EENA / DJI Pilot Project Report

The use of Remotely Piloted Aircraft Systems (RPAS) by the emergency services

A Report from the joint EENA and DJI Pilot Project

EENA / DJI Pilot Project Report
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Quotes from the Project participants:

"Mid and West Wales Fire and Rescue Service are proud to have been involved in this project to explore the wider use of drone technology to assist in the work of emergency responders. The opportunity to work with other European emergency responders who are pioneering the use of drones has been a really worthwhile and positive experience.

This technology has significantly improved situational awareness for our officers and crew whilst responding to dynamic and complex emergency situations. Without a doubt access to real-time thermal imagery and high resolution optical images has significantly improved situational awareness to support dynamic decision-making and therefore increase the safety of our operational crews and the communities which we are there to serve.

It is apparent the role of drones and the requirements of emergency services in regards to future technologies will increase substantially over the next 2 to 5 years. Issues such as longer endurance, able to operate in higher wind speeds, optical devices that work effectively in bad weather and deployable payloads will be a vital requirement for us.

In relation to software the ability to securely and quickly stream to remote locations determined by the end user as well as online virtual repositories for the images would be considered an advantage.

As a Service we have gained a considerable insight into the use of drones in other European countries and this information has enabled us to develop our operational procedures to deliver an effective and vital response capability for our communities and our staff."
- Mid and West Wales Fire Rescue Service, Steve McLinden

"Using drones as part of our response to incident callouts has enabled us to respond faster and with more accuracy. We are able to search larger areas with greater accuracy in a shorter time span than before which makes it possible to deploy other SAR specialists in places where their capabilities are of better use. Drones have become an inseparable part of our response and their involvement will only grow with time."
- REY-SAR, Olafur Jon Jonsson

"On a roof fire in an urban environment, we always have bad angle of view, now we have the possibility to get a bird's view. We found out that it is essential that the drone is as close to plug and play as possible, having a great deal of autonomy, but still being able to take control manually. Drones in the Fire and Rescue services are a tool and should be used as such; you can no hammer nails with a sponge."
- Greater Copenhagen Fire Department, Thomas Sylvest

"When Search and Rescue (SAR) teams respond to a request for help, they do so in the face of ever changing challenges that can have a direct impact on the success of a SAR mission. Nature of terrain, weather conditions, time constraints, availability of resources and equipment all play a part in determining how quickly we locate the casualty or missing person.

The introduction of drone technology and best practice protocols for its integration, alongside existing SAR methods and techniques, can expedite a successful outcome. Through this project we have realised that the use of a drone can help relay situational awareness to those responsible for coordinating the rescue, so that a life changing decisions can be made quicker. Their use also helps to mitigate the element of risk that team members have to face when responding, as well as saving on time to get to, and assessing difficult to reach, locations. "

- Donegal Mountain Search and Rescue, Leo Murray

"Our main goal of this project was to get a more detailed understanding of the needs of first responders and how off-the-shelf platforms can meet those needs. What we have realized is that a drone has evolved from being a flying device to a data collection device. Through that it has become a decision making tool, with applications beyond just locating a missing person or getting a simple bird's eye view. This knowledge allows DJI to continue building more capable hardware and software platforms."

- DJI, Romeo Durscher

"The project has been a real window into how RPAS are being used and may be used during emergency responses. We have seen that the pace of technological advancements will continue as the platforms become more intelligent, more resilient, more innovative and more impactful. This will lead to more and more RPAS Units being established leading to more user experience being shared along with best practice information. EENA will continue to focus on the topic as we firmly believe in the technology and what it can do help the emergency services to make more informed decisions. Ultimately it will lead to be better outcomes for our citizens. EENA would encourage all emergency services to evaluate the benefit of RPAS for themselves and we remain available to support them wherever possible. We also would encourage other RPAS platform manufacturers, integrators, software and hardware developers to continue to collaborate with the emergency services in an effort to understand their requirements and help to create future-proof products and applications"

- EENA, Tony O'Brien

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1 Executive Summary

The first responder community is quickly adopting RPAS technology as a standard device in the emergency management tool kit. As a response to the rapid development of RPAS integration in first responder missions, EENA decided to set up a working group on RPAS in 2015. The group quickly grew to a network of 125 members, a strong indication of the interest in the technology. In April 2016, EENA partnered with DJI for an in-depth study of how RPAS technology is used by first responders pioneering the integration of RPAS in their work. The aim of the project was to learn more about the use of RPAS for emergency response and to find best practice for RPAS use – in terms of operational, technical, safety, privacy and legal issues.

Four first responder teams were carefully selected as partners for the research project – Mid and West Wales Fire and Rescue Service (UK), Donegal Mountain Rescue (Ireland), Greater Copenhagen Fire Department (Denmark) and Reykjavik SAR Team (Iceland). Between May and October 2016, the teams used RPAS technology for operations ranging from searching for missing people to putting out chemical fires.

The key challenges listed below were identified at an early stage and the participants were challenged to identify best practices over the course of the project:

- Integration of RPAS in Standard Operating Procedure
- Training of teams on the use of RPAS
- Hardware needs and maintenance
- Logistics
- External framework for RPAS use

The insights from the project are outlined in this report and will be shared with the EENA RPAS group as well as with the broader international first responder community.

Overview of key challenges and recommendations:

Integration of RPAS in Standard Operating Procedure
Thanks to accessible and affordable technology, collecting data relating to the emergency has been made relatively easy. The challenge is oftentimes how to make the best use of that data – to get the relevant piece of information to the right person at the right time. Key recommendation includes having a set-up with a minimum of two people using the RPAS, with one person controlling the unit and one person searching the video feed for information that can be used for decision-making. Sharing data over an encrypted channel is a top priority and several third party solutions for this were examined over the course of the project.

Training of teams on the use of RPAS
While the RPAS team needs to get in-depth training on how to operate the technology, the broader team, including responsible authorities and team members, need to understand how RPAS fit into the operation. The RPAS team needs to have a clear role and reporting structure within the bigger mission.

Hardware needs and maintenance
RPAS manufacturers are improving the technology at a high speed and as RPAS become smarter, lighter and more powerful, the technology becomes easier to use. During the course of the project,

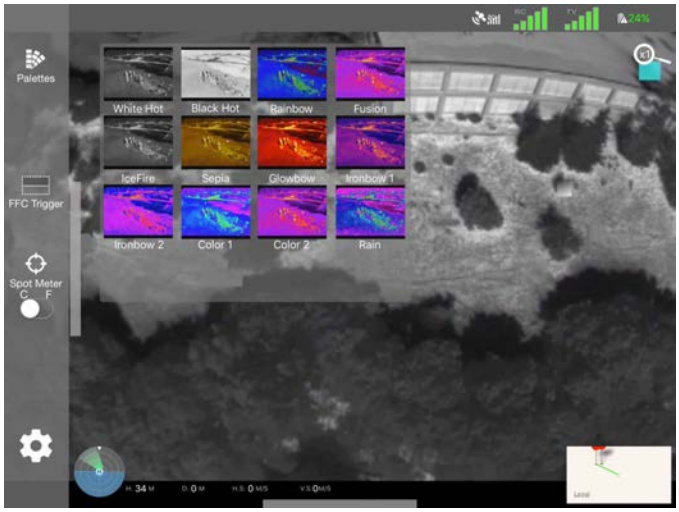
DJI's Phantom and Inspire series were used with both RGB[1] and thermal cameras. One of the test sites also used a Matrice unit (a developer platform) to develop new software for search and rescue. Key recommendations from the teams when considering hardware is to make sure the platforms are reliable and have redundant systems, powerful data transmission links, GPS[2] / GLONASS[3] integration, and integrated software development kits. Further, the first responder community articulated the need for weather-proof systems, more powerful lift capability, payload drop capacity and flashlights for night flying.

Logistics

RPAS technology adds the most value when used directly after an incident, to get a quick situational overview and to find missing people when time is critical. Therefore, making sure that the RPAS units are easily accessible is key. Basic recommendations include always inspecting the units for damage and making sure they are updated with latest firmware. Other key questions to address include where the units should be stored, how they are best transported to incident site, where they should be deployed and how battery management is best structured.

