SDU
CENTRE FOR INTEGRATIVE INNOVATION MANAGEMENT

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Drones for public safety and emergency response operations: Actual and planned use

February 2020

Colophon

This memo brings into focus a range of opportunities, challenges and actual uses of unmanned aerial vehicles, also known as drones, for public safety and emergency response operations in Denmark. The authors thank The Danish Industry Foundation for the financial support for the research behind the memo that was conducted as part of the “Innovation on Wings” project. The authors also thank the participating organizations and interviewees for their contributions. Nevertheless, all mistakes or misunderstandings are the sole responsibility of the authors.

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The research of Mette Præst Knudsen seeks to integrate market, management, and technological perspectives on innovation processes. The focus on commercialization is particularly useful in relation to the development of new technologies with unknown market potential, as for instance with innovative drone technologies and other emerging technologies.

Contents

1 General introduction

This is the fourth memo in a series of publications that focus on the opportunities and challenges in using unmanned aerial vehicles, also known as drones, for civil and commercial applications in Denmark. The aim of the publications is to inform existing and potential new businesses, inventors, investors, and policy makers about the opportunities for drones to develop into a new growth industry.

The series of publications are concerned with the following fields of application:

1. Drones for offshore and maritime missions: Opportunities and barriers
   https://www.sdu.dk/en/om_sdu/institutter_centre/i_marketing/marketing_nyheder/free+the+drones
   (the research for the memo was sponsored by Innovation Fund Denmark)
2. Drones for inspection of infrastructure: Barriers, opportunities and successful uses
   https://uasdenmark.dk/wp-content/uploads/2019/06/Final_Infrastructure-Memo_30.05.2019.pdf
   (the research for the memo was sponsored by The Danish Industry Foundation)
3. Status and expectations of the Danish drone industry: An ecosystem perspective
   https://www.sdu.dk/en/om_sdu/institutter_centre/sduuascenter/researchprojects/freed/publications
   (the research for the memo was sponsored by Innovation Fund Denmark)
4. Drones for public safety and emergency response operations: Actual and planned use (this memo).

This memo no. 4 is sponsored by The Danish Industry Foundation as part of the project “Innovation on Wings”[1]. The memo brings into focus successful uses of drones for public safety and emergency response operations, but also highlights identified challenges to such missions in a Danish context. Based on interviews with core actors within the field and a range of reports and articles that supplement the empirical findings, the memo offers deep insights into the actual and planned use of drones for public safety and emergency response operations. It is thereby intended to serve as inspiration for how to implement and operate a fleet of drones – also for commercial purposes in the future.

[1] The Innovation on Wings project: https://www.uasdenmark.dk/testcenter/innovation-pa-vinger/om-projektet

2 Why focus on drone applications?

The drone as a platform is by now a well-established and mature technology that has been used for military applications for decades and, more recently, enjoyed popular usage in the toy and leisure markets. The drone is characterized as a technology platform enabling a limited payload. Different types of drones are available on the market: Fixed-wing drones (similar to airplanes); drones with several horizontal propellers (similar to helicopters); and hybrids, i.e. fixed-wing drones capable of vertical take-off and landing. The enabled payloads include, e.g., thermal, electro-optical, infra-red, and multi/hyperspectral cameras; Radio/Light Detection and Ranging (RADAR/LiDAR); and particle/gas sensors, to name a few. Drones are controlled remotely by an operator, or they are flying autonomously. In the Danish context, the latter still requires substantial development related to failsafe software, communications and control equipment, and sense and avoid technology before being fully operational.

A multirotor drone. Photo: Ian Usher on Unsplash.

The prospects for drones have been widely praised, and there is a growing commercial interest in adapting drones to applications related to civil and commercial use to capture the promised market value. When assessing potential missions, the drone application augments or replaces an existing solution that involves humans (e.g., helicopter inspection of power lines or rope-based inspection of wind turbines). The drone is anticipated to do jobs considered dirty, dull, or dangerous – at a lower cost and/or with less risk compared to existing solutions. Since drones are capable of quickly reaching remote areas, which may even be difficult to access, and then transmit, e.g. still photographs, thermal images, or video footage, they can provide the data for creating an overview of a given situation. Thus, drones serve as either an extension or a replacement of the operator for the effective accomplishment of varied missions. In this way, time, personnel, and money are saved and perhaps even at a better quality.

3 Drones for public safety and emergency response operations

Around the world, drones aid in public safety and emergency response operations. Drones are, for example, used in connection with environmental disasters, e.g. for producing 3D maps and assessing damaged buildings, infrastructure etc., but also in humanitarian actions, especially for mapping areas during the recovery phase after a disaster.[2] Being able to fly drones beyond visual line of sight (BVLOS) is crucial for such operations, because hard-to-reach areas can then be accessed within minutes instead of perhaps hours[3].

A birdseye view, by means of a drone, on a fire and how it evolves. Photo: Harley Poulsen.

