Probability of Detection for the Search Manager

by Dave Perkins
The Centre for Search Research,
Ashington, Northumberland, UK

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Abstract

This paper has been written to support a presentation made by the author at the Arizona State SAR conference in April 2013. It is loosely based on the draft of a paper (which has yet to be published) on Probability of Detection (PoD) by The Centre for Search Research.

The proposal is that it is important for a Search Manager to have some way of knowing how effective their field teams are likely to be. Some alternative approaches are identified; the approach that is recommended is based on Search Theory.

The paper describes three standard search tactics that are likely to be used in any search. These are:

- searching a route
- searching an area by grid searching
- searching an area using purposeful wandering

Each of these is described in sufficient detail to enable readers to make use of the techniques, together with an explanation of how the PoD is calculated.

The paper ends with a list of topics that could be used to form of a training scheme for ground search teams, based on the three standard search tactics.

Contents

Introduction

The Search Manager should have some idea as to how effective their field teams are with their searching. Reasons for this include:

- to decide if a search task needs to be repeated because it hasn't been done sufficiently thoroughly (a search task is searching a route or an area)
- to allow for the use of Search Management software

There are three ways that field team effectiveness can be assessed:

- an informal, non-quantitative feel for how things are going (a hunch or gut feeling): we use common terminology ("that felt good" , or "not happy about how that went"); while there is nothing wrong with this, and in fact observations like this from an experienced field person may be valuable, it does not give us any kind of numerical measure that we can use
- by comparison with practice sessions or field experiments that the search unit has carried out: these are excellent ways for field teams to learn the techniques and to improve their skills, but the results are likely to vary so much that they can only give approximate guidelines rather than accurate values
- some method based on the principles of search theory: this is the preferred option, and will provide robust and reliable results; this is the method that will be used throughout this paper

The purpose of this document is:

- to identify and describe the most frequently used search tactics, and
- to provide PoD values for them

It is to be hoped that the outcome will be a better understanding of both the search tactics described as well as a more informed approach to PoD.

Types of searching: the Standard Search Tactics

In the majority of searches we tend to make use of the same search techniques. This paper concentrates on the three most frequently used. We will refer to them the **standard search tactics**. They are:

- searching a route using a search team consisting of a small number of searchers
- grid searching an area at Critical Separation
- searching an area using purposeful wandering with a nominal spacing of Critical Separation

In this paper we will show how to use search theory to calculate the PoD for each of these standard search tactics, and show how to calculate the PoD for variations on them.

This paper does not deal with searching buildings.

SEARCHING A ROUTE

In the Initial Response phase of a search for a missing person, the emphasis is likely to be on the rapid searching of routes (paths, trails or roads) that the missing person might have followed from the IPP (Initial Planning Point: either the LKP or PLS). This is best done by using small groups of searchers. The paper will deal first with searching in daylight, and then searching at night.

Using two searchers

Two searchers make an ideal team to search a route. The advantage of using just two searchers is that it allows for more teams to be sent into the field, which is useful if not many trained searchers are available. It is appreciated that some SAR units would not normally consider sending out teams of two, but two trained searchers can make a good job of searching a route. Using more than two searchers will be discussed later.

The corridor

The searchers position themselves one on either side of the route they are searching. As they move along, they will be searching a corridor that extends out on each side of the route. The searchers need to know how far this corridor extends so that when debriefed they can give a full and accurate account of what they have done.