External Framework

As with any new technology, educating regulators and the public is important to build trust for the technology and to ensure a legislative framework that is open for RPAS use. Developing an industry standard for first responder RPAS to use blue lights is widely supported by the community. Requirements being able to operate RPAS at night and beyond visual line of sight



Other key outcomes from the project

In addition to a set of best practices and recommendations for how to use RPAS technology, the project resulted in two new software solutions targeted to the first responder community:

1. DroneSAR – a Search and Rescue App developed by DroneSAR
2. DJI HotShot – a customized app for DJI's thermal camera providing a simpler user interface where it is easy to adjust settings and find relevant temperature ranges.

The way forward

We are still at the very beginning of the use of RPAS technology for first response missions. As hardware and software solutions mature and become customized to the emergency response community, there will be more case studies and proven best practice for how to integrate RPAS in standard operating procedures.

DJI and EENA will continue to search for best practices and concrete practical improvements for how the technology adds value. We welcome feedback and look forward to keeping a close dialogue with the community. Please feel free to contact us through EENA's website (http://www.eena.org) or through http://citizenship.dji.com/

[1] RGB = Red, Green, Blue
[2] Global Positioning System (US)
[3] Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation Satellite System (Russia)

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2 Introduction

2.1 Glossary of terms

EASA	European Aviation Safety Agency
EMS	Emergency Medical Services
FAA	Federal Aviation Authority
FLIR	Forward Looking Infra Red
FRS	Fire and Rescue Services
GLONASS	Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation Satellite System (Russia)
GPS	Global Positoning System (US)
HD	High Definition
ICAO	International Civil Aviation Organisation
IC	Incident Commander
IMU	Inertial Measurement Unit
LEA	Law Enforcement Agencies
RPAS	Remotely Piloted Aircraft Systems
SAR	Search and Rescue
SDK	Software Development Kit
UAS	Unmanned Aircraft Systems

Remotely Piloted Aircraft Systems (RPAS) is a term given to the more widely known term of 'drones' and is the term most commonly used by International Civil Aviation Organisation (ICAO)[4] to describe the civilian use of a remotely piloted aircraft, the remote pilot station and the data links. RPAS is in effect a subset of the other term that is used to describe drones which is Unmanned Aircraft Systems (UAS), which also includes aircraft that can be programmed to fly autonomously without the involvement of a pilot. RPAS as the name suggests are controlled by a pilot from a distance and by their nature, are able to fly closer to objects than traditional manned aircraft and the only difference is that the pilot is not on board the aircraft.

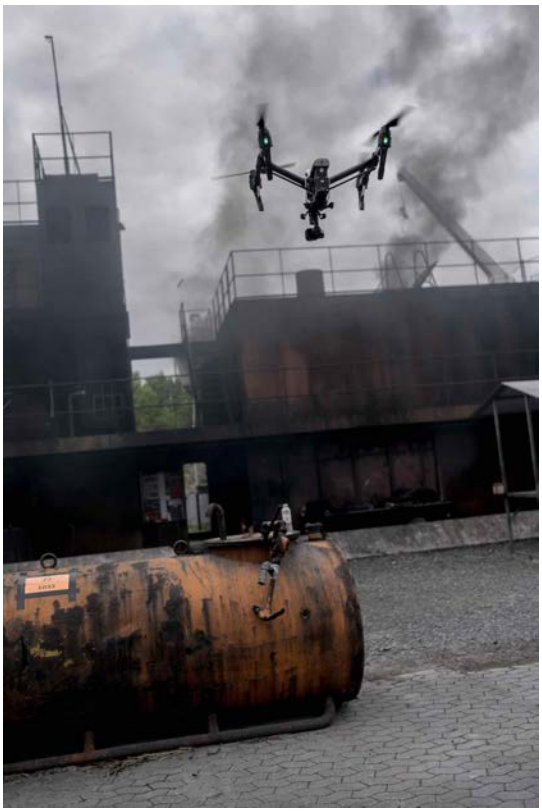
RPAS come in all shapes and sizes, weighing from just a few grams and can go up to several kilos and even greater. As they are defined as aircraft, their use must be controlled by observing certain rules and regulations. There are efforts across Europe and other parts of the World to create a legislative framework regarding the use of RPAS; many countries already have rules regarding their use and the European Aviation Safety Agency (EASA) are currently in the process of setting the rules for Europe[5]. In the US, the Federal Aviation Authority (FAA) have published their rules[6] on the use of RPAS and whilst the project scope was not to examine the regulatory rules, the fact of the matter is that all RPAS operators should be familiar with them and abide by them uniformly.

Their capabilities also vary with many platforms offering different functionalities and specifications. What is known however is the fact that the use of RPAS by the emergency services, SAR and First Responder communities is growing rapidly and that the technology onboard the RPAS is also changing rapidly. The RPAS used 2 years ago is almost certainly different to the ones available today

[4] ICAO Circular 328/2011
[5] EASA RPAS rules as at October 2016
[6] FAA RPAS rules as at October 2016

and with this pace of change, the RPAS in 2 years from now will look, perform and offer so much more than the platforms of today.

At a macro level, the European Commission stated in April 2014[7] that there were "1,708 different RPAS referenced worldwide of which 566 in Europe, being developed or produced by 471 manufacturers worldwide of which 176 in Europe". Whilst the real or current figure may be difficult to establish, the sale of RPAS has risen several fold since that date with US officials estimating that the sales of civilian drones in the US during the Christmas holiday season in 2015 was over 1 million units. Research firm Markets and Markets estimates that the global drone market will grow at a compound annual growth rate of 32% between 2015 and 2020 into a $5.6 billion industry[8]. The firm estimates that among applications, precision agricultural drones will enjoy the highest demand along with First Responders, media production, retail, inspection, mapping services, and education.



So why would the emergency services, SAR agencies and First Responder communities look to RPAS as a tool to support their work? First of all, the aforementioned communities have different requirements and not all of them would see RPAS as part of their toolkit. For example, many Emergency Medical Services (EMS) probably wouldn't use RPAS whilst SAR and particularly Fire and Rescue Services (FRS) have identified RPAS as a real asset and can readily identify with their capabilities. Law Enforcement Agencies (LEA) can also benefit from the RPAS technology particularly from a crowd management perspective and possible counter terrorism perspective. For their part, SAR organisations use RPAS during the search phase of an operation and use its capability to make fast, efficient and effective searches over vast swathes of land.

But there are many examples of where RPAS have not been used responsibly and we have seen reported issues where civilian operators have hampered the work of the emergency services by getting in way of rescue helicopters and fixed-wing aircraft. The media has reported on such issues previously and clearly work needs to be done in terms of educating RPAS operators about the rules that should adhered to.

RPAS are proving to be a real asset and can assist during emergencies and disaster relief operations by supporting better decision-making. They can help the emergency services to get an "eyes on" perspective of the operation and provide videos and images to the Incident Commander (IC) on the ground. With the availability of thermal imaging cameras, high resolution images and 4k video quality, the RPAS technology is delivering enhanced capabilities to the emergency services.

All of this ensures better outcomes for those in need of help and importantly also helps to keep our emergency services, SAR teams and First Responders protected and safer than ever before.

[7] COM(2014) 207
[8] Markets and Markets Research Report

2.2 Overall objective of the Pilot Project

In June 2015, EENA established a Working Group on Remotely Piloted Aircraft Systems (RPAS) in an effort to understand more about the technology and how it could support the work of the emergency services, search and rescue (SAR) and First Responder communities. The Working Group, now with 125 members from 39 countries, issued a White Paper[9] later in 2015 and in doing so made a number of key Recommendations. One of the Recommendations was that the RPAS manufacturers needed to get closer to the aforementioned communities in an effort to understand their requirements and thus create platforms and technology that were suited to their needs.

The project concept was developed by EENA following on from the discussions held during the RPAS Working Group and from the interest levels identified during the EENA Conference of 2015.

There were a number of objectives and targets for the project, namely:

- To learn about the various needs and requirements of the emergency services and SAR teams
- To establish and review several use-case scenarios in order to understand how RPAS technology could be implemented and optimized
- To gain a deeper understanding of the impact of data management and to identify what type of data is wanted/needed, what the impact of such data is, how it could be integrated into the command and control process and how it could be analyzed either in real-time or in a post-event review.
- To understand what the operational procedures are involved in a 'RPAS team', what the correct skill sets might be, their function, the reporting structure.
- To understand the criticality of communications within a 'RPAS team' and how communication in general is handled with the other members of the response team and/or other partner organizations and authorities
- To understand the post mission procedures carried out by the 'RPAS team' including the safe packing up of the technology, its cleaning and maintenance, logging of noticed problems, repair of the technology, storage of data and the compilation of the mission reports.

