Exercise Northumberland Research Report

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Introduction

Exercise Northumberland took place on the 6th and 7th of May 2017 in Northumberland, approximately 6 km northeast of Rothbury.

The aim of the exercise was to compare the effectiveness of ground and air assets during a search for targets and in particular to examine the use and performance of Unmanned Aerial Vehicles (Drones) in a search environment.

There are several terms in common usage to describe UAVs. As well as Unmanned Aerial Vehicle they may also be referred to as Small Unmanned Aircraft (SUAs), Autonomous Aerial Vehicles (AAVs) or simply drones. To enable a consistent approach, this report has adopted the term 'drone' to refer to all such remotely operated aerial assets.

The exercise had three objectives:

1. To update Home Office research undertaken in 1987 and 2008 on the effectiveness of air and ground search assets.
2. To observe and measure the search performance of air and ground assets in accordance with contemporary search management principles and practices.
3. To test and evaluate the use and effectiveness of drones during a search. (In comparison to the 1987 and 2008 studies, the use and evaluation of drones as search assets will be unique to the Northumberland research.)

An area of open moorland of just over 2 km^2 was identified as a suitable location for the exercise. The targets were randomly distributed TYVEC blue boiler suits with a white sheet attached, which had a letter to help identify which targets had been located. Live targets were used in one sector so that an air scenting dog could be used. Northumberland National Park Mountain Rescue Team (NNPMRT) provided ground-based search assets, whilst aircraft from the Civil Air Patrol (CAP) were used for part of the air search. The other part of the air search focused on the use of fixed wing and rotary wing drones.

O'Donnell Revisited

The reference point for the Northumberland research, to some extent, is the work first undertaken in 1987 by the Home Office, often referred to as 'The O'Donnell Theory', which set out to compare the cost-effectiveness of ground and air assets in the search for missing persons. In 2008, further

Home Office research on search effectiveness was undertaken by the Centre for Applied Science and Technology (CAST) but with some significant differences to the original work by O'Donnell. Since this work, there has been a growing interest in the use of drones as a search asset. However, little research exists on their effectiveness in multi-asset search situations and in situations where changing terrain and conditions present challenges to search assets and management. The exercise aimed to build on the previous work undertaken by the Home Office by evaluating the use of drone technology, utilising developments in ICT and incorporating contemporary search management principles and practices.

Research Design

We set out to add to the knowledge gained from the two Home Office experiments rather than just replicate these. The design of our experiment evolved over a period of time as our thoughts about search assets, the search area and what might constitute suitable terrain and suitable search targets, took shape. In doing so, we moved away from the O'Donnell focus on cost-effectiveness (the principle objective of that work) and towards the performance of assets during the different phases of a search for a missing person.

Exercise Northumberland: Rationale, Collaboration, Planning

Rationale

The original O'Donnell experiments had measured and compared the performance of manned aircraft and ground searchers. We felt that it would be desirable to extend the scope of Exercise Northumberland beyond this in three ways:

1. To include the new technologies that are available, in particular drones.
2. New methods for ground search teams have been developed by The Centre for Search Research (TCSR). These are widely used and should be included.
3. New approaches to Search Management devised, promoted and taught by TCSR suggest that a search for a missing person should be considered to be in separate phases; in particular, the Initial Response phase followed by subsequent phases. The search tasks and techniques will differ between these phases.

Therefore, while it was of interest to measure and compare search assets in the way that the original field trials had done, it seemed more important to us to determine which assets were best suited to each phase of a search. This would be reflected in the experimental design and the measureable properties we would be investigating.

Collaboration

TCSR has been in existence since 1997 and in that time has been involved, among other things, with teaching courses on searching and Search Management to a variety of organisations nationally and internationally. Consequently, it has developed a range of contacts with experience of searching for missing persons and from this pool, it was possible to gather a group of knowledgeable and experienced observers for the exercise.

The members of TCSR and Newcastle University Business School (NUBS) who designed, organised and participated in Exercise Northumberland are all current or former members of Northumberland National Park Mountain Rescue Team (NNPMRT).

The three members of TCSR have all served as NNPMRT Team Leaders and have extensive experience of organising and managing searches. Through teaching courses, TCSR has built up a thorough understanding of searching and Search Management principles.

A new contact for the purpose of Exercise Northumberland was with UK Civil Air Patrol (CAP), one of the largest charitable air observation organisations in Europe, with some 200 members and an air fleet that includes fixed and flex wing aircraft, light helicopters, autogyros and drones. For the purpose of Exercise Northumberland, CAP committed 6 air assets and was represented in the planning meetings throughout.

Funding for the research was provided by TCSR, Newcastle University and Northumberland National Park Authority.

Planning

Major items that had to be considered were:

- The choice of a suitable time of year; we were hoping for favourable weather and sufficient daylight together with a moderate growth of vegetation.
- The choice of a suitable location and permission to use it.
- The structure of the field trials; we wanted to reflect the current approach to managing a search for a missing person, with different styles of searching being used in the Initial Response and in subsequent phases.
- The choice of search assets; we were aware of the original O'Donnell experiments but also wanted to involve a range of search assets currently available.
- The choice of suitable targets.
- The infrastructure needed to support the experiment; accommodation for persons visiting the area, suitable locations for vehicles and aircraft, somewhere large enough to debrief and feed up to thirty people at the end of the first day.

Methodology and methods

The rationale outlined in the previous section provided a framework for the methodology and methods to be employed:

- Search Management principles as expounded by TCSR describe the different phases through which a search for a missing person may progress, in particular the Initial Response Phase, followed by Subsequent Phases, which gives rise to two different styles of searching:
  - Searching during the Initial Response Phase consists of small groups of trained searchers following travel aids[1] (such as paths, tracks, walls and fences leading away from the last point at which the missing person was known to be) and locations (destinations or waypoints to which travel aids lead).
  - Searching in subsequent phases consists of area searching by groups of trained searchers using grid searching at critical separation and purposeful wandering (proven methods of improving the rate of detection by effectively doubling the sweep width).
- The terrain chosen should be able to accommodate both types of searching.
- The purpose of the exercise was to produce results that would allow for a critical examination of the resources used rather than testing the management capabilities of search controllers. This suggested that the search targets should be randomly placed within the search area rather than positioned in a way that conformed to Missing Person Behaviour statistics.

Research Area

Location

The location chosen for Exercise Northumberland needed to be away from any significant areas of population that might inhibit the performance of some of the assets. This was not difficult given the rural nature of Northumberland.

A second requirement was the availability of parking for the large number of vehicles expected and proximity to suitable facilities for the aircraft involved.

The location selected was located immediately south of New Moor House (OS Explorer Series Map 332, Alnwick and Amble, grid ref. NU 098063), bounded by the A697 on the northeast side and

[1] A term taken from: Perkins *et al.* (2011). The UK missing person behaviour study.

B6341 on the northwest. These major roads provided easy access from all directions. The southeast and southwest boundaries were defined by well-maintained fences. The nearest significant areas of population were Rothbury (6 km southwest), Longframlington (6 km south) and Alnwick (10 km east). The airfield at Eshott (NZ 183986) is about 5 minutes' flying time to the east and was used as a forward base by CAP.

Size

What was needed was a single area that would be suitable for a search by aircraft and that could be easily divided into smaller areas (sectors) suitable for ground search. In addition, there should be no features that would restrict or hinder the performance of one type of resource over another, for example a cover of dense trees that would be more suitable for ground searching rather than searching from the air, or a large body of water that would be inappropriate for ground searching.

The area selected was 2.18 km^2 in total and consisted of moorland with very few trees and no significant bodies of water. It did contain suitable features (e.g. fence and wall lines), enabling it to be divided into a number of sectors for the ground search resources.

Geography

The area was suitable for Initial Response searching (there is a well-defined track running through it from northwest to southeast) and for area searching by all the assets involved.

Research Sectors

Location

The entire search area was divided into six sectors. These were contiguous, so that assets could be moved easily from one sector to another. The sector boundaries were clearly discernible on the ground (fence lines, walls and streams).

Size

The sector sizes were comparable to those identified in the O'Donnell experiments and were well-suited to being searched by small groups of trained ground searchers. Sector sizes ranged from a minimum of 0.11 km^2 to a maximum of 0.72 km^2.

Geography

Each sector consisted of terrain of a similar nature, although this was not always possible, as occasional streams in steep gullies crossed the sectors, some with adjacent bushes and trees.

Targets

Description

The original O'Donnell experiment had used 2ft x 4ft rectangles of black PVC sheeting. We felt that two dimensional targets such as these would be inappropriate for searchers on the ground since a human body is a three dimensional object. Consequently we used blue boiler suits, each of which was filled with a large roll of bubble wrap to give it a third dimension.

Each target was identified by an A4 size piece of white paper with a letter on it. This was pinned to the back of the target, and the target placed face down so that the letter was visible without having to touch the target. The targets were set out by the organisers using hand held GPS units giving 10-figure Ordnance Survey grid references to ensure accuracy in placing them at the pre-determined random locations. The targets were pegged down to prevent them blowing away.

Number

Initial Response searching: this involved the search of 1.2 km of the track through the search area and the areas immediately adjacent to it. A total of twenty targets were used, with ten on either side of the track.

Subsequent Phase searching of areas: the total search area had been divided into six sectors. A total of sixteen targets were deployed as follows (table 1):

Sector	Area (km^2)	Number of targets
Alfa	0.11	2
Bravo	0.18	2
Charlie	0.44	4
Delta	0.25	1
Echo	0.72	3
Foxtrot	0.48	4

Table 1. Distribution and number of targets during Subsequent Phase searching

Sector Echo was initially searched by an air scenting search dog. An air scenting search dog searches by looking for the airborne scent coming from a human target, therefore live human targets were needed for this. When the search dog had finished searching that sector, these live targets placed a boiler suit target in the location they had occupied and left the area before the arrival of the CAP aircraft.

