Sweep Width Estimation for Ground Search and Rescue

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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.

Searching is by its very nature a probabilistic process in which there is no guarantee of either success or failure. Searching remains a significant challenge, especially when lives are at risk. 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 and level of effort.

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" (ESW). This concept reduces the combined effects of all the factors affecting detection (sensor, environment, search object) in a given search situation to a single number characterizing search object "detectability" for that situation. Effective Sweep Width can be considered a "detectability index" that takes everything into consideration. It should not be thought as the "width" or spacing between sensors. Unfortunately, effective sweep width cannot be measured directly. It is necessary to perform detection experiments and reduce the data from them.

The objectives of this project were to:

- Validate and refine the experimental technique developed in *A Method for Determining Effective Sweep Widths For Land Searches: Procedures for Conducting Detection Experiments* for estimating the effective sweep width for a search object in wilderness or rural regions for ground searchers, using different SAR units in different ecological and geographical regions.
- Determine an appropriate search object that represents a typical immobile unresponsive search subject in the areas where experiments are to be conducted.
- Determine a typical physical object that provides a clue to the subject's location in the same areas.
- Conduct three experiments using the technique for a typical set of search conditions and report the results. The selection of the locations shall be based upon different ecological regions and use recognized ground SAR units as searchers to determine sweep width. These trials shall include an in-place estimate of the average maximum detection range of the object used for the demonstrations under the conditions existing when and where the demonstrations are conducted.
- Identify variables that may influence ground based sweep width and incorporate them into the data collection methodology.
- Select one area convenient to the contractor that allows repeated experiments in similar terrain but at different sites. This area shall be used to determine the repeatability and reliability of the methodology to determine effective visual sweep width.
- Provide a refined practical experimental procedure for estimating sweep width that inherently accounts for all variables at the time and place where the procedure is used, along with any appropriate explanations of the procedure. This procedure shall be suitable for publication and use by ground SAR personnel, with minimal need for expert supervision.
- Develop data compatible with search planning and POD estimation methods that are designed to use sweep width data.

An experimental methodology to determine effective sweep width had already been piloted and discussed in *A Method for Determining Effective Sweep Widths For Land Searches: Procedures for Conducting Detection Experiments.* That report made several suggestions for enhancements and noted several difficulties that occurred during the pilot experiment. This report describes several enhancements, changes, and innovations to the methodology. Several new tools were developed to assist in the design, collection, and analysis of the data. Standard search objects were constructed based upon research of actual ground missions and human dimensions. Modifications were made on how to scout and layout the experiment track. Changes were made in how to determine the Average Maximum Detection Range (AMDR). Several additional methods to characterize the vegetation and terrain were added. Laying out the actual search objects were greatly simplified by the development of a software tool. The data collected during the experiment from searchers and the environment were more thorough to allow identification of factors that may affect sweep width. The method used to score, enter, and analyze the data was further simplified and made automatic. It is now possible to have no understanding of search theory or mathematics but still derive a sweep width. These changes and enhancements are described in Part II – Experiment Methodology.

During the five experiments conducted, several important results were obtained. Both primary and secondary findings were obtained. Primary findings were the actual goal of the experiments – effective sweep widths for the search object in that particular environment. Relationships between the sweep widths and environmental measurements were also made. Secondary findings described possible correction factors to sweep width, searcher's ability (or inability) to estimate POD directly, searcher technique, and other relationships between the data. Experienced searchers participated in the experiment with the average number of years in SAR equal to 8.7 and the average number of searches equal to 47. The average search speed was remarkably consistent in all five experiments with searchers moving at 1.75 km/hr. The environmental measurements including AMDR varied widely at each experiment as expected due to different Ecoregions. The number of detection opportunities ranged from 128 – 434. An analysis of number of detection opportunities and the stability of the data showed once 100 detection opportunities had been achieved the sweep width value was stable. Effective sweep widths were calculated for each search object at each site. Sweep width values ranged from 142 meters for a high-visibility adult in the Virginia forest (Hot Continental Ecoregion) during the winter to 17 meters for a low –visibility adult in the dense Washington forest (Marine Ecoregion). Clue sized high visibility search objects ranged from a sweep width of 8 meters in Washington to 20 meters in California. It is clear that the land environment has an important influence on sweep width. This was not a surprising finding. A possible relationship was found between the high, medium, and low visibility search objects regardless of the Ecoregion (The dry domain of New Mexico provided an exception). A possible relationship was also found between AMDR and sweep width. More experiments need to be conducted before this possible shortcut (to conducting a full experiment) should be used. Several potential correction factors were measured to determine if they influenced the sweep width. Primary SAR training appeared important for Park Rangers and mantrackers. Search experience was expected to be a significant correction factor. However, the results indicate that search experience does not improve the number of detections. The age of the searcher showed that the probability of detection (POD) increased up to the age of 40 and then started to decline. Searcher speed when kept between 1-3 km/hr did not affect sweep width. Searcher's Height, color-blindness, self reported morale, and self-reported fatigue had dramatic effects on sweep-width. Gender was found to have no effect. While data was collected on weather conditions (temperature, wind, precipitation, cloud cover, and meteorological visibility), the experiments were not designed to examine these factors. Also, the need to collect light (lux) levels was identified. Other important findings included the importance of various search techniques or lack thereof. Perhaps the most important result was that sweep width results can easily be obtained in the ground environment and that the scoring and analysis can be highly automated.

For the first time ever in the ground SAR arena an experimental technique was developed that obtains effective sweep widths using automated planning tools. A practical model for ground SAR detection experiments was designed and demonstrated, including a data reduction technique that requires no computational skills. The technique worked equally well in vastly different Ecoregions, from dense Washington Marine forest to open grass of the California Mediterranean region. Implementing this model will make the cost of obtaining effective sweep width data minimal. All of the experiments used SAR volunteers as searchers and often as an important part of the command and control team. 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. Standard low-cost ($1-4/search object) search objects representative of high, medium, and low contrast adults were developed. A physical object (hat) based upon clues found on actual incidents was recommended. A total of five versus the required three experiments were conducted in widely different Ecoregions. Searchers with an average of 9 years of SAR experience were recruited. Average Maximum Detection Range was calculated for each search object. Furthermore, a possible relationship between AMDR and ESW is described. Further tests are required to validate the relationship. Several variables that may influence sweep width were measured during the experiments. Promising variables include SAR background, height, age, color-blindness, fatigue, and morale. The experiments did not allow analysis of environmental factors such as temperature, wind, precipitation, light levels, cloud cover, or meteorological visibility. It is also likely that search technique will be an important factor once additional studies are completed and 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. The next step is further development of the (Microsoft) Excel Experimental Design Calculator that is used to design, conduct, analyze, and provide storage of all experimental data. This tool was designed for use by the experimental development team and is not appropriate for the general public at this time. In addition, to further improve the briefing process a video briefing needs to be developed. Before other teams start implementing the methodology training sessions and limited assistance from the original experiment team should be scheduled. Important findings need to be validated and correction factors determined. Simple worksheets and software tools to put these findings into practice also need to be developed.

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Last, but certainly not least, the heartfelt gratitude and sincere appreciation of the entire experiment team is extended to all those volunteers—too numerous to name here—who took time from their activities during each of the experiments to participate in the experiments. Their participation not only produced the needed data, it also produced many useful and relevant comments, suggestions and observations.

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 Homeland Security, 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 forums 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.

About the Authors

Robert J. Koester has been associated with Ground Search and Rescue (SAR) for 24 years and has responded to hundreds of incidents, functioning as the Incident Commander on almost 100 of those missions. He received a M.S. from the University of Virginia with a specialization in neuroscience. Robert serves as a Type I Incident Commander with the Appalachian Search & Rescue Conference, SAR Instructor with the Virginia Department of Emergency Management, president of the Virginia Search & Rescue Council, Course Developer for the Virginia Department of Criminal Justice, Instructor for the Federal Emergency Management Agency, and president of dbS Productions. He has conducted original research on behavioral and statistical profiles of lost Alzheimer's, despondent, psychotic, and those with mental retardation. Recent work has included further analysis of lost person behavior broken into Ecoregions. Ongoing projects include the further creation of lost person categories using 17,000 incidents collected from SAR teams from around the world and further data collection. Coupled to this project is the development of computer software to aid in the management and planning of searches. Additional research areas include the impact of fatigue on sustained operations. He has authored numerous training programs; including texts on *Incident Commander for Ground Search and Rescue*, *Lost Alzheimer's Disease Search Management*, *Fatigue*, *Outdoor First Aid*, *GPS for Field Operations*, and FEMA courses. He has also authored several books and academic papers on search related topics. Much of his research can be found in the primary SAR textbooks. He is the publisher of NASAR's electronic newsletter, *SARNEWS*. In addition, he gives talks, keynote addresses, and workshops around the world to the International SAR community on a frequent basis.

Donald C. Cooper is Deputy Fire Chief with the City of Cuyahoga Falls Fire Department in Northeast Ohio where he has served as a fulltime fire officer, paramedic, and special operations instructor since 1979. In this capacity, he has responded to hundreds of SAR missions in urban, rural and wilderness settings. He chairs the National Fire Protection Association's (NFPA) Technical Rescue Committee, serves on the NFPA's Technical Committee on Disaster Management, serves as a management consultant to Ohio's FEMA Urban SAR Task Force (OH-TF-1), teaches research methodology in the Ohio Fire Executive program taught by the Ohio Fire Chiefs' Association (OFCA), and is qualified as a Type III Incident Commander with Ohio's Incident Management Team. He is President of National Rescue Consultants and, in 1984, researched, designed and developed the FUNSAR Basic Skills Project for the National Association for Search and Rescue (NASAR). Since that time, he has designed, developed and taught numerous search, rescue, survival and emergency response programs around the world. He also currently serves as the Research and Development Manager for NASAR and in 2002 was awarded the prestigious Hall Foss Award—NASAR's most prestigious award—for significant contributions to the field of search and rescue both nationally and internationally. He received his Ph.D. in Business Administration in 2003 and is the author of several emergency service textbooks including *FUNSAR: Fundamentals of Search and Rescue, Fundamentals of Mantracking: The Step-By-Step Method* (with Ab Taylor), and *The Aviation Survival Handbook*. He is co-author of *Compatibility of Land Search Procedures with Search Theory* for the National SAR Committee, co-author of the book *Managing Search Operations*, and a major contributor to the medical reference text *Wilderness Medicine: Management of Wilderness and Environmental Emergencies*. In addition, he frequently gives talks, keynote addresses, and workshops around the world to the International SAR community.

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.

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. He designed and conducted the prototype land detection experiment at Logan, WV in 2002 and authored the report: *A Method for Determining Effective Sweep Widths For Land Searches: Procedures for Conducting Detection Experiments.*

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Part I – Introduction and Background

1. Introduction

Searching, a common activity, is the process of seeking something in a conscious, careful manner. For this reason the process is often taken for granted. Searching in a limited uncomplicated environment may be simply a matter of just looking around for the lost or missing object. In the search and rescue context the circumstances and the environment of the search are often complex. This complexity requires a high level of organization familiar to those engaged in search and rescue. Much progress has been made in the organization of the management, logistics and teams necessary for a successful operation. A considerable amount of progress has been made in resolving the question of generally where to search. Much less attention has been directed toward the description and quantification of the detection process or the optimal allocation of searching effort. The detection process is the foundation on which a successful, quantifiable search planning structure can be built. In this report we are continuing the development of a method, suitable for use in a variety of land environments, for determining the Probability of Detection (POD) based upon actual field data. These data will take into account the parameters affecting a search, including searcher, search object, and the environment of the search. The successful application of accurate POD values will improve the search planning process and lead to an improved method of tracking the Probability of Success (POS) and allocating resources and effort. As always the goal of this work is to speed the safe return of persons who are missing.

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, p. 2). 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 only the basic concept of detection. 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.

1.1 The Report

This report records the design, conduct, and results from five land detection experiments. The experiments covered three seasons of the year and were conducted in five distinct environments (Ecoregion Provinces) in four regions (Ecoregion Divisions) of the United States. The locations of the experiments were the Shenandoah National Park in Virginia, the Lincoln National Forest in New Mexico, the Gifford Pinchot National Forest in Washington State, Northern Virginia near Lansdowne, and Mt. Diablo State Park in California. The report refines and expands the results of Robe and Frost, 2002 by increasing the regional, environmental, search object, and searcher scope of the data collection. It is the hope of the authors that the results and conclusion of this report will both provide useful search guidance for search planners in the form of verifiable POD's for non-responsive human sized objects and provide enough organizational material to permit SAR groups to collect and process detection data specific to their local conditions.

This report is divided into five major parts and several appendices. Part I provides an introduction and scientific background for the methods used in this project. Part II describes the procedures used in designing, setting up and performing these detection experiments 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 presents the experimental results of the five experiments. Part IV describes how POD is estimated. Part V contains conclusions and recommendations for future work. The appendixes contain ancillary information that would be of importance for someone desiring to explore the subject in greater depth, in conducting an independent experiment or a reanalysis of the data

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.

1.2 Previous Demonstration Project

The work described in this report is a follow-on to land search detection demonstration conducted near Logan, West Virginia on 15 June 2002 (Robe & Frost, 2002). That report documented a preliminary attempt to apply well-established search theory to the land search environment. The demonstration conducted at Logan, West Virginia was successful on the two levels necessary to proceed into the present phase of the work. (1) The experiment demonstrated that it was possible to organize and conduct a land search experiment that permitted individual searcher/search object interactions to be recorded with respect to searcher characteristics, search object characteristics, and the search environment. (2) The data presented in the report reflected a pattern that was consistent with search theory and experience. That is, detection opportunities could be characterized as either a detection or non-detection and that a search object's detectability decreased with increasing distance from the search trackline.

1.3 Probability of Detection (POD)

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 or define search methods and tactics. 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). To be precise, POD is an estimate of how likely a search of a particular well-defined area will be successful, *assuming the search object was there to be found*. That is, POD is a *conditional* probability, the condition being the assumption that the object is present 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.

1.4 Definitions

Due to the great quantity of special terms used herein, definitions have been listed in their own appendix (Appendix A).

2. Scientific Background

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. Prior to his work there was no published scientific literature on search theory. 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.

2.1 "Detectability"

One of the weaknesses of the original implementation of search theory by the U. S. Coast Guard 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.

2.2 Lateral Range

The method for estimating effective sweep width uses the concept of a "lateral range curve". This concept, introduced by Koopman (1946), 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 2-1 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.

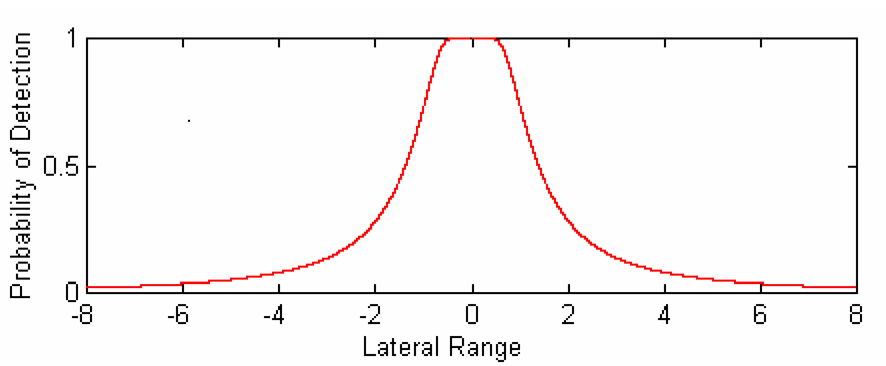


Figure 2-1. A lateral range curve (a.k.a. detection profile).

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. This is largely due to the simple physics of the eye, the closer the object the greater the visual angle. The visual angle versus distance for the two different size search objects used in the experiments (adult and glove) is shown in Figure 2-2. It can be noted how closely the simple physics of the eye matches the lateral range curve (detection profile) shown in Fig. 2-1. 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 may take 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.

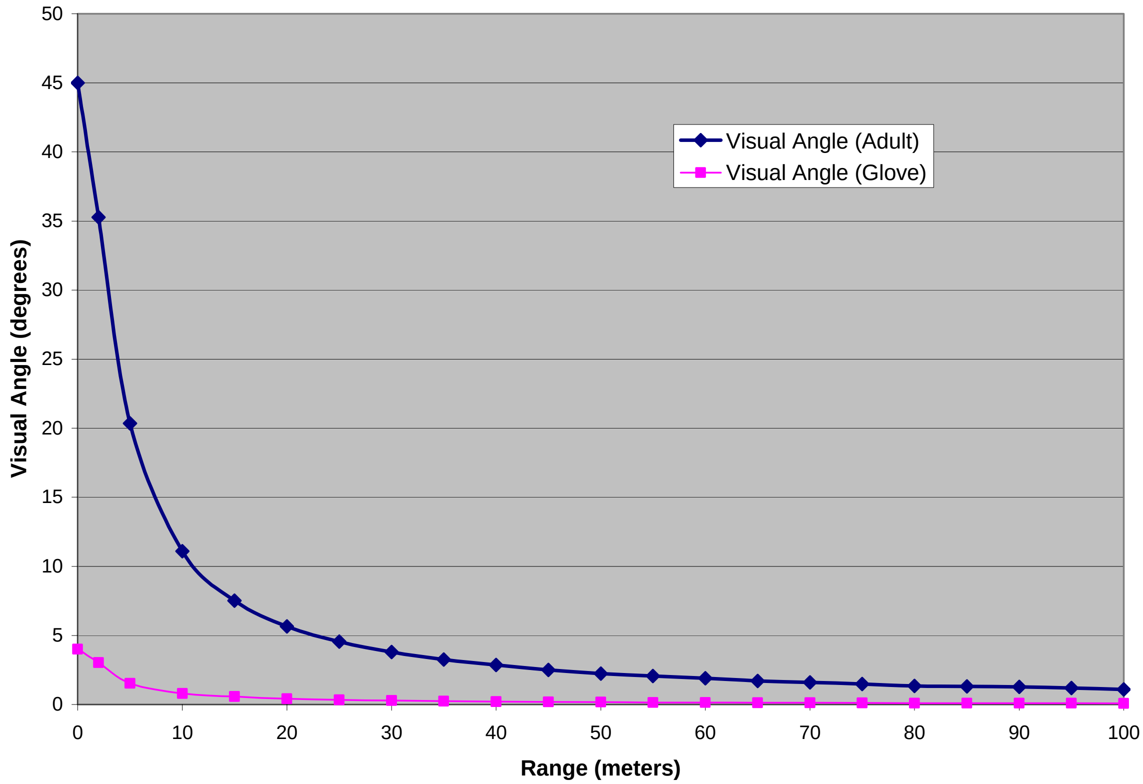


Figure 2-2. Angle versus range of adult (body) and glove (clue).

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?"

2.3 Effective Sweep Width

S*weep width* is one of the central concepts of search theory and its application to SAR. The term *sweep width* has a specific mathematical definition different from what one might infer from the usual meanings of its component words. Therefore, we should discuss the term at least briefly before proceeding further and provide at least one or more informal definitions. References to more complete and mathematically rigorous discussions will be provided.

Sweep width is a single number characterizing the average ability of a given sensor to detect a particular search object under a specific set of environmental conditions. Thus each combination of sensor, search object, and set of environmental conditions will have a particular associated sweep width. In the vernacular, sweep width might be called a measure of "raw detection power." Loosely paraphrasing Koopman (1980), sweep width may be described as follows:

Consider a sensor moving with constant velocity through (or over) a swarm of uniformly distributed, identical, stationary search objects under constant environmental conditions. If the average number of objects detected per unit time is divided by the object density (average number of objects per unit area), the resulting value is called the *effective search or sweep rate*. It is easy to see that the effective sweep rate has dimensions of area over time (e.g. square miles per hour). Dividing the effective sweep rate by the speed of the sensor gives the *effective search or sweep width*, which has units of length.

Notice that the above description does not imply that every object in the "swept area" is detected. Indeed, the meaning of "swept area" itself is not clear. To clarify how the term *sweep width* got its name, we will give an alternative description (also loosely derived from Koopman, 1980):

Consider an omnidirectional sensor that is "perfect" (i.e. 100% effective) within some definite range and completely ineffective beyond that range. That is, detection is guaranteed for any object the sensor approaches more closely than the definite detection range, and the sensor never detects any object beyond that range. This idea is analogous to setting a lawn mower's blade to a height of zero and then pushing it into tall grass. The lawn mower would leave behind it a swath of bare earth having a definite width (twice the definite detection range), while blades of grass outside this width would be untouched. Inserting this particular sensor into the previous description, it is easily seen that in this special case (and this special case alone), the sweep width is literally the width of the swept area where the detections took place, i.e. twice the definite detection range. The concept is generalized by defining the *effective sweep width* of any sensor as equal to the sweep width of a definite range sensor that detects the same number of objects per unit time as the given sensor does under identical circumstances (i.e., same sensor speed, same object density, same environmental conditions). Generally the word *effective* is dropped, shortening the term to just *sweep width*. This is sometimes a source of confusion to new students of search theory and also to search planners in the field.

We see that in only one situation, namely definite range detection, does the sweep width actually correspond to a physical, geometric width measurement. Otherwise, it is a more abstract concept, but nevertheless one of great value and utility on both the theoretical and operational fronts.

Additional treatments of the sweep width concept, some with illustrations, may be found in Koopman (1980), Stone (1989), and Frost (1998c, 1999b).

Unfortunately, sweep width cannot be measured directly for cases other than definite range detection. 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 10 meters either side of the searcher's track, and detected no objects outside that range. That is, the searchers were 100% effective within 10 meters 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 20 meters wide with no detections outside that swath. The effective sweep width in this case would be 20 meters. 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 20 meters either side of their tracks, but they detect, on average, only half the objects located in that swath of 40 meters. Note that there will be twice as many objects in a 40 meters swath as in a 20 meters swath of the same length. Therefore, even though the searchers detect only half of those present in the 40 meter 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 20 meters. That is, both groups of searchers detected the same number of objects as lay in a swath 20 meters 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. Knowing the maximum detection range does not help with POD estimation. But, the results of this report suggest that extensive and repeated experimentation may discern a relationship between the average maximum detection range (AMDR) and effective sweep width for a specific environment. 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.

The effective sweep width may be thought of as the width of the swath where the number of objects *NOT detected inside* the swath are equal to 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 2-3) equals the number that are detected at greater distances from the searcher's track (areas A below the curve in Figure 2-3), then one has found the effective sweep width.

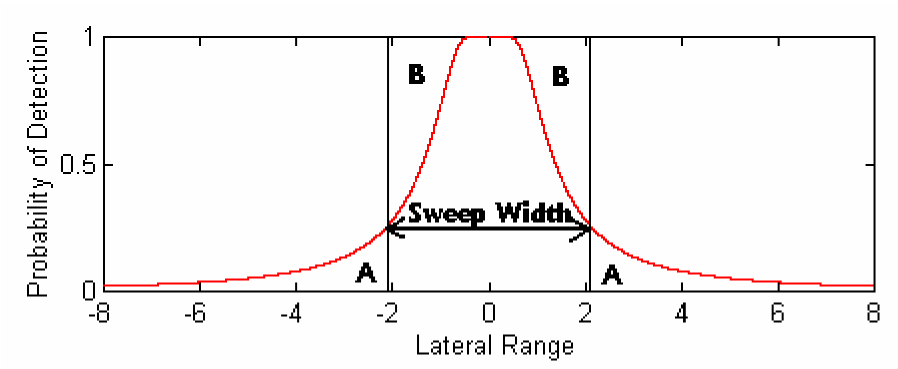


Figure 2-3. A lateral range curve showing effective sweep width. The number of missed detections (B) inside the effective sweep width equals the number of detections (A) that occur outside the sweep width.

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 some other data analysis methods.

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 2-4, 2-5, and 2-6 below illustrate the concept of effective sweep width in another way. The black dots in Figure 2-4 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.

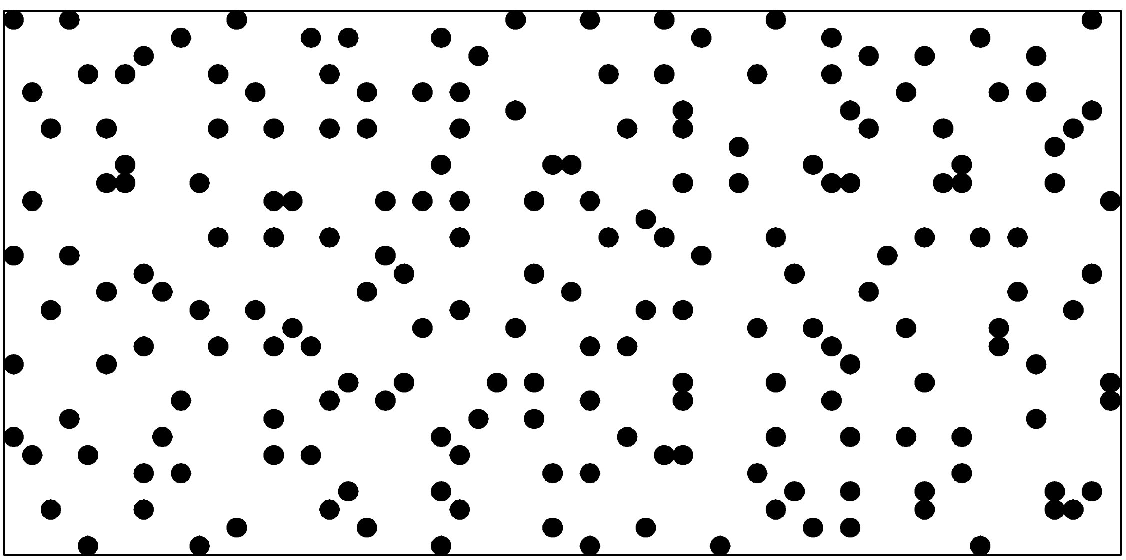


Figure 2-4. A uniform random distribution of search objects.

Figure 2-5 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.

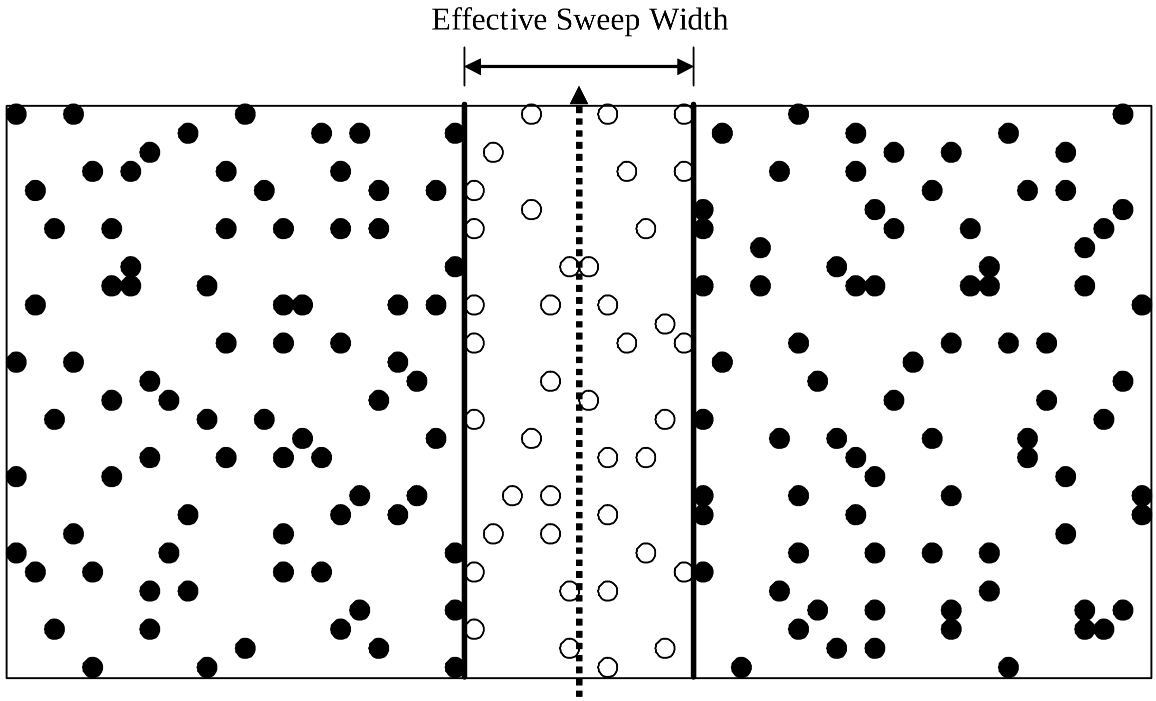


Figure 2-5. Effective Sweep Width for a clean sweep.
Dotted line represents searcher's track. Number missed within sweep width = 0.
Number detected outside sweep width = 0.

Figure 2-6 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.

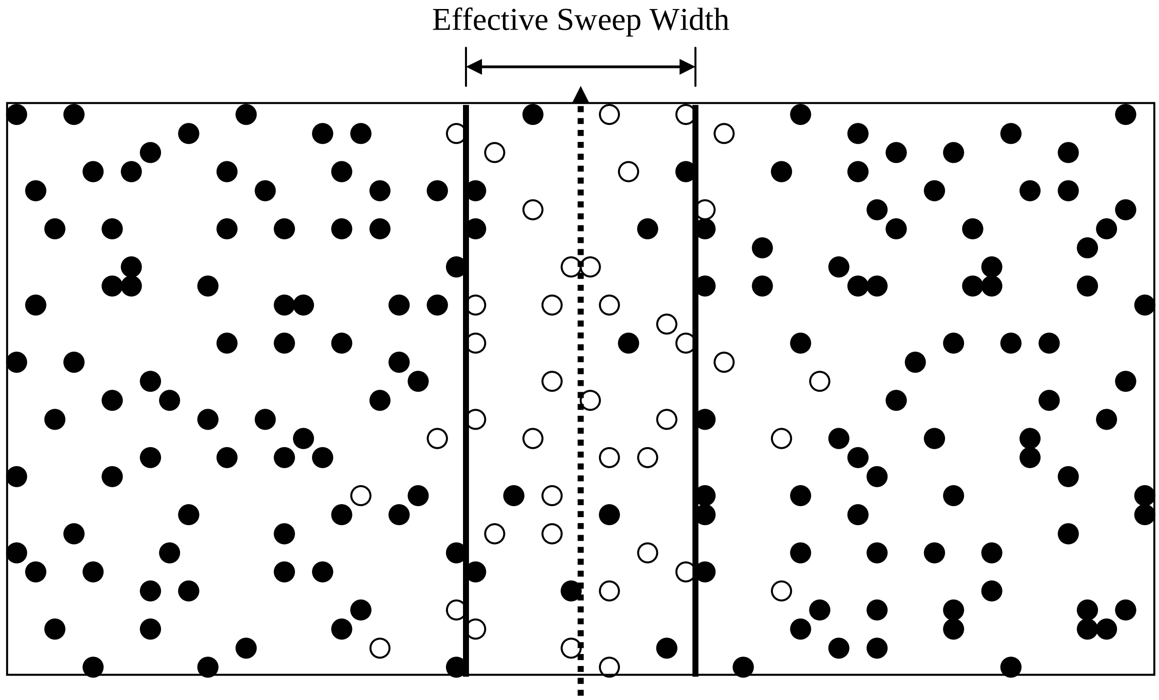


Figure 2-6. Effective Sweep Width.
Dotted line represents searcher's track. Number missed within sweep width = 11.
Number detected outside sweep width = 11.

Figure 2-6 also illustrates the property of effective sweep width where the number of undetected objects inside the swath equals the number of objects detected outside that swath.

Appendix B 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 (Figures 2-3 and 2-6). 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.

As a practical matter, it is not possible to directly "measure" sweep width at the place and time of a search. It is also impossible to develop sweep width values for the infinitely many possible combinations of sensor, search object, and environmental conditions. The Coast Guard has addressed these problems by designing and conducting numerous experiments to gather empirical data from which operationally useful sweep width estimates may be inferred. The Coast Guard's Research and Development Center has been conducting such experiments for more than twenty years, identifying the significant variables affecting operational sweep widths in the marine environment and producing extensive sweep width tables indexed to these variables. These tables are published in the U. S. *National SAR Supplement* (National Search and Rescue Committee [NSARC], 2000) and in a simplified derivative form in the *International Aeronautical and Maritime Search and Rescue Manual* (ICAO/IMO, 1999a-c).

2.4 "Effort" and "Search Effort" (Area Effectively Swept)

Effort is a measure of resource expenditure and may be defined as the amount of distance covered by the searcher(s) in a search segment while searching. It could be measured in several ways, but the usual metric for search theory purposes is the distance a sensor platform travels while in the search segment. 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.

Search effort is a measure of how much "effective" searching is done by the sensor as it moves through the search area. *Search effort* is simply the product of the sweep width and the distance the sensor travels while in the search area or:

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

It is easy to see that *search effort* has units of area. It is often called *area effectively swept.*

2.5 Coverage

Coverage (sometimes called *coverage factor*) is a relative measure of how thoroughly an area has been searched, or "covered." *Coverage* is defined as the ratio of the area effectively swept to the physical area of the segment that was searched:

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

Searching an area and achieving a *coverage* of 1.0 therefore means that the *area effectively swept* equals the area searched. Note that this does not necessarily mean that every piece of ground was scanned nor does it mean that the POD of a coverage 1.0 search is at or near 100%. 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 2-7 (POD versus Coverage curve) 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.

It is important to always remember that coverage and the corresponding level of effort are proportional. To double the coverage it is necessary to double the level of effort and doubling the level of effort doubles the coverage. In other words, although the relationship between POD and coverage is not linear, the relationship between coverage and effort is. This means, by extension, that the relationship between effort and POD is not linear, either. Doubling the effort assigned to a segment will not generally double the POD.

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 2-7 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.

It can be seen that *coverage* is proportional to *search effort density*, the constant of proportionality being the *sweep width*. Therefore, any solution to the optimal search density problem is also a solution to the optimal coverage problem. In this sense, the two terms may be used interchangeably when discussing optimal search plans.

2.6 Probability of Detection (POD)

The probability of detection (POD) is defined as the *conditional* probability that the search object will be detected during a single sortie *if* the search object is present in the area searched during the sortie. Cumulative POD (POD_{cum}) is the cumulative probability of detecting the search object given that it was in the searched area on each of several successive searches of that area.

Like coverage, it is a measure of how thoroughly an area was searched. The relationship between coverage and POD is usually plotted on a graph of POD vs. Coverage. Such a graph appears in Figure 2-7.

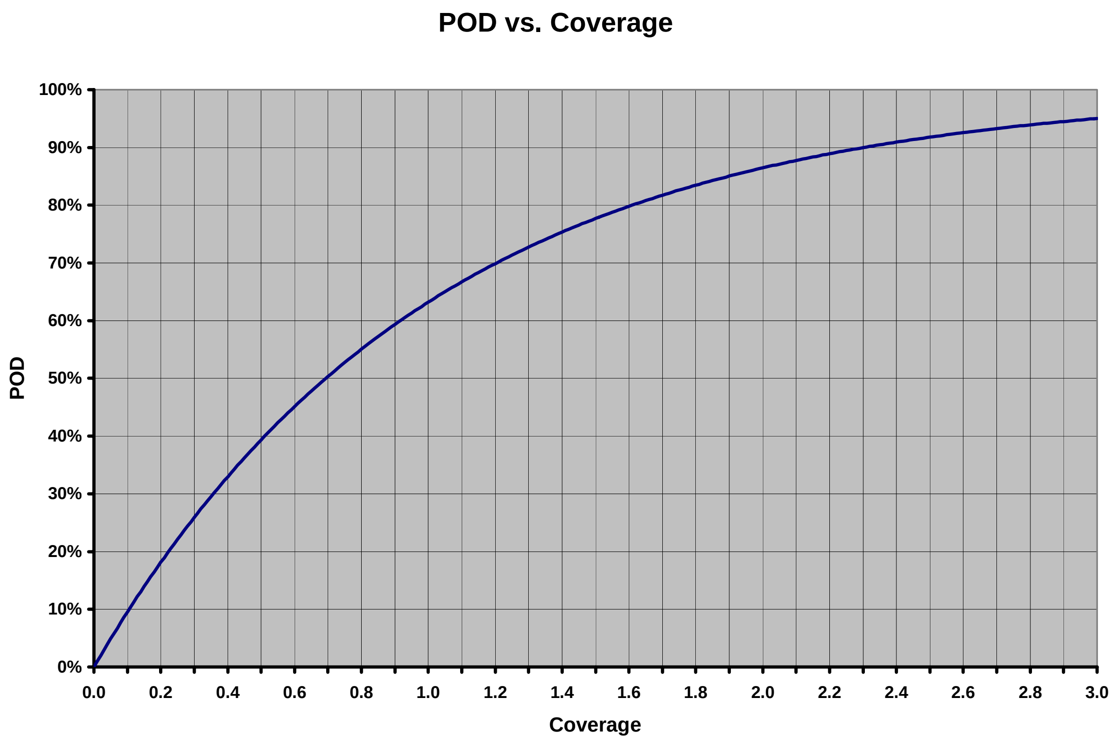


Figure 2-7. POD vs. Coverage (Koopman, 1946)

POD in itself is not the goal of search planning as some of the land search literature has suggested. POD is merely one part of a larger system.

Part II – Experiment Methodology

3. Pre-Experiment Setup

3.1 Experiment Design

The major goal of this report is to establish a methodology, useful to local and regional SAR organizations, which can be used to collect reliable detection data. These data will be adapted to local conditions and concerns. Every effort should be made to insure that the terrain, vegetation, search objects and searcher behavior are as realistic as is possible in the context of an experiment. Of necessity certain artificial elements will be introduced into the experiment mix. Two elements, which stand out, are the lack of urgency since no real persons are involved and the certain expectation of the searchers that, in their area there is going to be something to find and that they will in fact find something. In the experience of the authors these elements of an experiment tend to counteract each other. A lesser urgency is balanced by greater reinforcement. Another device that adds realism to the experimental situation is creating a long enough experiment period for each searcher so that the searcher tends to settle into (or revert to) normal search behavior.

The following sections will provide the current thinking of the authors as to the best way to deal with the individual parts which make up the experimental design template. We would expect and welcome suggestions for the improvement and simplification of the experimental process with the caveat that changes to the methodology must be consistent with the underlying search theory and practice. All of the steps required to setup, conduct, and analyze an experiment are summarized in a concise format in Appendix D. However, it is critical to be familiar with all the material in Part II, before attempting to conduct an experiment.

3.1.1 Selecting an Area

The area for the detection experiment must be selected with a terrain/vegetation type that closely resembles the physical environment typically encountered by the local 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 length of the track is critical for two reasons. First, to provide sufficient length to space the necessary number of search objects so that the detection of one of them does not interfere with the detection of a neighboring one. Second, to provide sufficient time and effort for the experimental searcher to settle into a "normal" search frame of mind.

The search track can be laid out along a trail, cross-country, or a mixture of both. 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. Combining both tends to take advantage of both features. 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.

3.1.1.1 Determining the Area's Ecoregion.
Search incidents on land occur in vastly different types of climate, terrain and vegetation. The best method to easily characterize different types of vegetation is with Ecoregions. The U.S. Department of Agriculture Forest Service uses Ecoregions developed by Robert Bailey (1995) which are based on climate, vegetation, soil, and terrain—but with emphasis on vegetation and terrain. Ecoregions are broken into four major domains: polar, humid temperate, dry, and humid tropical. Almost all of the continental United States falls into either the humid temperate or dry domain. The domains are then further broken down into Divisions, which are in turn further broken down into provinces (Figure 3-1). All sweep width experiments should identify and record the Ecoregion in which they are being conducted.

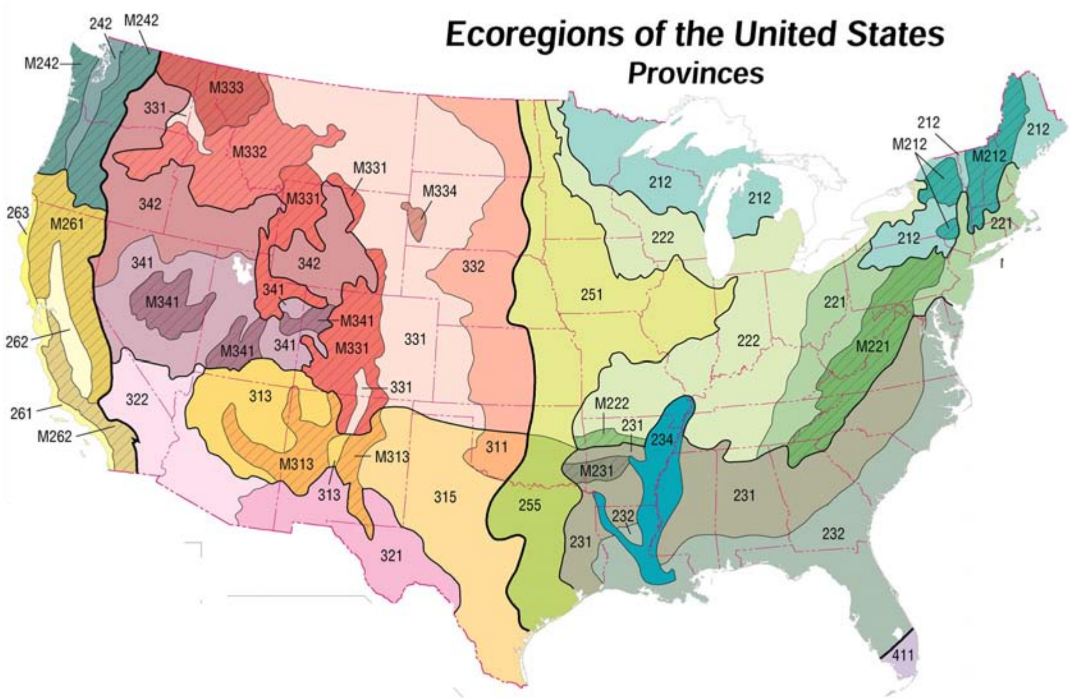


Figure 3-1. Ecoregions (Provinces) of the U.S. (www.fs.fed.us/institute/ecolink.html).

3.1.2 Selecting a Track Type

The detection experiments take place along a track. That fact creates an illusion that the detection experiment is based upon a certain type of search methodology such as grid search. The detection experiment is actually independent of the type of searching method. The track line serves to move the searcher past each search object creating a detection opportunity and an integrated measure of the likelihood that the search object would be detected when passed at various distances. Each detection opportunity along the trackline is an independent sample of this likelihood. The trackline serves to move the experimental searcher from one detection opportunity to the next.

There are basically three choices for laying out a trackline. They are cross country, road or trail, and a mixture. A general rule in selecting a track is that the distance to the command post should be small and that the start of the track should be near the end of the track.

3.1.2.1 Cross Country

Selecting an experimental track that that does not depend on established roads or trails and described as "cross country" is the choice that will provide the most realistic detection data. The searcher traveling cross country will not be as focused on only searching the track as may happen on a trail. The searcher must search into the vegetation and terrain. The searcher in a cross country situation will usually need to spend more time and attention on their footing and safety than they would on a trail or road. However, due to the numerous trips required to setup the track and the passage of prior teams even a cross-country track begins to take on some of the characteristics of a narrow footpath as the experiment progresses.

The logistics of a cross country track are more difficult than for trail or road. Selecting the route of the track requires several reconnaissance passes over the track to insure the proper length and the proper amount of uniformity of vegetation and terrain. A particular logistic problem with a cross country track is the deployment and recovery of the material used for the search objects. Road and trail crossings can speed and lighten this aspect of the experiment.

3.1.2.2 Road or Trail

A detection experiment set up along a road or trail system is easier to layout and populate with search objects. The length of the track is easier to predict and the end points are usually well defined. When selecting a road or trail an effort needs to be made to select one with very light vehicle or foot traffic. The searcher will need to be admonished to search off the track and into the vegetation and terrain. Along a trail or road the logistics of deploying and recovering search objects are greatly simplified. On a road or trail obtaining a uniformity of terrain and vegetation types may be more difficult since these tend to lead from one environment to another.

3.1.2.3 Mixed

A mixture of cross-country and road or trail is usually the most workable from the perspective of the team setting up the experiment. A mixed track helps to adjust the track to the proper length and also to satisfy the condition for the proximity of start and end points. With a mixed track it is also easier to maintain uniformity of the search environment. All of the courses constructed during the described experiments used a mixture of trail, road, and cross-country.

3.1.3 Selecting Venue

The chief requirement of a detection experiment is to generate detection opportunities. There are two ways to increase the number of detection opportunities. One is to place more search objects in the search area consistent with the independence of each detection opportunity (this increases the length/time of the experiment). The other way is to increase the number of searchers that participate in the experiment. The venue selected should have a population of searchers sufficient to keep the experimental track fully occupied during the entire period of the experiment. This often results in a difficult task of predicting the number of searchers likely to participate, the amount of time that will be acceptable to the searchers, and the minimum number of search objects necessary to achieve adequate data quantities.

3.1.3.1 SAR Conference

Since it is not always possible to assemble a group of searchers solely for the purpose of conducting an experiment the next best thing is to set the experiment up at a scheduled SAR conference. The conference needs to have an attendance great enough so that even with the activities of the conference there are still enough people who are willing to spare a couple of hours for the experiment.

3.1.3.2 Team Training

The training benefit of conducting detection experiments can not be overemphasized. Many participants in actual searches never actually see or find the things they are seeking. The detection experiments are structured so that all of the searchers will detect some of the search objects and the probability is very low that any searcher will detect all of the objects. Since a data recorder follows each searcher an evaluation of the searcher’s techniques can be noted as well as the number of detections/non-detections. During a debrief shortcomings and strengths exhibited by the searcher can be discussed.

3.1.4 Selecting a Time

3.1.4.1 Time of Year Considerations

The time of year for an experiment is usually dictated by the availability of experimental searchers. Coordination with the organizers of conferences and SAR teams can influence the timing of these events. It is highly desirable to have the different seasons represented in the data sets. The time of year will affect weather, lighting, vegetation (especially in deciduous forests), and searcher comfort and mobility.

3.1.4.2 Time to Complete Course

As mentioned above the length of the course should be such that a searcher needs at least one hour but not more that four to complete it. The considerations for course length have been discussed. It needs to be noted that the time of year for an experiment can severely limit the number of hours available for day time or night time searching. The number of searchers that can be run through a course in a given day can vary widely. Also the lighting near the time of sunrise and sunset can affect color, shadows, and contrast which in turn affect detection results.

3.1.5 Selecting Type of Search Object(s)

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. Almost 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 four 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. In developing acceptable search objects for these experiments that could easily serve as a replicable standard for future experiments around the country several factors were considered.

3.1.5.1 Size

The size of the experimental search objects should be selected to match the objectives of the particular experiment being conducted. The usual size will run from person size on the high end to small clue-like object on the low end. In an experiment designed to establish a sweep width for a downed aircraft or off road vehicle a larger mockup may be necessary. The size of the adult manikins used in the experiments was considered from several perspectives. The median height of an adult male in the United States is 175 cm (69.1 inches), the median surface area is $2.0m^2$, the median chest height is 25.4 cm (10 inches) and the “radar” cross-section of a prone human is $0.54m^2$ (Tilley & Dreyfuss, 1993). Disposable painter’s coveralls were commercially available in bulk (Appendix E) that when stuffed with cardboard shipping boxes and tubes were found to be 190 cm in height (174 without head), a surface area of 2.2 m^2, "chest" height of 23 cm, and a "radar" cross-section of 0.49 m^2. "Radar" cross section refers to the two-dimensional area the three-dimensional object presents to a viewer. Lamar et al (1947) has shown the actual shape of the target has little influence on detectability for objects with a length to width ratio of less than 50 (the manikin ratio is 190:23 or 8.26). Therefore since both the average human and manikin have similar "radar" cross-sections they can be considered identical for detectability purposes.

3.1.5.2 Color

The color used for search objects is determined by examining colors worn by lost search subjects. The last 100 records of clothing colors recorded on the Virginia Department of Emergency Management missing person database, with clothing information included, provided the breakdown of colors shown in Figures 3-2 and 3-3.

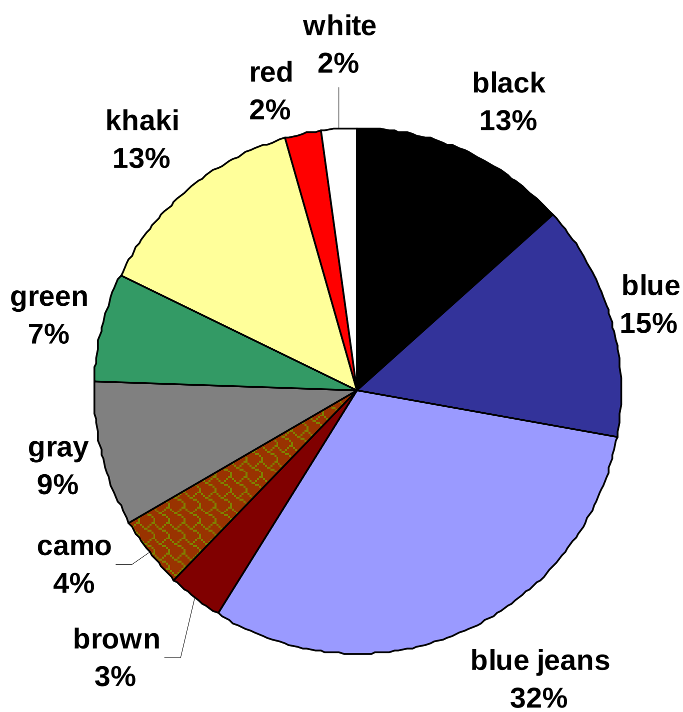


Figure 3-2. Distribution of trouser colors worn by lost subjects.
From the Virginia Department of Emergency Management database.

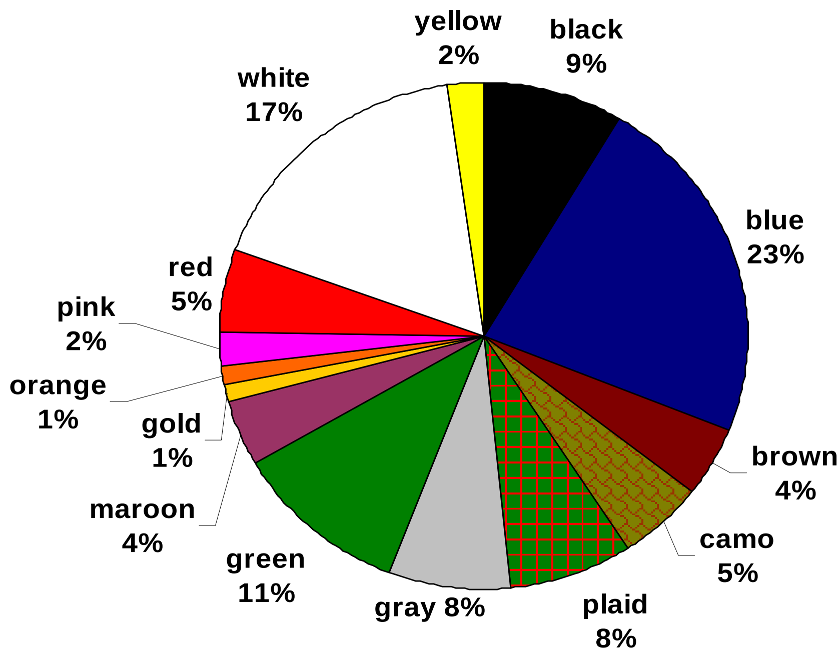


Figure 3-3. Distribution of outerwear colors worn by lost subjects.
From the Virginia Department of Emergency Management database.