In overall terms, the objectives were covering operational, technical, safety, privacy and legal issues with many issues overlapping between several objectives. In addition the project focused on the 'human' element and how communication, teamwork and individual behaviours would impact on the RPAS team.

2.3 Description of the 4 Pilot sites

And so in April 2016, EENA announced an exciting partnership with DJI to do exactly that. EENA and DJI invited applications from emergency services organizations to take part in the Pilot project. 41 applications were received from organizations not only from Europe but from the USA, Australia and New Zealand. Such a reaction is an indicator of the level of interest in the topic and demonstrates

[9] EENA White Paper 20 November 2015

that the Emergency Services and First Responders are keen to learn more about the technology and educate themselves on its capabilities.

EENA and DJI then selected four Pilot sites that have varying operational challenges. Whilst not a prerequisite, all of the Pilot sites selected had previous RPAS experience and were developing plans and strategies for integrating RPAS into their operation.

The four Pilot sites selected from the list of applicants were:

Donegal Mountain Rescue Team (Ireland)

Donegal MRT was established in 1982 and is a voluntary SAR service is located in the northwest of Ireland and covers a landmass of 4,861km^2. Its topography is predominantly mountainous with both coastal and inland mountain ranges. Approximately 1/3 of its SAR response is done in close cooperation with the Irish Coastguard units along the coastal mountain ranges. Typically it receives 50 callouts per year. It is comprised of 35 team members including one search dog unit. Donegal MRT works closely with all the other Agencies such as the Police, Aer Corp, Civil Defense and Irish Coastguard and they started testing and trialing RPAS in September 2015 in remote locations and in various weather conditions. Donegal MRT are keen to see the development of RPAS for SAR missions as well as protocols and techniques for using RPAS in remote and hard to reach locations. They also are keen to develop a first responder shared database facility to enable visualization / identification of images received live to team members remote from the SAR incident site. Donegal MRT also aim to develop a bespoke software solution with 'real time' networking capabilities including 'crowd sourcing' and to investigate potential drone use to act as a repeater system to improve visual line of sight issues.

The team predominantly use a DJI phantom 4 and Inspire drone with the Zenmuse X3 and XT camera. Operating as a 2-3 person team comprising a drone operator, drone op "attendent" who works and prepares in advance of the operators needs and a team member to forward plan, navigate, and relay communications and progress to incident command.

Greater Copenhagen Fire Department (Denmark)

GREATER COPENHAGEN FIRE DEPARTMENT

Greater Copenhagen Fire Department is a relatively new organization as Copenhagen Fire Department. merged with 7 other Fire Departments on 1 January 2016. The Copenhagen Fire Department was founded in 1687 and covered the center of Copenhagen, Now the Greater Copenhagen area covers approximately 1 million citizens and welcomes over 10 million tourists per year.

With 1000 employees, 12 stations and more than 80 rescue vehicles Greater Copenhagen Fire Department is by far the largest Fire and Rescue Service in Denmark. The area covers more than 100km coastline as well as key strategic and historical landmarks such as the Queens Palace, the main Government building, a large number of historical buildings in the heart of the old town In addition to this Greater Copenhagen Fire Department also covers Copenhagen harbour with its oil port and several large industrial production companies.

In crisis situations one of the first requirements is to get the best situational awareness information as quickly as possible and to that end, the RPAS is a key strategic asset.

Since Greater Copenhagen Fire Department began using a RPAS in 2014, Captain Thomas Sylvest has been the only pilot. At the start of 2017 they now expect to have an additional 6 pilots, so they'll be available 24/7. The RPAS unit uses three different setups with the DJI Inspire - one with a Z3 zoom camera, a FLIR XT Thermal camera, and the ZT zenmuse camera.

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Mid and West Wales (UK)

GWASANAETH TÂN AC ACHUB
Canolbarth a Gorllewin Cymru
Mid and West Wales
FIRE AND RESCUE SERVICE

Mid and West Wales Fire and Rescue Service makes up almost two-thirds of Wales, covering a predominantly rural area of 4,500 square miles (11,700 km2), comprising 58 stations and employing 1,200 staff. It is the third largest in the United Kingdom, behind the Scottish and Northern Ireland Fire Services.
There are a variety of risks found within the Service area, ranging from the petrochemical industries in Milford Haven, to the risks associated with heavily populated areas such as Swansea and Neath Port Talbot.

There is also a large farming community and many other light industries throughout the area. These, together with an extensive coastline and inland waterways, form some of the specialised risks found within the Service.

The Service currently has two RPAS platforms, The DJI Inspire1, with XT camera and forward pilot view camera, and the Aeryon Skyranger with 30x HD zoom camera and combined Thermal and optical camera.

The RPAS's are embedded within our Urban Search and Rescue Team and are deployed along with our search dogs. MAA currently have 10 CAA approved drone pilots who are 'flexi-duty' operational response managers. MAWW provide 24/7, 365 days a year cover and crew the RPAS as a minimum team of two, one pilot and one camera operator/flight coordinator.

Though the development of our capability they have acquired a number of accessories to assist effective RPAS deployment, this includes a pop -up darkroom tent which acts as a flight operations briefing point with large screen monitor; LTE WIFI mobile communication capabilities to enable live streaming and remote commander and pilot dynamic interface; LED illuminated landing mat and night time landing zone beacons.

The success of the Air Support Unit through the current RPAS capability has enabled a range of collaborative partnerships to be developed with key partners such as Dyfed Powys Police, Natural Resources Wales and South Wales Fire and Rescue Service.

Reykjavík Search and Rescue (Iceland)

Hjálparsveit skáta í Reykjavík (REY-SAR), founded in 1932, is one of the largest and oldest search and rescue teams in Iceland. It is located in Reykjavík, the capital of Iceland, which is surrounded by mountains, woodland areas, lakes and rivers, lava fields, international airport and the ocean. This creates a diverse area of activity which has resulted in the team adopting a wide range of capabilities.

Search and rescue operations are the mainstay of its deployments, counting for 74% of incidents, but the team also handles a wide range of service engagements for The Icelandic Road and Coastal Administration and other government agencies.

REY-SAR began studying the use of drones in early 2015. The goal was to systematically and methodically study their capabilities and find out where they could best fit into the team's operations. Drones were first used in an official capacity in September 2015 and are now fully integrated into the team's response mechanism.

Drones have been successfully deployed in multiple incidents over the past year. Their continued use has evolved and expanded during that time and continues to develop. The addition of a thermal camera was a game changer as it expanded the operational capability of the drones to 24/7 all year round. The thermal camera drone has been delivering positive results and with more use and more experience it will continue match and exceed expectations.

Each of the 4 Pilot sites were provided with DJI equipment to use during real emergency situations and their feedback as to how the technology was used, how it performed and how it could be improved was obtained. The project has had just short of a 6 month window and followed on from a kick-off Workshop which was held in Copenhagen in May. Throughout the project, the participants took part in various conference calls together and shared information on their use cases and the experiences they had using the equipment.

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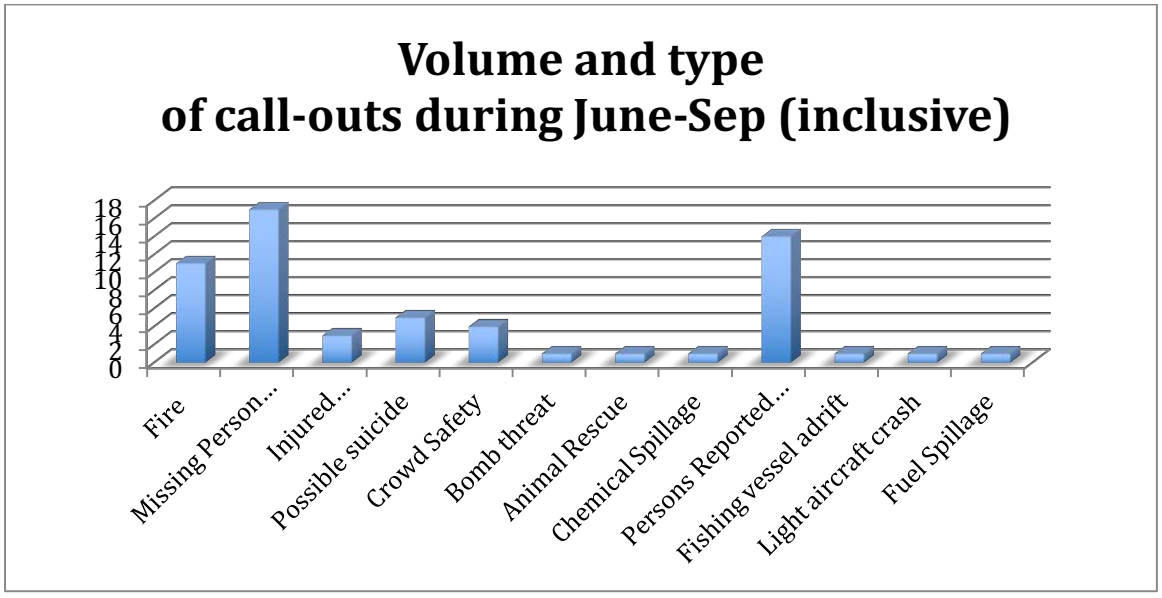
3 Use Case examples obtained