Distribution

The targets were placed at random locations along the track for the Initial Response search and at random locations within the search area for the area search. We were not trying to simulate a real incident by using Missing Person Behaviour statistics to influence our choice of target locations; to do so would have biased the results towards those people who were familiar with these statistics, which would most likely be the ground search teams.

For the Initial Response search along the track, two parameters were used for the placement of each target. These were: the distance along the track from the previous target and the distance out from the track to the target position. The length of track covered by this part of the experiment was about 1.5 km, so with ten targets on each side of the track the distance between successive targets should therefore be 150 metres maximum. A random number was generated with a value between 1 and 150 metres to provide this parameter.

Earlier visits to the search area had shown that the average distance at which at target could be detected at ground level (usually referred to as the Critical Distance) was 40 metres. In fact it varied considerably throughout the area, but 40 metres was an acceptable average. Therefore a second parameter was randomly generated with a value between 1 and 40 metres to give the distance out from the track.

Thus each target location was represented by two parameters: the distance along the track from the previous target position (between 1 and 150 metres) and the distance out from the track (between 1 and 40 metres). Twenty of these pairs of parameters were generated, giving ten on each side of the track. The precise locations of targets are shown in Table 2 overleaf.

Left Side of Track				Right Side of Track		
Target No.	**Distance from previous target**	**Distance out from track edge**		**Target No.**	**Distance from previous target**	**Distance out from track edge**
1	113	4		**1**	98	22
2	114	39		**2**	148	29
3	111	26		**3**	112	38
4	122	19		**4**	96	19
5	98	40		**5**	62	3
6	54	15		**6**	56	40
7	93	16		**7**	121	23
8	113	19		**8**	115	6
9	71	28		**9**	65	16
10	41	12		**10**	116	25

Table 2. Location of targets for search track

Area searching

This presented an interesting challenge in that it necessitated generating random six-figure grid references so that the target locations all fell within the search area. This was done in stages:

- Restricting the grid references generated to the area bounded by the eastings NU 090 to 120 and the northings NU 040 to 070. This contained our experimental search area and gave a total area of 9 km^2. At this stage, the exact number of targets to be placed in the search area was not known but was anticipated to be around 20 to give a reasonable range of success rates; if you have only one target in a sector then either the search team finds it (100% success rate) or they don't (0% success rate). By providing multiple targets, a set of more refined success rates is produced that is more suitable for comparing search assets.
- 120 random easting/northing pairs (random grid references) were generated for the 3 km x 3 km area; of these 64 were outside the experimental search area, leaving 56 inside.
- The 56 randomly generated grid references were reduced again by three criteria: we did not want targets to be so close together that finding one would inevitably lead to one close by being found; we did not want targets to be so close to sector boundaries that they might be seen by a group searching in an adjacent sector; we wanted to have a reasonable level of

similarity of target density between the sectors rather than a lot of targets in one sector and none in another.

- These processes reduced the number of targets to 16 in total, distributed in sectors as shown in Table 1.
- Overall the target density was 16 targets within 2.18 km^2 or 7.3 targets per km^2.

Location

No attempt was made to make the targets difficult to see by, for example, hiding them in holes in the ground, under vegetation or in trees etc. For both types of searching the targets were placed exactly as indicated by the random locations along the route or the random grid references.

Results

At the beginning of the exercise all search assets were briefed with respect to the objectives of the exercise and the search targets. No information was given with regard to the location or number of targets to be found.

The search targets were navy blue TYVEC boiler suits stuffed with bubble wrap to give them a similar size and profile to an adult human missing person. They were placed in a prone position, to simulate someone lying down and pegged to the ground to prevent them blowing away. Attached to each boiler suit was a sheet of laminated white A4 paper with a large (640 point), randomised, unique identifying letter printed on it in black.

It was recognised that key to understanding the efficacy of the various search assets would be an analysis of the results produced by each individual asset for each aspect of the exercise.

To this end, comprehensive details were kept by the exercise organisers regarding the search effort and the deployment and performance of each asset. On completion of the search task, each asset in turn was canvassed for the number and location of targets found and their own evaluation of their performance. To facilitate this process, a hotel-based debrief took place during the evening of day 1 involving feedback from air and drone pilots, MRT members and observers.

The results from the different search assets involved in the exercise have been evaluated alongside comments from the impartial observers. These observers were tasked to observe and monitor the activities and performance of specific assets.

The meteorological conditions were similar on both days of the exercise, with wind speed being at a fairly constant 18mph and gusting to a maximum of 31mph from the NNE. The cloud level, though mainly high enough for safe flight operations, did drop to around 300 feet AGL on several occasions during early afternoon on day 1 and similarly on several occasions on day 2.

These meteorological conditions had a significant impact on the availability and performance of the 'traditional' fixed wing aircraft and, whilst the conditions were towards the limit of the capabilities for the drones taking part, they were still able to operate. There was no notable impact on the performance of the ground searchers either human or canine.

Results: Initial Response Phase

All the ground and air assets were briefed to carry out a search along a 1.2km track and the ground adjacent to it and to simply report the number of targets located on each side of the track.

Air Assets

Cessna 210

Crew:	Pilot x 1, spotters x 3
Start Time	10.49
End Time	10.51
Time on Task:	2 minutes (Observer record. No time reported from pilots)
No. of targets reported:	6
Reported target location:	4 NE of track, 2 SW of track

Crew report: As we approached the area it looked reasonably clear and so we commenced the run, but observing another patch of drizzle and lower cloud approaching from the North, we sped up and turned to leave the area by the clear South route. This meant we had little time to look for targets although our observers did spot a few as we shot past. They were clearly visible and I am sure that had we been able to search at normal search speed, we would have spotted most in just a few minutes.

Vans RV12	Unable to attend due to the prevailing meteorological conditions

Robinson R22

Crew:	Pilot x 1, spotters x 1
Start Time	10.41
End Time	10.43
Time on Task:	2 minutes (Observer record. No time reported from pilots)
No. of targets reported:	20
Target Location:	9 NE of track 11 SW of track

Crew report:[2] Track search carried out at 500ft AGL.

[2] A summary of a written report submitted by email following the conclusion of the exercise.

Autogyro	Unable to attend due to the prevailing meteorological conditions
Flex Wing	Unable to attend due to the prevailing meteorological conditions

Drones

DATAhawk (Fixed Wing) - QuestUAV

Crew:	2
Duration of search:	10 minutes
Time to process images:	5 – 35 minutes
No. of targets in search sector:	20
No. of targets reported:	20

Comments: The flight path of the drone can be seen in image 1. Individual multiple images were able to be viewed and searched after landing. However, some difficulty was experienced in interpreting these as it was found that many of the camera images were rotated and hence the orientation of the view was constantly changing. This, coupled with image overlap, rendered the raw individual images difficult to interpret (image 2). However, within 35 minutes of landing all 20 targets had been confirmed. After the exercise, the images were 'stitched' together to form an orthomosaic[3] to find out how long it would take to do this. The orthomosaic of the full length of the track was generated in 20 minutes (image 3) and this proved much easier to search without the problems of overlap and orientation experienced with the individual images.

[3] A series of images 'stitched' together to form a composite view of a search area.

Image 1. Flight track of the Quest DATAhawk Drone

Image 2. All these images are of the same area and show the difficulties associated with image overlap and orientation

Image 3. These images show how much easier it is to interpret or search an area through a process of orthomosaic 'stitched' imaging

<u>DJI Inspire 1 Pro (Rotary Wing) - Clear Vision Security Ltd.</u>

Crew:	2
Duration of search:	9 minutes
Time to process images:	Real time live downlink of aerial imagery
No. of targets in search sector:	20
No. of targets reported:	16

<u>Comments</u>: Drone pilots currently have a general operational limit requiring the drone to be in sight at all times and a 120m ceiling. To provide (and test) greater operational flexibility over mixed terrain while maintaining visual, the pilot controlled the drone from the passenger seat of a moving Land Rover. The flight was monitored on an iPad and a spotter was again provided by NNPMRT. This person had significant MR experience but none in interpreting aerial imagery. The spotter sat behind the pilot and, looking over his shoulder, used the same iPad to conduct the search. Targets were spotted immediately upon take off and on the climb up to the operating height of 50m AGL. After 2min 50sec it became apparent to the spotter that the critical distance visible out from either side of

the track would be insufficient for the terrain type and he therefore asked the pilot to increase altitude. The remainder of the flight was carried out at 80m AGL (image 4). Communications between spotter and pilot were very clear and sixteen targets were located. It was commented that a separate monitor for the spotter may have been beneficial and made the task of searching somewhat easier as the iPad used also displayed flight telemetry data over the real-time image, which sometimes obscured the camera view.

Image 4. Target as seen from Clear Vision Security Ltd's DJI Inspire drone at an altitude of 80m AGL

DJI Inspire 1 Pro (Rotary Wing) - Northumberland National Park

Did not attend.

Ground Assets

Northumberland National Park Mountain Rescue Team (NNPMRT)

Seven fully trained search personnel from NNPMRT were available for the Initial Response searching. They were briefed to search for the same targets as the previous day and to employ Initial Response search tactics. They were split into three search groups; two groups of two personnel and one group of three. The results of the ground search teams are shown in table 3 below.

