A Method for Determining Effective Sweep Widths For Land Searches

Procedures for Conducting Detection Experiments

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About the Authors

R. Quincy Robe has been associated with maritime Search and Rescue (SAR) for over two decades during his 27 years as a scientist for the U. S. Coast Guard. From 1984 until his retirement in 1996 he headed the Search and Rescue program for the USCG Research and Development Center in Groton, CT. He was responsible for incorporating the experiment-based sweep width tables into the *National SAR Manual* and expanding the scope of the tables to include radar detection and night vision goggle detection. He conducted more than a dozen detection experiments for the USCG. He served as a technical expert for the Canadian Coast Guard during their detection experiments. He is the author of many reports and publications on probability of detection and SAR. He was instrumental in the development of the Self Locating Datum Marker buoy for tracking search areas in the ocean as they move with the currents. He is a life member of the National Association for Search and Rescue (NASAR) and has presented papers at their conferences.

J. R. (Jack) Frost has been associated with Search and Rescue (SAR) for the last 30 years, including 23 years of active duty as a U.S. Coast Guard officer. During his Coast Guard career, he served as a Rescue Coordination Center (RCC) controller where he planned searches that resulted in lives saved. In addition to other operational tours, he served as the senior analyst for the Coast Guard's Computer Assisted Search Planning (CASP) system, as the Commanding Officer of the Coast Guard's Operations Computer Center (now the Operations Systems Center in West Virginia), and as Special Project Officer to develop functional requirements for technology upgrades to the CASP system. Since leaving the Coast Guard, he has led and contributed to a number of SAR-related projects. He was the principal author of the search planning chapters of the *International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual* published jointly by the *International Civil Aviation Organization (ICAO)* and the *International Maritime Organization (IMO)*. He also authored a companion paper called *The Theory of Search* to explain the scientific underpinnings of both previous and current maritime search planning methods. The *IAMSAR Manual* is now recognized as the world standard SAR manual. He developed procedures for responding to reports of distress flare sightings and evaluated search planning support software for the Coast Guard. He is currently under contract to the Coast Guard in a consulting role for their latest search planning software upgrades. Mr. Frost has also entered the land SAR arena, has written several papers and has made presentations at *William G. Syrotuck Symposia on Search Theory and Practice* and at *SARSCENE*, the annual Canadian national search and rescue conference. He authored a series of four articles, *Principles of Search Theory*, which were published in *Response, The Journal of the National Association of Search and Rescue*, in 1999. He has also consulted with the Canadian defense research and development establishment on *SARPlan*, a software tool that supports planning aerial searches for aircraft missing over land in Canada.

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Last, but certainly not least, we would be remiss if we did not express our appreciation to all those volunteers, too numerous to name here, who took time from their activities during the Logan SAR Weekend to participate in this experiment. Your participation not only produced the data we needed, it also produced many useful and relevant comments, suggestions and observations.

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Abstract

For the first time, a standard, simple, practical, and low-cost method for conducting detection experiments for ground searches was successfully developed and demonstrated. This included a simple method for reducing the data obtained in such experiments that requires only minimal computation and the construction of a simple graph. Two types of objects were used—a fluorescent orange glove and a black balloon-filled 55-gallon plastic garbage bag. Twelve gloves and nine garbage bags were placed randomly along either side of a 2.25 kilometer track in a wooded area. Thirty-two searchers participated in the demonstration, providing 384 detection opportunities for gloves and 288 detection opportunities for garbage bags. Preliminary visual effective sweep width (a.k.a. "detectability index") estimates were obtained for each object type for the type of environment in which the demonstration was conducted.

Land search and rescue (SAR) organizations will now be able to conduct detection experiments in their own respective areas of responsibility using their own resources to produce effective sweep width values for their own use and the use of others in similar search situations. This work constitutes a major breakthrough for improving land search planning and evaluation methods by replacing subjective estimates for probability of detection (POD) with objective ones that are more reliable, repeatable, and accurate than current subjective techniques. This work will also make it possible to bring known and proven methods for the optimal allocation of search resources to each situation that requires areas to be searched, leading to multiple benefits. These benefits include finding survivors sooner on average and thereby saving more lives, reducing risks to searchers through reduced search times, reducing costs, reducing the time volunteers must take from their normal lives, and making resources more available for other missions if needed.

National Search and Rescue Committee

The National Search and Rescue Committee (NSARC) is a federal-level committee formed to oversee the U. S. *National Search and Rescue Plan* (NSP) and coordinate civil search and rescue (SAR) matters of interagency interest within the United States. Member agencies of NSARC are the Department of Transportation, Department of Defense, Department of Commerce, Department of Interior, Federal Communications Commission, and the National Aeronautical and Space Administration (NASA). The member (or alternate) of the Coast Guard, representing the Department of Transportation, is designated as the Committee Chair.

The Committee is responsible for coordinating and improving federal involvement in civil search and rescue (SAR) for the aeronautical, maritime, and land communities. It also handles U. S. involvement in various international fora concerned with SAR, including the *International Civil Aviation Organization* and the *International Maritime Organization*. An International Technical Group expands research and development (R&D) coordination beyond the U. S. The SAR Program Manager, NASA Goddard Space Flight Center, chairs both the NSARC R&D Working Group and the International Technical Group. More information about NSARC may be obtained from the Committee's web site at http://www.uscg.mil/hq/g-o/g-opr/nsarc/nsarc.htm.

The objectives of the Committee are to:

a) Serve as a standing forum for coordination of administrative and operational civil SAR matters;

b) Oversee the NSP and interagency guidance for its implementation;

c) Coordinate and facilitate the development of plans, policies, positions, manuals, etc., to:

  - resolve cross-agency jurisdictional issues;
  - develop joint solutions for SAR matters of common concern;
  - assign and coordinate SAR responsibilities;
  - develop and implement SAR requirements and standards; and
  - outline joint SAR tasking.

d) Effectively use all available resources for SAR, including global, regional, national, private, commercial, and volunteer resources (such resources may include advice, communications facilities and databases, ship reporting systems, training, SAR facilities, search planning expertise, technical assistance, foreigh language assistance, medical or fueling facilities, regulatory support, and others);

e) Develop common equipment, facilities, and procedures as appropriate;

f) Foster U.S. cooperation, support, representation, positions, arrangements, plans, exercises, and other appropriate U.S. involvement with international organizations or with appropriate authorities of other nations on matters relating to provision of civil SAR services;

g) Promote close cooperation and coordination between civilian and military authorities and organizations for the provision of effective SAR services;

h) Serve as a cooperative forum to exchange information and develop positions and policies of interest to more than one member agency;

i) Improve cooperation among the civil SAR communities;

j) Determine and recommend ways to enhance overall effectiveness and efficiency of SAR services;

k) Promote safety programs to help citizens avoid or cope with distress situations;

l) Consider, as appropriate, contingency plans for us of civil SAR resources during emergencies other than SAR; and

m) Use a strategic plan and member agency implementation plans to help to achieve the objectives of this paragraph.

Executive Summary

For the first time in history, a scientifically sound yet practical method for objectively determining detection probabilities for objects of importance to search and rescue (SAR) in the land environment was successfully developed and field-tested. Data was collected using volunteer searchers and analyzed with simplified analysis techniques, all at very low cost. This work opens the door for resolving search planning and evaluation issues that have been vigorously debated within the land SAR community for nearly 30 years but never settled.

Although many SAR missions involve less "search" than "rescue," searching remains a significant challenge, especially when lives are at risk. Searching is by its very nature a probabilistic process in which there is no guarantee of either success or failure. However, a carefully planned search using the right tools and concepts is significantly more likely to succeed and, of equal importance when lives are at stake, succeed sooner.

Planning a search consists of evaluating all the available information and then, since it is not generally possible to do a thorough search everywhere all at once, deciding how to best utilize the available, and often limited, search resources. Since "all available information" also includes any unsuccessful searching already done, a proper accounting is needed for how well each of the various segments or sub-divisions of the general search area have been searched. This becomes an input for planning subsequent search activity for the lost or missing person. For both pre-search planning and post-search evaluation, it is essential that the search planner be able to objectively estimate the probability of detecting a given object in a given segment of the search area with a given resource.

The probability of detection (POD) is a function of the level of effort, the size of the segment, and how easy or hard it is to detect the object(s) of the search. The ease or difficulty of detection is in turn a function of the sensor in use (usually the unaided human eye), the nature of the object being sought (size, color, etc.), and the environment at the time and place of the search (terrain, vegetation, weather, etc.). While planners of land searches usually know what they are searching for, what resources they have available, and the sizes and environmental characteristics of the segments where resources are to be or have been sent, they have had no way to quantify the ease or difficulty searchers will have in detecting the object of the search. This has left them without an objective method for estimating POD and has effectively thwarted attempts over the past 30 years to put land SAR search planning on a more scientific footing. Planners have been forced to either make subjective POD estimates without reliable data on which to base them, or depend on the even more subjective estimates of the searchers themselves.

The simplest metric for quantifying "detectability" is a value called the "effective sweep (or search) width." This concept reduces the combined effects of all the factors affecting detection in a given search situation to a single number characterizing search object "detectability" for that situation. Unfortunately, effective sweep width cannot be measured directly. It is necessary to perform detection experiments and reduce the data from them. Contracting for such experiments in a variety of settings and situations could be deemed cost-prohibitive despite the essential nature of the data they would produce. One goal of this very successful project was to find a more cost-effective solution.

The objectives of this project were to:

- Design, develop, describe, and demonstrate a standard model or blueprint for conducting simple, practical, inexpensive detection experiments, collecting data from them, and reducing that data to estimates of effective sweep width.
- Provide a description of the method for objectively estimating probability of detection (POD) from:
    - Effective sweep width for a given combination of search object, sensor and environmental conditions,
    - The level of effort expended in searching a defined region, and
    - The size (area) of that region.
- Provide a professional opinion of the reliability and repeatability of POD estimates based on effective sweep width, effort and area searched as compared to subjective estimation techniques.
- Describe future work needed to establish a practical methodology for planning and performing searches of areas that is based on sound search theory principles for allocating the available effort in a more nearly optimal manner.

For the first time ever in the land SAR arena the first of these objectives was accomplished. A practical model for ground SAR detection experiments was designed and demonstrated, including a data reduction technique that requires only minimal computational skills. Implementing this model will make the cost of obtaining effective sweep width data nearly zero. Perhaps even more importantly, it opens the door for substantial improvements in land SAR search planning techniques that have been sought for many years. An important threshold has been crossed that brings a practical adaptation of search theory tailored specifically for land SAR search planning one step closer.

The remaining objectives were also met. The technique for estimating POD based on sweep width, effort and area is described and an example is provided. A professional opinion on the objectivity, reliability and repeatability of this technique is rendered. A brief outline of future work needed to complete the establishment of a search planning methodology that is practical yet built on sound scientific principles is provided.

A Method for Determining Effective Sweep Width for Land Searches

Part I – Introduction and Background

INTRODUCTION

Searching is a truly ancient and ubiquitous activity. For this reason it is often taken for granted by the layman that searching is simply a matter of just looking around for the lost or missing object being sought. However, when a life may hang in the balance, such a simplistic approach is inappropriate, especially given the current state of knowledge about searching as a process.

During the Second World War a formal scientific discipline called search theory was established. The original work as well as all subsequent work has shown the "*…operation of search as an organic whole having a structure of its own—more than the sum of its parts.*" [Koopman, 1980] Although most would regard the mathematics of search theory as complex, it can be reduced for practical use to a few simple concepts and organizing principles. Implementing these concepts and principles in a manner appropriate to the type of search mission, operating environment and available search resources has repeatedly demonstrated its value. For the search and rescue (SAR) mission, the objective is to deploy the available resources in a fashion that achieves maximum probability of success (POS) in the minimum time.

Koopman (1980) described three basic pitfalls to avoid when studying the operation of search with a view toward improving it. These were:

- Focusing primarily on basic sensing capabilities without sufficient emphasis on how to use or deploy the available sensors to maximum effect in a search.
- Trying to provide practical search planning guidance without first obtaining the scientific background and data necessary to provide sound guidance.
- Inappropriate handling of the mathematics by either trying to eliminate it altogether, thus eliminating much of the reasoning essential to providing practical advice, or by going to the other extreme and elaborating it to a degree of generality not required by either the theory or the practice of searching.

This project has attempted to avoid these pitfalls. In particular, it examines just one of the basic concepts of applied search theory for the purpose of providing practical guidance about the concept and how it may be quantified into numeric values of practical use. In so doing, it opens the door to solving a fundamental issue that land SAR search planners have struggled with for many years. That issue is how to objectively and reliably estimate the probability of detecting (POD) a search object if it is in an area that is to be or has been searched.

The Report

This report is a preliminary attempt to apply well-established search theory to the land search environment. It attempts to fall somewhere between a scientific treatise with explanations and data to establish the validity of its conclusions and an operating manual consisting solely of instructions and procedures to be followed—rules without scientific explanation. The desire was to include enough technical background information to convince the reader that this work is built on a solid scientific foundation without overwhelming the reader with mathematical detail and jargon. Since the concepts involved are essentially mathematical in nature, it has not been possible to eliminate the mathematical explanations altogether, but they have been simplified to the maximum extent. Another reason for including at least a minimal amount of explanatory material is to avoid some very real problems in practice. Persons who have at least some knowledge of why a procedure is done in a certain way are likely to do a much better job of following it than someone who is just blindly following a recipe they do not comprehend. Another motivation for trying to impart at least a minimum level of understanding is to prevent procedural shortcuts that may seem harmless on the surface but which will actually invalidate the results. Incorrect information is often worse than no information, especially if the incorrect information required some effort to generate.

This report is divided into five major parts and several appendices. Part I provides some of the scientific background for the methods that were developed in this project. Part II describes the procedures to be followed in designing, setting up and performing a detection experiment along with descriptions of the data to be collected and the method for analyzing that data to obtain a numeric value for the effective sweep width ("detectability index"). Part III describes a demonstration of the procedure that was done near Logan, West Virginia, on 15 June 2002. Part IV describes how POD is estimated. Part V contains conclusions and recommendations for future work. Appendix A contains a description and explanation of *effective sweep width* in the least technical terms possible. Appendix B contains a set of data collection forms for recording detection experiment data. Appendix C contains the procedural steps to be followed in outline form without explanations—a "recipe" for performing detection experiments. Appendix D contains the actual data recorded during the demonstration. Appendix E contains some frequently asked questions with answers.

Probability of Detection

Successful search planning, whether in an urban, wilderness, or marine environment requires an objective standard for providing an estimate of the probability of detection (POD). In each of these settings the variables that describe the searcher, the search object, and the search environment will differ not only in kind but also in their influence on the estimate of the POD. What is constant, however, is that POD estimates should be based on objective measures and observations rather than on intuitive and therefore highly subjective assessments by either the search planner or the searchers. POD estimates are needed for both planning searches and evaluating unsuccessful search results as a prelude to planning the next search. POD is a function of the level of effort, the size of the search area segment where the effort was expended, and how easy or hard it is to detect the object(s) of the search. A searcher is generally a reliable source of information on the search environment experienced during the search and his/her physical condition, fatigue, level of training and experience that bear on the searcher's capabilities, etc. However, at the end of the day, the only direct detection information the searcher can reliably report is what objects, if any, they detected and approximately where and when they were detected. Searchers should be required to report only what they can observe; search planners and managers should estimate POD values based on those observations and the results of detection experiments performed as outlined in this report.

Detections are only a subset of all detection opportunities. Detection opportunities also include failures to detect the search object even when there was an opportunity to do so. Since no sensor is perfect, a scientific detection experiment must consider all detection opportunities in order to establish how "detectable" a particular type of object is by a given sensor in a given environment. The measure of "detectability" is called the ***effective search (or sweep) width*** in the scientific literature and in maritime search planning. This term is ***not*** to be confused with any of the following: search visibility, detection range, visibility distance, sweep searching, grid searching, parallel sweeps, sweep spacing, or track spacing. All of these latter terms describe either some measurement that does ***not*** reflect detection performance or they describe some aspect of how searching is done by the searchers. Effective sweep width, on the other hand, is a basic measure of how easy or hard it will be for a searcher to detect the search object under the environmental conditions that exist at the scene of the search. Effective sweep width may also be called a "detectability index," especially if that seems less confusing.

The procedures described in this report are intended for use by SAR managers to conduct experiments to establish *effective sweep width* values for their searchers, local operating environments, and typical search objects. It should not be confused with an attempt to provide search planning guidance. Effective sweep width is only one part, albeit a critical one, for planning efficient, effective searches. By establishing a set of search parameters that approximate a hypothetical search situation and then by collecting data on detection/non-detection performance for each detection opportunity, a SAR organization can develop a useful measure of search object "detectability" (effective sweep width) for planning and evaluating searches in its area of responsibility (AOR). This report provides a detailed outline of the steps necessary to estimate the effective sweep width applicable to a local situation. This will result in more accurate, reliable, and consistent POD estimates for planning and evaluating searches.

To be precise, POD is an estimate of how likely it will be (or was) for a search of a particular well-defined area to find the object, *assuming it was there to be found.* That is, POD is a *conditional* probability, the condition being the assumption of the object's presence in the area searched. The probability of success, POS, is the joint probability formed by the probability of the object being in the area searched (POA) and the probability of detecting the object if it was there (POD). That is, POS = POA × POD. POD depends on three things:

- The "detectability index" (a.k.a. effective sweep width) for the combination of search object, search environment, and sensor (e.g., visual search from the ground) present in a given search situation,
- The amount of effort expended in searching the area, and
- The size of the area where the effort was expended.

Given measures of these three factors in consistent units, it is possible to establish an objective, reliable, and accurate estimate of POD using a few simple computations and a graph. The method for doing this is shown in Part IV.

SCIENTIFIC BACKGROUND

A brilliant scientist named B. O. Koopman (1946, 1980) established the basis for a rigorous study of search theory and practice with his pioneering work for the U. S. Navy during WWII. Koopman was a member of the Navy's *Operations Evaluation Group* (OEG). An important characteristic of this group was that its members were required to spend several years in the field working directly with operations personnel. All work produced by this group had to be both scientifically sound and practical enough for operational use by Navy personnel without requiring them to have any special scientific training. It also had to show practical results. The work initially done by the OEG was instrumental in winning the Battle of the Atlantic against the German U-boats. Although this kind of application may seem far removed from searching for lost persons on land, the basic theory of search Koopman established applies to all types of searching. An essential part of Koopman's work was developing the concept of effective search (or sweep) width—an objective numeric measure of how easy or hard it is for a given sensor to detect a given object in a given operating environment. Whenever the basic theory has been applied, substantial improvements in search success rates and reductions in the average times and resources required to achieve success have been realized. It is Koopman's work that will form the basis for the effective sweep width estimation technique developed in this paper. For a detailed yet readable elaboration on the development of the theory see Frost (1999a, 1999b, 1999c, & 1999d).

Although search theory was applied to military SAR operations during and after WWII, the U. S. Coast Guard provided the first comprehensive application to civil SAR in the 1950s. The methodology was incorporated into the first edition of the *National Search and Rescue Manual* in 1959 and it quickly gained acceptance by maritime SAR agencies worldwide. It has remained in global use ever since. Various practical improvements and modifications to search planning techniques and data have been made over the years, but the application of the underlying theory remains unchanged, as shown in the *International Aeronautical and Maritime Search and Rescue Manual (IAMSAR Manual, 1999)* published jointly by the *International Maritime Organization* and the *International Civil Aviation Organization* and recognized globally as the standard text on aeronautical and maritime SAR operations and methods.

"Detectability"

One of the weaknesses of the original implementation was that the "detectability" data available until the late 1970s reflected primarily maximum detection ranges for maritime SAR objects such as life rafts. There is only a very loose relationship between maximum detection range and the measure of detectability known as the effective search (or sweep) width. In other words, the data originally available were not a very good measure of detectability and they tended to be optimistic, producing effective sweep width estimates, and POD values, that were larger than they should have been.

In 1978 the U.S. Coast Guard Research & Development Center began an extensive data collection project to measure the effective sweep widths for a wide variety of realistic SAR objects, under realistic environmental conditions using actual Coast Guard crews and Search and Rescue Units (SRUs). The experiments were conducted over a period of more than twenty years. The data collected and the lessons learned during this series of experiments formed the basis for the *National SAR Manual* and *IAMSAR Manual* sweep width tables and search planning guidance, including POD estimation. In developing the methodology for the estimation of effective sweep width for land search we have drawn on the experience of the maritime SAR community while acknowledging the considerable differences in search techniques and environments found on land. The common link between evaluating detectability in the maritime and land environments is that each searcher/search object interaction is resolved as either a detection or a non-detection.

Lateral Range

The method for estimating effective sweep width uses the concept of a "lateral range curve". This concept, introduced by Koopman, has a number of properties that recommend it for sweep width estimation. Lateral range refers to the perpendicular distance an object is to the left or right of the searcher's track where the track passes the object. Thus it represents the distance from the searcher to the object at the closest point of approach (CPA). A lateral range curve is a plot of the probability of detecting the object on a single pass as a function of the object's lateral range from the searcher's track, i.e., as a function of how closely the searcher approaches the object. Figure 1 shows a hypothetical relationship between POD on a single pass and an arbitrary scale of distances to the left (negative) and right (positive) of the searcher's track.

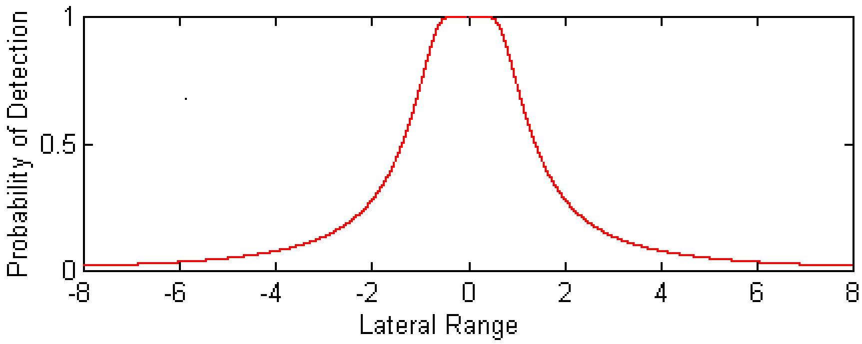

Figure 1. A Lateral Range Curve (a.k.a. Detection Profile)

Koopman (1946) derived this particular relationship from the physical geometry of an aircraft flying over the ocean in search of an object on the surface. Negative values are distances to the left of the searcher's track while positive values are distances to the right of the searcher's track.

Visual search (as anyone looking for their keys knows) is highly dependent on distance. At first one would think that the important measure in any detection is the actual range at which the detection takes place. This begs the question of what range should be assigned to a non-detection when the searcher passes the object without detecting it. The answer is that the non-detection took place at all ranges down to and including the closest point of approach (CPA) or the "lateral range" value. It is also true that an object may be detectable for some time before it actually ***is*** detected. That is, detections may occur at any distance between the point where the searcher first gets close enough to make detection possible down to the CPA and then beyond to where detection is no longer possible. Therefore, both detection and non-detection events will be referenced to the lateral range or off-track distance.

The lateral range method also functions as a natural integrator of the effects various factors have on the detection process during the experiment. Even in a fairly constant environment many factors may affect detection. The searcher may look elsewhere just at the time the object appears in an opening in the vegetation; wind or rain may affect visibility at a particular point; one searcher may have better scanning technique or eyesight than another; or the object may require several glimpses to register on the consciousness of the searcher, especially if it has a low contrast with its surroundings. For each searcher participating in a detection experiment, the lateral range concept makes detection data collection a matter of answering a simple question: "Did the searcher detect the object as he/she passed it or did the searcher not detect it?"