Colors are described as high visibility, medium visibility, and low visibility (Fig. 3-4). A high visibility and low visibility search-object represents the entire spectrum of possible sweep-widths when looking at colors. The high visibility search object was constructed using white coveralls and an orange vest. The low-visibility search object was painted a flat olive drab using spray paint on top of the white coveralls. A blue color was chosen for medium visibility due to its easy availability as a coverall color and its high frequency as a color worn by lost subjects. In experiments in snow the colors would need to be adjusted. However, future experiments should adhere to these colors to make direct comparisons possible.

Figure 3-4. High-, medium-, and low-visibility search objects used in the experiments.

3.1.5.3 Scenario

In order to conduct a realistic experiment a scenario needs to be developed that contains all of the elements of an actual search in the area of interest. The scenario should include information on the object of the search as well and detailed instructions to the searcher and other participants. All searchers were presented with the identical scenario throughout all the experiments. A copy of the information presented to the searchers is presented in the appendix. The scenario suggested a non-responsive deaf subject to prevent searchers from calling out the subject's name. The scenario also described a lost surveyor to help explain the high number of flags in the area (used to mark the experiment course) and the possibility of finding the three different colors used.

3.1.6 Experimental Design Calculator

In order to simplify and check that all the requirements for a valid experiment were adhered to the experiment team developed an experimental design calculator using MS Excel. Required inputs include the projected number of search participants, the number of different types of search objects, and the AMDR. The calculator would then determine the total number of targets required, expected length of course, and expected time to complete the course. If the number of targets or course time fell outside the experimental parameters the parameter was flagged by a change in color. The experimental design calculator was a useful tool for the experiment team but is not a finished product. While it could design an experiment for two similar clues, it was not designed for mixing high and low visibility targets or adult sized search objects with small clue sized objects.

3.1.7 Combined Experiments

Sweep width experiments can be combined with other experiments with search and rescue objectives in order to attract more support and optimize the use of logistics and resources. However, the combined experiments should not be viewed as a Christmas tree for experiments with incompatible requirements. Any combination of experiments should have the clear objective of completely fulfilling the requirements of each experiment included in the exercise.

The team did design experiments with high, medium, and low visibility adult –sized search objects along with clue sized objects. This required using the experimental design calculator twice. From the design perspective two separate experiments were laid out. From an actual perspective the course was setup for the high and medium visibility search objects first and then the low visibility and clue size search objects followed with their denser spacing and shorter lateral ranges (based upon smaller AMDR). It is the authors' recommendation to improve the Experimental Design Calculator to fully automate this process.

3.2 Initial Site Visit

3.2.1 Preparing for the Visit

In preparing for a site visit, select a general location that is well-known. This can be the location of a SAR conference or a training location. Also select several possible alternative sites in case the primary site does not meet the basic requirements. The basic requirement is land of sufficient size to allow setting out a course. Since most basic courses involve heading out and returning to a logistical staging area, the overall length should be slightly more than half of what is projected for the course and the width for an out and back course should be at least 7 times the AMDR (1.5 AMDR for both left and right outbound leg, plus a buffer of 1 AMDR, plus 1.5 AMDR left and right for the inbound leg.) An even wider area allows for natural wandering common if following a road or trail. The course area should not be unreasonably steep or go through several altitude changes unless that is representative of the area. The terrain should be as uniform throughout the course as possible. The vegetation should also be as uniform throughout the course as possible. The vegetation should also be representative of the area and meet the objectives of the experiment. The site should also be as close to the main event site as possible. A site where the team normally trains is acceptable since search objects will be placed in locations usually not used for training purposes. In preparing for the visit make sure you have:

- Good driving directions to the site
- Contact and alternative numbers for anyone you may be meeting at the site
- Permission to be on the land
- Knowledge of any hunting activity at the site
- Knowledge of any unique hazards on the site
- Copy of (or actual) topographic map (on waterproof paper or in waterproof container)

- Copy of aerial photography map (often more up-to-date than topos)
- Any special maps of the area showing trails, etc.
- GPS to record the path traveled during site visit.
- Lux meter to record light intensity
- Laser Range Finder to record AMDR
- One of each type of search object that will be used
- Digital camera
- Extra batteries (for each piece of equipment)
- Clipboard
- Forms to record observations (AMDR form see appendix)
- Flagging tape
- Vegetative density board
- Essential equipment for being safe in the field
- Daypack

3.2.2 Evaluating the Area

Upon arriving at a possible experiment site confirm everything that is known about the site (ownership, hunting, hazards, etc). If possible drive around the border of the area if it is not already familiar. The general site should be then be walked to confirm the general layout of the area. Identify features that may not appear on topographic or aerial maps. Confirm possible roads and trails in the area, the general topology of the area, hazards, obstructions to visibility, and the uniformity of vegetation. Walking an unfamiliar area may take the better part of a day. If the area appears generally acceptable consider starting to walk what may become the trail. Once one has a general feel for the land a decision to use any existing trails or shooting a straight compass bearing becomes more apparent. If possible, the course should bear a resemblance to the type of environment typically searched in the local area. Do not hesitate to view several possible areas and consult people knowledgeable about local terrain and vegetation.

3.2.3 Initial Measurements

3.2.3.1 AMDR

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.

After walking the general area and confirming that the vegetation and terrain are generally uniform, select a site for measuring AMDR. Select a site for the AMDR calculation by starting at a point along the trackline and then determine a distance and direction of travel to reach the AMDR location. This is accomplished by generating two random numbers. (flip coins, ask a teammate to select two numbers between two ranges, etc), one to represent distance and the other to represent direction. Pace off the distance represented by the first random number using the second random number as the compass heading. This helps to ensure the actual site for measuring the AMDR is determined somewhat randomly. The site may be rejected if it appears quite different than the surrounding terrain and vegetation. Place the first search object at the site.

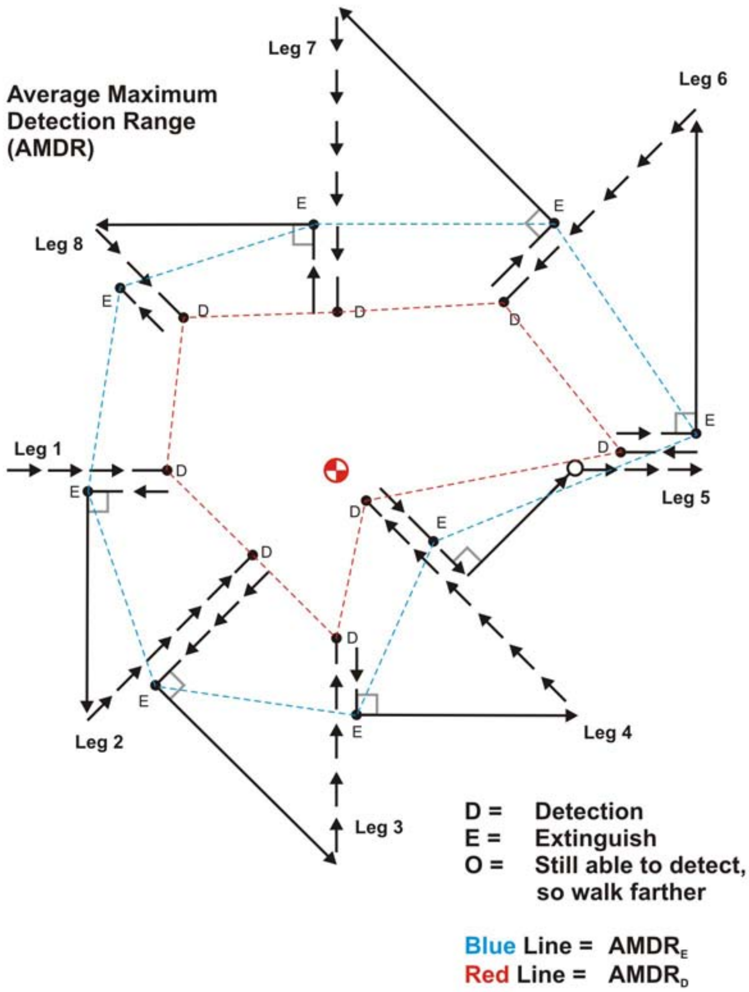


Figure 3-5. Method for estimating Average Maximum Detection Range (AMDR).

Starting from the search object choose a cardinal direction (this would be walking due west from the object in Fig. 3-5) for walking away from the search object a distance you feel will be far enough so that when you turn around you will no longer be able to see the search object. Walk this distance. Turn around, if you can still see the search object you need to walk further away. If the search object is no longer visible start walking back to the object. Walk forward at a normal search pace until you detect the search object (on Fig. 3-5, indicated by D at the east end of Leg 1). Using the laser range finder determine the distance from you to the search object. This initial "find" distance is the detection distance, which is recorded on the data sheet by you or by an assistant. Continue to walk backwards, keeping sight of the search object, until you are no longer able to see the search object. Record this distance (using the laser range finder) as the extinction distance (on Fig. 3-5, marked as an E on Leg 1). This is the first set of a total of 16 measurements taken on 8 different radials centered at the search object. To move to the next location, turn 90 degrees and walk the same distance as the last extinction distance. Turn 45 degrees towards the search object and start walking forward (Leg 2 on Fig. 3-5). Continue forward until the search object is detected. Record the second leg's detection distance. Move backwards until you can no longer see the search object, then record the second extinction distance. Repeat the 90-degree turn and moving the same distance as the last extinction distance. Following this procedure should result in detection and extinction distances being recorded along 8 different radials.

The entire procedure should be repeated for each search object type. In addition, after one complete set of measurements are taken for each search object a second altogether different area should be selected for a second set of measurements. All of these distances should be recorded on the AMDR form. The AMDR form should be printed on waterproof paper, kept under cover, and the appropriate writing instrument brought (some types of waterproof paper work best with pencil while others only work with pen).

If a laser range finder is not available, the distance must be determined by pacing.

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.

3.2.3.2 Vegetation Density

Vegetation structure was quantitatively assessed using the "cover-board" technique described by MacArthur & MacArthur (1961). This technique estimates leaf surface area and biomass of foliage in the study area. The technique has been studied and found reliable among different users (Conner & O'Halloran, 1986). The technique requires an observer to estimate when 50 percent of a black-and-white checkered board is obscured by foliage. The board measured 42 x 28 cm with one inch squares (Fig. 3-6). The board was placed at ground-level at the same location the search object was placed for the AMDR measurements. The researcher then moved backwards until 50 percent of the board was obscured (Fig. 3-7). The distance was measured using the Laser Range Finder (Fig. 3-8) and recorded on the AMDR form (Appendix C). A measurement was taken from due North, South, East, and West.

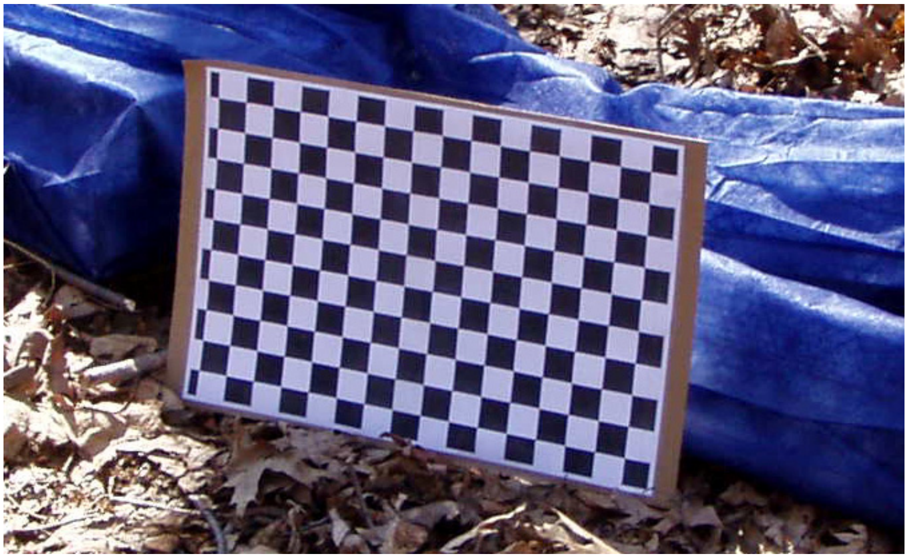


Figure 3-6. Vegetation Density Board.
Distance is measured when a searcher moving away from board can only see 50% of squares.

Figure 3-7. Distance at which only 50% of the squares on the Vegetation Density Board can be seen.

3.2.3.3 Laser Range Finder

A need for a quick and easy method to quantify the density of vertical obstructions at eye level was identified. A method was developed using the laser range finder when set at the last return setting (the only available setting on the model being used). The denser the trees or under story at eye level the shorter the distance until the laser beam would be reflect back. In less dense woods the average distance for a return would be greater. In preliminary studies the average distance was the same when measuring from different locations but in the same area.

Readings were taken from the location the search object was placed for AMDR measurement. Measurements were taken by facing due North with a laser range finder. The instrument was held at eye level with both eyes closed to avoid "deciding" where to aim the instrument. The reading button was depressed, the eyes opened, and the resulting distance recorded. The instrument was then rotated 22.5 degrees and the process repeated, for a total of 16 measurements. Data was entered on the AMDR form.

In extremely dense forests the operational limits of some Laser Range Finders may become a problem. The civilian version used during these experiments could not measure distances less than 10 meters. Some models do not suffer these limitations. In addition, inexpensive (approximately $40) ultrasonic range finders are available that only work for shorter distances. This technique is not appropriate for large open area.

Figure 3-8. Hand-held Laser Range Finder in use.

3.2.4 Initial Logistical Discussion

The logistical preparations for the experiment need to be completed well in advance. Last minute changes can lead to lost experimental time and lost data. The layout of the experiment area should be conducted so that the only activity necessary on the day before the experiment is the placement of the search objects. Additional logistical concerns that need to be considered or planned during the initial site visit include:

- Parking for participants
- Restroom facilities
- Shelter and remote command center for experiment team during experiment
- Radio communications (not required but enhances safety and overall control)
- Staging area
- Briefing area
- Electricity (not required but enhances overall command and control)
- On site copier (not required but enhances overall command and control)
- Lighting (may not be required depending upon experiment and time of year)
- Transportation if site away from main conference or other event
- Liability while conducting experiment
- Recruitment of participants if being held at SAR conference type event

3.3 Course Setup

3.3.1 Preparing for Setup

The first step for setup after selecting an area and environment is to thoroughly walk the area. The area selected should be large enough to accommodate the required trackline and have a sufficiently uniform environment in order to meet the experimental scenario and objectives. Several passes through the area will be necessary. This component is also discussed under section 3.2.2, Evaluating the Area.

3.3.2 Initial Layout of Track

After becoming thoroughly familiar with the area, collecting the AMDR information, and using the experimental design calculator the minimum length of the course can be calculated. With a working knowledge of the area a potential trackline should be established on a topographic/aerial map. With a working plan in hand, establish a rough trackline of the required length laid out through the experiment area using flags or surveyor's marking tape. It is common for the trackline to change somewhat when it is being laid out. The first pass should have just enough flags to guide the experimenter back through the course during latter passes.

3.3.3 Marking Track

After the trackline has been finalized it should be well marked with highly visible surveyor's tape and flags. The start, finish, and intervals along the trackline need to be marked. Three colors of flags need to be used. The first color of flag should be used to mark the start, finish and each five hundred meter distance. These flags should be placed in pairs, one on each side of the trackline and labeled as start, finish, or the appropriate 500 meter designation. This color of flag will help denote to the data logger locations where they are required to record the time. The second color flag should indicate the 100 meter intervals along the trackline (other than the 500 meter intervals). These flags should be labeled with the appropriate distance (100, 200, etc.). The third color flags are used to indicate each 25 meter interval between the even 100 meter intervals. These flags should be labeled with the appropriate distance (for example 75, 1225, 1550, etc).

Figure 3-9. Track marked with several different colors of surveyor's flags. Yellow flags used for start, every 500 meters, and finish. Green flag marked with distance every 25 meters, red flags help clearly mark the track. Flagging tape used to initially layout the track.

To measure each 25 meters it is easiest to use a measuring wheel. While rolling a wheel cross-country through dense terrain does pose a challenge it provided the most reliable method of measuring total trackline distances. The wheel is especially easy to use when on roads or trails. During the layout of the first course the odometer of a GPS unit was used. Due to frequent stopping and starting (to number and set the flags) the GPS derived distances had several seconds of lag. This resulted in a course that was actually twice as long as thought. The measuring wheel was used on all later experiments. During the Washington State experiment, which had the densest ground cover, the wheel was rolled twice. The first time to set out the 25-meter flags and the second time to determine the placement of search objects. Even after rolling the wheel for over a kilometer the distances agreed within a meter. The technique for rolling the wheel in rough terrain and dense vegetation consisted of rolling it on top of the ground cover. The accuracy of the total trackline distances does not affect the eventual sweep width, but are simply used to determine the placement of the search objects.

Figure 3-10. Measuring course length with measuring wheel.

At other points along the trackline surveyor's tape or a fourth color of surveyor's flag should be used to mark the trackline in areas that may be confusing. These areas are at turning points, in dense vegetation, or in very rough terrain. The searcher should be able to concentrate on searching during the experiment rather than navigating. Do not underestimate a searcher's ability to lose the trail, especially at turn/decision points. If any doubt exists, use additional flags. Searchers are often highly focused on searching and tend to not pay attention to navigation. In some dense vegetation it was required to put down a flag every three meters. Use surveyor's flags to the maximum extent possible. Many of the search participants commented that they found large amounts of surveyor's tape with long tails distracting, especially when the color was the same as the type of search object they were looking for. The exact colors will depend upon what is readily available, and the type of terrain. During most of the experiments, yellow flags were used for the start, stop, and 500 meter markers. Lime green was usually used for the 100-meter flags. However, in the dense green foliage of Washington State it was somewhat difficult to see. Orange flags were the typical color for the 25-meter markers. Red flags were the standard for directional or supplemental flags between 25-meter markers.

3.3.4 Determining Search Object Locations

3.3.4.1 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. The experiment design calculator uses a default searcher speed of 2 km/hr as the average and 1 km/hr as the minimum. The user can change the values.

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.

3.3.4.2 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 the 25-meter reference flags laid out along the trackline. Determining the search object's location is based upon random selection of the off-track distance and distance 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 extinction value. The AMDR extinction value will always be slightly greater than the AMDR value. This ensures that a sufficient number of objects are placed far enough away from the track to allow accurate estimation of the sweep width value. The experiment design calculator uses the AMDR extinction value times 1.5 times a randomly selected number between 0 and 1 to determine the off-track distance.

$$\text{AMDR extinction} \times 1.5 \times RAND(0-1) = \text{Off track dist.}$$

A second random number was used to determine whether the object would be placed left or right of the track. The design calculator translated values greater than 0.5 as being "Right" and those less than or equal to 0.5 as being Left. A third random number was used to determine the orientation of adult sized search objects, since a "person" lying parallel to the search track would offer a larger "radar surface area" than a person lying perpendicular to the track. It was decided to leave the orientation (direction the head was pointed) to chance. A third random number was generated to provide a compass heading between 0 and 360 degrees for this purpose.

In cases when multiple types of search objects were being used, a fourth random number was used to determine the type of search object that should be placed. Unfortunately, with multiple search objects it is possible for the random number generator to select almost all search objects of one type and almost no search objects of the second type. This would result in a failed experiment for the second type. Therefore, the worksheet was designed so that if the minimum number of search object types was not reached a completely different set of random numbers was generated with a new version number. An example of a Sweep Width Object Placement Worksheet is found in Appendix C (Forms).

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. In this case, the more general AMDR was used to determine the total trackline distance. Once again, the actual values were determined by the experimental design calculator.

Once the locations, types, and orientations for the search objects were determined they were printed out onto waterproof paper which could be carried into the field. An extra copy of this list should be generated and secured as it is the key to the entire experiment. Another copy of this list which contains field notes for the "as deployed" search object positions must also be created.

3.3.4.2.1 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. Fortunately, the experimental design calculator does this automatically.

The cross track distance for the search object placement will be between 150% of the AMDR extinction (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 trackline, rounded to the nearest whole meter. Table 3-1 shows the first five entries obtained following these rules (but with different AMDR values) taken from the Sweep Width Object Placement Worksheet (Appendix C).

Object #	**TTD**	**LR**	**L vs. R**	**Object Type**	**Orientation**
1	28	4	Left	Human hi-visability	119
2	63	35	Right	human blue	229
3	218	12	Left	human blue	186
4	321	29	Left	Human hi-visability	105
5	436	27	Left	human blue	314

Table 3-1. Example of search object placement locations.

Figure 3-11 shows a schematic representation of how search object location zones are defined.

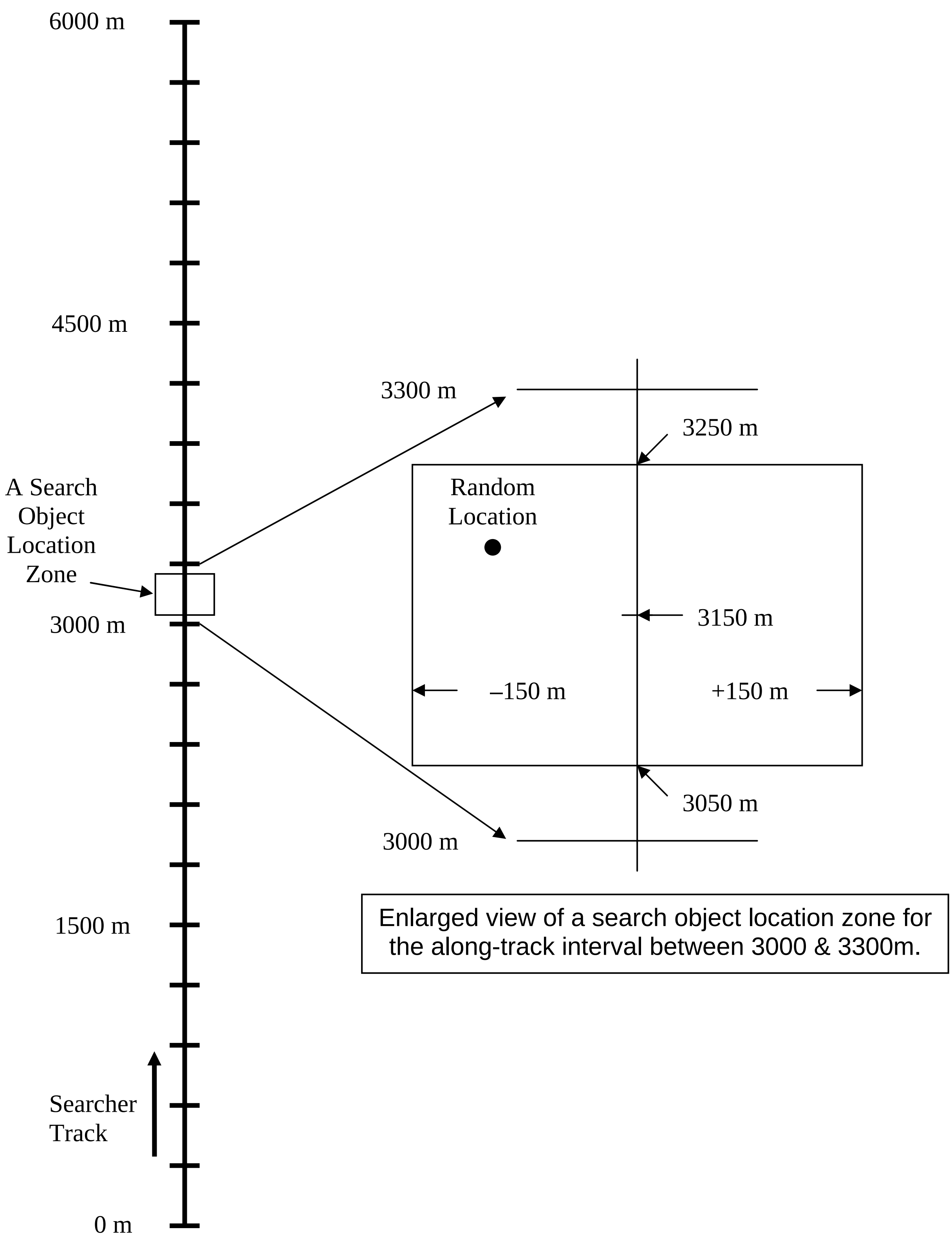


Figure 3-11. A schematic diagram for search object placement.

A new setup using a new set of random numbers would produce completely different locations from those shown in Table 3-1. 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 accurate. Over the course of several such experiments, the combined distribution of search objects with respect to lateral range will become more uniform.

3.3.4.3 Combining Experimental Layouts for Multiple Object Types

When using multiple search objects in an experiment care needs to be exercised to insure that the desire to have multiple objects does not compromise the ability to generate a sufficient number of detection opportunities for each search object type. Generally only two to four search object types should be used in a single experiment. Differing objects will have differing ADMR characteristic and therefore will have a different set of criteria for the off track placement. The along track integration of the differing object types should be such that the detection opportunities for one object type does not materially impact the detection opportunities for the other object types.

3.3.5 Laying Out Search Objects

Search objects should be chosen with a weight and bulk that can be conveniently transported to their assigned location. The adult-sized search objects previously described could easily be carried into the field "unassembled." Often trails and roads can provide access that can reduce the transportation of the search objects to the track.

3.3.5.1 Required Equipment

At the point in time when the search objects are deployed, the along track distance has been clearly marked with the 25-meter flags. The only measurement equipment needed at this point is a laser range finder for establishing the correct off track distance, a compass for determining orientation, orange vests to see the experimenters better in the field, the search objects, and a metal stake to ensure the search objects don't blow away.

3.3.5.2 Method of Setting Out Search Objects

The search objects are carried to their pre-selected locations along the trackline. They are assembled, if required on the trackline, and any tell-tale signs are removed from the assembly area.

3.3.5.2.1 General Technique

Two persons are needed to deploy an object. One will remain on the track to both measure the distance with a laser range finder and to provide a visual reference for the point selected on the track. The second person travels, with the search object, along the track to a point where any disturbance of the vegetation or soil will not be observable by the searcher. If all search participants will be walking the track in the same direction (preferred method) the person placing the object should leave the track well beyond the eventual location. This person then travels along a path to the off track location with as little disturbance to the environment as possible. After arriving at the approximate search object location the final placement is accomplished in cooperation with the person remaining on the track with the range finder. The use of the laser range finder is simple but does require some practice in dense vegetation. A useful technique to verify the range finder is locked onto the person/search object is to move forward and back a few meters. If locked onto the correct search object, the distances should change accordingly. In cases where for reason of vegetation or terrain the range finder cannot be used to the full distance the person deploying the search object should move toward the track until a laser range can be measured. From this point the distance to the deployment point can be determined by pacing or by using a second laser range finder carried by the person deploying the search object. This person, after deploying the object should return to the track by the same route they used previously.

The search object should be secured in its location by a pin, stake, or weight. The location should be checked off against the Search Object Location Log.

3.3.5.2.2 Resetting Positions

At times the selected location will be unsuitable. Usually this is because the location is blocked from use by restricted access which may be a waterway, no trespassing sign, or similar restriction. In other situations the trackline make a sharp turn, placing the object's planned location within the turn making its lateral range difficult to assess. An object placed outside the turn would not have this problem. When this situation occurs the location may be modified consistent with the experiment plan. The easiest adjustment is to move the location from right to left or left to right. The fact that a search object cannot be detected at it assigned location is not grounds to select an alternate location. The obscuring of a search object by terrain or vegetation is one of the factors being evaluated. It is critical to document any changes in location. Other teams may be sent at the end of the experiment to verify the search object's location and retrieve it from the field.

3.3.5.2.3 Virtual Search Objects

As noted in the previous paragraph a location selected for a search object may result in the object being impossible to detect by a searcher. In this situation no actual object needs to be placed at this location and the search object is assumed, for data collection, to be present. However, great care must be exercised when following this option as many times the object is detectable from an unanticipated point along the track. The trackline must be walked at least 100 meters in either direction with the person in orange standing next to the search object. The safest course is to deploy the search object if there is the slightest doubt that detection is truly impossible.

3.3.5.3 Recording Search Object Information

The persons deploying the search object must accurately record on a log the object type, the along track distance, and the off track distance (left or right). This record becomes critical to future data analysis.

3.3.5.4 Multiple Detection Opportunities

After the search objects have been deployed a survey of the objects should be conducted to discover if the objects might be detectable from other points on the track. If these other points are related to the intended location of the object it is assumed that the detection opportunity is the same as the primary one. If, however, the point along the track is sufficiently divorced from the primary detection location, then with careful consideration that point on the track can be considered a separate detection opportunity. This situation usually occurs when the track forms a loop and one side of the loop is within sight of the other side. In these cases, the lateral ranges from the second detection opportunity site must be measured and the documentation updated to reflect the "new" search object.

3.4 Experiment Preparation and Logistical Support

3.4.1 Required Materials

Required materials can be broken into several categories. Capital equipment needed to set-up an experiment, disposable equipment used in running an experiment (most related to search objects and marking the track), general equipment needed to operate a search command structure, and the proper equipment searchers typically carry out into the field on a search. Appendix E lists the capital and disposable equipment required to conduct the experiment. Conducting the experiment is much like running a search operation. Teams need to be assembled, briefed on their task, issued needed equipment (clipboards, maps, forms, radios, etc), sent out onto the course, tracked, and in the end debriefed. Fortunately, the actual task is the same for everyone so operational planning is simplified. Therefore, all of the tools and pieces of equipment used for command and control in the running of an actual mission are useful in conducting the experiment. Searchers, while in a highly controlled environment, should still carry the equipment they typically carry on similar types of tasks.

3.4.2 Required Forms

A list of all the forms needed for planning and conducting the experiment is listed in Appendix C. On the actual experiment day, the required forms include

- Sign-in Log (1)
- Team Sign-up (1) used to organize the times the team will be deployed
- Subject Information Sheet (1 for every searcher)
- Task Instruction form (1 for every searcher)
- Data Logging Briefing (1 for every data logger)
- Team Tracking (1 for every 22 teams sent out)
- Color Vision Test (1 printed with a color printer)
- Searcher Profile (1 for every searcher, print on waterproof paper)
- Detection Log (1 for every searcher, print on waterproof paper)

3.4.3 Logistical Support Considerations

Logistical support should be located near the area used as the experimental search area to avoid the loss of time and transportation difficulties. Ideally the experiment command post is within easy walking distance of both the beginning and end of the search track. This is especially true for an experiment planned in conjunction with a SAR conference.

3.4.3.1 Parking

When developing a plan for the experiment, assembly area, and command post, the availability of adequate parking for participants needs to be considered.

3.4.3.2 Shelter/Staging

The experiment command post and assembly area needs to be provided with shelter for participants and the experimental staff. Normally tables and chairs for eight people involved in scheduling, briefing and debriefing, and data archiving should be adequate. Shelter from the elements for the experiment staff and those preparing to participate needs to be provided.

3.4.3.3 Facilities

Sanitary facilities need to be available in the staging area.

3.4.3.4 Food and Water

Participants should be instructed to provide themselves with food and water. In a particularly hot experimental climate it is advisable to provide a supplemental source of water.

3.4.3.5 Clothing and Equipment

Participants should be instructed to provide their personal clothing and equipment suitable for a search in the selected environment.

3.4.4 Staffing

Staffing for the experiment consists of a scheduler, a data coordinator, and two briefers/debriefers. The greatest staff shortage for the experiment, especially at the beginning, is for data recorders. A searcher who has completed a search is ideal for the job of data recorder, if they are willing to devote the extra time to the experiment. If a person first acts as a data recorder on the experiment they are then disqualified to participate as a searcher. At the beginning of the experiment the briefers/debriefers can serve as data recorders in order to generate a pool of people who have completed the search phase so that they will then be available for data recording. When a backlog of people willing to search develops the prudent thing to do is to pair the volunteers into teams assigning one to be the searcher and one to be the data recorder even though this disqualifies potential searchers.

3.4.5 Scheduling Searcher Times

The experimental search teams, consisting of a searcher and a data recorder, should be scheduled so that each team operates independently of the other teams as far a sight and sound are concerned. Usually a 10-20 minute interval is sufficient for separation. Since teams travel and search at different speeds a protocol for one team overtaking and passing another team must be established. This protocol is published on the instruction to data loggers form. However, it should be reviewed during the briefing of new data loggers.

4. Conducting Experiment

4.1 Managing Searchers and Data Loggers

4.1.1 Signing In

All participants must sign in on the participant sign-in sheet and be assigned to a team (Team Sign-up form in Appendix C).

4.1.2 Scheduling

The activity of scheduling teams of searchers and data recorders should ideally begin the day before the start of the experiment so that the data collection can begin promptly at the beginning of the first experiment day. The first team should be scheduled to begin as early as the light meets the objectives of the scenario. The experimental search teams, consisting of a searcher and a data recorder, should be scheduled so that each team operates independently of the other teams as far as sight and sound are concerned. Usually a 10-20 minute interval is sufficient for separation. The last team of a particular day should be scheduled so that the team finishes while the lighting conditions still meet the requirements of the search scenario.

4.1.3 Collecting Searcher Data

Each searcher provides basic information on the Searcher Profile form or a locally produced form. The information is needed to establish physical characteristics (i.e. age, eyesight, etc.), experience, and training. This form may change to meet the needs of a particular experiment.

4.1.4 Briefing – The Searcher

The searcher is provided with a search scenario (Subject Information sheet) and a searcher briefing sheet (Task Instruction form). The experiment team did note during the course of the experiments that a short video that could be played on a laptop would help standardize the briefing process.

4.1.5 Briefing – The Data Logger

The data logger should receive a briefing separate from the searcher. In an ideal situation a small number of data loggers can be used throughout the day. This may require walking the course several times. The person who will ultimately score the data sheets should serve as the data logger at least once to help identify which search objects may have scoring issues such as multiple detection opportunities and natural or man-made features leading to false detections. The information for the data loggers briefing is included on the General Briefing for Data logger form. The use of the Detection Log form must also be fully explained. If possible a small course can be setup at the command post to ensure the data logger is able to understand the directions. Alternately, a member of the briefing team may follow the team for the first clue detection to ensure logging is done correctly. The instructions to the data logger should emphasize that the critical items of information that must be recorded for each detection called by the searcher are the along track distance at the point of detection, the clock bearing to the search object relative to the trackline, the distance to the target, and the time of detection. These data items anchor the data interpretation process.

4.1.6 Dispatching the Team

A dispatched team of searcher and data logger must have been briefed. The searcher only needs the equipment needed to safely function in the environment and a copy of the searcher information sheet and task assignment form. The data logger must have a detection log, clip board, pencil/pen plus a backup writing tool, and may have a radio. The team's departure must be tracked on the Team Tracking Log. This will insure the command post always knows what teams are out on the course and the appropriate time spacing. Radio communications sections often have independent methods for tracking the radio net.

A file folder is typically prepared for all teams assembled but not yet dispatched. This file is called the "To be Tasked" folder. Once teams are dispatched to the field, the Searcher Profile is placed in a folder called "Tasks in Progress."

4.1.7 Debriefing the Team

Every searcher must be debriefed upon returning from the field. The Searcher Profile form is retrieved from the "Tasks in Progress" folder and Searcher Profile Section C – Debriefing is completed by the debriefer. In some cases, Section B of the Searcher Profile (Physical Characteristics) may not have been completed prior to the team being dispatched. If this is the case, the debriefer must ensure this section is also completed. The debriefer must collect the Detection Log from the data logger, look over the form, and ask if any difficulties arose or if anything needs to be explained. The Detection Log should be stapled to the Searcher Profile form and placed in a "Tasks completed" folder.

4.2 Managing Forms and Data Collection

4.2.1 Sign-in Form

The sign-in process is an accepted practice at all search incidents. In one location, the Searcher Participant Log (Appendix C) tracks everyone who participates in the experiment. This may be important for several reasons including generating thank-you notes, statistical effort tracking, proving someone was present (workers' compensation, liability), or simply knowing who is present and able to be placed on a team. The form also collects emergency contact information in the event of an accident. Since the participant is required to sign-out, the form can be used to assure all personnel are accounted for before breaking down the command post and leaving the area.

4.2.2 Scheduling Form

The Team Sign-Up form is used to schedule the launch time of the search teams. Prior to conducting the experiment the times of sunrise and sunset should be determined to figure out the appropriate times to launch teams. Sign-up should be done in pencil since the expected launch time and actual launch time often change. If possible, teams can be scheduled well ahead of the actual experiment. The form currently is based upon 15 minute staggered starts. The most appropriate time will depend upon the nature of the actual course. During some experiments a ten-minute interval between starts was used with success when several teams all arrived at staging at the same time. The form also assists in keeping track of data loggers.

4.2.3 Task Package

The Task Package consists of all the forms given to the search team. They can be organized ahead of time and held together with a paperclip or on a clipboard. The searcher will receive a Subject Information Sheet, Task Assignment form, and a Searcher Profile. The data logger will receive a General Data Logger Briefing form and a Detection Log. At the conclusion of the experiment the forms that must be collected and stapled together are the Searcher Profile and the Detection Log.

4.2.4 Team Tracking

The Team Tracking Log is an operational log used to track the teams currently deployed and those that have completed the experiment. It provides all the names and contact information for everyone out on the experiment track. Since it also collects the time starting the course and the time finishing the course it can determine the time the team spent on the course if the data logger neglected to record the start and stop times.

4.2.5 Searcher Profile

The Searcher Profile form is one of the most important forms used during the experiment. The form is broken into three sections. Section A collects demographic information on the searcher. Section B collects physical characteristics such as height and vision. Section C is filled in during debriefing and includes collected weather information, estimated PODs, and self-reporting of morale and fatigue. The form is essential in looking at how secondary characteristics affect sweep width. Future analysis of the data may help determine important correction factors based upon the data collected on the Searcher Profile.

The form was used throughout all five experiments. However, it should still be considered a work in progress. One of the goals under search demographics was to determine the relationship, if any, between searcher experience and the outcome measurements. It was observed by the data loggers throughout all the experiments that some searchers with no to little search experience did quite well. A unifying theme among people who were more successful was their career. Pilots, ranchers, and park rangers all did well. Unfortunately, this type of information was not formally collected and the form should be changed. On the debriefing section almost all searchers were unfamiliar with the concept of sweep width. Therefore, when asked to estimate the sweep width, blank stares were a common response. During later experiments most debriefers did not even ask this question. This blank can be removed from future forms. An important physical measurement that was neglected during the experiment was light levels. Ideally, the form should collect a quantitative measurement of light such as lux. If a lux meter is not available a check off box using qualitative terms such as direct sunlight (50,000 lux), full daylight (10,000 lux), overcast (1,000 lux), dusk (100 lux), twilight (10 lux), deep twilight (1 lux), full moon (0.1 lux), etc. Another factor that should be recorded is how searchers respond to some physical forces. The effects of wearing ball caps, hoods, and sunglasses are unknown. These factors should be recorded. Another observation made by experienced data loggers was the large number of search techniques used by the searchers. Some effort needs to be made to capture these characteristics.

4.2.6 Detection Log

The Detection Log is used by the data logger during the experiment. It must be printed on waterproof paper and should be supported by a clipboard. During the California experiment with riders mounted on horseback it proved difficult to use. Additional refinements might be possible for special circumstances. The Detection Log was an important refinement over the original Logan, West Virginia pilot experiment. It allowed for the clear and rapid scoring of test results. It typically took three minutes to score each Detection Log. The form's use is further described below.

4.3 Searching

4.3.1 Instructions to Searchers

Searchers received information from both written instructions and from the briefing process. Information about the purpose of the experiment was not given till the end of the experiment. Written instructions were provided on the Task Assignment form and Subject Information Sheet. Oral instructions were given during the briefing process and often by the Data logger (especially if experienced). When searchers were paired with experienced briefers and or experienced data loggers they received a consistent set of instructions. However, when both the briefer and data logger were inexperienced consistency suffered somewhat. This was more the exception than the rule. Nevertheless, future experiments should have a short video produced to deliver a consistent briefing to all searchers. This video could be played on laptop computers and therefore could deployed successfully to the field.

4.3.2 Instructions to Data Loggers

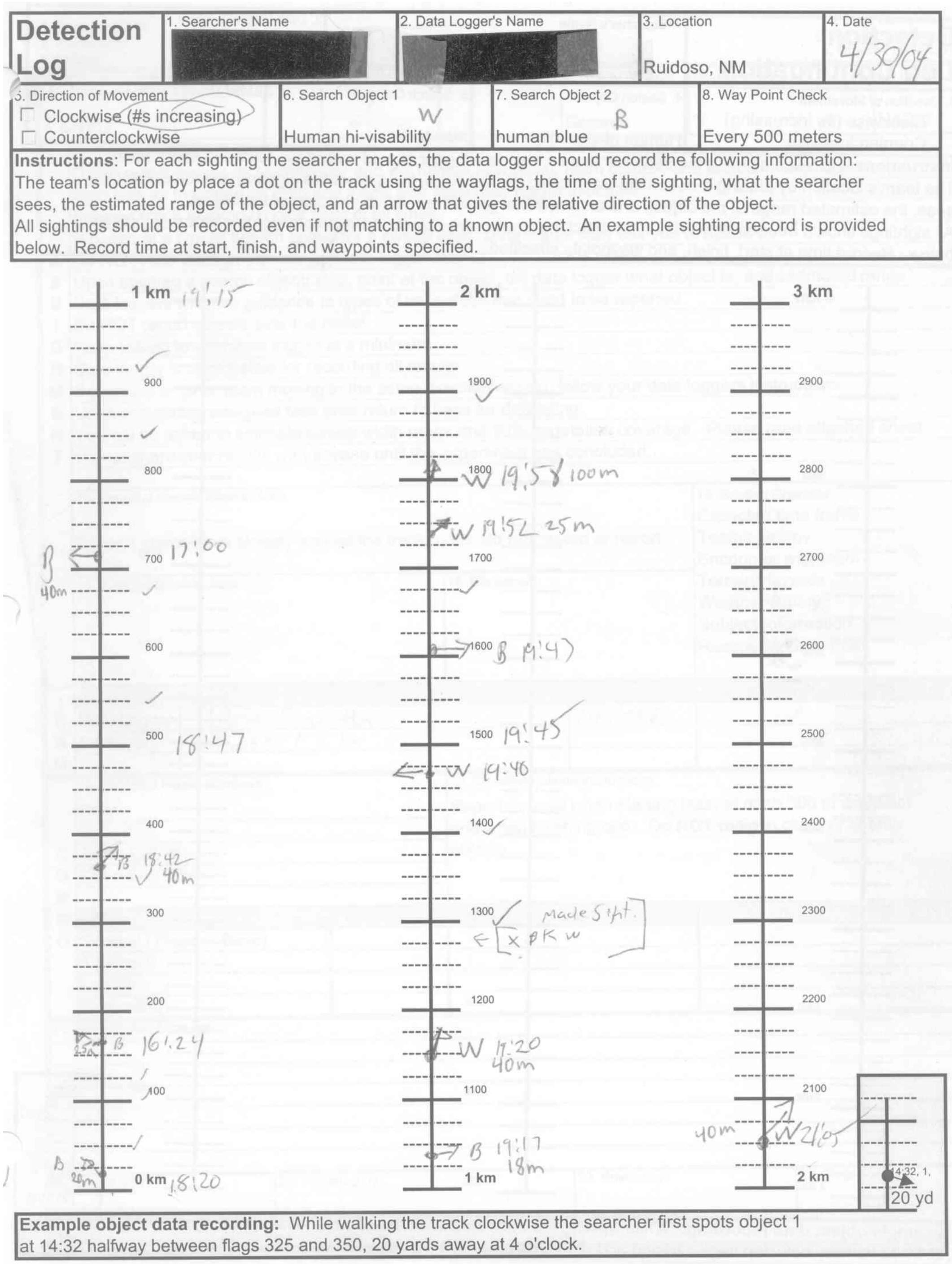
Instructions to Data Loggers were provided by both written and oral instructions. In most cases data loggers were members of the experiment team. In other cases, they were searchers who had gone through the course once and agreed to go through a second time as a data logger. Finally, in some cases a novice participant was used as a data logger. This is of course the least ideal of the situations. All data loggers received written instructions on the General Briefing to Data Logger form. This form was reviewed during the briefing process by the briefer. In many cases part of the experiment team escorted the team to the start of the course. Part of the experiment team would then ensure the data logger could clearly perform all the needed duties during the first 100 meters of the course. Samples of flags were also present at base during the briefing process as visual aids to better explain the course. Future experiments may consider setting up a short 50 meter course with one search object present to aid in training novice data loggers.

4.4 Search Data and Variables

4.4.1 Recording Data

The Detection Log form (Fig. 4-1, and Appendix C) has a linear representation of the search track labeled with a tic mark to represent each 25 meters along the track. The 100-meter tic marks are labeled. Each detection made by the searcher is announced to the data recorder by it description, estimated distance, and clock bearing relative to 12 o'clock being straight ahead on the track. The data recorder places a mark on the data sheet track line at the searcher's position on the track. Extending from the mark the data recorder draws an arrow, which represents the clock bearing to the detected object. Also recorded next to the mark is a shorthand description of the detection and the time of detection. Times are recorded on the data sheet at a minimum at the start point, the end point, at each 500-meter mark, and at the time of each detection. The recording of times more frequently is desirable. By placing yellow (or one appropriate color) flags at all of these points the instructions to data loggers can be simplified (record the time every time a yellow flag is passed.)

Figure 4-1 shows an actual Detection Log used during one of the experiments.



Detection Log	1. Searcher's Name	2. Data Logger's Name	3. Location	4. Date
	[redacted]	[redacted]	Ruidoso, NM	4/30/04

5. Direction of Movement	6. Search Object 1	7. Search Object 2	8. Way Point Check
☐ Clockwise (#s increasing) ☐ Counterclockwise	W Human hi-visability	B human blue	Every 500 meters

Instructions: For each sighting the searcher makes, the data logger should record the following information: The team's location by place a dot on the track using the wayflags, the time of the sighting, what the searcher sees, the estimated range of the object, and an arrow that gives the relative direction of the object. All sightings should be recorded even if not matching to a known object. An example sighting record is provided below. Record time at start, finish, and waypoints specified.

Example object data recording: While walking the track clockwise the searcher first spots object 1 at 14:32 halfway between flags 325 and 350, 20 yards away at 4 o'clock.

Figure 4-1. A Detection Log used in one of the experiments.

4.4.2 Search Objects

The searcher, at the time of detection, reports to the data recorder a description of the object detected. Detections, which the searcher believes could be one of the objects of interest, should be recorded. The only time a sighting should not be reported is when the data logger is 100% confident the reported detection does not relate to any of the search objects. This will help keep the Detection Log from becoming cluttered with irrelevant sightings that make scoring much more difficult.

4.4.3 Searcher

Data on the searcher is collected on the Searcher Profile form (Appendix C).

4.4.4 Weather

Current weather and changes in the weather conditions are recorded at the command post. The weather characteristics recorded should at a minimum cover precipitation, cloud cover, temperature, visibility, and wind speed. In future experiments the light level must be recorded.

4.4.5 Terrain

An accurate description of the geologic features is important. Representative photographs of the search area are helpful. Features that need to be recorded are the steepness and roughness of the terrain. The presence and size of rocks and boulders on the surface that affect detection should be described. A copy of the course overlaid onto a topographic map should also be included in the final report.

4.4.6 Vegetation

The density, height, and type of vegetation should be characterized and represented by photographs. The presence of ground cover, understory density, and heavy blow down should be noted, as should potentially hazardous vegetation such as poison ivy and poison oak (Fig. 4-2).

Figure 4-2. Poison Oak.
This was one potentially hazardous type of vegetation
Identified early and mentioned in briefings prior to field work.

4.4.7 Light

Light should be evaluated as to cloudiness, time of day, and terrain shadowing. Future experiments should include a direct measurement of lux for each searcher or the qualitative descriptions previously described.

5. Post Experiment

5.1 Onsite

5.1.1 Verification of Search Objects

At the conclusion of the experiment all search object locations must be physically verified. If a search object is missing or has been moved from its deployed location all data relating to that search object must be removed from the analysis. The only exception is when the time of the disturbance is definitely known. In that case the data collected prior to that disturbance may be used.

5.1.2 Recovery of Search Objects

At the conclusion of the experiment, after their locations have been verified, all search objects should be broken down and removed from the experiment area. The exception would be a course that is set-up for an extended period of time.

5.1.3 Cleaning Up Course

During set-up of the course surveyor's flags and tape have been used extensively. All such items used to mark the course need to be removed.

5.2 Post Site

5.2.1 Data Scoring

In order to score each searcher's results, the first step is collecting the documentation of each search object's actual location. The actual locations, as well as certain key characteristics (such as uphill or downhill from track, if it is a virtual object, notes on it ability to be seen, etc.), were recorded on the Search Object Location Log (Appendix C). During the five experiments, detailed notes were also made on the Object Placement Form and the Waypoint Form (which was not ever used as intended). Each search object must be verified at the end of the experiment. These verified locations were then used to complete the Detection Template Form.

The detection template form was printed out on clear acetate. A permanent magic marker was then used to place the location of the search objects onto the acetate copy of the form. The Detection Log scoring template was gridded so the precise distance along the track and off-track distance could be plotted. Each search object was also noted with its object number. The acetate form was then placed over the searcher's detection log. In order to determine whether a search object had been detected it was a simple matter of observing whether the search object had an arrow (on the detection log) pointing at it, along with a correct description of the object. In cases where it was difficult to decide because the arrow did not point exactly at the object, the distances noted on the Detection Log often became quite useful. All scoring should be done by one individual to ensure consistent results. Each search object would be scored as either being detected or missed. Virtual search objects were not placed onto the Detection Log scoring template and were all scored as misses.

Figure 5-1 gives an actual example of a Detection Log with a scoring template overlay.

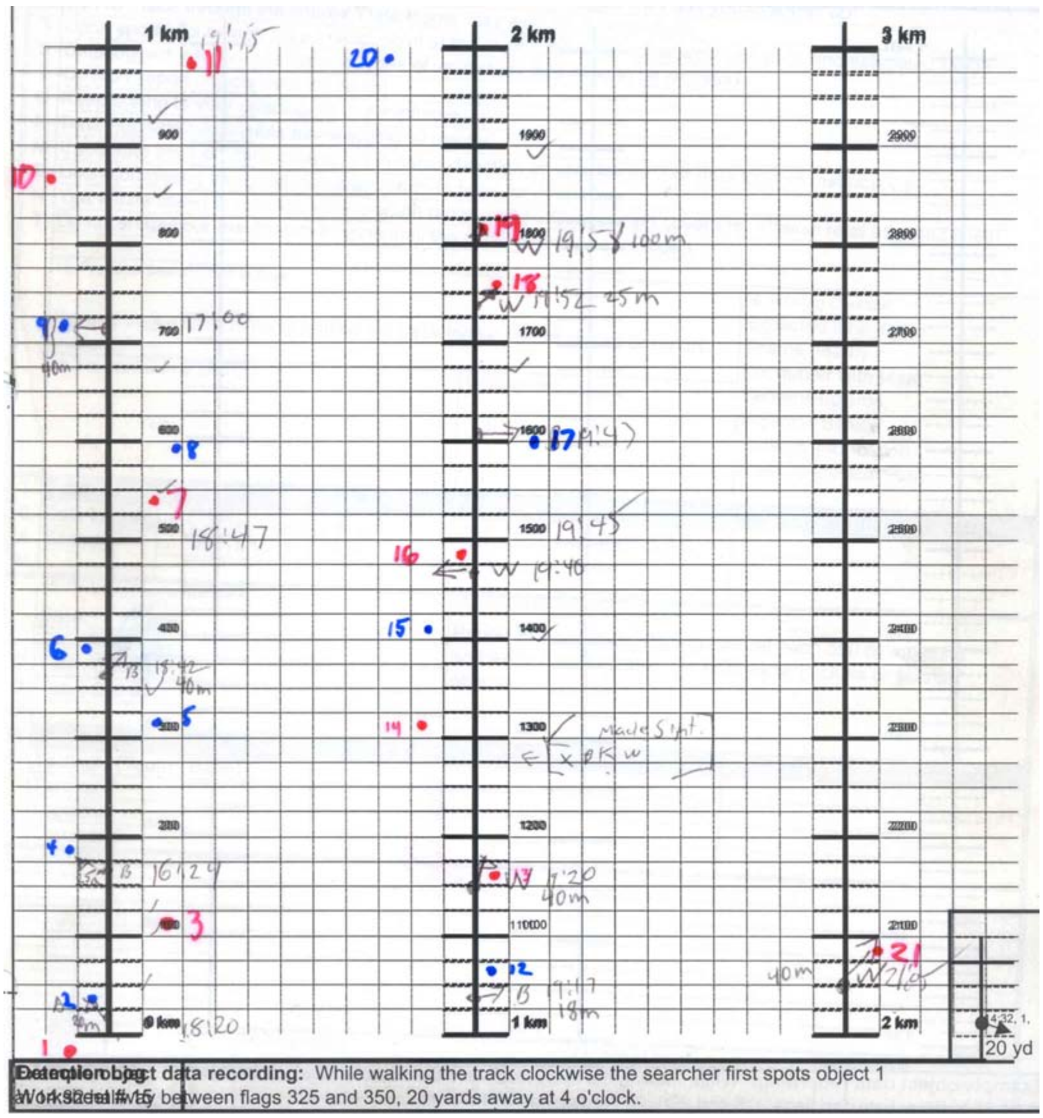


Figure 5-1. Part of a Detection Log with scoring template overlay.

