Probability of Detection

- POD - How likely were you to have detected the subject (or clue, object) if it had been present in the area you were searching?

\[ \text{POS} = \text{POC} \times \text{POD} \]

- To a Searcher, search is binary
  - We found the subject (POD = 100%)
  - We did not find the Subject (POD = 0%)

- POD is primarily for Planners
  - However!!… A desired POD can help determine the recommended spacing for a search and the tactic utilized to search an area.
Probability of Detection...Why it is important

- Has two basic applications *(National SAR School)*
  - Searching an individual segment
    - Helps to determine track spacing, as well as time and resources required to search a segment.
  - For the overall search
    - Measure the effectiveness of individual searchers and the progress of the overall search effort -> POS
    - A factor in determining when to re-search an area
    - Helps in determining when to suspend a mission.

- POD is a challenging parameter to measure and estimate
Probability Related to Searchers (POD)

Factors that influence POD?

- Subject (Search Object) – behavior and physical characteristics
- Environment – weather, season, vegetation, terrain, available light
- Searchers
  - Type of resource
  - Track spacing
  - Tactics/methods
  - Search speed
  - Available technology
  - Information provided
  - Searcher physical/mental state
  - Searcher capability
POD Estimation

- POD is estimated by searchers in the field
  - Very subjective and often times unreliable
  - Imagine having to estimate the likelihood of finding something that you did not see and providing that estimate for a large area (some of which you did not search).

Green line represents a perfect predict with the yellow lines at +/-10% a linear correlation

Actual data fits for high and med visibility targets suggests significant inaccuracies (78% of the time) in predicting POD

1. Koester, Cooper, Frost, Robe, “Sweep Width Estimation for Ground Search and Rescue”
POD - Determining Resource Demands

Total Acres = 342
Total Acres = 618

Use desired POD and size of Search Area to determine resource needs.
POD - Determining Resource Demands

1. Specify a desired POD prior to the search effort

"Search segment AA08 to a POD of 50%"

POD = 1 - exp(-C)

POD = 50%, requires a Coverage (C) = 0.693

Coverage = Area Effectively Search / Area Assigned

Area = 85.4 acres
Area Effectively Searched = 59.2 acres

If desire to search the entire area (85.4 acres):
Coverage = SW/Spacing

AMDR (Sweep Width) = 30 ft

Spacing = SW/C = 43.3 ft

Area Searched = Effort x Spacing = N x TL x Spacing
TL = Search Speed x Search Time = 1.0 mph x 4 hrs

N = 85.4 Acres / (4.0 mi x 43.3 ft) x 8.25 ft-mi/acre ~ 4

Would require 4 searchers, 4 hours at a speed of 1.0 mph and an average spacing of 43.3 ft.
POD – Search Effectiveness

2. Measure the effectiveness and completeness after a given search effort

Team reports a POD = 40%, N = 5, Spacing = 5 m = 16.43 ft

Area Assigned = 85.4 acres
Area Searched = Effort x Spacing = N x TL x Spacing
= 5 x (1 mi + 3461/5280 mi) x 16.43/5280 mi
= 5 x 1.66 mi x 16.43/5280 mi
= 0.026 mi² = 16.5 acres

AMDR (Sweep Width) = 30 ft

Effective Coverage = SW/Spacing = 30 / 16.43 = 1.83

Coverage = Eff Coverage x AS/AA
= 1.83 x 16.5 / 85.4 = 1.83 x 0.193
= 0.353

POD = 1-exp(-C) = 0.3 = 30%

35% of the assigned area was effectively searched (as opposed to 19%) resulting in a POD = 30% (based on random search theory)
Area Searched

- Area Searched = Spacing x Effort
  - Spacing – Average actual distance between searchers in the field
  - Effort = N x TL
    - N - number of searchers on team
    - TL – Track length
      - Obtained from GPS track, or
      - TL = Search speed x Search time

- Area Effectively Searched = Effective Coverage * Effort
Coverage

Relative measure of how thorough an area has been searched.

\[
\text{Effective Coverage} = \frac{\text{Area Effectively Searched}}{\text{Area Searched}}
\]

\[
\text{Total Coverage} = \text{Effective Coverage} \times \frac{\text{Area Searched}}{\text{Segment Area}}
\]

Limited studies are available that relate POD to coverage. The bulk of these studies produce a result similar to that of Koopman’s (1946) Random Search Theory.

**Koopman’s Random Search Theory**

\[
\text{POD} = 1 - e^{-\text{coverage}}
\]

Figure 2-5. POD vs. Coverage (Koopman, 1946)

Cooper, Frost and Robe, “Compatibility of Land SAR Procedures with SAR Theory.”
Determining Coverage and Cumulative POC

- Use the Measure Tool to trace the section of the track you are interested in.
- Right click for “Information” to obtain track length of desired section.
- Combine track length with team size and effective spacing to determine area searched.

\[
\text{Area Searched} = TL \times \# \text{ on team} \times \text{spacing}
\]

\[
\text{Coverage} = \frac{\text{Area Searched}}{\text{Area Assigned}}
\]

Related Coverage to POD using Koopman’s Random Search Theory

\[
POC_{s,n} = POC_{s,n-1} \times (1 - POD_{s,n})
\]
Sweep Width

- Measure of the average ability of a given sensor to detect a specific object under a specific set of environmental conditions.