In such situations, drones can rapidly provide situational awareness. This is also the case, when drones equipped with thermal imaging cameras help identify active “hot spots” of burning buildings and thereby areas that are dangerous for firefighters to enter[4]. According to Brad Beach, leader of the drone center at University of Southern Denmark, speed is the core added-value from drone flight; especially from flying non-stop and directly from A to B. Drones can fly ahead of safety crews (e.g. firefighters or paramedics) and deliver information to build their situational awareness beforehand, even from sites

[2] Report (funded by European Union Humanitarian Aid) on drones in humanitarian action: http://drones.fsd.ch/wp-content/uploads/2016/11/Drones-in-Humanitarian-Action.pdf

[3] Examples of the use of drones for emergency response operations in the USA: https://www.precisionhawk.com/blog/how-drones-aid-in-disaster-response.

[4] Ditto.

inaccessible to humans. Thus, a drone becomes a tool – by being the eye in the sky - to assist in managing a scene, by ensuring mission critical information in due time. Kjeld Jensen, associate professor at the University of Southern Denmark, explains how drones can be superior to humans[5]:

> *If you have a shoreline, and somebody is suddenly missing, and you can't find that person, you must assume that the person is below the water at the shore. What you then do is to form a chain of people and walk kind of like you are wiping a windscreen… trying to look through the water surface*.

Contrary to the chain of people, a drone can with its bird's eye view easily spot the person in distress.

There are numerous other examples of how drones can assist on critical missions. In the following, we introduce two such examples in the form of in-depth cases of actual and planned uses of drones for public safety and emergency response operations in a Danish setting.

3.1 In-depth case no. 1: The Police uses drones for a multitude of operations

A drone operated at nighttime by one of Fyns Politi's drone pilots.
Photo: Fyns Politi.

Fyns Politi[6] (police district for Funen in Denmark) is at the forefront of using drones for public safety and emergency response operations. In the summer of 2017, Fyns Politi decided to start implementing drones, which are now considered for any mission, as they have already proven to be useful in numerous situations. Today, drones are in the air at almost every watch all year round.

[5] Claesson et al. (2017). Drones may be used to save lives in out of hospital cardiac arrest due to drowning. *Resuscitation*, 114: 152-156.

[6] Fyns Politi is responsible for police tasks in the district of Funen, an island in southern Denmark, which comprises eight municipalities. www.politi.dk/fyns-politi

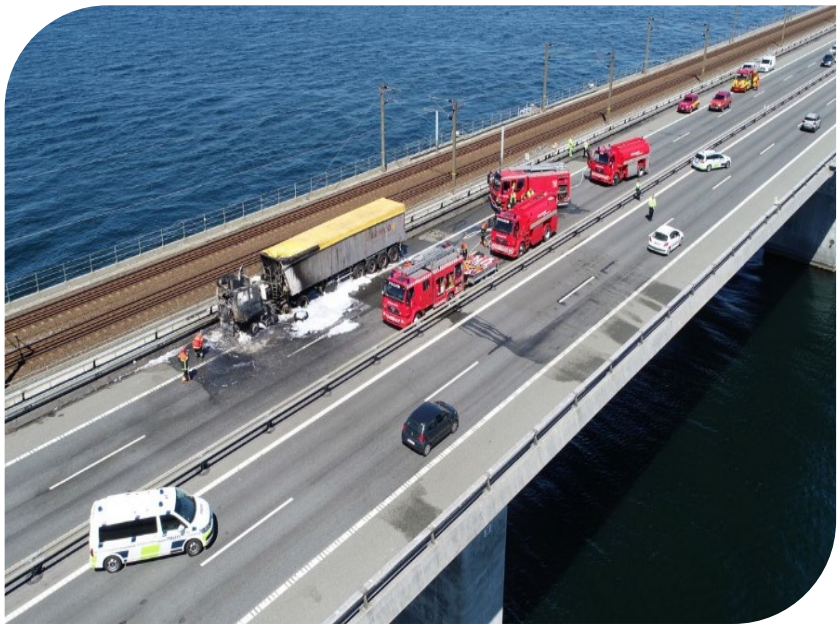
Kim Munksgaard, Deputy Assistant Commissioner (in Danish: Vicepolitiinspektør) and responsible for drone operations at Fyns Politi explains the overall aim of using drones as maintaining citizens' sense of security by improving their actual safety, e.g. by creating a better overview of traffic accidents or enabling faster rescuing of someone in distress. He further emphasizes the perspective of the policemen: *Our employees should feel that, when a drone is in the air, someone is keeping an eye on the situation for us; it adds a dimension*.

Kim Munksgaard.
Photo: Fyns Politi.

