Drone Efficacy Study

Evaluating the Impact of Drones for Locating Lost Persons in Search and Rescue Events

Version	1:0
Revision date	20/9/18
Status	Approved

Drone Efficacy Study (DES)

20 September 2018

Study carried out by **DJI**, **EENA** & **Black Channel** in **July 2018**.

This study required contributions from a large number of stakeholders and collaborating organisations. Special thanks to DJI and EENA and their staff for ongoing support of efforts to bring scientific rigor to the assessment of drone technology for public safety.

Key DJI contributors include **Romeo Durscher**, **Tautvydas Juskauskas**, and **Avery Bazan**. **Alfonso Zamarro** was a key contributor from EENA. **Joe Eyerman**, **Gloria Crispino,** and **Mike Dailey** were key contributors from Black Channel. Thanks also to **Maite Lauby** for data collection support.

A huge thank you to the key stakeholders who helped recruit participants and organise the sites for the local trials: **Michael O'Donnell** from the Dublin Fire Brigade, **Leo Murray** from the Donegal Branch of the Mountain Rescue Ireland, and **Steve McLinden** and **Noel Thompson** from the Mid and West Wales Fire and Rescue Service. Finally, thanks to all the contributors who helped make this study happen, including **Damian Doyle** from Coptershop Ireland, **Derek Balfe** with Nua Photography, **Kevin and Denis Houston** from Irish Civil Defence. A thank you to the Drone SAR team for their support.

Citation: Eyerman, J., Crispino, G., Zamarro, A., and Durscher, R. (2018). ***Drone Efficacy Study (DES): Evaluating the Impact of Drones for Locating Lost Persons in Search and Rescue Events*** Brussels, Belgium: DJI and European Emergency Number Association.

Photos credit: Derek Balfe - Nua Photography

CONTENTS

1. Executive Summary

**Unmanned Aerial Vehicles (UAVs), Remotely Piloted Aircraft Systems (RPAS), Unmanned Aerial System (UAS) are all terms to describe a drone and system. In this report we are using all these terms.*

Drones are increasingly being used to support the public safety and first responder community. Drones offer low-cost, easy to operate, and analytically sophisticated remote sensing solutions in search-and-rescue (SAR), structure fires, hazmat response, wildfires, medical supply delivery to remote locations, and many more.

However, unsupported, false, or inflated claims of efficacy can result in misappropriation of the limited funds available to public safety organisations. This may result in injuries and loss of life for both the victims and responders if the new applications are less efficacious than the current standard practice.

The primary objective of the Drone Efficacy Study (DES) is to conduct a rigorous assessment of the value added by the drone to the current standard practice used for SAR missions.

50 trials were conducted with SAR teams in Wicklow & Sligo (Ireland) and Wales (UK), where SAR professionals were distributed in 2 arms: drone-enabled teams and no-drone teams.

The results of the trials have shown that when a team equipped with a drone finds the victim, they do it **3.18 minutes (191 seconds) faster** than the no-drone team.

The DES has also raised valuable insights on where drone-enabled SAR needs to improve. For example, the lack of clear tactics and operational protocols for drone-enabled SAR having a direct impact on the teams performance. Or the need to create training for drone pilots specifically for SAR missions, to fully integrate them in the operations.

The final recommendations of this study focus on creating drone-enabled SAR tactics; developing specialised and standardised training for pilots; running optimisation tests to understand what is the best combination of aircraft, payload, technology, tactics and training; and validating all of them with rigorous research like Randomised Control Trials (RCT).

2. Introduction

Unmanned Aerial Vehicles, or drones, are increasingly being used to support the public safety and first responder community. Drones offer low-cost, easy to operate, and analytically sophisticated remote sensing solutions that appear to align with the technical objectives of the public safety mission. These applications include search-and-rescue (SAR), structure fires, hazmat response, wildfires, medical supply delivery to remote locations, and many more. The preliminary anecdotal evidence suggests that drone applications may be saving lives at a reduced cost when compared to current standard practice.

However, the introduction of new technologies and applications to the public safety field carries a risk if not conducted with scientific rigor. Unsupported, false, or inflated claims of efficacy can result in misappropriation of the limited funds available to public safety organisations. This may result in injuries and loss of life for both the victims and responders if the new applications are less efficacious than the current standard practice. Fortunately, the medical technology development community has methods than can be used to responsibly develop and evaluate new technologies for medical applications. The fields of clinical research and biostatistics can be applied to emerging drone technologies to bring them to the responder communities quickly, safely, and responsibly.