Team No.	1	2	3
No. of personnel	2	2	3
Search route	1.24km of track	1.24km of track	1.24km of track
No. of targets to find	20 (10 each side of track)	20 (10 each side of track)	20 (10 each side of track)
No of targets reported	19 (9 on left - 10 on right)	19 (9 on left - 10 on right)	19 (10 on left - 9 on right)
Time taken	31 mins	31 mins	24 mins

Table 3. Ground search team results

Initial Response Phase: Results Summary

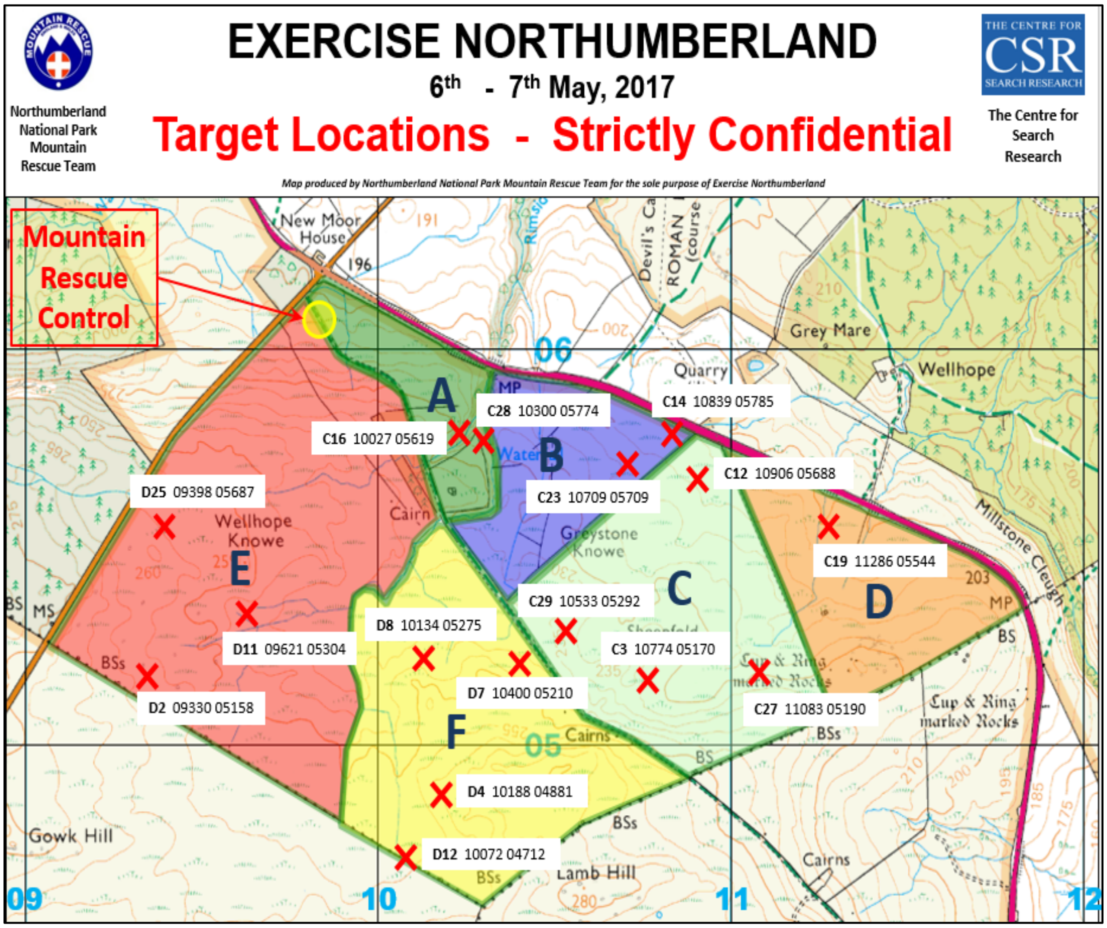
Search Asset	No. of People	Route Searched	Targets along Route	Confirmed Targets Located	Time on Task (mins)
Cessna 210 (High Wing)	4	1.24km of track	20 (10 each side of track)	6	2
Vans RV12 (Low Wing)	No data – unable to attend due to met. conditions				
Robinson R22 (Helicopter)	2	1.24km of track	20 (10 each side of track)	20	2
Autogyro	No data – unable to attend due to met. conditions				
Flex Wing	No data – unable to attend due to met. conditions				
DATAhawk Drone (Fixed Wing)	2	1.24km of track	20 (10 each side of track)	20	10[4]
DJI Inspire Drone (Rotary Wing)	2	1.24km of track	20 (10 each side of track)	16	9
DJI Inspire Drone (Rotary Wing)	No data – did not attend				
Ground Search Team 1	2	1.24km of track	20 (10 each side of track)	19 (9 left/10 right of track)	31
Ground Search Team 2	2	1.24km of track	20 (10 each side of track)	19 (9 left/10 right of track)	31
Ground Search Team 3	3	1.24km of track	20 (10 each side of track)	19 (10 left/9 right of track)	24

Table 4. Initial response phase results summary

[4] 35 mins to interpret imagery and confirm targets

Subsequent Search Phases: Sector Searching

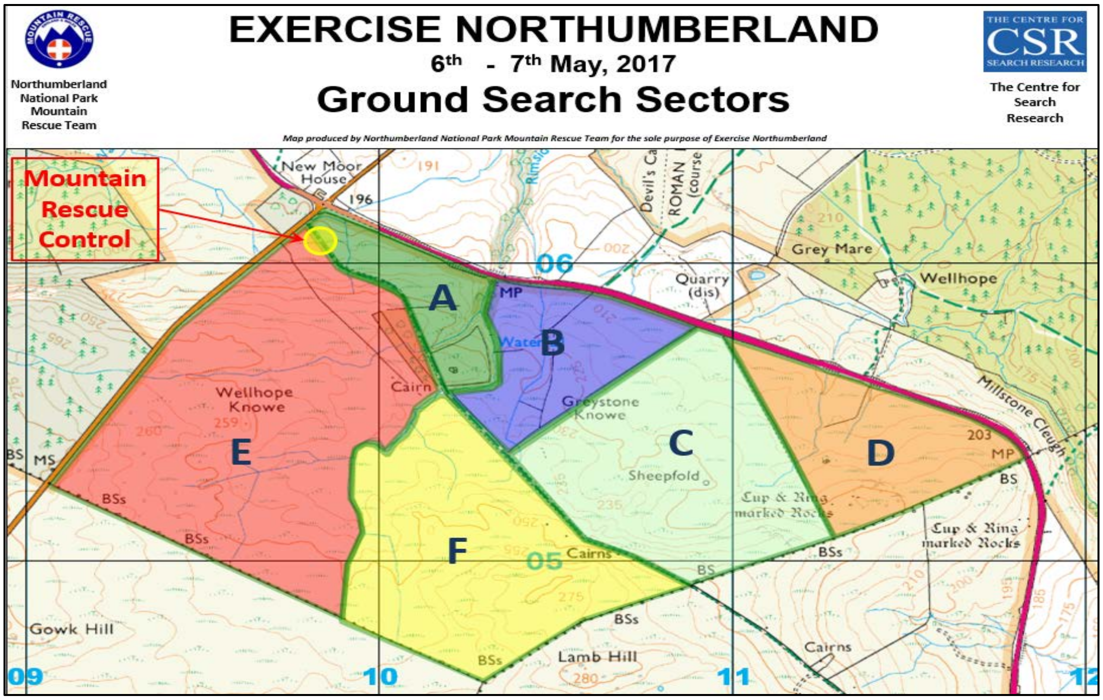
Target locations for the area searching are shown in Map 1 below.



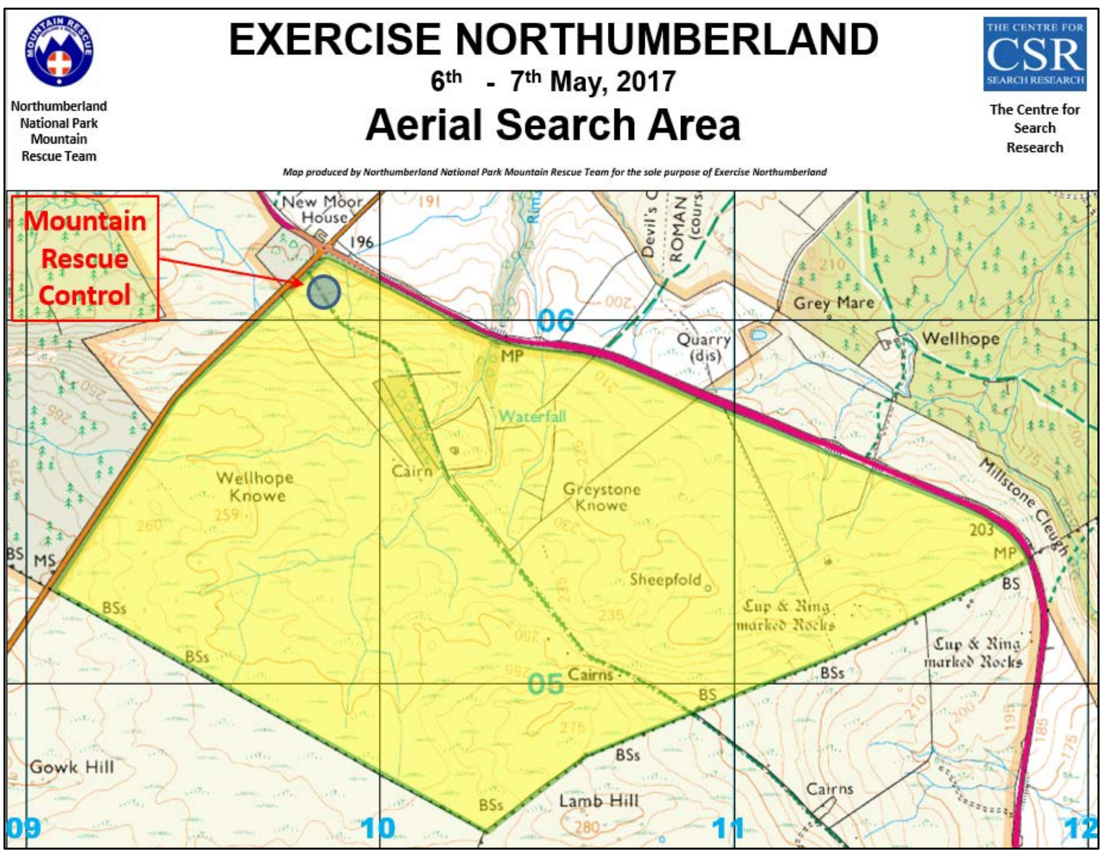
Map 1. Target locations for the area searching

For the purpose of the ground search the area was divided into six sectors labelled A-F. Fully trained ground searchers from NNPMRT were tasked to search the sectors A-D. A fully trained and qualified search dog and handler was tasked to search sector Echo, and sector Foxtrot was assigned to each of the drones in turn to search.