Effective Sweep Width

We have described the *effective sweep width* (usually shortened to just *sweep width*) as a measure of detectability but we have not yet given a definition or example of what it represents. Unfortunately, sweep width cannot be measured directly. This is one reason why it is difficult to explain. Another reason is the ease with which the term "sweep width" is confused with other, sometimes similar, terms that have quite different meanings and uses. We will now rectify this problem by giving several different, but equivalent, descriptions of what sweep width represents.

For all of the following descriptions, assume that search objects are uniformly, but randomly, spread over an area. A uniform random distribution means that the search object locations occur at random so their positions cannot be predicted, but the number of objects per unit of area is about the same everywhere. Also assume that the area covered with objects is very large compared to the maximum detection range.

Suppose an experiment was done where every searcher detected every object within a given lateral range, say 50 feet either side of the searcher's track, and detected no objects outside that range. That is, the searchers were 100% effective within 50 feet on either side of their track, and completely ineffective for objects farther from the searcher's track. This would constitute a "clean sweep" of a swath 100 feet wide with no detections outside that swath. The effective sweep width in this case would be 100 feet. In this "ideal" but unrealistic example, the effective sweep width is the same as the width of the swath where objects were detected.

Now suppose another experiment is done in another venue using the same number of objects per unit of area. Further suppose that the searchers in this experiment find objects that are up to 100 feet either side of their tracks, but they detect, on average, only half the objects located in that swath of 200 feet. Note that there will be twice as many objects in a 200-foot swath as in a 100-foot swath of the same length. Therefore, even though the searchers detect only half of those present in the 200-foot swath, they will detect just as many objects in one pass as the searchers in the previous experiment did. In this sense the two groups of searchers performed equivalently despite any differences in terrain, vegetation, searcher training, etc. So, for purposes of estimating how many objects will be detected in one pass, we would say the *effective sweep* *width* in both cases was 100 feet. That is, both groups of searchers detected the same number of objects as lay in a swath 100 feet wide even though only the first group did this in a literal sense.

This illustrates the difference between effective sweep width and maximum detection range. While it is possible to say that the width of the swath where searchers ***can*** detect objects will normally be about twice the maximum detection range, there is no way to predict from that information alone how many of the objects present in that swath ***will*** be detected, even if the number of objects present per unit of area is known. The effective sweep width, on the other hand, does allow us to estimate how many detections we should expect provided we also know the number of objects present per unit of area. Simply multiply the effective sweep width by the length of the searcher's track to get the *area effectively swept* then multiply this value by the number of objects per unit of area to get the number of detections that should be expected. Note that this value does not depend in any way on the maximum detection range and there is no known mathematical relationship between the two. Having a maximum detection range in one situation that is twice that of another situation does ***not*** mean objects in the first situation are twice as detectable, on average, as objects in the second situation. In fact, it is actually possible that a small, high-contrast object might have a very large maximum detection range in a given environment under just the right circumstances but be less detectable on average in that environment than a larger object with less contrast and a smaller maximum detection range. Also note that just as knowing the maximum detection range does not tell us the effective sweep width, knowing the effective sweep width provides no information about the maximum detection range. However, knowing the effective sweep width gives us a way to reliably estimate POD since it is a measure of expected detection performance.

Knowing the maximum detection range does not help with POD estimation.

The effective sweep width may be thought of as the width of the swath where the number of objects ***inside*** the swath that ***are not detected*** equals the number of objects that ***are detected outside*** the swath. That is, when one gets to the point where the number of objects missed within a certain distance either side of track (areas B above the curve in Figure 2) equals the number that are detected at greater distances from the searcher's track (areas A below the curve in Figure 2), then one has found the effective sweep width. This is the definition that will be used for the simplified data reduction procedures described later in Part II.

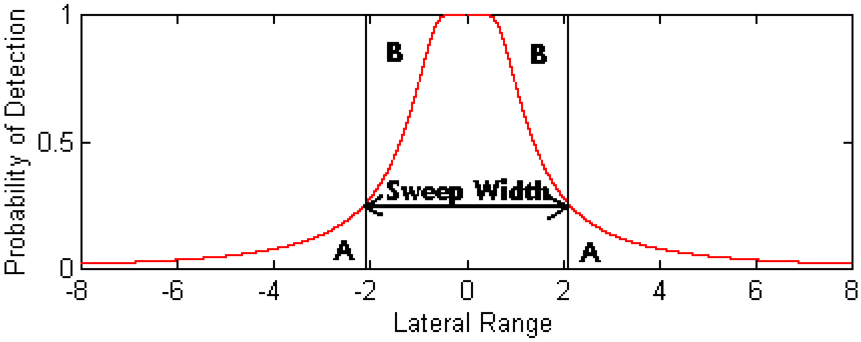

Figure 2. A Lateral Range Curve. The number of missed detections (B) inside the effective sweep width equals the number of detections (A) that occur outside the sweep width.

For the more mathematically inclined who are familiar with calculus, the effective sweep width is also numerically equal to the total area under the lateral range curve down to the horizontal axis of the graph. One way to estimate effective sweep width from experimental data is to analyze the detection/non-detection results to first get an estimate of the lateral range curve and then compute the area under that curve. However, this is significantly more difficult than the data analysis method chosen for the procedures that are described in Part II.

Finally, if detection were perfect (100% POD) within a swath of width ***W*** and completely ineffective (0% POD) outside that swath, then the effective sweep width would be ***W***. That is, if a "clean sweep" were possible with no detections outside the swept swath, the width of the swath would be, by definition, the effective sweep width. Sensors with perfect detection within some definite maximum detection range and perfectly sharp cutoffs at that definite maximum detection range do not exist. However, this perspective on sweep width reveals another important property: The effective sweep width can never exceed twice the maximum detection range. It is almost always considerably less than that value, but just how much less depends on the search situation and all the factors affecting detection. It is not possible to establish any general mathematical relationship between maximum detection range and effective sweep width.

Figures 3, 4, and 5 below illustrate the concept of effective sweep width in another way. The black dots in Figure 3 represent identical search objects that have been scattered randomly but approximately uniformly over an area. The distribution is "uniform" because in any reasonably large fraction of the area there are about the same number of objects as in any other fraction of the same size. The distribution is "random" because the exact location of each object was chosen at random to avoid producing either a predictable pattern or a bias favoring one portion of the area over another.

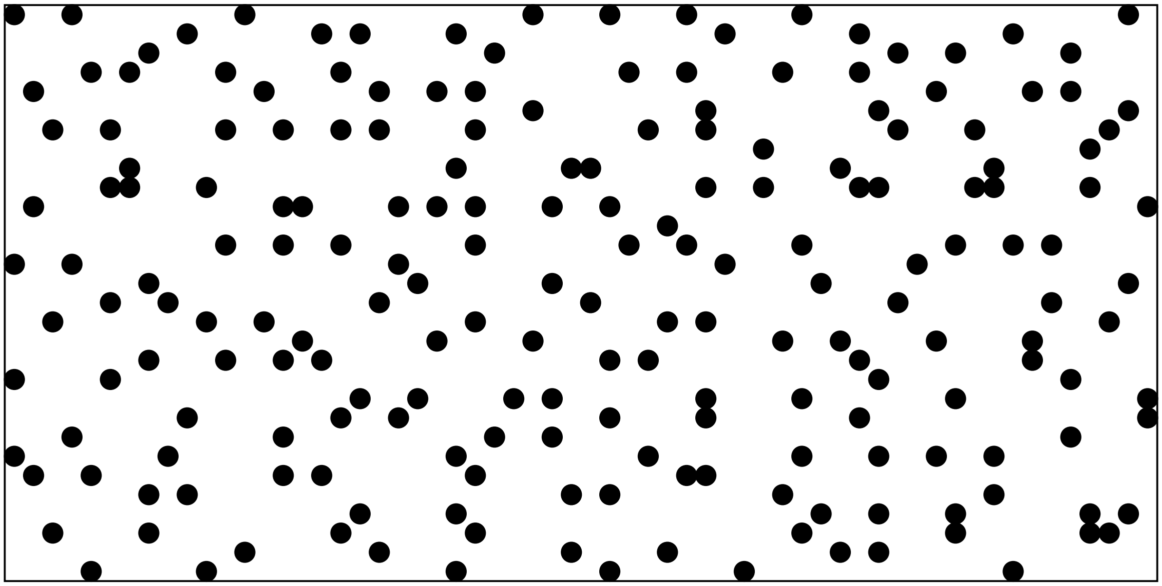

Figure 3. A Uniform Random Distribution of Search Objects

Figure 4 shows the effect of a "clean sweep" where all of the objects within a swath are detected and no objects outside the swath are sighted. In this case the effective sweep width is literally the width of the swept swath. A total of 40 objects lay within the sweep width and all 40 were detected, as indicated by the empty circles. A "clean sweep" where the searcher/sensor is 100% effective out to some definite range either side of the track is unrealistic, but it serves to illustrate the sweep width principle.

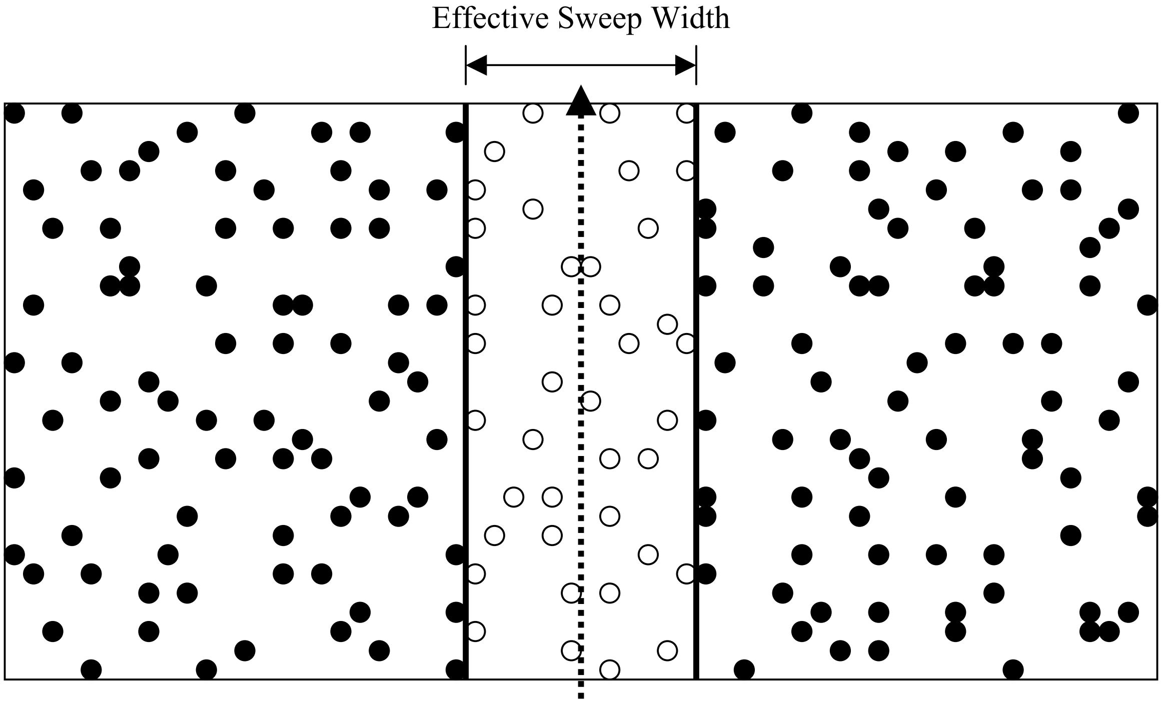

Figure 4. Effective Sweep Width for a Clean Sweep.
Dotted line represents searcher's track.
Number missed within sweep width = 0.
Number detected outside sweep width = 0.

Figure 5 represents a more realistic situation where objects are detected over a wider swath, but not all the objects within that swath are found. In this case, the total number of objects detected was also 40 but instead of making a "clean sweep," the detections are more widely distributed. However, because in both cases 40 objects were detected over the same length of searcher track when the number of objects per unit of area was also the same, we say the *effective* sweep widths for both cases are equal.

Effective sweep width is a measure of detectability because, in a hypothetical situation where the average number of objects per unit of area is known, if we know the sweep width we can accurately predict how many of the objects will be found, on average, by single searchers on one pass through the area. As we will show later in this report, knowing the sweep width for a given combination of sensor (e.g., visual search), search object (e.g., a person) and environment (weather, terrain, vegetation, etc.) will allow us to accurately predict the probability of detection for any search conducted under those or similar conditions.

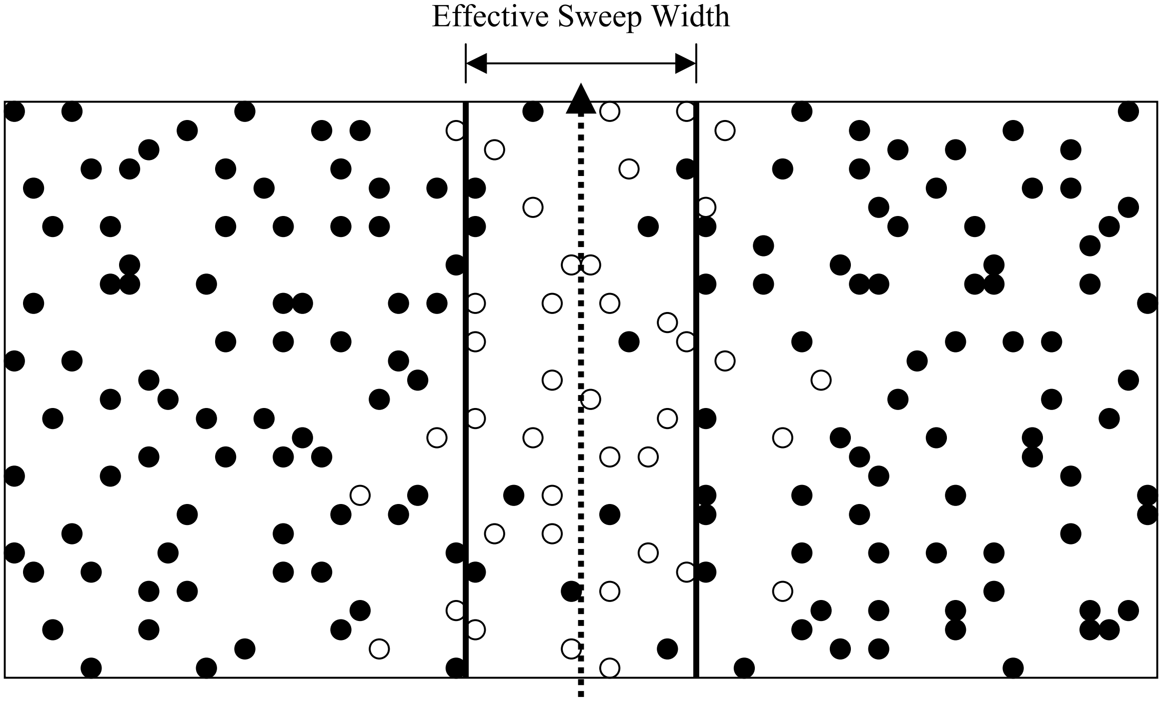

Figure 5. Effective Sweep Width.
Dotted line represents searcher's track.
Number missed within sweep width = 11.
Number detected outside sweep width = 11.

Figure 5 illustrates the property of effective sweep width we will use to reduce the detection data obtained from experiments to a single value characterizing detectability. Specifically, when the width of a swath is found where the number of undetected objects inside the swath equals the number of objects detected outside that swath, then the width of that swath is called the effective sweep width.

Appendix A contains further clarification of the sweep width concept. An analogy is drawn between searching and sweeping floors. This analogy is used to provide a simplified non-technical explanation of effective sweep width.

To summarize: Sweep width is the metric used for estimating an object's detectability for a given search scenario. It is a single number having the dimensions of length. It may be derived from the lateral range curve that is produced from detection/non-detection data of an experiment that is appropriately designed and performed. It has the property that, on average, the number of search objects detected outside the effective sweep width is numerically equal to the number of search objects not detected within the effective sweep width (Figure 2 and Figure 5). It is used together with the amount of effort expended in a given area (e.g., a search segment) and the size of the area to get an objective, reliable, and accurate estimate of POD.

Part II – Procedures For An Experiment

In order to make use of the theory outlined above (where concepts are described using an assumed uniform search object density over an area), a link has to be established with the world of the person conducting a search. The link between theory and practice is an experiment that satisfies the requirements of the theory while acknowledging enough of the messy real world environment to produce useful results. The experiment can control the distribution of search objects, the type of object, the type of terrain and vegetation, and to a certain extent the weather (given some scheduling flexibility). The following sections discuss the structure of such an experiment and the analysis of the resulting data that are needed to arrive at an estimate of effective sweep width for a given set of conditions.

Appendix C lists the steps described below in a condensed outline form.

ESTABLISHING THE SEARCH SCENARIO

Detectability depends on the particular circumstances and environment of the searcher/search object interaction. When developing an experiment to estimate effective sweep width the focus should be narrowed to an environment, search object, scanning technique, and search speed that is very specific, yet typical, for the search organization conducting the experiment.

Certain practical limitations should be observed when performing detection experiments. The temptation to conduct an experiment that is overly comprehensive and attempts to vary several factors during the course of the experiment should be resisted. Analysis becomes difficult and the sample size of the data for each situation or combination of factors is reduced. The search area should be limited to one type of terrain/vegetation for each experiment. Radical changes in weather should be treated as separate experiments. Two or possibly three distinct types of search objects are sufficient for one experiment although minor variations in appearance within search object classes are acceptable.

If the objective of the experiment is to estimate search performance using current techniques, the searchers should be briefed using the standard operating procedures of the team conducting the experiment. However, if the objective is to evaluate or develop, for example, a new scanning technique for individual searchers to use, the pre-experiment briefing should be carefully constructed to reflect the exact method of scanning desired.

These experimental techniques should be applied only to individual resources capable of independent operation. On the ground, this usually means individual searchers. In particular, establishing effective sweep width values for teams of searchers should not be attempted. For vessels and aircraft, the standard search configuration, number of crew, etc. should be used unless the objective is to evaluate the impact of changing some standard parameter.

Selecting An Area

It is necessary to select an area that has the terrain/vegetation type that closely resembles a type of physical environment typically encountered by search units. The area should be fairly consistent over a plot of land that will allow a search track of sufficient length. The length of track should satisfy both of the following criteria:

- It should take searchers moving at normal search speed at least one but not more than four hours to complete the track. Note that this ***does not*** imply there should be a large range of search speeds in any one experiment. All searchers in a given experiment should move at about the same speed and that speed should be whatever is normal for a typical searcher in that environment. This ***does*** mean that different tracks of different lengths should be used for different experiments in the same terrain with searchers from the same pool, but that none of the experimental tracks should require less one hour at normal search speed or more than four hours at normal search speed.
- The track length should be between 30 and 120 times the largest average maximum detection range (AMDR) found for the objects that are to be used in the experiment. (See "Establishing Average Maximum Detection Range" below).

The search track can be laid out along a trail or cross-country. The cross-country track is probably more realistic as searchers on a trail are taught to concentrate on the trail itself. Laying out the track along a trail is easier from a logistical standpoint. The length of the track in terms of both time and distance is important as it should permit the searcher to get into the searching "frame of mind" and provide enough length for adequate spacing of search objects. One hour is probably the minimum time needed for producing useful data. Four hours is probably the longest practical length for any single day. If the first searcher left at 07:00 a.m. in the morning and searchers were sent down the track at regular intervals over the next eight hours, the last searcher would not complete the track until 19:00 (7:00 p.m.) that evening.

Selecting Search Objects

Search objects used in the experiment should appear similar to actual search objects or clues that might be present if a person were lost or missing in an area similar to that where the experiment is to be conducted. These can be as simple as articles of clothing or other items a typical person might lose or discard, or homemade "mannequins" constructed from inexpensive materials. Most anything that is roughly the same size and shape of a person in a resting position (sitting or reclining) will do for a "mannequin," especially if the texture and color of the surface area is typical of how a person would appear. Ideally two or at most three types of objects are placed along a search track to prevent the searcher from becoming too focused on a particular object. This type of searching is an estimation of the visual search capability for stationary objects only. The objects will be non-responsive and will not move about. These estimations of effective sweep width are to be used in the search for clues and for when the subject is assumed to be non-responsive. The resulting effective sweep width estimate is conservative in that it provides a minimum but realistic value. The effective sweep width for a responsive subject who wants to be found will normally be greater.

Establishing Average Maximum Detection Range

A distance called here the Average Maximum Detection Range (AMDR) will be used to ensure that search objects are placed at a great enough lateral range. The lateral range of at least some of the search objects must be great enough so that they are not detected or are very rarely detected. AMDR can easily be determined for each search object type by means of the following technique. For each object type, place an example at a location judged to be representative of the conditions in the search area as a whole, usually on the search track. Beginning at the object walk away from the object until it is no longer visible. Keep track of the number of paces of known length (sometimes called a tally) and use these to estimate the distance. Record the distance to this point. Continue away from the object for another 50 to 100 meters. Travel clockwise around the object about 45 degrees and move toward the object until it is sighted. Record the distance from this point to the object by counting the paces to the object from the point of sighting while returning to it along a straight line. Then move away from the object at 90 degrees to the right of the initial departure, which should be about forty-five degrees from the direction of approach just used. Again measure the distance to the point at which the object disappears. Repeat this sequence until eight detection distances are established, as shown in Figure 6.

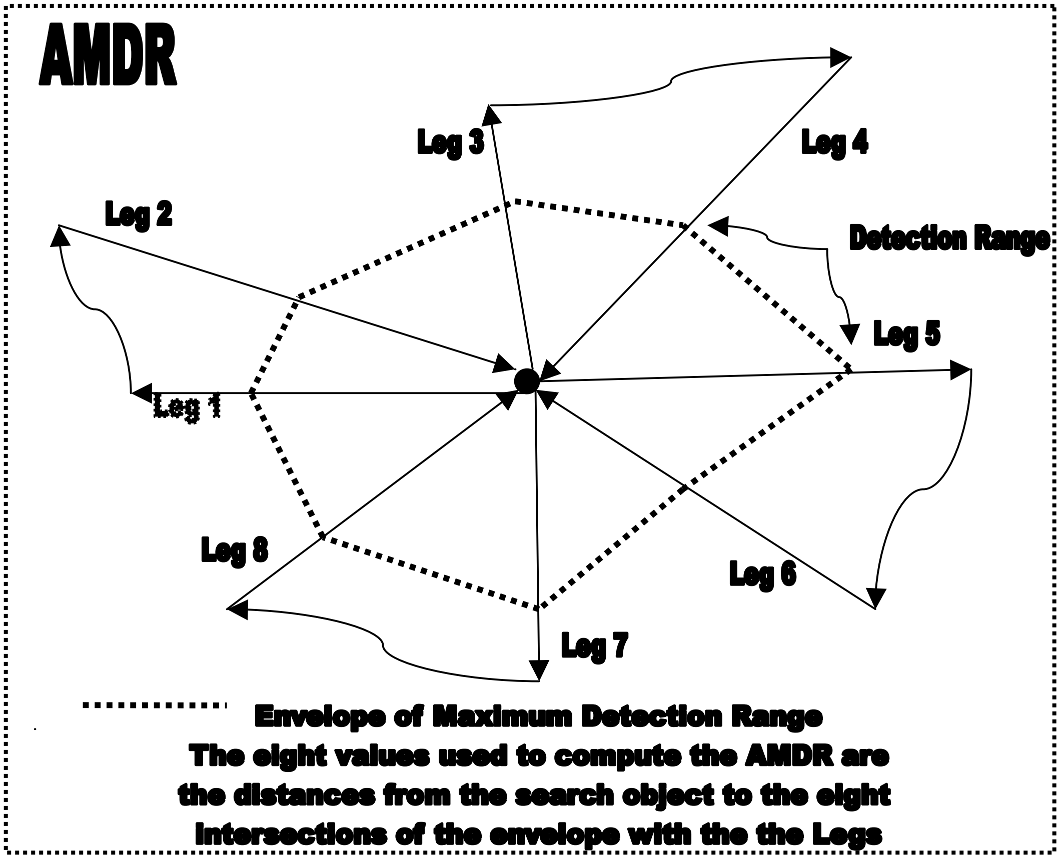

Figure 6. Method for Estimating Average Maximum Detection Range

Four of the distances in Figure 6 will have been measured while moving away from the object and four measured while moving toward the object. These distances can be easily estimated by having calibrated the length of one's pace and knowing the number of paces traveled. AMDR is the average of these eight distance values. The AMDR should be measured as accurately as possible. The AMDR should also be reevaluated for each search object and whenever there is a change in the environment sufficient to affect searcher visibility.