One of the most promising and popular drone applications for public safety is search-and-rescue (SAR)[1]. The SAR process is complex and can vary tremendously based on environmental conditions, weather, experience and skill level of the searchers, and the type of lost person.[2] The current standard practice for SAR has been developed, practised, and refined over many decades of training and testing, in different scenarios around the world. In the last few years, drones have been introduced in the SAR process on an *ad-hoc* approach and evidence of their initial success and long-term promise has been published in the literature.[3] However, very little rigorous research has been conducted to demonstrate the value of the drone-enabled SAR process as compared to the standard practice without the drone.

The SAR process varies based on environmental conditions, experience, skill level, type of lost person...

The purpose of the *Drone Efficacy Study (DES): Evaluating the Impact of Drones for Locating Lost Persons in Search and Rescue Events* is to conduct a rigorous assessment of the value added by the drone to the search process as compared to the current best practices in SAR without a drone. The study is a collaborative effort of DJI, the European Emergency Number Association (EENA), and Black Channel. Each of these organisations has conducted previous studies that contributed to this design and each organisation was active in the planning and implementation of this study. Significant contributions were also made by the Dublin Fire Brigade, the Donegal branch of Mountain Rescue Ireland, and the Mid and West Wales Fire and Rescue Service.

This report describes the previous research conducted by this team, the study design, the statistical sampling and analysis techniques, the quantitative and qualitative findings, and recommendations for the public safety community. Data were collected through 50 randomised control trials conducted in three locations in Ireland and Wales during 4 testing days over the course of 1 week in June and July of 2018.

[1] Gettinger, D. (2018). *Public Safety Drones: An Update.* Available at https://dronecenter.bard.edu/public-safety-drones-update/

[2] Koester, R (2008). Lost Person Behavior: a search and rescue guide on where to look - for land, air, and water. Charlottesville, Virginia. dbS Productions LLC. Available at https://books.google.com/books/about/Lost_Person_Behavior.html?id=YQeSIAAACAAJ&source=kp_cover

[3] DJI (2018). *More Lives Saved: A Year Of Drone Rescues Around The World. Available at https://www.dropbox.com/s/7f6lhzz5mt1fcz0/More%20Lives%20Saved%202018.pdf?dl=0*

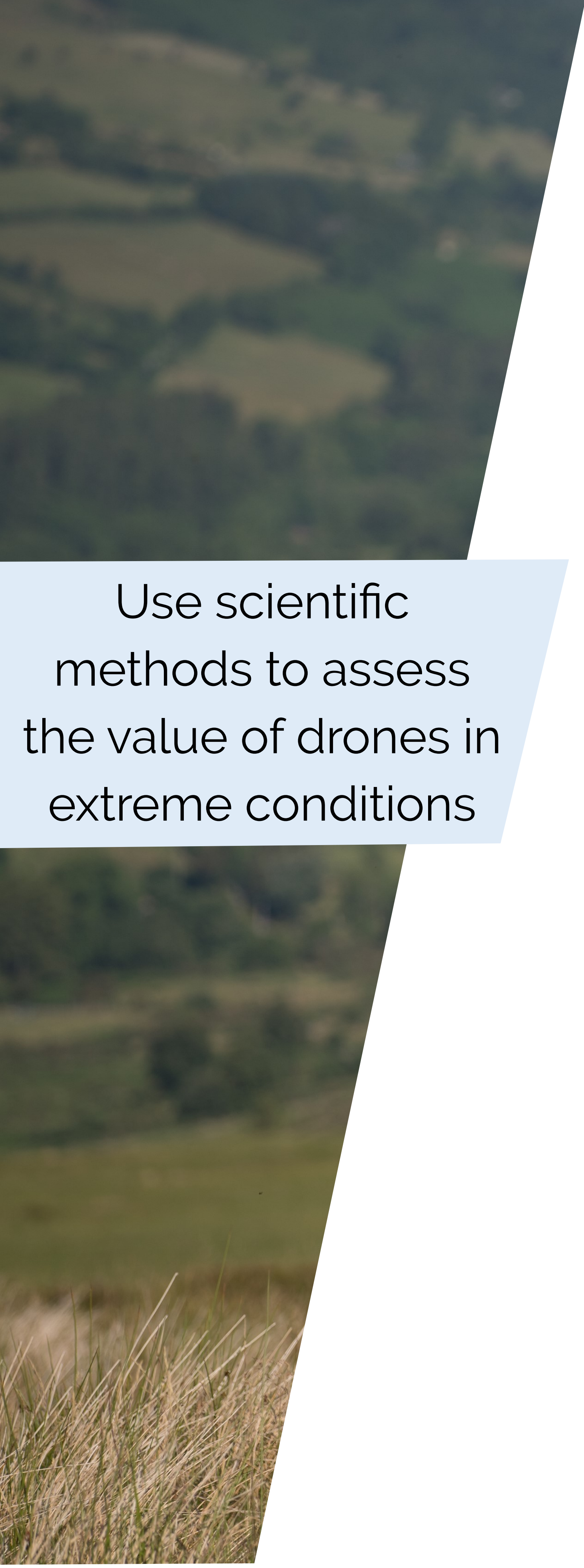
3.1 Fairhead, Northern Ireland and Wicklow County, Republic of Ireland, 2014.