Scoring of objects becomes quite apparent. Search object 1 was scored as a detection (data loggers were told not to score it since it fell right on the track). Object two was detected, object three was missed, four was detected, five was missed, six was detected (the arrow point the wrong direction but the course took a sharp turn – showing the value of having the scorer walk the course as a data logger), seven was missed, eight was missed, nine was detected, ten was missed, eleven was missed, twelve was detected, thirteen was detected, fourteen missed (able to see data logger notes about a possible detection the data logger made), fifteen missed, 16-19 detected, 20 missed, and 21 detected.

5.2.2 Data Entry

The actual misses and detections where recorded on the detection scoring form. Misses where recorded as “0” and detections where recorded as “1”. Then the Searcher Profile, Detection Log, and Detection Scoring form were all stapled together.

Data entry was then made into the MS Excel based Experiment Design Calculator Data input Search Object 1 sheet. The clue number, lateral range (or off-track distance), and clue type were entered. Then for each searcher (using their coded searcher number) the “0” and “1” were transcribed from the scoring form into the spreadsheet.

Information from the Searcher Profile form was entered into a separate spreadsheet. All the information was captured except for the searcher’s name and the data logger’s name. This ensures the searcher’s privacy is protected.

5.2.3 Data Analysis

Using the information provided on the spreadsheet, another spreadsheet automatically calculated the crossing over point of the cumulative detections and cumulative misses.

5.2.3.1 Determining Effective Sweep Width

The task of estimating the effective sweep width was reduced to a purely graphical process by making use of the properties of sweep width. Figure 5-2 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 provided 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 $12 \times 32 = 384$ 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.

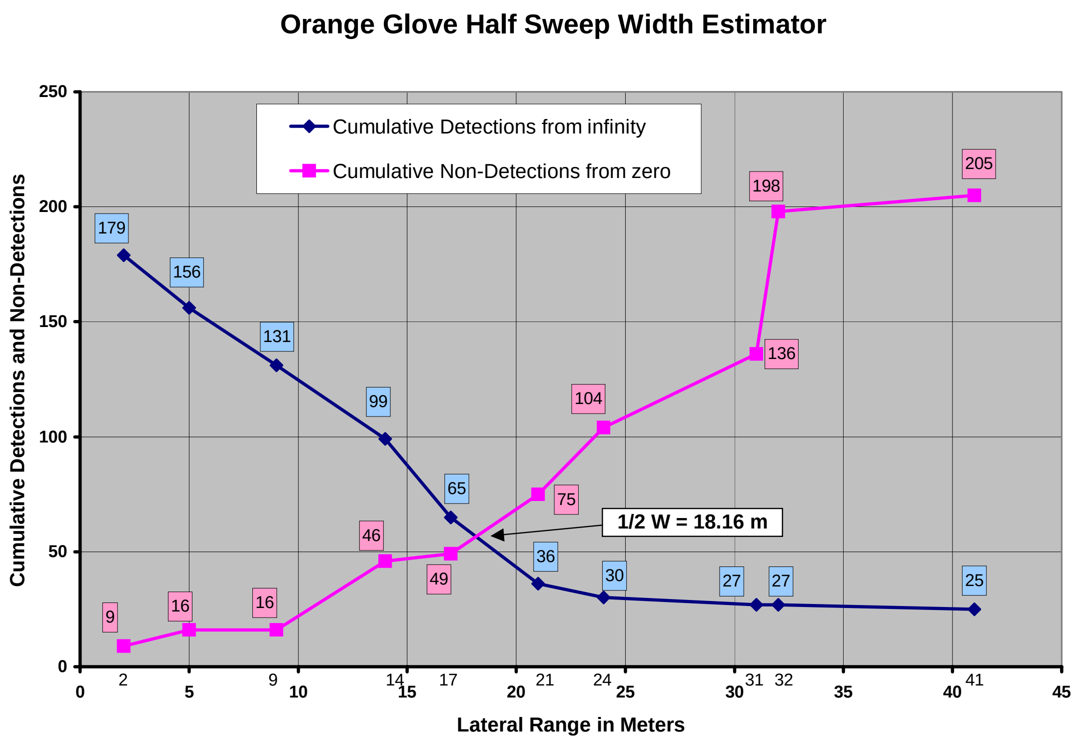


Figure 5-2. Example cross over graph used to estimate sweep width from detection data.

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.
- The graphs are automatically drawn by the spreadsheet using the detection scoring data entry.
- The Experimental Design Calculator also automatically calculates the crossing over point and multiplies it by two to determine the effective sweep width using the crossing over technique.

5.2.3.1.1 Lateral Range Curve

The Excel Experimental Design Calculator is also designated to make a traditional lateral range curve for each search object. Effective sweep width (ESW) can also be determined from the lateral range curve. It is possible to set-up a spreadsheet to calculate the ESW from the lateral range curve values. At this time, this calculation is not built into the Design Calculator. Indeed, the Logan, WV experiment found that the cross-over technique for determining ESW is superior to the lateral range curve on smaller experiments. These observations are discussed below.

5.2.3.1.2 Crossing-Point Versus Lateral Range Curve

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 during the Logan pilot experiment. 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.

5.2.3.2 Other Data Analysis

The principle purpose of these experiments is to determine the ESW in different environments for different types of search objects. However, with the considerable amount of data collected and entered into an MS Excel spreadsheet makes other data analysis possible. If searchers are able to correctly predict their POD it would simplify search management, since searchers could be asked directly. Previous research and these experiments show this is unlikely. The data collected from experiments will allow the construction of a graph that shows the searchers predicted POD versus their actual POD for each search object.

An important component to ESW is correction factors to account for important environmental and searcher factors. While beyond the scope of this experiment, all the data required for determination of correction factors is being collected and entered into the MS Excel spreadsheet. A cursory examination will be made to determine which factors hold promise for being important key correction factors.

Clearly the land with its multitude of different vegetations is a complex environment. In the United States 52 different ecoregions exist at the province level. Within California 8 provinces exist which can be further broken down into 19 sections. (ref: http://www.fs.fed.us/r5 /projects/ ecoregions/introduction_map_2nd_reference.htm) This requires a lot of sweep-width experiments. Therefore, these experiments are also collecting vegetation characterizing factors such as AMDR, vegetative density, and Laser returns to see if any relationship can be found between the factors and the ESW. This could represent an important short-cut searchers could take to determine the ESW when an actual experiment has not been conducted yet.

Part III – Experiment Results

6. Description of Venues

6.1 Shenandoah National Park – Winter

6.1.1 Location

Shenandoah National Park includes 300 square miles of the Blue Ridge Mountains, which form the eastern rampart of the Appalachian Mountains between Pennsylvania and Georgia. The Shenandoah River flows through the valley to the west, with Massanutten Mountain, 40 miles long, standing between the river's north and south forks. The rolling Piedmont country lies to the east of the park. Skyline Drive, a 105-mile road that winds along the crest of the mountains through the length of the park, provides vistas of the spectacular landscape to east and west. The park holds more than 500 miles of trails, including 101 miles of the Appalachian Trail, and many animals, including deer, black bears, and wild turkeys, flourish among the rich hardwood forests (National Park Service [NPS], 2004).

The specific area used in the experiment was the Big Meadows area of Shenandoah National Park (Fig. 6-1).

Figure 6-1. General overview of the Shenandoah experiment site.

Figure 6-2. A search object in the Shenandoah experiment site.

6.1.2 Ecoregion Description

In its description of Ecoregions of the United States (http://www.fs.fed.us/institute/ecoregions/ecoreg1_home.html), the U.S. Department of Agriculture, Forest Service, characterizes Shenandoah National Park as a Humid Temperature Domain, Hot Continental Division, Central Appalachian Broadleaf Forest--Coniferous Forest--Meadow Province (M221).

Most of Shenandoah's landscape is dominated by hardwood forests including the numerous rich growths of oak and hickory. The forests are the result of many disturbances, some measured in geologic time, others in minutes. Remnants of boreal forests remind us that continental glaciers came near. Strands of barbed wire embedded in trunks mark the edges of former pastures. Uprooted trees show the path Tropical Storm Fran made in 1996 (NPS, 2004).

In season, bushes and wildflowers bloom along the Drive and trails and fill the open spaces. Apple trees, stone foundations, and cemeteries are reminders of the families who once called this place home. The park rises from 600 feet above sea level beside Shenandoah River near Front Royal to 4,050 feet at the summit of Hawksbill Mountain. More than fifty peaks, many with hiking trails, rise above 3,000 feet (NPS, 2004).

Weather varies dramatically depending on elevation. The average low temperature during the month of January at Big Meadows (elevation 3,530') is 17 degrees Fahrenheit, while at Park Headquarters (1,100') the average is 21 degrees. The average snow depth during the winter months at Big Meadows is 6.3 inches (NPS, 2004).

During summer months, temperatures remain mild at Big Meadows with an average of 72 degrees F. In the valley at Park Headquarters, the average temperature is 92 degrees F, and in July 1988 the temperature reached a record high of 105 degrees F (NPS, 2004).

6.1.3 Map of Course

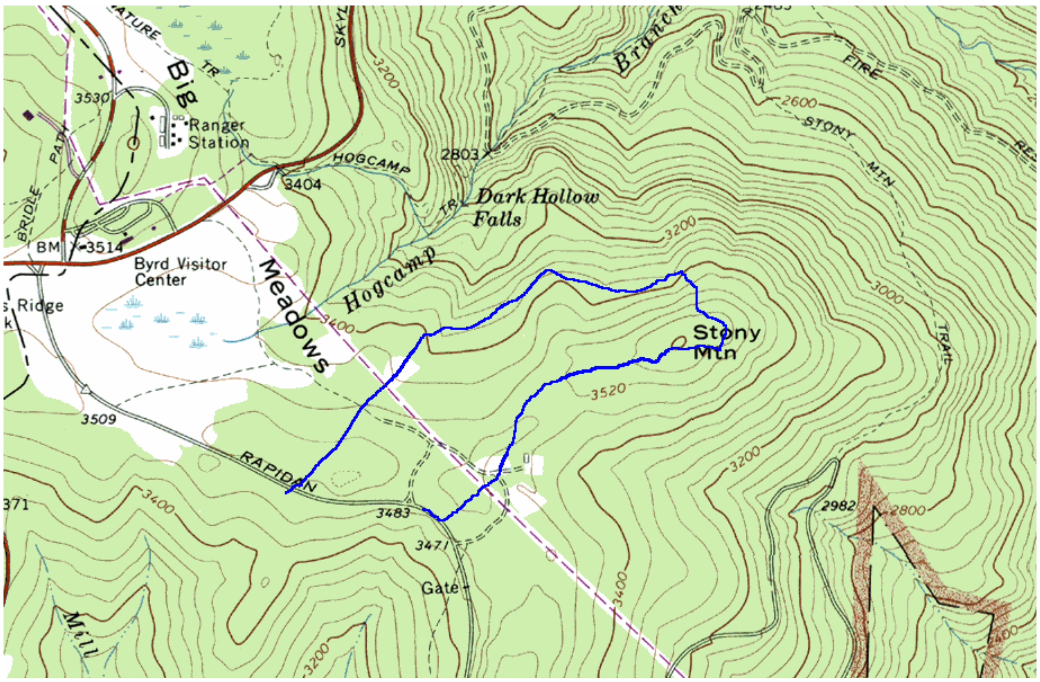


Figure 6-3. Map of Shenandoah course (course track is in blue).

6.1.4 Course Selection Discussion

The general location was chosen due to its proximity to Big Meadows Ranger Station in Shenandoah National Park. The Appalachian Search & Rescue Conference was holding its annual meeting at this location and several NPS rangers work out of this location, creating an ideal searcher pool. The Chief Ranger suggested the area around Stony Mountain where the NPS rangers have a practice orienteering course set up. The area was basically flat, avoiding steep drainages. The course set-up did not interfere with normal park operations, and the area's vegetation was representative of the park.

The original goal of the course design was to start at the Rapidan Road, head for the 3400-foot contour line, then follow that contour around the summit of Stony Mountain, and then continue back to the road on the other side of a ridge. The purpose of the ridge in the center of the course was to ensure search objects could not be spotted from both legs of the track. The entire path had not been scouted out prior to course setup.

The start of the course went as planned. However, once on the backside of Stony Mountain the terrain changed into significant boulder fields that were different from the terrain the AMDR readings where taken from. It was also felt that significant boulder scrambling would distract and be hazardous to searchers. The course was altered to head straight up the mountain to nearly the summit. The part of the course that had gone through the boulder fields was then eliminated. Once on the ridge, the walking proved easier and consistent with the rest of the course. The ridge was then followed back to the Rapidan road.

6.1.5 Participant Recruitment

The Big Meadows experiment was a dedicated experiment event held in Shenandoah National Park. Participants were recruited from three primary sources based on a close working relationship that exists between Virginia State SAR resources and Shenandoah National Park (SNP). The park supported the experiment by providing facilities to use as the command post, a staging site, access beyond locked gates, free entry to the park for participants, and assignment of Park Rangers to participate in the experiment. The Appalachian Search & Rescue Conference, a large search team consisting of over 300 members, also scheduled its annual membership meeting at SNP to coincide with the experiment. This allowed several members to participate in the experiment. Finally, members were recruited from member groups of the Virginia Search and Rescue Council. Announcements were made at the quarterly meeting and reminders sent via e-mail directly to member groups. In addition, the Virginia Department of Emergency Management was requested and provided SAR base personnel to help with the overall command and control. Recruitment was greatly aided by one the experimenters having extensive local contacts. All searchers belonged to a search and rescue team or were Shenandoah National Park rangers. A total of 31 teams were deployed with several other teams that could have been deployed if not limited by failing light.

6.1.6 Lessons Learned

This was the first experiment using the revised methodology and several important lessons were learned that caused revisions to later protocols.

- **Need for clipboards.** Clipboards should be made available and issued to data loggers. (This suggestion was incorporated on all future experiments and worked well.)
- **Waterproof detection logs.** The detection log and instructions for Data loggers must be printed on waterproof paper (All future detection logs were printed on Rite-in-the-Rain copier paper which was successful including on the Washington experiment where it rained hard.)
- **Create a briefing video**. A Briefing video should be developed to provide for a more consistent briefing to both searchers and data loggers. This would help reduce the load of the command and control staff. An oral briefing would still be needed to supplement the video with information specific to the experiment /scenario. The video should be in such a format

it can be played on a laptop computer. (Funding and time precluded the development of a video, the experiment team still strongly recommends this important project be undertaken)

- **Stratified random for off-track distances.** Use of the Experimental Design Calculator for the placement of clues provided quite successful. It allowed the random placement of clues requiring only a laptop. However, it became apparent that the random distribution of off-track distances could lead to a failed experiment. With the often small number of targets set out it was possible for the random numbers to generate locations clustered either close to the track or far from the track. It was decided that the optimal distribution for off-track placement should be a random stratified distribution. This change in protocol was accomplished using a manual method versus one built into the Excel spreadsheet. The manual method consisted of looking at 10 meter bins and making sure at least one search object was placed into each 10 meter bin. This was accomplished prior to departure to the field. The Excel spreadsheet would generate not only the needed search object locations but several extra up to a total of 40 locations on the Sweep Width Object Placement Worksheet. If no search object had been selected for one of the bin off-track distances, and multiple search objects were selected for another bin (often at an identical distance), then a manual adjustment was made. In order to arrive at a new off-track distance for the missing bin the Sweep Width Object Placement Worksheet was scanned for the first number that fell in the missing bin. It is important to note all decisions were made prior to deployment to the field to prevent the actual terrain and vegetation from influencing search object placement. This scheme for stratified random placement worked well throughout the experiments. However, it is difficult to describe. It is recommended that this feature be built into future Experimental Design Calculators.
- **Better scheduling of searchers.** As part of the recruitment effort for the Big Meadows experiment all potential participants were told to arrive at 07:00. This caused a major scheduling problem with most of the resources arriving at the same time. Better scheduling of the times people arrive makes everyone happier. (In future experiments participants were much better scheduled using the Team Sign-up Form, which was developed in response to this problem.)
- **Lack of forms**. An insufficient number of forms were brought to the first experiment. This resulted in the need to find a copier and make additional forms. In order to assist experiment planners with the correct numbers of forms a Table of Contents was added to the Experiment Design Calculator. This table gives the number of copies of each form required. The most critical forms are the Subject Information Sheet, Task Assignment Form, Data Logger Briefing, Searcher Profile, and Detection Log. This problem was not encountered on subsequent experiments.
- **Site setup schedule.** Sufficient prior site preparation is critical to a successful experiment. No site preparation should occur on the day of the experiment. The experiment planner will have several command, control, and logistics problems arise so that no time can be spent on setting up the course. The day before the course should be dedicated to placing the search objects. Search objects need to be transported to the field, constructed, carried to the correct off-track locations, measured accurately, staked, and documented. This often required more than 8 hours with a four person team. Therefore, prior to placing the targets sufficient time needs to be given for someone to scout the area, collect AMDR data, design the course, flag the course, mark the course with the 25 meter flags using the roller wheel, and then place additional flags and markers as needed. This may require two days depending upon the course (roads and trails take less time than cross-country). During the Big Meadows experiment the

course was not fully marked on the day the team arrived to setout the search objects. The terrain changed from the area initially scouted resulting in a required change to the course. With the limited amount of light the actual course was not marked and flagged until sunset. Placement of search objects then took place from dusk until after dark. This resulted in some of the search objects not being placed until early on the morning of the experiment. On subsequent experiments the following schedule was used.
  - First site visit consisted of scouting the terrain, looking at alternative locations, and obtaining AMDR information.
  - The second visit consisted of a travel day.
  - A day to layout the course and roller wheel it,
  - A day to finish marking/flagging the course,
  - The day the rest of the team set out the search objects,
  - The day of the experiment, and
  - The day after the experiment to breakdown the course.

  This schedule proved to be quite successful and allowed sufficient time for any mishaps.
- **Maps for searchers**. Provide maps of the course to searchers. Search and rescue personal are used to receiving topographic maps of their search area. During the first experiment they were not distributed. Since the search area was remote from the command and control center, many searchers did not feel confident of their location. (Maps printed on waterproof paper were distributed to the data loggers on subsequent experiments. The searchers themselves did not need to refer to the paper for any reason.)
- **Collect more searcher data.** During the first experiment the data loggers noticed several physical features that appeared to impair searching. The Searcher Profile sheet did not collect information on whether the searcher was wearing a hood, cap, sunglasses, or anything else that might limit vision. In addition, the search techniques the searcher used were not collected. (A good method was never established to collect this type of data during subsequent experiments; this does support the need to make further enhancements to the Searcher Profile form, the detection log, or some other form carried by the data logger.)
- **More data loggers.** A need for more data loggers especially at the onset of the experiment was identified. This learning point proved difficult to successfully solve on all the subsequent experiments. Initial data loggers were often the members of the experiment team. Afterwards, those who completed the course were often recruited. However, in many cases a data logger was not available. This meant a searcher needed to be paired up with another searcher who was pressed into service as the data logger. This reduced by half the number of potential teams that could go through the course and collect data. All experiments need to make some attempt to recruit people to help with data logging. It is most critical first thing in the morning.
- **Recruit to staff command and control.** Several volunteers assisted in the command and control portions of the experiment. They provided help with communications, transportation to the actual course, staging area control, organizing teams, paperwork support, briefing, and debriefing. They were invaluable to the experiment and freed up the experiment team to serve as data loggers. Experienced data loggers who were also members of the experiment team also assisted by briefing and debriefing the searcher. Many of the volunteer members of the command and control team used the experience as practice for an actual mission.
- **Make start and stop clear**. The start and end of course need to be well marked. Many searchers were not clear where the course started and finished. On subsequent courses, dif-

ferent colored flags where used for the start and finish of the course. This was well explained at the briefing with examples of the flags presented as a visual aid. This ended complaints about not being able to find the start and end of the course. Actual signs printed on waterproof paper would be helpful also.

- **Less flagging tape**. Since the course was laid out at night, it had lots of long streamers of orange or pink flagging tape. This was needed to help the experiment team find its way out of the course after setting out the search objects. During the day many searchers reported that such a large amount of flagging tape was quite distracting, especially when looking for orange search objects. On subsequent experiments more use was made of the ground surveyor flags to mark the trail. Some searchers still complained, but the number of complaints decreased.
- **Avoid field adjustments to lateral range**. Do not adjust off-track distances of search object out in the field at the last minute. As previously mentioned the search objects were set out around sundown. This led the experiment team to believe that a number of search objects would be undetectable. Hence the team adjusted the off-track distance with the result that many of the search objects were closer to the track than planned. Upon first light when the searchers started the experiment it was apparent that these search objects were obvious under good lighting conditions. Those objects (three) that had been moved closer to the track were spotted by almost every searcher. More valuable information would have been gained if they had been left in their original locations. The off-track locations should not be changed once determined by the Object Placement Worksheet. On subsequent experiments no object location was changed due to a fear of no one seeing the target in a difficult location. A protocol for virtual targets was developed which will be described later.
- **Do not put course out at night**. Several problems have already been described that result from attempting to put out a course at night. This resulted from insufficient time dedicated to setting up the course. Additional problems with a night setup included the inability to use the laser range finder to clearly determine the off-track distance. This meant that in setting out the search objects the off-track distance was estimated rather than measured. It was not until the course was broken down the next day that the laser range finder could be used to accurately measure the off-track distance. No future courses were put out at night. The setup schedule was followed which required adequate time for each stage.
- **First target close.** The adult size manikins while generally life-like with arms, legs, body, and head, still looked confusing depending upon the angle. Therefore, it was decided that a search object would be placed close to the start of the course at a small lateral range to give searchers an idea of what they are looking for. On subsequent experiments this feature was built into the Experimental Design Calculator. The first search object does not follow the normal random pattern but instead was placed at an off-track distance of one-tenth the AMDR and an along track line distance of 0.75 times the AMDR from the course start point. This automatic feature proved useful for the experiment.
- **Civilian laser range finder and GPS worked**. During first experiment professional survey grade GPS and Laser Range Finders were rented. During the setup of the experiment they were compared to the civilian grade GPS and laser range finder. It was found that for the purposes of the experiment (GPS gives general location of course onto a topographic map, laser range finder gives off-track distance accurate to a half meter) the civilian versions were equal to the survey grade. In addition, the civilian versions were lighter, more compact, and much less expensive than the survey equipment. The only noted limitation of the civilian la-

ser range finder was its inability to measure distances less than 10 meters. With the sweep width values being obtained this did not prove to be an important limitation.

- **25 Meter marker helped.** This was the first experiment that placed flags every 25 meters. This made it easy to position the search objects during setup, it also made it easy for the data loggers to determine their location when the searcher spotted a search object. While time consuming to set up, they greatly helped the eventual scoring of the detection logs and helped identify false positives.
- **Use roller wheel.** During the first experiment the roller wheel was not used to measure the 25 meter distance between the flags. Instead, the odometer component of the GPS unit was used. With all the starts and stops, time lags, and dropped satellites this did not prove to be accurate. The course as flagged (based upon 25 meter segments) was thought to be 2.3 km long, while in reality it was 3.9 km long. In all subsequent experiments the roller wheel was used. While sometimes difficult to roll cross-country and uphill, it proved repeatable and reliable even through dense vegetation. A wheel with a large diameter should be used (see Appendix E for type of wheel used).

6.2 New Mexico SAR Conference – Lincoln National Forest

6.2.1 Location

Located in South Central New Mexico, the Lincoln National Forest is known as the birthplace of the world-famous Smokey Bear, the living symbol of the campaign to prevent forest fires.
In the Forest, there are three major mountain ranges—Sacramento, Guadalupe and Capitan—that cover over 1.1 million acres in parts of four counties west and southwest of Roswell (U.S. Department of Agriculture [USDA] Forest Service, 2004b).

The experiment was conducted in the Sacramento Mountains in the White Mountain Wilderness area of the Smokey Bear Ranger District in the northern part of the forest.

Figure 6-4. General overview of the New Mexico experiment site.

Figure 6-5. A search object in the New Mexico experiment site.

6.2.2 Ecoregion Description

In its description of Ecoregions of the United States (http://www.fs.fed.us/institute/ecoregions/ecoreg1_home.html), the U.S. Department of Agriculture, Forest Service, characterizes the Lincoln National Forest as a Dry Domain, Tropical/Subtropical Steppe Division, Great Plains Steppe and Shrub Province (M311).

Elevations in the Lincoln national Forest range from 4,000 to 11,500 feet and pass through five different life zones (similar belts of vegetation associated with increasing latitude and elevation) from Chihuahuan desert to subalpine forest. Vegetation ranges from rare cacti in the lower elevations to Englemann spruce in the higher (USDA Forest Service, 2004b).

Temperatures also vary with elevation in the forest. At higher elevations (7,000 feet and up), summer temperatures range from 40 degrees F to 78 degrees F, while winter temperatures range from -15 degrees F to 40-50 degrees F. At lower elevations (6000-7000 feet) winter temperatures rarely fall below 0 (zero) F and usually range from the “teens” to 50s F. Summer temperatures range from 50-85 degrees F. At the lowest elevations (4,000 to 6,000 feet), temperatures are generally 10 degrees F higher throughout the year (USDA Forest Service, 2004b).

Spring is the windy season. High winds dry the forest to the point of extreme fire danger. Fire season usually starts in March or April and continues through mid-July. If the fire danger becomes too high, open fires may be prohibited, requiring the use of contained fuel stoves for cooking. The rainy season begins in July and continues through September. The first snows fall in late October or early November (USDA Forest Service, 2004b).

6.2.3 Map of Course

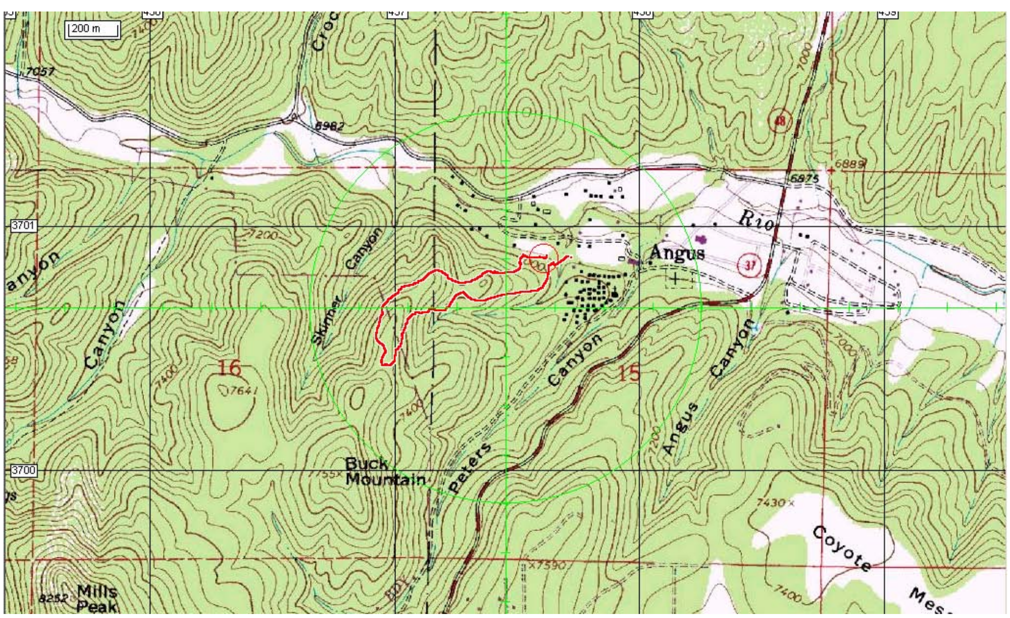


Figure 6-6. Map of New Mexico course (course track in red).

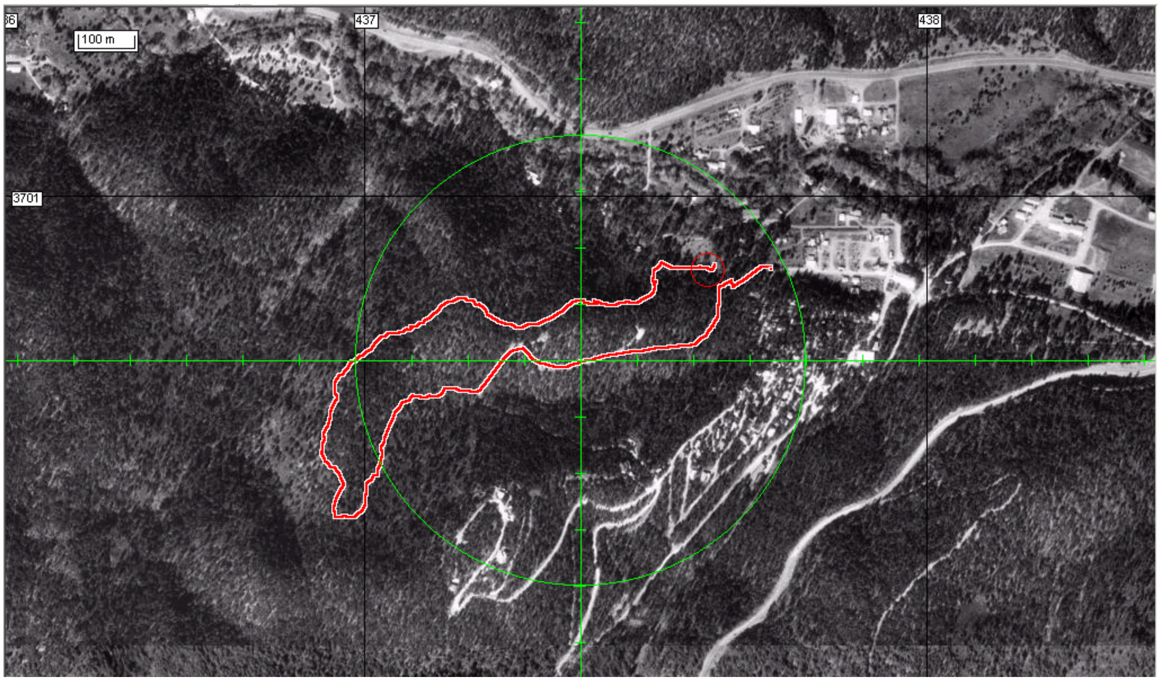


Figure 6-7. Aerial photo of New Mexico course.

6.2.4 Course Selection Discussion

The New Mexico course was held in conjunction with the New Mexico State SAR conference located in Angus, New Mexico. The conference had multiple educational tracks and the experiment would be competing for participants. It was decided for logistical purposes to make the course convenient for participants and to not take longer than the time allocated for one lecture. The Conference Center had some land available next to Lincoln National Forest.

After the Big Meadows course setup experience it was decided the entire course must be scouted out prior to search object placement. A day was spent out in the field walking around and finding an area with uniform vegetation. The basic strategy was once again to use a ridge to divide the course into an outward and return leg. Since the terrain was much steeper and the sandy-soil loose, it was decided to take advantage of footpaths, animal trails, and a road, along with cross-country travel. In addition, the total length of the course was shorter in order to ensure total time would be less than two hours.

The course started on a foot trail for the first segment's climb then went cross-country to reach the ridge. The course then followed the north side of the ridge. When the course was on the ridge (which had the easiest walking) the steep slopes on both sides limited the field of vision significantly more than did the general vegetation in the area. Therefore, the course was laid out to contour along the ridge using animal paths made by the numerous mule deer. The course then crossed over the ridge and started back the other side. Once again a combination of cross-country descents followed by contouring along animal trails was used. The course then descended until it intersected with a dirt jeep-trail. The road was used to return to the beginning of the course. The direction of the course was established so that the climbing was done at the beginning of the course and the descent at the end to minimize fatigue.

6.2.5 Participant Recruitment

The New Mexico experiment was held in conjunction with the New Mexico SAR Conference. The conference typically has 200 participants and a multi-track layout offering several different conference options at the same time. Recruitment was primarily done during conference registration. A table was set-up next to the registration desk so that participants could be approached and recruited for the experiment. Better signage was identified as something that would have assisted with recruitment. The experiment was listed in the conference events. However, the ongoing nature of the experiment should have been better explained. Significant recruitment occurred throughout the conference due to the active recruitment of teammates by experiment participants after going through the course. All searchers belonged to search and rescue teams. In addition, the position of the command and control table in the middle of the conference exhibit hall/conference events also raised visibility.

6.2.6 Lessons Learned

- **Site visit schedule worked well.** During the initial site visit, several different sites were examined. The final site was chosen due to proximity to the conference site. The initial scouting trip provided insight into the area and the initial AMDR. On the second trip the course was changed due to steep terrain. However, the course was laid out, rolled, and marked before the rest of the experiment team arrived. This allowed the search objects to be laid out ahead of time. Therefore, on the conference registration day some participants were able to conduct the experiment a day ahead of schedule. Otherwise these searchers may not have been able to participate during the actual conference. They also helped create “marketing momentum” which helped recruit other searchers.
- **Course adjacent to conference helps.** The fact the course was adjacent to the conference site did help with recruitment and logistical concerns. It minimized transportation time and simplified directions to the course’s start point. In several cases, it also allowed for one of the experiment team to escort the searcher and data logger to the course and verify they were following directions at the onset of the course.
- **More data loggers.** This point was never successfully solved. Several more teams could have gone through the course if more data loggers had been available.
- **Switching search objects left vs right.** During the layout of this course the track followed a foot path at several points. As the footpath gained elevation it often used switchbacks. Placement of a clue inside the switchback would have made determining a lateral range ambiguous. Therefore, the search object was switched to the other side of the track to avoid this problem. It was important to carefully document this change. This type of switch was not needed on straight sections of the course.
- **Useful to have roads in course.** This course had a road that was part of the course. When marking a dirt road it is important to set-out the marking flags to clearly indicate where the searcher should walk. The path was optimized to allow viewing of both the left and right hand side of the road. The road also made it easier to set out and retrieve search objects. Fi-

nally, in the case of failing light or health, the course could be shortened by taking a short cut at one point. This does not affect the validity of the detection data as long as the actual course taken is recorded on the detection log.

- **Consider placing course on ridge carefully.** During the outbound leg of the course it would have been possible to route the course along the top of a ridge. This made for flatter easier walking. The ridge was relatively flat with a sharp drop off on either side. This would have limited the visual range to about 5-10 meters on either side. Since the AMDR was greater than this distance it would have artificially decreased the lateral range of detection opportunities. Therefore, the course was routed well below the ridge line. This allowed for much greater detection distances that were more consistent with the actual terrain.
- **Create search object form.** After placing a search object rough notes were placed on the search object form regarding the ability to see the search object. Often qualitative terms where used such as easy, difficult, or impossible. In other cases a more objective approach was written down such as "visible between 1150–1160 track line distance, only while looking back". A new form that better characterizes the search objects placement could be a benefit to future search experiments, especially if improvements are made in describing how searchers actually scan the areas they pass through.

6.3 Washington State SAR Conference, Gifford Pinchot National Forest

6.3.1 Location

The Gifford Pinchot National Forest—one of the oldest National Forests in the United States—is located directly south of Mt. Rainer National Park and just north of the Columbia River in southwest Washington State. Included as part of the Mount Rainier Forest Reserve in 1897, this area was set aside as the Columbia National Forest in 1908. It was renamed the Gifford Pinchot National Forest in 1949 after the first Chief of the Forest Service. The Forest contains over 1.3 million acres and includes both the Mount St. Helens National Volcanic Monument and Mount Adams (12,276 feet), the second highest peak in Washington State (USDA Forest Service, 2004a).

The experiment was conducted in the northern part of the forest known as the Cowlitz Valley Ranger District.

Figure 6-8. General overview of the Washington State experiment site.

Figure 6-9. A search object in the Washington State experiment site.

6.3.2 Ecoregion Description

In its description of Ecoregions of the United States (http://www.fs.fed.us/institute/ecoregions /ecoreg1_home.html), the U.S. Department of Agriculture, Forest Service, characterizes the Gifford Pinchot National Forest as a Humid Temperate Domain, Marine Division (Mountain Provinces), Cascade Mixed Forest--Coniferous Forest--Alpine Meadow Province (M242).

The Gifford Pinchot National Forest is home to several Threatened and Endangered species including: bald eagle, bull trout, Chinook and chum salmon, northern spotted owl, and steelhead. The Forest also provides habitat for gray wolf, grizzly bear, and marbled murrelet.

The Cascade Province covers a series of steep, rugged mountains bordered in places by a narrow coastal plain. Mountains along the coast rise 5,000 ft (1,500 m) above sea level, with a local relief of 1,000-3,000 ft (300-900 m). The interior Cascade Range has mountains 8,000-9,000 feet (2,400-2,700 m) in altitude, dominated every 5-85 mi (8-135 km) by a volcano of much higher elevation. Mt. Rainier, for example, rises more than 14,000 ft (4,300 m) above sea level. Some parts of the province, especially its northern portion and the Cascade Range, have been glaciated.

Because this province borders on the Pacific Ocean, its climate is characterized by generally mild temperatures averaging 35 to 50F (2 to 10C) throughout the year. Rainfall is heavy, 30 to 150 in (770 to 3,800 mm) per year, with a maximum in winter. Humidity is always high, producing an extremely favorable precipitation/evaporation ratio. The southern part of this province is winter-wet with no snow; fog partially compensates for the summer drought. As one moves to the north, the summer dry season shortens, and the proportion of precipitation falling as snow increases. On high mountains, all precipitation may be snow, which reaches depths of 50 to 65 ft (15 to 20 m). East slopes are much drier than west slopes, accumulating less than 20 in (511 mm) of precipitation per year.

The Cascade Province is primarily montane, but it ranges from sea level to altitudes above 5,000 ft (1,500 m). At the lowest elevations, there is a dense conifer forest of Douglas-fir, western red cedar, western hemlock, grand fir, silver fir, Sitka spruce, and Alaska cedar. Numerous species of shrubs grow exceptionally well in this forest and around its margins. In many places, this vegetation is practically impenetrable. Although Douglas-fir is the most abundant tree at lower elevations in the region, it is not part of the climax forest. Western hemlock and several other species of fir are more tolerant of shade than Douglas-fir, and in mature forest stands, Douglas-fir cannot regenerate. On the western and southern slopes of the Olympic Mountains in Washington, hemlock is eventually displaced by the more shade-tolerant silver fir. In the humid conifer forests of southwestern Oregon, Alaska cedar is replaced by silver fir and redwood. In the fog belt along the coast of northwestern California, redwood is the characteristic tree. Douglas-fir and other conifers associate with it to form perhaps the densest of all coniferous forests, with the world's largest trees. Some redwoods attain heights of more than 325 ft (99 m) and girths of more than 65 ft (19.8 m).

A xerophytic forest of ponderosa pine grows along the dry eastern slopes of the Cascades, descending to 500 ft (150 m) along the eastern foot of the range at the Columbia River. This is typically open forest mixed with grass and shrubs. It occurs throughout the Southwest, the Sierra Nevada, the Rocky Mountains, and the Black Hills.

The high, snowcapped mountains of the Cascades have a well-marked subalpine forest belt that reaches into British Columbia. Important trees are mountain hemlock, subalpine fir, whitebark pine, and Alaska cedar. To the north, the subalpine forest becomes fragmentary or disappears completely.

All but the highest peaks are covered by forest. In the Cascade Mountains of Oregon, timberline varies from 7,700 to 10,000 ft (2,350 to 3,050 m). Above timberline, there is an alpine zone with rich communities of shrubs and herbs. Perpetual snow is confined to small patches. Riparian forests in the Pacific Northwest are an exception to the general rule that conifers dominate in the region. Along the region's many rivers and streams, needleleaf trees are replaced by broadleaf species such as black cottonwood and red alder. This kind of forest occurs from southern Alaska south through Washington, Oregon, Idaho, and western Montana, continuing into northern California and the Sierra Nevada.

Common large mammals include elk, deer, mountain lion, bobcat, and black bear. Small mammals include mice, Douglas squirrels, martens, Townsend chipmunks, red tree voles, and bushy-tail wood rats. The most important game birds are blue and ruffed grouse; there are hawks and owls in the northwestern part of the province. Spotted owl and marbled murrelet depend on remaining old-growth forests. Among the many species of amphibians that live in this region's moist, cool forests are the Pacific treefrog and the Pacific giant salamander. Reptiles include the northern alligator lizard and rubber boa.

6.3.3 Map of Course

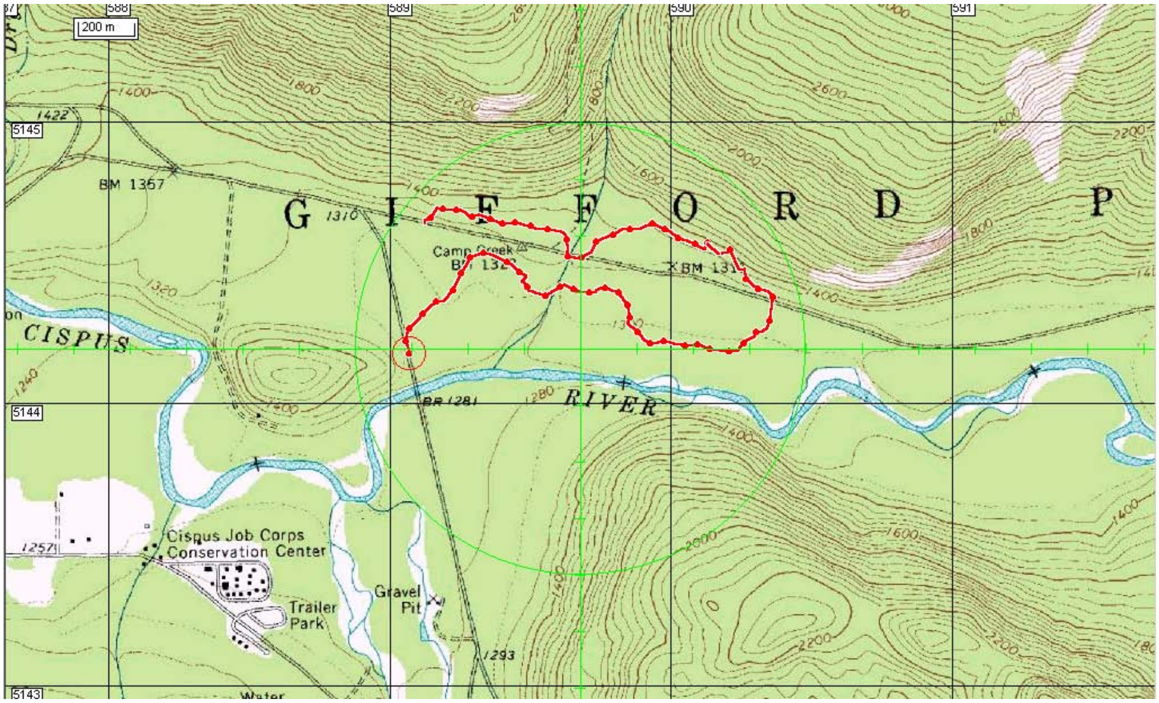


Figure 6-10. Map of Washington course (course track in red).

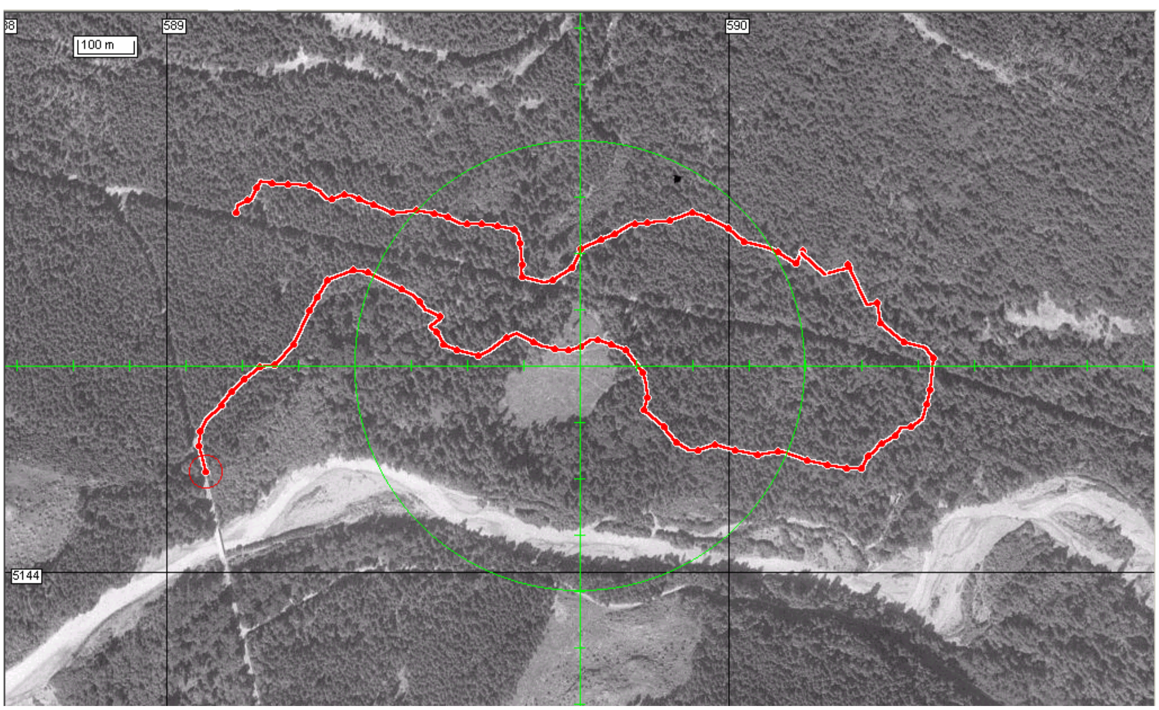


Figure 6-11. Aerial photo of Washington course.

6.3.4 Course Selection Discussion

The Washington experiment was held in conjunction with the Washington State SAR conference. Prior to the site visit, the host indicated no land at the actual conference site or adjacent to the conference site was suitable. The general guidelines for the course were that the land should be relatively flat without steep climbs or descents, be located in the woods, have vegetation representative of the Marine Ecoregion, and have owners that would permit an experiment on their property. The host scouted out several different sites. The only site that met the requirements was located thirty minutes away from the conference site in the Gifford Pinochle National Forest.

The course was located in the flood plain of the Cispus River making the terrain relatively flat. The course started by using an existing foot trail. The course departed from the foot trail where the trail started to hug an old riverbank that limited to the field of view on the left. From the riverbank the course climbed away from the bank to ensure vision both left and right was possible. The course then joined an old logging road. The trail then crossed a creek and started cross-country. Initially, laying out the course involved walking in thick ground cover. However, in the numerous trips it takes to layout a course a small foot trail was eventually created. The course then looped back using a dirt road which connected to another foot trail. The foot trail was followed until it intersected with a paved road. The course then paralleled the paved road in the woods taking advantage of an old logging road that was significantly overgrown with five-year-old pine trees in the road. The course did not complete a complete loop, since enough distance had already been obtained to setup a large number of search objects.

6.3.5 Participant Recruitment

The Washington experiment was held in conjunction with the Washington State SAR conference. The largest conference in North America, it typically attracts over 1000 participants. Recruitment consisted of a listing in the conference brochure, automatic registration on the conference web site, contacts with one local SAR team, and the ability to use some of the conference staff to participate in the experiment. A separate experiment recruitment table was not set up near the conference registration table due to its separate location and a lack of experiment staff. Most of the searchers were actually recruited from the one local SAR team and from the conference staff through local contacts. Better recruitment would have occurred with an active recruitment effort at the conference registration table and more direct contacts with larger SAR teams. Most importantly, recruitment would have benefited by having a course located closer to the conference.

6.3.6 Lessons Learned

- **Keep course close to conference site.** The Washington experiment provided excellent logistic support. The conference host provided communications, transportation, a web based registration site, food, scouting, command staff personal, mention in conference literature, and sent members to participate in the experiment. However, due to the distance between the conference and the actual site the number of participants was not as high as in previous experiments. The major factor was the distance between the conference and the course.

- **Use each search object's AMDR to determine lateral range.** During all the experiments the lateral range was determined by the most visible or longest range AMDR. This worked well when combining a high visibility adult manikin and a medium visibility adult manikin. It did not work well when combining a low visibility adult manikin with a small glove size clue. The off-track distances for all the gloves where determined by the adult size manikin. It became apparent out in the field that if the object placement worksheet was adhered to that almost no gloves would even have a chance of being seen. Therefore, the immediate strategy of dividing the specified distance by three was adopted. This strategy worked well, the locations were still based upon random numbers, but several of the gloves could actually be seen. The cross-over point occurred at a distance of 3.6 meters. This allowed four gloves to be at a distance shorter than the cross-over and seven gloves beyond the cross-over. However, such adjustments should not normally be made in the field, especially by those not familiar with experimental design. The better solution is to redesign the Experimental Design Calculator to be based upon each search objects AMDR when determining the off-track distance.
- **Better measure weather.** During the Washington experiment the weather was quite variable. The conditions varied from periods of hard rain, to limited visibility, to overcast skies with no precipitation. Better equipment to monitor and record environmental information could be useful for determination of correction factors.

6.4 NASAR Conference - National Conference Center, Lansdowne, Virginia

6.4.1 Location

The annual conference of the National Association for Search and Rescue (NASAR) was held at the National Conference Center in Lansdowne, Virginia, in June of 2004. The facility—located approximately forty miles northwest of Washington, D.C. in the north end of the state—owned a large, well timbered, parcel of land to the north of the campus. This wooded area was used to conduct the experiment.

Figure 6-12. General overview of the Lansdowne, Virginia, experiment site.

Figure 6-13. A search object in the Lansdowne, Virginia, experiment site.

6.4.2 Ecoregion Description

In its description of Ecoregions of the United States (http://www.fs.fed.us/institute/ecoregions /ecoreg1_home.html), the U.S. Department of Agriculture, Forest Service, characterizes Lansdowne, Virginia, as a Humid Temperate Domain, Subtropical Division, Southeastern Mixed Forest Province (231).