The calculation of AMDR requires that the person estimating the value make a reasoned judgment about the effects terrain and vegetation have on the resulting distance. For example, when moving away from the object, the searcher may descend into a small hollow that obscures the line of sight to the object. However, if the object was still clearly visible just before this descent and the searcher believes it will still be quite detectable when ascending the far side of the hollow, the searcher should continue away from the object. If the searcher is able to see the object after coming up out of the hollow, then the searcher should continue away from the object until it can no longer be seen. On the other hand, if the searcher is reasonably sure there is little to no chance of re-acquiring the object visually at a greater distance, there is no need to proceed further. AMDR will mostly be used as a guide for placing search objects. However, it may eventually have other uses in land search and therefore may be involved in a secondary analysis of the detection data that is generated.

LAYING OUT THE SEARCH TRACK

Track on a Trail

If possible (for a more efficient use of the data recorders, searchers, and the test manager) select a circuit trail that ends near where it begins or one that connects two staging areas that are easily accessible. As a way to keep track of searcher positions and times during the experiment, it will be necessary to establish a number of marked reference points along the trail. These reference points should never be more than 150 meters apart. Using a GPS device[1], record the trail using the waypoint function, establishing waypoints at frequent regular intervals and at every significant bend or turn in the trail. From the collected waypoints, select reference points at every 100 to 150 meters. A surveyor's flag or other easily placed item, marked with a numerical or alphabetic label, should be placed at each reference point.

Cross-country Track

To construct a cross-country trail select a route on a topographic map and establish reference points at intervals of 100 to 150 meters. The cross-country track should be a loop if possible in order to effectively use the time of the data collectors and searchers or it should connect two easily accessible staging areas. Either enter the reference points from a map plot of the track into the GPS device as waypoints and lay out the track on the ground using GPS navigation or follow a track on the ground and establish GPS waypoints while traveling. The trail should be flagged with surveyors tape placed frequently enough (every 10 to 15 meters) between the reference

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[1] A GPS unit has a nominal accuracy of ± 15 meters. If enabled for the Wide Area Augmentation System (WAAS) or a local differential GPS system, the accuracy is improved to better than ± 3 meters.

points so that the trail is easy to follow. The reference points should be marked with a labeled surveyor's flag or other easily placed item as a control for the data collectors and searchers. After laying out the trail on the ground, retrace the trail using the GPS device to accurately record the track and the reference point positions. The GPS location is more accurate than the location derived from the plotted map position.

SEARCH OBJECT LOCATION ZONES

Number of Search Objects

The track length and number of search objects used will be based on several factors. The total number of search objects should be between ten and forty. The shortest track length (30 times the AMDR of the most visible search object type) can only accommodate 10 objects and it will require the longest track (120 times the same AMDR) to accommodate 40 objects. In all cases, the number of objects should fall between the maximum number the track length can handle, based on the guidance provided below, and the minimum of 10. This will help prevent searchers from guessing how many objects have been deployed for any given experiment.

Another factor affecting track length is search speed. It should take searchers moving at normal search speed at least an hour, but no more than four hours, to complete the trail. If the normal search speed for a given situation is 0.5 miles per hour, then the trail should be at least 0.5 miles long and not more than 2.0 miles long. If a conflict occurs between the time to complete the trail and the number of search objects that can be placed, priority should always be given to having a track long enough to accommodate a minimum of 10 search objects.

Another consideration is the availability of searchers and data recorders. It is desirable for each experiment to generate at least a few hundred detection opportunities. If there are 10 objects, 30 searchers and sufficient data recorders to cover the searchers, then there will be 300 detection opportunities. On the other hand, if there are sufficient personnel available to accommodate only 10 searchers, it will require 30 objects to generate 300 detection opportunities.

Selecting Random Locations

Search objects should be separated sufficiently so that when a searcher reports a detection it will be possible to know which object was sighted based only on the searcher's location and the approximate direction and distance from that point to the object. The searcher's location is determined by assuming a fairly uniform progress between the labeled reference points along the track. Search objects should be placed at an off-track distance of up to at least one and a half (1.5) times the AMDR for the most visible object used. The distance along-track should be centered (± the AMDR distance) around points separated by an average of three (3) times the AMDR for the most visible search object.

The distances along the track and to the sides of the track should be random (series of random numbers can be obtained from many internet sites such as http://www.random.org/). If more than one object type is used in one experiment, the type of object for each position should also be chosen at random.

The detection data from the first day of the experiment should be reviewed for detections at various lateral ranges. The AMDR value is used in the experiment only to place the search objects. If the search objects at the greatest lateral ranges are detected at a frequency of greater than 10% of the time then the off-track distance should be modified based on a multiple of 2.0 times the AMDR value and the search objects repositioned based on this new value for the next set of searchers.

An Example

Suppose a 6000-meter (6 km) track with two types of search objects was selected. The AMDR was determined to be 75 meters for the least visible object and 100 meters for the most visible object. Three times the AMDR of the most visible object is 300 meters. This will result in a search object location on the average of every 300 meters along the track. All locations need not be filled with search objects.

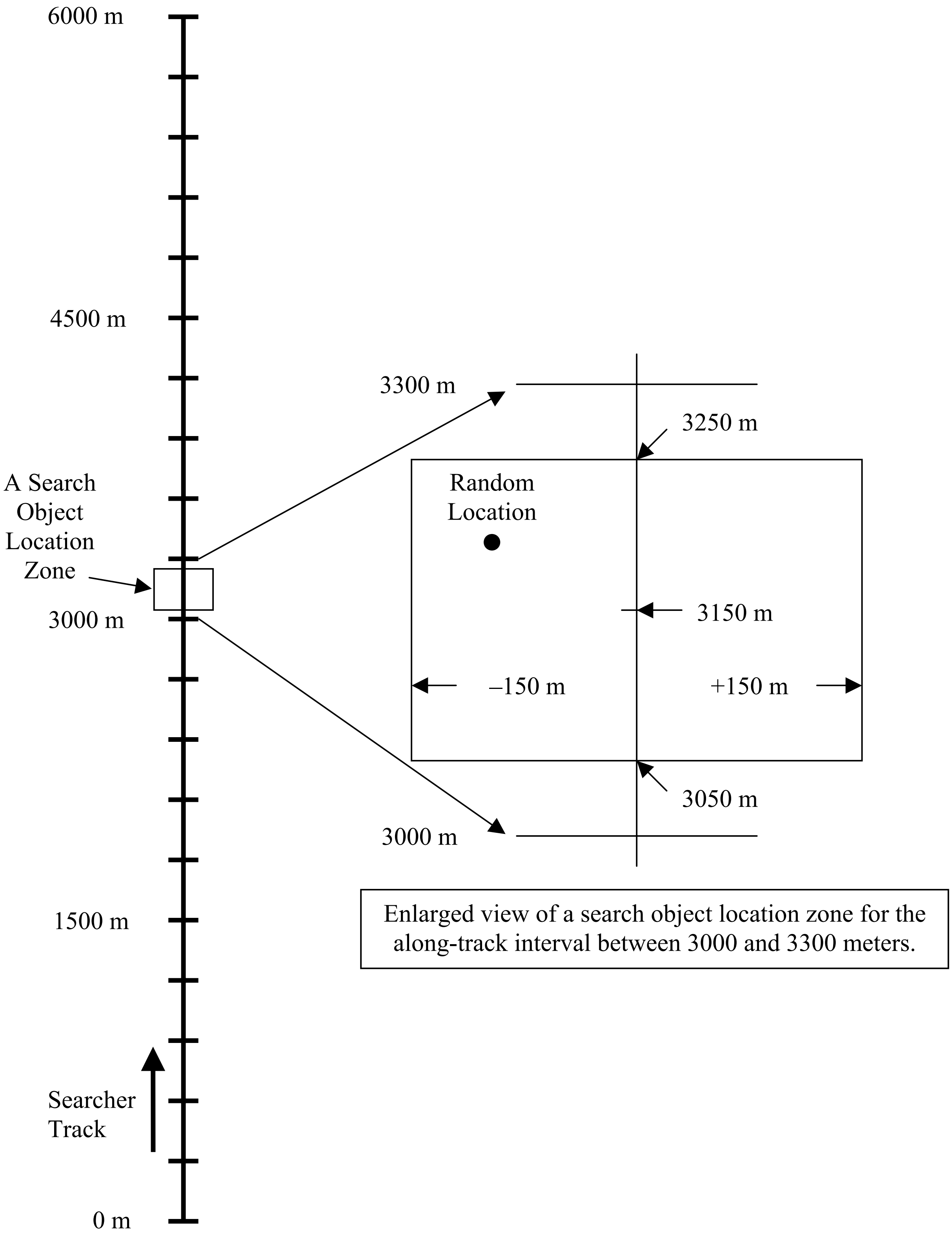
To determine the location of each search object we need an along-track distance and a cross-track or off-track distance. For this example, place the along-track position within ±100 meters (the AMDR of the most visible object) of the center of each 300-meter interval along the track. These center points will be at 150, 450, 750, …, and 5850 meters from the starting point. To calculate object positions, obtain one random number in each track interval between 50 and 250, 350 and 550, 650 and 850, … 5750 and 5950, until the track-line length is exhausted.

The cross track distance for the search object placement will be between 150% of the AMDR (of the most visible object) to the left of the track and 150% of AMDR to the right of the track. In this example the value will be between -150 meters (left) and +150 meters (right) of the track-line, rounded to the nearest whole meter. The two types of search objects in this example are called Type A and Type B. If the off-track distance is an odd number of meters, a type A object will be used, otherwise a type B object will be selected. Table 1 shows the first five entries obtained following these rules.

Search object location	Track interval	Along track location	Cross track location	Search object type
Location #1	50 to 250	141 m	82 m right	B
Location #2	350 to 550	542 m	47 m left	A
Location #3	650 to 850	786 m	69 m right	A
Location #4	950 to 1150	1033 m	22 m left	B
Location #5	1250 to 1450	1320 m	45 m left	A
More Locations	To end of track	Next location	Next location	Next search object type

Table 1. Example of Search Object Placement Locations

Figure 7 shows a schematic representation of how search object location zones are defined.



Enlarged view of a search object location zone for the along-track interval between 3000 and 3300 meters.

Figure 7. A Schematic Diagram for Search Object Placement

A new setup using a new set of random numbers would produce completely different locations from those shown in Table 1. Short runs of similar numbers are common in series of random numbers and should not cause concern. Random numbers are used to determine the search object locations to avoid predictable patterns or biases in the placement of search objects.

Although data from just one experiment may provide a usable result, several experiments performed under essentially the same conditions will be required to gather enough data for a good sweep width estimate and confirm that the first experiment's results were reasonably accurate. Over the course of several such experiments, the distribution of search objects with respect to lateral range will become more uniform when the data from those experiments are combined.

There are some considerations worth noting.

- If there were three search object types instead of two, the selection of the type for a given location would be made by selecting a whole number between one and three at random and independently of the selections made for other locations.
- The "even-odd" distance technique is a shortcut that may be used for making a random choice between two alternatives, but it may be used only once. It would be inappropriate, for example, to use it to determine both search object type and placement to the left or right of track. Such a scheme would result in all objects of one type falling to the left of track while all objects of the other type would fall to the right of track.
- It is usually wise to use a separate string of random numbers for each data type, especially for strings that are generated by computer-based pseudo-random number algorithms. For example, it would be appropriate to use one set to choose along-track locations, another to choose lateral ranges (cross-track locations), and another to choose search object type. This will usually prevent unintentional correlations from developing among the various items being chosen due to weaknesses in the random number selection process.

SEARCHERS

Time Intervals Between Searchers

Searchers and their recorders should be dispatched at intervals that are long enough to minimize the chances that two successive searchers will come within sight or hearing (for normal levels) of one another. The length of the interval can vary greatly depending on search speed and the nature of the environment. A slow search speed in rough but open terrain would probably require the longest interval between searchers. If a loop track is used, searchers may be started in opposite directions around the loop simultaneously under some circumstances. If this is done, searchers will meet somewhere along the track. As long as each searcher meets only about one other searcher per hour, the amount of time they are in sight of one another is limited to a few minutes, and they do not exchange information about search object locations, numbers found, etc., the validity of the data should not be harmed and the amount of data collected can be doubled as compared to using only one direction of travel at the same rate of dispatch. The same is true of tracks connecting two staging areas.

Number of Searchers

When the experiment is intended to produce the average sweep width for the population of searchers who might be called upon for an actual search, a sufficient number of different searchers from the population will be needed. For smaller organizations, this might mean including all searchers. For larger organizations or groups of smaller ones working together, this might mean using only a fraction of the available searcher population for a given experiment. Probably no more than 30 to 40 searchers per day can be accommodated. When fewer searchers are available, it may be necessary to either lengthen the searcher track and place more objects, or run the experiment multiple times over several days in the same environment with the same searchers, being sure to relocate the objects to new randomly selected positions, preferably along different trails, between experiments. The critical element is the number of detection opportunities each experiment will provide for each major variable, as discussed below.

NUMBER OF DETECTION OPPORTUNITIES

The three major variables affecting detection are the search object, the searcher/sensor, and the environmental conditions. Since each experiment automatically addresses the environmental conditions at the time and place of the experiment, significantly different environments must be addressed by separate experiments. For the remaining two variables, in any given experiment the number of detection opportunities for each object type used will be the product of the number of those objects placed in the experiment area and the number of searchers.

Sufficient numbers of detection opportunities are required in order to obtain a good estimate of the effective sweep width. Provided the randomly generated cross-track distances are reasonably uniformly distributed over the desired range of values (this will normally be the case but random number sources can occasionally produce strings of similar values rather than a uniformly distributed spread of values), an experiment that produces somewhere between 250 and 500 detection opportunities for a given type of object should normally produce a usable estimate of the sweep width for the combination of object type, searcher population, and environmental conditions at the time and place of the experiment. However, several experiments should be done under essentially the same conditions to establish full confidence in the resulting sweep width value. Some examples of how to obtain 300 detection opportunities are:

- Ten searchers and 30 objects of each type.
- Thirty searchers and 10 objects of each type.
- A two-part experiment under the same environmental conditions with 10 searchers and 15 objects of each type, the objects to be repositioned at random between parts.

SET-UP AND RECOVERY

Placement Of Search Objects

On an U.S. Geodetic Survey 1:24,000 topographic map the track-line can be plotted using the standard Universal Transverse Mercator (UTM) grid found on most topographical maps used for planning land searches. (Plotting is easier if the map is enlarged 400% to a scale of 1:6,000.)

This permits positions to be determined in meters from a reference point. The along-track and cross-track distances of the search objects are plotted in relation to the searcher track. The UTM coordinates are then determined for each plotted search object location. The UTM coordinates of the location are entered into a handheld GPS device as waypoints. A track constructed for the waypoints can be approximately followed using the GPS device to place the search objects.

Two or more persons will be required to set the search objects at their selected locations—a "pointer," one or two "spotters," and possibly a few others to help carry the objects. The "pointer" will follow the track-line using the search object waypoints and the compass function on the GPS device to indicate the direction to the search object waypoint. The compass function on the GPS device can aid in selecting the Closest Point of Approach (CPA) point when it is set to reflect the direction to the waypoint. In this mode the pointer will be at right angles to the direction of travel at the point where the referenced search object waypoint is passed most closely. The "pointer" will then stand on the track at the CPA of the search object and point in the direction where it is to be placed. The "spotter" will then travel a distance up or down the track to a point where any disturbance of the side of the track is least likely to be noticed and far enough from the object location to give no helpful clue to a searcher if it is noticed. The "spotter" will pace off the required lateral range either right or left of the track and then travel parallel to the track until they are at a point opposite the "pointer" in the direction he or she is pointing. The "spotter" will then place (or "spot") the search object at this pre-selected location without regard to whether it is thought to be visible from the track. As each object is placed, the "pointer" will place a check or other mark next to the object's location on the map or the corresponding entry in the search object location log (see Appendix B).

If a compact and easily carried range-finding device is readily available, there is an even better method for placing search objects when the vegetation and terrain permit. In this method, the "pointer" performs the same functions as just described. However, the "spotters" would travel parallel to the track keeping always to their assigned side while carrying range finders and the search objects to be placed on that side of the track. Each time the pointer stopped and pointed, the appropriate "spotter" (left or right) would proceed to the line along which the "pointer" was pointing and then proceed to the correct pre-determined lateral range.

No attempt should be made to improve or diminish the object's visibility. The obscuring of objects by vegetation, rocks or terrain is a natural part of the difficulty of detecting objects. Care must be exercised to not disturb the trail and leave tracks or other clues near the search objects that would give away their locations. Search objects located very near the searcher track can be accurately placed without leaving the track by using a marked pole. If a location falls at a sharp bend in the trail resulting in ambiguous lateral range because it can be seen from both legs of the track, then that location should be left vacant.

Recovery Of Search Objects

At the conclusion of the experiment the search object waypoints must be retraced to recover the objects. If an object is not found at the location where it was set out and the time when it went missing is not known, the data relating to that object should not be used in the analysis.

If the experiment is being done in two parts, the recovered objects must be placed at new pre-determined waypoints for the second part. Otherwise, they should be removed and either discarded or stored for use in future experiments.

SEARCH DATA AND VARIABLES

Recording Data

Variables that impact the detection process are in general related to the search object, the searcher, and the environment. Exactly which data are collected will depend largely on local conditions. It is important to collect and record variables beyond the minimum required for estimating sweep width from a single experiment. Variables that are not considered important when small data sets are collected may begin to stand out as more detection data is accumulated. Small, short term experiments are carried out under a very limited set of conditions may not allow a variable's full impact to be felt because only a small fraction of the of the variable's possible range is represented in the data. For instance if there was either no or steady precipitation during data collection, no precipitation effect would be noticed. However, when compared to other experiments where precipitation was different, the effects might be quite noticeable. The variables collected should be described and recorded in enough detail to allow other investigators performing secondary analyses to understand and quantify the conditions under which the data were collected. Some variables that should be considered include:

Search Object

- Size
- Color
- Shape
- Contrast with background

Searcher

- Experience
- Training
- Eyesight (acuity and color blindness)
- Age
- Height
- Time on task (fatigue)

Weather

- Precipitation (type and intensity)
- Temperature
- Clouds

- Wind
- Sun angle
- Visibility (short range effects such as smoke or dense fog)

Terrain

- Average slope along the track-line
- Average slope across the track-line
- Narrative description with photographs (Example of a narrative description for an area in eastern Ohio: "The terrain is characterized by rolling hill tops at the upper elevations cut frequently by steep ravines which may contain sandstone cliffs and caves. Elevation changes are on the order of 150 to 200 feet from hilltop to valley floor. Valleys are narrow with rapidly flowing streams.")
- Roughness (small scale, covered with boulders or smooth)

Vegetation

- Narrative description – provide photographs (eastern hardwood, northwest conifer, etc.)
- Type of canopy
- Type of understory
- Density (effects on travel and movement of the searcher)
- Line of sight (limits on line of sight from searcher eye level)

Instructions To Searchers

Each searcher must be briefed prior to starting on the searcher track. The briefing should ensure that all searchers are using scanning methods that are appropriate to the experiment being conducted. Emphasize that the search is not a contest either among searchers or between searchers and experimenters. What is desired for data collection is detection data for a typical search, not a perfect search. If every searcher found every object, the experiment would be repeated using a greater multiple of AMDR to calculate object locations and the data from the experiments would be combined.

1. Explain that the overall objective is to measure how detectable the search objects are. The purpose of the experiment is to generate detection opportunities. The record will reflect detections and misses and analysis of that data will lead to a "detectability index" that will be useful for estimating POD and making decisions on how, when, and where to deploy searchers during each operational period of a real search under similar conditions.
2. Describe the area and track.
3. Explain that the detection data is for an area search, not a trail or "hasty" search. The trail is used only as a convenient guide. Searchers should scan the area on both sides of the track out to as far as they could reasonably see a person.

4. Either describe the nature of the search objects or instruct searchers to report anything out of the ordinary. Record which was done, along with any descriptive information provided. All searchers should receive identical instructions.
5. Inform searchers to scan in their normal manner, e.g., looking left, right, up, down, front, and back.
6. The searcher should be instructed to move at a steady pace typical of normal searching.
7. Explain that this is a detection experiment and that it is not intended to simulate all aspects of an actual search. Therefore, searchers will be sent down the test track individually, not through the area in teams. They should stay on the designated track. They should report any object they detect that might be of interest in the context of the experiment. The rule of thumb is that the searcher should report a detection if he/she is either certain of the object's identity or is uncertain and would normally investigate further, whether by leaving the track to get closer or by using binoculars. However, searchers are to do neither of these things as the experiment is designed for initial detection data, not confirmed sightings. With the data being gathered, post-experiment analysis will reveal any "false positives." Objects that are clearly not part of the experiment need not be reported, even if they might otherwise be regarded as possible clues in a real search.
8. When a possible detection is made the searcher should point in the direction of the object and report to the data collector what they see, the clock bearing relative to the searcher's direction of travel along the track (ahead is 12 o'clock), and an estimated distance.
9. The searcher should be asked not to discuss their experience with the experiment, and especially not search object locations, with anyone, especially searchers who have not yet gone through the track, until all searchers have completed the experiment.
10. It should be emphasized that the data collected will not be used to assess individual searcher performance. While no one can prevent searchers from maintaining a mental tally of their detections, searchers will not be told how many objects are present until after the last participant has completed the track. If searchers want to know how "well" they did, no answer can be given except to say that if they did exactly what they were asked to do and did not "cheat" by either prying information out of an earlier participant before completing the track themselves or giving information to someone else before that person had completed the track, then they performed perfectly.

Instructions To Data Recorders

The data recorder is the key to collecting a valid data set on detections and misses. The data collector should be cautioned not to assist or provide any form of direction or hints to the searcher—either consciously or unconsciously. Data recorders should maintain a strict "poker face" at all times with respect to their body language. Time and approximate distance from a reference point will be recorded for each detection. (If enough GPS units were available for all of the data recorders to carry one, then the actual time and position of each reported detection could be recorded.) The recorder must record the <u>TIME</u> first.

1. The data recorder will follow the searcher and record all relevant information, comments, and data. Accurate recording of time is essential to the accurate reconstruction of searcher/search object interactions.
2. The data recorder will be furnished a map of the search area and search track. The map will be marked with reference points and the distances between them.
3. The data collector will have each searcher fill out a personal profile sheet prior to entering the experiment area.
4. The data collector will complete the data sheet header information.
5. During the experiment, the data collector will record on the data sheet the:
   a. Start time
   b. Time at each waypoint
   c. Time of each announced detection
   d. Searcher's estimated clock bearing to the detected object
   e. Searcher's estimated distance to the detected object
   f. The estimated position at the time of detection on a map of the search track
   g. Searcher description of what caused them to call a "detection"
   h. General comments of searcher
   i. End time
6. Fill out any searcher debriefing comments
7. Do not tell the searcher the number of search objects either before or after the exercise. That information cannot be made available until the end of the experiment.