During the course of the project there were 60 call-outs requiring the expertise and capability of the RPAS unit from each of the four Pilot sites. The call-outs varied in nature and were consistent with the role of the Pilot site and the availability of the RPAS team. Many of the Pilot sites were also providing cover and support to other emergency services during real emergencies. In addition many of the Pilot sites took part in multi-agency training exercises and national fora to discuss the future of RPAS in their country.

In the chart below all 60 call-outs have been classified together and presented in an anonymized fashion.



In approximately 40% (25) of these cases, the RPAS unit was deployed but it was 'stood down' by the Incident Commander either upon arrival on scene or prior to arrival. Looking deeper into these cases, 17 of them were stood down because the missing person had been located. The distance that the RPAS unit had to travel in order to reach the incident site may have been a factor in some of these cases.

One of the key elements of being able to respond to a call-out request is of course the weather. Weather conditions can vary and there were several examples during the project where the RPAS team was not able to deploy because the weather conditions were not safe to operate in and as a result they had to be stood down. Low visibility caused by low cloud, fog as well as high winds can hinder a RPAS unit from being deployed and as 'safety-first' is always the first consideration, the RPAS unit sometimes has no choice but to stand down. This is also the case with some fixed wing aircraft and even helicopters so it is not unusual.

Looking at the number of cases where the RPAS unit was stood down, 3 (5%) of them were caused by adverse weather conditions. Whilst this figure is low, it should be pointed out that the project took place mostly during the summer periods where the weather is more favourable.

Listed below are samples of the types of call-outs reported by the 4 Pilot sites during the project. They have are just examples of some of the types of call-outs and they have been anonymized in order to respect the relevant data privacy requirements that exist in the respective countries:

3.1 Example #1 – Fire at an electrical sub-station and Scrap yard

A high voltage electrical sub-station was on fire and had been well alight when the RPAS team arrived on scene. The radiated heat was already spreading to industrial recycling processing plant and nearby cylinders. The RPAS was deployed and used to provide an overall scene view to assist Incident Commander in terms of planning, track smoke plume etc. The thermal camera was used to monitor radiated heat transfer and guide defensive fire fighting operations. Images also used to check reports of children at rear of site and saved crews being deployed into the hazard area when the claim was discovered to be incorrect.

3.2 Example #2 – Fire involving highly volatile chemicals

A fire at a waste storage area at an industrial titanium milling company was reported. It was discovered upon arrival that the fire was in discarded oil soaked rags, which were in danger of heating and setting fire to highly volatile titanium swarf. Optical and thermal cameras were used for scene overview and risk assessment. The thermal camera was used to track the fire spread and temperature of the titanium swarf barrells close to the fire. Crews with covering jets, guided by the RPAS optical images, were used to ensure that the foam hit the seat of the fire whilst crews were behind concrete protection therefore minimising risk to crews.

3.3 Example #3 – Missing persons search

A missing person report was made known to the RPAS unit who deployed and begun a wide area search of the area where the person was reported missing from. In this case it was a river and marsh area. The RPAS unit used the thermal camera and located the missing person and supported the Police in approaching the person. The RPAS reduced the search time to less than 15 minutes whereas a ground team would have taken a multiple of this to locate the missing person. As well as an effective and efficient response, the RPAS unit afforded protection to the emergency services on site. Live streaming and image sharing with other agencies allowed for shared situational awareness information.

3.4 Example #4 – Missing persons search

The RPAS unit were informed of a missing person in an area of known lava fields that are extremely difficult to traverse. The Incident Commander suspected that the missing person was not in that location but nevertheless had to make certain and rule out the possibility for certain. The RPAS searched the wide area in 40 minutes confirming that the area was clear. A ground team searching on foot would have taken between four to six hours and possibly with a much greater degree of

uncertainty. The RPAS team had to fly in between rain showers, mist and gusts of wind but conducted a series of flights that were hugely beneficial to the operation and eventual location of the missing person.

In summary, there were many, many use cases where the RPAS units were deployed during the duration of the project; simply there were too many to list. Incidences like the ones above are good use-cases of how the RPAS unit could provide an overview perspective of the incident, provide live footage to the Incident / Search Commander and allow him/her to make more informed decisions. The technology also provided the responding teams with an added layer of protection and kept them safer ultimately.

4 Challenges and solutions identified

The integration of new technologies into first responder processes can provide challenges. This is especially true when the technology itself is new, its use cases are still being explored and tactical implementations are being explored. It was discovered that the majority of challenges were observed in both fire as well as search and rescue environments, leading to the conclusion that aerial drone technology requires an adjustment of thinking and implementation on a large scale.

4.1 Integration

The fundamental question "How can a drone be integrated?" is an interesting one as there is not one simple solution. Throughout the project it was discovered that the addition of an aerial platforms requires a level of adjustment of the first responder team and their processes.

Having an aerial view of an incident site provides very valuable information to the incident commander and the ground teams. However, the implementation processes to get to just that point are important;

- Who is/will be the drone operator and how big will the team be?
- Where will the drone be stored before an incident?
- How will the drone be transported to the incident site?
- When will a drone be deployed?
- What information is requested/required?
- How will the information be shared during the incident situation?
- What is the tactical approach? Will the drone be used as a single aerial point of view device? Will it move to get different perspectives?
- What is the proper training for drone operator?
- What are the regulatory requirements?

4.2 Training

Proper understanding of the hardware and software, as well as how to use it, is a fundamental factor of success and nothing new to the first responder community. In order to effectively use equipment

and technology, a proper training process has to be established. Furthermore, in order to keep proficiency, different training scenarios need to be executed throughout the year to simulate real-life scenarios.

The recommendation is to for not only the drone and camera operators, the visual observer, but also the incident commander to learn about the aerial technology, its capabilities, use cases, including the data output (video/images recorded, video live transmission, other data gathered), maintenance and data storage.

Initial training should be conducted in open and wide areas, away from people, structures and trees. If an operator is new to the technology, getting him/herself familiar with the functionalities is very important. Just basic flying skills are an absolute baseline before any further training.

First Responder Training Service providers have started to create and teach specific curriculums based on the needs of first responders. These training programs allow for very specific hands-on training, and also go into many of the tactical approach questions and scenarios.

4.3 Hardware

One of the most common questions has been what RPAS system should be used. This project evaluated a variety of off-the-shelf DJI platforms. From quadcopters (four arms, four motors, four propellers) to (six arms, six motors, six propellers). All had an integrated camera and the ability to live-stream HD footage and telemetry information to the RPAS operator. One of the quadcopter platforms (DJI Inspire 1) had a modular camera system set-up, allowing for easy exchange of camera payloads. Each pilot test site also received a DJI/FLIR XT thermal camera. FLIR System is the world's largest commercial company specializing in the design and production of thermal imaging cameras, components and imaging sensors.

A minimum RPAS configuration for first responders has to include/provide the following:

- Reliable platform with redundant system; i.e. dual IMUs (Inertial Measurement Unit, an electronic device that measures and reports a body's specific force and angular rate and allows a RPAS to work when there is no GPS), dual compass, dual battery etc.
- GPS and GLONNAS systems
- Integrated camera systems, preferably modular, with live downstream capabilities in HD format.
- Ability to fly in moderate winds and light rain
- Integrated SDK (Software Development Kit) so specific apps can be written to help operators. For example the DJI/DroneSAR Search and Rescue app, DroneDeploy for 2D and 3D mapping etc.