Black Channel conducted self-funded proof-of-concept tests in Fairhead, Northern Ireland and Wicklow County, Ireland in August 2014 to determine if drones could add value to the search and rescue process. A series of trials were conducted over 3-days to assess the value that the drones added to locating lost persons in a coastline and mountainous setting. The trials included simple searches for victims, drone-enabled searches that used radios to communicate the data from the sensors to the field searchers, and planning exercises designed to provide drone data to the searchers prior to the search.

Trials on the first two days were conducted on a boulder field below a large cliff next to the Irish Sea in Fairhead. Trials on the third day were conducted on a boulder field below a small cliff located inland in Wicklow Country. The weather during the test period in Fairhead ranged from heavy rain, to light rain, to dry, always with high winds pushing away from the cliffs towards the sea. The trials were conducted in both dry and light rain conditions. The weather conditions in Wicklow were sunny and dry with little wind. In both locations the search targets were members of the research team who positioned themselves near a boulder as if they had fallen while scrambling in the boulder field.

The team used a DJI Phantom 2 fitted with a GoPro Hero 4 to conduct the trials. Mountaineering experts (guides and climbers) conducted the drone -enabled searches. The mountaineering experts were interviewed by the project team to identify the value that the drones added to the search process. The experts stated the drones had potential to contribute to the search process but that the technology was not ready for use for SAR. The primary barriers were: time required to launch the aircraft, the inability of the drone observer to see the search objects in the streamed images, and the vulnerability of the aircraft to weather and environmental conditions, and barriers to radio communications such as cliffs. Overall, the experts felt that the search teams would be delayed if they used the drone technology that was available in 2014, but felt that the drones could contribute if some of these barriers could be surpassed.

3.2 Adamello Glacier, Dolomites, Italy, 2016.



Use scientific methods to assess the value of drones in extreme conditions

Black Channel teamed with DJI, Piano Giovani, and the Mountaineering Society of Trentino, Italy in 2016 to conduct more rigorous trials of the drone-enabled SAR process.

The research team adopted methods from the biostatistical regulatory field in an effort to create standards that draw design and analysis methods from a mature, rigorous, and validated field of inquiry. These standards can be shared with the SAR and scientific community so that future studies can contribute comparable evidence to advance our common understanding. Furthermore, this approach will help prepare the SAR and drone fields for the rigors of regulatory research that will be required as drones become more commonly used as medical devices.

The experiment was run as a randomised control trial (RCT) with 3 arms in 2 sites. The SAR participants were divided into 3 teams (arms), which included:

- Team 1 standard practice (SP)
- Team 2 SP + review of a orthomosaic map created from a drone flight over the search field pior to the search
- Team 3 SP + use of the drone i.e. drone acting as an additional searcher from the air.

The team members in each of the 3 arms were selected using stratified randomisation and they were 'blind' to the results of any other team. This study design reduced potential bias significantly. The drone-enabled searches used a Phantom 4 with the standard mounted camera. The 2 key measurements were: time to locate the casualty (visual) and time to meet (reach/contact the casualty).

From the analysis of the experimental data, in all 9 tests the ability of the two drone teams (either SP + orthomosaic map and SP + drone) to perform better than the SP team depended on 3 key factors: the knowledge of the searchers about the search field, the accuracy of the orthomosaic map produced with the drone data, and the ability of the personnel involved to read drone maps and footage.

In the most challenging scenario, the glacier, the time to locate the casualty for the SP team was equivalent to both of the drone teams. In the less challenging scenario, at lower altitude, flatter area, in the woods, and with the addition of the IR camera, the time to locate the casualty for the SP + orthomosaic map team was better than for the SP team. The SP + drone team performed with a time equivalent to that of the SP team but had the advantage to 'exclude' search areas, therefore reducing the resource effort by 50%.