DATA ANALYSIS

Reconstruction

Detection data reconstruction begins with constructing a plot on a map of the search track route and the search object locations for each searcher individually. Annotate this plot with the time at each reference point from the Detection Log (Appendix B). The next step in the process is to estimate the location of the searcher by noting the position at the time of detection recorded on the data recorder's map. This location can be cross-checked by interpolating the time of an announced detection between the times at the reference points preceding and following that time. The assumption is that the searcher's speed is constant between any two reference points. The estimated location is plotted on the map and a line representing the "clock bearing" from the Detection Log is drawn on the map. Using all of the information entered on the Detection Log at this "detection" location (clock bearing, estimated distance, and description) a judgment is made as to the validity of the detection. False detections may be noted but not used in the analysis. The known lateral range for the object detected is recorded.

Detection Opportunity Summary

As the reconstruction of each detection opportunity proceeds, a summary table that lists each detection opportunity individually with the appropriate supporting information on object description, terrain, weather, and searcher is assembled. Variables can either be represented by actual values such as temperature or by an index value such as search object type 1, 2, or 3. A suggested summary is located in Appendix B with the other forms. The goal is to capture all of the raw information needed not only for the immediate analysis, but to preserve the data for future research and analysis. At a minimum, the following information should be listed:

- Search object type
- Detection/non-detection
- Lateral range
- Terrain/Vegetation descriptors (terrain type, type(s) and density of vegetation, etc.)
- Weather descriptors (cloud cover, precipitation, wind, sun angle (time of day), etc.)
- Searcher descriptors (e.g., height, training level, experience level, etc.)

Estimating Effective Sweep Width

The task of estimating the effective sweep width will be reduced to a purely graphical process by making use of the properties of sweep width. Figure 8 below is the final result of this process. The property that is used to construct the graph is the fact that the number of detections for objects more than one-half of the sweep width from the nearest point on the searcher track is numerically equal to the number of missed detections for objects with smaller lateral ranges. Using the data from the Detection Opportunity Summary and beginning at the maximum lateral range, the cumulative ***detections*** versus lateral range are plotted on a graph, working back toward zero lateral range. On the same graph, the cumulative ***non-detections*** versus lateral range are plotted beginning at zero lateral range and working out to the maximum lateral range. This will provide a pair of curves. One is a curve that increases with increasing lateral range as the cumulative number of ***non-detections*** increases with off track distance. The other represents the increase in the total number of ***detections*** as lateral range decreases. It will have its maximum value near zero lateral range and its minimum value at the maximum lateral range. The lateral range where the two curves cross is one-half of the effective sweep width.

In this example scenario, there were 12 search objects of type "A" used in the experiment and 32 searchers for a total of 12 × 32 = 384 detection opportunities. There were a total of 179 detections and 205 non-detections for the type "A" objects. Note that 179 + 205 = 384 so all detection opportunities were accounted for. Also note that the data points were plotted without regard to whether the object(s) at the given lateral range were to the right or left of track. The estimated effective sweep width W was 36 meters (18 meters either side of the searcher's track) for this type of object.

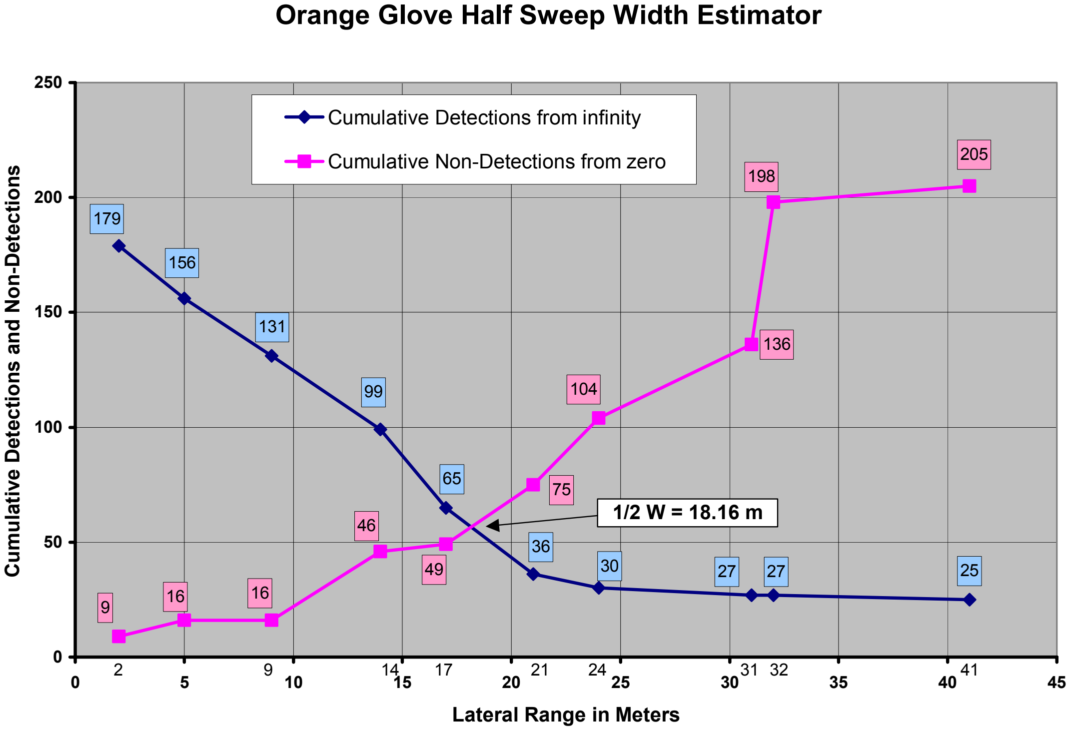


Figure 8. Estimating Sweep Width From Detection Data

The graph was constructed as follows:

- For detections, there were 25 detections of the object at 41 meters from the searcher track. There were then 2 detections of the object at 32 meters for a cumulative total of 27 detections counting from 41 meters in toward the searcher track. There were no detections of the object at 31 meters off the track (recall that the objects are far apart in terms of along-track distance) so the cumulative total remains at 27. There were three detections of the object that was 24 meters off track, bring the cumulative total to 30. This process was continued and the corresponding points plotted until the minimum lateral range of 2 meters was reached and all 179 detections were accounted for.

- For non-detections, there were 9 non-detections or “misses” at a lateral range of 2 meters. Working away from the searcher’s track the object that was 5 meters off-track was missed 7 times, bringing the cumulative total of non-detections up to 16. There were no misses for the object that was 9 meters off-track, so the cumulative total non-detections remained at 16. This process was continued and the corresponding points plotted until the maximum lateral range of 41 meters was reached and all 205 non-detections were accounted for.

- The curves formed by connecting the plotted points of both cumulative detections and cumulative non-detections will cross at some point. The lateral range value at this crossing point is one-half of the effective sweep width for the search scenario being studied.

Appendix C contains a condensed outline of the steps required for a detection experiment.

Part III – Demonstration Experiment

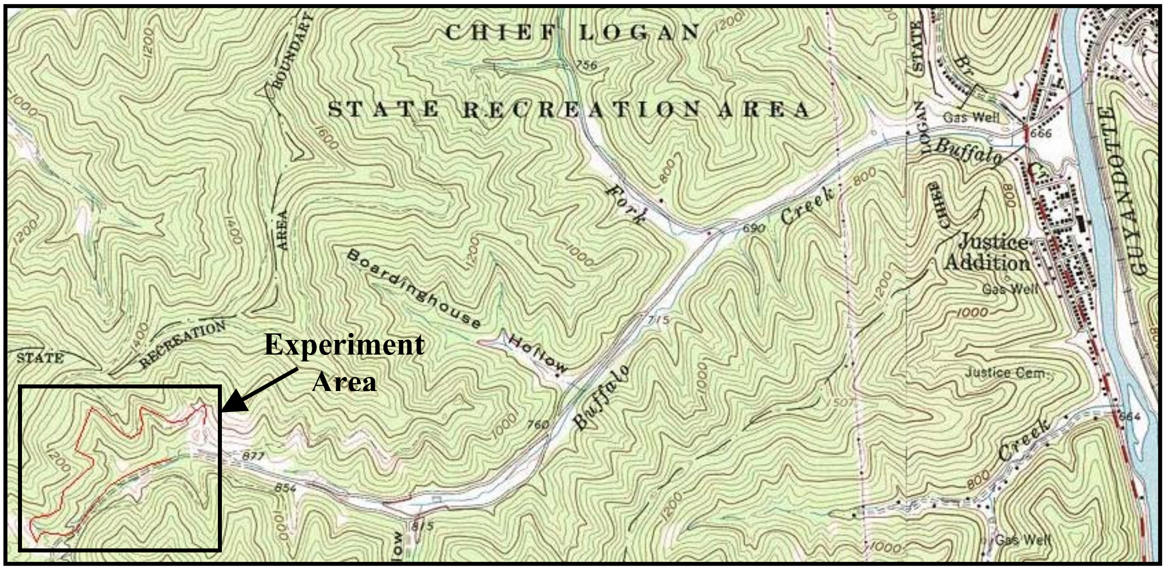
OBJECTIVE

On 15 June 2002 a demonstration experiment for a procedure to estimate effective sweep width for land search was conducted. The objective of this demonstration was to validate the procedures outlined in Part II and Appendix C. The test was used to demonstrate the practicality of the techniques for determining effective sweep width outlined in this report. The procedures outlined in Part II and Appendix C reflect lessons learned during the experiment, therefore the report of the experiment below will not precisely correspond to the recommended procedures in Part II. The goal of effective sweep width development based on actual detection data is to provide search planners with an improved method for estimating ***realistic*** Probability of Detection (POD) values that can then be used to reliably obtain an improved estimate of the Probability of Success (POS). The POS is the product of Probability of Area (POA) times Probability of Detection (POD). Methods for increasing POS at the maximum rate will enable search planners to improve the utilization of time and resources and minimize the average time required to find and assist distressed persons.

DESCRIPTION OF VENUE

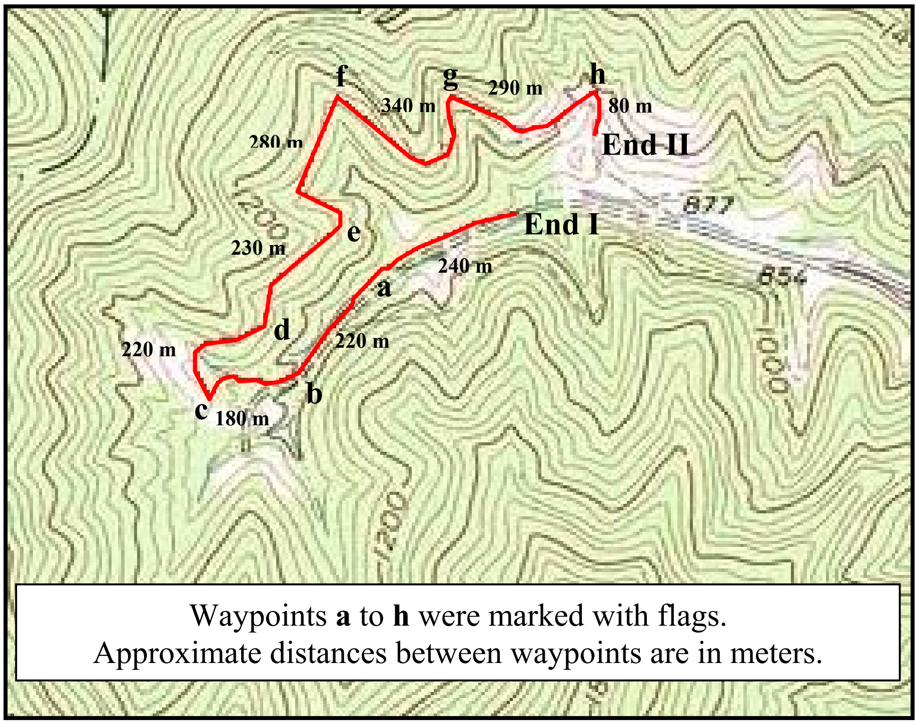
Location

The experiment was conducted on the property of the Chief Logan State Park near Logan, WV. Existing trails within the park were used. The trail used is shown in Figures 9 and 10. The experiment was conducted in conjunction with the Logan Search and Rescue Weekend 2002.



Experiment Area

Figure 9. Chief Logan State Recreation Area and Experiment Area



Waypoints **a** to **h** were marked with flags.
Approximate distances between waypoints are in meters.

Figure 10. Searcher Track

Vegetation

The vegetation type was mixed eastern hardwood with tree diameters of six to twenty inches. The understory was light to medium (Figure 11). There was very little ground vegetation.

Figure 11. Vegetation Type at Chief Logan State Park, Logan, WV

Terrain

The along-track profile was moderate with an average slope of 15% (Figure 12). The cross track profile was much steeper with an average slope of 37% based on five cross trail slope estimates. These slope estimates were taken at the locations indicated in Figure 13.

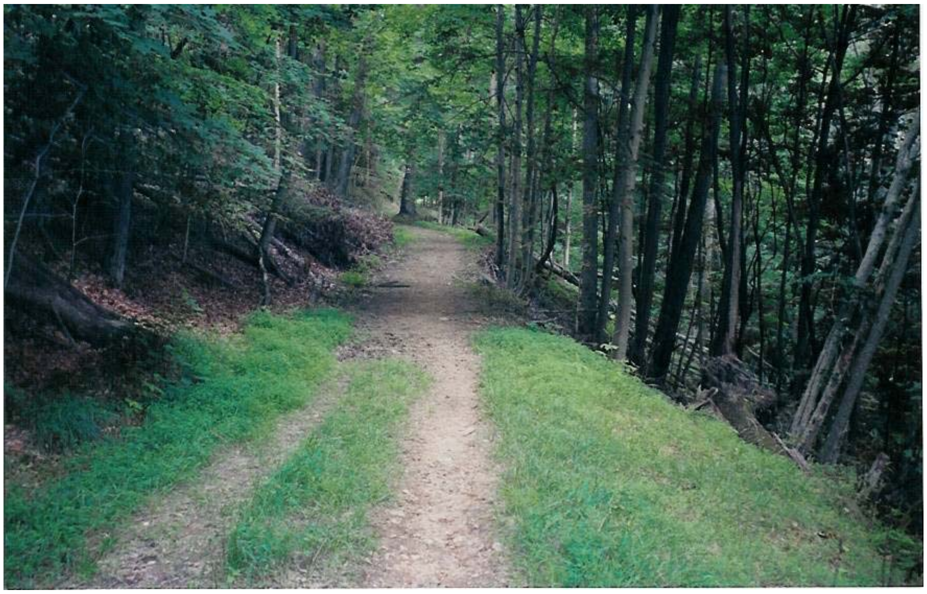


Figure 12. Typical search track, Chief Logan State Park, Logan, WV

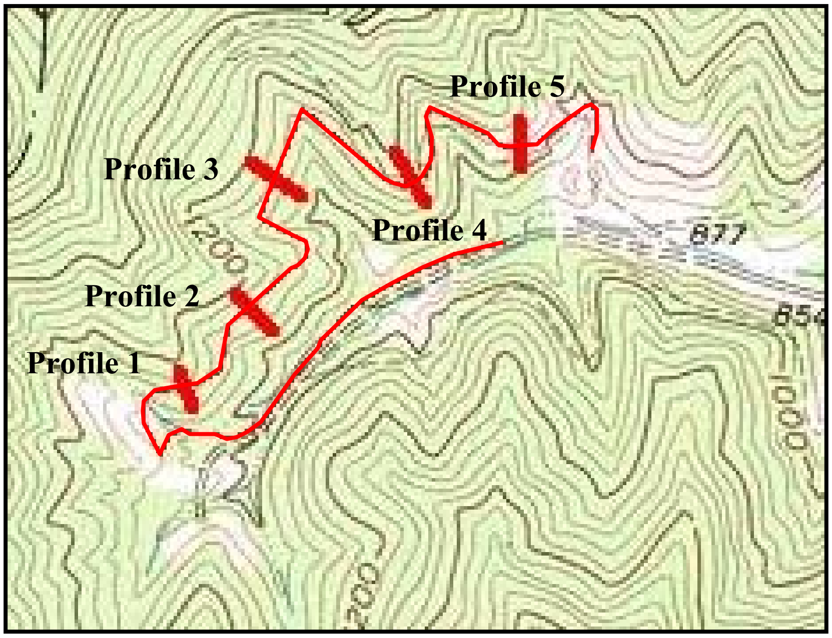


Figure 13. Locations of cross-track slope profile estimates.

DESCRIPTION OF THE EXPERIMENT

A search track was laid out along existing trails. Scattered in a quasi-random manner along this track were two types of objects used to simulate search objects. These objects were placed at pre-determined locations with respect to the track according to instructions in Part II of this report. Volunteer searchers followed by a recorder/data collector followed the track conducting a search. The searcher reported detections to the recorder.

Participants

The National Search and Rescue Committee funded this experiment. Participants included:

- Potomac Management Group, Inc. – Test Manager
- Logan Emergency Ambulance Service Authority – Host Organization/Support
- West Virginia SAR Network – Volunteer Searchers
- Chief Logan State Park, West Virginia Department of Natural Resources – Experiment Location

Search Object Descriptions

Two types of search objects were used during the searches. The first was a florescent orange glove (Figure 14) that is small in size but high in contrast. The second search object was a 55 gallon black garbage bag filled out with five 12” balloons to give it bulk (Figure 15). The garbage bag is about the size of a person and has low contrast with the forest background.

Figure 14. Florescent Orange Glove used as a Search Object

Figure 15. Fifty-five Gallon Garbage Bag filled with five 12" Balloons used as a Search Object.

Average Maximum Detection Range (AMDR)

An AMDR distance for each search object type was determined using the method outlined in Part II of this report. The AMDR distance for the Orange Glove was determined to be 19 meters. The AMDR for the Fifty-five Gallon Garbage Bag was determined to be 25 meters.

Search Object Locations

The number of search objects used was based on the track length and the visibility of the object. Search objects were separated sufficiently so that when a searcher reported a detection it was possible to know which object was sighted based only on the searcher's location and the approximate direction and distance from that point to the object. Search objects were placed at an off-track distance of up to at least one and a half (1.5) times the AMDR for the most visible object used. (The intended maximum off-track distance was 1.5 × 25 = 37.5 meters. However, in one instance an orange glove placed 28 meters from track was not visible from that leg but was highly visible from another section of the track where the lateral range was 41 meters.) The search object location zones were determined as shown in Figure 7, except that the average distance between zone centers was 75 meters (rather than the 300 meters used in the example with Figure 7) and the maximum off-track distance was 37.5 meters (rather than the 150 meters used in Figure 7). The distances used for object placement along the track and to the sides of the track were derived from a series of random numbers (series of random numbers can be obtained from many internet sites such as http://www.random.org/). The type of search object placed at each position was also chosen at random.

The distribution of locations for the search objects is presented in Table 2 below are based on an initial AMDR of 19 meters for the orange glove and 25 meters for the plastic garbage bag. The plastic bag is the most visible search object primarily because of its size, bulk and height.

Location Number	Along Track Distance from Waypoint "A" in meters	Easting UTM Coordinates (Zone 17)	Northing UTM Coordinates	Search Object Type	Clockwise* Lateral Range in meters (Left or Right)
1	94	408918	4193415	Bag	26 L
2	130	408848	4193418	Glove	17 R
3	226	408796	4193280	Glove	14 L
4	299	408725	4193348	Glove	41 R
5	399	SKIP**		Glove	26 R
6	451	408612	4193318	Glove	21 L
7	545	408673	4193392	Bag	12 L
8	594	408721	4193412	Bag	21 L
9	657	408760	4193441	Bag	5 R
10	753	408840	4193498	Glove	32 R
11	824	408829	4193573	Glove	32 L
12	919	408827	4193604	Glove	14 L
13	950	408802	4193630	Glove	9 L
14	1047	408849	4193727	Glove	2 R
15	1131	SKIP**		Bag	11 R
16	1184	408920	4193762	Bag	3 R
17	1259	408975	4193725	Bag	6 L
18	1360	409073	4193709	Glove	5 R
19	1444	409103	4193773	Bag	37 R
20	1505	409102	4193785	Bag	1 L
21	1559	409174	4193799	Bag	37 L
22	1669	409276	4193738	Glove	31 R
23	1719	409272	4193800	Glove	24 L

* Based on an AMDR of 25 meters for the most visible search object type. Left and Right are based on the clockwise direction of movement from End I to End II.

** Location occurred exactly at a sharp bend and was not used.

Table 2. Initial Search Object Locations

Placement and Recovery of the Search Objects

Making use of USGS 1:24,000 topographic maps, the track was plotted using the UTM grid. This permits positions to be determined in meters from a reference point. The along-track and cross-track distances of the search objects were plotted in relation to the searcher track on a 400% blow-up of the topographic maps resulting in a 1:6,000 scale. The UTM coordinates were then determined for each plotted search object location. The placement of the search objects followed the procedure in Part II of this report.

At the conclusion of the experiment the search object waypoints were retraced to recover the objects. All search objects were found in their original locations.

DETERMINING THE EFFECTIVE SWEEP WIDTH

The data from this experiment is listed and described in Appendix D of this report. This data summary is the basis for determining the effective sweep width value for the conditions of this experiment. These data were collected under limiting circumstances and are not intended to produce field-tested sweep width values. The detection data in Appendix D are intended as a demonstration and test of the techniques outlined in Part II of this report. Because of the limited data quantity and the limited range of variables observed during the data collection, the only variables that will be examined are detection, lateral range, and search object type.

Orange Glove

The 32 searchers participating in this experiment produced 384 searcher/orange glove interactions over lateral ranges of 2 to 41 meters (the 41 meter lateral range was greater than 1.5 times the AMDR of the most visible search object and was unintended). This search object was visible at true ranges in excess of 100 meters if the sight line to the object was unobstructed and the glove presented its broad side to the searcher. On the other hand, the detection range of the glove was limited by its low profile and small size causing it to be easily blocked by vegetation and uneven terrain. The high detection rate of the glove at a lateral range of 41 meters resulted from a fortuitous placement in an open area on a slope with low grass that was bathed in bright sunlight most of the day giving the glove a high contrast with its surroundings and clear line of sight to the glove's broad side across a ravine from the searcher track above. Many detection opportunities at shorter lateral ranges were missed.

We used the method of determining effective sweep width outlined in Part II of this report which makes use of the property of sweep width where the number of detections beyond the half-sweep-width value from track are equal numerically to the non-detections closer to the track (Figure 16). From the figure the half sweep width value is approximately 18 meters giving a sweep width value of 36 meters. This compares reasonably well with the value of 40 meters computed from the area under the lateral range curve, which may have been somewhat inflated due to the large number of detections at the greatest lateral range. One half of the lateral range curve is shown in Figure 17 below. Note the extreme reversal of the general downward trend created by the last data point along with the significant additional area it creates.