This province is composed of the Piedmont and the irregular Gulf Coastal Plains, where 50 to 80 percent of the area slopes gently toward the sea. Local relief is 100 to 600 ft (30 to 180 m) on the Gulf Coastal Plains, and 300 to 1,000 ft (90 to 300 m) on the Piedmont. The flat coastal plains have gentle slopes and local relief of less than 100 ft (30 m). Most of the numerous streams in the region are sluggish; marshes, lakes, and swamps are numerous.

The climate is roughly uniform throughout the region. Mild winters and hot, humid summers are the rule; the average annual temperature is 60 to 70F (15 to 21C). The growing season is long (200 to 300 days), but frost occurs nearly every winter. Precipitation, which averages from 40 to 60 in (1,020 to 1,530 mm) annually, is rather evenly distributed throughout the year, but peaks slightly in midsummer or early spring, when it falls mostly during thunderstorms. Precipitation exceeds evaporation, but summer droughts occur. Snow falls rarely and melts almost immediately.

Climax vegetation is provided by medium-tall to tall forests of broadleaf deciduous and needleleaf evergreen trees. At least 50 percent of the stands are made up of loblolly pine, shortleaf pine, and other southern yellow pine species, singly or in combination. Common associates include oak, hickory, sweetgum, blackgum, red maple, and winged elm. The main grasses are bluestem, panicums, and longleaf uniola. Dogwood, viburnum, haw, blueberry, American beautyberry, youpon, and numerous woody vines are common. The West Gulf Coast is bordered along its shores by salt marshes characterized by the marsh grass Spartina.

Fauna vary with the age and stocking of timber stands, percent of deciduous trees, proximity to openings, and presence of bottom-land forest types. Whitetail deer and cottontail rabbits are widespread. When deciduous trees are present on uplands, the fox squirrel is common. Gray squirrels live along intersecting drainages. Raccoon and fox inhabit the whole region and are hunted in many areas. Among mammals frequently encountered in the western part of this province is the nine-banded armadillo.

The eastern wild turkey, bobwhite, and mourning dove are widespread. Of the 20-odd bird species present in mature forest, the most common are the pine warbler, cardinal, summer tanager, Carolina wren, ruby-throated hummingbird, blue jay, hooded warbler, eastern towhee, and tufted titmouse. The red-cockaded woodpecker is an endangered species.

Forest snakes include cottonmouth moccasin, copperhead, rough green snake, rat snake, coachwhip, and speckled kingsnake. Fench and glass lizards are also found, as is the slimy salamander.

6.4.3 Map of Course

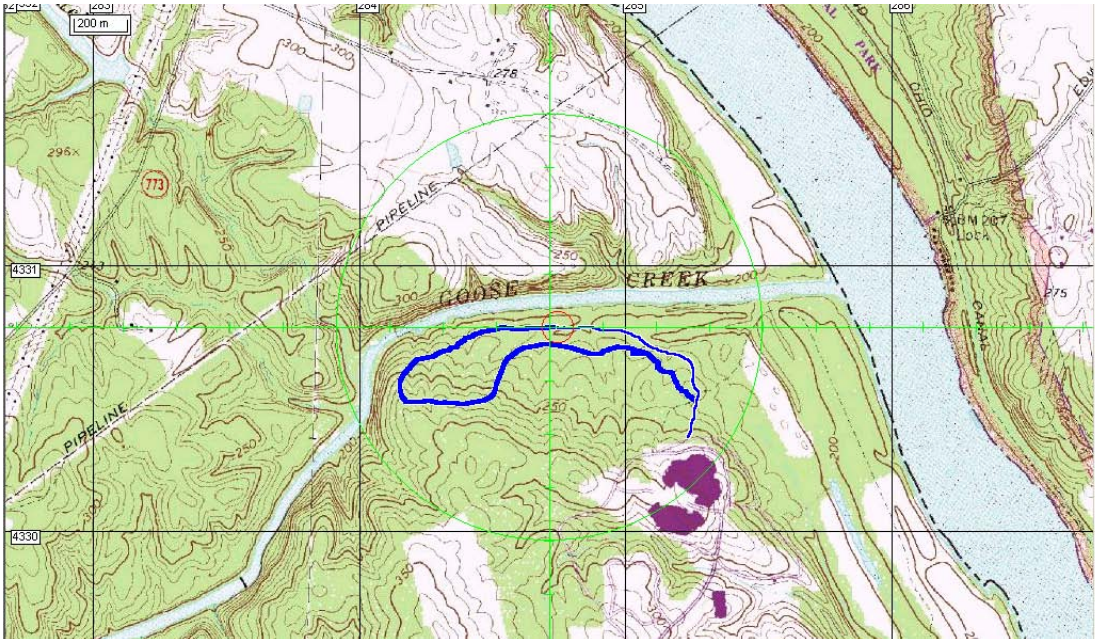


Figure 6-14. Map of Lansdowne, VA, course (course track in blue).

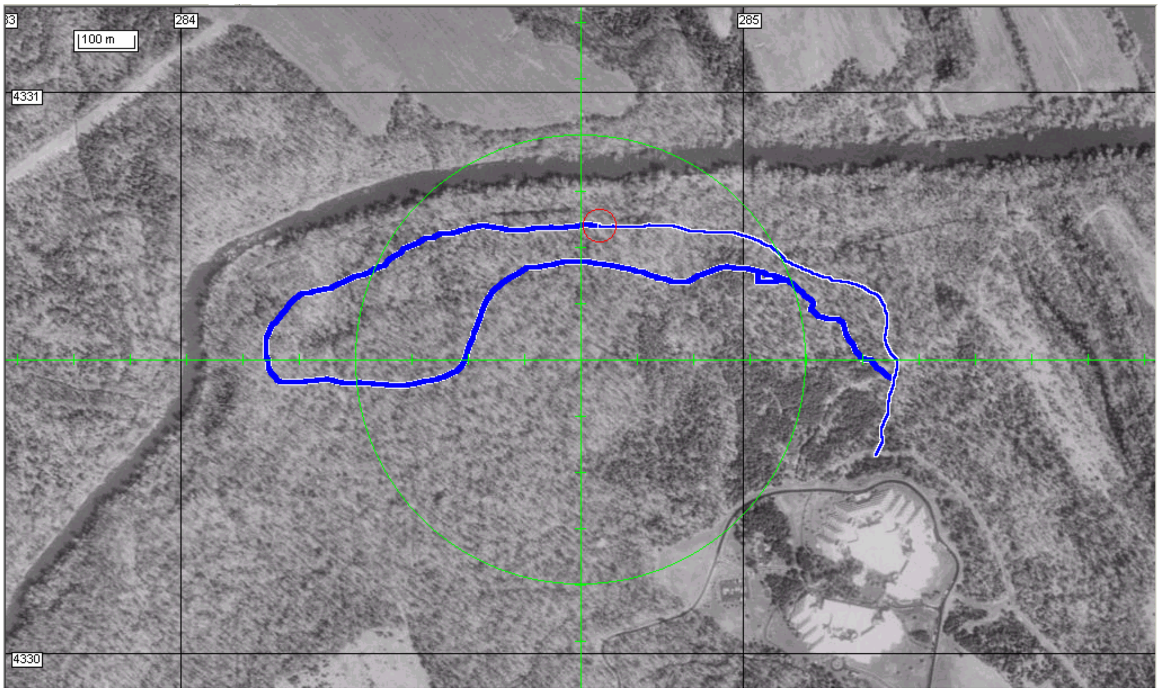


Figure 6-15. Aerial photo of Lansdowne, VA, course.

6.4.4 Course Selection Discussion

The Virginia-summer course was held in conjunction with the NASAR conference held at the National Conference Center in Lansdowne, Virginia. The site used to serve as Xerox's national training center, but recently the surrounding land had been sold to developers. Permission had been secured from the developer to conduct the experiment in woods that had not yet been cleared. In addition, part of the course was conducted on land deeded to the state as a conservation buffer area. While the aerial photograph show an area of largely undisturbed woods, in fact considerable clearing had already taken place.

The area where woods still remained became the only logical place to setup the course. The important question was could a course be setup that allowed an outward and return leg without significant overlap or confusion between the targets. The woods consisted of ground cover, a dense understory of paw paw trees, significant mid-story beech trees, and mature hardwood and softwood trees. The density resulted in small sight lines. Therefore, it was possible to create a course based upon a loop. The legs did come close together near the beginning and end. However, in order to minimize any confusion only green targets were used at the end, while the Orange/White search objects were placed at the beginning and middle of the course.

Once targets were put in place and the experiment conducted, it was noticed it was possible to detect some green targets from the beginning leg and some orange and blue search objects from the return leg. The lateral ranges were determined and the search objects included as additional detection opportunities. Due to the long nature of the course and lack of any substantial landmark in the flat terrain seeing a search object on the outbound leg did not assist in locating the search object on the return leg.

6.4.5 Participant Recruitment

The NASAR experiment was held in conjunction with the NASAR Response Conference. This was a significantly larger conference than the New Mexico conference with about 350 people in attendance. Recruitment was primarily done during conference registration. In addition, the experiment team had extensive personal contacts among conference participants. This also greatly assisted in recruitment. The command and control center located in the Conference building was less visible than at the New Mexico conference. Therefore, efforts at registration and using personal contacts became more critical. Searchers were representative of NASAR's membership. Most belong to ground SAR teams. A small number were active duty military or government representatives. In addition, the NASAR Conference staff assisted with recruitment.

6.4.6 Lessons Learned

- **Recruitment by conference staff critical.** During the NASAR Conference the experiment team did not have a table set up next to the registration booth. Fortunately, recruitment depended upon the excellent efforts of the NASAR staff to direct people to the experiment. Personnel contacts of the experiment team also greatly assisted recruitment. In the future for conference based experiments it is recommended to recruit in advance a core group in order to put together a command and control staff and to staff a recruitment table next to the registration booth at all appropriate times.

- **Recruiting command staff helps.** Several searchers from the earlier Virginia experiment volunteered to assist with the command and control of the NASAR experiment. This freed the experimental team to serve as data loggers. The value of the experiment team serving as data loggers cannot be stressed enough.
- **Importance of lead time.** The original course identified during the scouting phase of the experiment was different than the final course. The land surrounding the conference site had been purchased by developers. Permission had been secured by NASAR to conduct the experiments on the developers land. After the scouting trip and prior to the experiment much of the identified course had been cut down and turned into a mud bowl. Since sufficient time had been set aside for laying out the course a new course could be developed.
- **Discarding search objects.** Some search objects may need to be thrown out of the experiment. During the experiment day a small segment of the course was attacked by the developer's bulldozer. While previous assurances of no further encroachment of the experimental course had been given by the developer, the word apparently did not reach the construction crew. In the end, the bulldozer knocked down all the trees in a section of the course and ran over one of the green adult sized search objects. After one of the data loggers approached the bulldozer operator no further incursions occurred. The course was rerouted through the knocked over area. Several teams walked through the area while the bulldozer was operating in close proximity. All of the searchers reported this as being highly distracting. In fact two searchers were observed to actually walk on top of the search object without noticing. However, since the land had dramatically changed, the bulldozer was an unnatural distraction, and the search object was moved, it was decided to discard all the data related to that object.
- **Creation of virtual search objects.** The placement of one search object fell into a six foot deep drainage canal. It was readily apparent that at the distance it was away from the track it was impossible for anyone to detect. Since this location was randomly chosen it had value, since on real searches such features exist (often searchers are not even aware of the "holes" in the search area). However, during sweep width experiments each search object has a lot of value since relatively few can be placed during a typical experiment. Each object needs to be purchased, carried out into the field, assembled, and eventually carried out of the field. Therefore, it seemed a waste of effort to place it in the ditch. It would also be equally as wrong to place it in an alternative location since that would change the randomness of the experiment. It was decided to create a virtual target. The location chosen at random was still recorded as having a virtual search object. The actual search object was then placed at a shorter off-track distance where it became visible again. The new off-track distance was also recorded. In entering data into the data input spreadsheet, two clues would be entered. The virtual clue at the original off-track distance with no detections and the actual clue with its revised off-track distance with the actual results from the experiment.
- **Need to collect occupation.** During this experiment searchers participated who had never been on an actual search. Several of these participants detected far above the average numbers of search objects when compared to the rest of the participants. The data loggers in conversations noted that while these participants were lacking traditional search experience they had considerable visual experience from activities that required looking for objects, often at visual infinity. Occupation or some other questions that collects information on visual experience needs to be added to the Searcher Profile form.

- **One legged manikin identical.** During the construction of the manikins not enough of the cardboard boxes that make the legs were hauled into the field. Therefore, some manikins were constructed with only one leg. From a short distance away these manikins looked no different than a manikin with two legs. This could prove a useful short-cut if cardboard boxes prove difficult to obtain or carry into the field.

6.5 Mt. Diablo, California – Summer

6.5.1 Location

Mount Diablo State Park in California is found on the eastern fringe of the San Francisco Bay Region, about 50 miles east of Oakland. Mt. Diablo (3849 feet) stands alone on the edge of California's great Central Valley. At this point, the Coast Range consists only of low hills, none high enough to block the view from the upper slopes of the mountain. As a result, the view is spectacular.

The site chosen for the experiment was the Barbecue Terrace, which can be found about four miles southwest of the Mt. Diablo Summit in the south central region of the park.

Figure 6-16. General overview of the California experiment site.

Figure 6-17. A search object in the California experiment site.

6.5.2 Ecoregion Description

In its description of Ecoregions of the United States (http://www.fs.fed.us/institute/ecoregions/ecoreg1_home.html), the U.S. Department of Agriculture, Forest Service, characterizes Mt. Diablo, California, as a Humid Temperate Domain, Mediterranean Division, California Coastal Chaparral Forest and Shrub Province (M261).

Elevations in the park range from 300 to 3849 feet. This wide range of elevations creates broad variations in temperature, rainfall and wind exposure that have resulted in a wide variety of plant life on the mountain. Summers are hot and dry, and only rarely does it snow on the mountain's peak.

Most of the park is typical California oak and grassland country with extensive areas of chaparral. Riparian woodland occurs on the lower slopes of the mountain, where the streams have water in them throughout most of the year. Several isolated stands of knobcone pine occur within the park, and foothill pine is found in many places. The northernmost groves of coulter pine occur on the lower northerly slopes of the mountain, near Nortonville and Somersville just outside the park. Other trees include the coast live oak, broadleaf maple, California laurel (Oregon myrtle), maul oak, blue oak and buckeye. In all, over 400 species of plants have been identified with the park's 20,000 acres.

Wildlife is also abundant. Coastal black-tailed deer, raccoons, California ground squirrels, eastern fox squirrels and gray foxes are often seen, but striped and spotted skunks, bobcats, mountain lions, coyotes, deer mice, cottontail rabbits, black-tailed hares and many other animals call the mountain home.

This province includes the discontinuous coastal plains, low mountains, and interior valleys adjacent to the Pacific Ocean from San Francisco to San Diego. Elevations range from sea level to 2,400 feet (730 m).

The climate is characterized by hot, dry summers and rainy, mild winters. Annual temperatures average 50 to 65F (10 to 18C). Annual precipitation ranges from 10 to 50 in (260 to 1,280 mm), with a pronounced summer drought. This coastal province has a more moderate climate than the interior and receives some moisture from fog in summer. Fire is common, usually set by lightning during the summer dry season.

Plant communities are well marked in this province. Several tree species are endemic to the region, including the Monterey cypress, Torrey pine, Monterey pine, and Bishop pine. The coastal plains and larger valleys have sagebrush and grassland communities. A riparian forest containing many broadleaf species grows along streams. On the hills and lower mountains, there is sclerophyll forest consisting of low trees with small, leathery leaves that can withstand the lack of summer precipitation. Live oak or white oak woodland is found here. On steep hill and mountain slopes too dry to support oak woodland or oak forest, much of the vegetation is scrub or "dwarf forest" known as chaparral, which varies in composition with elevation and exposure. It consists of chamise and various manzanitas that are adapted to periodic occurrence of fire. Exposed coastal areas support desert-like shrub communities called coastal scrub, dominated by coyote bush, California sagebrush, and bush lupine. Toward southern California, sages become abundant within coastal scrub communities.

Most of the coastal plains and interior valleys have been converted to urban use or irrigated agriculture. Citrus, grapes, avocados, nuts (such as almonds and walnuts), and deciduous fruits are grown extensively. Irrigated alluvial soils are also highly productive of vegetable crops. Bluegum eucalyptus and other species imported from Australia are abundant along roadsides and much of the coastline as well as farther inland.

The brushy rabbit is common, as is the opossum, North America's only marsupial. Several species of seals and sea lions live along the California coast, and sea otters often float among kelp, feeding on sea urchins. The blue whale, the world's largest animal species, is found in California's coastal waters.

6.5.3 Map of Course

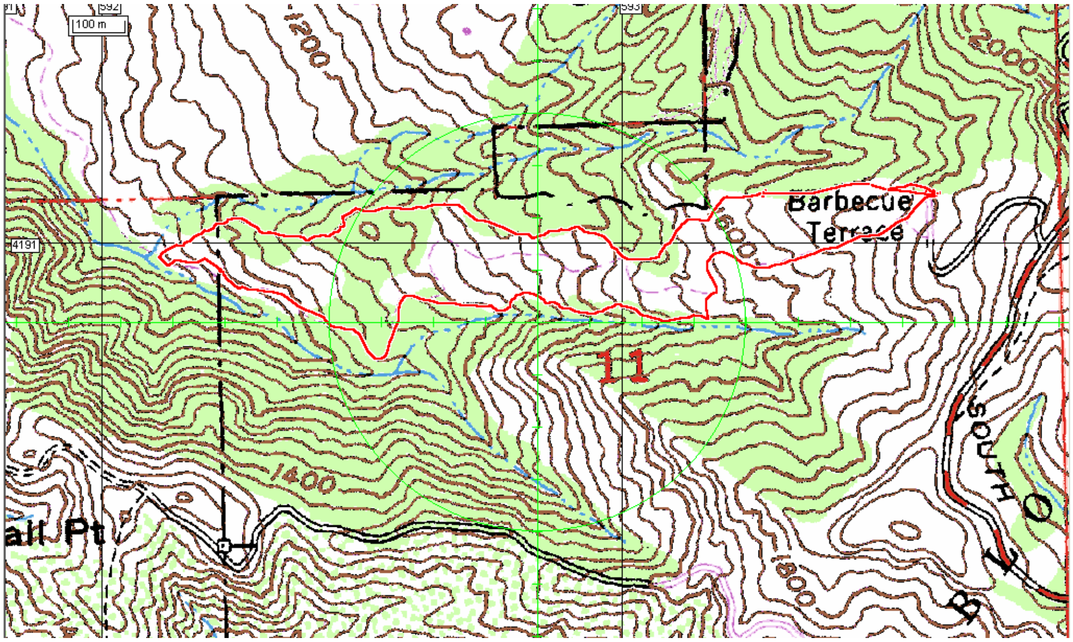


Figure 6-18. Map of California course (course track in red).

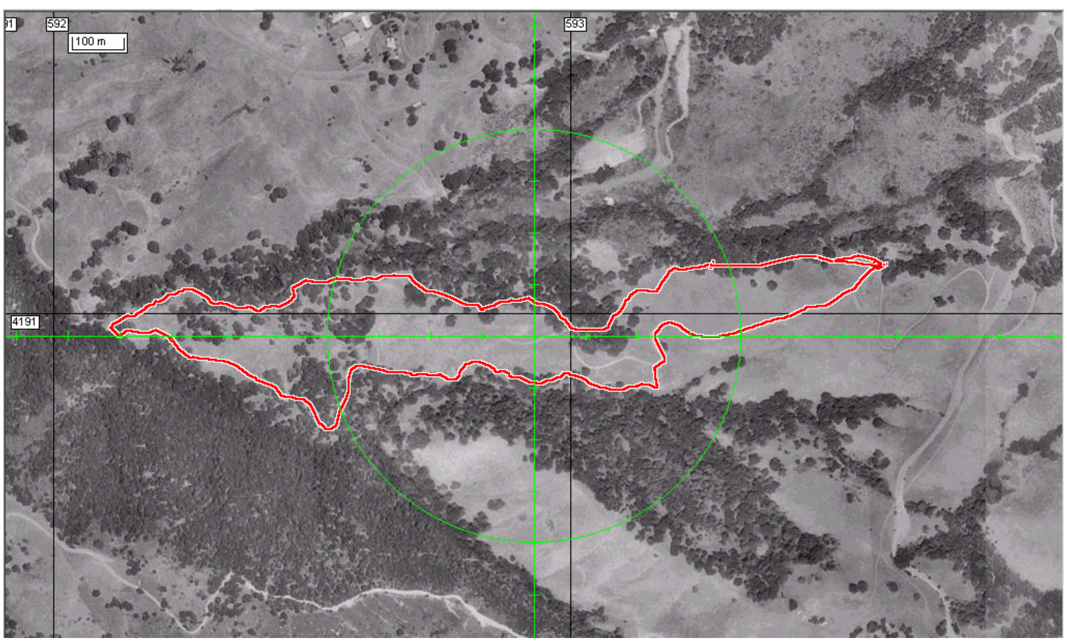


Figure 6-19. Aerial photo of California course.

6.5.4 Course Selection Discussion

The California experiment was a dedicated experiment so a wide variety of options were available for site selection. The primary goals were to select a site located near the Bay Area in order to recruit members from the several SAR teams based in the Bay area, find a site representative of the Mediterranean Ecoregion, located in "wilderness space", and not too rigorous. Mt. Diablo State Park was examined first since it was closest to the central area and found to meet all the overall requirements. Within the park several options were available. Three different types of vegetation areas existed, open grasslands, scrub oak, and chaparral. The area of chaparral was completely avoided due to density, the plants cut into searchers clothes, and leaves a stain, and lost people tend to avoid this type of vegetation. Since the experiment was going to be conducted in June, heat had the potential of being a significant problem. Therefore, it was decided to try to keep the course in the scrub oak as much as possible. The course started at a campground that had toilet facilities, parking, picnic benches, and running water. The outbound course track started downhill, in the scrub oak, going cross-country. It was easy to move cross-country due to shorter grasses found underneath the scrub oak. Since the course was going to be used for both ground searchers and mounted (horse) searchers, some consideration was given to setup the course so that a rider could navigate through trees and brush. This would allow the riders to stay on the course. The outbound leg ended once it intersected with a major dirt road and bounded by a small drainage. The return leg was limited to the dirt road heading uphill, which made the climb easier. After a climb the road started to leave the scrub oaks and head into the open grasslands. Therefore, the course trail started cross-country again to stay in the scrub oaks and out of the sun. Eventually, the area under vegetation became too dense as it began to fall in a steeper drainage. So the course was taken out of the scrub oak, into the grasslands, and rejoined the dirt road. The final ascent was through the open grassland.

Due to the difference between scrub oak and grasslands it was important to not mix the slightly different terrain types when placing the search objects. Therefore, the search object placement was setup so that the Orange/White and Blue search objects would fall in the scrub oak regions and the Green and Clue size objects would be placed in open grasslands. Due to the open space it was possible to see some green search objects on the outbound leg. As before, after the experiment lateral ranges were determined and the objects were scored as two different detection opportunities.

6.5.5 Participant Recruitment

The California experiment was a dedicated experiment held in conjunction with training for several Bay Area SAR teams. Recruitment of searchers was all done by local contacts. The experiment team was not required to make any recruitment efforts and instead could focus on setting up the experiment. It was also decided to send ground searchers through the course on Saturday and then send Mounted (horse) searchers through the identical course on Sunday. This extra effort for recruitment and organization was also completely run by local resources. All the searchers were members of SAR groups belonging to the Bay Area SAR Council. The experiment team simply provided the command and control element of the experiment.

The most successful (largest turnout) of searchers occurred where the experiment team had a large number of contacts. For teams conducting their own experiments in conjunction with other teams this should not be a problem. When conducting experiments in conjunction with SAR conferences when competing with other events for participants, recruitment becomes crucial. Recruitment should consist of making direct contact with several SAR teams prior to the event and securing searchers, listing the experiment in the conference brochure as an all day event but only requiring a small block of time, registration system on the conference web site, separate flyer placed in any material mailed to conference participants, setting up guaranteed searchers/data loggers if not enough volunteer at the conference, having an experiment registration table setup at the conference registration table, and having the course located at the conference site.

6.5.6 Lessons Learned

6.5.6.1 Ground Experiment

- **Use local support.** Since the experiment team was traveling from the eastern part of the country it was not familiar with all local hazards. During the scouting for the California site on Mt. Diablo several hazards were identified. Since the setting up of a course requires considerable time cross-country in laying out targets, locally knowledgeable members of SAR teams were recruited to help guide the experiment team. This allowed for identification of poison oak and rattlesnake dens that otherwise might have been missed by the experiment team. Local resources should be used as much as possible when setting up an experiment.
- **Good logistics critical.** The California experiment was conducted in July and was potentially subject to hot weather. Therefore, finding a site that provided shade and water was critical to its success.
- **Conduct AMDR in multiple sites**. The need to conduct AMDR in multiple sites was reinforced. The California Mediterranean Ecoregion consists of open grass fields, scrub oak, and mesquite. The mesquite was avoided altogether. The course was run through both the open grass areas and the scrub oak. AMDR was collected in both types of vegetation and found to be different. The Experimental Design Calculator was able to make use of the different AMDR readings.

6.5.6.2 Horse Experiment

- **Have horse handler walk trail.** A course laid out for humans may or may not be appropriate for a mounted rider to follow. The California course while steep in sections and challenging for inexperienced riders could still be ridden. If not knowledgeable in the capabilities of riders use an experienced rider to help set up or verify the course.
- **Mark 25 meter flags differently.** The mounted riders found it difficult to read the small surveyor flags that were close to the ground to obtain the along-track distance where a sighting was made. Alternative strategies include writing the distance on a piece of waterproof paper and sticking the flag stake through it so it can easily be read from the horse, or setting up flagging tape with the distances, so they can be read from the horse.
- **Searcher serves as data logger.** During the mounted experiment only ten horses were available. It was decided to have each rider be both searcher and data logger. Two horses on the cross-country aspects of the trail would have also been difficult to manage. A longer more through briefing was required. In addition, a member of the experiment team accompanied the rider to the first search object to make sure they logged the object correctly. A short trial course setup would have also assisted in training the searcher/data logger.

- **Redesign detection log for mounted riders.** The detection log with the full size clipboard proved somewhat awkward for the riders. Suggestions for improvement included smaller clipboards and forms, cords around clipboards, a small 4”x 6” form to simply record the sighting data that could be later transferred to a detection log for scoring. The card would simply contain a table with columns for time, total track length, clock direction, estimated distance, and object seen.

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7. Primary Results

7.1 Course Characteristics

Table 7.1 provides the general characteristics of each of the five courses set up for the experiments. All experiments were conducted on public land except for the Summertime Virginia experiment, which was conducted on private land owned by a developer adjoining the NASAR conference site. Course locations where selected for different Ecoregions. Actual scheduling of experiments was largely based upon existing SAR conferences with the exception of the first Virginia and last California experiment. The March Virginia experiment while conducted March 27 was classified as winter due to the climatic definition of winter and the status of vegetation. The May Washington experiment was classified as summer due to full vegetation on the ground and leaf cover on the understory.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
Ecoregion	Marine	Subtropical	Hot Continental	Mediterranean	Tropical/ Sub-tropical Steppe
Season	Summer	Summer	Winter	Summer	Spring
Month	May	June	March	July	April
Event	WA SAR conference	NASAR conference	Experiment	Experiment	NM SAR conference
Length	3.5 km	2.8 km	3.9 km	3.6 km	2.1 km
Elevation change	100 ft	80 ft	280 ft	920 ft	480 ft
Layout	trail/ cross-country	cross-country/ road	cross-country	cross-country/ road	trail/cross-country/road
Temp	58 F	75 F	55 F	80 F	59 F
Wind	0 mph	2 mph	4 mph	4 mph	2.2 mph
Cloud cover	96%	20%	99%	0%	2%
Visibility	Unl. - 1 mile	Unlimited	Unlimited	Unlimited	Unlimited
Precipitation	None-heavy	None	None-sprinkle	None	None

Table 7-1. General course characteristics.

The detailed descriptions of the courses have already been presented in Section 6. Each course had a different length depending upon several factors. Courses setup during SAR Conferences tended to be shorter due to the need to allow participants to also attend classes. The Washington course, while a conference-based course, was longer due to the large number of participants attending the Washington State SAR Conference (over 1000).

Weather conditions for each of the courses are reported for the period the experiment was conducted.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
N	16	31	32	17	20
Avg. Time	2.0 hr	1.6 hr	2.2 hr	2.2 hr	1.38 hr
Avg. Speed	1.75 km/hr	1.75 km/hr	1.77 km/hr	1.63 km/hr	1.40 km/hr
Avg. Age	24.7	43.6	38.7	28.6	46
Avg SAR years	3.9	11.5	9.9	7.1	7.5
Avg # searches	42.6	76.3	31.2	46.1	31.1

Table 7-2. Participant characteristics.

Table 7-2 provides details on the overall characteristics of the experiment participants. The goal for each experiment was to have 30 teams (searcher and data logger) go through each experiment. This goal was achieved during both Virginia experiments. In the Shenandoah National Park experiment search and rescue personnel were recruited from the Virginia Search and Rescue Council, one SAR team scheduled its annual membership meeting in the park, and personal from Shenandoah National Park participated. The experiment started at sunrise and continued to sunset, with light being the limiting factor. Additional staff from Shenandoah National Park were on standby if the need to fill any empty timeslots had existed. The second Virginia experiment was held during the National Association for Search and Rescue (NASAR) conference. Extensive recruitment occurred during the conference (largely due to the excellent cooperation of NASAR staff) with the experimental course within easy walking distance of the conference site. The NASAR conference had approximately 450 conference attendees.

The number of participants during the New Mexico, California, and Washington experiments did not meet the target goal. The New Mexico SAR conference was a smaller conference with approximately 200 attendees. Recruitment was done during the initial check-in procedure. Throughout the conference enthusiastic participants who went through the course recruited their fellow teammates. The close proximity of the experimental course to the conference site did greatly assist with recruitment. The Washington experiment had excellent staff support. Due to logistical constraints the course was setup thirty-minutes from the conference site. Recruitment was done by inclusion in the Conference program and signage at the conference site. An active presence was not maintained at the conference check-in (over 1000 attendees). The majority of experiment participants were conference staff generously released to conduct the experiment. Rainy environmental conditions did not aid with recruitment. The California experiment was a dual experiment with one day for ground searchers and the second for mounted riders. While a dedicated experiment, recruitment was not as large as expected. Many teams in the Bay Area had sudden unexpected commitments to provide standby services in their coverage areas.

It is remarkable to note the consistency of the average search speed for all five experiments. Only the New Mexico experiment varied from the average speed of 1.75 km/hr (1.0 mph). In the New Mexico experiment, slower search speeds can be attributed to the nature of the course. The course was the shortest course but had the second largest change in elevation. Participants were required to make two steep climbs over loose sandy soil while traveling cross-country at higher altitudes. In addition, they were required to make a steep descent also over loose soil. Half of the descent was cross-country, while the final descent was along a well-graded road. The finding of an average search speed of 1.75 km/hr is significantly higher than the average searcher speed of 0.5 km/hr (0.3 mph) reported in Wartes' (1974). However, it is similar to the values used in a "POD" software calculation tool developed by Cairns & Cooke (1995). The consistency among the experiments is not only for the different types of environments but also for the different types of courses. The ratio of cross-country, road, or trail varied for each course. Although, often by the time the course had been fully set-up and walked by the first searcher, even the cross-country portions had been worn down to a foot-trail.

Experiment participants differed from previously reported detection experiments by having considerably more search experience and age. The Wartes (1974) experiments used high-school aged Explorer Scouts (now called *Venturing*). During all five ESW experiments, the age and experience of the searchers were fairly consistent. The average age was 38 while the average number of prior searches was 47. The Washington and California experiments had slightly younger participants (25, 29) but still considerable average search experience (42, 46 prior searches). One of the major goals from the West Virginia Logan pilot experiment was to recruit more experienced searchers. These experiments achieved that goal.

7.2 Environment Characteristics

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
EcoRegion Code	M242	231	M221	M261	M311
EcoRegion Domain	Humid Temperate	Humid Temperate	Humid Temperate	Humid Temperate	Dry
EcoRegion Division	Marine	Subtropical	Hot Continental	Mediterranean	Tropical/ Subtropical Steppe
Season	Summer	Summer	Winter	Summer	Spring
Terrain	Mountainous	Piedmont	Mountainous	Mountainous	Mountainous
Ground Cover	2 feet	10 inches	none	1-1.5 feet	none
Laser Range	23 m	25 m	38 m	53 m	34 m
Vegetative Density	17 m	15 m	71 m	N/A	22 m
Coordinate E	10T 0589299	18S 0285149	17S 0724717	10S 0593515	13S 0437634
Coordinate N	5144240	4330412	4265792	4190802	3700566
Cloud cover	100%	100%	10%	0	90%
Lux	1,960 lux	260 lux	14,500 lux	50,000 lux	2,500 lux
O/W AMDRe	37	38	84	43	41
O/W AMDRd	31	28	76	39	33
O/W AMDRmax	56	45	103	75	78
O/W AMDRmin	17	20	30	21	17
O/W AMDRavg	34	33	80	41	37
Blue AMDRe	32	30	85	35	38
Blue AMDRd	27	24	78	29	30
Blue AMDRmax	62	40	99	55	61
Blue AMDRmin	16	15	65	12	13
Blue AMDRavg	29	27	82	32	34
Green AMDRe	19	25	-	15	-
Green AMDRd	15	19	-	12	-
Green AMDRmax	24	32	-	20	-
Green AMDRmin	10	10	-	4	-
Green AMDRavg	17	22	-	14	-
Clue AMDRe	-	10	-	11	-
Clue AMDRd	-	8	-	9	-
Clue AMDRmax	-	16	-	16	-
Clue AMDRmin	-	5	-	5	-
Clue AMDRavg	-	9	-	10	-

Table 7-3. Course vegetative characterization.

Table 7-3 characterizes the vegetative conditions found in each environment. Ground cover varied widely in each environment. Virginia – winter is considerably different than Virginia – summer. Even in the dry domain of New Mexico important differences in seasons exist. During the spring conditions a ground cover of small scrub oak was apparent, but had yet to bud the leaves. Each of the Ecoregions had different factors that largely influenced the sweep width value. In the Ecoregions without ground cover (New Mexico, Virginia-Winter) trees and undulations in the land obscured search objects. In the Ecoregions with moderate ground cover (Virginia – Summer) it was a combination of all factors. While in Ecoregions with high ground cover (Washington, California) the ground cover was the most significant factor obscuring the search objects. The Vegetative Ground Density was measured for all the experiments except for the California experiment where the board was completely obscured by the tall grass at every distance. Other methods of measuring ground cover are better suited in this environment and should be used in future experiments. No correlations between the vegetative density and ESW were observed. The Laser Range Finder was an index of the density of vertical obstructions. As a single measurement it failed to show any clear correlation with ESW.

The environmental measurement that takes into consideration the nature of the search object, environment, and searcher is the Average Maximum Detection Range (AMDR). The AMDR was determined both to layout the course and to characterize the search environment. It remained unknown what, if any, correlation between AMDR and ESW may exist. The Detection range showed great variability in some environments. In Virginia – Winter the maximum range for the Orange/white adult search object was 103 meters with a minimum of 30 meters. In New Mexico the maximum was 78 meters with a minimum of 17 meters. In more dense environments the variability was reduced. In Washington the maximum was 56 meters with a minimum of 17 meters and an average of 34 meters. Important differences also exist between using the average distance a search object is first detected ($AMDR_{detection}$) versus the distance you can no longer see a previously detected search object ($AMDR_{extinction}$). During the collection of AMDR data the searcher always had a rough idea of where the search object was located. Still, the difference between $AMDR_d$ and $AMDR_e$ ranged between 4-10 meters or 9-26% of each other. The AMDR value was the average of both the $AMDR_d$ and $AMDR_e$. It was clear from the AMDR data collection process that a single reading from only one direction should not be used to characterize the detection range.

7.3 Sweep Width Results

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
N	16[a]	31	32	17	20[a]
# O/W (#DO)	12 (185)	14 (434)	4 (128)	15 (255)	11 (198)
# Blue (#DO)	12 (183)	13 (403)	12 (384)	18 (306)	10 (182)
# Green (#DO)	11 (165)	14 (434)	-	11 (187)	-
# Clue (#DO)	11 (165)	-	-	12 (204)	-
TOTAL Objects	35	41	16	56	21

[a] Some participants followed an abbreviated course resulting in less detection opportunities (DO)

Table 7-4. Number of search subjects and detection opportunities by course.

Table 7-4 provides summary information on the type, number, and number of detection opportunities for each search object. The orange/white adult manikin (O/W), blue adult manikin (Blue), green adult manikin (Green), and clue sized (white hat or orange glove) search objects have already been described in Part II. The Virginia-Winter course was not measured with the wheel. At the time of determining the number of search objects that could be placed in the course it was thought that sufficient length only existed for one adult search object. The Orange/White adult target was only placed in locations where blue search objects were decided to be left void. The search objects were placed during a steep climb up a ridge and at the end of the course where participants were returning along a road to the course starting point. The sweep width value for the Orange/White search object must be highly suspect and should not be used for actual search purposes until verified by additional experiments. This search object also had the lowest number of detection opportunities at 128.

Object Type	Actual Count	Detection Opportunities
Orange/White Body	56	1200
Blue Body	65	1458
Green Body	36	786
Clue	23	369

Table 7-5. Summary of quantity of detection opportunities by object type.

The Virginia-Summer experiment had the greatest number of detection opportunities. This resulted from both 31 participating teams and a large number of search objects. In several cases due to the layout of the course search objects could be detected while traveling West to East and during the return leg East to West. Objects were easy to distinguish (for scoring purposes) due to

Orange/white targets being placed during the East to West leg and Green search objects placed on the West to East leg where the double detection opportunity took place. An identical situation existed during the California experiment, where search objects could be detected from either direction. In the California experiment the recorded ranges and angles of detection become important in correctly scoring detections.

Most of the experiments had detection opportunities approaching or slightly exceeding 200 detection opportunities (DO). This was the case for the Washington, New Mexico, and California experiment. The importance of the number of detection opportunities is further explored in the next table.

n	Orange/White Object	Blue Object	Green Object
	ESW (DO)	ESW (DO)	ESW (DO)
1	68 (14)	70 (13)	34 (14)
5	68 (70)	55 (65)	32 (70)
7	73 (98)	56 (91)	31 (98)
10	76 (140)	55 (130)	31 (140)
15	74 (210)	53 (195)	31 (210)
20	72 (280)	53 (260)	31 (280)
30	74 (420)	54 (390)	31 (420)
31	73 (434)	54 (403)	31 (434)

Note. "DO" is detection opportunities.

Table 7-6. Stability of data using cross-over technique (from Lansdowne, Virginia).

Table 7-6 examines the relationship between the number of participants, detection opportunities, and the effective sweep width determined using the crossover technique. With the crossover technique it is possible to calculate the effective sweep width after only one team has completed the course. As additional teams complete the course changes in the number of detection opportunities and the ESW can easily be monitored. The initial ESW after the first team completed the course (13-14 detection opportunities) is a close approximation of the final stated ESW (403-434 detection opportunities). The values were within 10% except for the blue search object. After approximately 100 detection opportunities (7 teams) the ESW values were within 1 meter for all the search objects. At approximately 200 and 300 detection opportunities the ESW values remained stable, falling within 1 meter of the final value. Similar stability calculations were done with the California data and similar stability was seen at 100 detection opportunities.

n	Orange/White Object	Blue Object	Green Object	Clue
	ESW (DO)	ESW (DO)	ESW (DO)	ESW (DO)
1	70 (15)	82 (18)	24 (11)	19 (12)
5	67 (75)	61 (90)	18 (55)	20 (60)
7	70 (105)	57 (126)	15 (77)	20 (84)
10	77 (150)	62 (180)	18 (110)	20 (120)
15	80 (225)	60 (270)	17 (165)	20 (180)
17	82 (255)	61 (306)	16 (187)	20 (204)

Note. "DO" is detection opportunities.

Table 7-7. Stability of data using cross-over technique (from California).

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
EcoRegion Code	M241	231	M221	M261	M311
Season	Summer	Summer	Winter	Summer	Spring
ESW O/W	36 m	73 m	142 m	82 m	62 m
ESW Blue	32 m	54 m	106 m	61 m	67 m
ESW Green	17 m	31 m	-	16 m	-
ESW Clue	8 m	-	-	20 m	-

Table 7-8. Summary of effective sweep widths (all experiments).

Table 7-8 provides a summary of the sweep width values determined using the crossover technique for the different search objects from each of the five experiments. It is clear that the land environment has an important influence on sweep width. The sweep width value for the high visibility orange/white adult target was nearly four (4) times greater for winter time subtropical hardwood Virginia forest (142 m) than for the dense high ground cover coniferous Marine Washington forest (36 m). It was expected that each unique Ecoregion would have a different sweep – width value. Since 36 different Ecoregion provinces exist within the continental United States and 52 exist worldwide additional experiments at the local level are clearly required. Indeed, the need for additional experiments should be clear. Comparisons can readily be made since search objects were identical and the experience levels of searchers were comparable.

In addition to making comparisons between different search objects in different Ecoregions, conducting the experiment and calculating sweep width values also allows for comparison between different search resources. During the California experiment, ground searchers completed the course on one day, and the same course completed by mounted teams (horse and rider) the second day. While the course had significant elevation changes, loose soil, steep climbs and descents, and went through trees the Mounted teams were able to complete the course. Experience riders reported the terrain was typical for areas they are used to searching in, while more inexperienced riders reported the terrain as being challenging. In both cases, riders needed to dismount for brief periods to complete portions of the course. Table 7-9 shows the results. Due to the largely cross-country nature of the course the mounted teams needed to spent considerable effort controlling the horses. The last half of the course was largely on a dirt road making a gradual climb. All of the green adult-sized targets were placed on the last half of the course.

	Ground Searchers	Mounted
ESW O/W	82 m	57 m
ESW Blue	61 m	33 m
ESW Green	16 m	22 m
ESW Clue	20 m	20 m
Speed	1.75 km/hr	2.1 km/hr

Table 7-9. Summary of effective sweep widths (Ground teams vs. Mounted teams) in CA experiment.

Ground searchers had larger sweep width values for the Orange/white (82 vs. 57) and blue search objects (61 vs. 33). This difference may be hypothesized due to the added distraction of managing the horse in difficult terrain. The horses also moved at a slightly higher speed, the effects of speed on sweep width are unknown at this point in time. The mounted teams had a higher sweep-width value for the green search objects than the ground searchers (22 vs. 16). The higher vantage point offered to mounted teams coupled to the easier terrain of walking on a dirt road, may potentially explain this. For the clue-sized white hat both resources had an identical sweep width.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
Ecoregion Division	Marine	Subtropical	Hot Continental	Mediterranean	Tropical/ Subtropical Steppe
Season	Summer	Summer	Winter	Summer	Spring
ESW O/W	100% (36m)	100% (73m)	100% (142m)	100% (82m)	93%
ESW Blue	89%	74%	75%	74%	100% (67m)
ESW Green	47%	42%	-	20%	-
ESW Clue	22%	-	-	24%	-

Table 7-10. The relationship between different search object types (all ground search experiments).

Table 7-10 summarizes the relationship, expressed as a percentage of the largest ESW found in that experiment, between different search object types for each of the ground searcher experiments. In all experiments, except for New Mexico, the Orange/White hi-visibility adult manikin had the greatest sweep-width. It is difficult to clearly explain the results from the New Mexico experiment. The AMDR values were greater for the Orange/White (37) search object than the blue one (34)(Table 7-11). Three participants out of the seventeen were colorblind. If their scores are removed, the sweep width for the Orange/White target increases from 62m to 64m, which is still less than the ESW of 67m for the Blue search object. Some searchers did comment they felt it was easier to detect the Blue search object. This may be attributed to either the rust – brown background providing less contrast with the Orange/White object or the white colored patches of natural sunlight through the coniferous forest. Clearly this is an important topic for future experiments to address. The remaining four experiments demonstrated a strong relationship between the Orange/white, Blue, Green, and high visibility clue sized search objects. The Orange/White adult sized manikin had the greatest ESW. Another term for this search object is the high-visibility search object. The Blue or medium-visibility search object had a sweep width approximately 75% of the Orange/White's. The Green or low-visibility adult sized search object had a sweep width approximately 47%-20% of the Orange/White target. Clearly, more experiments need to be conducted to determine the relationship. The relationship was closer between the Washington and Virginia-Summer experiment (47% and 42%) than the California experiment (20%). The high-visibility clue sized search object (white hat or orange glove) had a sweep width of 22-24% of the Orange/White target. With only two experiments it is premature to state a stable correlation exists. The hat had a "radar" cross-section of 0.04 sq meters compared to the 0.5 sq meter "radar" cross section of the adult size targets. This less than 20% but a linear relationship is not expected to exist between sizes and sweep width.

If all these relationships (Blue = 75%, Green=45%, Hi-visibility Clue=20%) continue to hold up among different environments in different conditions (light, precipitation, etc.), then this might greatly simplify future experiments. Instead of needing to conduct an experiment that places high-visibility, medium-visibility, and low-visibility search objects in the field, it might be possible to only place high-visibility search objects of the appropriate size and then apply correction factors to determine the ESW. At this time more Ecoregions need to be tested to confirm whether these relationships hold true.

ESW (AMDR)	VA	NM	WA	VA	CA
Location	Shenandoah NP	Lincoln National Forest	Gifford National Forest	Lansdowne	Mt. Diablo State Park
Ecoregion code	M221	M311	M242	231	M261
Season	Winter	Spring	Summer	Summer	Summer
White/Orange	142 (80)	62 (37)	36 (34)	73 (33)	82 (41)
Blue	106 (82)	67 (34)	32 (29)	54 (27)	61 (32)
Green	-	-	17 (17)	31 (22)	16 (14)
Clue	-	-	8 (-)[b]	- (9)[a]	20 (10)

Note. AMDR values are in parentheses. All values are in meters.
[a] Clues were not used in Lansdowne although an AMDR was determined for them (glove).
[b] Clues were used in Washington but an AMDR was not determined for them (glove).

Table 7-11. Relationship between $AMDR_{avg}$ and ESW.

One of the goals of the experiment was to look at simple field measurements that might predict ESW values. The method used to determine the Average Maximum Detection Range (AMDR) has already been described (Fig. 3.3). The relationship between ESW and AMDR cannot be determined at this time; however, the experiments did indicate that certain trends may be developing (Table 7-11). These possible relationships are further explained in Section 11.

7.4 Lateral Range Curves

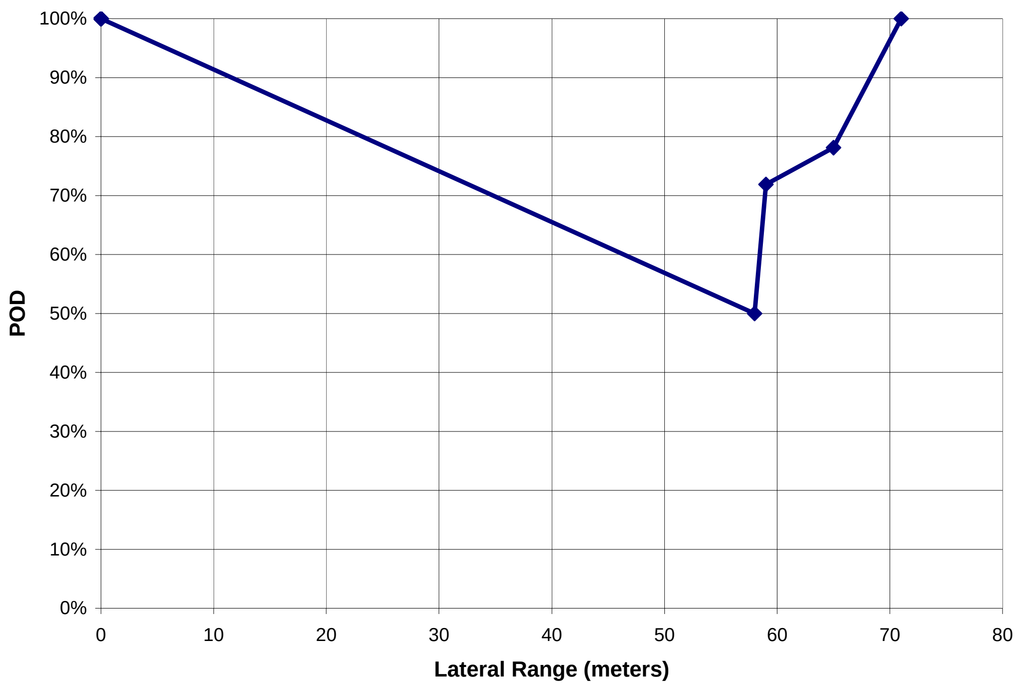

Figure 7-1. Shenandoah NP (VA) half lateral range curve for white/orange human-sized target.

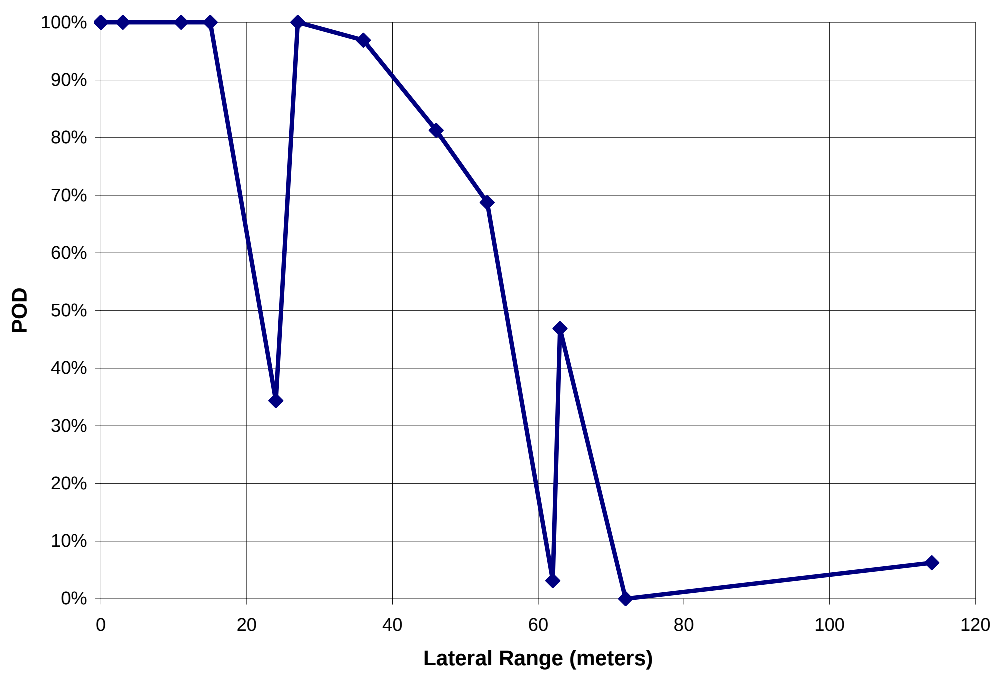

Figure 7-2. Shenandoah NP (VA) half lateral range curve for blue human-sized target.