- Distance at which the likelihood of detection is equal to the likelihood on non-detection.

- Number of objects missed inside the width is equal to the number of objects outside the width that were detected.
Improving POD Estimation

- Researchers have development methods for predetermining optimal distances between searchers to achieve a desired POD.
  - Sweep Width is difficult to measure
  - AMDR or “one-half critical separation” is a conservative estimate, in absence of experimental data.

- Benefits of predetermined values
  - Improves accuracy of field team estimates
  - Assists SAR Managers with effort allocation and estimating resource needs
Average Maximum Detection Range

- Similar in concept to CS
  - Searchers are situated around the object at a range where the object cannot be seen. Searchers then move toward the object to a location where it can be detected. (Detection Range) The distance to the object is recorded.
  - Next the searchers move away until they cannot see any part, piece or portion of the object. An average is determined for the distance of Extinguishment for each leg.

- The average of those two values (Detection and Extinguishment) will be the AMDR for that object in that environment.

Critical Separation (Perkins and Roberts, 1989)

- CS - the visual horizon for each searcher falls at roughly the middle of the measured distance between any two searchers¹.
  - Combined both increasing efficiency and establishing a reasonable POD estimation
  - Searchers are stationed around the object at a distance beyond where they can see the object. They then turn and walk toward the object until they can clearly see it. Searchers then paces off the distance from “detection” to the object. All of the distances are then averaged. Twice the average distance is what is called Critical Separation.

Critical Separation

Determining Critical Separation
Using the Raindance


Appalachian Search and Rescue Conference
Mountaineer Area Rescue Group
Critical Separation

Critical Separation

Limitations

- Doesn’t account variations in terrain, environment, search object
- Effect of searcher speed not considered.

SAR Managers and Planners often identify a series of Objectives for a given Operational Period.

How does the Planning team estimate the resources needed to accomplish these objectives?
Search Planner Worksheet

- The latest version of the Search Planner Worksheet was derived from BASARC Form SAR-138.
  - Some corrections were made and the form was expanded.

- This current version of the form is only for ground searchers

- Has multiple uses
  - Estimate time/resource requirements to accomplish a desired POD
  - Estimate post-search POD
SAR Planner Worksheet

Example of completed worksheet

C = \frac{\text{Eff COV} \times \text{Area Searched}}{\text{Area Assigned}}

\text{POD} = 1 - \exp(-C)

(based on Random Search Theory)

Track Length

Search Speed

Track Length from GPS, or

\text{Track Length} = \text{Search Speed} \times \text{Search Time}

\text{Number of Searchers}

Area Searched

\text{Eff COV} = \frac{\text{AMDR}}{\text{Spacing}}

\text{Effort} = N \times \text{Track Length}

\text{Effective COVerageage}

\text{Spacing} = \frac{\text{Area Searched}}{\text{Effort}}

\text{Track Length} = \frac{\text{Search Speed} \times \text{Search Time}}{\text{Effort}}

\text{Spacing} = \frac{\text{Area Searched}}{\text{Effort}} \times \frac{5280 \text{ ft}^2}{640 \text{ acres-mi}} \times \frac{1000 \text{ ft} / \text{km}}{1 \text{ mi} / \text{km}}

SAR 138
MARG 4/2012

PREPARED BY

Appalachian Search and Rescue Conference
Mountaineer Area Rescue Group
POD Two Primary Uses

1. Specify a desired POD prior to the search effort

"Search segment AA08 to a POD of 50%"

\[
POD = 1 - \exp(-C)
\]

POD = 50%, requires a Coverage (C) = 0.693

\[
Coverage = \frac{\text{Area Effectively Search}}{\text{Area Assigned}}
\]

Area = 85.4 acres
Area Effectively Searched = 59.2 acres

If desire to search the entire area (85.4 acres):

\[
Coverage = \frac{\text{AMDR (Sweep Width)}}{\text{Spacing}}
\]

AMDR (Sweep Width) = 30 ft
Spacing = \frac{\text{AMDR}}{\text{Coverage}} = 43.3 ft

Area Searched = \text{Effort} \times \text{Spacing} = N \times \text{TL} \times \text{Spacing}
\[
\text{TL} = \text{Search Speed} \times \text{Search Time} = 1.0 \text{ mph} \times 4 \text{ hrs}
\]

\[
N = \frac{85.4 \text{ Acres}}{(4.0 \text{ mi} \times 43.3 \text{ ft})} \times 8.25 \text{ ft-mi/acre} \approx 4
\]

Would require 4 searchers, 4 hours at a speed of 1.0 mph and an average spacing of 43.3 ft.
Exercise... Search Planning Worksheet

- Pass out worksheet
Search Planning Worksheet – Resource Needs

1. Desire POD = 50%
2. Since you are planning to search the entire assigned area (85.4 acres), Area Searched / Area Assigned = 1.0
3. Determine the Effective Coverage
4. You have measured your AMDR to be used as a surrogate for Sweep Width, AMDR = 30 ft
5. Determine your needed spacing relative to your AMDR in order to achieve a POD = 50%
Search Planning Worksheet – Resource Needs

6. Area Searched = 85.4 acres
7. Determine your Effort

8. Track Length = Search Speed (1 mph) x Search Time (4 hours) = 4 miles

9. Draw a line between Track Length and Effort in order to estimate the Number of Searchers required to complete this task in the allotted 4 hours.