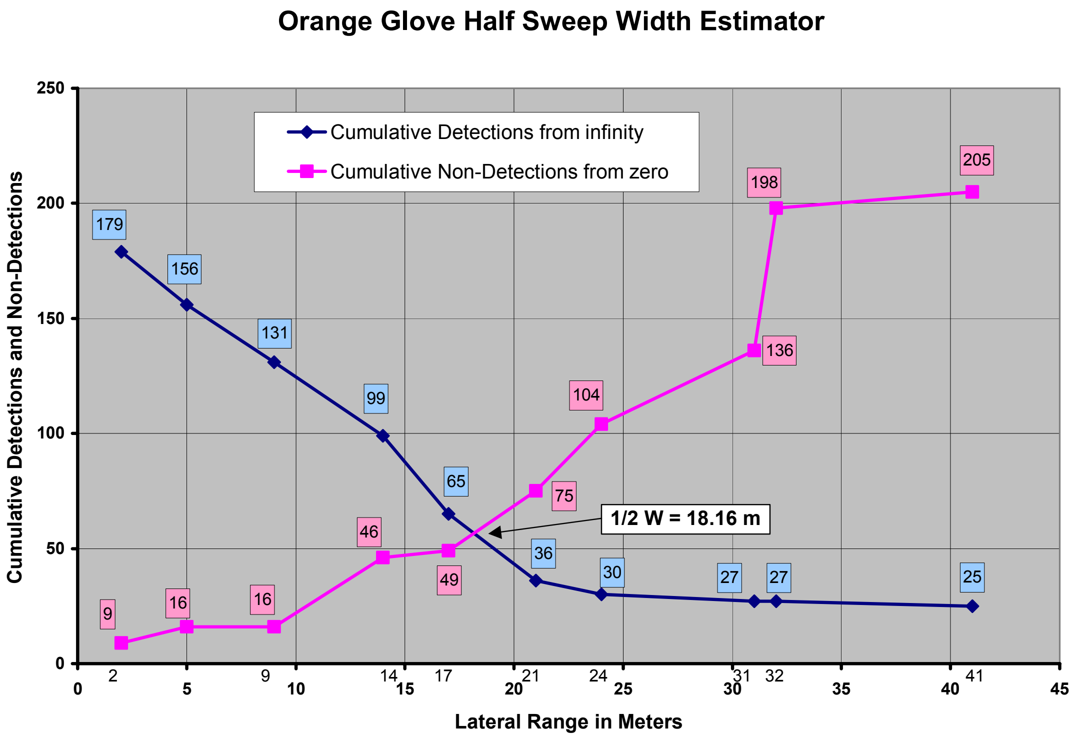


Figure 16. Orange Glove Detection Data—**W** = 36 meters.
(Crossing point equals one-half effective sweep width value.)

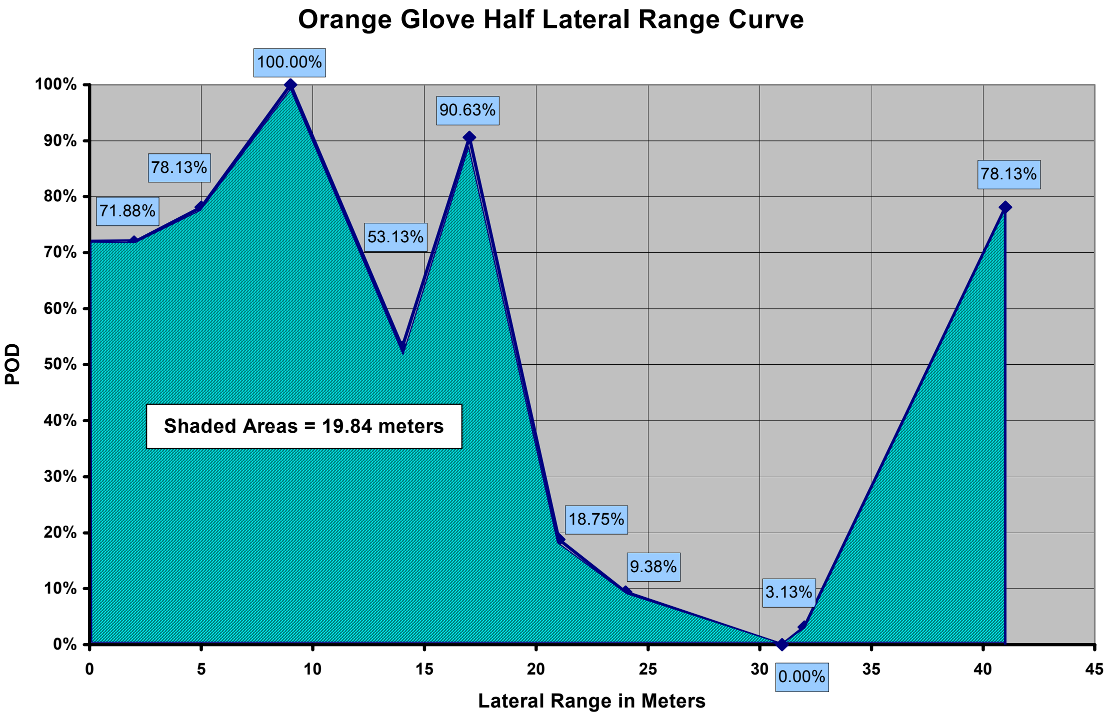


Figure 17. Orange Glove Half Lateral Range Curve—**W** = 40 meters
(Areas under this portion equal one-half effective sweep width value.)

As with the values in Figure 16, left-right symmetry was assumed and the detections at each lateral range in Figure 17 were used regardless of whether they were to the right or left of the searcher's track. The POD percentages computed for each lateral range were simply the number of detections divided by the number of detection opportunities. Some lateral ranges were duplicated (e.g., 14 and 32 meters) but occurred at widely separated places along the searcher track.

Since the detection rate for the glove that was 41 meters from the track was so high (78%), a second plot was done where the detection rate at that range was set to zero. This increased the total non-detections to 230 and decreased the total detections to 154. This plot is shown in Figure 18 below. The effect of this change was to decrease the sweep width estimate from 36 meters down to 33 meters—a change of less than 10%. Therefore, this method seems to be quite robust and relatively insensitive to apparently anomalous situations like the fortuitous placement of one of the test objects.

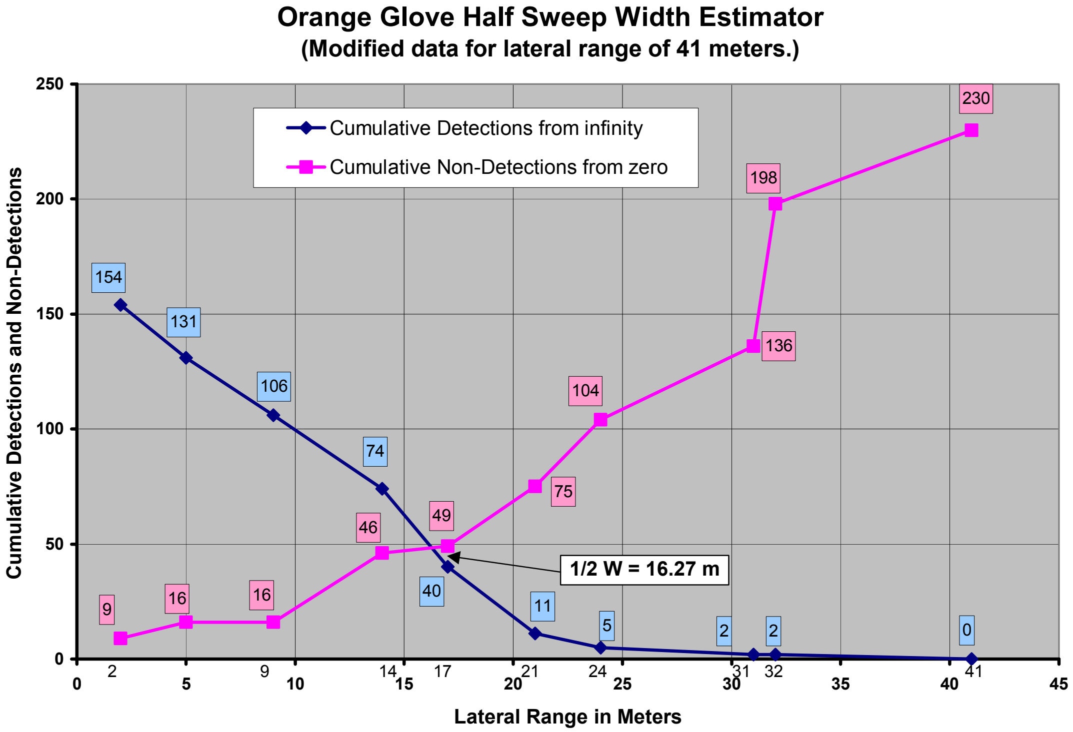


Figure 18. Modified Orange Glove Detection Data—**W** = 33 meters.
(Crossing point equals one-half effective sweep width value.)

The corresponding lateral range curve is shown in Figure 19 below. Note that adjusting the anomalous number of detections at the extreme lateral range gives the curve a form much closer to that which would normally be expected for visual search. In addition, it produces a very nearly exact agreement between the area under the lateral range curve and the crossing point shown in Figure 18. The computed sweep width values for Figures 18 and 19 were 32.54 meters and 32.66 meters respectively.

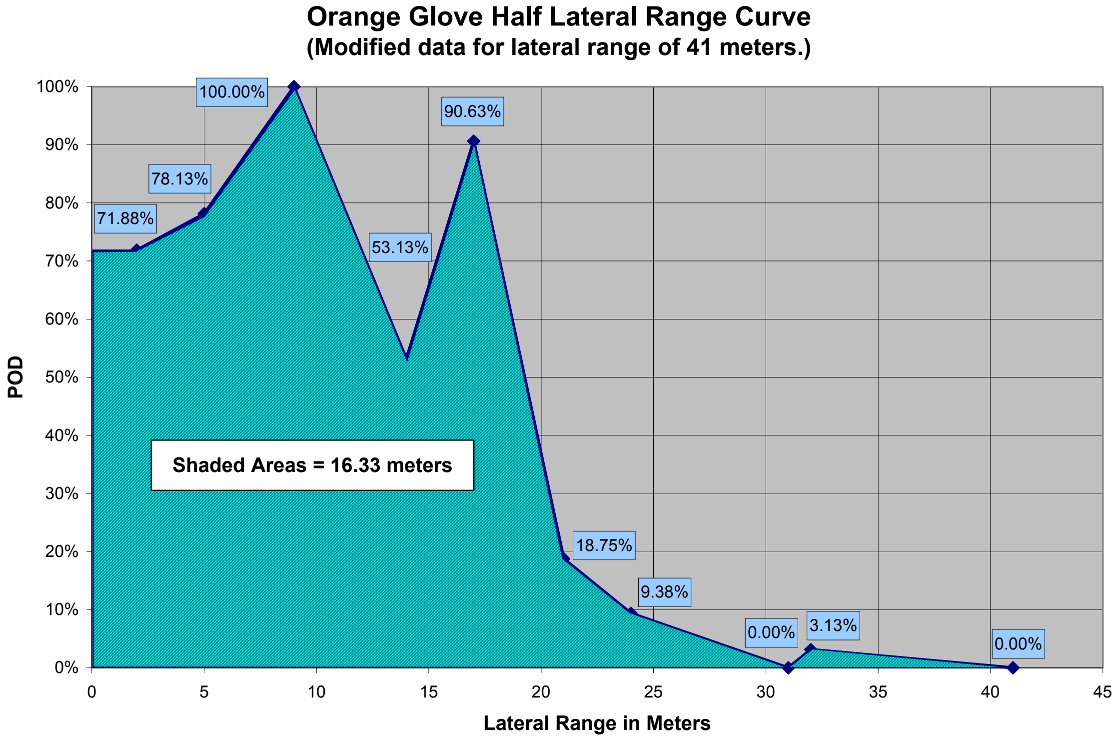


Figure 19. Modified Orange Glove Half Lateral Range Curve—**W** = 33 meters.
(Areas under this portion equal one-half effective sweep width value.)

Repeating sweep width experiments many times under essentially the same conditions and aggregating the data would tend to produce smoother curves as more data for more lateral ranges became available. This would be especially true of lateral range curves, which tend to be quite rough for single experiments. Nevertheless, the fact that such a significant modification of the data at one extreme had a relatively minor effect on the effective sweep width value found by the crossing-point technique suggests that the crossing-point method is quite capable of absorbing an anomalous effect like the one encountered in this experiment without serious consequences. The method would be most sensitive to large anomalies at lateral ranges near one-half the effective sweep width, but even here it will take the right combination of data to produce significant problems.

Black Garbage Bag

The 32 searchers participating in this experiment produced 288 searcher/garbage bag interactions over lateral ranges of 1 to 37 meters. This search object had the advantage of bulk. The bag tended to stand above the surrounding vegetation, rocks and logs. Another key to detecting this search object was the smooth, slick appearance of the plastic material even though the color of the bag tended to blend with the forest background. While on average the garbage bag was detected at a greater lateral ranges than the orange glove, under ideal conditions the orange glove was noticed at a very great distances in true range. Figures 20 and 21 below show the detection data for the black garbage-bag “mannequins.”

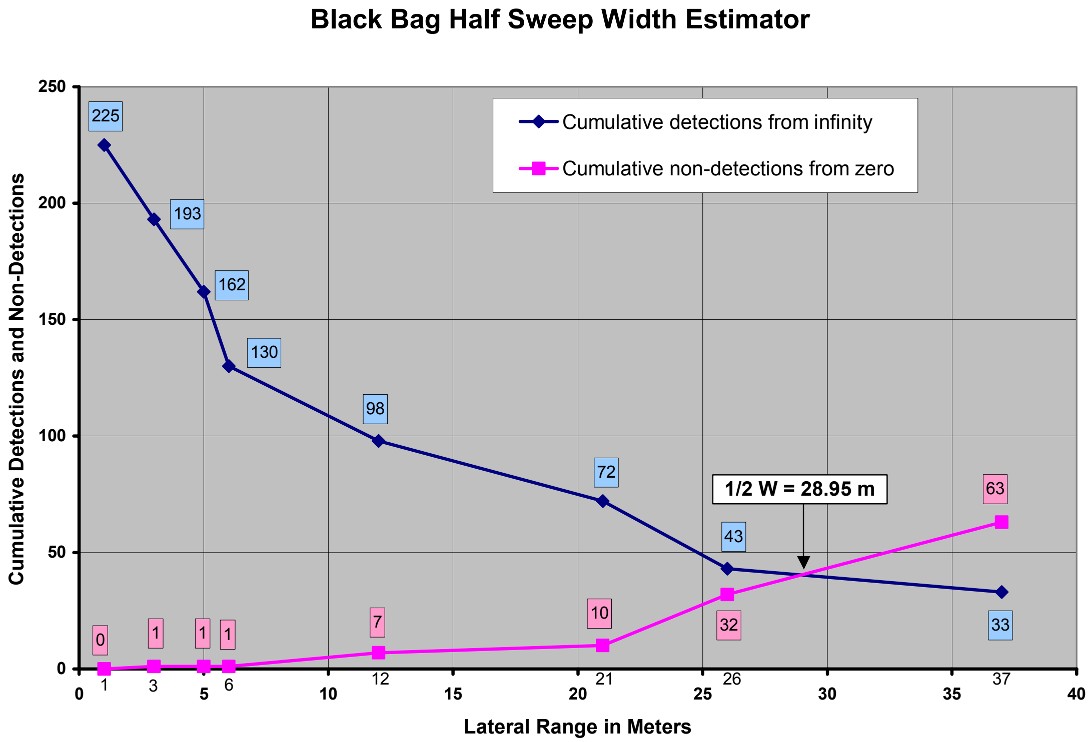


Figure 20. Black Garbage Bag Detection Data—**W** = 58 meters.
(Crossing point is equal to half sweep width value.)

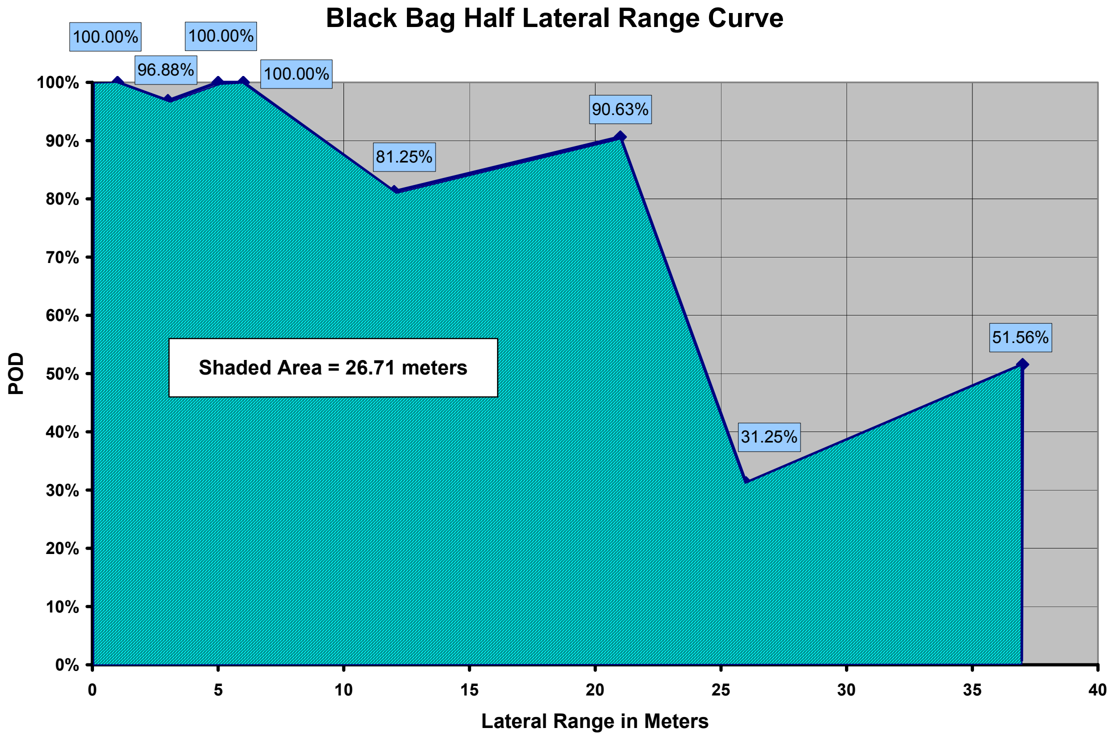


Figure 21. Black Garbage Bag Half Lateral Range Curve—**W** = 53 meters.
(Area under this portion equals one-half effective sweep width value.)

We used the method of determining effective sweep width outlined in Part II of this report which makes use of the property of sweep width where the detection beyond the sweep width value are equal numerically to the non-detections within the sweep width. From Figure 20, the half sweep value is estimated as approximately 29 meters giving a sweep width value of 58 meters. This compares reasonably well with the value of 53 meters computed from the area under the lateral range curve in Figure 21, especially considering that the curve may have been truncated somewhat due to an apparently low estimate of the average maximum detection range (AMDR).

The apparently low estimate of AMDR very nearly caused this portion of the experiment to "fail." The cumulative detection and non-detection curves did not cross until the very last segments farthest from the searcher track were plotted. If the AMDR estimate had been much lower, the two curves might not have crossed at all. Without a crossing point, the technique would not have produced an effective sweep width value. This means the AMDR experiment should be repeated at several points along the searcher track to obtain a larger data set that more accurately reflects the average maximum detection range over the length of the track rather than at only one point along it. Clearly, any repetition of the experiment with the black balloon-filled garbage bags should use a larger AMDR value when determining search object placement.

Even if the experiment had failed to produce a crossing point on the half sweep width plots, the detection data is still valid over the limited lateral range and should not be discarded. It may be combined with data from other experiments conducted under essentially the same conditions at a later date.

Crossing-Points versus Lateral Range Curve Areas

It is worth noting that in both the case of the orange glove and that of the black garbage bag, the crossing-point method for estimating effective sweep width probably gave more accurate estimates than those obtained from the areas under their respective lateral range curves as plotted crudely from the experimental data. In the case of the orange glove, the anomalous results at the maximum lateral range tended to add considerable area to the lateral range curve, leading to a probable over-estimation of sweep width. The crossing-point method did a good job of damping the effects of this anomaly, producing a lower sweep width value that is probably more accurate. In the case of the black garbage bag, it is virtually certain that the maximum detection range was under-estimated, causing the lateral range curve as plotted from the available data to be truncated, thus under-estimating the effective sweep width. Again, the crossing-point method absorbed this anomaly and produced a somewhat larger effective sweep width value that is probably the more accurate of the two estimates. In short, unless enough data have been collected to ensure that a reasonably smooth and complete lateral range curve can be fitted to it, the crossing-point method is not only simpler but probably more accurate as well.

Part IV – Estimating POD

POD VARIABLES

As stated in Part I, the probability of detection (POD) is a function of three variables:

- The amount of effort expended in a given segment or region that is to be or has been searched,
- The effective sweep width (detectability index) for the combination of search object, environmental conditions, and sensor present in the segment or region at the time of the search, and
- The physical size (area) of the segment or region that is to be or has been searched.

Given these three factors quantified as numeric values, an accurate, reliable estimate of POD can be obtained with relatively little computation.

Effort

Effort may be defined as the amount of distance covered by the searcher(s) in a search segment while searching. A search segment is defined as some bounded geographic area that a particular resource, such as a team of searchers, has been assigned to search. The distance a searcher covers while searching may be estimated by either estimating or recording the amounts of time spent searching (exclusive of rest or meal breaks, transit times to and from the assigned segment, etc.) and multiplying that value by the estimated average search speed using the familiar formula

$$d = rt$$

for ***d***istance equals ***r***ate times ***t***ime. When a team of searchers is assigned a given segment, the total distance traveled by all members of the team will be needed. This value may be found by summing all the individual team member distances or, if all members moved at about the same speeds for about the same amounts of time while searching, then the distance covered by one searcher could be multiplied by the number of persons in the team to get the total distance covered in the segment. That is,

$$Effort = \sum_{i=1}^{n} d_i \text{ or } Effort = nd$$

where n is the number of searchers on the search team.

Effective Sweep Width

For our purposes we will assume the effective sweep width has been determined using the methods described earlier or that the effective sweep width has been estimated from the results of such experiments if the prevailing conditions for the actual search are different from those that were prevailing when the experiments were conducted.

Area Effectively Swept

Given the total distance covered by the searchers in a segment and the effective sweep width, the *area effectively swept* (also known as *search effort*) may be computed as the product of the distance covered and the effective sweep width:

$$Area\ Effectively\ Swept = Effort \times Effective\ Sweep\ Width$$

Segment's Area

In land search, segments are usually irregular shapes with boundaries determined by various natural and man-made features. For example, a ridgeline, streambed, power transmission lines, a fire road, and other features may define the "sides" of a segment. The area of such a segment may be estimated by using a transparent overlay covered with dots on a regular grid, as shown in Figure 22. The dots represent the centers of small squares. A rectangular area larger than the segment is chosen and the number of small squares in the rectangle is computed as the number along one side times the number along a perpendicular side. The rectangle's area is also computed as the length of one side times the length of a perpendicular side ("length times width") or as the number of small squares times the area of one such square. The number of dots falling within the segment's boundaries are then counted and divided by the number falling inside the larger rectangle. This gives the ratio, to a good approximation if the dots are sufficiently dense, of the segment's area to that of the rectangle. Since the rectangle's area is known, a simple multiplication by this ratio gives the segment's area:

$$Segment\ Area = Rectangle\ Area \times \frac{Number\ of\ dots\ in\ Segment}{Number\ of\ dots\ in\ Rectangle}$$

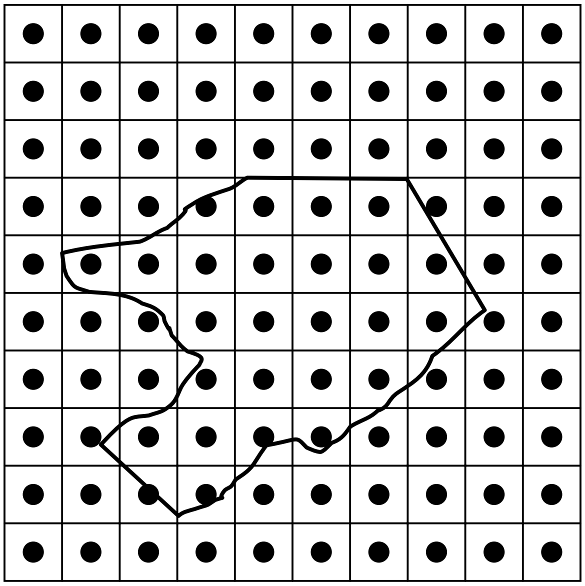


Figure 22. Estimating Segment Area
with Dots on a Grid

There are 100 dots in the large square of Figure 22. Of these, 25 fall inside the segment shown. If the large square is one kilometer on a side, then the segment's area using the equation above would be estimated as 0.25 square kilometers.