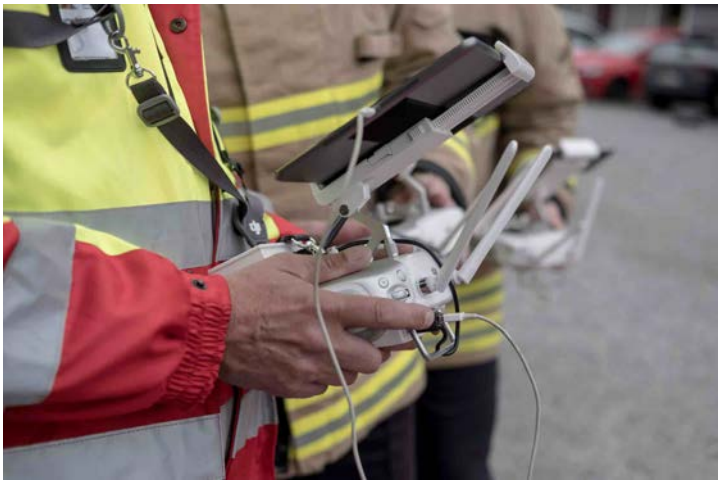
The following features enhance the RPAS capabilities and are not considered part of the minimal configuration.

- All weather proof; while helpful to be able to fly in moderate to strong winds, using an RPAS in rainy conditions impact video and still image quality to the point where it becomes less helpful.
- Dual operation; ability to have a dedicated pilot and a dedicated camera operator can provide advantages.
- Lift capabilities beyond the camera payload weight; this could be helpful for delivery of supplies, such as life vest, first aid kit, blanket or radio during a search and rescue mission.
- Flashlight / beam light for night time flying and illumination

4.4 Live video stream capabilities

Very early on during the project period it was determined that the ability to live stream the RPAS footage to not only the operator, but to a incident command centre and/or other crews on the ground, was an important feature.

The challenge is that if only the RPAS operator sees the live footage, the operators has to "digest" all the footage and data and then communicate the data and information to incident command. That creates a bottleneck in the data and information flow and minimises the impact the RPAS platform has. Furthermore, this distracts the operator from the pilot in charge tasks and can lead to tactical use issues. Also, communicating and describing visual clues from the RPAS operators to incident command not only slows down the process, but could lead to miscommunication and misunderstandings.



Since the platforms used on this project all use a smart device as the viewing device, the DJI Go app allows for live or near-live broadcast to YouTube. By creating a private channel, incident command could view the footage by going onto that private channel on YouTube (via web browser). The original footage continues being stored on a micro-SD card on board the aerial platform and can be retrieved post flight.

During this project a variety of solutions were looked at, including a backpack with several cellular modems that get the data from the RPAS's radio controller via an HDMI out and broadcast it to a specific server. Copenhagen Fire Department used and implemented this solution.

Future solutions could be seen through DJI's SDK (Software Development Kit) and could include functionality to broadcast video stream to additional platforms.

4.5 Tactical approaches

Different first responder incidents and scenarios require a different tactical approach on how an aerial platform is being used. Furthermore, depending on the terrain, the goal of the mission and the flight, that determines how the RPAS is being used.

For example during a structural multi story house fire, the RPAS operator may just want to select a fixed position above and slightly to the side of the incident to gather an overall view. This bird eye view could be provide data by either utilizing a regular or a thermal imaging camera. The operator would watch for the plum of smoke and try to always stay clear from the smoke by slightly adjusting location or altitude.

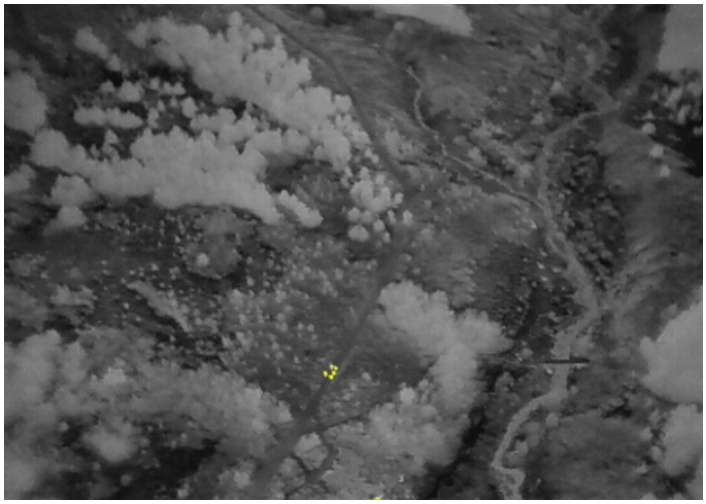
However, if the goal is to get a more detailed view of the incident site, the operator may choose to set-up an autonomous flight route, such as a Point Of Interest. The RPAS, in that flight mode, will fly a predetermined sized circle around the incident area, keeping the camera pointed at the centre. This allows the operators to observe the incident side from all sides.

Similarly during search and rescue missions there are multiple ways to execute a mission. Depending on the environment and the terrain different tactical approaches are available to the operator. A flat area with high grass and brushes may result in flying a Z-pattern approach with the camera on the RPAS pointing straight down (-90 degrees). While a hill or mountain side may require a different flight pattern.

4.6 Use of thermal imaging camera

A clearly-visible, glowing heat signature amidst a mass of snow or water can make a life-saving difference. Thermal sensors can see in total darkness, see through obscurants such as smoke, light fog, rain, dust and foliage, can measure temperature in non-contact assessments and diagnosis, reduce atmospheric interference and provide better contrast and are an ideal platform for reliable analytics and stand-off detection of gas emissions.

During initial early search and rescue tests it was noted that in certain conditions, and with the incorrect thermal imaging camera settings, the results showed many false positives and that the software interface, the DJI Go app, was too complex to dial in the appropriate thermal imaging camera/isotherm settings.



That feedback lead to the development of an internal standalone app named "DJI Hotshot" for use with the DJI XT thermal imaging camera. The app provides a much simpler approach and user experience with bigger buttons and sliders to adjust thermal imaging camera settings and isotherm settings, making it much simpler and faster to dial in temperature ranges.

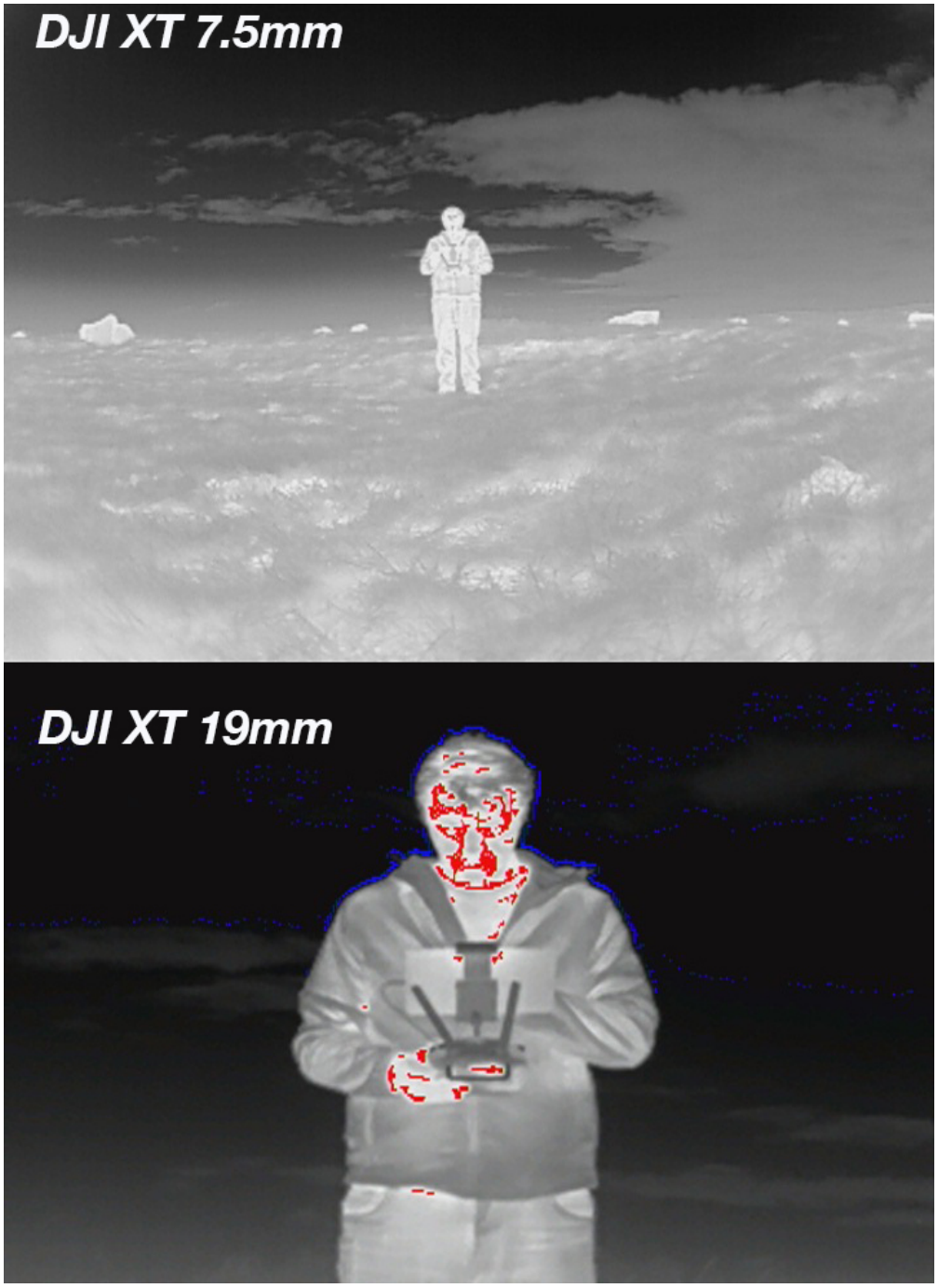
And additional challenge when flying with a thermal imaging camera is to keep situational awareness and orientation. Due to the fact that a thermal imaging camera is using infrared radiation, instead of using visible light like regular photography/videography cameras, a familiar surrounding can appear very different looking. The use of DJI telemetry becomes even more helpful during flights with a thermal imaging camera.