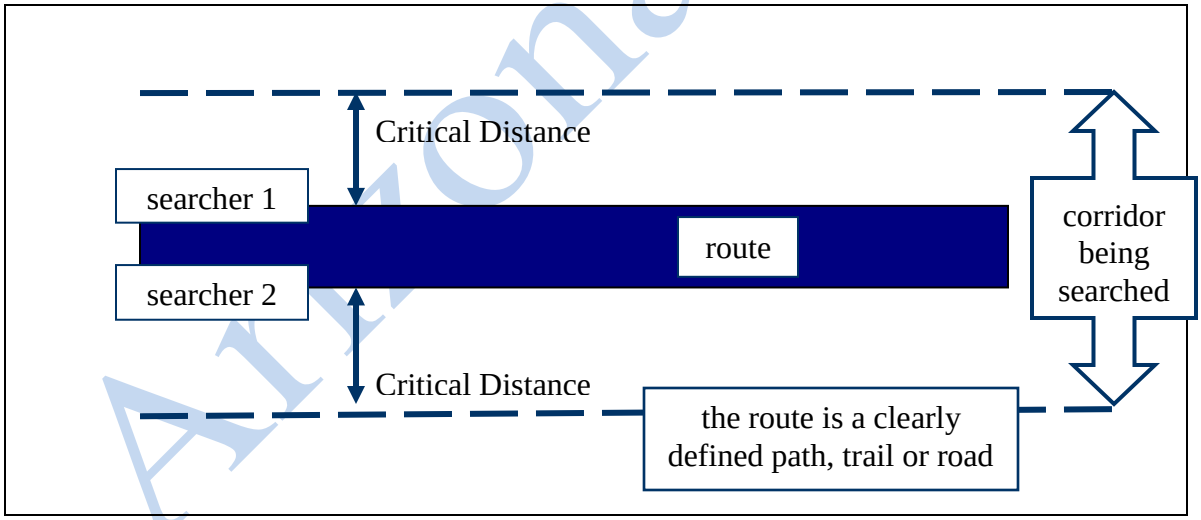


Fig. 1: two searchers searching a corridor that extends out to Critical Distance on either side of the route they are following.

Critical Distance

The corridor extends out on either side of the route to a distance called Critical Distance. Critical Distance is the furthest distance from the route at which the searcher can detect the object that they are searching for. Critical Distance depends on the terrain and the object. This is how the searchers find it.

a. As far as possible, the location chosen should be representative of the terrain and vegetation that the route passes through. If there is a significant change in either of these at some point along the route then the searchers will need to make a note of where this occurs and repeat the procedure.
b. A large pack is a suitable object to represent an adult; a daysack is a suitable object to represent a child. If the missing person was known to be wearing clothing of a particular colour, and is likely to be still wearing it, then the pack can be covered with an appropriately coloured item.
c. Each searcher places a suitable object in the vegetation on the edge of the route on their side of it.
d. Starting next to the object, the searchers walk into the vegetation at right angles to the route. They need to take care.
e. They look back towards the object at regular intervals. How often they do this will depend on the terrain and vegetation, but typically it might be after every pace in thick vegetation, or after every five paces where the vegetation is sparse and the terrain is fairly level. It can be useful to place a marker of some kind that can be easily seen at the point where they left the route; a walking pole is ideal for this. It shows them where the route is, and gives them a direction in which to look for the object.
f. They stop moving away from the route when they are unable to see the object. They slowly retrace their steps until it reappears. They are now at the furthest point from the route at which the object can be seen.
g. They each measure the distance back to the object from this point by counting paces. Each of them records how far this is. This is the Critical Distance, and they will need to report it when they are debriefed.

In practice

Each searcher is responsible for searching the corridor on their side of the route, and must give it their full attention. It works best if the two searchers keep level with each other, and move along together.

In the Initial Response phase, the searchers need to keep moving at a reasonable pace. A good target to aim for is to travel at around half normal walking speed, so that for example if under non-search conditions they could walk the route in 30 minutes then their target time for searching the corridor will be about 1 hour. This gives them an idea of the speed to move at, and gives the search controllers an indication of how long the task is likely to take.

Search Theory and searching a route

Coverage

In Search Theory, PoD is related to a factor known as coverage. Coverage is a measure of how much of the area that they have been assigned into the searchers have searched. Intuitively we would say that the more of it that they have searched the higher will be their PoD. The parameter that measures how much ground each searcher searches is called sweep width. The value of sweep width is very similar to Critical Distance[1], and for all practical purposes the two can be taken to be the same.

Coverage is calculated by the following formula:

$$\text{coverage } C = \frac{\text{number of searchers x distance travelled x sweep width}}{\text{size of the area being searched}} \qquad (1)$$

where, in our case,

the number of searchers is 2
the distance travelled is the length of the route
sweep width is equivalent to the Critical Distance
the size of the area being searched is the length of the corridor x its width, where the width is 2 x Critical Distance (ignoring the width of the route that the searchers are following)

If we substitute these values in equation (1), we get

$$\text{coverage } C = \frac{\text{2 x length of route x Critical Distance}}{\text{2 x length of route x Critical Distance}}$$

which reduces to C = 1.

Coverage and PoD

At the end of this paper, there is a graph with two PoD curves. One curve is for searching a route in the manner described above, and the other is for searching an area. Searching an area will be described later.