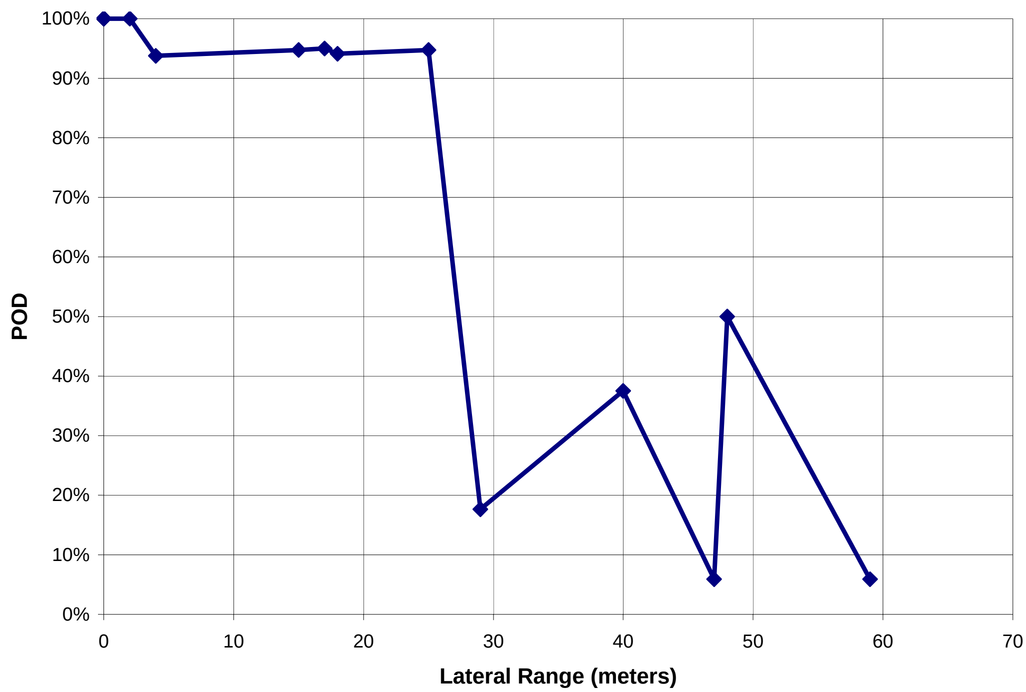

Figure 7-3. Lincoln NF (NM) half lateral range curve for white/orange human-sized target.

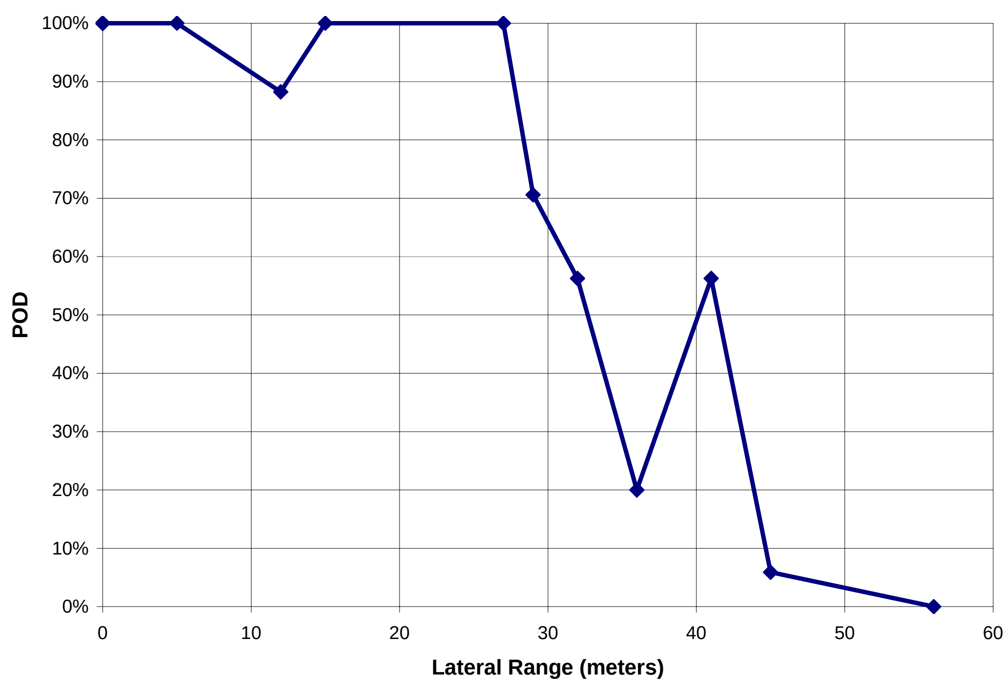

Figure 7-4. Lincoln NF (NM) half lateral range curve for blue human-sized target.

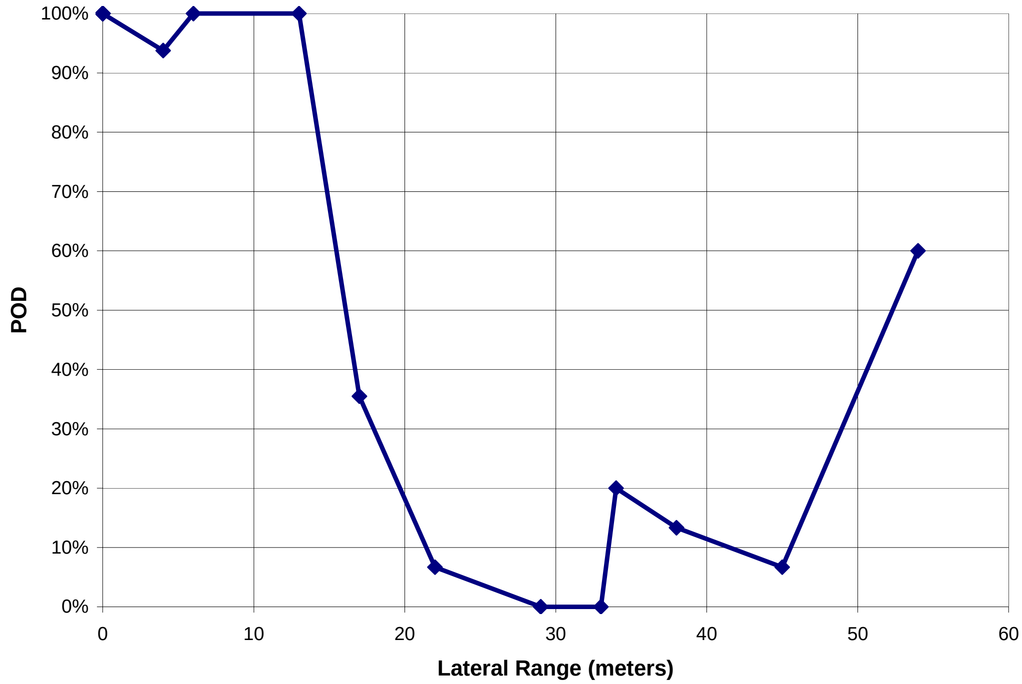

Figure 7-5. Gifford NF (WA) half lateral range curve for orange/white human-sized target.

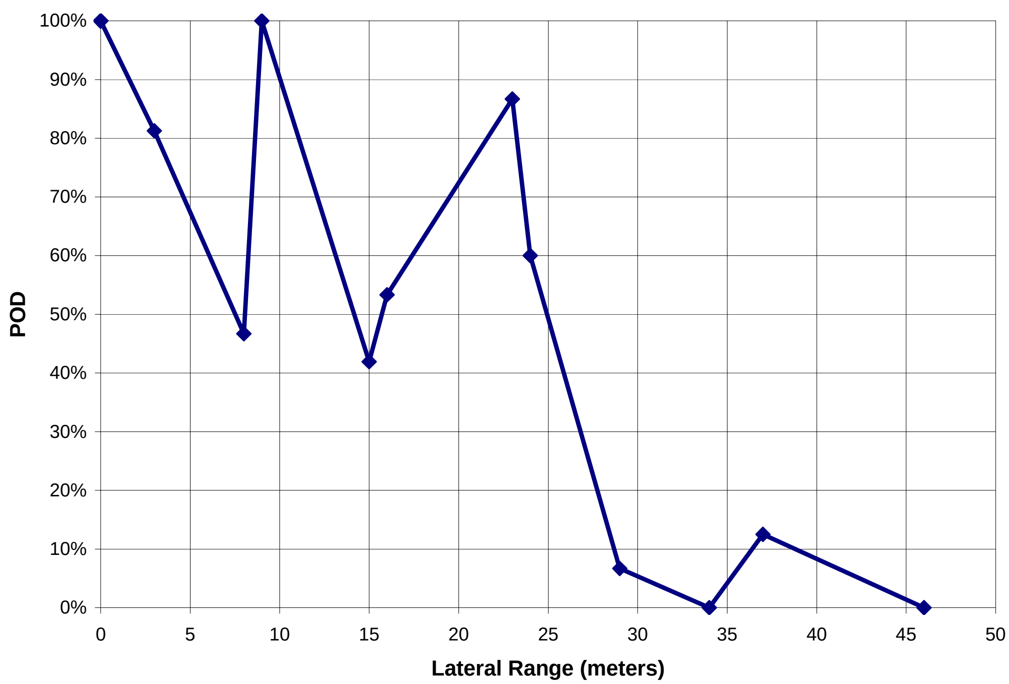

Figure 7-6. Gifford NF (WA) half lateral range curve for blue human-sized target.

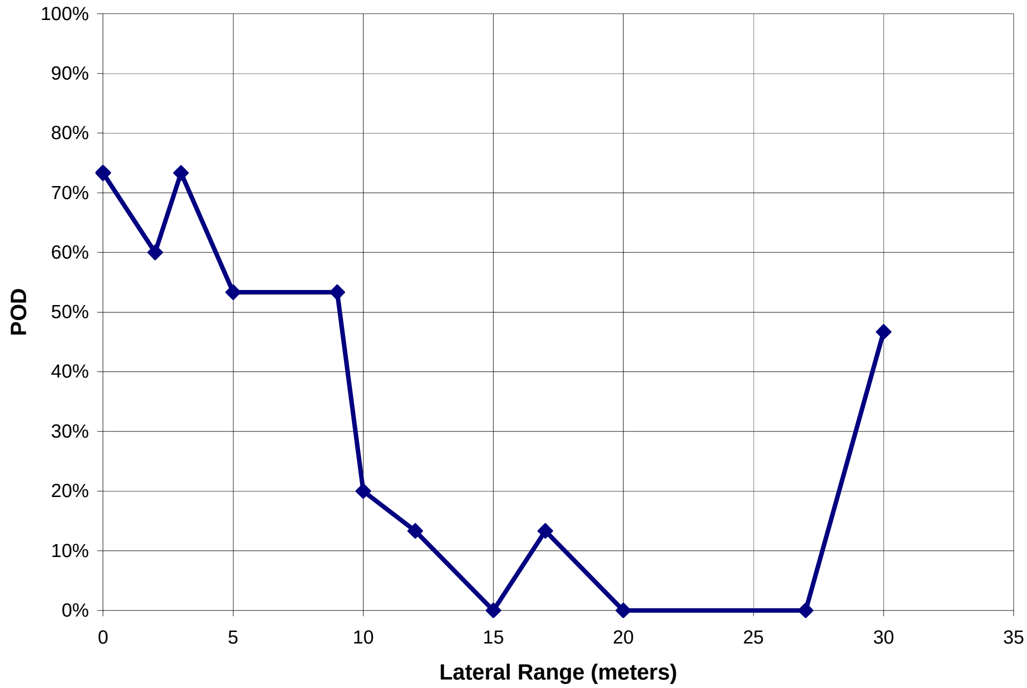

Figure 7-7. Gifford NF (WA) half lateral range curve for green human-sized target.

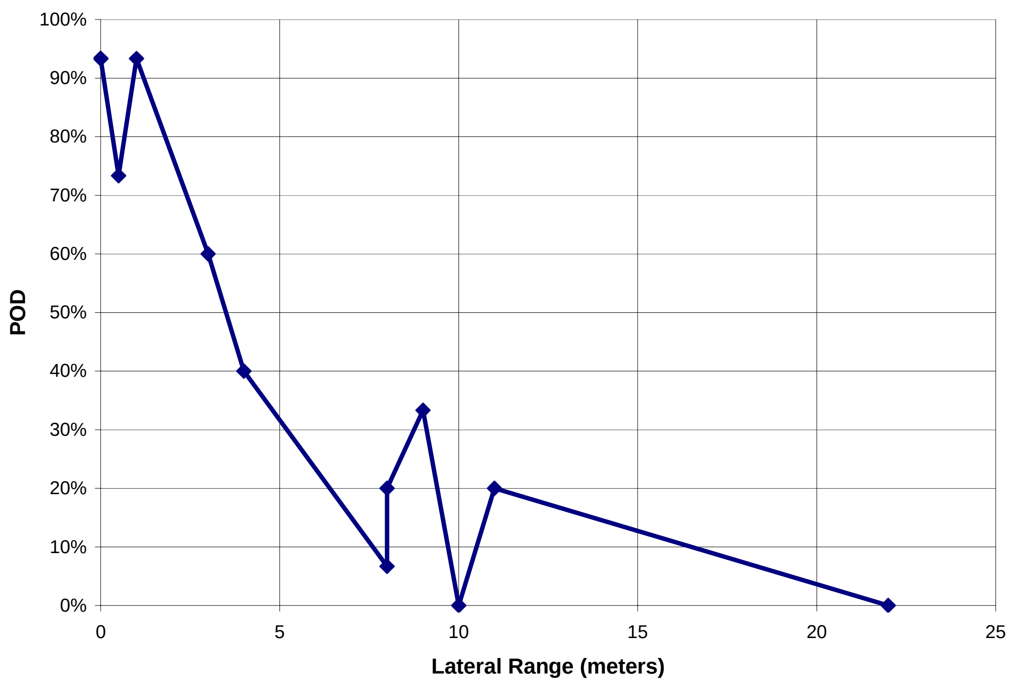

Figure 7-8. Gifford NF (WA) half lateral range curve for clue (glove).

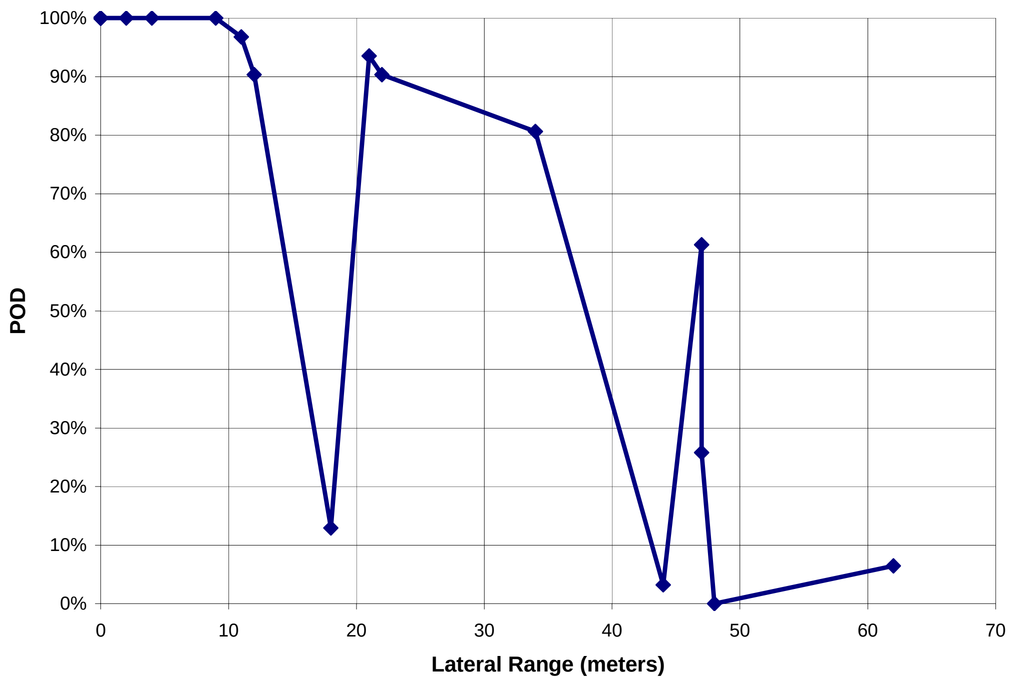

Figure 7-9. Lansdowne, Virginia, half lateral range curve for white/orange human-sized target.

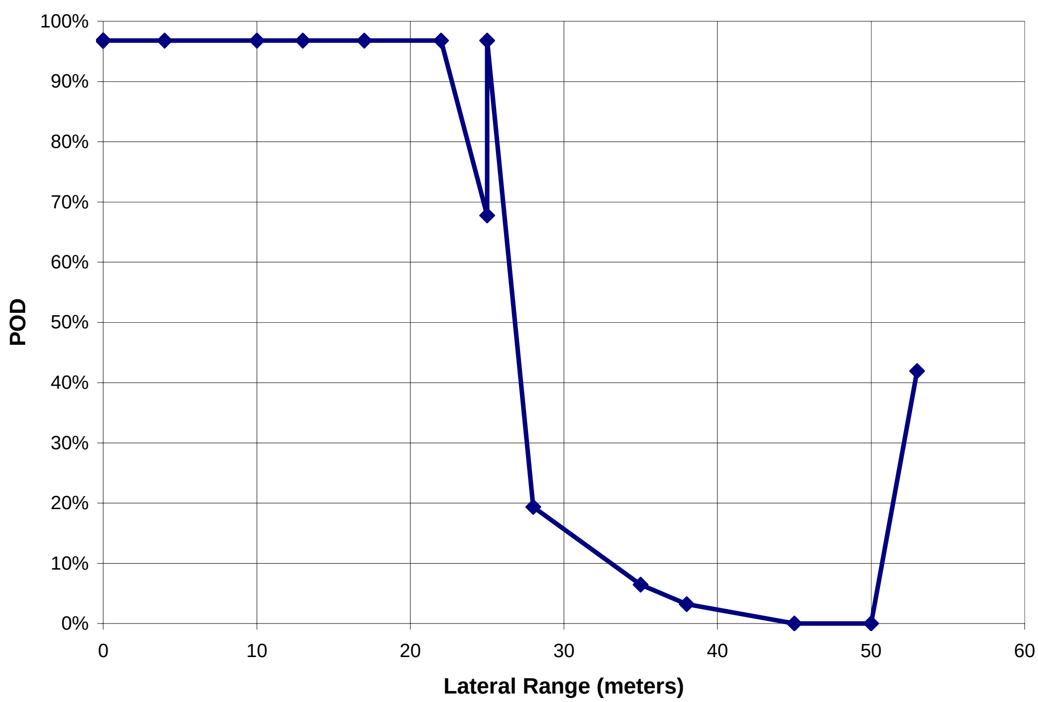

Figure 7-10. Lansdowne, Virginia, half lateral range curve for blue human-sized target.

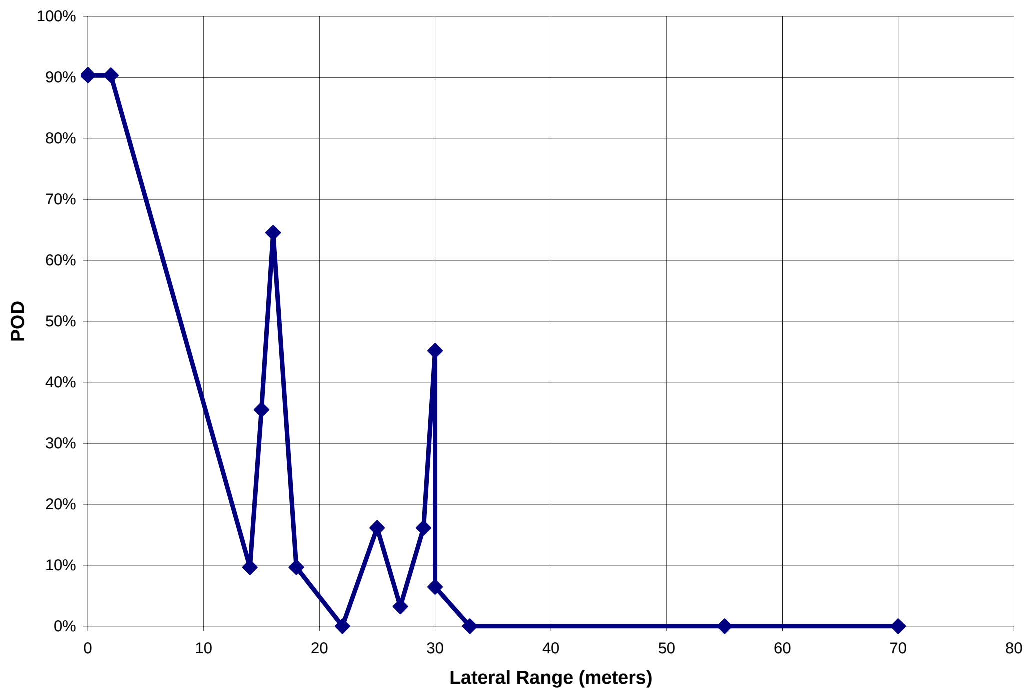

Figure 7-11. Lansdowne, Virginia, half lateral range curve for green human-sized target.

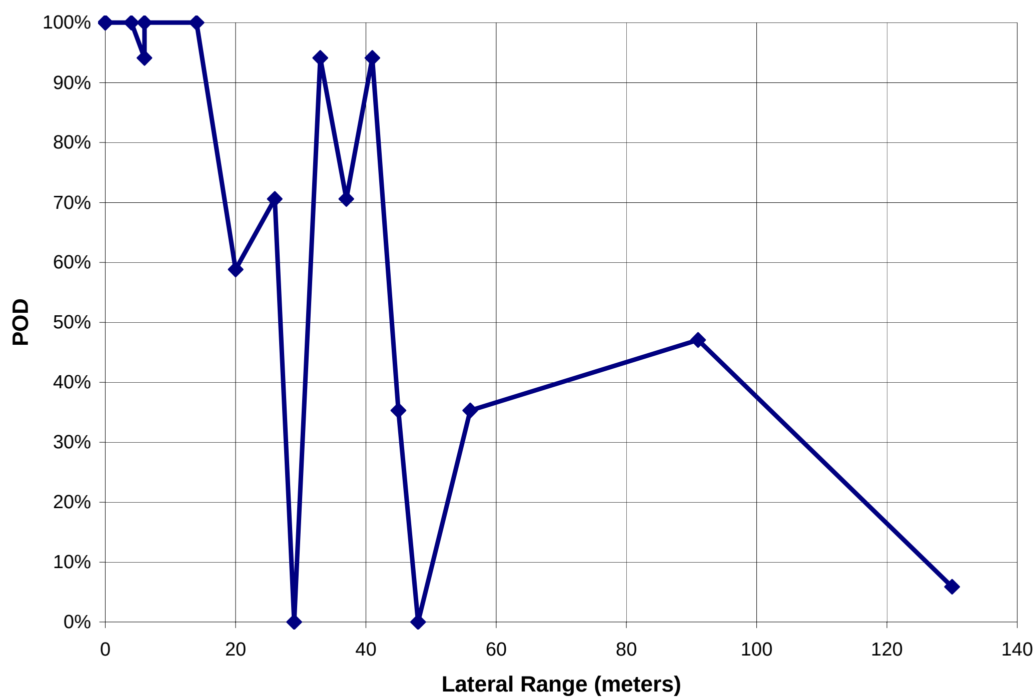

Figure 7-12. Mt. Diablo SP (CA) half lateral range curve for white/orange human-sized target.

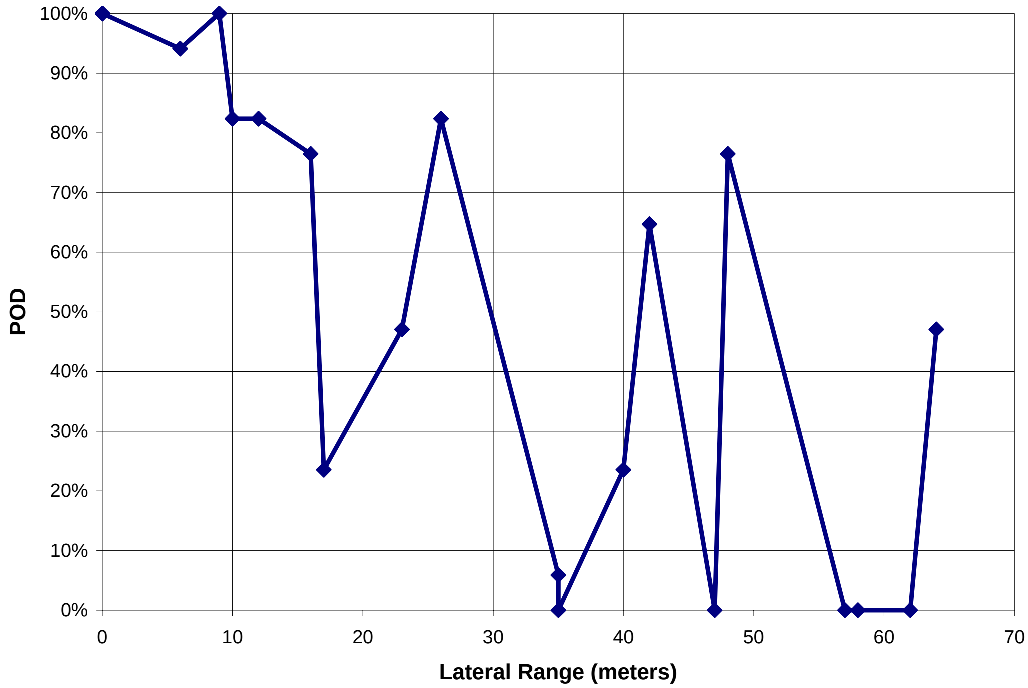

Figure 7-13. Mt. Diablo SP (CA) half lateral range curve for blue human-sized target.

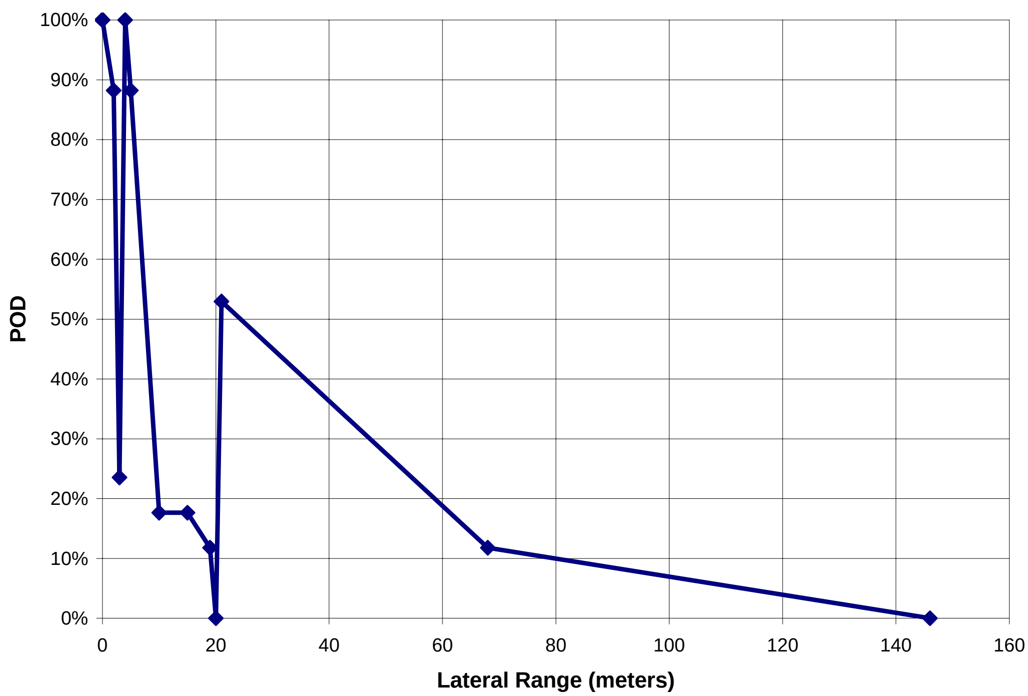

Figure 7-14. Mt. Diablo SP (CA) half lateral range curve for green human-sized target.

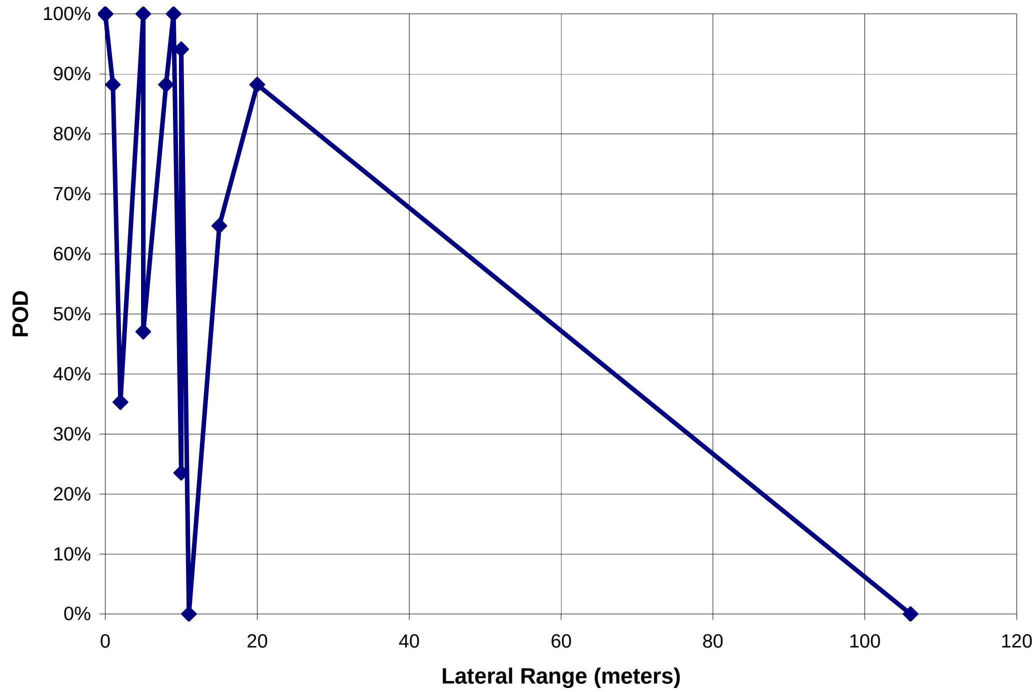

Figure 7-15. Mt. Diablo SP (CA) half lateral range curve for clue (hat).

7.5 Crossover Graphs

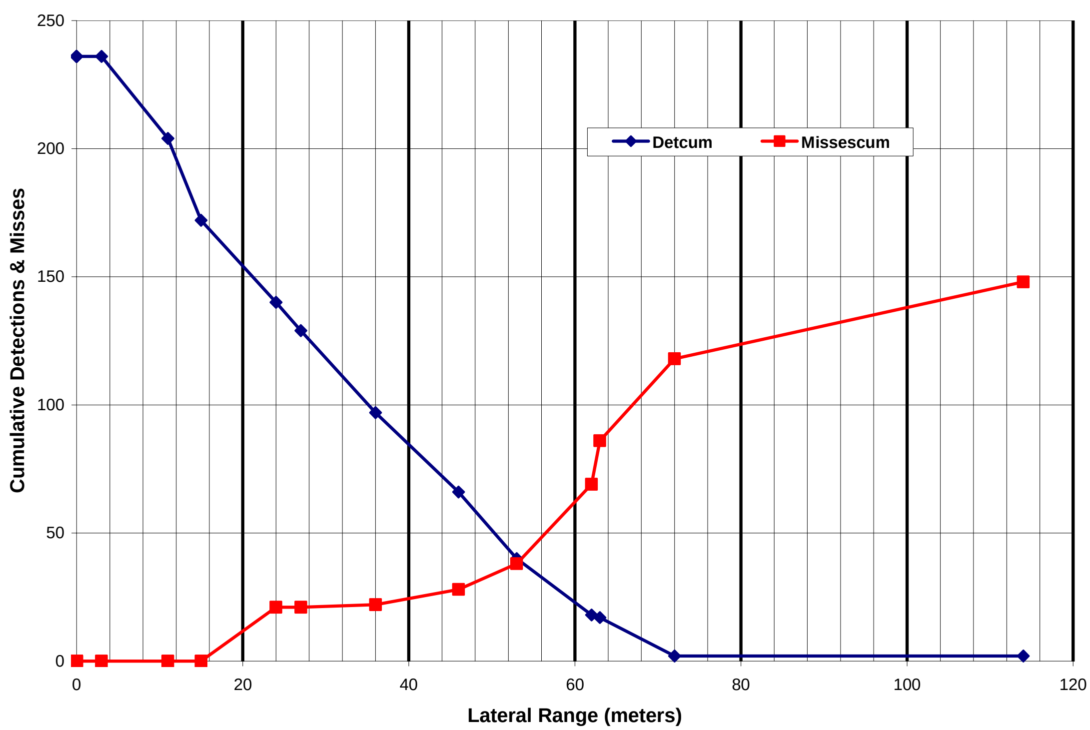

Figure 7-16. Shenandoah NP (VA) crossover graph for blue human-sized targets.

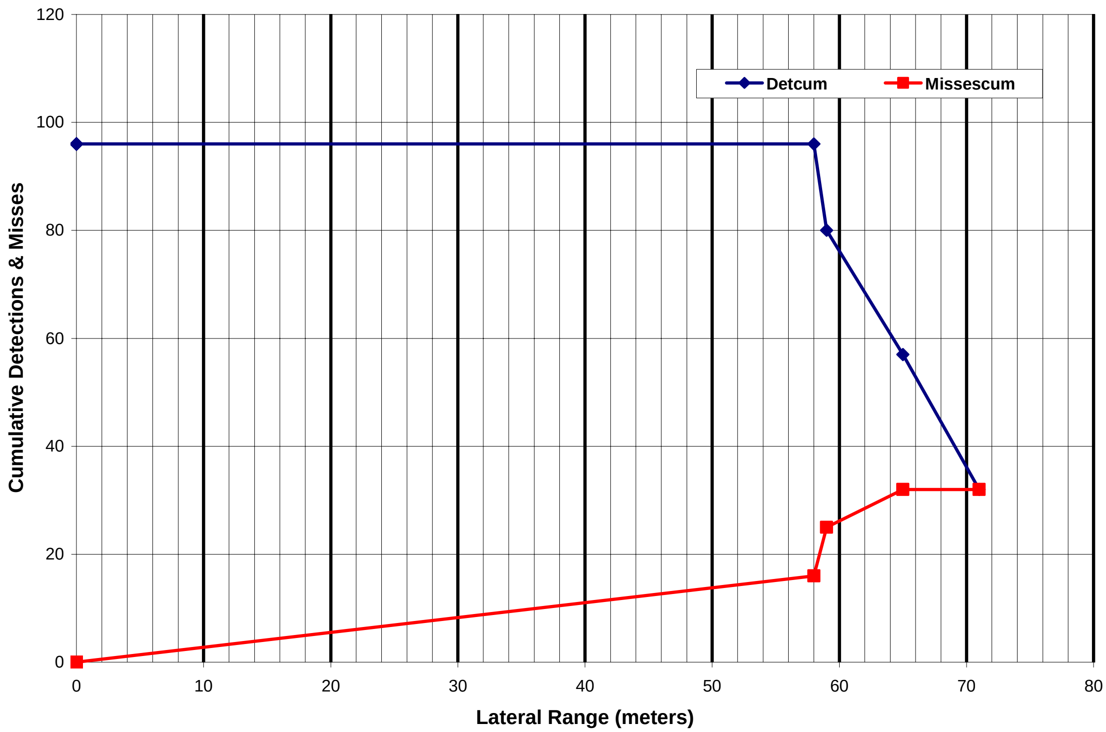

Figure 7-17. Shenandoah NP (VA) crossover graph for white/orange human-sized targets.

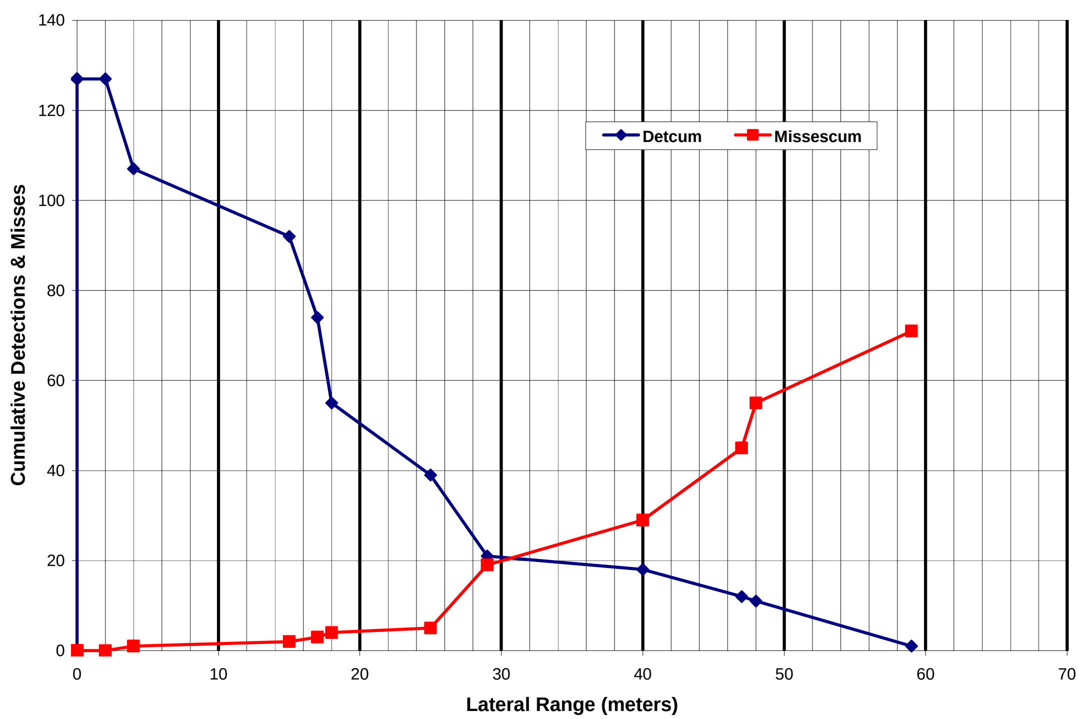

Figure 7-18. Lincoln NF (NM) crossover graph for white/orange human-sized targets.

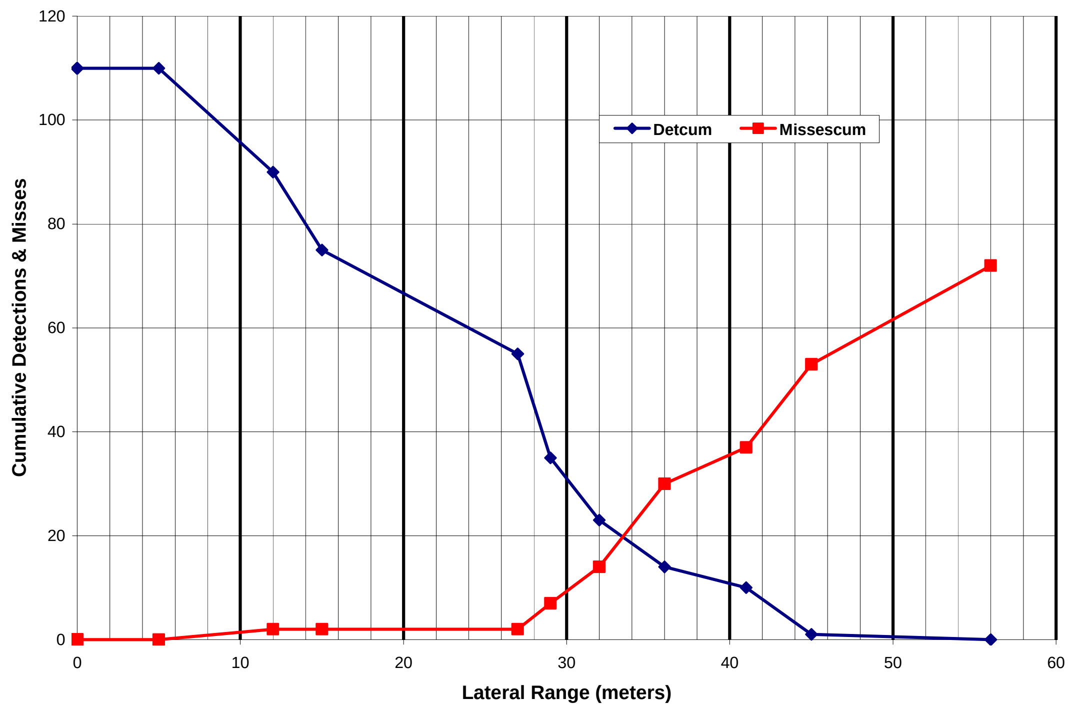

Figure 7-19. Lincoln NF (NM) crossover graph for blue human-sized targets.

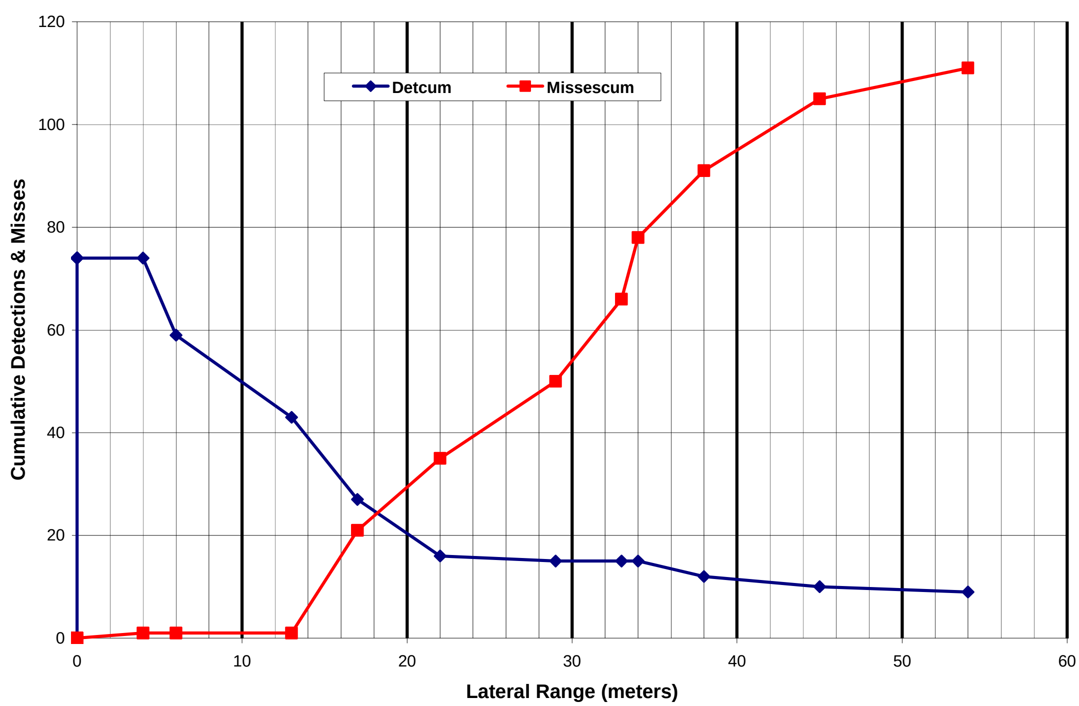

Figure 7-20. Gifford NF (WA) crossover graph for white/orange human-sized targets.

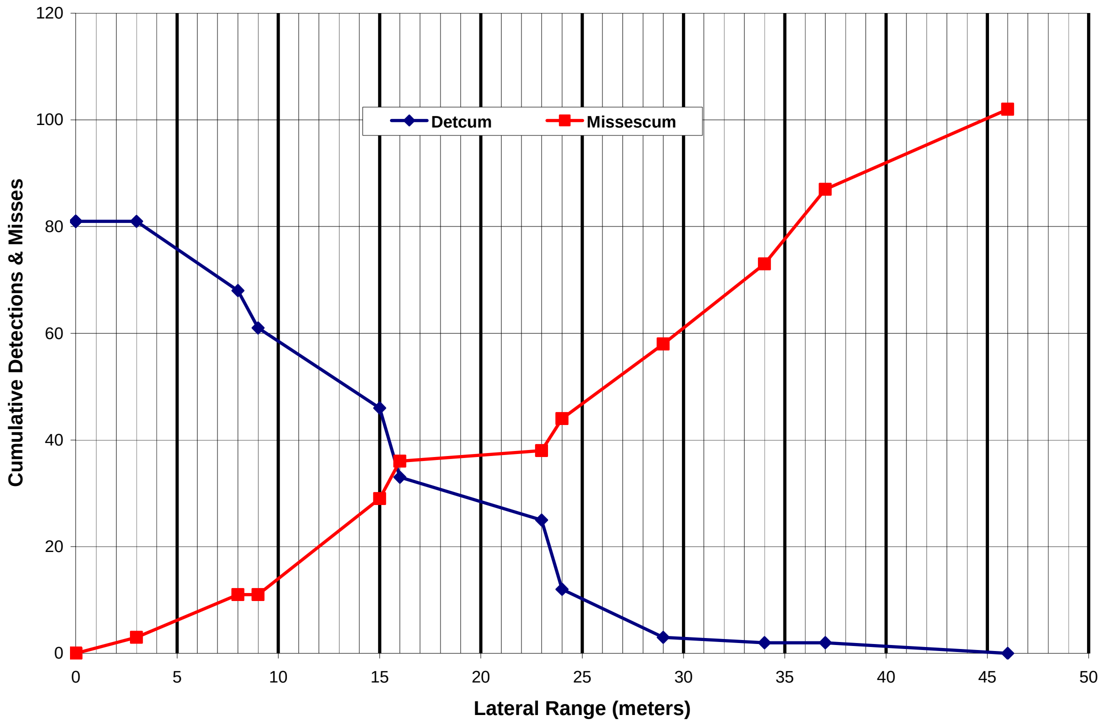

Figure 7-21. Gifford NF (WA) crossover graph for blue human-sized targets.

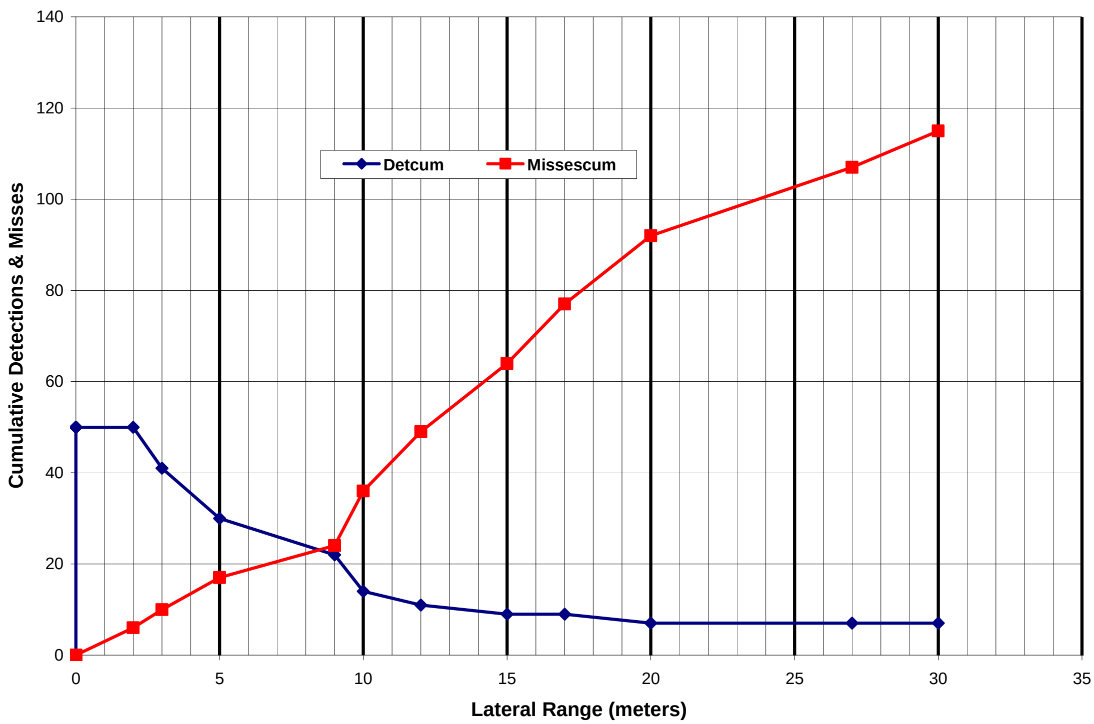

Figure 7-22. Gifford NF (WA) crossover graph for green human-sized targets.

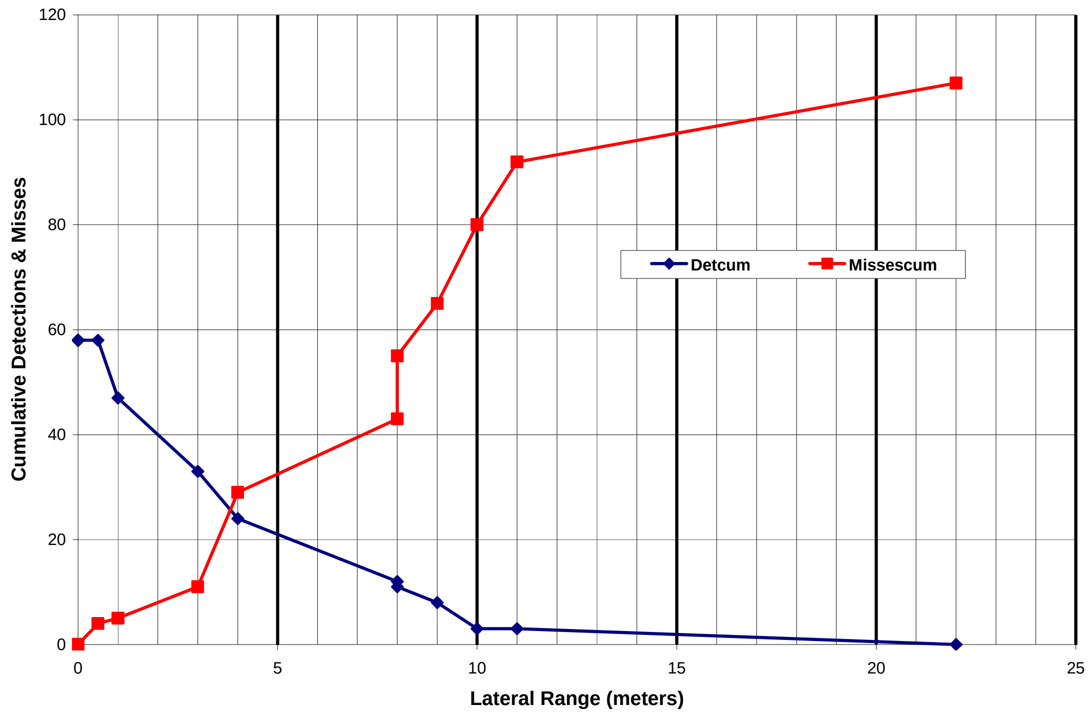

Figure 7-23. Gifford NF (WA) crossover graph for clue (orange glove).