The selection of the appropriate XT lens size is another important factor.

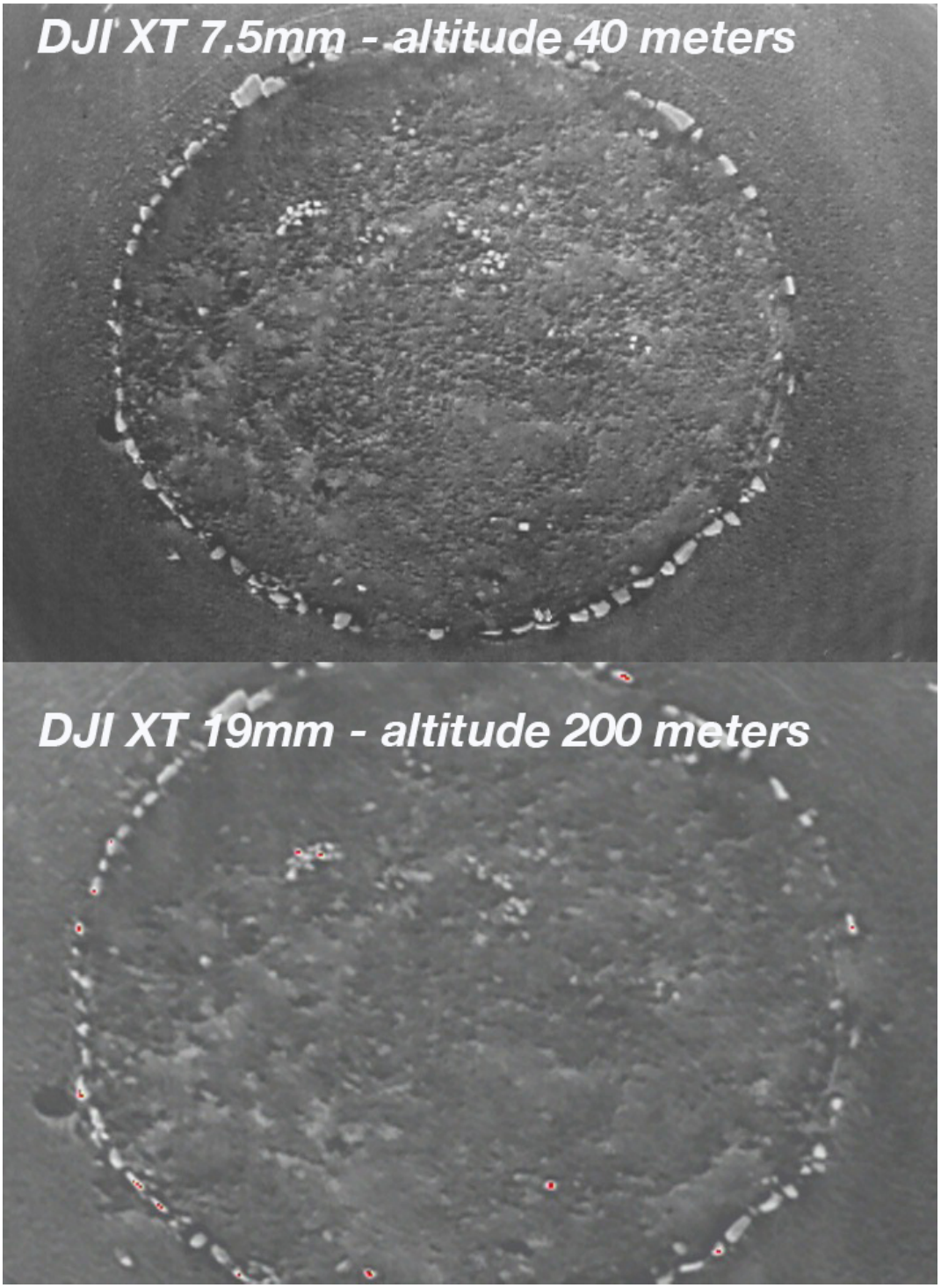
The highest resolution thermal imaging camera DJI is offering, at 640x512 FPA/Digital Video Display Formats size, has four different lens options; 7.5mm, 9mm, 13mm & 19mm. While the camera also offers 2x, 4x and 8x digital zoom, the smaller lens options (7.5mm and 9mm) appear to be the more useful lens size as it provides a wider field of view. Below is a comparison between the 7.5mm and the 19mm.

The first comparison has the XT thermal imaging camera on the DJI Inspire 1 on the ground with the subject the same distance away from the platform. The 19mm lens has a much narrow field of view and captures the upper body only. In order to capture the entire body, the distance between the platform and the individual would have to be increased dramatically.

This is better shown in the second comparison. This time the DJI Inspire 1 with the XT thermal imaging camera is airborne over a stone circle. The diameter of the circle is 44m. With the 7.5mm lens the platform has to only be raised 40m above the ground to capture the entire circle while with the 19mm the platform has to be raised to 200m in order to capture almost the entire circle.



Ground comparison between the 7.5mm and 19mm lens options on the DJI XT thermal imaging camera. Distance from camera to subject is the same in both.



In air comparison between the 7.5mm and 19mm lens options on the DJI XT thermal imaging camera.

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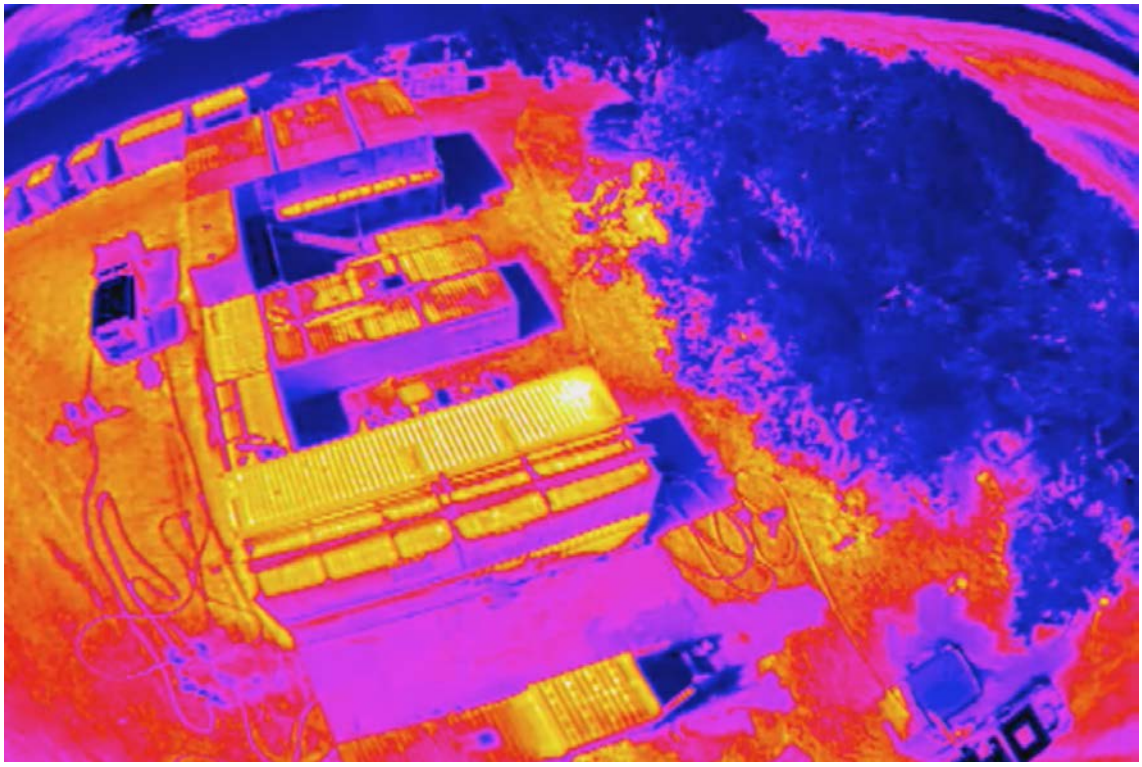
4.7 Data from the thermal imaging camera