Ground search teams and drone pilots were provided with an outline map with the sectors identified (Map 2). The aircraft pilots requested an outline map identifying the whole area but without the sectors marked (Map 3).



Map 2. Outline map provided to ground search teams and drone pilots



Map 3. Outline map without sectors provided to aircraft pilots

Results: Sector Searching

Air Assets

Cessna 210

Crew:[5]	Pilot x 1, spotters x 3
Start Time:[6]	12:39
End Time:[7]	13:00
Time on Task:[8]	21 minutes
No. of targets reported:[9]	9
No. of targets marked on map:[10]	8
No. correlating to actual targets:[11]	6
No. of targets positively identified:[12]	0

Crew Report:[13] Cloud base marginal in some directions so unable to complete full search pattern. Left area early due to adverse weather conditions. Unsearched areas identified on map. Unable to fly a search pattern, height 500-800 feet AGL. Features from the air difficult to translate to map. Featureless ground was challenging. Speed over area (10-15s E-W) increased difficulty. Three spotters were useful.

Comments: The search was aborted after 21 minutes during which the C210 noted 8 targets plus two possible but only marked 6 on the map (of these 5 correlated with actual target locations). The final results reported above were submitted following a post flight review of camera and GPS track information.

[5] Number of people on board the aircraft and their respective roles.
[6] Time in BST (British Summer Time) at which the asset commenced its search.
[7] Time in BST (British Summer Time) at which the asset completed its search.
[8] Time taken to complete the search.
[9] Number of targets recorded as found on the 'Flight Details' form completed by each crewed air asset.
[10] Number of targets marked by the air crew on the laminated map of the search area they were supplied with.
[11] Number of targets recorded by the air crew which corresponded to the actual location of targets on the ground.
[12] Number of targets identified by recording their unique identifying letter.
[13] A written report provided by the crew on the 'Flight Details' form.

Vans RV12

Crew:	Pilot x 1, spotters x 1
Start Time:	15:14
End Time:	15:36
Time on Task:	22 minutes
No. of targets claimed:	17 (crew acknowledged possibility of duplication)
No. of targets marked on map:	17
No. correlating to actual targets:	11
No. of targets positively identified:	0

Crew Report: Targets were relatively easy to spot; the challenge was accurately recording their location. There is a significant chance some targets were duplicated due to a lack of ground features to translate to the map and the high number of targets to record in the time available. A creeping line ahead search was adopted then modified to an expanding box search[14] with further attention given to specific hollows and gullies etc.

Comments: This was a second attempt to search the area following an earlier flight at 13:21, which was aborted after 3 minutes at 13:24 due to safety concerns with the prevailing meteorological conditions.

Robinson R22

Crew:	Pilot x 1, spotter x 1
Start Time:	13:57
End Time:	14:32
Time on Task:	35 minutes
No. of targets reported:	17
No. of targets marked on map:	17
No. correlating to actual targets:	16
No. of targets positively identified:	12

Crew Report: Search conducted from a height of 500 feet AGL utilising a creeping line ahead search pattern. Navigation system used to plot targets found was the View Ranger app on a mobile phone. It was felt to be a heavy workload for a single spotter.

[14] See Note 1.

Comments: The search was conducted with the doors removed to maximise visibility. Each target was photographed and position plotted on a map. All targets were located although four were not positively identified with their unique identifying letter.

Autogyro

Unable to attend due to a combination of prevailing meteorological conditions and mechanical problems.

Flex Wing

Unable to attend due to the prevailing meteorological conditions.

Drones

DATAhawk (fixed wing) - QuestUAV

Crew:	2
Duration of search:	13 minutes
Time to process and analyse images:	65 minutes
No. of targets in search sector:	4
No. of targets reported:	5

Comments: The DATAhawk does not have a real-time downlink of imagery and flies a pre-planned search pattern, capturing a series of still images onto a memory card. On landing, these images are retrieved and software is used to stitch them together into a geo-referenced orthomosaic. As seen in the data reported above, there were time implications in locating the first target. The image, once produced was of fairly low resolution and initially difficult to interpret hence the time to locate the first target (flight time+imageprocess+interpretation). Through close visual inspection the targets were able to be identified (image 5). A higher resolution image can be produced but further time is required to enable this to be processed. Due to a software problem, which resulted in the camera not operating on the first flight of 20 minutes duration, a second flight was required to capture the aerial imagery. The timings above reflect the times from the second, successful, flight.

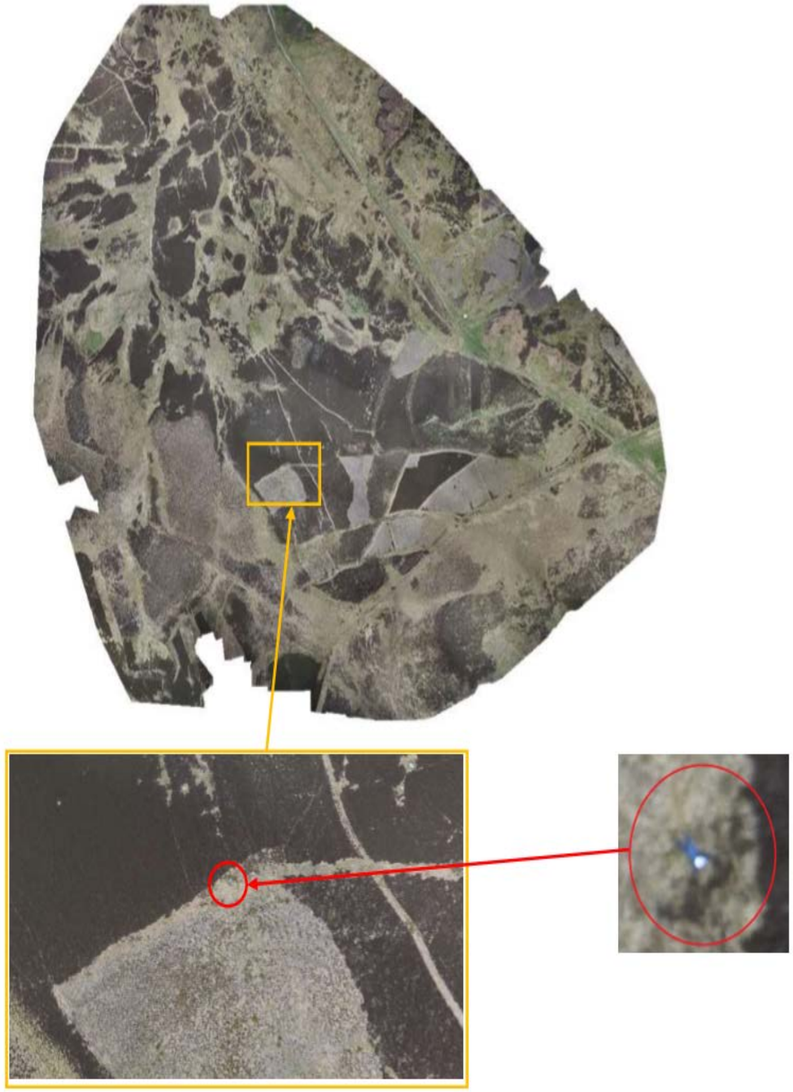


Image 5. This sequence of images shows the orthomosaic of sector Foxtrot and the degree of zoom required for effective searching. As can be seen, the operator or searcher needs to zoom in considerably in order to detect the targets. There was then some difficulty during the exercise in accurately translating the location of the targets to an Ordnance Survey map due to a lack of any grid overlay on the orthomosaic.

DJI Inspire 1 Pro (rotary wing) - Clear Vision Security Ltd.

Crew:	Pilot x 1, spotter x 1
Duration of search:	47 minutes
Time to process images:	Real time live downlink of aerial imagery
No. of targets in search sector:	4
No. of targets reported:	3

Comments: This search was conducted in real time via a live video downlink to a 21” HD monitor located within a vehicle. A spotter was supplied by the NNPMRT to search the images and, whilst they had many years’ experience as a member of the MRT, they were new to the field of aerial image interpretation. While the strong and gusty wind characteristics did present some difficulties in flying in a straight line, the flight track indicates a reasonable parallel track search pattern flying at an altitude of 50m/150ft AGL (see Note 1). The spotter was able to direct the pilot to any features of interest. This enabled the drone to hover down to 20m AGL to zoom in on the area of interest. The search was cut short, without the full sector being covered, due to time constraints beyond the control of the pilot.