4 searchers required
Search Planning Worksheet – Resource Needs

SEARCH PLANNING WORKSHEET

1. INCIDENT NAME

2. DATE

3. ASSIGNMENT IDENTIFIER

Example of completed worksheet

C = Eff COV x \frac{Area Searched}{Area Assigned}

If Area Searched = Area Assigned, C = Eff COV

POD = 1 - \exp(-C)
(based on Random Search Theory)

Track Length from GPS, or

Track Length = Search Speed x Search Time

Effort = N x Track Length

Spacing = \frac{Area Searched}{Effort}

\text{Effective COV}erage

\text{Eff COV} = \frac{AMDR}{\text{Spacing}}

SAR 138
MARCH 4/2012

5. PREPARED BY

Appalachian Search and Rescue Conference

Mountaineer Area Rescue Group
2. Measure the effectiveness and completeness after a given search effort

Team reports a POD = 40%, N = 5, Spacing = 5 m = 16.43 ft

Area Assigned = 85.4 acres
Area Searched = Effort x Spacing = N x TL x Spacing
= 5 x (1 mi + 3461/5280 mi) x 16.43/5280 mi
= 5 x 1.66 mi x 16.43/5280 mi
= 0.026 mi² = 16.5 acres

AMDR (Sweep Width) = 30 ft
Effective Coverage = SW/Spacing = 30 / 16.43 = 1.83
Coverage = Eff Coverage x AS/AA
= 1.83 x 16.5 / 85.4 = 1.83 x 0.193
= 0.353

POD = 1-exp(-C) = 0.3 = 30%

35% of the assigned area was effectively searched (as opposed to 19%) resulting in a POD = 30% (based on Koopman’s Random Search Theory)
Search Planning Worksheet – POD Estimate

1. Team estimates their POD = 40%
2. Track Length is measured by GPS to be \((1 \text{ mi} + \frac{3461}{5280} \text{ mi}) = 1.66 \text{ miles}\)
3. Five searchers were assigned to the team, \(N = 5\).
4. Determine the Effort
5. The team indicated their average Spacing = 5 m = 16.43 ft
   This produces an Area Searched equal to \(~ 16.5 \text{ acres}\)
Search Planning Worksheet – POD Estimate

6. Knowing that the AMDR = 30 ft
7. Determine the Effective Coverage

8. Area Searched / Area Assigned = 0.193

POD = 28%
As opposed to the team estimated 40%
## Search Planning Worksheet - POD Estimate

### Search Planning Worksheet

<table>
<thead>
<tr>
<th>1. INCIDENT NAME</th>
<th>2. DATE</th>
<th>3. ASSIGNMENT IDENTIFIER</th>
</tr>
</thead>
</table>

### Example of completed worksheet

- **Track Length**
  - Track Length from GPS, or
  - Track Length = Search Speed x Search Time

- **Search Speed**
  - Search Speed = mph or kph

- **Search Time**
  - Search Time = hours

- **Effort**
  - Effort = N x Track Length

- **Number of Searchers**
  - Number of Searchers

- **Effort km**
  - Effort km = 0.5 x Track Length

- **Spacing**
  - Spacing = Area Searched / Effort

- **Effective Coverage**
  - Effective Coverage = Area Searched / Effort

- **AMDR**
  - AMDR = ft/m x m

- **Eff COV**
  - Eff COV = AMDR / Spacing

- **Area Searched**
  - Area Searched = acres

- **Area Assigned**
  - Area Assigned

- **C = Eff x COV**
  - C = Eff x COV

- **POD = 1 - exp(-C)**
  - (based on Random Search Theory)

- **Track Length miles**
  - Track Length miles

- **Track Length km**
  - Track Length km

- **Search Planning Worksheet**
  - SAR 138

- **Prepared by**
  - MARG 4/2012
Utilizing GIS to Determine Coverage

- Use GPS tracks, operational team information and search segment/probability region details to calculate the ratio of area search to area of the segment or region.
- Coverage provide a more accurate description of how well the team performed than a Team Leader estimate of POD.
- Often times teams accidentally or purposefully search outside of their assigned search area. Only using reported POD for their assignment does not credit the unassigned areas for being searched.
Utilizing Coverage to Estimate POD

- POD Estimates from teams tend to be inaccurate
  - Estimating a single POD for the entire area
  - Only consider area assigned
- Utilize GPS tracks to estimate “Coverage”

Coverage = Area Effectively Search/Segment Area * Eff COV

Random Search Theory
POD = 1 - e^{-\text{coverage}}

Tracks are buffered to account for team size and spacing

GPS tracks collected from field teams

Pden from POD estimates

Original Pden estimates

Pden from Coverage