Examples of drone operations. Kim Munksgaard lists numerous examples of where drones are used:

- In case of traffic accidents, drones help save time for the involved persons and for those being stuck in the tailback. Normally, policemen will manually measure the position of implicated cars compared to each other to enable a decision, at a later point, of who is to blame. Instead, the drone can be used for taking a picture and thereby reduce what could easily take a couple of hours to around half an hour. Consequently, the accident site is cleared earlier, and traffic will ease faster.

- Pictures taken by means of a drone can be used for detecting polluting spill, as was the case when a truck crashed on The Great Belt Bridge and leaked its content of coli bacteria into the ocean near the city of Nyborg. The pictures were sent to a chemical expert who, based on information about the type of bacteria, the current of the ocean, and the spread of the bacteria (visible as a thin layer on top of the water), concluded that it was not a dangerous situation; neither at sea nor to those on land. Without the drone image, this expert would have to come to the site. To secure his work zone, lanes are even closed for hours. Instead, in the case of the spill, the real-time pictorial assessment meant that Fyns Politi only had to be standby and keep both lanes closed for around 15 minutes.



Drone providing an overview of the truck incident at the Great Belt Bridge.
Photo: Fyns Politi.

- Fyns Politi also uses drones for monitoring crowds, e.g. for obtaining an overview of a stadium to detect any disturbances in connection with a football match. Hovering the drone in one corner is an efficient way of surveying the entire stadium.

Monitoring football fans outside of a stadium by means of a drone. Photo: Fyns Politi.

- In connection with an emergency response to a fire at night, the on-site commander assistant operated a drone equipped with a thermal imaging camera to gain an overview of how the fire developed. On the screen of the drone's ground control, he spotted two persons standing behind a shrub a short distance from the fire. He flew closer and hovered the drone over them, which made them break into a run and try to get out of the searchlight of the drone. The commander assistant chased and caught them, and they are now charged with arson. Thus, the drone was a useful tool for detecting potential criminals – a positive side effect to the original purpose of overseeing the fire.

- Drones are also useful when having to reconstruct a crime scene. In one instance, a woman, who had been a victim of a drug rape, had to be transported to the hospital before Fyns Politi could search for and mark any clues. A picture, including a GPS-generated position, had been taken by means of a drone. The day after, this information enabled Fyns Politi to locate the exact spot where the woman was found, and soon after a police dog had picked up the scent of someone's sperm, which then led to a DNA match and an arrest.

- Drones are also used when preparing special operations, e.g. as when a dangerous perpetrator had barricaded a building. By using a drone to carry out reconnaissance of the building, Fyns Politi created an overview of how windows and doors would open. This gave valuable prior knowledge needed to enter the building and what tools to apply, and it gave indications of where the person was inside the house. The special operations force could then carry out the mission with a greater sense of overview and less risk.

Implementation and use considerations

With the practical experiences already obtained, Fyns Politi has identified a range of considerations to make drones part of daily work.

Costs, benefits, and quality. To date, around half of the 12 police districts in Denmark have started implementing and/or uses drones regularly. At the national level, it has been decided that all police

districts will, in some way or another, have its own drone unit. Fyns Politi intends to support these efforts on implementing drones by sharing its experiences with the other districts. As an example, establishing and maintaining a fleet of drones is expensive, and the fast pace of drone technology development entails that the equipment dates rapidly. Therefore, it is relevant to apply a cost-benefit perspective when implementing drones. Fyns Politi has not implemented drones with the ambition to save money. Rather, as stated by Kim Munksgaard, *we use drones if it increases the safety of our employees, brings quality to solving the task and/or saves some resources*. However, he adds that the use of drones most likely saves money too.

He illustrates this point by an example. The police investigated what happened to a man who was found dead on the beach north of Odense. Normally, in such a situation, a dog patrol is sent out to gain an overview of how the man got there, e.g. by detecting footprints. In this case, the drone gave a faster overview of the area and the situation. Soon, the police knew the route of the man based on where he had put his clothes. The alternative to the drone would have been sending out a patrol with six dogs that would spend an hour or so searching the large area, while having to step cautiously to not ruin any evidence. It took three minutes for the drone – and it left no marks. Thus, a drone can give an overview of the situation and help pinpoint where the dogs should search further. In such a case, the drone does not replace the dog patrol, but simply narrows down the search area and therefore the time in the field for the patrol. So even if the drones are not aimed to be cost saving, there are certainly cost reducing aspects related to the use of drones as many of the examples listed above illustrate.

Legislative conditions. In September 2018, The Danish Police got its own executive order for drone operations[7]. According to Kim Munksgaard, the executive order is equivalent to the rules for emergency response of cars on the ground. Therefore, the Danish Police can – with the responsibilities it entails – override the general drone legislation in Denmark. As an example, the Danish Police can, if needed, fly drones beyond visual line of sight – also over densely populated areas like cities or crowds. Thus, although certain precautions must be made, e.g. near and at airports, the Danish Police can operate drones at long distances and at almost every altitude (although most of its urban flights are at altitudes of 60-80 meters). The requirements for education and training are stricter than for drone pilots in general. Fyns Politi is very aware that its drones – weighing from around 400 grams to around 10 kilos – can cause fatal damages. Even though the drone pilots have successfully completed many hundreds of flights in public space, they are instructed not to fly over people, unless it is a critical situation, requiring the overview to secure the situation.