Depending on the thermal imaging camera settings, reviewing the live data during an incident can result in too much data being displayed. This is especially true when the operator is not familiar with the functionality and the way data from thermal imaging cameras are being displayed.

Thermal imaging cameras have different pre-set palettes available, with distinct colours used to show temperature differences in the thermal image, which are related to the grayscale intensity. However, these palettes may show too much data, data outside of the useful temperature range. Here is an example of a heat source inside a structure in two different views. First view is a standard Fusion palette view. The second image is using the Isotherm settings, which allows for easier review and analysis of thermal data, as it immediately shows the hot-spot. Isotherm is an analysis tool to give the operator a specific temperature range which stands out from the rest.



Example of structural fire as seen with the DJI XT thermal imaging camera in the Fusion palette.

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Example of structural fire as seen with the DJI XT thermal imaging camera and Isotherm settings ON.

5 Future opportunities identified

The development of RPAS hardware will continue to provide users with more capable platforms in the future. Integration of sensors in platforms will continue and through the data gathered with all the sensors, the platforms can make appropriate flight corrections. For example forward facing sensors on newly released platforms allow for the detection and avoidance of objects, during not only autonomous flight, but also manual flight.

On the software side we will be seeing a more SDK streamlined platform, allowing for the creation of more powerful SDK applications and solutions. The combination of hardware and software improvements will allow future platforms to perform more challenging tasks, utilise more autonomous functions and provide more useful real-time data to the operator and other team members.

5.1 Pre-incident use of RPAS

Throughout this project it was realized that the use of RPAS extends beyond just being used on and during an incident. The project learned about the desire to prepare for incidents, such as a fire and flooding, by creating up-to-date 2D, 3D or elevation maps ahead of time. By use of SDK solutions for mapping (i.e. DroneDeploy, Propeller, Pix4D etc.) and a Phantom 4 or Inspire 1 platform, areas or buildings can be mapped from the air. These maps are not only more current than Google Satellite views, but also offer higher resolution and allow for very precise measurements.

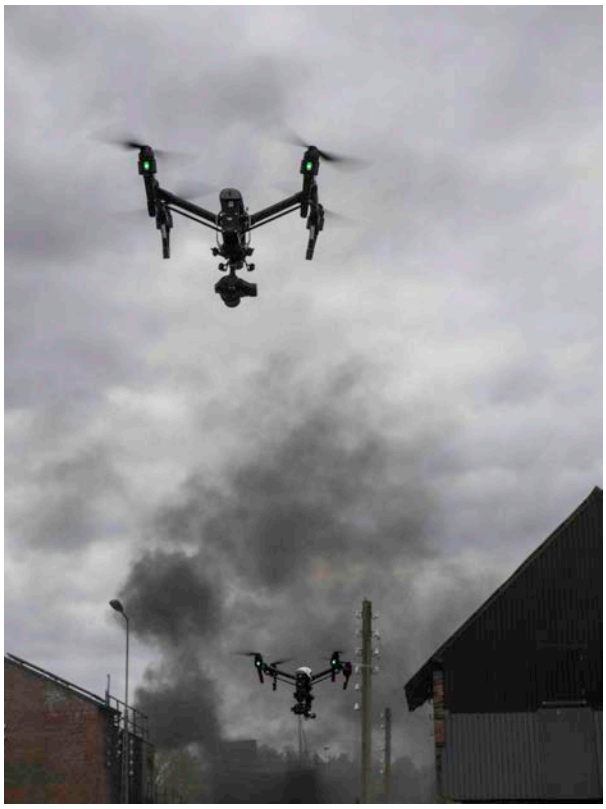
This functionality can provide valuable data to first responders before an incident strikes. That allows for more effective pre-incident planning and training.

5.2 Post-incident use of RPAS

Similarly, RPAS platforms with mapping applications can also be used for post-incident forensic evidence gathering. For example after a structural fire or a flood the aerial platform can assist in not only getting aerial videos and still images of the incident site, but to also gather data for ultra high resolution photogrammetry for 2D and 3D mapping.

The use of RPAS for mapping and visualization pre and post-incident offers additional benefits. For instance, imagery acquired over heavy travelled areas, such as a road or an intersection, can produce, through sophisticated software algorithms, a final overview of the area with all traffic removed.

5.3 Use of multiple RPAS



We have already seen the multi-RPAS use during an incident. These are either flown one at a time (depending on the needs of the mission and the general location/weather conditions) or then multiple RPAS are airborne at the same time (for search and rescue tasks, for example). Currently flying multiple RPAS systems can introduce additional challenges, from potential flight-path interference to video signal interference. As with any team-work tasks, proper communication is needed between the drone operators and support teams.

In the future we will be seeing more autonomous RPAS flight patterns, as well as more integrated detect and avoid capabilities for platforms to not only avoid obstacles flying flower to the ground, but also detecting other objects in the air. Future platforms may have the capabilities to communicate with each other and send/receive location information. This "Swarm RPAS" approach may lead to several RPAS being used to scan certain areas for a missing person simultaneously and cover more ground quicker. Or a "Lead RPAS" could, through computer vision and algorithms, send potential findings to a "Follow RPAS" that will then fly directly to that location for a closer look, while "Lead RPAS" will continue its search pattern.

6 Recommendations

6.1 Multi-person RPAS units

One of the most interesting learnings from the project relates to the RPAS unit and how the team members work together. The challenges of communications and how the team members perform their roles was identified in the early phase of the project. Whilst it may be obvious, it is clear that the Pilot should only be focused on the flight operation itself and not be tasked with other related items such as the overall management of the mission or even 'spotting'. Therefore it is recommended that the RPAS unit is at least a 2-person operation and in some cases such as lengthy and complex search missions may even need 3 or 4 persons in order to perform effectively. Fatigue and other externalities should also be a consideration towards having other Pilots available also to support the operation.

6.2 Weather-resistant platforms

As mentioned earlier in the report, the capability of the RPAS is sometimes hampered by the weather conditions especially wind, low cloud and rain. Whilst it is not possible to completely weather-proof the RPAS platform, the manufacturers should make efforts to improve the durability and capability of the hardware to be able to fly in difficult weather conditions. The skill levels of the Pilot can have an impact clearly on the decision to deploy or not but hopefully in the future technological advancements can see the RPAS being deployed in weather conditions that at the moment are beyond the safety limits.

6.3 Drop capabilities

There are circumstances where the RPAS unit may need to drop an item(s) to the injured casualty such as a life-ring, thermal blanket, a mobile phone, a beacon marker etc. At the moment, the capability to do so is limited as the platform, and sometimes the legislation, does not permit this to happen.

As a consequence, the platform manufacturers, together with other partners such as 3D printing technology providers, should make future platforms 'drop ready' or make them customizable to allow for drop capabilities to be added easily to them. The legislation may also need to be amended so it is recommended that the national Aviation Authorities look to make this capability possible for the emergency services in the future.

6.4 Identification markers and safety lights

Safety is of paramount importance when RPAS are being used. Public confidence in the use of RPAS by the emergency services is also extremely important and many citizens have concerns about seeing RPAS in the skies. Safety is also important when the RPAS is being used in conjunction with emergency service helicopters and/or other aerial equipment from different emergency services.