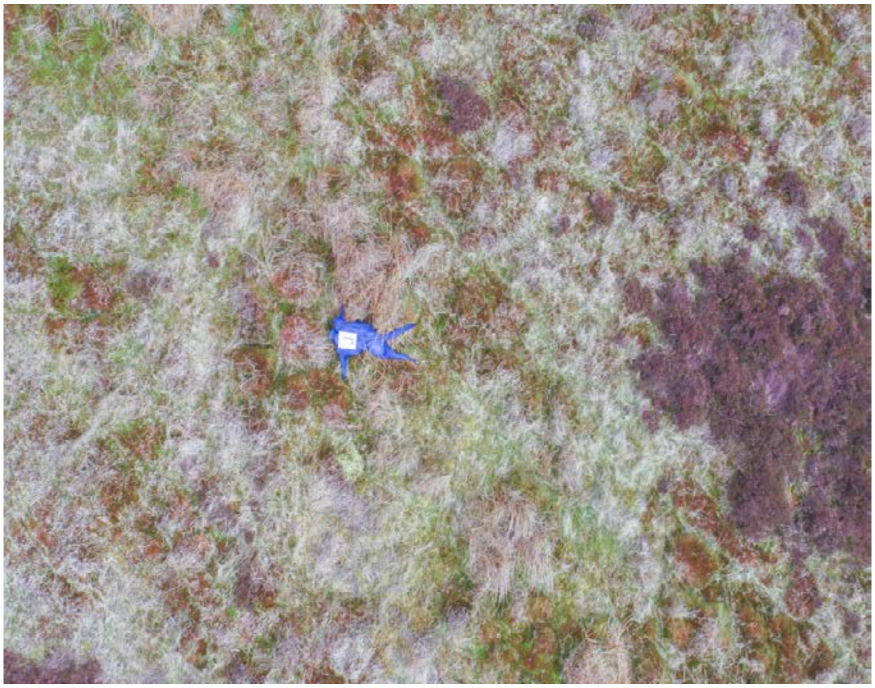


Image 6. An example of the level of visibility of the targets as observed by the DJI Inspire drone from Clear Vision Security Ltd. The letter J was clearly identifiable by the spotter during the exercise.

<u>DJI Inspire 1 Pro (rotary wing) - Northumberland National Park</u>

Crew:	Pilot x 1, spotter x 1
Duration of search:	13 minutes
Time to process images:	Real time live downlink of aerial imagery
No. of targets in search sector:	4
No. of targets reported:	2

<u>Comments</u>: This search was conducted in real time via a live video downlink to an iPad. The spotter who was used to analysing imagery from the Clear Vision Security drone was again supplied by the NNPMRT to search the images. He reported that it was considerably easier to operate using the iPad than it had been with the larger monitor used previously. The spotter also felt it a significant advantage that the National Park system gave him control of the camera so he could investigate anything of interest with ease and gave less potential for confusion in communications between pilot and spotter. A visual briefing was staged prior to the search with a person dressed in the same

colour as the targets lying down in the field. The drone then climbed to normal operating height above this person and focused on them for the spotter to see. The spotter reported this as being extremely helpful as he became more tuned in and had a good mental picture of what they were searching for. It is noteworthy that this was a considerably faster search than the previous attempt.

Ground Assets

Northumberland National Park Mountain Rescue Team

Mountain rescue control received a briefing with regard to the exercise at approximately 08:30. Eleven trained and experienced personnel were available for searching and they were divided into three separate search groups; two groups of 3 personnel and one group of 5. Each group had a group leader appointed and they were each allocated a sector to search, and briefed with information on target size and colour. Each group leader then cascaded this briefing to the members of their respective groups. Groups were deployed and searched areas Alpha, Bravo and Charlie. Group 3 went on to also search sector Delta upon their completion of sector Charlie. Each group carried a Spot Tracker which enabled their precise tracks to be uploaded and overlaid on a map at MR control. Group members used the principles of Critical Separation and Purposeful Wandering to ensure good coverage and any possible areas of concealment investigated. Groups were thoroughly debriefed upon return to control to establish how well each sector had been searched and how likely it was to require a re-search due to areas that were difficult to cover. The results for each search group are shown in table 5 below.

Team No.	1	2	3	4
No. of personnel	3	3	5	5
Search sector	Alpha	Bravo	Charlie	Delta
No. of targets in sector	2	2	4	1
No of targets reported	2	2	4	1
Time taken	60 mins	115 mins	105 mins	60 mins

Table 5. MRT Search Group Results

Search Dog

The search dog handler received the same briefing as other search personnel and was tasked to search sector Echo, which contained three live targets. The results of the search by the search dog can be seen in table 6 below.

No. of personnel	1
Search sector	Echo
No. of targets in sector	3
No of targets reported	3
Time taken	90 mins

Table 6. Search Dog Results

Sector Searching: Results Summary

Search Asset	No. of People	Sector Searched	Targets in Sector	Confirmed Targets Located	Time on Task (mins)
Cessna 210 (High Wing)	4	All Sectors	16	6	21
Vans RV12 (Low Wing)	2	All Sectors	16	11	22
Robinson R22 (Helicopter)	2	All Sectors	16	16	35
Autogyro	No data – unable to attend due to met. conditions				
Flex Wing	No data – unable to attend due to met. conditions				
DATAhawk Drone (Fixed Wing)	2	Foxtrot	4	4	13
DJI Inspire Drone (Rotary Wing) – Clear Vision Security Ltd.	2	Foxtrot	4	3	47
DJI Inspire Drone (Rotary Wing) – Northumberland National Park	2	Foxtrot	4	2	13
Ground Search Team 1	3	Alfa	2	2	60
Ground Search Team 2	3	Beta	2	2	115
Ground Search Team 3	5	Charlie	4	4	105
Ground Search Team 3	5	Delta	1	2	60
Search Dog	1	Echo	3	3	90

Table 7. Sector Searching: Results Summary

Findings and Analysis

The following is based on the results reported in the previous section with comments provided by participants.

Limitations

It should be remembered, particularly later in this section when overall comments and conclusions are presented, that this field trial has provided a very limited amount of data. It dealt with one type of terrain at one time of year and one type of target. In one part of the experiment there was only one fixed wing aircraft and in the other only two; one helicopter was involved and so on. Under current CAA regulations, drones are restricted to line of sight operation between pilot and drone. In practice, this equates to a 500m unaided visual line and a maximum altitude of 400ft. Moreover, Exercise Northumberland took place during daylight hours and evaluated asset performance accordingly. Statistics from Mountain Rescue England and Wales (MREW) show that >60% of callouts for missing persons searches occur between the hours of 16:00hrs and 22:00hrs, which at UK latitudes means darkness for a significant proportion of the year.

While these limitations do not prevent us from drawing conclusions, it does mean that we are careful about the degree of confidence and certainty that we attach to them.

Findings

From a search management point of view it makes sense to think about resources in terms of when they are best suited to be used in a search. This was described in the research rationale, but is worth saying again:

1. Initial Response Phase: the Initial Response phase of an incident is roughly the first twelve hours and describes the time when expert resources might be in short supply. Approximately 90% of missing persons are found during this phase. Based on data from the UK Missing Person Behaviour statistics and related research,[15] the focus of the Initial Response phase is on searching travel aids such as roads, paths, tracks and obvious discernible routes heading out from the Last Known Point, and buildings. Searching buildings is not usually undertaken by SAR volunteers, so in analysing these results, this section will relate only to the searching

[15] The Centre for Search Research, 2014. 'Search Tactics for the Immediate Response'; 2011, 'UK Missing Person Behaviour Study'. Both available from www.searchresearch.org.uk

of the track. In Initial Response searching, the emphasis is generally on speed and rapid results rather than being slow and thorough.

2. Subsequent Phases: this is when searching of areas takes place. Here, the need for speed tends not to be as important as in the Initial Response phase. The search progresses more slowly and the emphasis is on thoroughness.

The following analysis therefore is divided between Initial Response Searching and Area Searching for each type of resource, and summarises the results given previously.

Initial Response Searching:

Searching a route (this was not part of the 1987 O'Donnell investigation).

Search Theory makes use of the notion of the 'instantaneous glimpse' from the air of a target at ground level, and from that develops a relationship between coverage and Probability of Detection (PoD). All participating aircrew were therefore told not to try to read the identifying letter on each target, merely to count the number they saw as they performed two passes along the route (one on each side).

Fixed wing aircraft

Only one aircraft took part (Cessna 210 high wing), locating 6 out of 20 targets along the route in 2 minutes.

Helicopter

Out of the 20 targets, the R22 located a total of 20 in 2 minutes.

The influence of meteorological conditions impacted the performance of fixed-wing aircraft. As the C120 commenced its run into the search area, it observed deteriorating weather coming in from the North. In response, aircraft speed was increased and a quick search was completed before the aircraft headed south. The same conditions had no notable impact on the performance of the R22.

Drone with no real time downlink (QuestUAV)

This covered the route in 10 minutes' flying time, then took 35 minutes to process and analyse the images collected. All 20 targets were located. After the conclusions of the exercise, an alternative image processing technique was tried in which a composite of the entire route was produced. This took 20 minutes and made it easier to analyse the images but it is not clear what effect this would have on the overall time taken from the start of flying to locating targets in the composite image.

Drone with real time downlink (Clear Vision Security)

Only one of the two drones was available for this activity. It located 16 out of 20 targets in 9 minutes, although the rate of detection might have been adversely affected by the drone initially flying too low.