Before anyone starts operating a drone, the on-site commander assistant goes through the standard operating procedures, such as checking the propellers to ensure that these are intact. Technical precautions are also made, since all the drones in the fleet are equipped with redundant components to enable e.g. emergency landing and to reduce inertia if the drone crashes to the ground. Kim Munksgaard expects that coming public EU-procurements for drones will include requirements for fail-safe and navigable components. He adds that, generally, standards for maintenance of drones must be formulated and procedures, e.g. for when a motor needs to be replaced, must be decided. This is also on his agenda.

[7] The executive order for how the Danish Police can use drones: https://www.retsinformation.dk/Forms/R0710.aspx?id=203002

Training of drone pilots at nighttime. Photo: Fyns Politi.

Educating and training the pilots. To live up to the executive order for police drones, the drone pilots at the Danish Police must pass a four-day intensive course including e.g. tactical flights based on dynamic scenarios. Today, Fyns Politi's drone fleet is operated by 17 staff members, but the plan is to educate all on-site commander assistants to become even more flexible when needing a drone in the air in connection with e.g. emergency responses. In pace with the increasing number of drone pilots, the need for a structured approach to continuing education, training, knowledge sharing, etc. is noticeable. As an example, Kim Munksgaard draws attention to his requirements for having highly skilled pilots with extensive training and a special certification operating the large drones to ensure expedient reactions to adverse incidents. This is one of the reasons that Fyns Politi has its own tailored training program, which is more demanding than ordinary drone pilot training.

The weather impacts uptime. The drones used by Fyns Politi are recommended for flights up to wind speed of maximum 10 m/s. However, the drones are sometimes used at or above 20 m/s. According to Kim Munksgaard, this has thus far not constituted any risk to the drone pilots and has only been taking place in situations with no civilians nearby. Rainy weather is generally an obstacle to flying the drones. Fyns Politi has a DJI Matrice 210, which is water resistant with an IP43[8] rating and therefore can be used despite drizzle – if it is aired afterwards, that is.

The right equipment. Fyns Politi has invested in advanced technology to accommodate the demands associated with its diverse missions. Now, the payload for the drones encompass e.g. a thermographic camera and a large zoom camera. The latter can be used for taking pictures from a distance up to 500 meters. Moreover, the smallest drones in the fleet can be mounted with speakers and LED-projectors, which enable the drone pilots to fly close to and direct a crowd or to light up an area and thereby assist police officers carrying out searches in the dark.

[8] IP43-rating = protected from water spray less than 60 degrees from vertical.

The fleet currently consists solely of multi-rotor drones, ranging from the small DJI Mavic Air to the big DJI Matrice 600 Pro. The DJI Matrice 210 is the drone that Fyns Politi uses the most.

The drone fleet of Fyns Politi:
Top left: DJI Matrice 210
Top right: DJI Mavic Air
Bottom left: DJI Phantom 4 Pro+
Bottom right: DJI Matrice 600 Pro.
Photos: Unsplash and DJI.

Adding VTOL drones (fixed-wing capable of vertical take-off and landing) is currently considered, as these are flexible in many situations and enable both long range and high-speed operations. Kim Munksgaard emphasizes that battery life is an issue that Fyns Politi currently solves by bringing charged batteries in sufficient quantities on its missions or by using a vehicle equipped with a charging station. However, if operations continue non-stop for more than ten hours, lack of power becomes an issue. In that case, Fyns Politi switches between two drones.

Data is an issue. Developing the set-up for live streaming from the drone can be demanding. Fortunately, a couple of employees at Fyns Politi are sufficiently IT-savvy and have enabled the video feed and the extraction of data. The use of drones potentially generates a lot of data. Fyns Politi does not record all data; in fact, far from. But when data is recorded, it is saved and treated in agreement with the rules of GDPR[9].

Reactions to police drones. To date, Fyns Politi has already used drones for more than 100 missions but received no complaints or criticism. A contributing factor in preventing negative reactions from the general public might be that the drone pilots always wear a vest imprinted with the police logo to signal that a drone is in the air on a police mission.