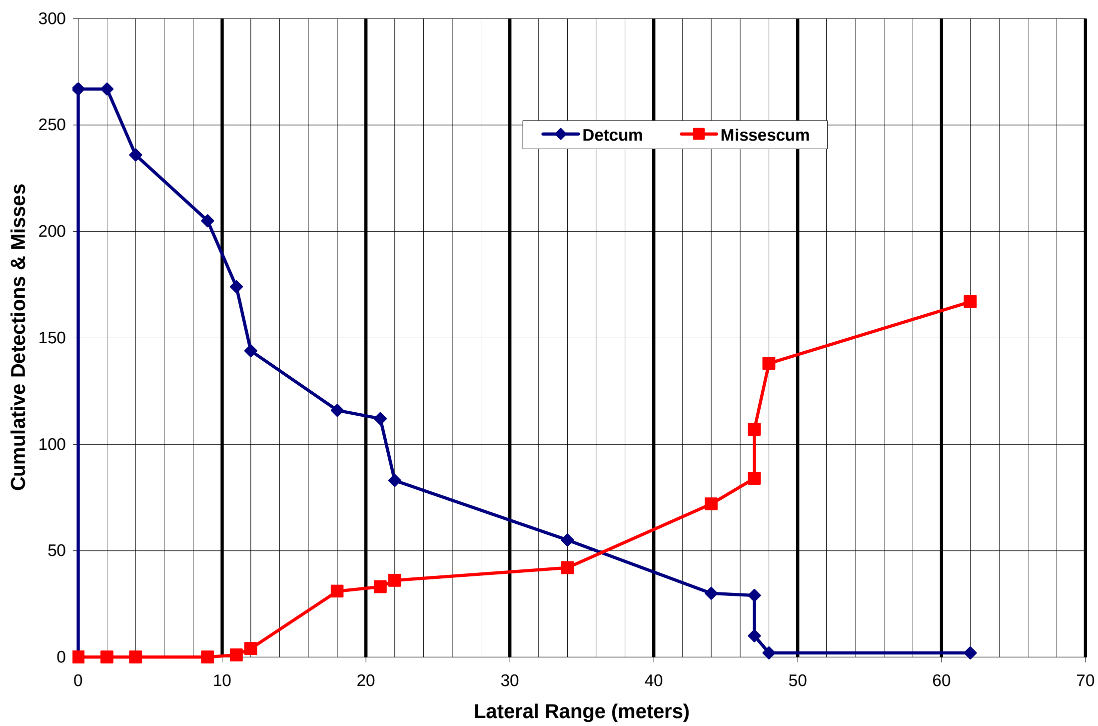

Figure 7-24. Lansdowne, Virginia, crossover graph for white/orange human-sized targets.

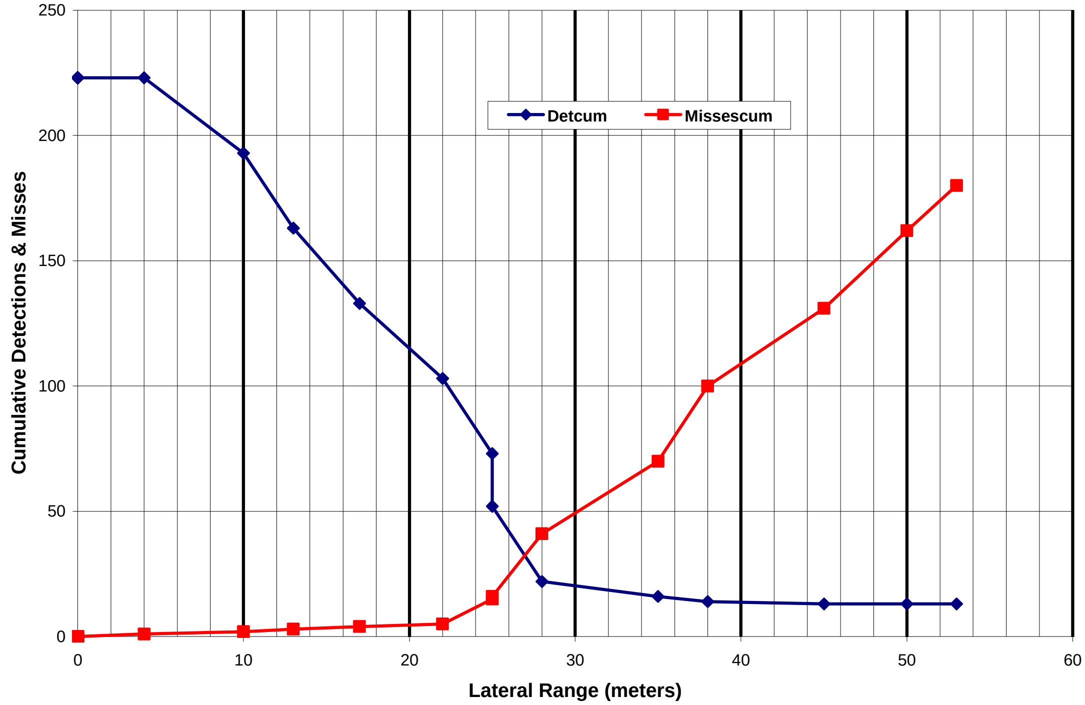

Figure 7-25. Lansdowne, Virginia, crossover graph for blue human-sized targets.

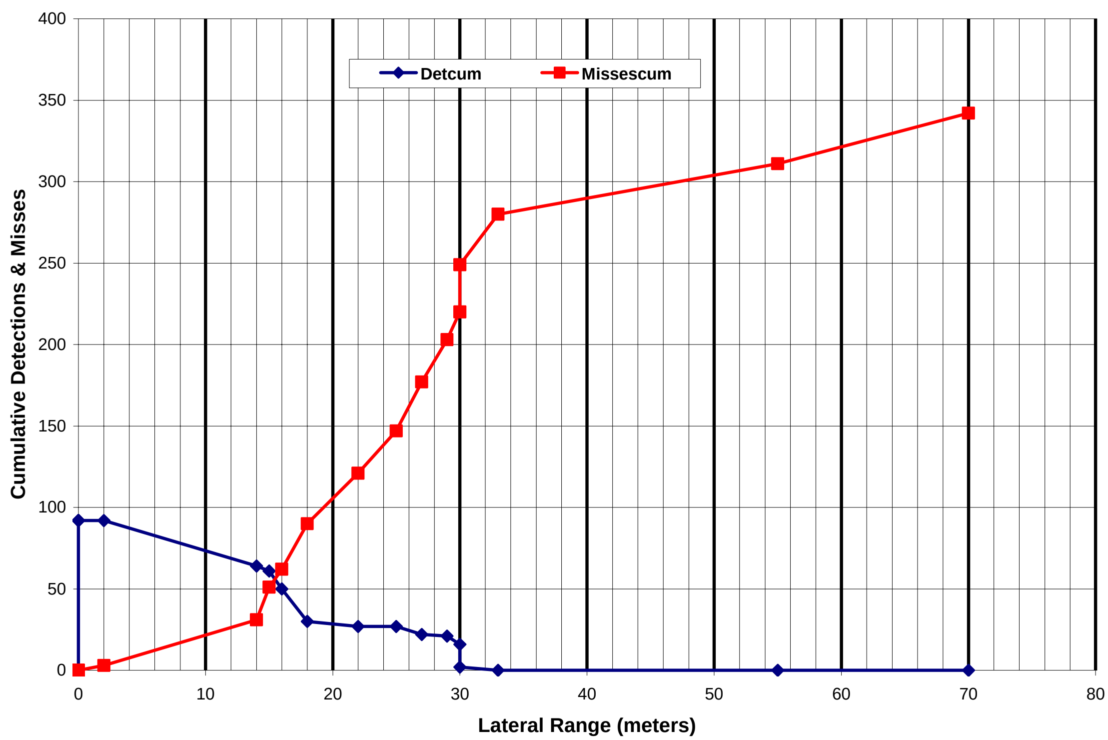

Figure 7-26. Lansdowne, Virginia, crossover graph for green human-sized targets.

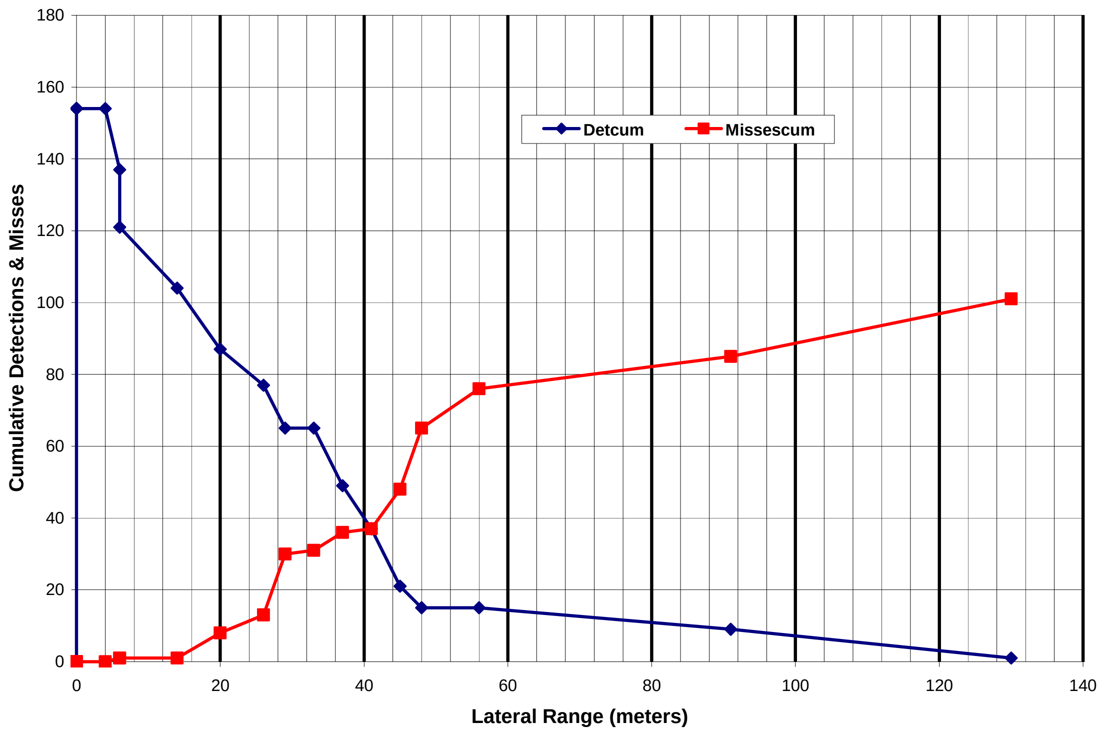

Figure 7-27. Mt. Diablo SP (CA) crossover graph for white/orange human-sized targets.

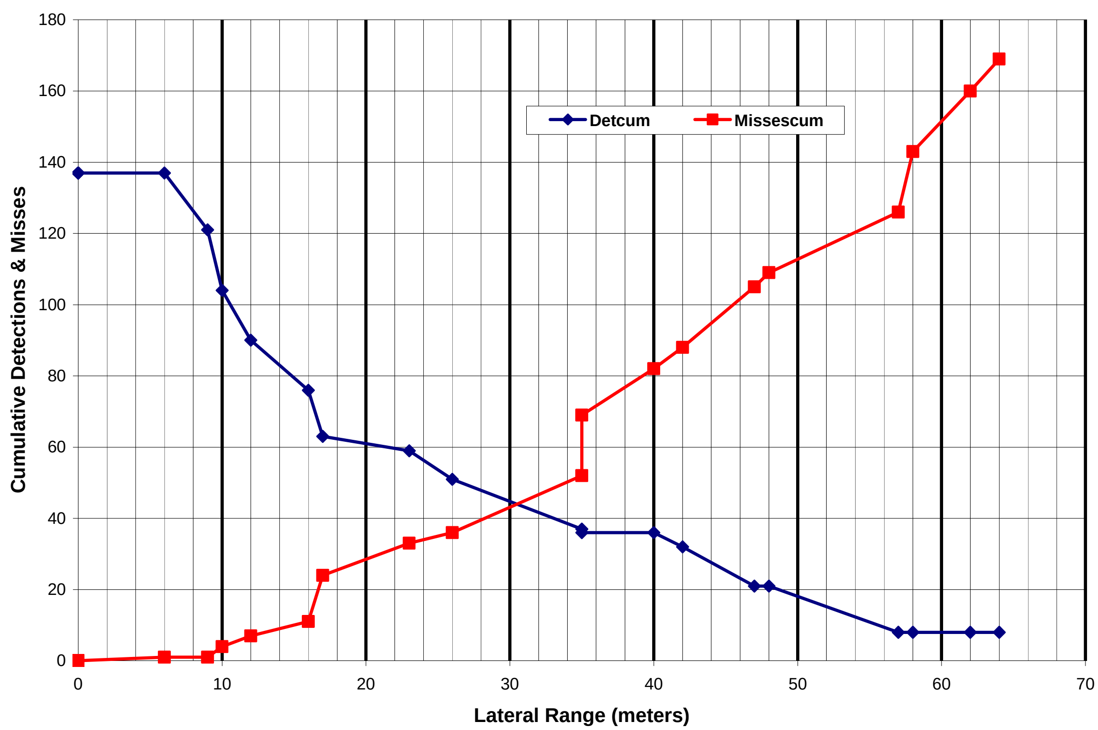

Figure 7-28. Mt. Diablo SP (CA) crossover graph for blue human-sized targets.

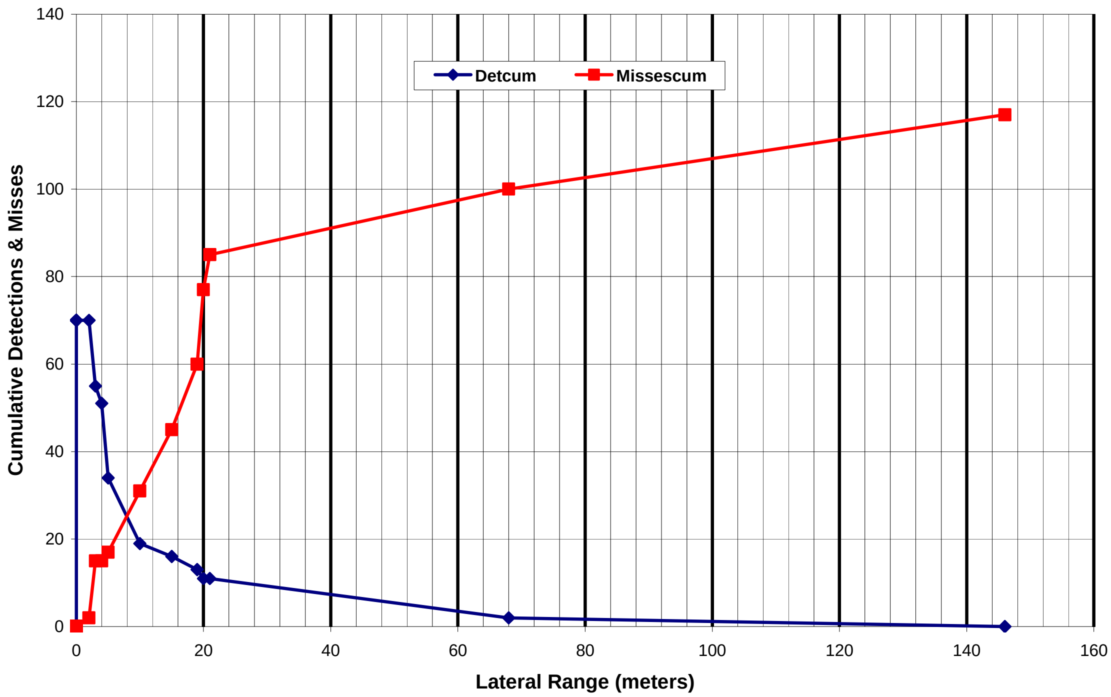

Figure 7-29. Mt. Diablo SP (CA) crossover graph for green human-sized targets.

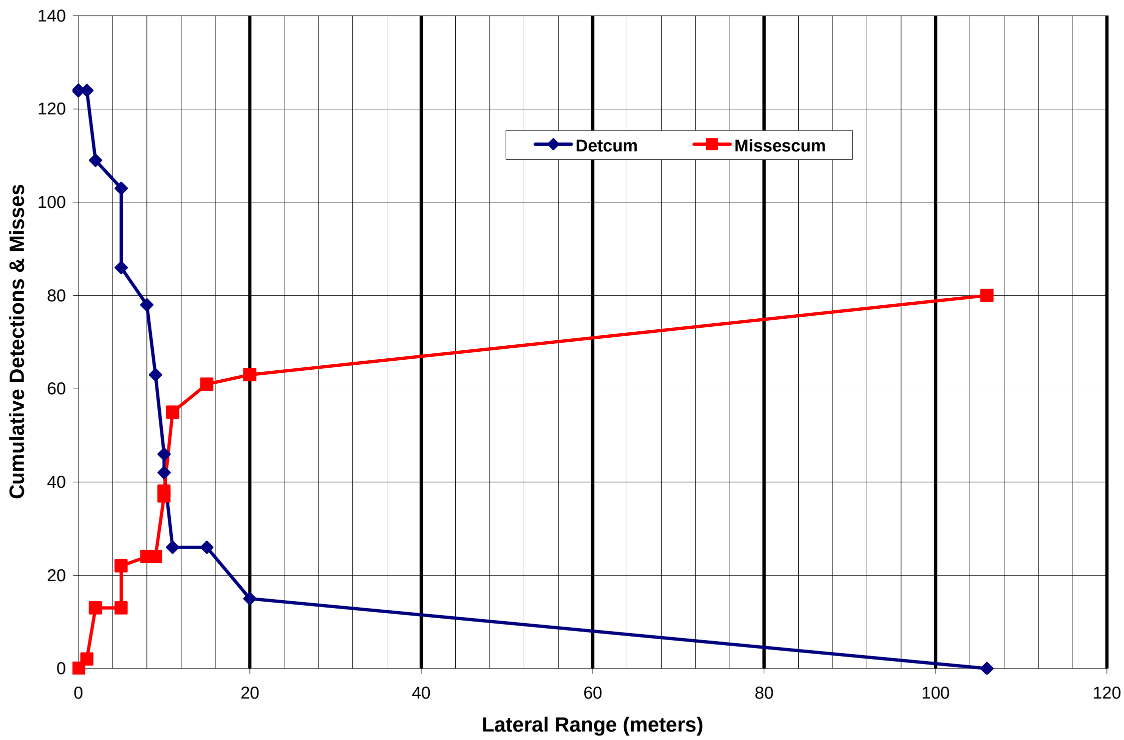

Figure 7-30. Mt. Diablo SP (CA) crossover graph for clue (white cap).

8. Secondary Findings

The primary purpose of the sweep width experiments was to develop and refine a methodology to determine Effective Sweep Widths in a variety of Ecoregions. However, in collecting information on several secondary characteristics several valuable lessons have been learned. Some SAR field practitioners may even find the secondary findings more interesting than the Effective SW values. Secondary findings addressed issues such as factors that may eventually serve as correction factors, searcher technique, and the ability to estimate probability of detection.

8.1 Data Collection Tools

Two tools assisted with the collection of secondary data. The first was the Searcher Profile form (Appendix C). This form collected basic information of the searcher's demographics, search experience, training, physical characteristics, and self-assessment of performance. The searcher normally completed Part A of the form (Searcher Demographics) prior to departure. The experiment staff administered the vision tests and collected the other required information for Part B (Physical Characteristics). This information was collected either prior to departure or after the team returned from the task. The experiment staff debriefed each team after return from the experiment in order to complete Part C (Debriefing). After the second experiment, question number 28 was no longer asked, since most participants did not have sufficient understanding of sweep width in order to make a meaningful estimate.

The data tool, while a significant enhancement over the previous information collected during the pilot Logan experiment still requires further improvement. It neglected to collect lighting conditions in the form of Lux levels. It failed to collect information that may have restricted searcher's vision or visual fields, such as wearing sunglasses, caps, or hoods. No attempt to note searcher's techniques on the form or other data logger tools was made. During the experiments data loggers noted several different search techniques and at an intuitive level some were far more successful than others. Another important information element that was not collected was the searcher's primary occupation and whether it involved a significant amount of scanning for objects at significant distances from the individual.

8.2 Participant's Primary SAR Specialty

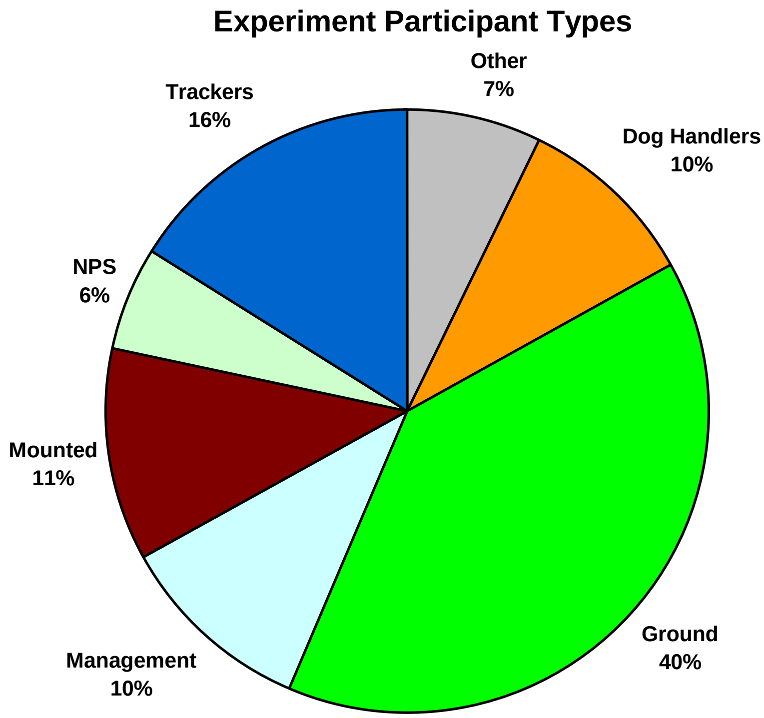

Figure 8-1. Types of SAR personnel that participated in the experiments.

Figure 8-1 shows the types of SAR personnel that participated in the experiments. On the searcher profile participants was asked to identify their primary SAR specialty. The “other” category consisted of bike team, pilot, law enforcement, swift water rescue specialist, fire fighter, communication specialist, and technical rescue specialist.

8.3 Possible Correction Factors to ESW

Since the primary purpose of the experiment was to determine ESW in different regions a through examination of secondary factors that may eventually serve as correction factors is beyond the scope of this report. Data is presented here to indicate where further work is required and give a general indication of which factors appear to require eventual correction factors.

8.3.1 Primary Training Specialty

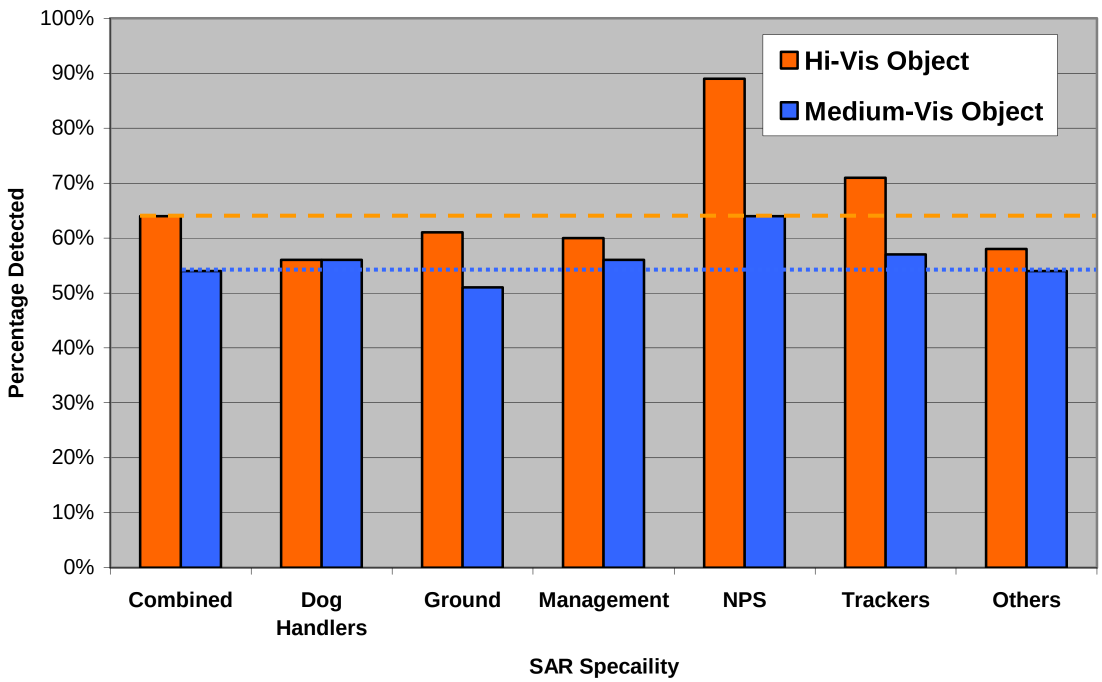

Figure 8-2. Percentage of detections for the high-visibility Orange/white adult manikin and the medium-visibility blue manikin broken down into the participant's primary specialty.

Figure 8-2 shows the percentage of detections for the high-visibility Orange/white adult manikin and the medium-visibility blue manikin broken down by the participant's primary specialty. It is worth noting that the entry-level classification of most SAR members is ground. After they have mastered the basics of ground SAR they then often further specialize into tracking or management. Dog handlers typically enter into SAR specifically to be a dog handler. The National Park Service (NPS) members were law enforcement rangers who both participate in SAR missions and patrol the backcountry. All NPS members were from Shenandoah National Park. The two groups that appeared to have performed better than the combined average across the board were the NPS rangers and trackers. These findings are not particularly surprising. NPS rangers use visual searching on a daily basis and spend a majority of their time in the outdoors. Trackers also invest a significant amount of time in visual search and tended to use the more successful visual search techniques.

8.3.2 Searcher Experience

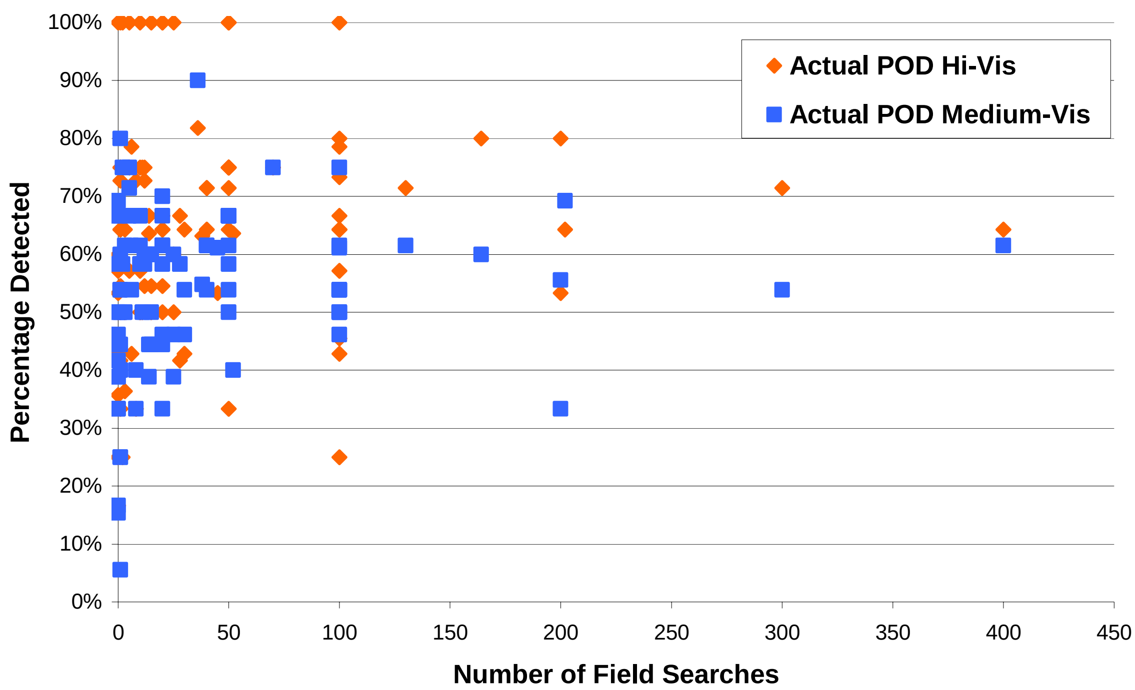

Figure 8-3. Relationship between searcher experience (searches in the field) versus the percentage of search objects detected for both the high and medium visibility search objects.

Figure 8-3 shows the relationship between searcher experience (searches in the field) versus the percentage of search objects detected for both the high and medium visibility search objects. No significant trend line was found. It was expected that with additional experience the detection percentage would increase. While those with less experience showed wider variability their overall performance was identical to those with considerable field experience. It was expected that search experience was going to be an important correction factor for ESW, but this data suggests simply the number of searches in the field does not predict any changes in the ESW. Similar analysis was done for total years in SAR and no trend was seen as shown in Figure 8-4.

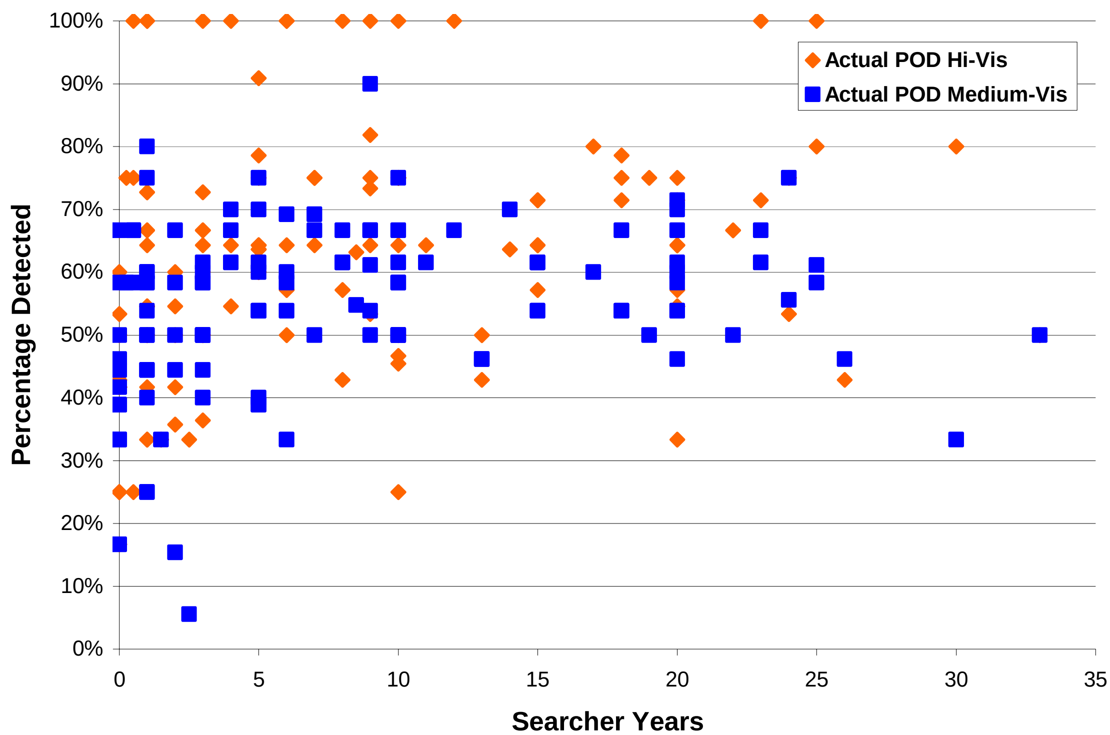

Figure 8-4. Relationship between reported searcher years in SAR versus the percentage of search objects detected for both the high and medium visibility search objects.

8.3.3 Searcher's Age

A wide range of ages contributed to the experiments. Participants ranged from young explorer scouts to seasoned veterans of search and rescue. It is difficult to hypothesize the effects of age because of the interaction between experience and physical condition. Figure 8-5 shows the relationship between age and actual POD.

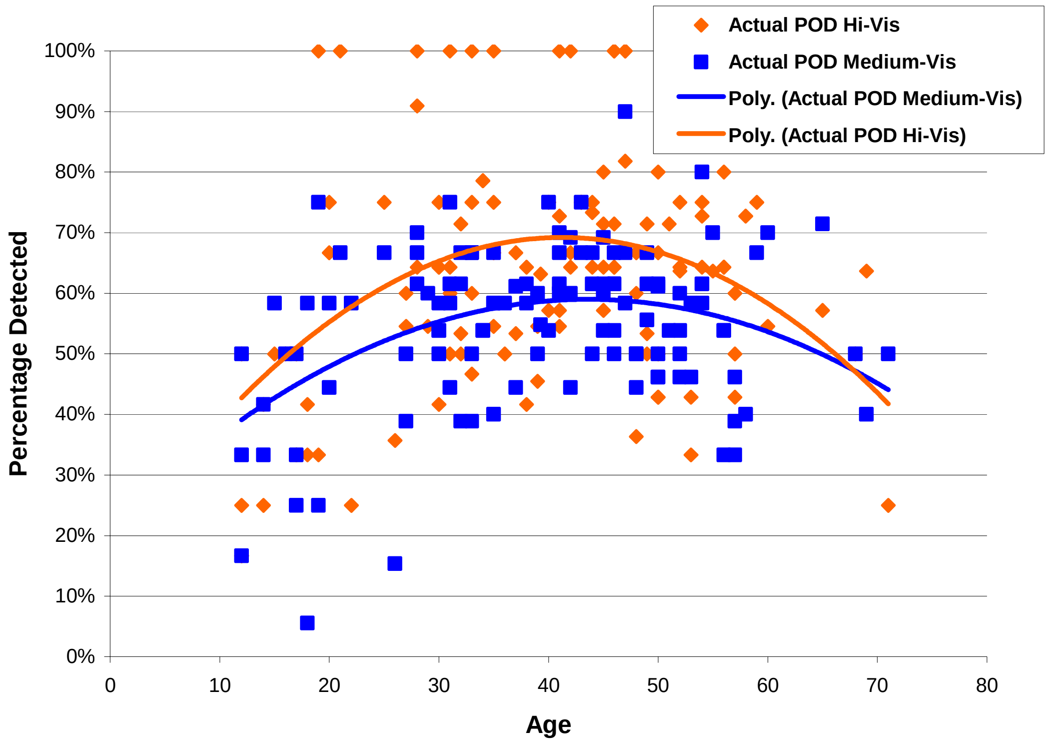

Figure 8-5. The relationship between age and actual POD.

The graph shows that the POD increases with age up to the age of 40. After 40 it begins to decline. Exactly how age should be taken into account for creating correction factors will require additional analysis and is beyond the scope of this report.

8.3.4 Searcher Speed

Another important factor that might impact ESW is searcher speed. All five experiments had similar average speeds, so all the data is once again pooled.

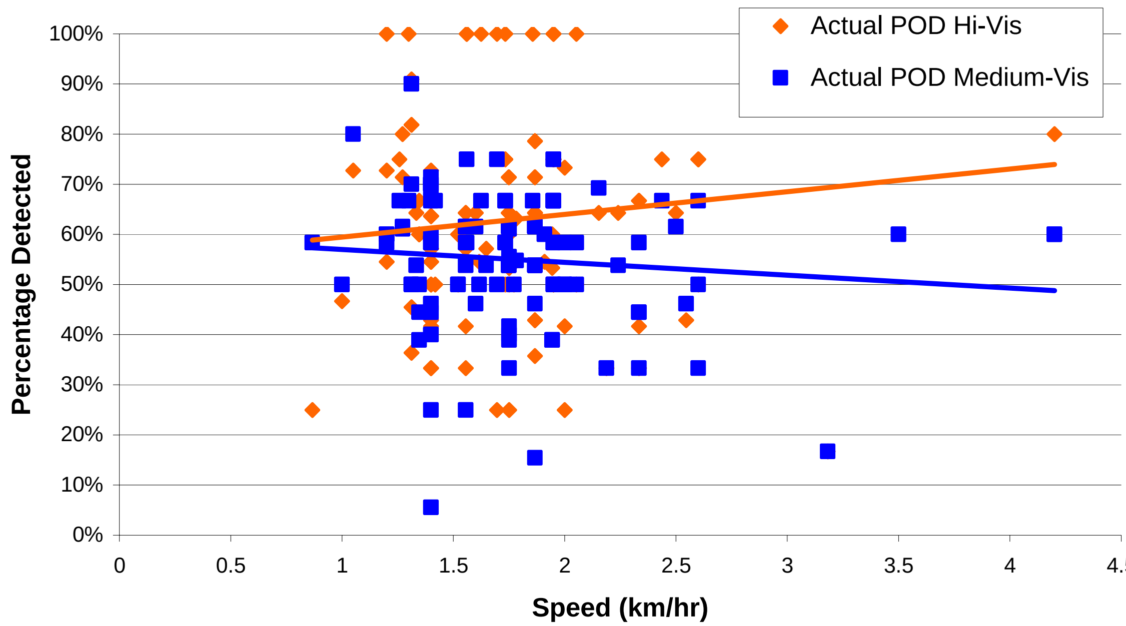

Figure 8-6. The relationship between speed and actual POD.

Fig. 8-6 shows that speed had no apparent effect of the percentage detected. While the trend lines show a positive and negative trend, when taken together give a perfectly flat trend line. It is assumed that at much slower or faster speeds a difference would occur. Searchers were restricted to a range of speeds. After searching for 100 meters the data logger would note the time and tell searchers to speed up if moving slower than 1.0 km/hr and to slow down if moving faster than 3.0 km/hr. This addition to the methodology was added after the first experiment where considerable variability was experienced. The data shows these directions where well followed in the subsequent experiments. Moving slow was usually attributed to either being out of shape or highly through searching.

8.3.5 Searcher's Height

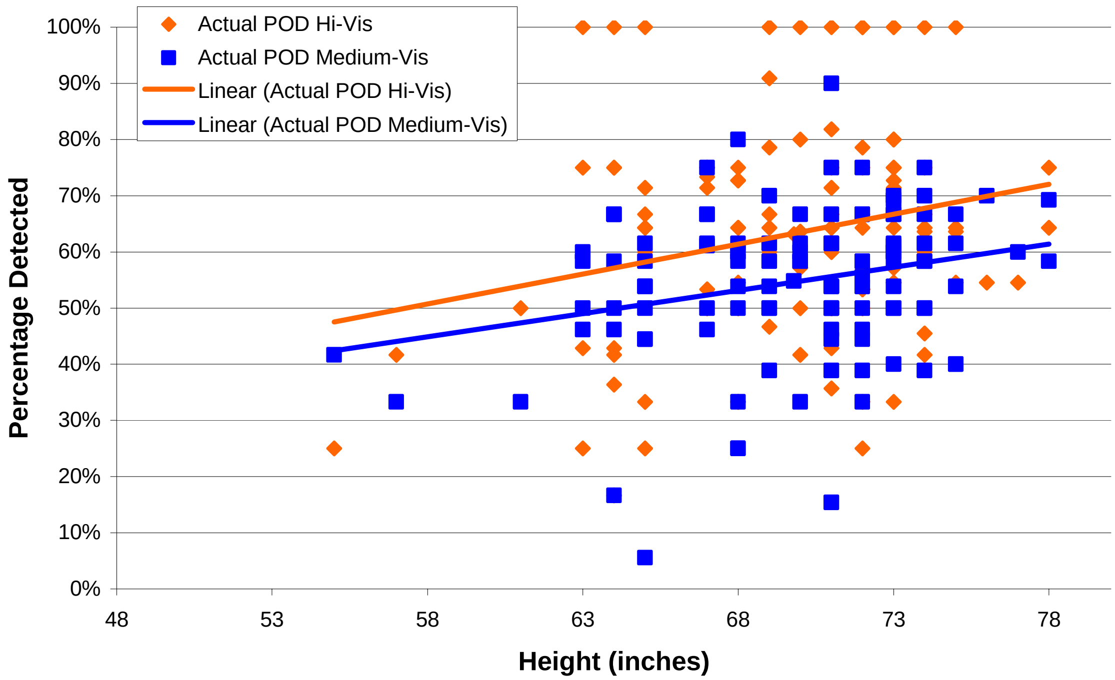

Figure 8-7. The relationship between searcher's height and actual POD.

The height of the participants was recorded as a possible correction factor. Height gives an advantage in terrain where ground cover may obscure the search object. A consistent trend line did exist showing that additional height did improve the percentage of search objects detected. These results are somewhat confounded by the age findings. Younger teenage searchers (often smaller) did not, on average, detect as many search objects as those in there 40's. As before, additional analysis is required before a correction factor is calculated.

8.3.6 Searcher's Self-Reported Morale

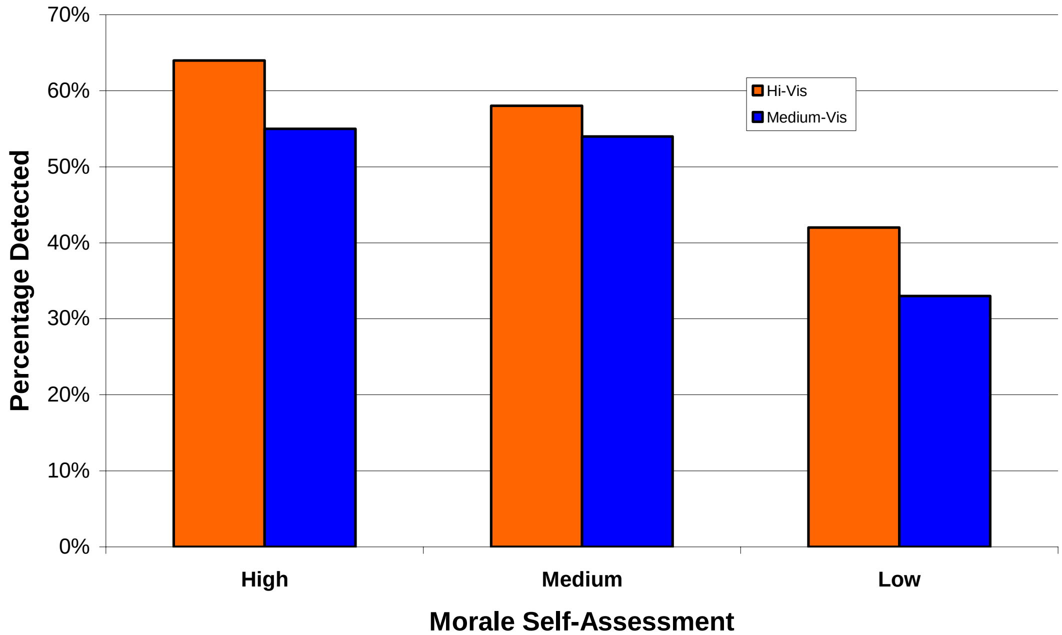

Figure 8-8. The relationship between self-assessed morale and actual POD.

Participants after completing the course were debriefed. Recorded on the Searcher Profile form was the searcher's personal assessment of their morale. As expected the majority of respondents reported high morale (n=103), only a handful reported medium morale (n=12) and only one reported low morale. High morale was expected due to motivated professional searchers, participating in an experiment where human-like search objects are expected, making detections provides positive feedback, and peer pressure creates a competitive sprit. A searcher's self-assessment of morale does appear to influence the percentage of search objects detected. Before a correction factors can be made additional analysis is required.

On actual search missions an assessment of morale is often made by the debriefer when questioning the field team leader. The field team leader makes an overall assessment of the entire team's morale. Some researchers have questioned whether, on actual missions, team leaders are willing to report less than high morale. It is expected that, since the assessment is of the entire team and not just the reporting party, a fair assessment is possible. Certainly during the actual experiments participants were willing to report less than high morale.

8.3.7 Searcher Fatigue

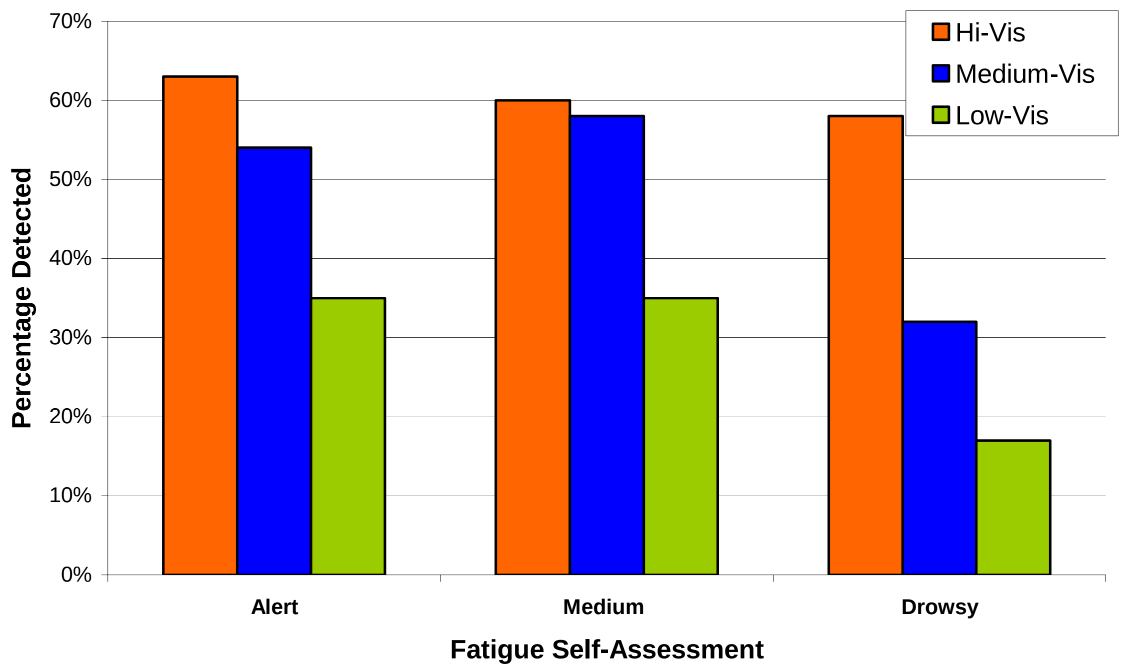

Figure 8-9. The relationship between searcher fatigue and actual POD.

Another important domain affecting searcher performance is fatigue level. Fatigue can be a difficult factor to measure. The most objective measure is to perform Mean Sleep Latency Tests (MSLTs), which require a sleep laboratory environment. Objective questions that give an indication of fatigue levels include hours since last sleep or hours on task. The *IAMSAR Manual* uses a correction factor of 10% for tasks lasting longer than 8 hours (IMO/ICAO, 1999). During all the experiments no task took longer than 4 hours, with most lasting approximately 2 hours. All tasks were performed during the day (half in the morning and half in the afternoon). Searchers by objective measures should have been alert. In fact 93 searchers did report feeling alert at the end of the task. Seventeen searchers reported feeling just medium alertness. Three searchers reported feeling drowsy at the end of the task. These self-assessments did appear to correlate with decreases in performance. The decrease in all search objects was negligible between the Alert to Medium alertness level. However a significant drop occurred for searchers reporting feeling drowsy. From Alert to Drowsy an 8% drop occurred for the high-visibility search object. This corresponds well to the 10% correction factor used by the USCG for fatigue. However, for the medium-visibility and low-visibility search objects the drop was much greater (42% and 51% respectively). It may be hypothesized that detecting medium and low visibility search objects require significantly more concentration and effort. Therefore, when significantly fatigued they are that much more easy to miss. Fig. 8-10 illustrates a clue located at 4 meters lateral range that a searcher missed that reported her fatigue level as drowsy.

Figure 8-10. A clue located at 4 meters lateral range that a searcher missed and reported her fatigue level as drowsy.

8.3.8 Searcher's Gender

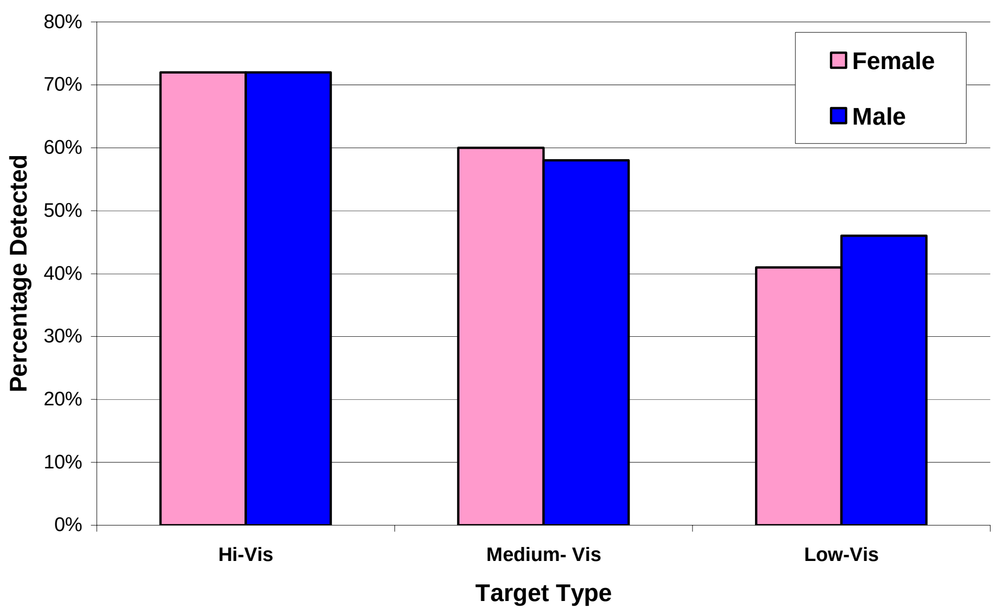

Figure 8-11. The relationship between searcher gender and actual POD.

During the course of the experiment several participants hypothesized a gender difference in the ability to detect search objects. The researchers could not hypothesize any difference based upon known physiological factors but decided it warranted examination as a possible correction factor. Figure 8-11 shows essentially no difference exists between the ability of males and females to detect search objects. Statistical analysis also demonstrates no significant difference (ANOVA). Both males and females make important and equal contributions to search object detection.

8.3.9 Color Blindness

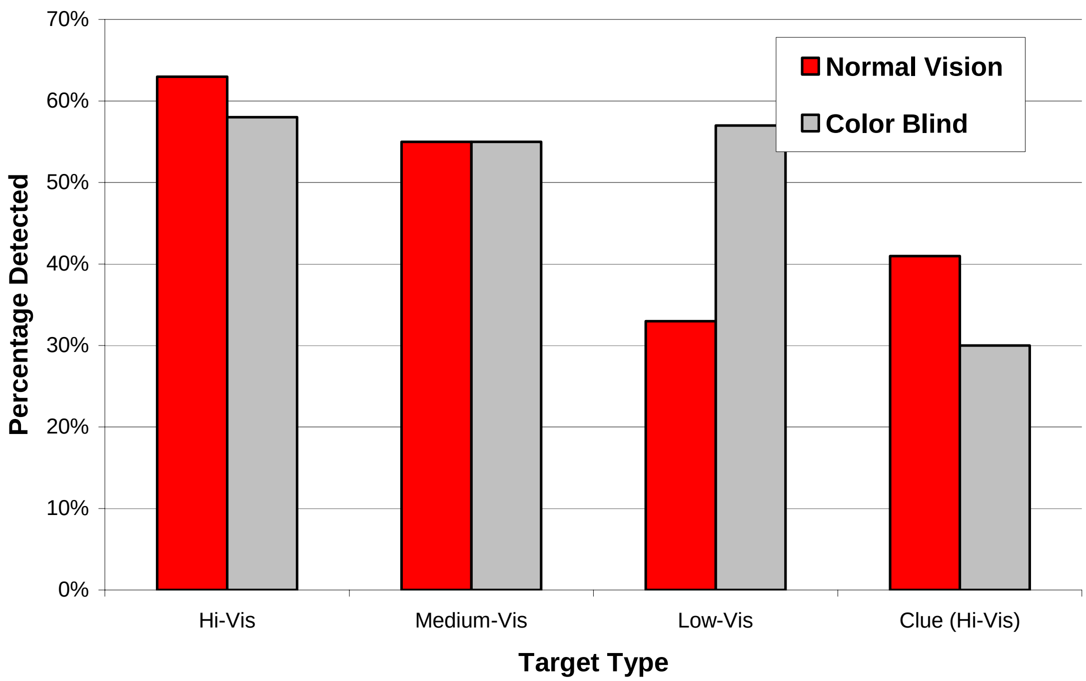

Figure 8-12. The effects of color blindness on actual POD.