Coverage

Coverage is defined as the ratio of the area effectively swept to the physical area of the segment:

$$Coverage = \frac{Area\ Effectively\ Swept}{Segment's\ Area}$$

Coverage is a measure of how "thoroughly" the segment was searched. The higher the coverage, the higher the POD will be. However, the relationship is not linear. That is, doubling the coverage does not double the POD. Figure 23 shows the relationship between coverage and POD as derived by Koopman (1946, 1980) for situations where searchers do not move along a set of long, perfectly straight, parallel, equally spaced tracks but instead follow more irregular paths.

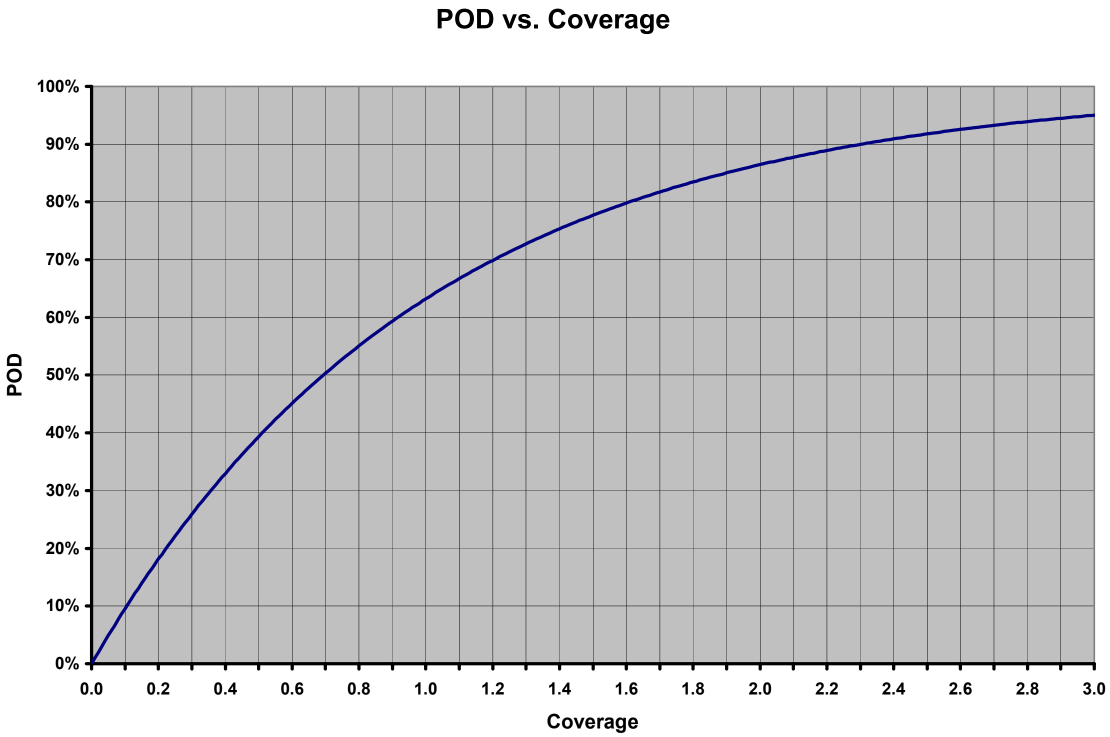


Figure 23. POD versus Coverage

Since terrain and vegetation often prevent ground searchers from following a mathematically precise pattern of parallel tracks, and since ground searchers frequently alter their tracks to investigate possible sightings, look behind major obstructions, etc., the exponential detection function, as the curve in Figure 23 is called, seems to be the most appropriate for estimating ground search POD. This curve also works well when other “random” influences are present, such as uneven terrain and vegetation, even when the searcher tracks are perfectly straight, parallel, and equally spaced. The equation of this curve is

$$POD = 1 - e^{-Coverage}$$

where e is the base of the natural logarithms (approximately 2.718282). The function e^x or EXP is available with most handheld scientific calculators and electronic spreadsheet programs.

AN EXAMPLE OF POD ESTIMATION

Suppose a segment was searched under the following circumstances:

- A team of three searchers was assigned to the segment for an eight-hour “shift” where an hour was required to access the segment from the staging area, two 15-minute rest breaks and one half-hour meal break were taken in the segment and another hour was required to return to the staging area from the segment. The remaining five hours were spent searching at an average search speed of 0.5 kilometers per hour.
- The search object was a missing person and the effective sweep width was estimated to be 58 meters.
- The area of the segment was estimated to be 1.5 square kilometers.

Using the above data, the distance covered by each searcher is computed to be

$$d_i = 0.5\,km/hr \times 5\,hrs = 2.5\,km\,.$$

The total distance covered by the team is then computed as

$$Effort = 3\,searchers \times 2.5\,km/searcher = 7.5\,km\,.$$

Before the area effectively swept can be computed, it is necessary to convert the effective sweep width from meters to kilometers so as to keep the units of measure consistent. Hence, the sweep width is converted from 58 meters to 0.058 kilometers. Now the area effectively swept is computed as

$$Area\ Effectively\ Swept = 0.058\,km \times 7.5\,km = 0.435\,km^2\,.$$

The coverage may now be computed as

$$Coverage = \frac{0.435\,km^2}{1.5\,km^2} = 0.29\,.$$

From the graph in Figure 23 or by computation, the POD is then estimated to be about 25% or one chance in four of having detected the search object if it was present in the segment during the search.

Part V – Conclusions and Recommendations

PROJECT OBJECTIVES

The objectives of this project were to:

- Design, develop, describe, and demonstrate a standard model or blueprint for conducting simple, practical, inexpensive detection experiments, collecting data from them, and reducing that data to estimates of effective sweep width.
- Provide a description of the method for objectively estimating probability of detection (POD) from:
    - Effective sweep width for a given combination of search object, sensor and environmental conditions,
    - The level of effort expended in searching a defined region, and
    - The size (area) of that region.
- Provide a professional opinion of the reliability and repeatability of POD estimates based on effective sweep width, effort and area searched as compared to subjective estimation techniques.
- Describe future work needed to establish a practical methodology for planning and performing searches of areas that is based on sound search theory principles for allocating the available effort in a more nearly optimal manner.

For the first time ever in the land SAR arena the first of these objectives was accomplished. A practical model for ground SAR detection experiments was designed and demonstrated, including a data reduction technique that requires only minimal computational skills. Implementing this model will make the cost of obtaining effective sweep width data nearly zero. Perhaps even more importantly, it opens the door for substantial improvements in land SAR search planning techniques that have been sought for many years. An important threshold has been crossed that brings a practical adaptation of search theory tailored specifically for land SAR search planning one step closer.

The remaining objectives were also met. The technique for estimating POD based on sweep width, effort and area is described and an example is provided. A professional opinion on the objectivity, reliability and repeatability of this technique is rendered. A brief outline of future work needed to complete the establishment of a search planning methodology that is practical yet built on sound scientific principles is provided.

ESTIMATING EFFECTIVE SWEEP WIDTH

Part I of this report describes the scientific background behind sweep width and the procedures used for detection experiments. Part II describes the procedures for setting up detection experiments and reducing the data obtained from them to produce an effective sweep width value for visual search at the time and place of the experiment and similar situations. Based on the experience gained from the demonstration in West Virginia that was described in Part III, the following conclusions were drawn:

1) Both the experimental and data reduction procedures were shown to be quite practical and economical. It is our opinion that the results will also be quite reliable. Unfortunately, reliability could not be demonstrated by a single experiment.
2) Although not technically difficult, setting up a proper experiment and reducing the data from it requires considerable effort. However, the level of effort required is within reasonable bounds and is comparable to that required for a well-run SAR exercise.
3) For those unfamiliar with the sweep width concept and unfamiliar with the design and conduct of experiments, the descriptions given in Part II and Appendix C of this report may not be sufficient to guarantee reliable results. Since very few in the ground search community are familiar with these matters, a much more detailed, step-by-step description that anticipates and answers the most common questions is needed. Ideally, a subject matter expert in the design and conduct of detection experiments should be consulted and available on site for all phases of a group's first experiment. In fact, some number of such "first time" consultations with several different SAR groups would provide additional insights and help improve the instructions provided in this report.

POD ESTIMATION

Part IV of this report addresses the POD estimation technique. Based on other experience and observations, a number of conclusions were reached.

1) Either a simple computer/calculator program or a step-by-step worksheet and graph like Figure 23 would be the best way to implement the POD estimation method described in Part IV.
2) Since the POD estimation technique of Part IV is based on measurable factors (effort, effective sweep width, area searched) and a proven mathematical relationship, it should be far more objective and reliable than the present subjective methods that are ultimately based on how well either the search manager or the searchers themselves believe they were able to do their assigned tasks. As many psychological tests have shown, humans are very poor at estimating probabilities directly, even when such estimates do not involve rendering opinions on their own efforts. Present subjective methods of POD estimation require searchers to directly estimate the probability that they would have found the search object if it had been in their assigned segment. Such estimates must be regarded as unreliable at best.
3) The POD estimation technique given in Part IV will prove to be more repeatable than the present subjective techniques, which typically (almost inevitably) produce different POD values for identical situations.
4) Bringing more accuracy and discipline to POD estimation will help dispel erroneous beliefs about effort allocation that now pervade the land SAR community. One of these is that two low-POD (i.e., low coverage) searches for a given object in a given area under

identical conditions will normally produce a higher cumulative POD than a single high-POD (i.e., high coverage) search when both search methods expend exactly the same amount of effort. This is not physically possible, but subjective POD estimation techniques have allowed some to "prove" this point by choosing, subjectively, sufficiently high POD estimates for the low coverage searches and a sufficiently low POD estimate for the high coverage search to make the cumulative POD from the low coverage searches seem to exceed that of the high coverage search. In reality, the likelihood is greater that two low coverage searches will produce a lower cumulative POD than a single search when both methods expend the same effort under the same conditions. In any case, it is easily proven from the principles of search theory [Koopman 1946, 1980] that the two-search technique can never do better than to equal the single-search POD and, importantly, it usually takes longer in terms of elapsed time. It seems very likely that the erroneous belief about the efficacy of low coverage searches has caused some, perhaps many, searches to take longer, and may even have caused some searches to fail.

5) Bringing more accuracy and discipline to POD estimation will produce more accurate estimates of the Probability of Success (POS) for individual segments, operational periods and cumulatively for all searching done to date. In so doing, it will allow known, proven techniques for maximizing POS in the shortest possible time to be applied, resulting in better resource allocation decisions.

RECOMMENDATIONS FOR FUTURE WORK

Objectives

1. Provide a practical probability of detection (POD) estimation procedure with worksheets, graphs and/or other appropriate job aids that is suitable for land SAR and based on proven scientific concepts. The procedure will produce objective, accurate, consistent, and reliable POD estimates, replacing current subjective techniques.
2. Based on proven scientific principles, provide a practical search planning (as opposed to search management) methodology that will allow land search planners to maximize the effectiveness of their available resources during every operational period of every search. The advantages of such optimal resource allocation are:
   a. More successful searches.
   b. Reduced average time and resources required for finding the search object.
   c. More lives saved as a result of reduced average search time
   d. Reduced risk to searchers as a result of reduced exposure time to the risks of searching.

Steps To Accomplish The Objectives

Step 1 – Validate and Refine Data Collection and Analysis Procedures for Establishing Sweep Width Values

Refine and validate the preliminary detection data collection and analysis procedures developed and demonstrated in 2002 for ground searchers.

a. Conduct four additional test demonstrations in different terrain and with different SAR groups.

b. Develop data analysis software using readily available commercial off-the-shelf software to automate the data analysis procedures and reduce the opportunity for human-induced error.

c. Conclude with a set of experiments in one venue to produce actual detectability (sweep width) data for realistic search objects in that venue.

d. Final procedures and software for ground search detection experiments are to be suitable for use by SAR organizations without assistance from professional analysts or special scientific training.

The current effort, outlined in this report, could do no more than demonstrate whether the procedure under development shows promise of being practical for general use by SAR teams/agencies to develop search object detectability (sweep width) estimates in their respective geographic areas of responsibility (AORs). Although it has shown such promise, the procedure still requires further development and refinement. It must also be shown to be practical for use in a variety of environments by a variety of personnel. Therefore, it should be tried in several geographic areas with differing environments. This will also provide the opportunity to involve and train more SAR personnel and prove the utility of the procedure.

The current effort has been of insufficient scope to actually produce reliable detectability (sweep width) data. This was known from the outset. Valid values for use in actual searches was not, and in fact could not be, a goal of the first demonstration. The experiment procedure should be exercised sufficiently to convincingly demonstrate practicality, usefulness and reliability of results.

A (full) set of experiments should be done in at least one location that will be sufficient to produce enough data for obtaining an actual sweep width estimate for a given set of conditions.

Step 2 – Extend and Modify to Include Detection Data for Aerial Search from Aircraft

The detection data collection and analysis procedures should be extended and modified as needed for aerial searches over land for the use of the Civil Air Patrol (CAP) and other agencies that search from the air.

a. Conduct two additional test demonstrations in different terrain and with different CAP wings to adapt and refine the sweep width experiment procedures as necessary for searches conducted from aircraft.

b. Extend data analysis software as needed to apply to aerial search, to automate the data analysis procedures and reduce the opportunity for human-induced error.

c. Finalize procedures and software suitable for use by SAR organizations without special scientific training assistance from professional analysts.

The sweep width data currently published in the *IAMSAR Manual* for aerial search over land are quite limited and of uncertain origin. No supporting studies for these data have been found to date. At a minimum, these data should be validated. The above procedures for ground searchers should be expanded to make them applicable to aerial search over land where there is an even greater potential for improving search effectiveness stemming from the natural advantages of aerial search. Due to their high speed, a procedure to obtain detectability (sweep width) data for search objects on the ground when an aircraft is performing the search will necessarily involve the need to populate much larger areas with objects. This is likely to introduce some unique procedural and logistics issues to be addressed. In addition, it will be necessary to accurately track the movements of aircraft during the procedure. This tracking can easily be accomplished by means of a GPS receiver that uses a laptop computer as a data-logging device. Substantial Civil Air Patrol involvement in both the adaptation of the ground detectability (sweep width) procedure and its implementation will be highly desirable.

Step 3 – Develop Improved Procedures for Estimating POD

Develop procedures for reliably estimating probability of detection (POD) that are suitable for use in all types of ground and aerial search of areas. These procedures would be based on the detectability index (sweep width) for a given search, the amount of effort expended in a given area, and the size of the area that was covered by the search resources.

Note: A sample procedure is provided in Part IV of this report but it may require further explanation or changes before it will be suitable for field-level users. This type of procedure will be new to the land search community. Understanding and proper use will require development and explanation of a new (to the land SAR community, but standard elsewhere) paradigm for the search problem. The explanation must be written in clear terms that are appropriate to the land search problem. This will require discussions with and assistance from recognized authorities on land search.

POD is a function of the search object's detectability (sweep width), the amount of effort expended in an area, and the size of the area where the effort is expended. There are no authoritative and generally applicable procedures, graphs, job aids, etc. currently available to the land SAR community as a whole for estimating POD based on these parameters. Currently, ground search POD estimates are either purely subjective and based on how well searchers think they could have detected the search object, or they are based on data from "experiments" done many years ago that attempted to relate POD directly to searcher spacing without any estimate of object detectability, effort expenditure, or area searched. The forms of the POD vs. Spacing graphs that resulted from those experiments, and hence a significant portion of their values, can be shown to be inconsistent with the scientifically established principles of search theory.

Therefore, there is a need to develop practical procedures, graphs, job aids, etc. to estimate POD values from sweep width data, effort estimates and area estimates.

Step 4 – Develop Outline for Practical Search Planning Methodology

Develop an outline for a practical search planning methodology for use in land searches involving static search objects. This project will review existing published land search planning methods to determine which are already consistent with known search theory principles and best practices, which can be modified to become consistent with known principles and best practices, and which should be discarded. It will then go on to outline a practical search planning methodology that is consistent with search theory and will allow search planners/managers to make better resource allocation decisions.

Step 5 – Describe Functional Requirements for Software Tools

Develop a functional description for software tools to aid the land SAR search planner. Truly optimal resource allocation is a computationally complex problem that requires computer assistance. Tracking the progress of a search, updating probabilities based on search results and allocating the next amount of available search effort optimally based on these updates are all activities where computer assistance would be extremely useful and enabling.

The goal of any search planning system is to provide a method for optimally allocating the available search resources so that the probability of success (finding the object being sought) is maximized, the expected time required to find the object is minimized, the resources are used in the most efficient manner, and the risks to search personnel are reduced (primarily through reduced exposure times). The more quickly a distressed person can be found, the more quickly lifesaving assistance can be provided. The proper deployment of the available search resources is extremely important to achieving this goal. However, finding the optimal allocation for the available search effort is a computationally intensive and complex process better left to an appropriately programmed computer.

Requirements for developing such software that will be suitable for use by the land SAR community need to be developed and documented.

Step 6 – Survey Existing Software

Survey existing search management software packages and evaluate the feasibility of integrating a search planning module meeting the requirements found in step 4 above with each.

There are a few software packages available now that aid land SAR users with the search management function but provide little to no search planning or effort allocation advice. The little that does exist is merely a codification of manual procedures that have no scientific, and on close inspection often have no sound empirical, foundation. A survey of search management software currently in use should be done with a view toward determining whether and how a search planning module meeting the requirements determined by the previous task may be integrated with them.

Step 7 – Develop Complete Land Search Planning Support Software

Develop a complete, practical, robust land SAR search planning methodology and supporting software similar in scope and level of detail to that already available for other SAR communities.

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Appendix A

A SIMPLIFIED EXPLANATION

OF

EFFECTIVE SWEEP WIDTH

A SIMPLIFIED EXPLANATION OF EFFECTIVE SWEEP WIDTH

An Analogy

Even though *effective sweep width* (usually shortened to just *sweep width*) is essentially a mathematical concept, it can be explained or at least illustrated in mostly non-mathematical terms. To avoid descending too deeply into the pit of mathematics, we will need a common, easily visualized activity that can be used as a model, or analogy, for detection. So, let us pick the mundane activity of sweeping floors as an analogy for "sweeping" an area in search of a lost or missing person. We will use this analogy to describe hypothetical experiments that illustrate the basic principles of *effective sweep width*.

Suppose we wish to compare the performance of four different push-broom designs. In the first design, the broom head is one-half meter (50 cm) in width and has fine, closely-set bristles. In the second design, the broom head is a full meter in width but the bristles are more coarse and not as dense as with the first broom. The third broom is two meters in width with bristles that are even coarser and less dense than those of the second design. The fourth broom is again one meter in width, but it is a hybrid design where the center 20 cm is identical to the first broom, the 20 cm sections to the right and left of the center section are identical to the second broom, and the outboard 20 cm sections at each end are identical to the third design. **Figure A-1** shows a schematic representation of the four different designs. We construct the brooms and label them as B1, B2, B3, and B4 respectively.

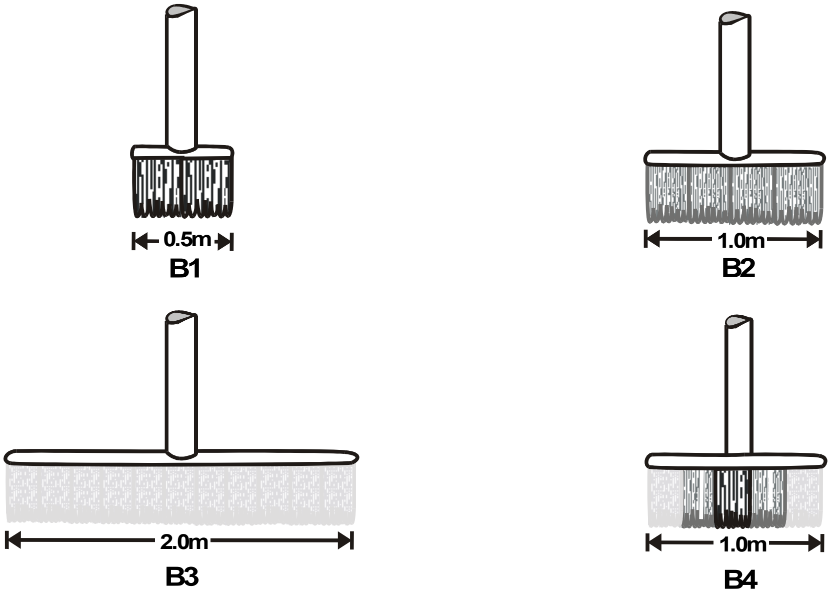


Figure A-1

In our first experiment, we want to know how the brooms compare to one another on a single sweep through a previously unswept area. To perform this test, we choose a smooth floor and mark off a square test area measuring 10 meters on a side. Using sand to simulate dirt on the floor, we cover the test area lightly, and uniformly, so that the "density" of sand is 10 grams per square meter (g/m^2) of floor surface. We then push each broom in a straight line from one side of the test area to the other at a constant speed of 0.5 m/sec (1.8 km/hr or a little over 1 mph), collect the sand that was swept up, and weigh it.

When B1 is pushed through the test area, it appears to do a very good job. In fact, it makes a "clean sweep" with a width of 0.5 meters (or width of the broom head), as illustrated in **Figure A-2**.

Figure A-2

It swept up 50 grams of sand—all the sand within the 0.5 m x 10 m swept area. Thus we may say that B1 is 100% effective out to a distance of 25 cm either side of the center of its track, and, because of the physical limitation of the broom's width, it is completely ineffective at greater distances. The maximum lateral (side-to-side) range of the broom is 0.25 meters from the center of its track. Finally, since it took 20 seconds to traverse the 10-meter "test course," B1 swept up the sand at the average rate of 2.5 grams per second.

Broom B2 is not as thorough as B1, but it makes a swath twice as wide as illustrated in **Figure A-3**.

Figure A-3

When the sand from B2 is weighed, it turns out that it too swept up 50 grams of sand. As a quick calculation will show, B2 swept up 50% of the sand in the one-meter-wide swath it made.

Further analysis shows that all parts of the broom performed equally, and both the sand swept up and that left on the floor were uniformly distributed across the width of the swath. Thus B2 is 50% effective out to a distance of 0.5 meters on either side of the center of its track, and completely ineffective beyond that distance. The maximum lateral range of B2 is 0.5 meters from the center of its track. Just as with B1, broom B2 swept up the sand at the average rate of 2.5 grams per second.

Broom B3 is even less thorough than B2, but it makes a swath twice as wide as B2 and four times as wide as B1, as shown in **Figure A-4**.

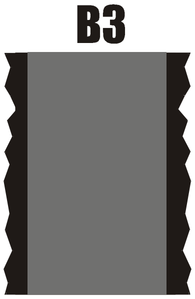


Figure A-4

Furthermore, it too sweeps up 50 grams of sand and is found to be uniformly 25% effective over the two-meter swath it makes. The maximum lateral range is one meter either side of track and it swept up sand at the same rate of 2.5 grams per second.

Finally we push B4 through an unswept portion of the test area. When the sand from B4 is weighed, again we find we have 50 grams. More detailed analysis shows the center section made a clean sweep 20 cm wide, getting 20 grams of sand in the process. The two adjacent 20-cm sections swept up 10 grams of sand each for another 20 grams. This amounts to 50% of the sand present in the two corresponding 20-cm strips on the floor. Finally, the two outboard 20-cm sections got only 5 grams of sand each, which means they were only 25% effective in their respective strips. **Figure A-5** illustrates the uneven performance of broom B4.