The process of implementing drones. Although drones are merely a supplementary technology for successfully accomplishing police missions, Fyns Politi has already benefitted significantly from using them. Kim Munksgaard emphasizes that equally important ingredients to success are dedicated staff and managerial support. The people operating the drones must be sufficiently motivated to acquire the needed skills and to “go the extra mile” during the oftentimes demanding process of implementing the technology. And top management must create ownership in the organization by underlining the expediency and goal of implementing drones. Moreover, top management must be willing to allocate the necessary resources, including funding, time for training drone pilots, time for experimenting, and time for developing standard operating procedures. Fyns Politi started with three drone pilots operating

[9] GDPR is an abbreviation of EU’s general data protection regulation.

three DJI Phantom 4 Pro+ drones, i.e. small drones that are easy to operate and merely equipped with a fixed camera. Through this simple set-up, Fyns Politi gained first-hand exploratory experience of when, where, and how drones could be successfully used for its missions. Since then, Fyns Politi has followed an agile process and thereby been *asphalting while driving*, as stated by Kim Munksgaard. This has turned out to be an expedient approach, as drones have quickly proved beneficial leading to plans for further missions being laid out.

3.2 In-depth case no. 2: Drones for emergency response operations

The Danish Emergency Management Agency[10] (DEMA) began focusing on drones in 2014 and started using them in 2015. Today, DEMA has three drone units located strategically to cover most of Denmark: one in Herning and one in Næstved – both respond within five minutes – and one in Hedehusene that responds within 60 minutes[11]. Overall, the use of drones helps qualify the basis for decisions in emergency situations.

Orthomosaic of the port of Fredericia in connection with a fire in a tank containing palm oil. Photo: DEMA.

DEMA's drone fleet consists of both multirotor and fixed-wing drones. Multirotor drones are useful when there is a need for live feeds at e.g. a site of damage, whereas fixed-wing drones can be used for capturing aerial photos that, via the software Pix4D, can be transformed into orthomosaics (maps) and

[10] Website of the Danish Emergency Management Agency (Beredskabsstyrelsen): https://brs.dk/Pages/Forside.aspx

[11] Leaflet from DEMA explaining their drone emergency response and use: https://brs.dk/beredskab/idk/statsligt_beredskab/resursekatalog/saerligtmateriel/droner/Documents/trefoldet-drone-folder23-jan-2019B.pdf

3D models of the site of damage[12]. This makes it possible to juxtapose pictures before, during, and after an event.[13]

Henrik Kruse Nielsen, Master Sergeant (in Danish: seniorsergent) and responsible for drones at DEMA College, lists six crucial factors that must be considered when using drones for firefighting operations. In order of priority:

1) Is it a situation posing a special danger to the on-site personnel?
2) Are any other humans and/or animals in danger?
3) Where is it burning?
4) What is burning?
5) Can the fire spread and where to?
6) Where are the access roads, and are they clear?

Henrik Kruse Nielsen.
Photo: DEMA.

Examples of drone operations

- Gas used for jointing felt roofing plates can cause a fire in the roof construction. In that case, the roofer must leave the rooftop in a hurry and will leave the gas cylinder there. This creates a situation with a particular danger, as firefighters risk dying, if the gas cylinder explodes. A drone providing live footage by means of a video camera can help identify if such situations are about to occur. Thus, detecting the gas cylinder in time helps the on-site commander direct the firefighters.

- In 2016, a large tank with palm oil at the port of Fredericia had caught fire. A small, fixed-wing eBee drone was used to generate a map of the area (see image above). Later, right after the situation had been deemed under control by the on-site commander, the drone pilot continued operating the drone and discovered that flames flared between the tanks. Neither the on-site commander nor the firefighters had a chance of detecting from the ground what was happening between the tanks. But with the exact location of the fire provided by the drone, the firefighters could quickly be sent to the exact spot. Without the drone, the situation would most likely have escalated.

eBee Plus foam drone by senseFly.
Photo: senseFly.

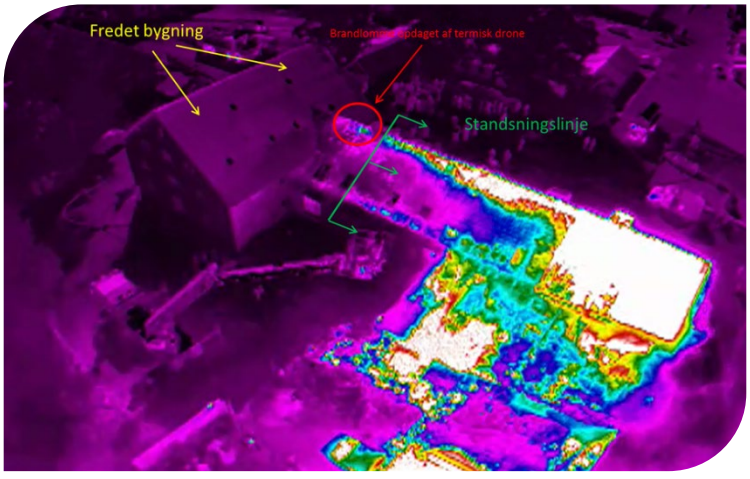
[12] The fixed-wing drone is an eBee by Sensefly: https://www.sensefly.com/drone/ebee-mapping-drone/

[13] From DEMA's website:
https://brs.dk/beredskab/idk/statsligt_beredskab/resursekatalog/saerligtmateriel/droner/Pages/Droner.aspx

- Detecting smoke formation is likewise critical; especially, if it is a chemical fire that causes toxic smoke. Based on the direction of the smoke formation, the drone can be used for establishing not only which areas will be affected, but also who is at site or nearby, e.g. if there is a tailback on a nearby motorway with people waiting in their cars or if kids are playing in a schoolyard. The drone overview can assist the on-site commander decide whom to warn and whom to evacuate in due time. Thus, the drone provides richer information than a map of the area would do.