Ground Search Teams

All three teams found 19 out of 20 targets. The two two-member teams took around 30% longer to cover the route in comparison to the three-member team.

Area Searching

Once all the likely routes leading from the point at which the missing person was last known or suspected to be have been searched, the areas adjacent to these routes are searched. This usually represents a considerable task that is beyond the scope of the available resources, so the areas are prioritised to allow those most likely to contain the missing person to be searched first while the least likely are left until later.

Fixed wing aircraft

Two fixed wing aircraft took part in this activity. Both were adversely affected by weather conditions to the extent that one (high wing Cessna) abandoned the search after an estimated 62% of the area had been covered. This took 21 minutes and in this time 6 out of an estimated 12 targets in the area searched were located. The other aircraft (low wing RV12) covered the entire area in 22 minutes and located 11 out of 16 targets. These two results give rates of search of 15 min/km^2 and 10 min/km^2 respectively. O'Donnell's (1987) study gives a value of about 20 minutes to search 1 square mile, which is equivalent to about 8 min/km^2. We would suggest that the increase in time taken in the current study was in part due to the size of the search area (the 1987 search area was roughly 50% larger than the current search area), which meant that a larger proportion of the time was spent in turning outside the search area.

Helicopter

This found all 16 targets in the search area in 35 minutes, giving a value of 16 min/km^2 search time, comparing with about 5 min/km^2 in the 1987 study.

These results make for an interesting comparison between the rates of searching:

1987 study:	Fixed Wing 8 min km^2	**2017 study:**	Fixed Wing 12 min/km^2 average
	Helicopter 5 min/km^2		Helicopter 16 min/km^2

In the 1987 study, the helicopter took approximately one third less time than the fixed wing while in the 2017 study, it took one third longer. No explanation is offered for this time difference although the weather might have played a part in 2017.

Drone with no real time downlink (QuestUAV)

This located all 4 of the targets in the search area in a total of 78 minutes (13 minutes flying time plus 65 minutes processing and analysis time). In terms of flying time only, this represents a rate of 27 min/km^2. It is not known how the processing and analysis time varies with the size of the search area. There were no equivalent resources in the 1987 study.

Drones with real time downlink (Clear Vision Security and Northumberland National Park)

The first of these, Clear Vision Security, had its search cut short. It is estimated that it had covered 80% of the search area in 47 minutes and located all 3 targets in the area searched. This gives a rate of 124 min/km^2. The second drone, NNP, found 2 out of 4 targets in 13 minutes, giving a search rate of 27 min/km^2. There were no equivalent resources in the 1987 study.

Ground Search Teams

These consisted of volunteers from NNPMRT, who are fully trained in current search techniques, rather than police officers as in the 1987 study. They were deployed in three groups, all of whom located all the targets in the areas they searched. Overall, their rate of progress was equivalent to 23 man hours/km^2, compared with a rate of 175 man hours/km^2 in the 1987 study. The difference is most likely due to the fact that: whereas the twelve police officers in the 1987 study operated together in a line search over the whole area, the ground search teams in the current study were deployed in small groups in small search areas, which is a more efficient way of tackling the problem. In both trials, the ground searchers found all of the targets in the areas searched.

It should be noted that the observed rate of searching of 23 man hours/km^2 applies only to this type of terrain; for example, the rate for searching in open agricultural land would be quicker than this and for searching through dense vegetation it would be slower. In addition, it relates only to one type of target; the colour and size of the target would affect the rate of searching.

Air scenting search dog

The dog found all three targets in its area in 90 minutes, giving a rate of searching of 125 min/km^2.

Analysis

We can use a comparison of rate of searching and success rate to provide guidelines as to the suitability of each of the resources considered for each phase of the search (table 8).

Resource	Minutes taken	Min/km	Success rate %	Footnote [16]
Fixed Wing Aircraft	2	0.8	30	A
Helicopter	2	0.8	95	A
Drone (no real-time downlink)	45	8	100	B
Drone (real-time downlink)	9	7	80	C
Ground Search Team	29	23	95	D

Table 8. Initial Response searching of a route; rate of searching and success rate for five search resources

16

A. Each aircraft flew the route twice (about 1.25 km each way); their speed is based on this. All other resources covered the route once only.
B. The speed is based on the reported 10 minutes flying time; additional time for processing and analysis would be incurred regardless of the length of the route and the corresponding flying time.
C. The drone pilot and spotter followed the drone in a Land Rover.
D. The speed is the average speed for the three groups.

The analysis of the results is made easier by the use of a chart of Percentage Success Rate vs Rate of Searching (chart 1).

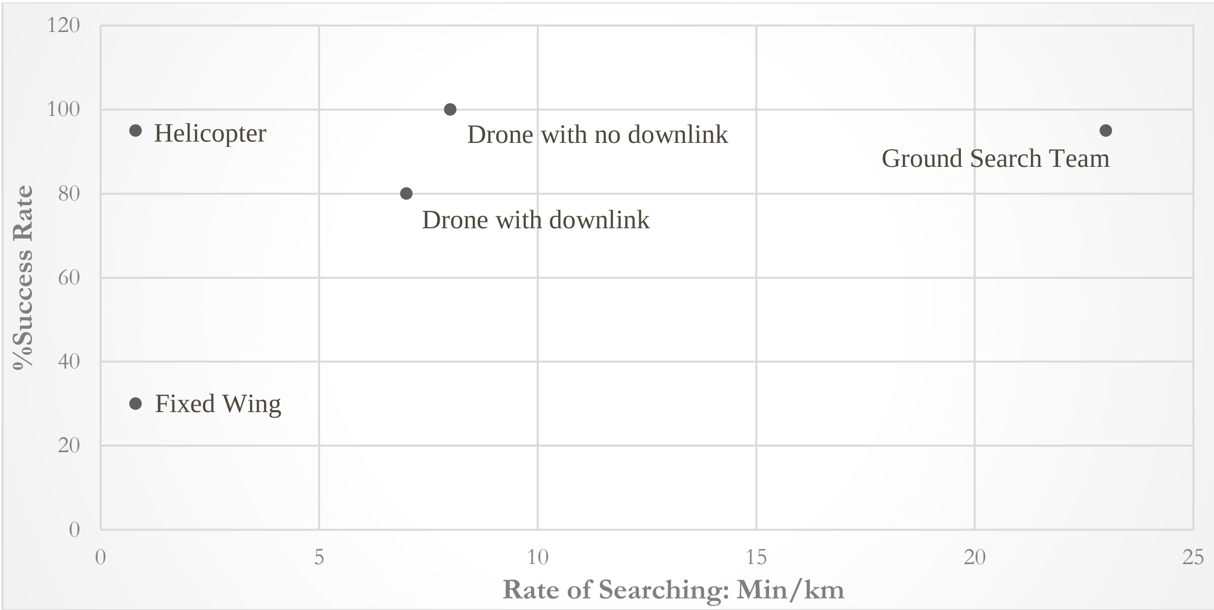


Chart 1. Percentage Success Rate vs. Rate of Searching in min/km, Initial Response

The most suitable resources for Initial Response searching of a route are quick and will yield a fairly high success rate. The chart shows that the fixed wing aircraft, while quick, did not yield a high success rate. Best overall was the helicopter, with the two drones performing well, although the time for image processing and analysing for the QuestUAV drone with no real time link seems to put it at a significant disadvantage. Ground search teams yield a high success rate but are slower.

A similar analysis can be done for the resources involved in the area searching component of the field trial (table 9).

Resource	Minutes/km²	Success rate %	Footnote [17]
Fixed wing (high wing)	15	50	
Fixed wing (low wing)	11	69	
Helicopter	16	100	
Drone (no real-time downlink)	92	100	A
Drone (real time downlink)	124	100	B
Drone (real time downlink)	27	50	C
Ground Search Team	23 man hours	100	D
Search Dog	120	100	

Table 9. Searching an area, rate of searching in minutes / km2 and % success rate for the six types of search resource involved

As before, these results can be shown in chart form (chart 2).

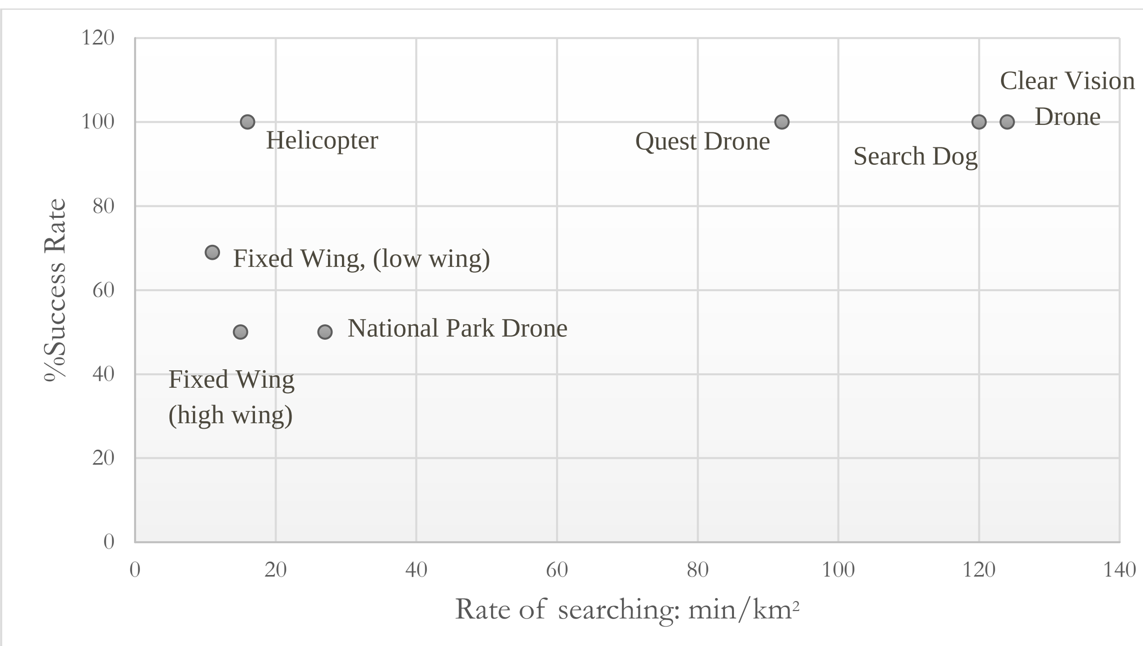


Chart 2. Percentage Success Rate vs Rate of Searching in minutes/km2, searching an area

17

A. The time taken for the drone with no real time down link is based on 27 minutes flying time plus 65 minutes to process and analyse the images.
B. Clear Vision Security Ltd. drone.
C. Northumberland National Park drone.
D. Time is calculated from the time taken for the three search groups to search four areas; based on this, the time for a five-person search group to search 1 km² of moorland is 4.6 hours.