In order to build our citizen's confidence in the use of RPAS during emergencies and rescue missions, the emergency services, together with the platform manufacturers, should ensure that their RPAS is identifiable as a 'blue light' platform with the provision of suitable lights, beacons and markings. In addition, the emergency services should consider using a landing mat with lights and markings within a demarcated area in order to ensure even safer landings.

In addition to this, one of the interesting initiatives devised by Mid and West Wales was the introduction of a pop-up darkroom to support and assist the pilot and camera operator/flight coordinator. The experience of the team combating glare on their screens and other weather issues that hampered their operation led them to developing the solution that would protect them from the elements and enhance their capabilities. See picture below of their pop-up darkroom taken from a recent operation in Wales:

6.5 Integrated broadcasting capabilities

One of the many 'value add' capabilities that a RPAS unit can deliver is the use of the live data (images, video, telemetry) that it captures. The technology on-board the RPAS is advancing rapidly and the quality and stability of the images are tremendous. Whilst the SD-card on board the RPAS

records the images and videos, getting this feed from the RPAS in almost 'real-time' to the Incident Commander is at this moment still a struggle for many emergency services and SAR teams.

In order to this the data must be transported securely and efficiently across a telecommunications network and for some scenarios 3G and 4G networks exist; for some there are no such networks available and maybe only satellite networks exist.

Regardless of the telecommunications networks that are available, the RPAS manufacturers should ensure that the platform has the capability to send the data to the Incident Commander in a secure manner. Some 3rd party products exist at the moment to do this and they are indeed being used by some emergency services at the moment. However, the capital and operating costs may put the technology out of reach of many emergency services and therefore an integrated broadcasting capability should be built into the RPAS in the future.

6.6 Multi-camera operations

During the course of the project, the different Pilot sites had the opportunity to use different cameras, including the thermal imaging camera. Both cameras have different capabilities and uses and are very much complimentary of each other. One of the restrictions initially however was that there was time lost during an emergency response when the Pilot had to land and with the ground team, swap the cameras as they needed.

It is therefore recommended that the emergency services consider the use of a dual camera capability if the RPAS platform allows for this. Using both the regular camera and the thermal imaging camera on the RPAS at the same time would provide the emergency services with considerable flexibility, effectiveness and efficiency.

6.7 RPAS bundles

Getting a RPAS system likely means also having to get additional items to support the operation. That can go from a storage/carrying case, to a smart device used in combination with the remote controller for live camera views (for DJI products, IOS or Android device, such as an iPad or Android tablet) and spare parts and accessories, such as propellers, extra power supply or batteries. RPAS manufacturers are encouraged to put together bundles for first responders that include everything they need from a hardware perspective and also provide them with options to add software solutions to the package. This will make the purchasing process easier and provide the customer with a strong package to get operations started and going.

7 Summary and conclusions

At the outset of the project there were many questions and uncertainties with respect to the role of an RPAS unit as part of the overall toolkit during an emergency response or search and rescue operation.

The uncertainties were borne out of the fact the technology was and is relatively new and many off-the-shelf platforms not designed for such mission critical operations. After all, many of the platforms are designed for other uses such as agricultural, photography, videography and construction. It was never intended that many of them would be used during emergency response, disaster relief or search and rescue operations.

However, with the examples of the use cases identified during this project and other examples we have witnessed all over the world as well as the rapid technological advancements, we know precisely how impactful they can be. We have seen RPAS bring used to find missing persons quickly and efficiently, we have seen them provide an aerial perspective over burning buildings containing highly dangerous chemicals, we have seen them used to detect fire 'hot spots' within buildings on fire and guide emergency first responders away from danger. All together, they help the emergency services to make more informed decisions that lead to better outcomes for our citizens and help keep our emergency services safer.

RPAS will not replace firemen, police officers or helicopter crews; they simply will become integrated into the overall emergency response and disaster relief efforts leading to more informed decisions and better outcomes.

The technology is moving quickly and who knows that the RPAS of tomorrow will look like; what is sure is that they will be more intelligent, quicker, more resilient with improved capabilities such as collision avoidance, longer flight time and data sharing. We are certain also that the emergency services of the future will be using RPAS in their daily operations and helping to support each other in so doing. We are certain that they will be used even more during night-time operations with even autonomous flight intelligence whilst all the time becoming more and more cost effective.

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8 Annex A – Reports from media outlets related to the project

Source	Hyperlink
Engadget	http://www.engadget.com/2016/04/07/dji-eena-drones-emergency-europe/
Wired	http://www.wired.co.uk/news/archive/2016-04/08/dji-emergency-services-europe-drones
Irish Independent	http://www.independent.ie/business/technology/donegal-mountain-rescue-team-chosen-as-test-site-for-emergency-services-by-drone-giant-dji-34610623.html
Newsweek	http://europe.newsweek.com/drones-rescue-dji-phantom-eena-eu-445467?rm=eu
Daily Telegraph	http://www.telegraph.co.uk/technology/2016/04/08/european-emergency-services-trial-drones-for-firefighting-and-hu/
Highland Radio	http://www.highlandradio.com/2016/04/09/donegal-chosen-as-test-site-for-worlds-biggest-drone-company/
Market Business News	http://marketbusinessnews.com/eena-partners-dji-test-use-drones-response-emergency-incidents/131138
Yahoo News	https://www.yahoo.com/tech/drones-may-one-day-save-155837177.html
Silicon Republic	https://www.siliconrepublic.com/machines/2016/04/08/rescue-drones-donegal-mountains-dji
The Journal	http://www.thejournal.ie/donegal-drones-saving-lives-2705257-Apr2016/
Air Med and Rescue	http://www.airmedandrescue.com/story1335
The Verge	http://www.theverge.com/2016/4/7/11385464/europe-first-responders-dji-drones-emergency-rescue-operations
PR Newswire	http://www.prnewswire.com/news-releases/dji-and-eena-partner-to-promote-first-response-missions-300247747.html
Slashgear	http://www.slashgear.com/djis-new-european-partnership-tests-drones-in-emergency-missions-07435342/
Dronelife	http://dronelife.com/2016/04/08/dji-partners-european-first-responders/
Geospatialworld	http://geospatialworld.net/News/View.aspx?id=33605_Article
Firechief.com	http://www.firechief.com/2016/04/11/european-fire-departments-test-drone-response/
Digital Trends.com	http://www.digitaltrends.com/cool-tech/first-responders-using-drones/
The Hill.com	http://thehill.com/policy/transportation/275700-drones-eyed-as-first-responders
Electronic Engineering Journal	http://www.eejournal.com/archives/fresh-bytes/european-first-responders-will-use-dji-drones-in-rescue-operations
Danish TV	http://nyheder.tv2.dk/samfund/2016-05-18-se-billederne-saadan-kan-brande-bekaempes-fra-luften
Sky News	http://news.sky.com/story/1703298/drones-saving-lives-of-emergency-workers
CCS Insight	http://www.ccsinsight.com/blog/drones-to-the-rescue-in-europe
France24	http://www.france24.com/en/20160610-down-earth-drones-ambulance-denmark-fire-fighting-rwanda-delivery-medical-supplies
The hill.com	http://thehill.com/policy/technology/284173-drone-use-growing-in-surprising-ways
Canadian TV News	http://www.ctvnews.ca/sci-tech/drones-a-great-tool-but-no-replacement-for-humans-rescue-official-1.2954903
New York Times	http://www.nytimes.com/2016/06/20/technology/europe-emergency-drones.html?_r=0
Irish Times	http://www.irishtimes.com/news/ireland/irish-news/drone-technology-could-make-mountain-searches-much-quicker-1.2850728
RTÉ	http://www.rte.ie/news/player/2016/1103/21082342-mountain-rescuers-learn-to-use-drones-for-search-operations/

Editor's Note:
We are grateful to the teams from the four different Pilot Sites for their time, commitment and professionalism during the course of the project. The teams from Denmark, Ireland, Wales and Iceland were generous in sharing their expertise with each other and with the teams from EENA and DJI and the wider emergency service, first responder and search and rescue communities.

The project could not have been successful without the expertise and support of DJI and the team involved directly in the day-to-day operation. We thank them also for their energy and enthusiasm since the project was first proposed and we look forward to further collaboration on the topic and to the sharing of knowledge and deeper understanding on the technology.

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