Smoke formation and impact.
Photo: DEMA.

- Drones also assist when housing is on fire, e.g. listed buildings, which are crucial to preserve. The drone can help detect how the fire develops and if it crosses the line set by the on-site commander for where the fire must not develop further. This was the case when a drone carrying a thermal imaging camera helped detect that flames had developed underneath the rooftop construction during a fire and crossed the sectioning between apartment buildings; a fire that was invisible to the human eye. In this situation, the drone provides invaluable information to the firefigthers.



Flames (red circle) have crossed the sectioning.
Photo: DEMA.

- Another example is when the drone pilot arrives before the on-site commander and can deploy the drone only minutes after the emergency call. The pilot uses the drone and in a particular case an operator circulating over a burning building realized that something looked peculiar. It looked like multiple bonfires had been made, which leads to the conclusion that an arsonist must have caused the fire. This informed the on-site commander about the need for approaching the building with extra caution; among other things to preserve any clues that may have been left by the arsonist.

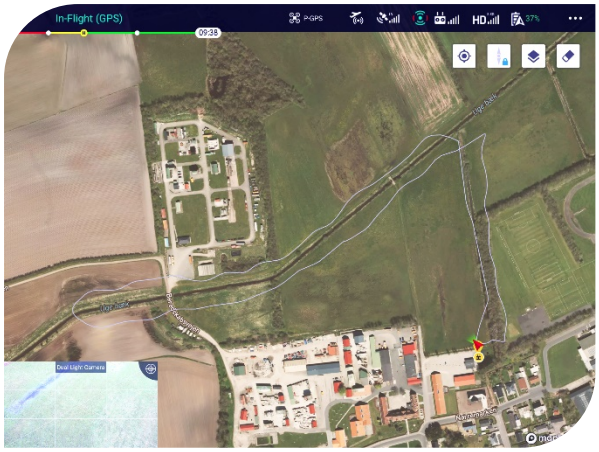
In connection with some types of operations, three on-site commanders are present and need to coordinate: one from the police, one from the fire department and one from the health sector.

Three on-site commanders busy coordinating an operation.
Photo: DEMA.

Generally, on-site commanders need as much information as possible to be able to plan an operation. Sometimes this entails that the on-site commander must run all the way round a property to get an overview of the situation. However, this is time-consuming; especially if it is large building. Therefore, the on-site commander may not have time to do so and may be forced to bring the personnel into action based on experience although he has limited information. The drone can help collect valuable information and thereby enrich the basis for planning the rescue operation.

Besides helping in connection with firefighting, DEMA also uses drones for reconnaissance of large areas in connection with protracting operations that can go on for hours or days. According to Brian Wesselhoff, head of section and overall responsible for drones at DEMA, DEMA collaborates with the Danish Defence's unit for search and rescue on developing a concept for the use of drones in connection with coastal humanitarian searches. This includes a collaboration with the Danish Defence's air medical services (helicopters).

- As an example of such missions, a drone was used when searching along a stream for a missing person. To not miss anything, e.g. by overlooking something in a blind angle, both sides of the stream were overflown and scanned. While doing the reconnaissance, the drone also documented the areas that it had searched. Of course, the missing person could move into an area already searched, but the overview helped focus the operation on uncharted areas.



Documentation of the stream overflown by a drone.
Photo: DEMA.

Although it sounds appealing to use drones to search for missing people, it can in fact be very difficult to detect humans by means of a drone. The operator creates a flying path and lets the drone fly autonomously, but it does not suffice. Instead, a drone search must include both the pilot, a spotter

directing the pilot and someone keeping an eye on the pictures generated by the video camera mounted on the drone. This means that using a drone for search and rescue missions requires an operating crew equivalent to or bigger than that of using a helicopter. Sometimes, three drones are deployed to search an area. In that case there is no economy of scale, as each drone requires both a pilot and someone directing the pilot to have the necessary agility during the operation.