The helicopter appeared to perform well, giving a success rate of 100% while searching at a rate of 16 min/km^2. The other two drones, the search dog and the ground search teams (not shown) all performed well in terms of % success. In comparison, the two fixed wing aircraft and the National Park drone did not perform as well.

Summary

Unlike the 1987 study, we did not include any measures of cost effectiveness. In O'Donnell's original study, all resources were police-funded and therefore costs were relatively easy to uncover. The resources taking part in the 2017 study were volunteers with no costs that could easily be associated with an overall authority.

The study investigated searching done by five types of resource, namely fixed wing aircraft, helicopter, drones, ground search teams and a search dog. Four of these have been regularly used in missing person searches. One objective of the study was to examine how drones performed as a search asset.

In doing so, it should be remembered that while these results are useful and instructive guidelines, they do not provide definitive measures of performance for the resources involved. They provide a useful but small data set; they relate to one type of terrain only with vegetation levels and visibility consistent with one time of year.

Missing person incidents take place at all times of the year, at all times of day and in all weathers. Over the duration of the exercise, the ground search resources, the drones (albeit working close to their operational limits) and the helicopter all performed as requested in conditions that affected the attendance and performance of the fixed wing aircraft. This needs to be taken into account in considering suitability for an emergency response situation.

The targets were blue with a conspicuous label attached. Although blue is a popular colour for hikers, it probably isn't for despondents and persons with dementia, who also don't usually carry conspicuous labels. We need to be careful about generalising into real life situations from these results.

This one weekend of field trials indicate the following:

- Searching a route in the Initial Response: the helicopter and the drone with the real time downlink came out best. While the fixed wing drone had a high % success rate it took 35 minutes to interpret the imagery and confirm the targets. The fixed wing aircraft was quick but gave a poor % success rate (again, prevailing weather conditions were a factor) whereas the ground search teams gave a good % success rate but were slower.

- Searching an area in Subsequent Phases: speed is not as important after the Initial Response, but nevertheless the helicopter had a high % success in a short time. The Quest and Clear Vision drones and the search dog had a high success rate in a moderate time. The ground search teams did likewise but took longer. The fixed (low) wing aircraft had a good success rate in a quick time while both the fixed (high) wing aircraft and NNP drone had only moderate success rates.

- This was a limited set of trials undertaken over two days in one type of terrain. While we are able to draw conclusions from the work we have done, it is perhaps inappropriate to take these as anything other than pointers towards further research. This relates in particular to the drones. Our initial research has addressed the objectives we set and in doing so, further questions have been raised that point to the need for further and more extensive research.

Conclusions and Recommendations

Conclusions

We set out to add to the existing knowledge that came from the 1987 O'Donnell experiment and the follow-up CAST research of 2008. In doing so, we eschewed the emphasis on asset cost-effectiveness employed by O'Donnell and instead focused on evaluating search-effectiveness during the Initial Response Phase (speed of search) and Subsequent Phases (thoroughness of search). We assessed search assets for their roles in both phases and included drones in the list of resources studied.

Exercise Northumberland took place during daylight hours and evaluated asset performance accordingly. Statistics from Mountain Rescue England and Wales (MREW) show that >60% of callouts for missing persons searches occur between the hours of 16:00hrs and 22:00hrs, which at UK latitudes means darkness for a significant proportion of the year.

From this work we draw the following conclusions:

1. Traditional search resources (teams of ground searchers and air scenting search dogs) generally performed with a high find rate but do so at a comparatively slower rate to that of air assets.
2. The helicopter and drones showed that they could provide an equally high success rate to that of ground teams but at a greater speed.
3. In utilising current technologies, producing drone-generated high resolution geo-referenced orthomosaic images for large areas is a time consuming process. However, it was found that that it took only 20 minutes to produce a drone-generated orthomosaic image of the well-defined 1.2km track used for the Initial Response Phase.
4. Interpreting drone-generated low resolution images can be a challenging and time consuming process.
5. The time taken to produce and interpret drone-generated images needs to be factored when planning to commit a drone resource to Initial and Subsequent phases of a search.
6. In facilitating closer inter-agency collaboration a member of a ground team can, with rudimentary training, serve as a drone co-pilot/spotter during a search incident.
7. In preparation for drone deployment, staging a visual briefing involving a drone climbing to normal operating height to focus on a person dressed in the same colour as the targets lying down in the field can help a spotter develop a good mental picture of what they are searching for.

8. Control of the drone camera by the spotter offered flexibility to investigate potential target sightings and reduced potential communication issues between pilot and spotter.
9. Meteorological conditions proved to be significant (no flight) and influential (aborted flight) in limiting the availability and performance of fixed-wing aircraft.
10. Size and topography of the search area had an influential impact on the performance of the fixed-wing aircraft.
11. Ground search teams, search dog, helicopter and drones (performing at their operational limits) were able to perform in meteorological conditions that had an adverse effect on the availability and performance of the fixed wing aircraft.
12. Ground search teams, search dog, helicopter and drones (taking into account their operational limits) should be considered as suitable resources for all phases of a search incident during daylight hours; in addition, it should be noted that ground search teams and search dogs regularly search at night.
13. A marked improvement in the rate at which search sectors were covered by the ground search teams compared with the original O'Donnell experiment reflects contemporary approaches to area searching. These include: breaking the area down into small sectors and using small groups of trained searchers utilising search techniques such as Critical Separation and Purposeful Wandering, and search management technologies such as Spot Tracker and MX Sarman.
14. The two-day field trial provided a small dataset so any extrapolation beyond our initial conclusions should be treated with caution.

Recommendations

1. Our findings provide empirical support for drones as an effective search resource in a multi-search setting. We recommend that further field trials are undertaken to evaluate the utility of fixed-wing and rotary-wing drones in a range of topographies and search scenarios.
2. In providing insight into both the capabilities and limitations of drones as search assets, further work is needed to utilise this knowledge in optimising operational integration during a multi-agency search setting.
3. The increasing sophistication and use of new technologies in search situations requires the training of search team members in new skills such as image interpretation.
4. Integrating the deployment of new technologies such as drones into search management thinking and planning needs further investigation.

5. Traditional search resources (teams of ground searchers and air scenting search dogs) as well as helicopters and drones should be considered as suitable resources for all phases of a search incident.
6. Further work is needed to assess the search performance of fixed wing aircraft and to determine callout scenarios in which CAP resources can be deployed to their optimum effectiveness.
7. Communication between air and ground search teams engaged in a multi-agency search setting requires:
    a. designing,
    b. testing and developing.
8. Investigate the use of drones for searching at night.

Priority research on emerging drone technology

The use of drones is becoming more widespread and influential in the thinking and operation of emergency services. A principal aim of our work is to provide research-informed guidelines for the use of this rapidly developing technology. There is therefore an urgent need to develop our understanding of its operational use in emergency situations such as missing person searches. As such, we consider that the following research needs to be prioritised:

1. Establishing the parameters involved and relationships between time taken to accomplish a search task (both searching a route and an area) and the size of the task. These parameters include the time taken to produce and analyse drone-generated orthomosaic images.
2. Searching in different types of terrain, for example urban settings, mountain and forest areas or along a river in order to establish best practice in the use of drones during the management of inter-agency search and rescue operations.
3. Investigating the use of several drones simultaneously during a search and rescue incident.
4. The quick detection of missing persons is a major issue for search teams. Work is needed to examine and assess the use of drones fitted with assistive technologies such as night vision, thermal imagining and FLIR during a night search, searching in low visibility and for targets with low visibility.
5. One reason for the low levels of interoperability among professional and voluntary ground and air search teams lies in there being insufficient harmonisation and standardisation of training, search management and use of new technologies. There is an urgent need to evaluate inter-agency collaboration in a range of search and rescue scenarios.
6. How do different search patterns impact and aid the performance of search assets such as drones? See Note 1.
7. To further extend the application of Search Theory, in particular investigating the influence of height and terrain on sweep width and how this can be easily calculated for drone use in search situations. Early work done by TCSR provides some insight into the kind of approach that might be used (See 'Report on a Field Trial conducted from RAF Boulmer, Northumberland, 28.4.2000', available at www.isaralliance.com/general-library/).