Developing controlled test methodologies to continue collecting rigorous data on how drones can save lives

The key lessons learnt were:

- rigorous tests designed with regulatory grade study protocols similar to the ones used in the medical industry are feasible in extreme environments: challenging but feasible.
- standardised measurements can be collected with robust and easy-to-use data collection tools which are suitable for a hard-to-reach environment
- the ability of reviewing drone data (maps, footage, etc.) is impacted by the knowledge of the mountain area, mountaineering skills and SAR practices.

3.3 EENA and DJI Study, Wales, Ireland, Denmark, and Iceland, 2016.[4]

In April 2016, EENA partnered with DJI for an in-depth study of how drone technology is used by first responders pioneering the integration of drone in their work. The aim of the project was to learn more about the use of drones for emergency response and to find best practices for drone use – in terms of operational, technical, safety, privacy and legal perspectives.

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 drone technology for operations ranging from searching for missing people to responding to 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 drones in Standard Operating Procedure
- Training of teams on the use of drones
- Hardware needs and maintenance
- Logistics
- External framework for drone use.

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 recommendations include having a set-up

[4]EENA-DJI Pilot Project Report (2016). *"The use of Remotely Piloted Aircraft Systems (RPAS) by the emergency services."* Available at http://eena.org/download.asp?item_id=207.

As with any new technology, educating regulators and the public is important.

with a minimum of two people using the drones, with one person controlling the unit and one person analysing 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.

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

In terms of hardware, software and maintenance, drone manufacturers are improving the technology at a high speed and as drones 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 (Red, Green, Blue) and thermal cameras. One of the test sites also used a Matrice 100 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.

Drone 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 drone units are easily accessible is key. Basic recommendations include always inspecting the units for damage and making sure they are updated with the latest firmware. Other key questions to address include where the units should be stored, how they are best transported to the incident site, where they should be deployed and how battery management is best structured.

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 drone use. Developing an industry standard for first responder drones to use blue lights is widely supported by the community. Requirements being able to operate drones at night and beyond visual line of sight.

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

4. DES Study Overview

Objective

The primary objective of the Drone Efficacy Study (DES) is to conduct a rigorous assessment of the value added by the drone to the current standard practice used for SAR events. The secondary objective is to advance the work started in the previous research projects and to continue to develop the methods required for robust assessment of drones.

Method

The study was conducted as a randomised control trial (RCT) with 2 arms in 3 sites across 4 different search conditions. Trials were conducted in Wicklow County, Ireland on June 30th, Sligo County, Ireland on July 1st, and Mid and West Wales region on July 5th and 6th. The same search field was used both days in Wales but the search target was moved between the two days.

Two arms were compared:

- Arm 1: Ground searchers using standard SAR methods
- Arm 2: Ground Searchers using standard SAR methods with drone-support

The primary endpoint is the difference in the time-to-locate between the two arms.

Participants were recruited from the public safety community and were randomly assigned to one of the two arms: drone assisted searching or standard practice searching without the drone. They were then randomly assigned to a team of 4 searchers. Randomisation is important in this case because there are many factors that could impact the time required to locate a lost person. Searcher experience, fitness, knowledge of the search field, prior training, relationship with the other searchers, etc. could benefit one team over the other. If this happens then it would not be possible to determine if the observed difference between the two arms was due to the drone or some other factor. Randomisation controls this by giving each participant an equal chance of being in either arm or on any team, hence distributing the potential bias equally between the two arms.

The teams from both arms were given the same search scenario on the same fields and were asked to locate the lost person quickly and safely. The time required for the drone enabled team to locate the lost person was compared to the teams without drones.

Table 1. Aircraft, sensors, and other supporting equipment used by the drone team

Aircraft	Sensors	Search Software	Additional Hardware
DJI Mavic Pro DJI Phantom 4 DJI Inspire 1 DJI Inspire 2 DJI Matrice 600 Aeryon SkyRanger	Optical, visible light camera systems	Manual flights, no automated flight patterns	DJI Fully Immersed Goggles HDMI from radio to external monitor inside a SUV Pop-up tents to reduce glare

Primary Endpoint

The primary efficacy outcome measure of the DES is the time-to-locate (TTL) the search target. The timing started when the first member of the search team (drone or no-drone team) made a positive move toward finding the lost person. For the no-drone team this meant entering the search field. For the drone team this could include entering the search field or powering on the aircraft prior to launch. The timing ended when the search target (a yellow and black full body swift water rescue suit) was located by either the field searchers or the drone searchers.

The primary efficacy endpoint is the difference in time-to-locate between the 2 arms in each trial. The data are right censored as the search period is limited to 60 minutes from the start of the search. If the lost person is not located in 60 minutes the trial is ended and coded as "not found".

