On-board computer.

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6 Missions and RPAS selection

6.1 Search and Rescue

6.1.1 Locating people on shore

One of the most frequent emergency response situations involve search and rescue of people on shore. Definitely by using RPAS's as the aerial 'eye' to the first responders is a valuable asset. The RPAS should be able to search, recognize, and geo-reference missing people over challenging and complicate areas. Some cases may involve areas that are impossible to be accessed by a first responder without the aid of an aerial mean. For the purpose of this situation, the RPAS should be capable of accessing difficult areas so it is desirable to have a rotary wing and also carry high-definition camera payloads capable of both daylight and nightlight operations. It will also be huge advantage to have an on board processing platform for performing automatic real-time human detection so it can perform an autonomous search. The RPAS could also be equipped with a release mechanism to carry a first aid kit in case it is needed or even a bottle of water. Depending on the needs of the first responder team; it may be useful to carry a high lumens flash light.

6.1.2 Locating people at sea

Search and rescue over open waters may be simpler in terms of obstacle avoidance and complexity of the terrain, however, a missing person may be travelled large distances due to the water streams. This requires an aircraft capable of covering large areas and travelling at relatively high velocities while at the same time maintain the capability of automatically detect and recognize people on sea. A thermal camera in this kind of scenario is extremely useful because of the contrast in temperature between water and human body. Another requirement in this situation is that the RPAS should be able to carry equipment capable of long range communications and long endurance flight times to be able to cover a large area.

6.2 Outdoor Assessment and Mapping

The purpose of outdoor assessment and mapping mission is to collect as much imagery as possible of a disaster area and build a virtual reality model either 2-Dimensional or 3-Dimensional to perform an assessment of the situation. Depending on the area that needs to be covered, a corresponding type of RPAS is required. If the area is large then ideally a fixed-wing RPAS will be used to perform the task faster and more efficiently. On the other hand, if the situation requires accurate inspection of structures, then rotary wing RPAS will be more advantageous as it can be more precise. The RPAS used in this task should be able to perform a high resolution ortho-mosaic mapping of the area and be able to recognize the coordinates of criticalities in the area. It may also be required to be capable of transmitting the data in

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real time back to ground station for data analytic purposes. For performing this task effectively, the RPAS should be equipped with at least a high-definition visual camera for daylight assessment purposes and an infrared camera for nightlight assessment. Additionally, if it is available a LIDAR could also help in 3D reconstruction of a scene. Finally, the data processing and analysis of the data collected could be integrated into the unit or transmitted remotely via a dedicated communication channel. Disasters that require monitoring, assessment and mapping include flooded areas and areas suffered from an earthquake.

6.3 Indoor Assessment and Mapping

Similarly, to outdoor assessment and mapping indoor shares the same purpose; to collect as much imagery as possible of an indoor scene and perform a virtual model of the scene for evaluation and assessment purposes. However, this task is much more complicated because of the indoor complex environments. Therefore, the RPAS should be able to fly in confined spaces without geo-referencing. This can only be achieved by using rotary micro RPAS. Furthermore, the RPAS should carry a dual gimbal camera setup having both an optical and a thermal camera for navigation and data collection purposes since indoors may have total darkness spots. For this kind of mission, it is important to make sure that the RPAS's communication equipment is capable of transmitting data back to the remote data analysis center while maintaining uninterrupted communication signal. The RPAS should also be equipped with an object detection and avoidance system so it can navigate safely inside indoor tight spaces.

6.4 Forest fires monitoring

Forest fire monitoring is subdivided in two main tasks. The first task involves a continuous monitoring of the propagation of the fire in order to give situational awareness into the command and control center as well as decide whether evacuation maybe required in certain areas such as villages. Although this could be very helpful, it is not an easy task due to the fact that manned aircraft may be performing a fire extinguishing procedures during the event. This will require the RPAS to loiter in a separated airspace usually in very high altitudes, therefore, the RPAS should be able to fly at high altitudes and also carry optical sensors that will be able to monitor with high-resolution imagery the terrain from such an altitude. This task may be performed using either a fixed wing or a rotary wing aircraft. The second task is performed after the fire is extinguished and involves detection, localization and monitoring of any possible hotspots. This scenario could also be performed either using a fixed wing or a rotary wing depending on the actual size of the area.

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7 Conclusions

RPAS technologies and capabilities are growing in an exponential pace. As shown in this report, RPAS prove to be a valuable asset for emergency response operations. Since new technologies continuously seek to further expand the already wide field of capabilities of RPAS, it is important to frequently review the current technologies available and be able to identify their potential for specific missions. As already been discussed in this report, every mission has its unique requirements in terms of technical specifications so as to fully utilize the capabilities of each platform and its payloads.

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