Searching a route and searching an area are different activities. When two searchers search a route in the way that has been described, each of them will be responsible for searching on one side only. The other searcher is not involved in that activity, and the two of them do not inter-act in their searching[2]. The PoD curve for searching an area is different because adjacent searchers are both looking into the same region[3].

We have already shown that the coverage is 1 for this activity. The PoD curve for searching a route shows that, for C=1, the PoD for the corridor is 63%.

More than two searchers

If there are more than two people involved, and the additional people are not doing any searching (maybe their role in the team is radio operator or medic), in other words there are still only two people actively searching, then the coverage is still 1 and the PoD is still 63%.

If the additional people are searching (for example, a third searcher walking down the centre of the route or two searchers each side) then equation (1) can be used to calculate coverage by inserting the appropriate value for the number of searchers, for example:

- using a third searcher who walks down the centre of the route and looks to first one side then the other: putting the number of searchers equal to 3 in equation (1) gives a value of C equal to 1.5, and the graph shows that the PoD is 73%
- using two searchers each side: the total number of searchers is now 4, and substituting in equation (1) gives a value of C equal to 2; the graph gives a PoD of 78%

Searching a route at night

Initial Response searching often takes place at night, with searchers equipped with hand-held lights. The principles are exactly the same, in that a small group of searchers is searching a narrow corridor that extends to either side of the route that they are following. There are two things to consider:

- The width of the corridor. Many searchers carry hand-held lights that give out a long, powerful beam; the temptation therefore is to try to search as far from the route as the beam extends. This should be avoided. In the Initial Response we search the routes that the missing person might have followed, and while we include within our corridor the narrow strip that they might have drifted or fallen into, this is unlikely to extend for tens of metres on either side.
- Speed. As a result of falling into the trap of trying to search a corridor that is too wide, searchers often find that they are moving too slowly. A useful way to remember the target speeds for searching a route is:

    - typical normal **walking** speed is 6 kph (**100 metres in 1 minute**)
    - target speed for **searching a route in daylight** is 3 kph (**100 metres in 2 minutes**)
    - target speed for **searching a route at night** is 2 kph (**100 metres in 3 minutes**)

These values will vary depending on the terrain and conditions underfoot. The equivalent times per 100 metres have been found to be useful for training purposes. They are intended as guidelines only, and should be taken as such. If training officers can establish times that relate to their own area then so much the better.

SEARCHING AN AREA

The traditional way of searching an area is for a team of searchers to line up at one end of the area and move forward until they reach the other end. The variables involved in this are their spacing, and whether or not they are using purposeful wandering. Searching in straight lines (i.e. without using purposeful wandering) is often referred to as Grid Searching. Searching areas is generally done only in daylight.

We will first deal with searcher spacing, then with grid searching, and finally purposeful wandering.

Searcher spacing

Grid searching is usually, but not always, done by searchers spaced at Critical Separation. If the spacing is not Critical Separation then, as we will see, it is useful to express it in terms of Critical Separation since that simplifies the calculation of coverage.

What is Critical Separation?

Two searchers are at Critical Separation spacing if an object placed between them is at the furthest distance at which it can be seen by each of them.

Finding Critical Separation

This is similar to the procedure described earlier to find Critical Distance, except that in this case there is one object for all the searchers taking part. Four is an ideal number of searchers for this, and the procedure will be described as though it was being done by four searchers. The purpose is to find the furthest distance for each searcher at which they can see the object.

a. A suitable object is placed on the ground in a location that is representative of the area to be searched; the comments made about suitable objects in the section on finding Critical Distance apply here also.
b. The four searchers gather round the object.
c. They walk away from it such that each searcher's direction of travel is perpendicular to the direction of travel of each of the searchers on either side of them (think of north, south, east and west). From now on, each of them is working independently.
d. They look back towards the object at regular intervals. How often they do this will depend on the terrain and vegetation, but typically it could be after every pace in thick vegetation, or after every five paces where the vegetation is sparse, or the terrain is fairly level.
e. They stop when they are unable to see it.
f. They retrace their steps until it reappears, and mark the point where this happens. A walking pole is suitable for this.
g. When all four searchers have found the point at which the object reappears, one of them measures the four distances back to the object from the four places marked by

the walking poles (or whatever has been used). The simplest way to do this is by counting paces.

h. They report these four distances to Search Control.

i. Search Control calculates Critical Separation as twice the average of these four distances. The field party is told what their Critical Separation is.

The searchers then space themselves with a constant spacing equal to Critical Separation, and then begin to search the area.