Data collectors were instructed to record the stamp when a target was reported as located, and to continue timing until the target was confirmed by the field searchers. Once a target was confirmed, the time stamp for the location was used to define the TTL.

Secondary Endpoint

Secondary outcomes include the number of successful locations by each team, the percentage of successful locations by each arm and the overall average of time-to-locate per arm. The secondary efficacy endpoint is the difference in the proportion of successful locations between each arm out of all trials conducted.

Qualitative Endpoints

The study design provided 3 opportunities to capture qualitative data about the search process and the study implementation. Participants and observers were asked to provide comments during the trials, at the end of each day of trials, and after the completion of the overall study. These qualitative data provide a valuable context to frame the quantitative results.

Recruitment

A two stage recruitment process was used for this study. The first stage recruited key stakeholders from each study site who knew the local search-and-rescue community and who were willing and able to assist with field logistics. A key stakeholder was recruited from the Dublin Fire Brigade to assist with the East Ireland site, another from the Donegal branch of Mountain Rescue Ireland to assist with West Ireland, and a third from the Mid and West Wales Fire and Rescue to assist with the sites in Wales. The project team provided these key stakeholders with summary project materials and outreach documents. The key stakeholders conducted the second phase of recruitment by sharing the documents with their search-and-rescue network to generate a list of participants. The results of the recruiting efforts are summarised in Table 2.

All participants were required to be members of an established search-and-rescue organisation. All participating pilots were required to have the necessary license requirements to fly in the airspace used for the trial and to have some experience with flying drones as part of search and rescue missions. Pilots were also asked to bring the drone equipment they would normally use for SAR as standard practice.

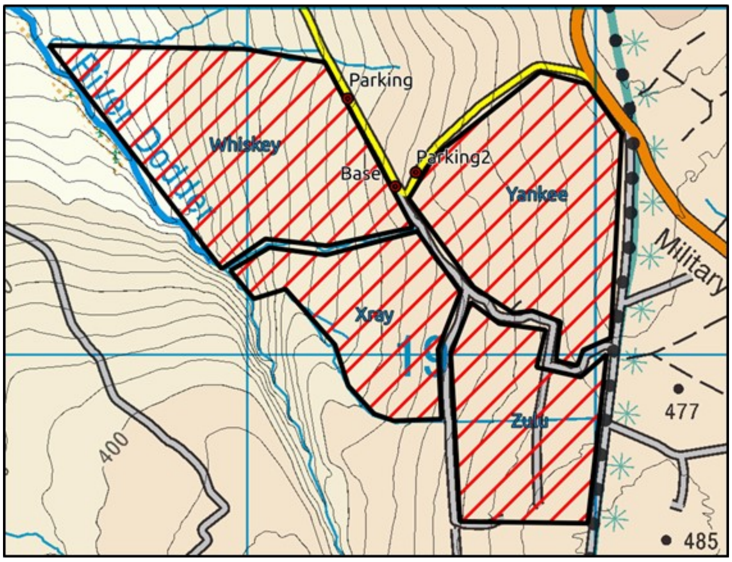
Table 2. Number of Participants Eligible for Analysis

	Study Subjects		Teams	
Location	Recruited	Participated	Drone	No-Drone
Wicklow	12	8	1	1
Sligo	14	12	2	1
Wales Day 1	18	16	3	1
Wales Day 2	19	16	2	2
Total	63	52	8	5

Field Implementation

Trials were conducted in Wicklow County, Ireland on June 30th, Sligo County, Ireland on July 1st, and Mid and West Wales region on July 5th and 6th, 2018. The same search field was used both days in Wales, but the search targets was moved between the two days. The weather was dry and clear with little wind on all 4 trials days. The fields were mountainous areas of moderate difficulty. They included hills, valleys, creeks, cliffs and grasslands. None of the sites were coastal.

Figure 1. Example of Search Fields at a Trial Location



The search targets were swift water rescue suits that were fully body length with boots but no head cover, black below waste, yellow above. The search targets were placed by the project team in locations where a hiker could have fallen or stopped, such as the base of a cliff, in a hole, or the bottom of a hill. The search targets were placed before the participants arrived at the site. The search targets in Wales were moved between first and second days because we used the same fields and because some of the participants searched on both days.

5. Results

Quantitative Results

The primary analysis of the DES study is the comparison of the time-to-locate (TTL) a casualty between the drone arm and the no-drone arm.

The time-to-locate results were paired for each field and the difference in the time-to-locate a casualty between the drone arm and no-drone arm was computed.