During the experiments several participants noted they were colorblind on the searcher profile. In several incidents the participants did not know or disclose this information until they completed the Ishihara color vision test that was part of the data collection process. The simplicity of the screening test did not differentiate among different types of colorblindness. Normal color vision was noted for 110 participants and 6 had colorblindness. The high-visibility search object was a predominantly white overall with an orange safety vest placed on it. To a searcher with normal color vision it was often the orange that first raised awareness. A slight drop in performance was noted for this target between those with normal vision versus those with colorblindness (63% vs. 58%). This represents a 5% difference or a 7% decrease. The change in actual ESW for normal vs. color blind was calculated for the New Mexico experiment where three of the seventeen participants were colorblind. The ESW for the high-visibility search object was 64 m for those with normal vision and 57 m for those with color blindness. This represents a 7-meter difference or a 12% decrease. No difference was seen for the blue medium-visibility search object. An interesting finding was made for the low-visibility green search object. Those with colorblindness detected significantly more search objects. This finding is not surprising when recalling people with colorblindness have been used to detect camouflage (low contrast), due to heightened sensitivity to visual patterns and a different sensitivity curve (Free Dictionary, encyclopedia.thefreedictionary.com/camouflage). The clue sized high visibility object was either a white hat (California experiment) or an Orange glove. Those with colorblindness once again had greater difficulty making a detection. It was noted that one colorblind participant was not able to detect any of the all orange-gloves after doing a good job with the Orange/White manikins. Search team managers should become aware of the advantages and disadvantages of those that have colorblindness. Correction factors to sweep width should be made after additional analysis.

Figure 8-13. An illustration of the difference in appearance between those with normal color vision (left) and those that suffer from Deuteranope (a form of red/green color deficit), which is the most common type of color blindness.

Fig. 8-13 illustrates the difference in appearance for those with normal color vision (left) and those that suffer from Deuteranope (a form of red/green color deficit), which is the most common type of color blindness (right). This loss in performance for orange and the no effect on blue search objects are readily apparent. The enhancement for low-contrast green targets is largely lost on those with normal color vision.

The occurrence of color blindness is estimated at 8% of the male population (Jaeger, 1972). During the course of the experiments 6 males reported colorblindness compared to a total of 85 males participating. The 7% occurrence corresponds well to the 8% occurrence rate seen in the general population. Correction factors for colorblindness will need to be based upon the target type and may either increase the ESW or decrease it. The determination of the correction factor is beyond the scope of this report.

8.4 Searcher's Ability to Estimate POD Directly

One of the most common methods of determining POD for ground SAR still used in many regions is the direct estimation of POD by the field resources. In some cases the field reports are further modified by incident staff. A common technique is to simply halve the field report for inexperienced teams. If direct estimation of POD is accurate it would save experiment time, computational resources, and be a much quicker method of arriving at POD. For many of these reasons direct estimation is still used. Since searchers were asked to estimate their POD for each of the search objects an analysis can be made of searcher's ability to estimate POD.

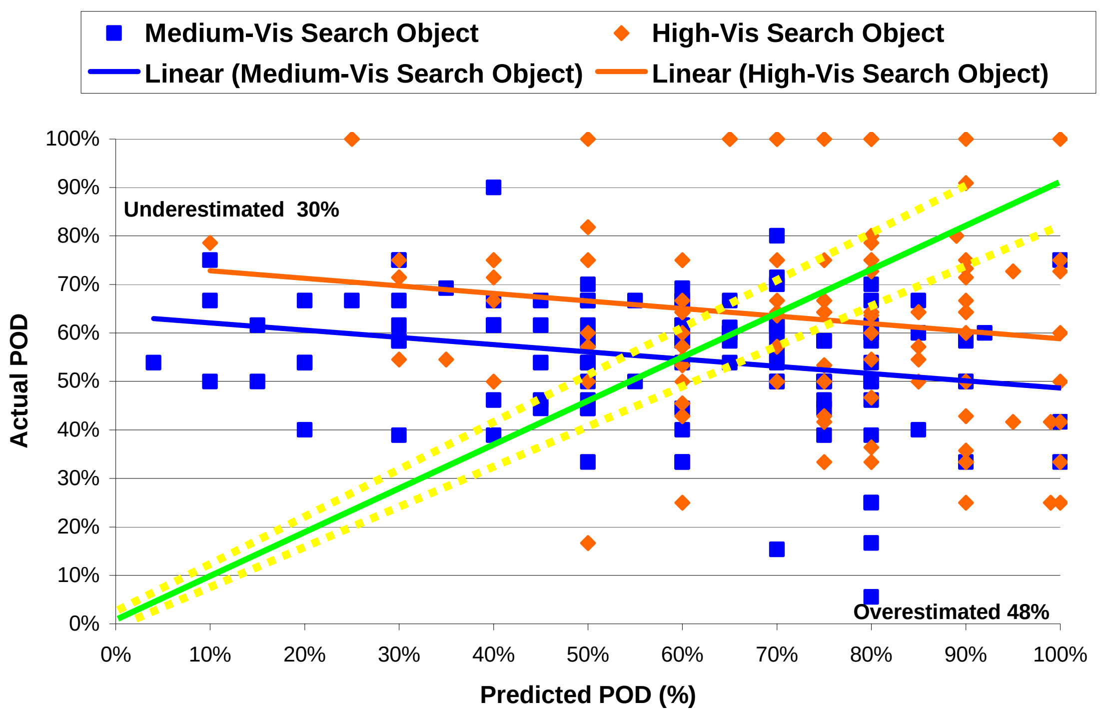

Fig. 8-14. Actual versus predicted POD for medium and high visibility targets.

The graph plots the searcher's estimated POD for each search object against the Percentage Detected (termed actual POD) obtained in the field. The green line represents a perfect prediction. The area between the two dashed yellow lines represents a prediction within 10% of the actual percentage detected. This area includes overestimates and underestimates within 10%. The area above the top yellow line means the searcher underestimated their ability to detect the search object. The area below the bottom yellow line means the searcher overestimated their abilities. The most common scenario was for searchers to overestimate their detection skills (48%). The second most common scenario was underestimating (30%). The remaining 22% were able to estimate within 10%. This includes both under and overestimation, representing a range of 20%. Random chance can account for the percentage that fell within this range.

The solid blue line is the trend line for the medium-visibility search object and the orange line is the trend line for the high-visibility search object. Both trend lines have a negative slope. This indicates the searcher's ability to estimate has a negative correlation with actual results. In other words, the higher the searcher's predicted POD the worse their actual performance. This relationship may be related to searcher experience. With more experienced searchers giving lower estimated POD. Recall that from section 8.4.2 no relationship was found that showed experienced increased POD. The next graph will examine if more experienced searchers give lower estimated PODs.

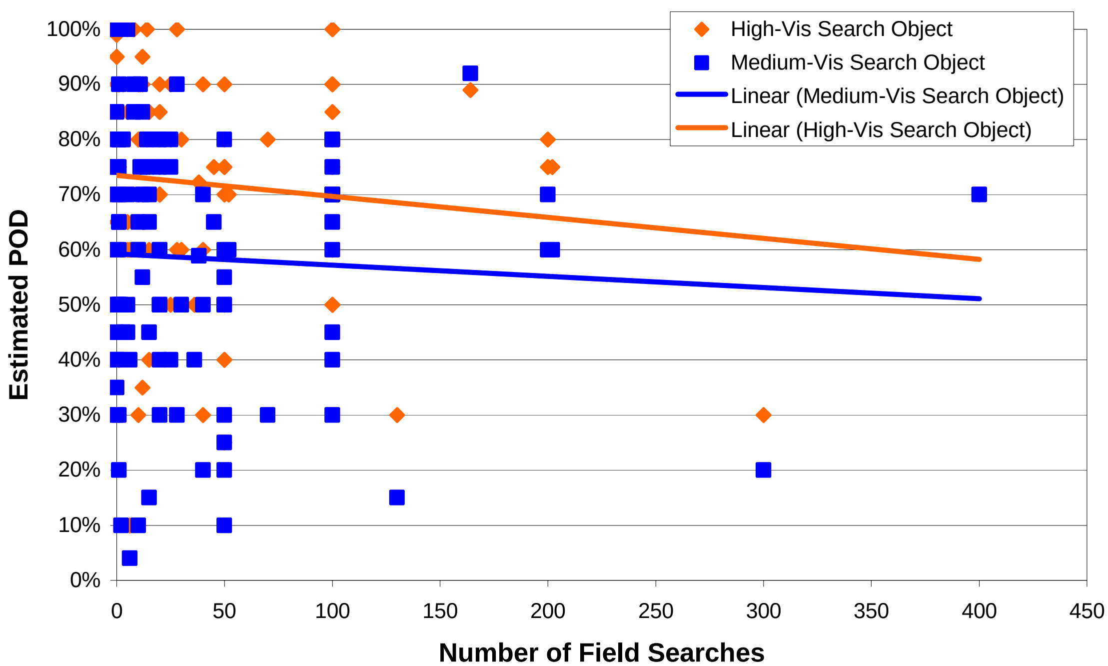

Fig. 8-15. Estimated POD versus field search experience.

The graph demonstrates only a weak negative correlation between searcher's field experience and the estimated POD they give. On average a searcher with 50 searches would give an estimated POD that was only 2% lower than those without any search experience. Since searcher experience does not account for higher estimated POD resulting in lower actual detections an alternative hypothesis is required. Random chance may offer the best explanation. For searchers who give higher estimated POD, it is more likely the actual POD will be lower if the estimate has no basis. For searcher's who give low estimated PODs, it is more likely the actual POD will be higher. The data suggests that an estimated POD may be no better than random chance, such as picking POD values out of a hat.

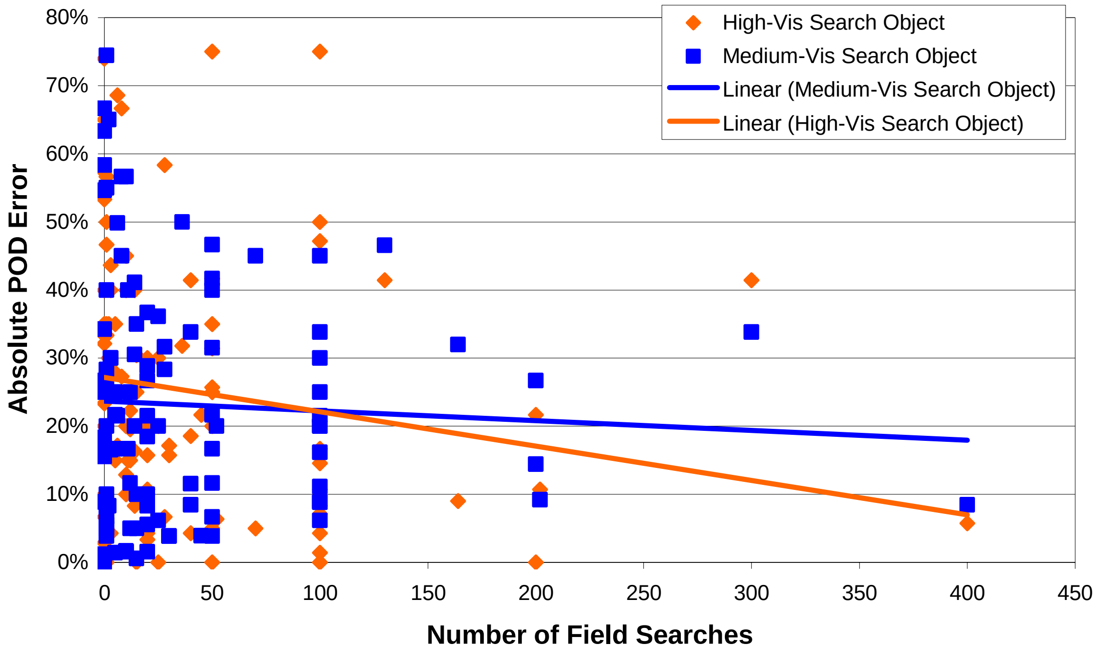

Fig. 8-16. Field experience (number of reported searches) versus absolute POD error.

The absolute POD error (difference between actual POD and predicted POD) in general did not improve appreciably with field experience. The range of error was slightly higher for those with little search experience. The overall average for absolute POD error was 23% for the high-visibility search object and 25% for the medium-visibility search object. This means given an estimated POD of 50% on average the actual POD was either 74% or 26%. The average range of error approaches 50%.

The experience of searchers has no meaningful impact on their ability to predict POD. Searchers are almost as likely to underestimate (30%) POD as overestimate it (48%). Therefore simplistic rules such as cutting the reported value in half are not valid. The average amount of error was approximately 25% with represents a range of average error of 50%. The ability of ground searchers appears on par with the ability of maritime searchers. For all of these reasons Maritime SAR has long abandoned direct estimation of POD and instead uses sweep width or simple tables based upon sweep widths.

8.5 Searcher Technique

The methodology was designed to determine effective sweep widths in different Ecoregions. It was not designed to examine the effectiveness of different search techniques used by the participants. For this reason objective data was not collected to quantify the effectiveness of different techniques. However, a valuable secondary benefit of the experiments was information gained by watching searchers detect or miss a search object while being observed by a data logger. Searchers seldom have an opportunity to get feedback on why they missed a search object and hence an opportunity to improve their skills.

8.5.1 Data Collection Tools

Observations where made by members of the experiment staff who had been involved in placing targets. Therefore, they knew where the search objects where located and could closely observe searcher technique when they detected a search object. After the first experiment, additional details where recorded concerning the search objects. This information included the location along the track the search object first became visible, the maximum range at which it remained visible, what percentage of the time during the visible range it could actually be detected, a qualitative term describing its visibility, and any features that may have complicated its detectability. Unfortunately, since this was not an aim of the experiment no form was made to collect this data in a standardized format.

The data logger form had no fields related to search technique. Instead, the experiment staff serving as data logger would discuss common attributes for those searchers who performed above average and those under average. In future experiments, valuable lessons could be gained by creating a standard tool that captures searcher technique and common reasons why targets where missed.

Based upon the observations of the experiment data loggers, the following are the most common errors in technique that lead to targets that were visible being missed.

8.5.2 Failure to Look Behind

As previously described, the location of targets were randomly assigned and placed. Still, many targets where only visible if the searcher looked behind. Many searchers never looked behind. Other searchers only looked behind once or twice during the entire course (often at the beginning). On actual searches, missing subjects are even more likely to sit next to a tree or rock, making detection by looking behind even more prevalent than the randomly chosen locations.

8.5.3 Failure to Stop and Scan

The most successful searchers would walk a short distance, stop, and then perform a thorough scan in all directions. A searcher's ability to make detections appears to be higher when stopped than when in motion. Future research may have the potential to help determine the best distances as they relate to ESW and to stop and scan techniques.

8.5.4 Looking Beyond the ESW

The importance of looking beyond the ESW as already been well established. Many searcher's who are focused on small clues, did not scan at greater distances.

8.5.5 Scan Beyond the First Foliage

Several searchers stopped their visual scanning at the first encounter with foliage/brush/ or a visual obstruction. In the ground environment it is often possible to see through gaps in the trees well beyond the AMDR. In some cases search objects were visible over a 75-meter range, had excellent contrast with the environment (orange against green) but since they were approximately 50% obscured and at a greater distance, were often missed. Two Orange/White clues particularly meet this description. In the Virginia-Summer experiment the lateral range was 48 meters, the object was obvious to an alerted searcher, visible for 50 meters, but nobody detected the search object.

8.5.6 Regroup and Scan After a Distraction

It was readily apparent that when a searcher crosses a log, jumps over a creek, or works through a barbed wire fence they stop any effective searching. Such distractions are common in the outdoors. While target placement was randomly selected, several search objects could only be seen while engaged with a distraction. Distractions are not limited to problems of moving through the area. In one case an orange glove lay less than a foot off the track, not far from some animal bones. No one missed the bones but many missed the orange glove that was near their feet as they were looking at the bones. Apparently such a sight was so unexpected (the kill was relatively fresh), the searchers completely forgot about the object of their search for a few moments. The searchers who were able to detect the search objects made a conscious effort to scan after an encounter with a distraction.

8.5.7 Get Low if Applicable

In some of the search environments significant vegetation existed above one meter. However, little to no ground vegetation existed. In this environment those searchers who would bend over to search low and under the existing vegetation made detections others missed.

8.5.8 Use Corrected Vision

In several cases searchers started on the course without their glasses. After a search period they realized they could not see well and returned to base to retrieve their glasses. On actual searches it is rare for a team to return to base so a team member may retrieve forgotten glasses. In addition, many searchers remove their glasses when it rains.

8.5.9 Talking While Searching

Whether the searcher was talking or not at the time of detection was not recorded. However, from observations two contradictory statements can be made. The first was that some searchers engaged in conversation missed several obvious search objects, even if they did relatively well at making other, sometimes very difficult, detections. Ironically, sometimes these misses occurred while a more experienced searcher was lecturing a less experienced data logger, who saw the object, about scanning techniques. The second was that conversation seemed to have no negative impact on their ability to make detections. Data loggers could not discern any predictors of whether talking would have a negative impact. Data loggers were instructed not to start conversation or to engage in talking. However, it was noted that if a searcher initiated a conversation the data logger would often maintain it.

Perhaps the only way a searcher can become aware of whether talking impacts their detection ability is to receive feedback from a similarly designed sweep-width experiment.

Part IV – Estimating POD

9. 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.

9.1 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 simplest method of determining the distance a single searcher covered it to measure it. This can be done when the distance of the path is already known (searching a measured trail) or measuring the searcher's actual distance traveled (pedometer or GPS).

The distance a searcher covers while searching may also 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.

If a search team consisting of 4 individuals conducted a sweep search for a total search time of 2 hours at an average speed of 0.5 km/hr, then their total effort would be 4 km (4 people x 2 hours x 0.5 km/hr = 4 km).

9.2 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 by upward or downward subjective revisions if the prevailing conditions for the actual search are different from those that were prevailing when the experiments were conducted.

9.3 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:

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

If the team from the example given in Section 9.1 is searching for a medium-visibility adult-sized person in winter, deciduous forest (Ecoregion M220), the effective sweep width is 106 meters (or 0.106 km).

The sweep search team with four searchers effectively sweeps:

$$0.106\,km \times 4\,km = 0.43\,km^2.$$

9.4 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 Fig. 9-1. 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:

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

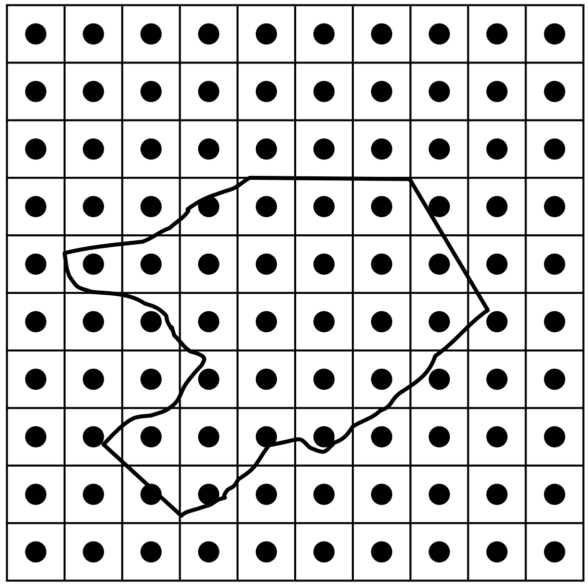

Figure 9-1. Estimating Segment Area with Dots on a Grid

There are 100 dots in the large square of Fig. 9-1. 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. In addition, most mapping software programs include features that allow the determination of area.

9.5 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 9-2 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.

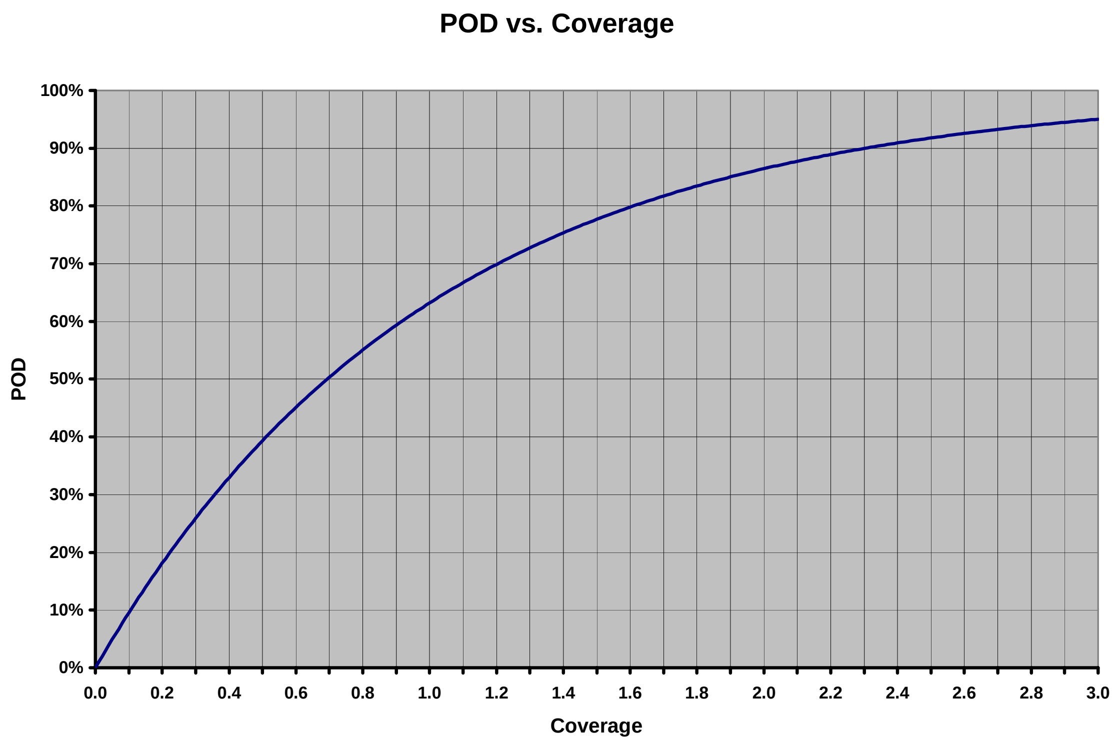

Figure 9-2. POD versus Coverage curve, a.k.a., the exponential detection function.

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 9-2 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.

Using our previous example of the sweep search, we need to calculate the coverage first. Recalling the formula to calculate coverage is:

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

For the sweep search who effectively swept 0.43 km^2 while searching a segment estimated at 0.25 km^2, the coverage is:

$$\frac{0.43\,km^2}{0.25\,km^2} = 1.7$$

To determine the POD based on coverage either the curve in Figure 9-2 could be used or the equation of the curve could be solved using a simple calculator. The sweep team in open terrain and the rather small segment of 0.25 km^2 achieved a POD of 82%.

9.6 Another Example of POD Estimation

Another example is given putting all the concepts together in one place. 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 travel to 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 Fig. 9-2 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.

9.7 Example Using Experimental Data

ESW (AMDR)	VA	NM	WA	VA	CA
Location	Shenandoah NP	Lincoln National Forest	Gifford National Forest	Lansdowne	Mt. Diablo State Park
Ecoregion code	M221	M311	M242	231	M261
Season	Winter	Spring	Summer	Summer	Summer
White/Orange	142 (80)	62 (37)	36 (34)	73 (33)	82 (41)
Blue	106 (82)	67 (34)	32 (29)	54 (27)	61 (32)
Green	-	-	17 (17)	31 (22)	16 (14)
Clue	-	-	8 (-)[b]	- (9)[a]	20 (10)

Note. Values in parentheses are AMDR values. All values in meters.
[a] Clues were not used in Lansdowne although an AMDR was determined for them (glove).
[b] Clues were used in Washington but an AMDR was not determined for them (glove).

Table 9-1. Relationship between $AMDR_{avg}$ and ESW.

Using the ESW values derived from the experiments, it is possible to compute a POD for each search object. This makes possible a comparison between the computed (estimated) POD values and the actual number of detections obtained. Using the Lansdowne, Virginia, experiment—since it had the greatest number of participants—the POD for the White/Orange, Blue, and Green search objects can be computed (Table 9-2).

Orange/White Search Object	Blue Search Object	Green Search Object
Effort		
1 searcher x 2.0 km = 2.0 km	1 searcher x 2.0 km = 2.0 km	1 searcher x 0.8 km = 0.8 km
Area Effectively Swept		
2.0 km x 0.073 km = 0.146 km^2	2.0 km x 0.054 km = 0.108 km^2	0.8 km x 0.031 km = 0.025 km^2
Segment Area		
2.0 km x 0.106 km = 0.212 km^2	2.0 km x 0.106 km = 0.212 km^2	0.8 km x 0.066 km = 0.053 km^2
Coverage		
0.689	0.509	0.472
POD Using Exponential Detection		
50%	40%	38%
Actual Experiment Detection Percentages [a]		
62%	54%	29%

Note. The course length for the Orange/White and Blue search objects was 2.0 km, and for the Green search objects it was 0.8 km.
[a] "Actual Experiment Detection Percentages" refers to the total percentage of search objects of the specified type that were found (# detections/detection opportunities) by all searchers in the Lansdowne (VA) experiment.

Table 9-2. Computed POD values and actual detections for various search objects in the Lansdowne (VA) experiment.

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Part V – Conclusions and Recommendations

10. Project Objectives

The Research and Development Group of the National Search and Rescue Committee (NSARC) recommended a multi-year plan in 2001 for performing a series of research projects to develop improved tools and procedures for planning searches on land. This plan was subsequently endorsed by the U. S. Air Force Rescue Coordination Center (AFRCC) and the National Association for Search and Rescue (NASAR). As the first project in the series, a preliminary ground sweep width experiment was conducted in 2002 and reported to NSARC in *A Method for Determining Effective Sweep Widths for Land Searches: Procedures for Conducting Detection Experiments.* The report established a successful methodology but recognized the need for further refinements and experiments, and recommended that such work be undertaken.

The scope of this project was to further validate and refine the preliminary experimental procedures described in *A Method for Determining Effective Sweep Widths For Land Searches: Procedures for Conducting Detection Experiments*, prepared for the U. S. National Search and Rescue Committee under U. S. Coast Guard Contract Number DTCG39-00-D-R00009, Task Order Number DTCG32-01-F-000022, 30 September 2002. The scope included the coordination and supervision of additional experiments in different ecological and geographic venues.

Secondary to the statement of work for this project, a contractor was selected (Potomac Management Group [PMG], Inc.) and tasked with meeting the objectives found in the following paragraphs (10.1 – 10.10). Precisely how these individual objectives were met is described beneath each listed objective.

10.1 The contractor shall further validate and refine the experimental technique developed in *A Method for Determining Effective Sweep Widths for Land Searches: Procedures for Conducting Detection Experiments* for estimating the effective sweep width for a search object in wilderness or rural regions for searchers on the ground by working with different SAR units in ecological and geographical regions.

This project involved the application and refinement of the experimental techniques forwarded in Robe & Frost (2002). For this project, five experiments were conducted in five ecoregions across the United States, and many SAR teams assisted. Part II of this report describes the experimental methodology used in these experiments, and Part III of this report describes the results of these experiments.

10.2 The contractor shall review the ground SAR literature and determine an appropriate search object that represents a typical immobile unresponsive search subject in the areas where experiments are to be conducted.

Section 3.1.5 of this report describes the selection process for the three human-sized primary targets (high-visibility, medium-visibility, low-visibility) used in the five experiments conducted.

10.3 The contractor shall conduct a similar review of the literature or records to select a search object that represents a typical physical object that provides a clue to the subject's location. It is assumed that the technique need only apply to visual search in an unpopulated area and under environmental conditions that are typical for the area concerned.

Section 3.1.5 of this report describes the selection process for the two secondary clue-sized targets (high-visibility and medium-visibility) used in the five experiments conducted.

10.4 The contractor shall provide oversight for three demonstrations of the technique for a typical set of search conditions and report the results. The selection of the three locations shall be based upon different level 1 ecological regions established by the Commission for Environmental Cooperation created under the North American Agreement on Environmental Cooperation. It is anticipated that volunteer search resources will be available from recognized ground SAR units to provide searchers, data recorders and other assistance in performing the experiments. Volunteer resource availability will be a factor in site selection. The contractor shall, in cooperation with the U.S. Air Force Rescue Coordination Center, Civil Air Patrol, National Association for Search and Rescue, State SAR Coordinators, identify volunteer resources. The contractor shall use a typical cross-section of ground searchers (persons who would actually be tasked with searching in an actual SAR case) to determine effective visual sweep widths. These trials shall include an in-place estimate of the average maximum detection range of the object used for the demonstrations under the conditions existing when and where the demonstrations are conducted.

Five demonstrations of a revised experimental technique described in Robe & Frost (2002) were conducted—two more than required by the statement of work. Each of the experiment sites was located in a different ecoregion, which are described in Section 6 of this report. Many different ground SAR volunteers assisted with each experiment. These volunteers are described in section 6.x.5 of this report (Participant Recruitment, under the Description of Venue for each experiment site). The average maximum detection range for each target used was also measured under the conditions existing at each experiment site. A description of these measurements can be found in Section 3.2.3 and the results of are described in Table 7-11 in this report.

10.5 The contractor shall research and identify variables that may influence ground based sweep width. Note that experimental methodology and data collection tools will allow collection and documentation of identified variables.

The variables studied in this project are identified and described in Part II of this report (Experiment Methodology). Measurement and documentation of these variables are described in Parts II (Experiment Methodology) and III (Experiment Results) of this report.

10.6 The contractor shall select one area convenient to the contractor that allows repeated experiments in similar terrain but at different sites. This area shall be used to determine the repeatability and reliability of the methodology to determine effective visual sweep width.

An area is recommended for the establishment of a semi-permanent course in section 13.2.

Although repeated experiments were conducted at different sites, the use of one area for multiple experiments was not done for two reasons:

1. Experiments depend on volunteer participants and the quantity and nature of the available volunteers would not allow repeated use of them in the same area.

2. Ensuring the same weather conditions, even when all other environmental factors were maintained by using the same site, together with the difficulties and lead time associated with obtaining a sufficient quantity of volunteer participants, was impossible from a scheduling perspective.

10.7 The contractor shall provide a refined practical experimental procedure for estimating sweep width that inherently accounts for all variables at the time and place where the procedure is used, along with any appropriate explanations of the procedure. This procedure shall be suitable for publication and use by ground SAR personnel, with minimal need for expert supervision, to develop data compatible with search planning and POD estimation methods that are designed to use sweep width data.

The experimental procedures used in this project for estimating ESW, and suggested for use by others, are identified, described, and explained in Part II of this report (Experiment Methodology). Appendix D of this report (Simplified Procedure for Conducting Experiments) contains a simplified summary of the procedure recommended for conducting ESW experiments.

10.8 The contractor shall produce a final report of findings that addresses each of the requirements 10.1 – 10.7 above, including the effective sweep width values from each experiment, along with all the data collected for each experiment. The procedure described in 10.7 above shall be included as an appendix. **(Deliverable No. 1)**.

This report fulfills this requirement and serves as the first deliverable. The experimental procedures used in this project for estimating ESW, and suggested for use by others, are identified, described, and explained in Part II of this report (Experiment Methodology).

10.9 The contractor shall report all efforts, results, and progress in a Monthly Progress Report **(Deliverable No. 2)**.

Monthly progress reports were submitted throughout the prosecution of this contract.

10.10 At the end of the period of performance, the contractor shall provide an archive CD-ROM of all deliverables under this task order. The CD-ROM shall be marked with the Contract Number, Task Order Number, and the Operating System, including the office suite and software products used to create the deliverables contained on the CD-ROM **(Deliverable No. 3)**.

The contents of the CD that serves as deliverable 3 include an electronic version of this report as well as some supporting documents. The contents of this CD are listed in Appendix H.

11. Estimating Effective Sweep Width

One of the goals of the experiment was to look at simple field measurements that might predict ESW values. A field method to quickly estimate the effective sweep width would be a tremendous benefit to the search community. In order to plan, conduct, and analyze a sweep width experiment currently takes 56 hours per experiment. This serves as a major impediment to the quick adoption of sweep width to better determine POD. However, as previously explained in section 2.3 a direct relationship between AMDR and sweep width does not exist. Any relationship would have to be experimentally observed for each major ecoregion. The method used to determine the Average Maximum Detection Range (AMDR) has already been described (Fig. 3.3). The AMDR measurement (as described in this report) integrates the three major factors that influence detections in the land environment. These factors are the amount of vertical obstructions (density of trees), horizontal obstructions (height of ground cover), and nature of terrain (objects can be hidden in small dips or gullys). In addition, the procedure takes into account the ability of the sensor (searcher), the environment, and the search object. The AMDR procedure is also based upon both the initial detection range and the distance the object can no longer be sighted (the usual description of maximum detection range).

ESW (AMDR)	VA	NM	WA	VA	CA
Location	Shenandoah NP	Lincoln National Forest	Gifford National Forest	Lansdowne	Mt. Diablo State Park
Ecoregion code	M221	M311	M242	231	M261
Season	Winter	Spring	Summer	Summer	Summer
White/Orange	142 (80)	62 (37)	36 (34)	73 (33)	82 (41)
Blue	106 (82)	67 (34)	32 (29)	54 (27)	61 (32)
Green	-	-	17 (17)	31 (22)	16 (14)
Clue	-	-	8 (-)[b]	- (9)[a]	20 (10)

Note. Values in parentheses are AMDR values. All values in meters.
[a] Clues were not used in Lansdowne although an AMDR was determined for them (glove).
[b] Clues were used in Washington but an AMDR was not determined for them (glove).

Table 11-1. Relationship between $AMDR_{avg}$ and ESW.

Table 11-1 gives both the ESW and AMDR values (in parentheses) determined from all the experiments. Table 11-2 gives the ESW and AMDR values (in parentheses) derived from the West Virginia Logan Experiment.

ESW (AMDR)	WV
Location	Logan
Ecoregion code	M221
Season	Summer
White/Orange	-
Blue	58 (25)
Green	-
Clue	32 (15)

Note. In parentheses are AMDR values. All values in meters.

Table 11-2. Relationship between $AMDR_{avg}$ and ESW for Logan experiment.

The relationship between ESW and AMDR cannot be determined at this time; however, the results are tabulated below in Table 11-1. The results from the West Virginia pilot experiment are included since they used a similar methodology. The black plastic bags used in the WV experiment are most similar to the dark blue adult manikins used in this study. The West Virginia results are shown in table 11-2. In order to best see the relationship between ESW and AMDR, Table 11-3 shows the ratio between ESW and AMDR.

	Washington	Virginia	Virginia	California	New Mexico	WVA
Season	Summer	Summer	Winter	Summer	Spring	Summer
ESW O/W	36 m (34) 1.1	73 m (33) 2.2	142 m (80) 1.8	82 m (41) 2.0	62 m (37) 1.7	
ESW Blue	32 m (29) 1.1	54 m (27) 2.0	106 m (82) 1.3	61 m (32) 1.9	67 m (34) 2.0	58 (25) 2.3
ESW Green	17 m (17) 1.0	31 m (22) 1.4	-	16 m (14) 1.1	-	
ESW Clue	8 m (NA) NA	-	-	20 m (10) 2.0	-	32 m (15) 2.1

Note. Estimated sweep width (ESW) values are listed first in each cell above, AMDR values are in parentheses, the ratio of ESW to AMDR is shown in bold, and all values are in meters. Values darkly shaded in orange had a ratio close to 1. Values lightly shaded in green had a ratio close to 2.

Table 11-3. Relationship between $AMDR_{avg}$ and effective sweep width.

As shown in these tables, the comparative values of ESW and AMDR seemed to be divided into two distinct groups. One group seemed to cluster around a one-to-one relationship where ESW and AMDR were about the same value. The other group seemed to cluster around a two-to-one relationship where ESW was about twice the AMDR value. Since there is no theoretical basis for believing that any consistent relationship exists, more experiments with more searchers and more objects in more environments may show a more continuous range of ratios. In fact, even with the same environment and same object this may turn out to be the case over the course of several experiments. This is because an AMDR experiment involves only one ***alerted*** searcher at one specific point in the environment looking at one placement of an object for one brief period of time. In contrast, the full detection experiment involves a number of ***unalerted*** searchers traveling for a significant length of time through a significant area searching for a number of identical search objects.

It is worth noting that in many cases the ESW was approximately twice the AMDR. This was often the case for the high-visibility adult size and high-visibility clue size search objects. This was also the case for the medium-visibility blue adult size search objects for four of the six experiments. The ESW equaled—or nearly so—the AMDR for the low-visibility green adult-sized search objects in all of the experiments. During the Washington experiment the relationship between ESW and AMDR was close to one for all the search object types. Factors unique to the Washington experiment included the highest ground vegetation (1.5 – 2 feet) coupled with the densest vertical growth (lowest laser range finder return distance), limitations in atmospheric visibility (falling to one mile at some points), nearly constant cloud cover (96% average), and precipitation ranging from none to heavy. At this point in time no correction factors for any of these conditions exist for the ground SAR environment. However, experience from maritime and air SAR experiments suggest several of these factors may have affected the results.

At this time it is premature to state that any reliable and quantifiable relationship exists between AMDR and ESW, even at an empirical level. While it appears in the data gathered so far that ESW is double the AMDR for high and medium visibility search objects, the same for low visibility search objects, and the same for all search objects in a dense environment, there is simply not enough data to support this attractive simple "rule of thumb." In order to confirm the relationship, several steps need to be taken. First, the Washington experiment needs to be repeated on a day without precipitation and limiting meteorological factors. Experiments also need to be conducted in the other six major Ecoregion divisions. It would also be useful to repeat the experiments in those Ecoregions already tested to confirm the finding. Then it might be possible to suggest relationships for various situations based on empirical evidence. However, this tempting possibility may also turn out to be a chimera.

The statement that the ESW will usually fall somewhere between 1 and 2 times the AMDR does seem to be reasonable. Search theory dictates that the ESW cannot be greater than twice the maximum detection range and that it can reach such a value only with "perfect" definite range detection. It seems plausible that the practical upper bound for ESW would probably be around twice the ***Average*** Maximum Detection Range (AMDR) that is found using the procedure described in Chapter 3. It is still possible to detect objects beyond the AMDR since it is only an average of detection ranges and not the maximum value, just as objects may be detected outside of the ESW. In fact, it is important that searchers look beyond the distance established by the ESW because, by definition, some detections will be made beyond it. The lower bound is less clear but a normal lower bound of one times the AMDR in practice would not be too surprising, even though lower values are definitely possible.

The desire to find a reliable, quantitative relationship between AMDR and ESW is understandable for several reasons. First, AMDR experiments are much easier and faster to perform. Second, they can be performed at the scene of an actual search without detracting significantly from the available search resources. Third, if the benefits of ESW, namely objective POD estimation and optimal effort allocation, are to be realized in the near term before a significantly large number of detection experiments can be undertaken to determine ESW values for the very large variety of search objects and environments that are routinely encountered, some interim estimation technique for ESW values is needed. In light of the analysis and discussion given above, it is recommended, with considerable trepidation, that in the absence of ESW values found by the experimental technique described in this report, the ESW be estimated as 1.5 times the AMDR.

However, the temptation to forgo detection experiments entirely by taking the easy way out and use only the rough guess that ESW is about 1.5 times AMDR on average should be strongly resisted. Detection experiments of the type described in this report provide not only valid ESW results, they also provide a unique training opportunity and learning experience for searchers. This was borne out repeatedly by comments from the participants in all the experiments done to date. The experiments would have been even more instructive for the searchers if there had been time to walk each searcher through the course a second time to show them which objects they detected and, more importantly, which objects they missed. Observing the techniques of different searchers is also very instructive for those who must train searchers.

12. 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 that used the graph in Figure 9-2 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 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. 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 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.

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.

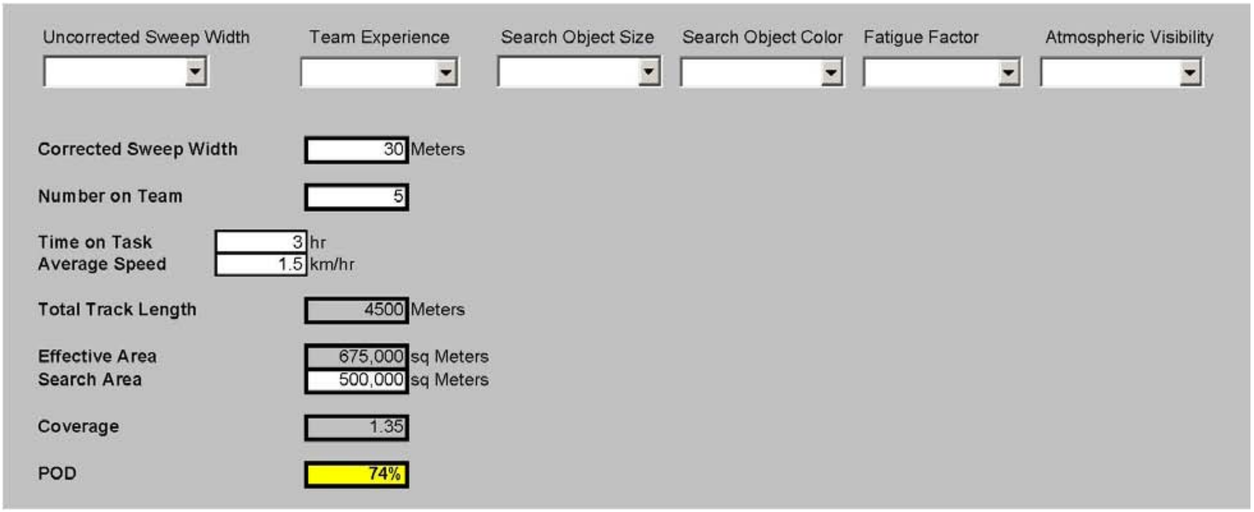

Figure 12-1. POD Calculator (potential spreadsheet).

Figure 12-1 illustrates a potential spreadsheet used to determine a team's POD. The uncorrected sweep width value is selected by choosing a list of options of potential vegetation types. The actual sweep width values are determined through experimentation. Pictures may be included to assist the briefer or search planner find the most appropriate terrain and vegetation. The debriefer then can ask a series of objective questions that help determine possible correction factors. The spreadsheet will then automatically calculate the corrected sweep width. The debriefer only needs to input the number of searchers on the team, time on task, average speed, and the size of the search area. Based upon search theory the POD is then calculated and displayed in yellow. The above illustration should only be viewed as a potential guide.

13. Recommendations for Future Work

13.1 Develop Experiment Design Calculator Software

The Experimental Design Calculator should be designed using Microsoft Excel, or something equivalent, which will aid field personnel in:

a. Computing search object positions according to field-derived data at the experiment site,
b. Determining if current experiment design is acceptable
c. Providing a method to input environmental measurements
d. Providing all required forms
e. Providing instructions on all required forms
f. Collecting information on searchers
g. Tabulating the detection results,
h. Graphing the results as lateral range curves and cumulative detection/non-detection (cross-over) curves,
i. Reducing the detection data to obtain sweep width values from both crossover values and area under the lateral range curves,
j. Automating the data analysis procedures and reducing the opportunity for human-induced error.
k. Putting all the data collected into a standard format inclusion in a centralized data set for later analyses—principally to look at secondary effects and estimate correction factors to extend the useful range of the data collected from actual experiments, etc.

Some elements of the above requirements have already been completed in a crude manner for initial use. Some of these features still need refinement and are not suitable for general use as they require considerable manual intervention by someone familiar with the experiment protocol. In addition, the software and briefing materials are not deliverables under the present contract (but they are in the long-range plan).

Additional development already identified for making the Experiment Design Calculator useable for general use includes the following.

13.1.1 Better Automatic Design of the Experiment

Improved automation of the design of the experiment could accomplish the following:

- **Stratified random selection for off-track distances.** Use of the Experimental Design Calculator for the placement of clues proved quite successful. It allowed the calculation of random locations for the placement of clues using only a laptop computer. It became apparent, however, that the unconstrained random distribution of off-track distances could lead to failed experiments. With the small number of targets set-out it was possible for the random numbers to generate clue locations clustered either close to the track or far from the track. It was decided that the optimal distribution for off-track placement should be a random stratified distribution. This change in protocol was accomplished using a manual method versus one built into the Excel spreadsheet. The manual method consisted of looking at 10 meter bins and making sure at least one search object was placed into each 10 meter bin. This step was accomplished prior to search object deployment. The Excel spreadsheet generates not only the needed search object locations but several extra locations, up to a total of 40 locations on the Sweep Width Object Placement Worksheet. If no search object was selected for one of the bin off-track distances, and multiple search objects were selected for another bin (often at an identical distance), then a manual adjustment was made. In order to arrive at a new off-track distance for the missing bin the Sweep Width Object Placement Worksheet was scanned for the first number that fell in the missing bin. It is important to note all decisions were made prior to deployment to the field to prevent the actual terrain and vegetation from influencing search object placement. This scheme for stratified random placement worked well throughout the experiments. However, it is difficult to describe. It is recommended that this feature be built into the future Experimental Design Calculator.

- **Use each search objects' AMDR to determine lateral range.** During all the experiments the lateral range was determined by the most visible or longest range AMDR. This worked well when combining a high visibility adult manikin and a medium visibility adult manikin. It did not work well when combining a low visibility adult manikin with a small glove size clue. The off-track distances for all the gloves where determined by the adult size manikin. It became apparent out in the field that if the object placement worksheet was strictly followed, almost no gloves would have any chance of being seen. Therefore, the immediate strategy of dividing the specified distance by three was adopted. This strategy worked well, the locations were still based upon random numbers, but several of the gloves could actually be seen. The cross-over point occurred at a distance of 3.6 meters. This allowed four gloves to be at a distance shorter than the cross-over and seven gloves beyond the cross-over. However, such adjustments should not normally be made in the field, especially by those not familiar with experimental design. The better solution is to redesign the Experimental Design Calculator to be based upon each search objects AMDR when determining the off-track distance for each object type.

- **Combine more search objects.** Currently the Experimental Design Calculator is limited to two search objects. This was done in part since the lateral range was determined by the most visible object's AMDR. In fact, two experiments had four search objects, one had three search objects, and two had the listed two search objects. The addition of more than two search objects had to be handled manually and is difficult to explain but easy to put into practice. No practical programming reason limits the Calculator to just two clues. In fact, the addition of AMDR measurements for all search objects, will facilitate better record keeping. It will also solve the problem of different off-track distance calculations.

13.1.2 Redesign or Create additional Forms

- **Collect more searcher data.** During the first experiment, the data loggers noticed several physical features that appear to impair searching. The Searcher Profile sheet did not collect information on whether the searcher was wearing a hood, cap, sunglasses, or anything else that might limit vision. In addition, searcher techniques were not collected. (A suitable methodology was never developed to collect this type of data during subsequent experiments.

An enhancement to the Searcher Profile form, detection log or some additional form carried by the data logger could capture information on searcher technique.)

- **Need to collect occupation.** During this experiment searchers participated who had never been on an actual search. Several of these participants detected far above normal numbers of search objects compared to the rest of the participants. The data loggers in conversations noted that, while lacking traditional search experience, the searchers had considerable visual experience that required looking for objects often at visual infinity. Questions that collect information on visual experience or occupation need to be added to the Searcher Profile form.

- **Delete portions of the Searcher Profile**. Some questions on the Searcher Profile form were not asked by debriefers due to complexity or lack of understanding on the part of the searchers. These questions can be dropped from the form.

- **Create search object form.** After placing a search object, rough notes were placed on the search object form regarding the ability to see the search object. Often qualitative terms where used such as easy, difficult, or impossible. In other cases a more objective approach was written down such as "visible from 1150m–1160m track line distance, only while looking back." A revised Search Object Location Log form that better characterizes the search object's placement could be a benefit in future search experiments, especially if improvements are made in describing how searchers actually look.

- **Better measure weather.** During the Washington experiment the weather was quite variable. From periods of hard rain, to limited visibility, to overcast skies. Better equipment to monitor and record environmental information could be useful for determination of correction factors.

13.2 Determine and Calculate Significant ESW Correction Factors

- Identify correction factors. Determining correction factors was beyond the scope of the current experiments. However, data was collected that would allow calculation of several correction factors. More importantly at this initial stage, factors that were significant could be identified. In addition and often as a surprise to the researchers, factors were identified that were not significant. No statistical analysis has been conducted to calculate what the actual correction factors should be.

- Correction factors that appear significant were colorblindness, height, age, fatigue, morale, and specific type of SAR training. Physical environmental factors were not controlled for during these experiments, therefore the traditional correction factors such as light, precipitation, metrological visibility, and wind were not tested. Since more than half of all ground SAR incidents occur at night, that correction factor is critical to determine for the adoption of Effective Sweep Width concepts. The importance of light levels on detection is well documented (Koopman, 1980, Appendix E) and any nighttime experiment would need to be set up differently from a daytime experiment. Determining the correction factor for precipitation will require setting up a more permanent course in a location where searchers can be sent through the course on a sunny day and one with precipitation.

- Correction factors that appeared insignificant were gender, years of experience in SAR, number of field searches in SAR, and searcher speed (within the narrow confines of 1-3 km/hr).

- Determination of many correction factors would require setting up one course in a location convenient to the researchers. This single course would allow control for vegetation and terrain when other factors are examined. A semi-permanent course would save considerable logistical effort. It would need to be scouted, flagged, and marked only once. Search objects could easily be moved to allow the same searchers to participate multiple times when looking at different factors. Such a course could be used for determine weather factors, results of different type of headwear, different types of search techniques, etc. The requirement for such a course:
    - Convenient to researchers to minimize cost
    - Area subject to four seasons
    - Contains both deciduous forest and coniferous forest
    - Area subject to snow
    - Falls into the humid temperate domain
    - Has a large pool of search volunteers available from different teams
    - Facilities for coordinating all search volunteers
    - Site has good logistical support
    - Site is uniform and representative of area.

  Potential sites have been identified in Virginia (site of two highly successful experiments) that satisfies these conditions. Additional logistical work would be required to establish a semi- permanent course.

13.3 Conduct additional experiments.

- Additional experiments are needed to determine Effective Sweep Width values in several other Ecoregions. The current experiments only covered 5 Ecoregions. The results clearly show that each Ecoregion gives a different Effective Sweep Width. Unfortunately, the United States has 52 different Ecoregion provinces. One of the purposes of these experiments was to develop a methodology and set of instructions that would allow others to conduct detection experiments. The research team is greatly encouraged by all who have participated in the experiments so far and who have expressed a great deal of interest and enthusiasm for this work. Many individuals have volunteered, without prompting, to participate in future experiments as either searchers or data recorders (getting sufficient data recorders is always a problem, it seems). Some organizations, such as the state of Maryland, have volunteered to set up experiments if they can get some expert assistance. However, after conducting several experiments it is clear that they cannot be easily and reliably reproduced by others without some amount of hands on training.

- All members of the experiment team are skeptical that someone will be able to read this document and with that reading alone will then be able to conduct a valid experiment. It may be possible for those with an experimental scientific background, but required adjustments that may needed in the field may be difficult to understand and implement. For those unfamiliar with this research subject, reading this document for the first time will probably prove inadequate. It simply is too different from anything they have done before, and will appear even more demanding than it actually is. A completed Experimental Design Calculator will be an important and useful tool, but as it exists right now, it requires too many manual modifications for the layout of an experiment. Therefore the team recommends

  - Holding classroom training sessions, either by special arrangements or at places like SAR conferences for those interested in hosting experiments. Such training would be specifically aimed at the set up, operation of the experiment, break down, and analysis using the revised Experimental Design Calculator. It would be followed by actual on-site practical exercises.