Search Theory and searching an area

Coverage at Critical Separation

We can use equation (1) to calculate the coverage. Since Critical Separation is twice Critical Distance, the sweep width will be equal to half Critical Separation. These are the values that we will use in equation (1):

the number of searchers is 4 (in fact the Coverage is the same regardless of the number of searchers)
the distance travelled is the length of the search area
sweep width is ½ x Critical Separation
the area being searched is the length of the search area x its width; the width of the search area is calculated as the number of searchers x Critical Separation, which allows for searching to a distance equal to half a Critical Separation outside each of the searchers on the end of the line

Substituting these values in equation (1) gives

$$\text{Coverage C} = \frac{\text{4 x length of area x ½ x Critical Separation}}{\text{length of search area x 4 x Critical Separation}}$$

which reduces to C = ½. The PoD curve for searching an area gives a PoD of 72% when C = ½.

Searching at other searcher spacings

It has been shown[4] that if the searchers are spaced at *n* x sweep width, coverage is given by:

$$\text{Coverage } C = \frac{1}{n} \qquad (2)$$

For our purposes it is more useful to express equation (2) in terms of Critical Separation, and, remembering that sweep width is ½ x Critical Separation, equation (2) becomes

$$\text{Coverage } C = \frac{1}{2m} \qquad (3)$$

where the searcher spacing is *m* x Critical Separation. For example, at Critical Separation, *m* = 1 and so C = ½, which is the value calculated a little earlier. If the searchers are at ½ x Critical Separation then m = ½, C = 1 and the PoD curve for searching an area tells us that the PoD is 87%.

Equation (3) gives a quick way of calculating the coverage for any spacing that the field team uses, provided that they also know how to find Critical Separation.

Finding the searcher spacing needed to achieve a particular PoD

Suppose a field team carries out the procedure described earlier to find Critical Separation. They tell Search Control what the four distances were that one of them had paced out, and Search Control works out that Critical Separation is 20 paces. What spacing should they be at to achieve a PoD of 90%?

From the PoD curve for searching an area we can see that to achieve a PoD of 90% we need coverage of 1.2. Substituting C = 1.2 in equation (3) gives

$$1.2 = \frac{1}{2m}$$

from which we get m = 0.42. Since Critical Separation is 20 paces, the spacing needed for a PoD of 90% is therefore 0.42 x 20 paces, which is 8½ paces.

Purposeful Wandering

In an area where there is a lot of vegetation or the features of the terrain create obstructions that might conceal a person, searchers can use a technique referred to as purposeful wandering. The following extract[5] explains what this means, and how it is done:

"Experienced searchers often use a technique called purposeful wandering. Instead of walking in a straight line and keeping at a constant spacing from the searchers on either side of them, they move around within the strip of ground that they are responsible for searching in the manner described below. This enables them to see into locations that would otherwise be hidden from their view. The way in which they perform purposeful wandering is as follows:

1. the searcher takes up a position in the centre of the strip of ground that is theirs to search
2. they walk down the centre of the strip until their view of the outer edge of the strip is blocked by an obstacle
3. they then walk across to the obstacle (this is the purposeful wandering part) and take a look behind it
4. if there is nothing there, they return to their last position in the centre of the search strip
5. they continue in a straight line down the centre of the strip"

where the 'obstacle' referred to is either vegetation, a dip or hollow in the ground, or a rock or boulder, or could even be a man-made object such as a wall.

It has been shown[6] that the effect of using purposeful wandering is to double the sweep width. Thus, for a field team using purposeful wandering, equation (3) becomes

$$C = \frac{1}{m}$$

where their original spacing is m x Critical Separation. For example, for a field team at Critical Separation spacing (m = 1), coverage is 1, and the graph for area searching gives them a PoD of 87% when they use purposeful wandering.