Overall, the results can be summarized as follows:

- No-drone teams using standard search practice found the search target in 85% of the trials, while the drone-enabled teams found the target in 77% of the trials (see Table 7.1.1).
- When drone-enabled teams found the victim, they did it **3.18 minutes (191 seconds) faster** than the no-drone team.
- The data show a trend of faster locates with the drone enable search, but the variability and spread of the values do not allow us to generalise our findings.

The average difference in the time-to-locate between the 2 arms was tested using the following approach:

1. Summary statistics of time-to-locate by arm. Summary statistics include: mean, median, standard deviation, Max/min value, missing values. See Table 3.1.
2. Summary statistics of the difference in the time-to -locate between drone and no-drone arm. Summary statistics include: mean, median, standard deviation, Max/min value, missing values. See Table 3.2.
3. The success rate to locate a casualty is summarised for each arm and tested with a Chi-square test. See Table 3.3.

Table 3.1. Time to Locate Lost Person - Overall Summary Statistics by Arm

	Drone Arm	No-Drone Arm	Total
N (number of events)	30	20	50
Mean (SD), seconds	1150	1268	1200
Median (seconds)	855	1188	1980
Min,Max (seconds)	210,3110	60,3160	60,3160
Missing (Number of events 'not found')	7	3	10
Percent Located	76.7%	85.0%	80.0%

Table 3.2. Difference between Drone and No-Drone Arms on Time to Locate Lost Person - Paired Events - Summary Statistics

	Drone Arm	NoDrone Arm	NoDrone -Drone
N (number of PAIRED events)	19	19	19
Mean (SD), in seconds	1180	1371	**191**

Table 3.3. Comparison of Number of Located vs. Not Located - Chi-Square Test

	Drone Arm	NoDrone Arm	NoDrone -Drone
N (number of events)	30	20	50
N1 (Number of event 'locate')	23	17	40
N2 (Number of events 'not found'	7	3	10
Comparison of Proportions	Difference (mean, stdev)	95% Conf. Int	p-value
Chi-square with Yates correction	9%	-15%, 29%	0.45

Qualitative Results

The data collected during the daily debriefings is summarised in Table 4.

Table 4. Summary of Comments from Participants during Daily Debriefings

Category	Comment
Planning	Most groups from drone and no-drone teams spent time planning their search process prior to starting the search.
Overall Time	The drone teams took longer to do most steps in the search process: preparation, planning, transitioning fields, etc.
Experience	Experience is critical to both drone and no-drone teams. Both the pilot and the visual observer need experience with drone enabled searches to be effective.
	No-drone team knew each other but had never worked together. They were able to quickly plan and implement a search because they had been trained on common standard practices.
	Participants came from a wide range of first responder groups. Some were volunteer mountain rescue, others full time professional civil defence, others professional fire brigade. Each has different training on SAR, different SAR job requirements, and different personal equipment. All of these could impact on how they search and how they use the drones.
	Some of the drone operators did not know how to use all of the camera settings. Could have performed better with better training.
	Would like to see a mix of terrains. It could be that the drone performs better in different terrains.
	Drone team wanted more information about the lost person, more backstory to guide the search process. No-drone team said they often search with little information about the lost person.
	Effective deployments of drones allow for aerial searches in hard to reach areas and the ability to clear areas so ground assets can focus on other areas. i.e. knowing where the victim is not, is beneficial but doesn't give potential "win" to the drone team.
	Maps had a big impact on ability to plan and implement searches. Important to have high quality maps, or at least as good as they would have in standard practice.
	Human bodies look different than swift water rescue suits. Should change search target.

Barriers	Drone team had a lot of false positives. Communication protocols and search strategies weren't standardised, impacting their performance. Drone-enabled SAR is a new process and the training, communications process, and field protocols are not as well developed as that used by the standard practice without the drone. These things need to be developed in order to realise the true potential of the drone for SAR.
	Some issues with communications because the field searchers were behind the hill and drone operators were at base.
	Drone operators did not have correct equipment for a full day of searching. Some exhausted their batteries. Others did not perform well under the conditions. Even the well resourced units did not always have enough or the correct gear.
	Drone team had trouble seeing the search target because it was black and yellow, hard to see in the full sun. Hot, sunny weather seems to be a disadvantage for the drones.
	None of the search teams brought thermal. The weather was too warm to use the thermal, it would have produced too many false positives. Could help in cooler weather and low light conditions.
	Colour of suit (yellow and black) did not favour the drone. Red shows up better in drone video.
	Drone team struggled to find items placed at base of cliff because they could only see 3 sides.
	Perceptions from drone not as accurate (cliff height, etc) as they are in person.
Benefits of Drone	Areas with cliffs were easier for drone team to navigate than for the non-drone team.
	Goggles for visual observer seemed to be effective.