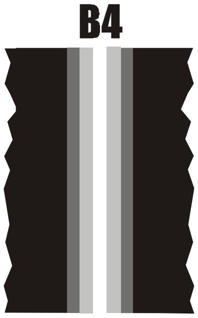
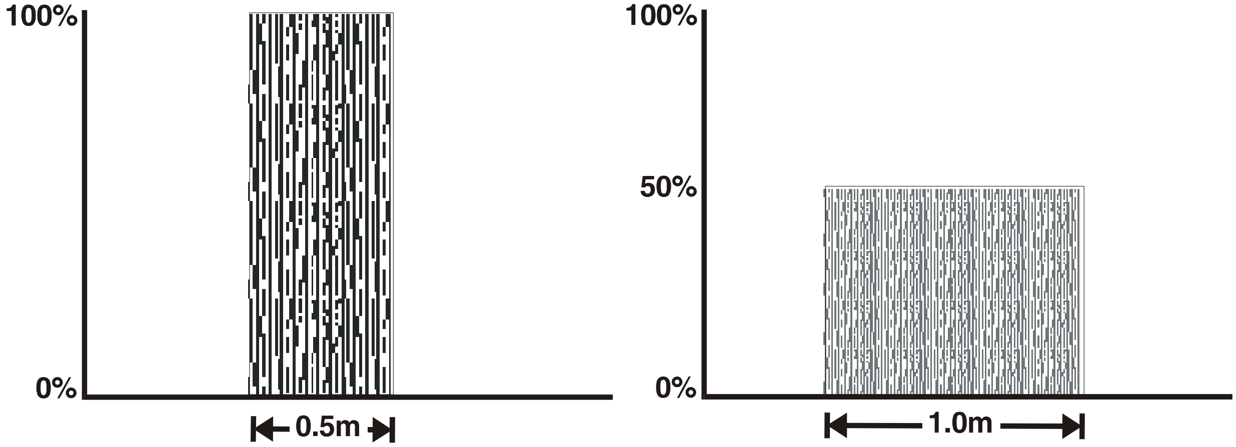


Figure A-5

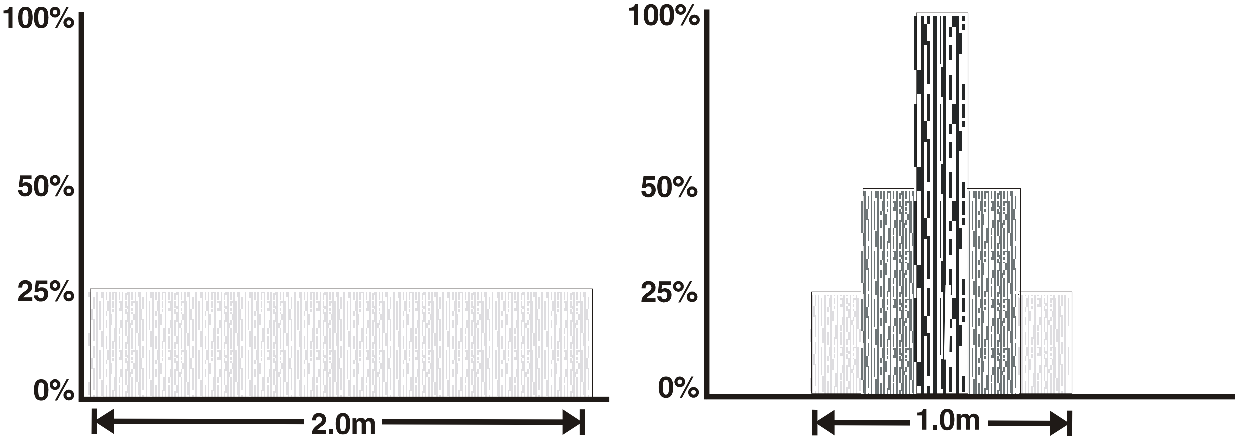
Based on the physical size of B4, the maximum lateral range of B4 is 0.5 meters from the center of its track. Finally, just as with the other brooms, B4 swept up the sand at the average rate of 2.5 grams per second.

If we graph each broom's *performance profile* as the *proportion of dirt (pod)* lying in the broom's path that is swept up across the width of the broom head as it moves forward, we get the graphs shown in **Figure A-6**.



Performance Profile for B1

Performance Profile for B2



Performance Profile for B3

Performance Profile for B4

Figure A-6

When looking at how the four brooms performed, we see that all four swept up the same amount of sand at the same rate under the conditions of our experiment, even if each broom did so in a different way. How can we characterize their "equivalent" performance? Note that the amount of sand swept up by each broom (50g) is exactly the amount found in a strip 50 cm wide and 10 m long. In fact, it is easy to show that no matter how far each broom is pushed under these same conditions, it will sweep up the amount of sand found in a strip 50 cm wide over the length of the broom's movement. That is, we can say the ***effective sweep width*** of each broom, for the purposes of computing the amount of sand swept up, is 50 cm (or 0.5 m). If we convert the percentages on the vertical axes of **Figure A-6** to decimal values (e.g., 100% = 1.0), the amount of area "under the curve" (the shaded areas in the figure) is exactly equal to the *effective sweep width* in each case. This is **not** a mere coincidence. In fact, this is one of several equivalent definitions of *effective sweep width*.

One of the alternative, but equivalent, definitions is that the *effective sweep width* equals the width of the swath where the amount of sand left behind equals the amount swept up outside that swath in one pass over the floor. It is easy to confirm mentally without computation that this is the case for brooms B1 and B2. Now consider broom B3. In a central swath 50 cm wide, it leaves behind 75% of the sand or 37.5 grams. Over the remaining 150 cm, consisting of two 75 cm swaths either side of the central 50 cm swath, it sweeps up 25% of the sand or 150 g × 0.25 = 37.5 grams. It takes a little more computation, but a similar analysis of broom B4's performance will also agree with the result obtained by weighing the amount of sand swept up.

The results of our experiments and some values of interest that may be computed from them are shown in the table below. Although the utility of some of the computed values may not be immediately apparent, their usefulness will become clear in the search planning process.

	Broom B1	**Broom B2**	**Broom B3**	**Broom B4**
Broom Width	0.5 m	1.0 m	2.0 m	1.0 m
Maximum Lateral Range	0.25 m	0.5 m	1.0 m	0.5 m
Bristle Density	Dense	Less dense	Much less dense	Composite
Broom Effectiveness (avg.)	100 %	50 %	25 %	50%
Sand "Density"	10 g/m^2	10 g/m^2	10 g/m^2	10 g/m^2
Sweeping Speed	0.5 m/sec	0.5 m/sec	0.5 m/sec	0.5 m/sec
Time	20 sec	20 sec	20 sec	20 sec
Distance Moved	10 m	10 m	10 m	10 m
Area Swept	0.5 m x 10 m	1.0 m x 10 m	2.0 m x 10 m	1.0 m x 10 m
Amount of Sand Swept Up	50 g	50 g	50 g	50 g
Average Sand Removal Rate	2.5 g/sec	2.5 g/sec	2.5 g/sec	2.5 g/sec
Effective Sweep Width	0.5 m	0.5 m	0.5 m	0.5 m
Area Effectively Swept	0.5 m x 10 m	0.5 m x 10 m	0.5 m x 10 m	0.5 m x 10 m
Effective Sweep Rate	0.25 m^2/sec	0.25 m^2/sec	0.25 m^2/sec	0.25 m^2/sec

Although strictly speaking the results tabulated above are valid only for situations that are exactly like our experiment, *effective sweep width* tends to be relatively stable and not prone to sudden large variations as conditions change. A small change in the search situation produces only a small change in *sweep width*. Therefore, the results of tests performed for a typical search situation are useful for a fairly large range of similar situations. Furthermore, it is probably more practical and less error-prone for search planners to subjectively adjust the *sweep width* value determined by experiment for a known situation to a larger or smaller estimated value for a different situation than to subjectively estimate POD values directly based on no data at all.

In our floor-sweeping analogy of detection, the different brooms represented different sensors, the sand on the floor represented probability, the sweeping action represented the detection process, the amount of sand swept up represented the amount of probability "removed" by searching and the amount of sand left behind represented the probability that still remained after searching.

Importance of *Sweep Width*

Koopman (1946) defined the *effective search (or sweep) width* in his groundbreaking work on search theory. In the ensuing years right up to the present, it has withstood the tests of time, much scientific scrutiny, and a great deal of operational usage, especially in search and rescue. *Sweep width* is a basic, objective, quantitative measure of *detectability*. Larger *sweep widths* are associated with situations where detection is easier while smaller *sweep widths* imply detection is more difficult. It should be clear that it must be important to know, in some quantitative way, how detectable the search object is in a particular search situation if we are to reliably estimate the probability of detecting that object, assuming it is present, with a given amount of searching.

The concept of *effective sweep width* is extremely powerful and lies at the very core of applied search theory.

The *sweep width* concept is extremely robust and extremely practical. An important property of *sweep width* is its relative independence from the details of the detection processes themselves, such as the exact shape of the detection profile, or exactly how the searcher's eyes and brain function to see and recognize the search object. In fact, *sweep width* integrates the effects of all the myriad factors affecting detection in a given situation into a single numeric value that is then easy for search planners to use. *Sweep width* is simply a measure (or estimate) of the average detection potential of a single specific "resource" (e.g., a person on the ground, an aircraft or vessel and its crew, etc.) while seeking a particular search object in a particular environment. Thus the concept may be applied to any sensor looking for any object under any set of conditions. For visual search, it will work for either relatively unobstructed views, such as searches conducted from aircraft over the ocean, or situations where obstructions are common, such as searching in or over forests. That is, *sweep width* may be applied to any SAR search situation, although it makes more sense to apply single *sweep width* values to situations where conditions are roughly uniform. Where there is a significant difference in environmental conditions (e.g., open fields vs. forests), sensor/searcher performance (e.g., trained vs. untrained searchers) and/or search objects (e.g., a person vs. "clues" like footprints or discarded objects), there will normally be a significant difference in *effective sweep width* as well. Where differences in these factors are small, the difference in sweep width will also be small.

Appendix B

Forms

- Environmental Data Log
- Detection Log
- Detection Opportunity Summary
- Search Object Location Log
- Track Waypoint Log
- Searcher/Participant Profile
- Searcher/Participant Log

Environmental Data Log

Date______________

Test Manager _________________________ **Organization** ____________________
Phone Number ________________________ **E-mail** __________________________

Location (attach area map) ____

Terrain Description (attach photos) ____

Vegetation (attach photos) ____

Search Objects (attach photos) ____

Weather (record hourly or when conditions change)

Time (local)	Temperature (ºF or ºC)	Wind Speed (none, breeze, moderate wind, strong wind)	Cloud Cover (percent)	Precipitation (drizzle, light snow, heavy rain, etc.)	Visibility (light fog, haze, heavy fog, etc.)

Organization(s) supplying searchers ____
Number of searchers __________

Record of data sheets and logs

Detection Log

Date and Time ______________________ **Direction of Travel**
Location ______________________ **(clockwise/counter clockwise)** _______
Name - Recorder ______________________ **Page** _______
Name - Searcher ______________________ **of** _______

TIME	EVENT (Start, waypoint, detection, etc.)	Clock Bearing (12 o'clock-Ahead as if track was straight)	Est. Distance (Indicate units used)	Comments?

Detection Opportunity Summary

Date and Time ________________________

Location ________________________________

Search Object Type	Detection? Detection = 1 Non-detection = 0	Lateral Range (provide units)	Variables (provide as many columns as needed)	Variables (provide as many columns as needed)

Search Object Location Log

Date and Time ______________________

Location ____

Object Designation *	Object Type	Along-track Distance in meters from starting point moving clockwise.	Cross-track Distance in meters to the right (+) or left (-) moving clockwise	UTM Coordinate Easting	UTM Coordinate Northing

* Attach search object location plotted on a map.

Track Waypoint Log

Date and Time ________________________

Location ____

Waypoint Designation*	UTM Zone	UTM Coordinate Easting	UTM Coordinate Northing	Dist. from start (m) and Comments
START				

* Attach map plot of track

Searcher/Participant Profile

NAME

ORGANIZATION

YEARS OF SAR PARTICIPATION		**SAR RELATED CERTIFICATIONS**
SAR SPECIALTY		
AGE	**GENDER**	**SAR COURSES COMPLETED**
CORRECTIVE LENS?	**COLORBLIND?**	
HEIGHT		

Searcher/Participant Log

Date________________________________ **Location**__________________________________

Printed Name	Organization	Time In	Time Out

Appendix C

Procedures for Conducting Experiments

To

Determine Effective Sweep Widths in Land SAR

Procedures for Conducting Experiments to Determine Effective Sweep Width in Land SAR

Any person or organization considering determining effective sweep width experimentally should be familiar with the report “A Method for Determining Effective Sweep Width for Land Searches” prepared for the U.S. National Search and Rescue Committee. The following is a step-by-step procedure.

Overview: The purpose of a detection experiment is to gather data that will indicate how “detectable” search objects are. Therefore, there will be some significant differences between the way a search is conducted and the way the detection experiment is conducted. In a detection experiment, the objective is to provide a number of detection opportunities under known conditions and to record the number of reported detections, along with enough information to determine exactly which object the searcher was looking at when each actual detection was made. A detection opportunity is defined as one complete pass by the object. Since we are interested only in initial detections, multiple detections of the same object by the same searcher will be counted as only one detection. Likewise, passing by an object without detecting it will be counted as only one non-detection. Post-experiment analysis of the data will reveal both multiple reports by a searcher detecting the same object as well as “false positives” where there was no object present near a reported detection location.

A single searcher track is selected and marked as needed for both ease in following and ease in estimating the searcher’s location along the track at any time. Search objects are placed at randomly selected locations either side of the track. Methods for selecting locations are discussed below. Searchers who are to participate in the experiment should be given no advance knowledge, nor any opportunity to obtain advance knowledge, of the object locations, number of objects, etc. prior to their actual participation.

On the day of the experiment, searchers are sent down the track one at a time, trailed closely by a data recorder. Both are to remain on the designated track and neither is to have visual aids, such as binoculars. Obviously, corrective lenses (eyeglasses or contacts) are acceptable. The searcher reports what he or she sees when they believe they have sighted a search object and the data recorder notes the time, the relevant content of the searcher’s report (object description, direction and distance from sighting location as estimated by the searcher), the location of the searcher along the track, etc. Every reported detection is recorded, regardless of whether the recorder believes it to be a previously detected object or a “false positive.” The recorder is very careful to neither cue nor interfere with the searcher in any way. The interval between searchers should be large enough so that the searchers are never within sight or earshot of one another. Occasional brief exceptions may be acceptable, however, as discussed more fully below.

Once searchers have completed the track, they are released and cautioned not to discuss their experience within earshot of any other searcher who has not yet participated. The data recorder turns in the data sheet and, depending on how many recorders are available, prepares to follow another searcher. Once all the searchers have completed the track and had their detection data turned in, the search objects and track markers are retrieved.

The collected data is then analyzed to provide an average "detectability index" or *effective sweep width* for the combination of environment, object(s) used, and the type of sensor (unaided human eye). The analysis procedure is described in the "Analyze Results" section below. This index will provide a means at later dates for objectively estimating average probability of detection (POD) under similar conditions in a search segment based on the amount of effort expended in the segment (number of searchers, average search speed, and time spent searching to give total distance traveled by the searchers while searching) and the size (area) of the segment. Once reliable POD estimates are available, other useful values may also be computed, such as probability of success (POS). In addition, POD estimates based on detectability indices (sweep widths) may be used with probability of containment (POC, also known as probability of area, POA) estimates, the number of available searchers and the search speeds in the various segments as inputs to a computer program that will help the search manager decide how to deploy those resources so as to maximize the POS as quickly as possible.

Prepare for the Experiment

Establishing the Search Scenario

1. Consider the mission and operating environment of the organization proposing to conduct the experiment.
2. Establish a scenario that is representative of one that is likely to involve the organization.
3. Decide whether the experiment is designed to establish effective sweep width (detectability index) for existing search procedures or to evaluate alternate search procedures.
4. Outline specific goals and objectives for the effective sweep width experiment.
5. Establish a minimum number of search objects for the experiment between 10 and 40.

Select a Search Experiment Area

1. Select an area that is typical, with respect to vegetation and terrain, of the conditions outlined in the search scenario.
2. Select an area with sufficient size and uniformity so that a search track within the area can accommodate a one to four hour search at normal search speeds.
3. Select either a search track laid out along a trail or one that goes cross-country.

Selecting Search Objects

1. Select a size and appearance for the search objects, often called targets, that is compatible with the search scenario.
2. Select no more than three types of search objects for any given experiment.
3. Once the size and appearance of the search objects are decided upon, choose low cost and easily transported materials to achieve this size and appearance in the experiment area.

Laying Out the Search Track on a Trail

1. Select a trail that has a start point and end point near each other.
2. Use a GPS unit to record the shape and location of the trail.
3. GPS waypoints should be determined at frequent intervals and established at every significant bend, but never more than 100 meters apart.
4. From among GPS waypoints select reference points at least every 100 to 150 meters for position control.
5. At the selected reference points place an easily visible marker, each labeled with a consecutive number or letter, to be used by the data recorder to establish distance along the track.

Laying Out the Search Track Cross-country

1. Lay out a search track on a 1:24,000 topographic map, matching the terrain and vegetation to the scenario.
2. Lay out a trail that has the start point and end point near each other.
3. Use a GPS unit to record the shape and location of the trail.

4. GPS waypoints should be determined at frequent intervals and established at every significant bend, but never more than 100 meters apart.
5. From among GPS waypoints select reference points every 100 to 150 meters for position control.
6. Flag the trail with surveyors tape frequently enough (every 10-15 meters) so that the trail is easy to follow.
7. At the selected reference points place an easily visible marker, each labeled with a consecutive number or letter, to be used by the data recorder to establish distance along the track.

Establishing Average Maximum Detection Range (AMDR)

1. Determine an AMDR for each search object type (to be used in determining the layout of the search objects):
   a. Place a search object on the track at a place representative of the average conditions in the search area.
   b. Walk away from the search object until it is lost from sight and record the distance. Out of sight of the search object travel clockwise through an angle of about 45 degrees and then approach the search object until sighted. Record the distance.
   c. Repeat this process around the points of the compass every 45 degrees.
   d. Average the eight values of detection range to arrive at AMDR.
   e. Repeat steps 2 to 5 for each search object type.
   f. Select the greatest AMDR for use in search object positioning.

Number of Search Objects

1. The number of search object locations is dependent on the track length and AMDR.
2. Check the track length and insure that it is between 30 and 120 times the AMDR.
3. Divide the track length by three times the AMDR for the most visible search object type to arrive at the number of search object locations.
4. A track length of 30 times the AMDR will provide 10 search object locations and one of 120 times the AMDR will provide 40 search object locations.

Location of Search Objects

1. Select centers for search object location zones along the track at intervals of three times the AMDR for the least visible search object type (largest AMDR). The first location will be 1.5 AMDR from the initial point of the track. For example, if the AMDR is 100 meters, the first nominal location along the track will be at 150 meters.
2. Define each zone's extent along the track as ± one AMDR either side of its center along the track. For example, if the AMDR is 100 meters the first zone will be 50 to 250 meters, the second zone will be 350 to 550 meters, etc.
3. Obtain one random number in each zone to provide the along track location (the point on the track that will have the closest point of approach (CPA) to the selected search object location). Continuing our example for an AMDR of 100 meters, a random number between 50 and 250 would be needed for the first zone, a random number between 350 and 550 would be needed for the second zone, etc. Random numbers can be obtained at many websites such as http://www.random.org/.

4. Plot each along-track location on a topographic map of the area. Determine whether any locations should be left vacant due to the location coinciding with sharp hairpin bends in the track.
5. Select the cross-track distance (the distance from the track at the CPA to the selected search object location) for the search object by obtaining a random number between the values of plus 1.5 AMDR (right of track) to minus 1.5 AMDR (left of track).
6. The selection of search object type for each zone along the track should also be random. If only two types are used the choice can be made based on whether the cross-track distance random number is odd or even. If three search object types are used, a value between zero and three may be chosen at random. Values between zero and one would indicate the first type of object should be used, values between one and two would indicate the second type should be used and values between two and three would indicate the third type of object should be used.

Placement of Search Objects

1. Accurately plot the along-track distance and the cross-track distance on a 400% enlargement of the 1:24,000 scale topographic maps giving a final scale of 1:6,000.
2. Determine the UTM coordinates for each search object.
3. Enter the UTM coordinates of the search object locations into a GPS unit as waypoints.
4. Follow the track using the GPS to determine the closest point of approach.
5. At that point depart either left or right of the track as indicated by the cross-track range value and place the appropriate search object at that cross-track range as determined by pacing. It may be necessary to move up or down the track a considerable distance so that the departure to set the search object in place will not create an obvious disturbance along the track that will cue searchers who are part of the experiment. The best solution is to have three persons involved, a "pointer" who moves along the track, stopping at the along track locations, and two "spotters," one either side of track who never come to the track itself but move parallel to it. However, this requires a range finding device such as a laser range finder.

Conduct the Experiment

Record Search Variables

1. Observe and record variables associated with the search object, the terrain, the vegetation, the weather, and the searcher.

Instructions to Searchers

1. Explain objectives of the experiment and the experiment scenario.
2. Describe the search area and track.
3. Describe the nature of the search objects or instruct searchers to report anything out of the ordinary. Record which was done. All searchers should be given identical instructions.
4. Report as detections all objects in the area that fit the description of the search objects.
5. When a detection is made the searcher should point at the object and give its distance and a clock bearing relative to the direction of travel.
6. The searcher should be asked not to discuss the search with volunteers yet to participate.

Instructions to Data Recorders

1. The data recorder will follow the searcher and record all relevant information, comments, and data.
2. The data recorder will be furnished with a map of the search area and search track. The map will be marked with reference points and distances between them.
3. The data recorder will have each searcher fill out a personal profile sheet.
4. The data collector will fill out the data sheet header information.
5. During the experiment, while following the searcher, the data recorder will record:
    a. Start time
    b. Time at each reference point
    c. Time of each announced detection
    d. Searcher's estimated clock bearing to the detected object
    e. Searcher's estimated distance to the detected object
    f. The estimated position at the time of detection on a map of the search track
    g. Searcher description of what caused them to call a "detection"
    h. General comments of searcher
    i. End time
6. Provide any searcher debriefing comments
7. Do not tell the searcher the results of the search until the experiment is completed.

Record Detection Data

1. Individual searchers followed by data recorders will search the area along the track. The data recorders will record all detections reported by the searcher.
2. Collect the detection data sheets from the recorders as each searcher completes the track.

Recovery of Search Objects

1. At the conclusion of the experiment recover all search objects and confirm their locations. Data for any search object not in its set location should be discarded and should not be used in any analysis.

Analyze Results

Data Reconstruction

1. Using the detection log, estimate the location of the searcher at the time of each announced detection using the detection time and the times at adjacent reference points.
2. Use the searcher location, search object type, searcher description, clock bearing to search object, and reference point times to determine whether a detection occurred. Discard any "false positives."
3. Use the known lateral range for the search object detected.
4. Create a detection opportunity summary that identifies each detection opportunity for each searcher and assigns each detection opportunity a value indicating a detection or non-detection. (Values of 0 for non-detection and 1 for detection are usually convenient.)
5. Summarize the detection opportunities along with all searcher, environmental, search object, terrain, and vegetation data collected and recorded.
6. Sort the summary of detection opportunities by search object type.

Estimating Effective Sweep Width

1. Sort the detection opportunities for each search object type by detection/non-detection and then by lateral range.
2. From the summary of detection opportunities plot the cumulative non-detection counts versus lateral range beginning at zero lateral range and working away from the searcher track.
3. From the summary of detection opportunities plot the cumulative detection counts beginning at the largest lateral range for the search object and working back towards the searcher track.
4. Observe the value of the point at which the two plot cross. The value of the lateral range at this point is one-half the effective sweep width for the conditions of the experiment for that particular search object.