A suggested training programme for ground search teams

There are plenty of search activities described in this paper that can be used to create a searcher training programme. They are:

- finding Critical Distance in various types of terrain
- searching a route in daylight with two searchers
- searching a route in daylight with more than two searchers
- searching a route at night, using hand-held lights
- finding the preferred speed for the types of route in your area in daylight and at night
- finding Critical Separation in various types of terrain
- grid searching an area at a spacing of Critical Separation
- grid searching an area at other searcher spacings
- searching an area using purposeful wandering

References

1 Perkins, D., (2011), *Some Consequences of a Computer Model to Simulate the performance of a Land SAR Searcher*, The Centre for Search Research, pages 10 to 12; this can be downloaded from URL: http://www.searchresearch.org.uk/www/published_papers/

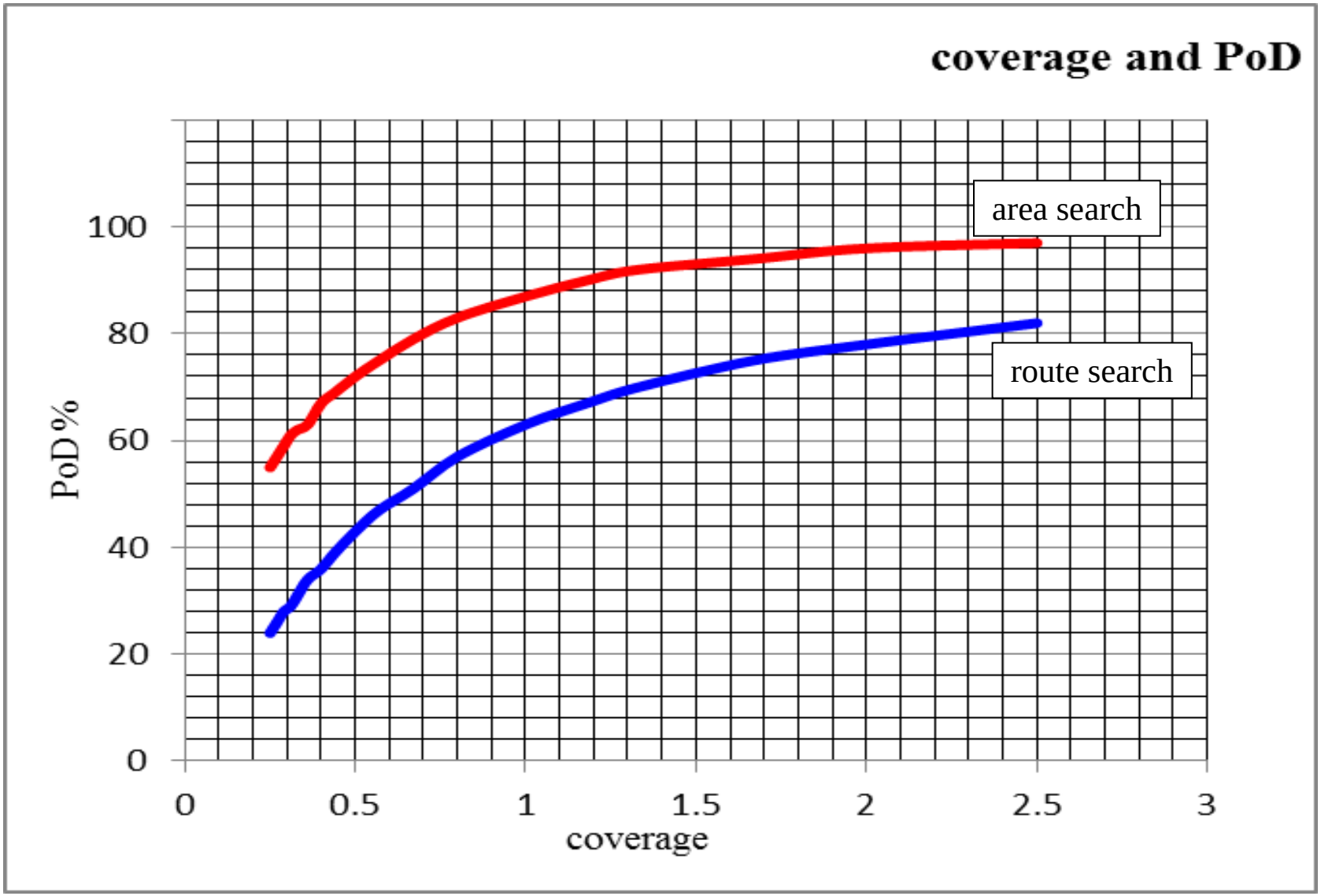
2 as 1, pages 12 and 13

3 as 1, pages 13 to 16

4 Perkins, D., Lovelock, D., (2008), *Lateral Range Curves, Search Probabilities, and Grid Searching*, The Centre for Search Research, pages 3 and 4; this can be downloaded from URL: http://www.searchresearch.org.uk/www/published_papers/

5 as 1, page 17

6 as 1, page 18


coverage and PoD
area search
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PoD%
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