Table 5. Overall Qualitative Results

Overall Qualitative Results
Searching with drones is difficult. This study highlights how difficult.
No clear drone enabled SAR process, each team seemed to do it their own way, no one could provide a documented process or evidence of training, still very exploratory.
No clear guidance on what combination of aircraft, sensor, software, training, and search process is optimal. Need a study to understand which work best for different search conditions.

6. Conclusions

The DES study shows that there are differences in success rate and in the time-to-locate a casualty between the drone and the no-drone SAR. Overall and by location, the variability in the data is large.

The data show a trend of faster locates with the drone-enabled search, but the variability and spread of the values do not allow us to generalise our findings. A study with a greater number of trials would be feasible with a similar study design and similar adherence to the study protocol, as they have proven feasible and valuable in the DES.

Drone arm shows quicker time-to-locate. No-drone arm has higher success rate.

Summarising the Trends:

- The drone arm shows a quicker time-to-locate. The difference in time-to-locate is 191 seconds (3.18 minutes).
- Overall, the no-drone arm has a higher success rate than the drone arm. The lack of standardised protocols and strategies for drone SAR may have been the reason.
- The randomisation scheme together with a high adherence to the study protocol have produced homogeneously distributed data per arm. It is a promising result too as it shows that RCTs can be conducted in extreme scenarios and, if conducted in compliance to the study design and the protocol, they provide statistically valid results.

7. Recommendations

The *Drone Efficacy Study (DES): Evaluating the Impact of Drones for Locating Lost Persons in Search and Rescue Events* is the product of great passion and considerable efforts of a very large team. It was a rare opportunity to conduct rigorous research about the value that this emerging technology can add to the public safety mission. It was also a rare opportunity to contribute to the development of new methods and standards. This field of research should continue and expand. Some recommendations are below.

Continued Research

1. Create drone-enabled SAR strategies

Develop protocols to integrate drones in current SAR missions effectively. The SAR process needs to be carefully examined by public safety and SAR experts so it can be identified where drone-enabled SAR efforts can add the most value.

2. Rigorous testing

These high value areas need to be tested with more rigorous studies like the DES. Ground based SAR has matured over the past decades thanks to many research studies and tests. We expect that same to happen with drone-enabled SAR in a much quicker fashion.

3. Conduct calibration studies

Help public safety professionals review the aircraft, sensors, software, training, and field operation options that are realistically available to the SAR community given their budget constraints. Combinations of these options should be tested to understand which meet the threshold for acceptable use, and which provide the best solutions for the public safety community.

4. Develop communications protocols

Create standards for communication between the drone operators, the field searchers, incident command and any other stakeholder. These standards need to be readily accessible and need to be integrated across agencies so that fire, police, search and rescue, and emergency medical services are ready to utilise the drones for missions they encounter.

5. Continue to conduct rigorous research

More drone-enabled SAR research with a wider number of trials is needed to obtain evidence-based conclusions. Only through careful analysis can unstated assumptions be evaluated.

6. Rigorous research is possible

The DES study has proved the concept that RCTs can be run effectively in this field to provide statistically

valid answers comparable to those of other devices in the medical field. Given the large variability in the data, it is recommended that larger studies with a greater number of trials that include stratification by factors should be considered so that a full understanding of the impact of drones in SAR can be measured.

7. Extend study to other fields of public safety

It is reasonable to expect the results to vary based on the type of public safety mission. Additional research in these other fields, such as fire, law enforcement, disaster relief, medical emergencies, can help optimise the drone system and procedures for each mission.

8. Technology development for efficient ops

It is imperative that we continue to develop hardware and software solutions that help with automatisation of the whole operation. For example, flight automation, image recognition, artificial intelligence, livestreaming, resilient telecommunications, that allow teams to operate more effectively, efficiently, while mitigating risks.

9. Share your knowledge

Share your lessons learned so others don't have to reinvent the wheel. Report back to the research community on the challenges and lessons learned from conducting RCT in remote settings. This will improve subsequent studies and help develop standards and a body of evidence that will inform other researchers, first responders, industry, and policy makers.

Recommendations for Operations

1. More than a drone

Recognise that a drone-enabled search solution is part of a larger process that may require more equipment, training, planning, and expense than simply purchasing an off-the-self system and flying it.