Appendix D

Visual Detection Data Summary

VISUAL DETECTION DATA - Chief Logan State Park, Logan, WV - 15 June 2002

TERRAIN DESCRIPTION: Steep wooded hillsides with an average cross-track slope of 37%.
SEARCH TRACK-LINE DESCRIPTION: Generally level to moderate with an average slope of 15%.
VEGETATION DESCRIPTION: Eastern hardwood forest with tree diameters of 6 to 20 inches DBH. Light to moderate undergrowth.

Column 1: Search Object Description 1=Orange Glove, 2=Balloon filled plastic bag

Column 2: Detection Results Detection = 1, Non-detection = 0
Column 3: Lateral Range in meters
Column 4: Level of search object wrt track Higher elevation = 1, Level = 0, Lower elevation = -1
Column 5. Searcher average speed in km/h
Column 6: Direction of searcher travel on loop track Clockwise = 1, Counter-clockwise = 2
Column 7: Searcher SAR experience in years, Not reported=999
Column 8: Searcher corrective lens Yes = 1, No = 0, Not reported = 2
Column 9: Searcher colorblind Yes = 1, No = 0, Not reported = 2
Column 10: Search height in inches
Column 11: Age of searcher in years, Not reported 999

Column 12: Gender, M = male, F = female
Column 13: Temperature in degrees F
Column 14: Wind speed in mph
Column 15: Cloud cover in percent
Column 16: Precipitation type and intensity
Column 17: Meteorological visibility (need not be reported if much greater than the Average Maximum Detection Range)

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	17	0	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	14	0	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	21	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	41	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	32	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	32	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	14	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	9	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	2	0	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	1	5	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	31	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	24	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
1	0	17	0	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	14	0	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	21	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	1	41	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	32	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	32	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	14	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	1	9	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	1	2	0	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	1	5	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	31	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	0	24	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
1	1	17	0	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	14	0	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	21	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	1	41	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	32	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
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1	1	2	0	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	1	5	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	31	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	24	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
1	0	17	0	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	14	0	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	21	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	1	41	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	32	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	32	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	14	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	1	9	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	1	2	0	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	1	5	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	31	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	24	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
1	0	17	0	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	14	0	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	21	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	41	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	32	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	32	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	14	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	9	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	2	0	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	5	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	31	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	24	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	17	0	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	14	0	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	21	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	41	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	32	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	32	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	14	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	9	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	2	0	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	5	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	31	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	0	24	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
1	1	17	0	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	14	0	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	0	21	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	41	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	0	32	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	0	32	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	14	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	9	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	2	0	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	5	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	0	31	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	0	24	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
1	1	17	0	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	0	14	0	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	21	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	41	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	0	32	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	0	32	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	14	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	9	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	2	0	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	5	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	0	31	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	24	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
1	1	17	0	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	0	14	0	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	0	21	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	41	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	0	32	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	0	32	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	14	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	9	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	2	0	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	5	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	31	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	0	24	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
1	1	17	0	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	14	0	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	21	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	41	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	32	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	32	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	14	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	9	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	2	0	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	5	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	31	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	0	24	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
1	1	17	0	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	14	0	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	21	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	41	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	0	32	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	0	32	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	14	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	9	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	2	0	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	0	5	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	0	31	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	24	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
1	1	17	0	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	14	0	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	21	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	41	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	0	32	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	0	32	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	0	14	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	9	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	2	0	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	5	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	0	31	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	0	24	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
1	1	17	0	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	14	0	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	21	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	41	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	32	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	0	32	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	14	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	9	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	2	0	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	5	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	0	31	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	0	24	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
1	1	17	0	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	14	0	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	21	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	1	41	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	32	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	32	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	14	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	1	9	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	1	2	0	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	1	5	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	31	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	0	24	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
1	1	17	0	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	14	0	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	21	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	1	41	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	32	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	32	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	1	14	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	1	9	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	1	2	0	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	5	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	31	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	0	24	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
1	1	17	0	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	14	0	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	0	21	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	41	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	0	32	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	0	32	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	14	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	9	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	0	2	0	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	5	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	31	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	24	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
1	1	17	0	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	14	0	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	21	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	41	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	32	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	32	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	1	14	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	1	9	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	2	0	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	1	5	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	31	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	0	24	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
1	1	17	0	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	14	0	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	21	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	41	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	0	32	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	0	32	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	14	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	9	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	2	0	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	5	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	0	31	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	0	24	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
1	1	17	0	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	0	14	0	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	21	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	41	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	32	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	0	32	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	0	14	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	9	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	2	0	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	5	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	0	31	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	0	24	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
1	1	17	0	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	14	0	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	21	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	41	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	32	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	32	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	1	14	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	1	9	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	1	2	0	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	1	5	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	31	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	0	24	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
1	1	17	0	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	14	0	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	21	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	41	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	32	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	32	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	14	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	1	9	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	2	0	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	1	5	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	31	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	0	24	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
1	1	17	0	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	14	0	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	21	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	41	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	32	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	32	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	14	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	9	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	2	0	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	5	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	31	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	0	24	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
1	1	17	0	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	14	0	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	0	21	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	41	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	0	32	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	0	32	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	14	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	9	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	2	0	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	5	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	31	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	0	24	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
1	1	17	0	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	14	0	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	21	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	41	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	32	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	32	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	14	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	9	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	2	0	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	5	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	31	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	0	24	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
1	1	17	0	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	1	14	0	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	21	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	1	41	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	32	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	32	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	14	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	1	9	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	2	0	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	1	5	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	31	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	0	24	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
1	1	17	0	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	14	0	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	21	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	41	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	32	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	32	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	14	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	1	9	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	2	0	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	5	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	31	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	0	24	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
1	1	17	0	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	14	0	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	21	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	41	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	32	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	32	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	14	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	1	9	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	1	2	0	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	5	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	31	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	0	24	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
1	1	17	0	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	14	0	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	21	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	41	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	32	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	32	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	1	14	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	1	9	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	1	2	0	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	1	5	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	31	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	0	24	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
1	1	17	0	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	14	0	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	0	21	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	41	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	0	32	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	0	32	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	14	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	9	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	2	0	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	5	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	0	31	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	0	24	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
1	1	17	0	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	14	0	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	21	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	41	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	32	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	32	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	14	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	1	9	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	2	0	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	5	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
1	0	31	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	0	24	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
1	1	17	0	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	14	0	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	21	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	41	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	32	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	32	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	14	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	9	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	2	0	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	5	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	31	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	0	24	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
1	1	17	0	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	14	0	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	21	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	1	41	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	32	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	32	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	1	14	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	1	9	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	2	0	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	5	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	31	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
1	0	24	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	0	26	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	12	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	21	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	5	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	3	0	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	6	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	37	-1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	1	1	0	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	0	37	1	2.11	1	25	1	0	69	43	M	60	0	5	none	unlimited
2	0	26	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	12	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	21	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	5	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	3	0	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	6	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	37	-1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	1	1	0	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	0	37	1	1.41	1	0	0	0	64	49	F	60	0	5	none	unlimited
2	0	26	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	12	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	21	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	5	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	3	0	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	6	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	37	-1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	1	0	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	1	37	1	1.45	2	0	0	0	67	64	F	60	0	5	none	unlimited
2	0	26	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	0	12	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	0	21	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	5	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	1	3	0	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	1	6	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	0	37	-1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	1	1	0	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	0	37	1	1.96	2	0	1	0	60	74	F	60	0	5	none	unlimited
2	0	26	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	12	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	0	21	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	5	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	3	0	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	6	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	37	-1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	1	0	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	0	37	1	1.64	2	999	2	2	999	999	F	60	5	90	none	unlimited
2	0	26	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	12	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	21	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	5	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	3	0	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	6	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	37	-1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	1	1	0	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	0	37	1	1.33	1	999	2	2	999	999	F	60	5	90	none	unlimited
2	0	26	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	12	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	21	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	5	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	3	0	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	6	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	37	-1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	1	1	0	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	0	37	1	1.85	1	20	1	0	67	48	M	60	5	90	none	unlimited
2	0	26	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	12	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	21	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	5	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	3	0	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	6	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	37	-1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	1	0	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	1	37	1	1.04	2	9	1	0	75	54	M	60	5	90	none	unlimited
2	0	26	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	12	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	21	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	5	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	3	0	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	6	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	0	37	-1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	1	1	0	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	0	37	1	2.3	1	0	1	0	69	60	M	65	10	90	none	unlimited
2	0	26	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	12	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	21	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	5	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	3	0	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	6	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	37	-1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	1	0	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	0	37	1	1.51	2	0	0	0	72	40	M	65	10	90	none	unlimited
2	1	26	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	12	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	21	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	5	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	3	0	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	6	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	37	-1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	1	0	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	0	37	1	1.25	1	0	1	0	71	20	M	65	10	90	none	unlimited
2	1	26	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	0	12	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	21	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	5	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	3	0	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	6	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	37	-1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	1	0	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	1	37	1	2.03	2	3	1	0	70	32	M	65	10	90	none	unlimited
2	0	26	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	12	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	21	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	5	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	0	3	0	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	6	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	37	-1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	1	0	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	37	1	1.29	1	0	0	0	71	50	M	65	10	90	none	unlimited
2	1	26	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	12	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	21	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	5	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	3	0	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	6	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	0	37	-1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	1	0	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	37	1	1.15	2	1.5	1	0	64	29	F	65	10	90	none	unlimited
2	1	26	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	12	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	21	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	5	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	3	0	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	6	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	37	-1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	1	1	0	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	0	37	1	1.61	1	0.16	0	0	67	38	F	65	10	90	none	unlimited
2	0	26	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	12	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	21	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	5	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	3	0	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	6	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	1	37	-1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	1	0	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	0	37	1	1.14	2	5	1	0	71	24	M	65	10	90	none	unlimited
2	0	26	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	12	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	21	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	5	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	3	0	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	6	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	37	-1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	1	1	0	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	0	37	1	1.49	1	0	1	0	66	45	F	72	10	90	none	unlimited
2	0	26	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	12	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	21	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	5	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	3	0	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	6	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	37	-1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	1	0	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	37	1	0.76	2	6	1	0	74	28	M	72	10	90	none	unlimited
2	1	26	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	12	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	21	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	5	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	3	0	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	6	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	37	-1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	1	0	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	0	37	1	1.16	1	0	0	0	64	37	F	72	10	90	none	unlimited
2	1	26	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	12	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	21	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	5	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	3	0	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	6	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	37	-1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	1	1	0	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	0	37	1	1.21	2	0	1	0	61	23	F	72	10	90	none	unlimited
2	0	26	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	12	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	21	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	5	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	3	0	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	6	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	37	-1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	1	0	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	0	37	1	1.89	1	0	1	0	63	49	F	72	10	90	none	unlimited
2	1	26	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	12	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	21	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	5	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	3	0	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	6	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	37	-1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	1	0	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited
2	1	37	1	1.6	2	12	1	0	70	40	M	72	10	90	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	26	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	12	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	21	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	5	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	3	0	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	6	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	37	-1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	1	0	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	1	37	1	1.32	2	0.5	0	0	60	32	F	72	10	90	none	unlimited
2	0	26	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	12	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	21	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	5	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	3	0	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	6	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	37	-1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	1	0	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	0	37	1	1.35	1	0.75	1	0	66	42	F	72	10	90	none	unlimited
2	1	26	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	12	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	21	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	5	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	3	0	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	6	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	37	-1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	1	1	0	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	0	37	1	1.37	1	20	1	0	67	55	M	72	10	90	none	unlimited
2	0	26	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	0	12	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	21	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	5	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	3	0	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	6	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	0	37	-1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	1	0	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	0	37	1	3.02	1	1	0	0	67	15	M	75	5	50	none	unlimited
2	1	26	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	0	12	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	1	21	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	1	5	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	1	3	0	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	1	6	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	0	37	-1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	1	1	0	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	0	37	1	2.38	2	1	0	0	70	17	M	75	5	50	none	unlimited
2	0	26	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	12	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	21	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	5	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	3	0	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	6	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	0	37	-1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	1	1	0	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	0	37	1	1.85	1	6	1	1	64	64	F	75	5	50	none	unlimited
2	0	26	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	0	12	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	21	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	1	5	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	1	3	0	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	1	6	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	1	37	-1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	1	1	0	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	0	37	1	1.29	2	5	1	1	65	50	M	75	5	50	none	unlimited
2	0	26	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	0	12	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	0	21	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	1	5	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	1	3	0	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	1	6	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	0	37	-1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	1	1	0	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	0	37	1	1.7	2	2	0	0	67	45	M	75	5	50	none	unlimited
2	0	26	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	12	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	21	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	5	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	3	0	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	6	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	0	37	-1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	1	0	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	1	37	1	2.64	1	20	0	0	68	38	M	75	5	50	none	unlimited
2	0	26	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	12	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	21	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col.10	Col. 11	Col. 12	Col. 13	Col. 14	Col. 15	Col. 16	Col. 17
2	1	5	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	3	0	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	6	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	37	-1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	1	1	0	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited
2	0	37	1	2.81	1	1	0	0	74	26	M	75	5	50	none	unlimited

Appendix E

Frequently Asked Questions

Frequently Asked Questions

1. Why isn't searcher spacing ever mentioned in the report?

   A. The objective of the experiment is to obtain data on how detectable individual objects are by individual searchers on average. That really has nothing to do with how searchers are spaced or whether they are even trying to maintain some specific spacing.

2. Isn't POD dependent upon searcher spacing?

   A. Yes and no.

      i. The POD for searching a segment is really dependent upon how much (searching) ***effort*** is expended in that segment. It takes more effort (more searchers, more hours, or both to give more total distance traveled while searching) to uniformly cover the segment at a smaller spacing than a larger spacing. A smaller spacing is expected to produce a higher POD than a larger one because more effort has to be expended to achieve the smaller spacing than the larger one. On the other hand, if two searchers are sent through a segment at ***any*** spacing sufficiently large that there is no chance of "visual overlap," and if the search object is uniformly likely to be anywhere in the segment, then the chances of finding it (POD) are not at all dependent upon the spacing between the two searchers. However, it is still dependent upon the amount of (searching) ***effort*** the two searchers represent and as long as that ***effort*** remains the same, so will the POD.

      ii. For search patterns that uniformly cover a segment with perfectly straight, parallel, equally spaced searcher tracks, it is permissible to compute the *Coverage* using the following shortcut formula:

$$Coverage = \frac{Sweep\,Width}{Searcher\,Spacing}.$$

      The graph in Part IV, Figure 23 can then be used to estimate POD. However, any significant departure from the searcher tracks meeting ***all*** the requirements (perfectly straight, parallel, and equally spaced) will invalidate this formula and lead to erroneous POD estimates.

      iii. One advantage of the method given in Part IV is that it can be used with any search method that uniformly covers some amount of area. It does not matter whether a team covers the area with "purposeful wandering" or tries to maintain a fixed spacing along straight parallel tracks. As long as the size of the area, the amount of effort expended, and the effective sweep width are all known, the POD can be accurately estimated.

3. There are so many variables affecting detection, how can a reasonable number of experiments address all of them?

   A. The answer to this question has several parts.

      i. When a field experiment is done, all the factors affecting detection during the experiment are present and are therefore reflected in the detection data that is gathered. As a result, the effective sweep width obtained from that data automatically accounts for the combined effects of all those factors.

ii. While it is possible to imagine and list a very large number of factors that might affect visual detection, all experiments to date (mostly in the marine environment) have shown that only a few are truly significant. By far the most significant factor has been the lateral range or the distance between the searcher and the object at the closest point of approach. The more closely a searcher approaches an object, the more likely it is that the searcher will detect it. The results of the demonstration in West Virginia seem to support this finding, as does common sense. If one can identify and account for how variations in the few most significant other factors affect sweep width, then one can explain virtually all of the variation in sweep widths from one situation to another. This is why more than just the minimum data needed for estimating sweep width for the experimental situations themselves are being collected. Those additional data items listed on the forms in Appendix D are based on experience gained from detection experiments in the marine environment, making allowance for differences between that environment and the land environment. These additional data elements will support secondary analysis of detection experiment results. One goal of such secondary analysis would be to develop correction factors or other methods that can be applied to baseline sweep widths to estimate sweep widths for other situations without having to do an experiment for each of the infinitely many possible combinations of factors.

iii. The effective sweep width is a stable value not sensitive to small changes in search conditions. A small variation in one of the factors affecting detection will cause only a small change in the effective sweep width. In addition, however much the error may be in the sweep width estimate, the error in the resulting POD estimate will be less. For example, suppose a search is done where the computed coverage is 1.0. The estimated POD would be about 63.2%. If the sweep width were actually 10% larger than the estimated value, the coverage would also have been 10% larger than the computed value, or 1.1. As the graph of Koopman's (1946, 1980) exponential detection function (Part IV, Figure 23) shows, the POD for a coverage of 1.1 is about 66.7% or only 3.5 percentage points above the estimated value. Similarly, if the actual sweep width were 10% smaller, the coverage would have come out to be 0.9, giving a POD of about 59.3%, which is only 3.9 percentage points below the estimated value.

iv. Finally, given a standard experimental procedure like the one described in the body of this report, the number of experiments need not be kept small. SAR organizations everywhere could do experiments within their respective areas of responsibility. For the U. S., if only one experiment per year were done in each state, that would be 50 experiments in 50 potentially different venues producing thousands of data points. In just four years 200 experiments could be done, and since many if not all states have several SAR organizations, the workload for each should be quite reasonable. The major issues that have not yet been addressed are creating and maintaining a central repository for the data and identifying resources to perform the secondary analyses.

4. How does sweep width relate to average maximum detection range (AMDR)?

A. There is no direct relationship between sweep width and AMDR. AMDR, as the name implies, measures the maximum distance at which an object can be seen on average. Some people think that searchers should be separated by twice the AMDR to minimize "visual overlap" between adjacent searchers on parallel tracks. This is a grossly oversimplified view of searching. AMDR does not measure how much detection potential exists for the searcher to locate the object, whereas sweep width does. There is a great deal of difference between measuring the maximum range at which an object whose exact location is known ***can*** be detected by a searcher, and a "detectability index" (effective sweep width) that measures the potential for whether an object whose location is not known ***will*** be detected by a searcher.

5. Aren't the searchers the most qualified people to estimate the POD for their efforts since they were the ones actually doing the searching and have first-hand knowledge of conditions in the segment?

A. Searchers are certainly the most qualified persons to report on what conditions were like in the segment they just searched, how fast they were moving while searching and how much time they actually spent searching, exclusive of breaks and time to get to and from the segment. The reported search conditions should certainly be factored into the search manager's estimate of the effective sweep width. Then, together with the other information, the search manager can compute the area effectively swept, the coverage and the POD. This is a far more objective and reliable technique than any subjective estimate can ever be. The following points are also worth considering:

i. As a general rule, humans are very poor at estimating probabilities of any kind. Many psychological studies attest to this, as do the business practices and wealth of gambling establishments.

ii. Furthermore, even the most experienced searcher is unlikely to have any experience base (much less actual recorded data) on which to base POD estimates. Most actual "live" searches have only one search object (although all searchers should be "clue-aware"). Such searches usually involve tens, sometimes hundreds, occasionally even thousands of searchers. At most, one of these searchers will be the one to find the subject. SAR volunteers could easily, and through no fault of their own many probably do, go their entire lives without ever finding either the object of a real search or a clue, even if every search in which they participated was successful.

iii. Finally, and perhaps most importantly, searchers can realistically report only what they have seen, not what they have not seen. That is why a well-run experiment is so valuable. Both the detections and the misses are recorded so that a complete picture of the detection process emerges.

6. Assuming searchers are going to follow perfectly straight, parallel, equally spaced tracks, what is the most efficient spacing in terms of sweep width?

   A. When looking at a single search of a single segment, there is no such thing as "most efficient spacing." When taken in the context of other segments, their POA values, the sweep width values and search speeds in them, and the total amount of (searching) effort available, there is an optimal allocation of the available effort that maximizes the total POS attainable with that amount of effort. That is, each segment should receive some fraction of the available effort, with the amount for each segment depending on the values of the variables just mentioned in all of the segments. However, this is a subject that requires much more time and space than that available here to treat it adequately. In practice, determining optimal allocations also usually requires an appropriately programmed computer due to the potentially large number of computations needed.

7. Isn't it more efficient to cover a segment twice with low-POD searches than once with a high-POD search since two low-POD searches typically have a cumulative POD that is higher than the POD of a single high-POD search?

   A. No. This question is based on a false premise. As a general rule, if a fixed level of effort is applied approximately uniformly over an area, the resulting POD will be highest when all the effort is applied at once rather than piecemeal. The piecemeal approach can never do better than equal the single search POD value. This can be easily proven from the principles of search theory, but it is also easy to do a convincing "thought experiment" that involves no computation. Suppose ten searchers are available. Consider two alternatives for a parallel track search:

      i. Send five searchers through the segment at a spacing of 2***S*** followed by the other five at the same spacing but with their tracks offset from those of the first group by ***S*** so the second set of tracks fall exactly halfway between those of the first set.

      ii. Send all ten searchers through the segment at a spacing of ***S***.

   Both alternatives end up with the same ten searchers following the same ten tracks. How can different POD values result? Also note that in the two-search case, if the second set of tracks does not fall halfway between those of the first set due to some error or simply not knowing exactly where the first group of searchers went, then the two-search alternative has potentially less chance of finding the object than the one-search alternative, which is less likely to have the tracks unequally spaced.

   There is another disadvantage to the two-search alternative—it may take longer. If the second group of five searchers is available as early as the first group and the second group cannot be more productively employed elsewhere, then that group might as well search with the first group rather than waiting for the first group to finish.

   However, it ***is*** true that if the search object is equally likely to be anywhere in the search area and the search speeds, sweep widths, etc. are also the same everywhere, then, in theory, the most efficient thing to do in terms of increasing POS as quickly as possible is to spread all of the available effort evenly over the entire search area, even if the coverage (and consequently the POD) is very low. That is, searching two equal segments (same areas, POAs, sweep widths, search speeds, etc.) at a coverage of ***C*** under the circumstances just stated will produce a higher **POS** (***not*** POD) than searching one of them at a coverage of 2***C***.

It is easy to see why this is true when looking at the POD vs. Coverage curve in Part IV Figure 23. Doubling the coverage always produces significantly less than double the POD. Thus POD is governed by a law of diminishing returns in terms of effort investment. To make the POS in one of two equal segments equal the POS of searching both equally, one would have to double the POD in that segment which would require more than double the coverage (and effort). Therefore, there are times when it is better to search more segments at lower coverages than fewer at higher coverages.

However, the opposite can also be true. In more typical situations where area, POA, sweep width, search speed, etc. vary from segment to segment there are often times when it is better to search fewer segments at higher coverages. Exactly how much of the available effort should be applied to each segment to maximize the overall POS is the optimal effort allocation problem that we put off answering in question 6 above.

8. Isn't it inefficient to place searchers at spacings less than twice the average maximum detection range (AMDR) since some of the area between them will be looked at twice due to visual overlap?

   A. Not necessarily. If searchers are separated so far that they leave areas of zero POD between them, then some means of covering those areas later will be needed if the search object is not found. In addition, the individual searcher's POD is very dependent on how close the searcher gets to the object and tends to be very low at large lateral ranges. Some visual overlapping is necessary if the cumulative POD value from "visual overlap" between searchers is to reach a reasonable level. Again, the word "efficiency" really has no meaning when associated with searcher spacing. In fact, it is better not to think in terms of searcher spacing within a single segment or "efficiency" at all but in terms of coverage, as defined in the body of this report, and maximizing the overall POS through an optimal allocation of the available resources. The most efficient search is the one that produces the highest overall POS.