Implementation and use considerations

Costs and benefits. Overall, DEMA uses drones in connection with firefighting, toxic emission or spill control, and search and rescue missions. In comparison, the use of helicopters is limited mainly to search and rescue missions, because it is significantly cheaper to fly a drone for one hour compared to a manned aircraft. As illustrated above, drones are used in various types of situations and seldomly supplement or replace a helicopter but rather constitute new opportunities for the use of aerial vehicles. One of DEMA's overall objectives is to be a trustworthy and professional actor within the field of drones and to lead the way for the development of simple and efficient concepts and methods to be used for emergency response operations. DEMA uses commercial off the shelf drones from DJI. The fleet is quite large and hence the drones must be acquired at a price friendly level. Overall, drones provide the current and updated information to the on-site commander, who uses it as supplementary to other information sources, when planning an operation, e.g. how to approach a situation and when to call in more staff. Drones have proved especially useful in connection with firefighting missions. But the use of drones has also prevented that lives were lost, as when a missing person was found by means of a drone around the time it was decided to end the search and rescue mission.

The right equipment. DEMA's most used drone payload is a standard DJI zoom camera, which by and large covers the need for monitoring at both short and long distances. DEMA has vans equipped with drone-related technology, such as spare batteries for the drones or large screens enabling the on-site commanders to watch live feeds from the drone.

Spare batteries for drones. Photo: DEMA.

DEMA uses tools[14] for secure live streaming in the shape of a backpack with 4-5 SIM cards that bond signals and constantly make use of all providers' signals to obtain the best signal at any time. Therefore, DEMA is almost 100% certain of having a connection for live streaming of data anywhere in Denmark.

Technical shortcomings. According to Henrik Kruse Nielsen, drones still need some development. First, the time for deploying drones should be improved. Today, despite the well-equipped drone vans, it can easily take five minutes to unpack and make the drone ready to fly. One challenge is that the

[14] Incendium's homepage: https://www.incendium.dk/

propellers must be dismounted when storing and fitting the drone into its box to save available space in the van. Nevertheless, time is not always an issue, as the trip to the destination may be long anyway. Thus, whether deployment is done in three or five minutes may not matter so much.
Although DEMA sometimes would like to use drones in connection with flammable chemicals, the drones are not designed according to the ATEX directive[15]. This prevents the use of drones and is not likely to be solved in the foreseeable future, as drones that are designed for operating in environments with an explosive atmosphere are much more costly than the drones currently in DEMA's fleet.

The weather limits the opportunities. One of DEMA's drones is a DJI Matrice 210, which is water resistant with an IP43 rating and therefore can be flown in drizzling weather if aired afterwards. However, according to Henrik Kruse Nielsen, "*the cameras cannot withstand rain, which makes it a super* [bad] *combination*". Windspeed is challenging to the smaller drones in the fleet, whereas the DJI Matrice 210 flies well in open areas at wind speed up to as much as 16-18 meters per second – but less well in built-up areas, where turbulence can impact the performance of the drone.

Legislative conditions. DEMA can operate drones according to a published standard scenario specified in connection with the implementation of the new EU legislation. In fact, there is both a full and a light version of the scenario. The full version becomes effective once DEMA has completed an operational handbook, whereas the light version is already effective and used by DEMA. Flying according to the light version suffice for many operations. Contrary to commercial drone pilots, DEMA does not have to inform the police 24 hours in advance of its operations. Moreover, again contrary to commercial drone pilots, DEMA can fly closer than 250 meters of a site of damage as well as overfly private property without asking for permission. Although Henrik Kruse Nielsen is aware that no law dictates it yet and that *one is perhaps willing to accept an increased risk when the purpose* [of a mission] *is to save lives*, he aims at providing redundant capability of the drones in DEMA's fleet, among other things by mounting parachutes on the drones.

Educating and training the pilots. To be of assistance to an on-site commander, the drone pilot must have a tactical understanding, e.g. of how, where, and how fast a fire can develop.[16] DEMA's technical school in Tinglev in the southern part of Denmark is where on-site commanders from fire departments, the police, and the health sector as well as emergency response team leaders are educated.

One of DEMA's drone pilots operating a drone. Photo: DEMA.

[15] The ATEX directive consists of two EU directives describing what equipment and workspace is allowed in an environment with an explosive atmosphere.

[16] Publication by the Danish Emergency Management Agency on the use of drones for emergency response operations: https://brs.dk/viden/publikationer/Documents/Taktisk%20anvendelse%20af%20droner%20v%203%20201216_1030%20(2).pdf

And it is also the place where DEMA's drone pilots are educated. Depending on the stage of an operation, generating thermal images of where a fire is may not always be news to the on-site commander. Therefore, the drone pilots are trained in situational awareness to be able to know where to fly and what to look for and thereby add value to an operation. Today, DEMA uses live feeds that are occasionally saved on the camera's SD-cards. DEMA would like to learn from such footage.

The process of implementing drones. Before implementing drones, DEMA made field tests to understand whether and how these unmanned aerial vehicles would be a gain to the on-site commanders – or whether they would simply become a source of information overflow. On-site commanders operate in extremely busy environments and it was therefore important to assess the value added from drones. It is by no means certain that another tool in the box automatically constitutes an advantage. However, drones are now acknowledged as very useful in many situations.