2. Proper budgeting

A careful cost-benefit and budgeting exercise should be conducted to determine the cost of a sufficient system which meets the minimum requirements for use in life-saving missions. It is likely that such a system will include a large cache of batteries, redundant charging systems, generators, field internet and livestreaming solutions, trained staff to fly and to search, systems for viewing the drone sensor data in the field, and many more items.

3. Focused, hands-on training

Do regular training exercises specifially focused on search and rescue. It's not just about flying the drone, it's about the ability to effectively use the drone, analyse the live data, properly communicate and coordinate with the field team.

Since the community hasn't developed drone-enabled search and rescue standards, utlise the knowledge of experienced first responder drone operators.

4. Plan to coordinate better

Before drone-enabled search starts, the drone team and the ground assets should properly coordinate their action plan.

The drone doesn't have to be the asset locating the casualty; utilising the drone to search hard-to-reach areas and knowing where the casualty is NOT, allows for more effective resource management.

Annex: About the authors

About EENA

The European Emergency Number Association (EENA) is a Brussels-based NGO and was established back in 1999. Our main strategic mission is to improve the responses made by emergency services on behalf of citizens, principally when the pan-European emergency number (112) is used. As an NGO, EENA is an independent and impartial organisation and does not seek to represent the interests of any one organisation, technology or product.

Tactically, this manifests itself with the creation of several engagement platforms (conferences, workshops, working groups, web meetings) to bring the supply-side (vendors, manufacturers, integrators) and the demand-side (Fire and Rescue Services, Emergency Services Organisations, Government Ministries, Regulators etc) together with a view to discussing legal, technical and operational matters in a thought-leadership and impactful style. EENA has c1500 public safety officials from 80 countries in its network, whilst 90 vendors and manufacturers make up the supply-side equation.

About DJI

DJI is a global leader in developing and manufacturing civilian drones and aerial imaging technology for personal and professional use. DJI was founded and is run by people with a passion for remote-controlled helicopters and experts in flight-control technology and camera stabilisation. The company is dedicated to making aerial photography and filmmaking equipment and platforms more accessible, reliable and easier to use for creators and innovators around the world. DJI's global operations currently span across the Americas, Europe and Asia, and its revolutionary products and solutions have been chosen by customers in over 100 countries for applications in filmmaking, construction, emergency response, agriculture, conservation and many other industries.

About Black Channel

An Irish research firm specialising in the application of extreme statistics, that is, the use of state-of-the-science study designs conducted in remote and challenging locations. Black Channel draws on the field of clinical research to design and implement evaluations of public safety technologies to provide evidence to support the transition of new technologies into the first responder mission. Black Channel has been conducting extreme statistics in support of the first responder mission since 2014 and has conducted evaluations of the value of drones for search and rescue in remote locations, cliffs, mountains, and glaciers in Ireland, Italy, and Wales. The Black Channel study designs are intended to produce regulatory grade results.

Annex: References

DJI (2018). *More Lives Saved: A Year Of Drone Rescues Around The World. Available at https://www.dropbox.com/s/7f6lhzz5mt1fcz0/More%20Lives%20Saved%202018.pdf?dl=0*

Doke, J. (2012). *Analysis of Search Incidents and Lost Person Behavior in Yosemite National Park*. PhD Dissertation, University of Kansas. Available at https://kuscholarworks.ku.edu/bitstream/handle/1808/10846/Doke_ku_0099M_12509_DATA_1.pdf;sequence=1

European Emergency Number Association (2016). *Remote Piloted Airborne Systems (RPAS) and the Emergency Services*. Available at http://www.eena.org/download.asp?item_id=153

EENA-DJI Pilot Project Report (2016). *"The use of Remotely Piloted Aircraft Systems (RPAS) by the emergency services."* Available at http://eena.org/download.asp?item_id=207.

Eyerman, J. D., Mooring, B., Catlow, M., Datta, S., & Akella, S. (2018). *Low-light collision scene reconstruction using unmanned aerial systems*. Research Triangle Park, NC: RTI International; Charlotte, NC: University of North Carolina at Charlotte. Available at https://www.rti.org/publication/low-light-collision-scene-reconstruction-using-unmanned-aerial-systems

Gettinger, D. (2018). *Public Safety Drones: An Update.* Available at *https://dronecenter.bard.edu/public-safety-drones-update/*

Koester, R (2008). Lost Person Behavior: a search and rescue guide on where to look - for land, air, and water. Charlottesville, Virginia. dbS Productions LLC. Available at https://books.google.com/books/about/Lost_Person_Behavior.html?id=YQeSIAAACAAJ&source=kp_cover