Notes

1. **Search Patterns**

In preparation for and during Exercise Northumberland, it was decided not to direct search teams toward the use of a particular search pattern, such as Creeping Line Ahead, Expanding Box, etc. (see Appendix). Instead, it was left to team leaders and drone pilots to brief or conduct the search approach of their assets as they thought appropriate. Pre-exercise, it was felt that terrain and ambient weather conditions would dictate.

There was a mixed response as shown in the search tracks illustrated below. This is an area in need of further research, i.e. to investigate what effect, if any, a particular search pattern can have on search effectiveness.

Image 7. Search track of DataHawk in Sector Foxtrot

Image 8. Search track of Cessna 210

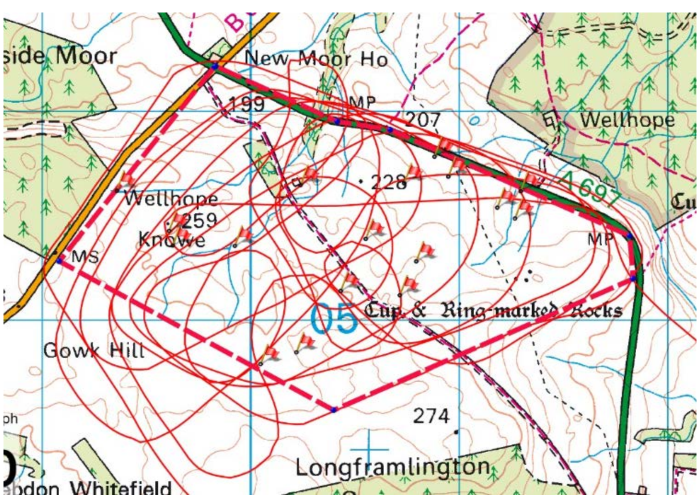


Image 9. Search track of Vans RV12

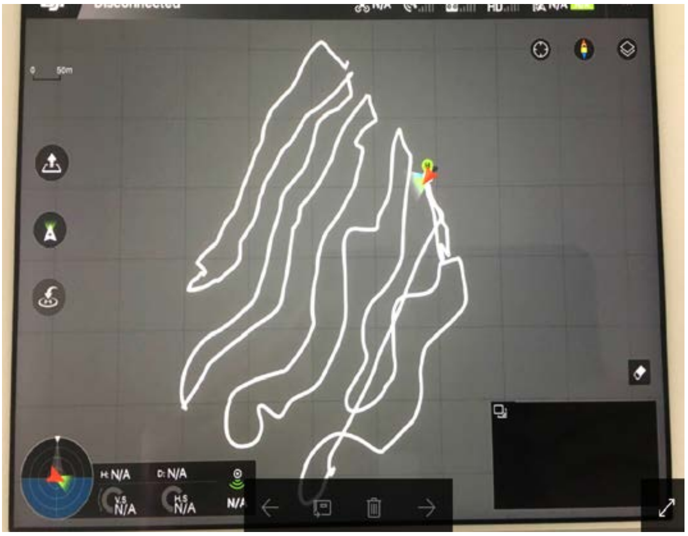


Image 10. Search track of the DJI Inspire drone in Sector Foxtrot

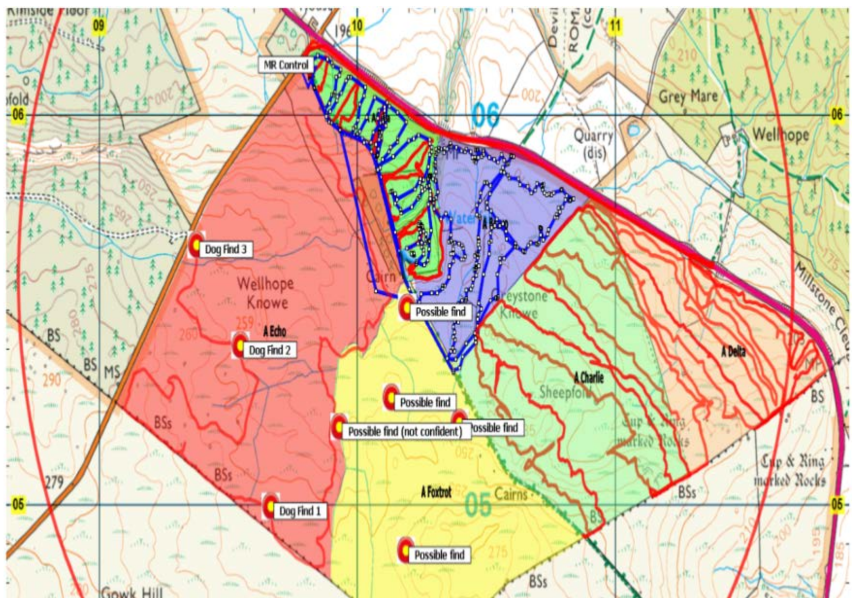
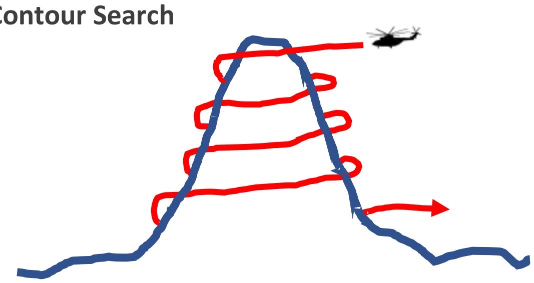


Image 11. Search track of the ground searchers in Sectors Alpha, Bravo and Charlie, and the search dog in Sector Echo

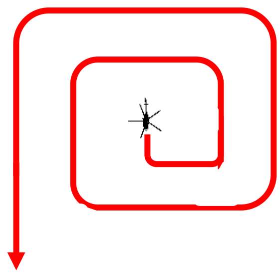
Appendix

Aircraft Search Patterns[18]

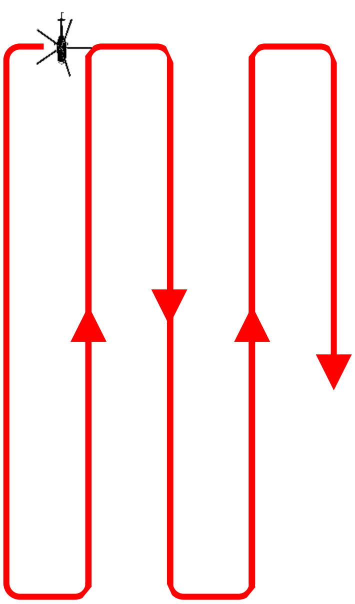
Contour Search



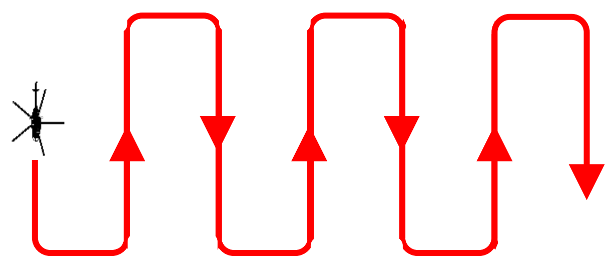
Expanding Box Search



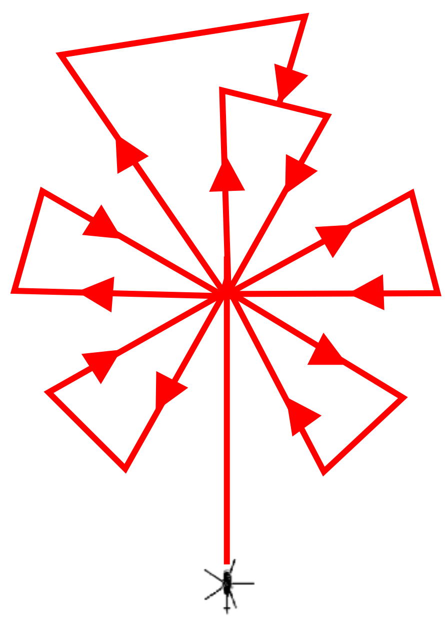
Parallel Track Search



Creeping Line Ahead Search



Sector Search



[18] Source: The International Aeronautical and Maritime Search and Rescue Manual, 2016. Vol III, 10th Edition, IMO Publishing.

Glossary

AAV	Autonomous Aerial Vehicle
AGL	Above Ground Level
BST	British Summer Time
CAA	Civil Aviation Authority
CAP	Civil Air Patrol
CAST	Centre for Applied Science and Technology
Crew	The number of persons on board the aircraft and their respective roles
Crew Comments	The written comments provided by the crew on the 'Flight Details' form
Critical Distance	An alternative term for sweep width
FLIR	Forward Looking Infra-Red
GPS	Global Positioning Satellite
HD	High Definition
MR	Mountain Rescue
MRT	Mountain Rescue Team
NNPMRT	Northumberland National Park Mountain Rescue Team
No. of targets reported	The number of targets recorded as found on the 'Flight Details' form completed by each crewed air asset
No. of targets marked on map	The number of targets marked by the air crew on the laminated map of the search area
No. correlating to actual targets	The number of targets recorded by the air crew which corresponded to the actual location of targets on the ground
No. of targets positively identified	The number of targets which were identified by recording their unique identifying letter
NV	Night Vision
OS	Ordinance Survey
Orthomosaic	a grouping of many overlapping images of a defined area which are processed to create a new, larger composite image in true scale.
PoD	Probability of Detection
SAR	Search and Rescue
Sweep Width	From Search Theory; in practical terms, the maximum distance at which a searcher can detect a target
SUA	Small Unmanned Aircraft
Time on Task	Time in BST (British Summer Time) at which the asset commenced their search.
Total Time on Task	Amount of time taken to complete a search
UAV	Unmanned Aerial Vehicle

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