Vision on how to use drones in the future. Today, drones are deployed from vans or simply from a temporary landing ground. Henrik Kruse Nielsen states that *my biggest dream is that we have buildings at strategic locations where some kind of fixed-wing drone is positioned on the rooftop and deployed to fly to a defined GPS-coordinate*. He continues by explaining how the drone streams data to the control center and maybe also to the on-site commander's or emergency response team leader's tablet. This would enable them to gain an overview of the situation at the site as they are approaching it making the drone even more valuable than today.

4 Main take-aways

This memo presents important insights from two organizations that are on the forefront of using drones. The two cases are meant to serve as inspiration for the general implementation of drones, including how to operate an entire fleet – also for commercial purposes. These are the key take-aways:

Organizational aspects. Both Fyns Politi and DEMA have demonstrated a willingness to take risks. Public safety and emergency response operations are in themselves typically critical missions with potentially extreme situations occurring, which leave no room for distractions or failures. Further, any scene is governed by strong organizational procedures. Nonetheless, the two organizations have had the courage to experiment by adding a new technology to an already complex and critical situation. Their implementation of drones has been successful, because it has been done in a controlled way, step-by-step. This has also prevented intra-organizational resistance towards this new technology, as only very few of already scarce resources have been allocated in the beginning and news about well-accomplished drone operations spread to support internal motivation and commitment. Moreover, the necessary managerial support has been present in both Fyns Politi and DEMA. The support includes investments to build, operate, and maintain not only single but entire drone fleets, but also time and resources for training personnel and establishing operating procedures, and establishment of facilities for maintenance and repair. In conclusion, a fully functioning fleet of drones is not simply implemented overnight and having successful use of drones (as shown in the cases) require more than one or two drones for operational purposes.

Considerations of usefulness and usage. The two cases illustrate that drones equipped with various types of payload are already valuable and highly useful tools for public safety and emergency response operations in Denmark. In these settings, the drone is mainly a supplement to existing solutions. It does not fully substitute jobs. Rather it provides an overview – the big picture – of a situation, which makes it easier for the man on the ground to accomplish his mission. In this way, BVLOS is not only sufficient but also necessary to fully benefit from the eye in the sky, in such a way that those on the ground can get a quick and extensive overview of the situation and focus their efforts on solving the critical situation at hand. Also, to ensure flexibility and be able to deploy drones whenever needed, a fleet of drones is necessary. This is not only with reference to covering specific geographical (and unknown) positions within a short response time, but also to better carry out the task by use of swarms of drones that fly autonomously. Moreover, drones that are weather resistant to a larger degree than today – and still not too expensive – would make it possible to gain situational awareness of damages e.g. already when a storm is at its peak. In conclusion, some technological solutions still lack for drones to be fully operable and useful – also in a commercial setting.

Safety considerations. Fyns Politi and DEMA have a fair amount of latitude in determining when and how to deploy their drones, which they manage by taking precautions to ensure applying drones as safely as possible. Apart from planning routes to avoid flying over built-up areas if possible, the precautions also include standard operating procedures for maintenance and repair, advanced and continued training of drone pilots as well as the use of drones equipped with navigable and fail-safe

components to provide redundant capability. Both organizations have come a long way in defining their drone-related requirements and procedures and continue to improve these as well as the capability and safety of the drones in their fleets. If the general drone legislation would support commercial use of drones within the scope of how Fyns Politi and DEMA use them, all these safety measures would have to be taken by commercial operators too. Moreover, issues regarding data protection and public reactions to drones need to be considered carefully. Generally, Fyns Politi and DEMA experience no resistance to their use of drones; probably due to the respectable purposes of their missions. This public acceptance is not necessarily there for commercially-oriented applications of drones. When freeing the drones to fly BVLOS for commercial operations these cases from Fyns Politi and DEMA demonstrate how users of drones my scale their use from no or a single drone to a larger fleet may be adopted and implemented successfully.

5 Methods

This memo draws on a combination of desk research and primary data. Semi-structured interviews and general dialogue with stakeholders in Denmark (Table 1) took place between April 2018 and August 2019 by researchers from the University of Southern Denmark (SDU). The interview data was transcribed and coded to enable categorization and analysis of the most important aspects in relation to the use of drones for public safety and emergency response operations.

Role	Organization	Interviewee	Position in the organization
Experts on drone technology	SDU UAS Center	Kjeld Jensen	Associate Professor
		Brad Beach	Center Leader
Public safety and emergency reponse	Fyns Politi	Kim Munksgaard	Deputy assistant commissioner and responsible for drone operations
	Danish Emergency Management Agency (DEMA; and in Danish: Beredskabsstyrelsen)	Henrik Kruse Nielsen	Master sergeant and responsible for drones at DEMA College
		Brian Wesselhoff	Head of section and overall responsible for drones at DEMA

Table 1: Overview of those who kindly contributed to this memo.

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SDU CENTRE FOR INTEGRATIVE INNOVATION MANAGEMENT