  - An alternative method and the preferred recommendation is to couple the training session with the assignment of an experienced experiment team member for actual on-site assistance during the first experiment conducted by each interested group. With such training and some planning, the logistics burden experienced during the experiments could be significantly less. This scenario would couple a train-the-trainer classroom experience with mentored on the job training.

- Additional experiments are required to determine highly significant factors for ground searches. At this time no experiments have been conducted for child size search objects, responsive subjects, missing aircraft, in most of the Ecoregion provinces, and for determining whether a reliable empirical relationship between AMDR and ESW exists.

  - A sweep width experiment needs to be conducted in each of the 14 Ecoregion divisions found in the US. The current set of experiments covered five different Ecoregion divisions. At the very least additional experiments are required to discover if the relationship seen between AMDR and Sweep Width holds true over a wider range of Ecoregions. Only one Ecoregion province was tested from the dry domain during the five experiments. Before stating that AMDR may be used to estimate the ESW further experiments are required. Additional experiments are also required in dense vegetation to see if the "exception" to the relationship is true.

  - The initial results of the experiments suggest a relationship between the AMDR and the ESW. If these results prove to be valid from additional experiments from different Ecoregions then it could prove to be a significant short-cut to determining ESW values. Instead of the need to conduct an ESW in each of the 52 Ecoregion provinces, experiments could be limited to the 14 Ecoregion divisions and validating the relationship between AMDR and ESW validated. More importantly, searchers could collect AMDR measurement for the unique terrain and vegetation they are conducting the search. The relationship must be tested in at least all 14 of the Ecoregion divisions. The Washington experiment (Marine environment) should be repeated to see if the exception to the AMDR/ESW relationship was due to the density of the terrain or the overcast/rain conditions that occurred.

  - None of the experiments used a child size search objects. Lost children make up a significant portion of a search and rescue team's case load. Using data from adults or clues would be misleading. An appropriate manikin needs to be developed following the same development protocol used for constructing the adult manikins (research into the physical dimensions of the average child, determination of the “radar” cross-section that is seen by a searcher, finding light-weight, portable, inexpensive material that can be used to make an appropriately sized “child-manikin”, etc.). Finally, conducting trail sweep width experiments for a high, medium, and low visibility child.

- None of the experiments were designed to determine the sweep width for an upright responsive subject. This represents the most common scenario seen on search incidents. A method would need to be developed that would allow the search object to be affixed upright and to make a calibrated amount of sound at random intervals and in response to searcher’s calls. It would be expected that correction factors may also be different in this scenario. Light levels may become less important and ambient wind generated noise and searchers hearing acuity could be the most significant correction factors.

- Experiments need to be conducted for several different SAR resources. The current design methodology proved successful for testing riders mounted on horses. However, it was also observed that some simple modifications to the markers on the course and the form used to collect detection data would have benefited mounted searchers. Other SAR resources would only require minor modifications. Resources that operate by staying on a road or trail include bike teams, motorcycle teams, snowmobiles, and ATVs. Only minor modifications to the markings on the track would be required to account for higher speeds. Extensive modification of the methodology is required to determine whether valid ESW values can be determined for, and account for the unique operating method of, air-scent dogs.

- Existing 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.

  - Conduct 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 (both fixed and rotary wing).
  - 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.
  - 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 (IMO/ICAO, 1999a-c) 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.

13.4 Create a Central Depository for All Land Sweep Width Experiments

- The current Experimental Design Calculator's last spreadsheet summarizes all of the data for the entire experiment, including individual data. While still in a rough format and needing further improvement, this can be an important tool for future researchers. The Calculator needs to be improved so all of the experiments' data exists in one database.

- Putting all the data collected into a standard format that could be sent to a centralized data collection point for later analysis would be an immeasurable benefit.

- A central depository needs to be identified, funded, and advertised so that future experiments are archived. Additional funding to have a skilled analyst perform additional data analysis should be supported.

13.5 Create Computer-Based Tools for Land SAR

- The potential value of computers applied to the search problem is certainly nothing new. Nearly three decades ago, Syrotuck (1975) realized the potential of the devices when the author made this statement on their use:

  Detailed search plans could easily be called from the computer, such as specific areas to search and by which resource, the time it would take, and the probability of success.… A centralized Computer Search Planning System that was used by many agencies, in a short time, would gain far more "experience" than any individual contributor. However, each contributor would gain by the collective experience of all the others.… The cost of the entire system may be more than its' ultimate value. However, what is the value of a "life?" (p. 35).

- Although some tools exist, and at least one would come close to correctly performing the optimal effort allocation function if given the correct data and enough running time, it does not appear that any adequate computer-based search planning aids exist. Even for a tool like CASIE III that could find a near optimal effort allocation solution in a large but finite set of possible resource-segment assignments, sweep width data and some significant off-line work would be required to correctly generate the needed inputs. Computerized tools based on a correct implementation of search theory principles are needed just as badly as the basic methodology itself. The computer tools must be fully integrated with this improved approach. Furthermore, it should be possible to develop such tools, suitable for use on laptop computers, for only a relatively modest investment.

13.6 Create a Tool that Calculates POD using ESW and Correction Factors

- Provide a practical probability of detection (POD) estimation procedure with worksheets, graphs and/or other appropriate job aids that is suitable for land SAR based on proven scientific concepts. The procedure will produce objective, accurate, consistent, and reliable POD estimates, replacing current subjective techniques.

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Appendix A

Selected Inland Search Definitions

From Cooper & Frost, 1999a

Introduction

In reviewing the inland search literature, it quickly becomes apparent that confusion is likely when a term is defined differently in various locations or when two terms are used to mean the same thing. It is recognized that many of these terms are not currently in general use in the ground search and rescue (SAR) literature. It is the intention of the authors here to offer factual, scientifically based definitions for terms that may be used in ground SAR operations and planning. In the interest of standardizing this terminology and reducing confusion, the authors also suggest that the following list of definitions and terminology be accepted and used by the inland search and rescue community.

The origins of many of the terms contained herein vary widely but includes operations research literature, international SAR literature (e.g., *The International Aeronautical and Maritime Search and Rescue* (IAMSAR) *Manual*) as well as conventional probability and statistics references.

Notation

A descriptive and complete notation is required to insure that terms are not confused. The notations illustrated in Sidebar A1 will be used to insure accuracy and consistency.

Selected Definitions

Area Effectively Swept (Z) – A measure of the area that can be (or was) effectively searched by searchers within the limits of search speed, endurance, and effective sweep width (IMO/ICAO, 1999b). The *area effectively swept* (Z) equals the effective sweep width (W) times search speed (V) times hours spent searching (exclusive of transits, breaks, etc.) in the search area (T) (Z = W x V x T) for one searcher or one resource (such as a boat or aircraft and its crew). Alternately, Z = W x D, where D is the linear distance traveled while searching. The *area effectively swept* is described in units of area (i.e., square miles, etc.). If multiple searchers simultaneously follow independent paths when searching and together achieve approximately uniform coverage of the segment, then the total *area effectively swept* is given by Z = n x W x V x T where n is the number of searchers. "*Area Effectively Swept*" is also referred to as "Search Effort" and the linear distance traveled is also referred to as "Resource Effort" or just "Effort." Note: The amount of *area effectively swept* does **not** equal the amount of ground actually viewed by the searchers while searching. The amount of *area effectively swept* is the amount of area that would have been swept by a hypothetical sensor that was perfect (100% effective) over a swath as wide as the effective sweep width centered on each searcher's track and completely ineffective (i.e., made no detections) outside that swath. No such sensor exists, of course, but the concept of "*area effectively swept*" is nevertheless valid and useful for computing coverage, and using coverage to estimate probability of detection (POD).

Coverage (C, also known as Coverage Factor, Normalized Effort Density) – The ratio of the area effectively swept (Z) to the area searched (A) or C = Z/A (IMO/ICAO, 1999b). For parallel sweep searches where the searcher tracks are perfectly straight, parallel, equally spaced, and the area covered is a parallelogram one-half track space larger than the pattern of parallel tracks on all sides, *Coverage* may be computed as the ratio of effective sweep width (W) to track spacing (S) or C = W/S. "A" (area searched) and "Z" (area effectively swept) must be described in the same units of area. "W" (effective sweep width) and "S" (track spacing) must be expressed in the same units of length. *Coverage* may be thought of as a measure of "thoroughness." The POD of a search is determined by the coverage, as shown in Figure A1 (Koopman 1946). Perfectly executed parallel sweep searches under ideal search conditions may achieve POD values somewhat higher than those shown in Figure A1. On the other hand, systematic errors or biases in the actual performance of a search that prevent uniform coverage may result in POD values below the curve shown in Figure A1.

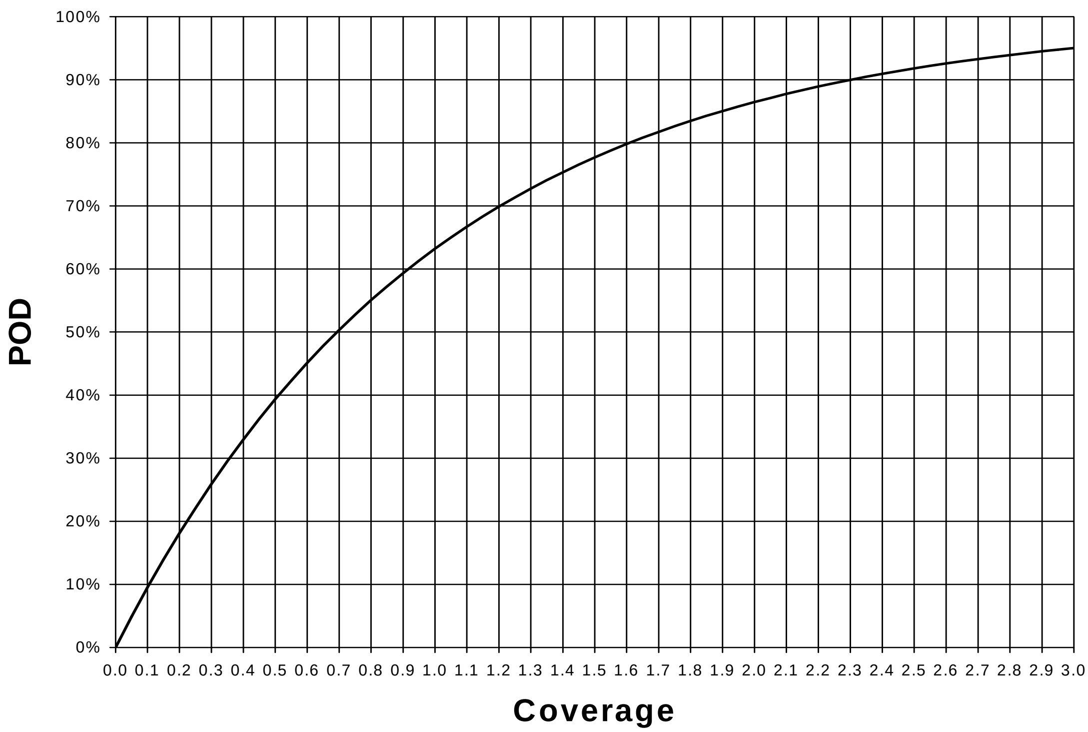

Figure A1. POD vs. Coverage (Koopman, 1946)

Defective Distribution (also known as Defective Probability Density Distribution) – A probability density distribution that contains less than 100% of the search object's possible locations under a given scenario or set of scenarios. (Stone, 1989).

Effective Sweep Width (W) **–** A measure of the effectiveness with which a particular sensor can detect a particular object under specific environmental conditions (IMO/ICAO, 1999b). A measure of "detectability." *Effective sweep width* depends on the search object, the sensor and the environmental conditions prevailing at the time and place of the search. There is no truly simple or intuitive definition. Actual *effective sweep width* values for specific situations must be determined by rigorous scientific experiments. However, reasonably accurate estimates may be made from tables of *effective sweep widths* that have been determined by rigorous experiments for various typical search situations by applying appropriate "correction factors" to accommodate other search situations. A less accurate method of estimation for visual search is to assume the *effective sweep width* equals the "visual distance," or average maximum detection range (both of which are different ways of thinking of the same value). Since the relationship between *effective sweep width* and maximum detection range is not consistent across all search situations, this method may either over-estimate or under-estimate the correct value. Therefore, it should be used only until more accurate *effective sweep width* data is available. Robe and Frost (2002) describes a procedure for conducting detection experiments from which effective sweep width values may be estimated.

The *effective sweep width* may be thought of as the width of a swath centered on the sensor's track such that the probability of failing to detect an object within that width equals the probability of detecting the same object if it lies outside that width, assuming the object is equally likely to be anywhere. Another equivalent definition is: If a searcher passes through a swarm of identical stationary objects uniformly distributed over a large area, then the *effective search (or sweep) width* (*W*) is defined by the equation,

$$W = \frac{\text{Number of Objects Detected Per Unit Time}}{(\text{Number of Objects Per Unit Area}) \times (\text{Searcher Speed})},$$

where all values are averages over a statistically significant sampling period (Koopman 1946). Note that *effective sweep width* values are at least partially dependent on search speed. Generally speaking, a significant increase in search speed will decrease the *effective sweep width*. *Sweep width* (W) is needed to compute the area effectively swept (search effort or Z), and Z is needed to compute the coverage (C) based on the amount of search effort expended in the segment relative to the segment's physical area. The POD may then be derived from the POD vs. Coverage graph (Figure A1).

Effort – The linear distance traveled by searcher(s) or resource(s) while searching in a segment. For one searcher or resource, it is computed as (V x T). For multiple searchers it is computed as the sum of the distances traveled by each searcher, or, if all searched for the same amount of time at the same speed, it may be computed as (n x V x T) where n is the number of searchers. Also known as *track line length* (TLL). The unit of measure for *Effort* is in linear distance. Used in the calculation of *Area Effectively Swept.*

Estimated Position (EP) **–** Last computed or estimated position for a lost search object.

Last Known Position (LKP) **–** Last witnessed or reported position of a lost search object (IMO/ICAO, 1999b).

On Scene Endurance – The amount of time a facility (resource) may spend at the scene engaged in search and rescue activities (IMO/ICAO, 1999b).

Optimal Resource Allocation – The process of determining where to assign the available search resources so that they produce the maximum possible probability of success (POS) in the minimum time.

Optimal Search Plan – A plan that maximizes the probability of finding the search object in the minimum amount of time by using the results of the optimal resource allocation process.

Parallel Sweep Search – A search tactic where one or more sensors, searchers, or resources (e.g., a helicopter) search an area by following a pattern of straight equally-spaced parallel tracks. Primarily used by vessels and aircraft, and for very thorough ground searches (e.g., evidence searches in conjunction with police investigations). Advantages include more uniform coverage of open areas and often a somewhat higher POD in such areas for a given level of effort than other techniques. While it is always a good idea to search any area in an organized fashion with a uniform coverage (until sufficient evidence is discovered to suggest another technique, such as tracking), in many ground search situations the terrain and ground cover make strict maintenance of straight tracks and equal spacing both impractical and counter-productive. However, an approximation to a *parallel sweep search*, such as "purposeful wandering" in parallel corridors, is often useful to help assure reasonably uniform coverage. Care must be taken to ensure the level of effort (distance traveled) is accurately estimated when searches do not follow straight, parallel tracks, even when they remain in parallel corridors. The C = W/S formula only works when the searcher tracks themselves are perfectly straight, parallel, and equally spaced, and the area covered is a parallelogram one-half track space larger than the pattern of parallel tracks on all sides. The formula should never be used under other circumstances. The formula C = Z/A always works, however.

Possibility Area – (1) The smallest area containing all possible survivor or search object locations. (2) For a scenario, the *possibility area* is the smallest area containing all possible survivor or search object locations that are consistent with the facts and assumptions used to form the scenario (IMO/ICAO, 1999b).

Probability Density (Pden) **–** The ratio of a region's or a segment's probability of area (POA) to its physical area.

[1]
$$\text{Pden} = \frac{\text{POA}}{\text{Area}}$$

Probability Map – An illustration of the distribution of search object location probability over the possibility area where each cell or region is labeled with the probability of the search object being in that cell or region (IMO/ICAO, 1999b). Initially, *probability maps* are formed from a largely subjective analysis of the available information (LKP, terrain, evidence, clues, historical trends, lost person behavior profiles, etc.). This information is evaluated to determine regions (see "Region") where the subject might be at the time of the search based on one or more scenarios (see “Scenario”). It quantifies the probability of the subject being in each region, as shown in Figure A2. (See “Initial POA” under “Probability of Area.”)

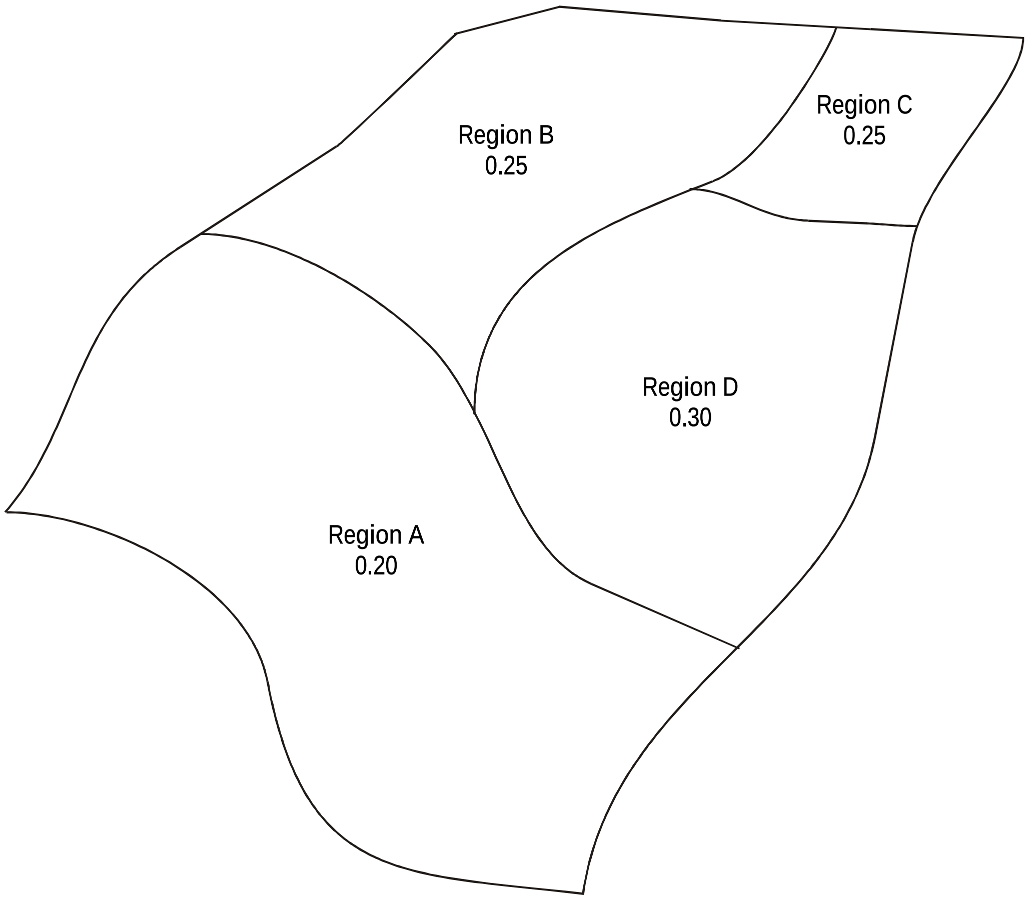

Figure A2. A search area with four regions and their POA values after a consensus.

If the regions are subdivided into searchable segments, segment POA values are determined from the regional POA in proportion to the segment areas. It is assumed that the probability density (Pden) is constant throughout any one region. That is, the ratio of segment POA to region POA is the same as the ratio of segment area to region area, as shown in Figure A3. If the Pden is not constant throughout any one region, the number of regions and choice of regional boundaries should be refined until it is no longer possible to distinguish parts of regions on the basis of Pden.

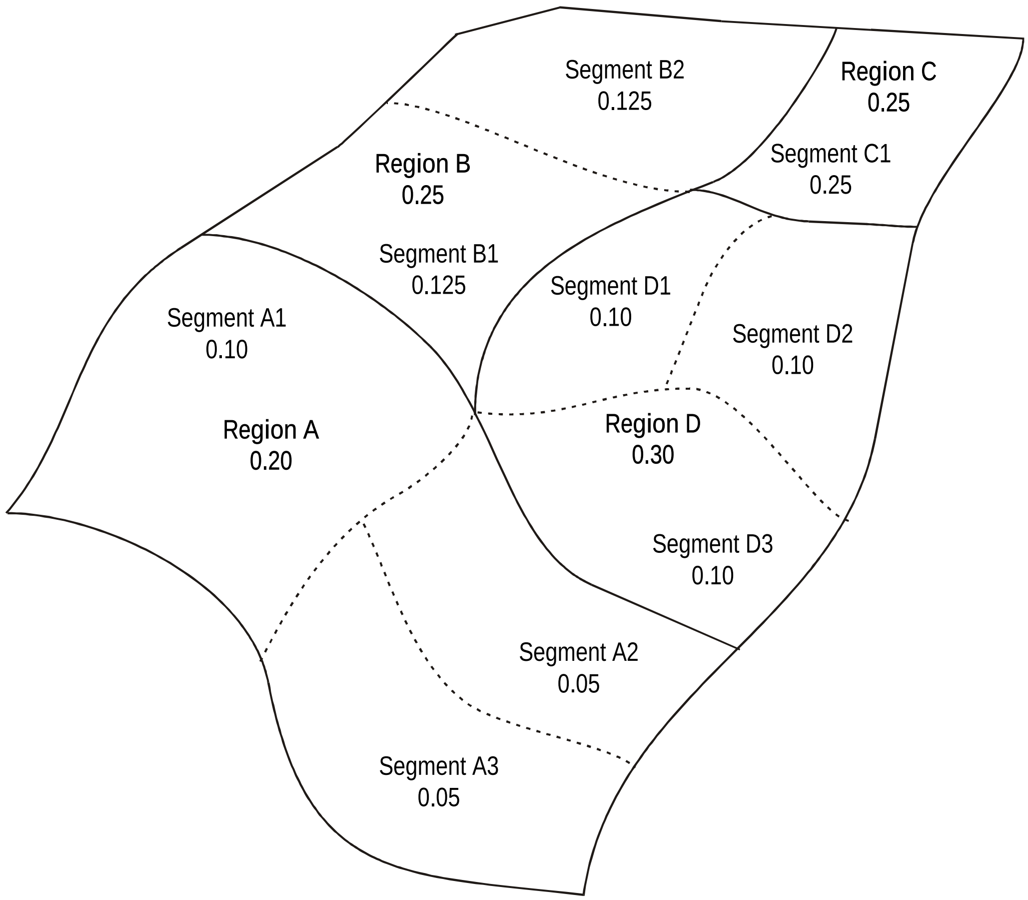

Figure A3. Segments within regions and their associated POA values.

In its purest mathematical form, a *probability map* consists of a regular grid of cells all of equal area as shown in Figure A4. Cellular probabilities are determined in the same way as segment probabilities. That is, each cell is assigned a fraction of the region's POA value in proportion to the fraction of the region's area contained in each cell. For cells that span regional boundaries, POA values are computed as the sum of the contributions from each region, pro-rated by the fractions of the regional areas contained in the cell. Although most useful in an open "unbounded" uniform environment (e.g., the ocean), this type of display may also be useful in mixed environments and has at least one advantage. When all the cells all have the same area, the POA values are proportional to the probability density (Pden) values so it is easy to tell at a glance where both POA and Pden values are high and where they are low. Note that by examining those cells that are completely contained within a region, it is clear that Region C has the highest density. It is also possible to tell that the Pden in Region C is nearly three times that of Region D. With segments or regions having unequal areas, it is possible to have a high POA and a low Pden and vice versa. Note that the POA of Region C is less than that of Region D. In general, Pden is more important to optimal resource allocation than POA.

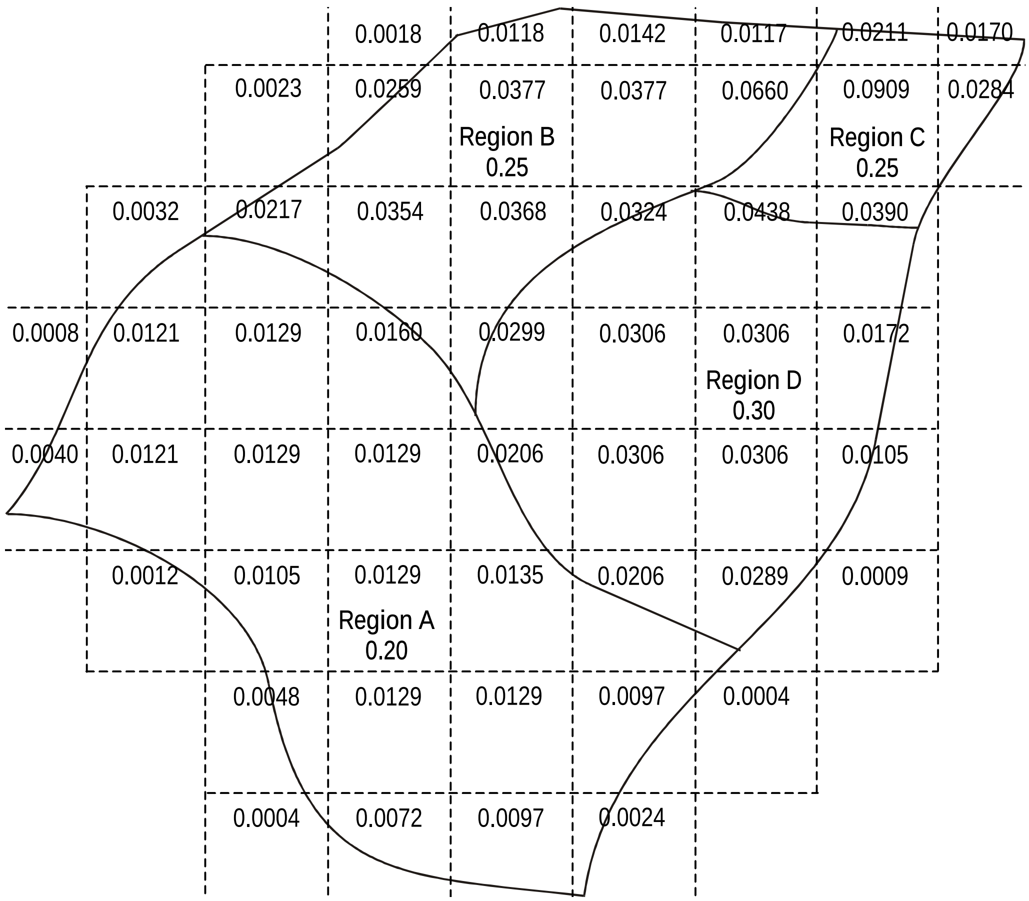

Figure A4. A search area showing regions and a grid overlay.

A *probability map* may be made more readable by multiplying all the probabilities by some convenient constant. For example, if the cellular probabilities were all multiplied by 100, then 0.0129 would become 1.29%. Another technique (used in the original version of the U. S. Coast Guard's Computer Assisted Search Planning (CASP) system) is to multiply all the cellular probabilities by 10,000 and record the results as whole numbers. In this case, 0.0129 would become 129.

Probability of Area (POA, also known as Probability of Containment or POC) – The probability that the search object is contained within the boundaries of a region, segment, or other geographic area. Regional *POA* values are generally determined by consensus and scenario analysis. Segment *POA* values may be computed from regional probability densities and segment areas.

Adjusted, Shifted or Updated POA ($POA_{s,n}$) – The modified POA of a segment after an unsuccessful search in that segment. Used to measure the decrease in the probability that the search object is in the segment after the segment has been searched. The following equations represent various methods of obtaining $POA_{s,n}$.

[2] $$POA_{s,n} = POA_{s,n-1} \times (1 - POD_{s,n})$$

[3] $$POA_{s,n} = POA_{s,n-1} - (POD_{s,n} \times POA_{s,n-1})$$

[4] $$POA_{s,n} = POA_{s,n-1} - POS_{s,n}$$

[5] $$POA_{s,n} = POA_{s,0} \times (1 - PODcum_{s})$$

[6] $$POA_{s,n} = POA_{s,0} - (PODcum_{s} \times POA_{s,0})$$

[7] $$POA_{s,n} = POA_{s,0} - POScum_{s}$$

Note: The *adjusted POA* values computed by the above formulas are not normalized. That is, the sum of the *adjusted POA* values will not equal the sum of the initial POA values. The omission of normalization is deliberate and necessary to the correctness of the formulas and definitions presented herein. Removal of the normalization computations does not violate the laws of probability and statistics in this context. Removal of normalization also substantially reduces the computational burden of maintaining *adjusted POA* values and preserves enough information about the search to make all other probability values of interest easily computable.

Initial POA (POAinitial) or *Consensus POA* ($POA_{s,0,c}$) – The initial POA assigned prior to any searching. *Initial POA* values must be based on a careful and thorough evaluation of all the available evidence, data, clues, etc., pertinent to the incident. *Initial POA* values, or the relative values used to compute them, must be in the correct proportions to one another. A region with an assessed value of “8” on a scale of 0 to 10 must be twice as likely, in the view of the evaluator making the assessment, to contain the search object as a region that is assigned a “4.” Similarly, a region with a POA of 20% must actually be viewed as twice as likely to contain the object as one with a POA of 10%. If, upon review before the evaluator submits his/her values the proportional relationships among the regional assessment values do not pass this test, then they should be revised until the evaluator feels they do correctly reflect his/her views in this regard. If the relative assessment values used are in the correct proportions, the POA percentages computed from them will also be in the correct proportions. The consensus POA values computed from the individual assessments should then be an accurate reflection of the collective views of the evaluators.

Ideally, the search area will be divided into some number of regions based on the available evidence, data, clues, etc., which bear on where the subject is more likely and less likely to be at the time of the first search. POA values would then be assigned to these regions. If necessary, these regions may be sub-divided into searchable segments. Segment POA values would be computed by prorating the region's POA among the region's segments by segment area. That is, a segment one-third as large as the region would get one-third of the region's initial POA as its initial POA value. Stated as a formula:

[8] $$POA_{s,0,c} = POA_{R,0,c} \times \frac{A_{s,c}}{A_{R,c}}$$

Where: $POA_{s,0,c}$ is the initial POA value for segment s in region R based on consensus c. Hereafter, it will be assumed that all values are based on the same consensus c if this subscript is omitted.

$POA_{R,0,c}$ is the initial POA value for region R based on consensus c.

$A_{R,c}$ represents the area of region R from consensus c.

$A_{s,c}$ represents the area of segment s in region R.

If a new consensus is necessary and new initial regional and segment POA values are established there is no need to discard all information about previous searching (i.e., segment POD values). Assuming that segment boundaries do not change, new adjusted segment POA values may be computed using the following procedure (the formulas show how to get from the adjusted POA values of the first consensus to those of the second consensus):

- Compute new initial segment POA values based on the new regional POA values from the new consensus using equation [7] above. (Note that $A_{s,2} = A_{s,1}$.)

$$POA_{s,0,2} = POA_{R,0,2} \times \frac{A_{s,2}}{A_{R,2}}$$

- Compute the cumulative POD for each segment (see *Cumulative Segment POD* ($PODcum_{s,n}$) under Probability of Detection below) using equation [9] (preferred) or [10] or [11] below.

$$PODcum_{s,n} = 1 - \left(\frac{POA_{s,n,1}}{POA_{s,0,1}}\right)$$

- Multiply the new initial segment POA by one minus the cumulative segment POD to get the new adjusted POA by using equation [5] above.

$$POA_{s,n,2} = POA_{s,0,2} \times (1 - PODcum_{s,n})$$

Probability of Detection (POD, $POD_{s,n}$) – The probability of the search object being detected, assuming it was in the segment searched. $POD_{s,n}$ measures sensor effectiveness, thoroughness, and quality for search n of segment s. $POD_{s,n}$ is a function of the coverage (C) achieved in segment s by search n, as shown in Figure A1.

Cumulative Segment POD ($PODcum_s$) - After the same segment is searched multiple times, the chances of having detected the search object, if it was present in the segment the whole time, are increased as compared to having searched the segment only once. This increasing probability of detecting a search object after multiple searches in the same segment is called *cumulative segment POD.*

[9] $$PODcum_{s,n} = 1 - \left(\frac{POA_{s,n,1}}{POA_{s,0,1}}\right)$$

[10] $$PODcum_{s,n} = \frac{POScum_{s,n,c}}{POA_{s,0,c}}$$

[11] $$PODcum_s = 1 - ((1 - POD_{s,1,c}) \times (1 - POD_{s,2,c}) \times \ldots \times (1 - POD_{s,n,c}))$$

Predictive POD – estimated POD computed by search planners prior to the search of a segment based on predicted values for effective sweep width (W), area that will be effectively swept (Z), and coverage (C).

Retrospective POD – POD computed by using information obtained from debriefing the searchers to estimate the effective sweep width (W), area effectively swept (Z) and coverage (C) after the search of a segment.

Probability of Success (POS) - The probability of finding the search object with a particular search. POS measures search effectiveness.

Cumulative Probability of Success (POScum) - The accumulated probability of finding the search object with all the search effort expended over all searches to date (IMO/ICAO, 1999b). POS_{cum} may be computed for a segment, in which case it can never exceed the initial segment POA, or it may be computed for all searching in all segments to date (overall POS_{cum} or $OPOS_{cum}$ [see below]), in which case it can never exceed the total of all initial POA values (usually 1.0 or 100%).

Segment POS ($POS_{s,n}$) – The probability of finding the search object in the segment on a particular search (i.e., during a particular operational period).

[12] $$POS_{s,n} = POA_{s,n-1} - POA_{s,n}$$

Segment POS_{cum} ($POScum_s$) – The sum of the POS values for each search in a particular segment.Used to measure the increasing probability that has been "extracted" from the segment by searching. This value can never exceed the initial POA value assigned to the segment. $POScum_s$ is a measure of search effectiveness to date in this segment.

[13] $$POScum_s = POS_{s,1} + POS_{s,2} + \ldots + POS_{s,n}$$

[14] $$POScum_s = POA_{s,0} - POA_{s,n}$$

[15] $$POScum_s = POA_{s,0} \times PODcum_s$$

Overall POS_{cum} ($OPOS_{cum}$) - The sum of all individual segment POScum values. Used to measure the increasing possibility that the search object is outside of the search area and the decreasing probability (1- OPOScum) that further searching based on the present scenario(s) will be successful. $OPOS_{cum}$ is a measure of overall search effectiveness.

[16] $$OPOS_{cum} = \Sigma POA_{s,0} - \Sigma POA_{s,n}$$

[17] $$OPOS_{cum} = \sum_{s=1}^{m} POScum_s$$

Probable Success Rate (PSR) – The rate at which the probability of success (POS) is increased over time as the search progresses. An optimal search plan attains the maximum PSR possible from the available resources.

[18] $$PSR = W \times V \times Pden$$

Where: *W* is the effective sweep width.
V is the search speed.
Pden is the probability density.

Resource Effort – See "Effort."

Region (R) – A subset of the search area based only on factors that affect POA (*regions* may require segmentation prior to searching). *Regions* are based on probability of the search object's location, not on suitability for assigning search resources. A *region* may contain searchable segments, or a *region*, itself, may be a searchable segment. A searchable segment may also contain one or more *regions* (based on probability) but rarely is the available data good enough to distinguish such small r*egions* in ground search situations.

Scenario – A consistent set of known facts and assumptions describing what may have happened to the survivors (IMO/ICAO, 1999b). A description of what the subject(s) may have done and what the subject(s) may have experienced since last seen or known to be safe. A *scenario* should be consistent with a significant part of the available evidence and data. Normally, multiple *scenarios* should be considered, especially when not all the available pieces of evidence and data are consistent with all other pieces.

Search – An operation, normally coordinated, that uses available resources, personnel and facilities to find persons in distress or objects whose exact location is unknown (IMO/ICAO, 1999b).

Search Area – The area, determined by the search planner, that is to be searched. The *search area* may be divided into regions based on the probable scenarios and into segments for the purpose of assigning specific responsibilities to the available search resources (IMO/ICAO, 1999b).

Search and Rescue Facility – Any mobile resource, including designated search and rescue units, used to conduct search and rescue operations (IMO/ICAO, 1999b).

Search and Rescue Unit (SRU) **–** A unit comprised of trained personnel and provided with equipment suitable for the expeditious conduct of search and rescue operations (IMO/ICAO, 1999b).

Search Effort – See “Area Effectively Swept.”

Search Endurance – The amount of “productive” search time available at the scene. (IMO/ICAO, 1999b).

Search Object – A ship, aircraft or other craft missing or in distress or survivors or related search objects or evidence for which a search is being conducted (IMO/ICAO, 1999b). A generic term used to indicate evidence (clue) related to a lost subject or the lost subject. In the same segment, different search objects generally have different effective sweep widths (or “detectabilities”). This means that for any given search of a segment, different coverages, and hence different POD values, will be achieved for different *search objects*.

Search Speed (V) **–** The average rate of travel (speed over the ground) of searchers while engaged in search operations within a segment (IMO/ICAO, 1999b).

Segment (s) **–** A designated sub-area (subset of the search area) to be searched by one or more specifically assigned search resources. The search planner determines the size of a *segment*. The boundaries of a *segment* are identifiable both in the field and on a map and are based on searchability, not probability.

Sensor – Human senses (sight, hearing, touch, etc.), those of specially trained animals (such as dogs), or electronic devices used to detect the object of a search (IMO/ICAO, 1999b). A human, multi-sensor platform is often referred to as a “searcher.”

Sensor Track – The actual path followed by a sensor while engaged in searching. The length of this path is called *Effort*. For example, the actual path followed by a searcher carrying a GPS tracking device can be displayed on several computer-based mapping systems. Often these systems or the GPS receiver itself can compute and display the length of the path between any two recorded points.

Sortie – The individual movement of a resource in conducting a search or rendering assistance (IMO/ICAO, 1999b).

Sweep Width – See “Effective Sweep Width.”

Track Spacing – The perpendicular distance between adjacent tracks of a parallel sweep search pattern.

Sidebar A1 - Notation Used Herein

The first subscript (s) designates the segment or region, i.e., segment s, in this example.

The second subscript (n) designates the search number, i.e., search number n, in this example.

This is the adjusted POA value of segment s after search n, and is based on consensus c.

This is the adjusted POA value of segment s prior to search k, and is based on consensus c.

"k-1" designates the search just prior to search k.

$$POA_{s,n,c} = POA_{s,k-1,c} \times (1 - PODcum_{s,(k,\ldots n)})$$

The third subscript (c) designates the consensus number; that is, consensus 1, consensus 2, etc. This subscript will usually be omitted and presumed to be 1 (the first consensus) unless otherwise specified.

This is the cumulative POD for segment s where (k,…n) is optional and denotes the searches (k through n) included in the computation. For example, $PODcum_{s,(3,4,5)}$ denotes the cumulative POD for searches 3, 4, and 5 only in segment s.

If the (k,…n) subscript is not shown with $PODcum_s$, the inclusion of all searches (i.e., 1, … n) in segment s is implied, making k = 1 everywhere in this equation.

Sidebar A2 – Standard Symbols for Terms Defined Herein

A	Area
C	Coverage
c	Consensus (usually denotes the consensus number, e.g., first consensus, second consensus, etc.)
CASP	Computer Assisted Search Planning (US Coast Guard software)
cum	(as subscript) denotes cumulative value of associated term (e.g., POD_{cum} is cumulative POD)
EP	Estimated Position (usually computed)
LKP	Last Known Position
n	Search number
Pden	Probability Density
POA	Probability of Area
POC	Probability of Containment (identical to POA)
POD	Probability of Detection
POS	Probability of Success
PSR	Probable Success Rate
R	Region
S	(upper case) Track Spacing
s	(lower case) Segment
SRU	Search and Rescue Unit
T	Time
V	Velocity or Speed
W	Effective Sweep Width
Z	Area Effectively Swept (also known as Search Effort)

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Appendix B

Simplified Explanation of 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 C1 shows a schematic representation of the four different designs. We construct the brooms and label them as B1, B2, B3, and B4 respectively.

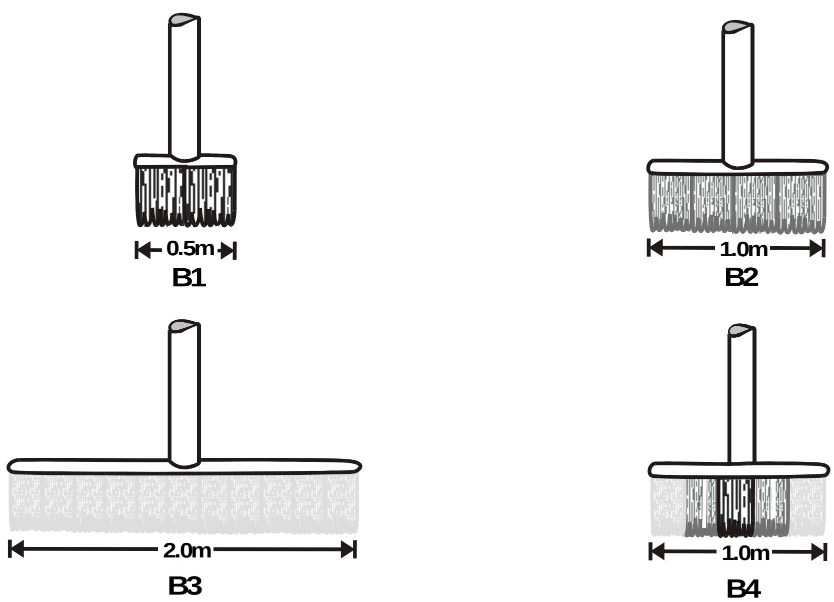

Figure C1. Four brooms (B1, B2, B3, and B4).

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 C2.

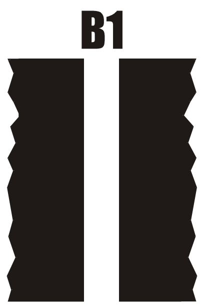

Figure C2. Broom 1 (B1)

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 C3.

Figure C3. Broom 2 (B2).

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 C4.

B3

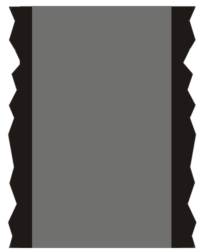

Figure C4. Broom 3 (B3).

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 C5 illustrates the uneven performance of broom B4.

B4

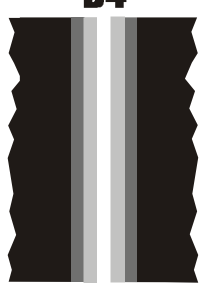

Figure C5. Broom 4 (B4).

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 C6.

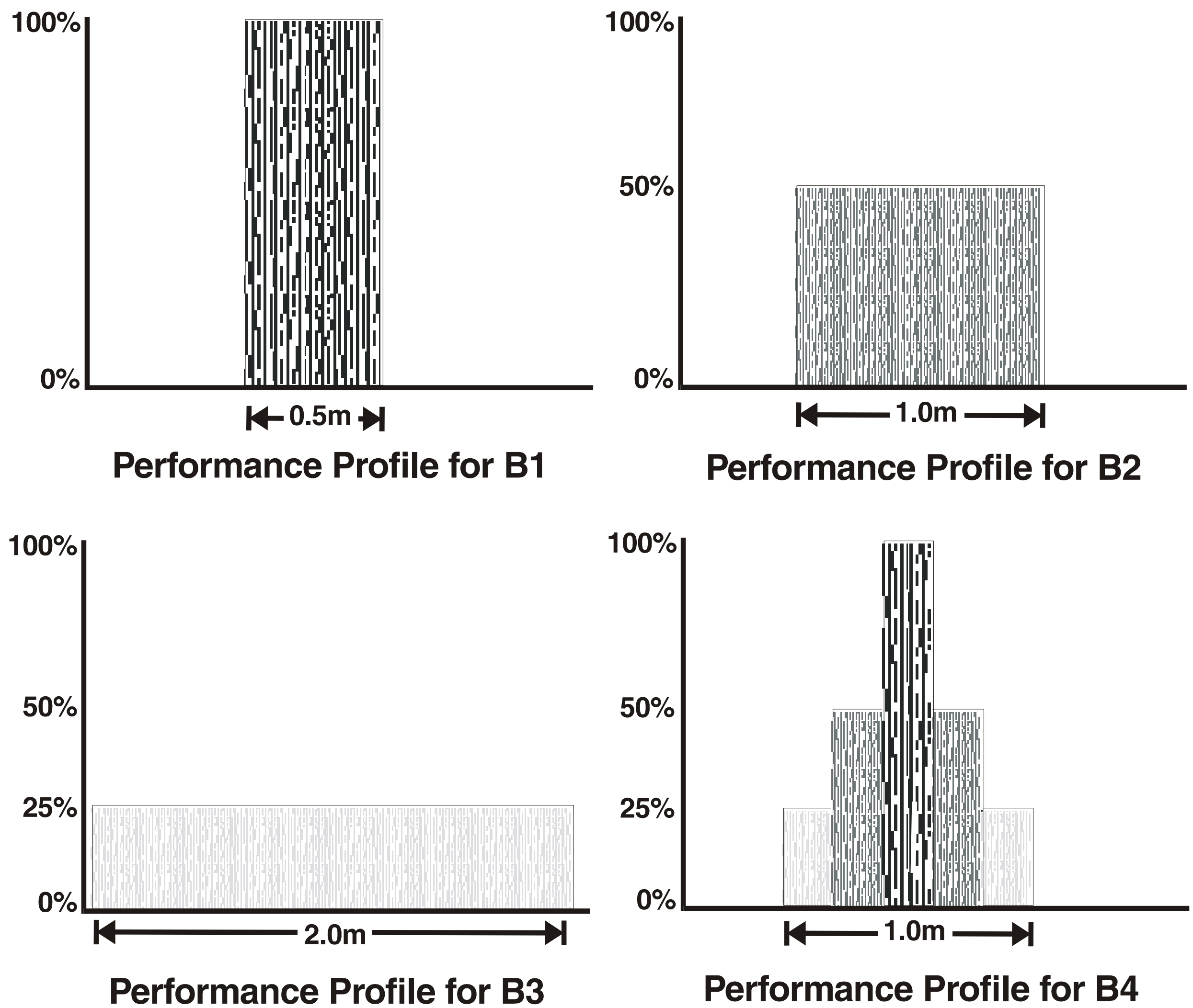

Figure C6. Broom performance profiles.

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 C6 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 Table C1 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.

Table C1. Broom Experimental Results

	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 C – Forms and Worksheets

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Determining AMDR Worksheet

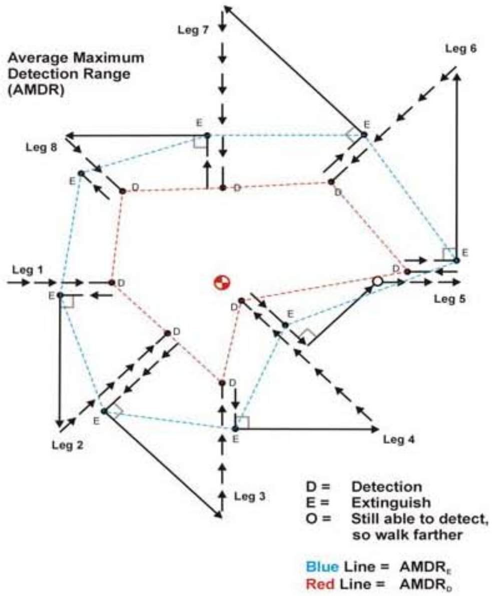
Determining AMDR Worksheet*

The Determining Average Maximum Detection (AMDR) Worksheet allows the researcher to determine and document AMDR and other measures to quantitate field visability. The values entered will automatically be used to determine several other experimental values on later worksheets.

1. Date	2. Time	3. Object Type	4. GPS E	GPS N
5. Location		6. Terrain Type	7. Cloud Cover	8. Precipitation

AMDR Measurements

Starting on Leg 1 move toward the target until the target is detected. Record the distance the target was first detected in the red AMRDd column. Move backwards until the target is no longer seen and record the distance in the blue AMDRe column. Pace the same distance at a right angle to start Leg 2 and repeat the procedure.



	Trial #1		Trial #2	
Leg #	AMDRd	AMDRe	AMDRd	AMDRe
1	18	20		
2	18	20		
3	12	17		
4	9	12		
5	14	20		
6	11	14		
7	4	7		
8	11	13		
AVG	12	15		
MAX	18	20		
AVG	12	15		
AVG$_{all}$	14	meters		

Suggested equipment:
Highest visability target, Laser Range finder, tape measure, GPS, topographic map, Vegatative density board, notebook, pencil, Determining AMDR worksheet, digital camera, compass.

Laser Range Finder (LRF) maximum distance

Standing at the target take a LRF reading every 22.5 degrees. Do not sight the LRF on any particular object. Make sure LRF on last return. Record results.

Sighting	Distance	Sighting	Distance	
1		1		
2		2		
3		3		AVG Trial 1
4		4		0
5		5		
6		6		AVG Trial 2
7		7		0
8		8		
9		9		AVG$_{all}$
10		10		0
11		11		
12		12		
13		13		
14		14		
15		15		
16		16		

Vegatative Density Index

Standing at the target. Move the Vden board back until 50% of the board is obscured by foliage. Record The distance between the board and the target. Take a reading every 45 degrees.

Trial #1		Trial #2	
Reading	Distance	Reading	Distance
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
AVG	0	AVG	0
Median	0	Median	0
	meters		meters

*Color Code Index for Cells
- WHITE: Input data in these cells.
- YELLOW: Automatically calculated cells.

Sweep Width Object Placement Worksheet

(example)

This worksheet randomly determines the placement of search objects based upon the AMDR.

11/11/04 Version # 1

# of Suggested 24
AMDRe = 15
AMDR = 14

Object #	TTD	LR	L vs. R	Object Type	Orientation
1	10	2	Left	Orange-White	137
2	24	10	Left	White Cap	291
3	80	4	Left	White Cap	351
4	123	19	Left	White Cap	58
5	164	22	Right	White Cap	170
6	180	0	Left	Orange-White	22
7	240	13	Left	Orange-White	318
8	267	5	Right	White Cap	283
9	321	13	Left	Orange-White	198
10	347	13	Left	Orange-White	279
11	409	10	Left	Orange-White	340
12	446	20	Right	White Cap	56
13	477	20	Right	Orange-White	54
14	536	0	Right	Orange-White	210
15	572	8	Left	Orange-White	96
16	592	6	Left	Orange-White	168
17	652	1	Right	Orange-White	63
18	698	7	Left	Orange-White	201
19	736	3	Right	Orange-White	273
20	761	4	Right	White Cap	75
21	822	3	Right	White Cap	270
22	852	19	Left	White Cap	359
23	903	20	Right	White Cap	93
24	922	8	Left	White Cap	209
25	977	19	Left	Orange-White	36
26	1027	19	Right	Orange-White	320
27	1047	21	Left	White Cap	250
28	1088	14	Left	White Cap	54
29	1132	8	Left	Orange-White	308
30	1186	13	Right	White Cap	356
31	1216	2	Right	White Cap	173
32	1274	21	Right	White Cap	45
33	1307	16	Left	Orange-White	251
34	1357	15	Left	White Cap	304
35	1379	22	Left	Orange-White	154
36	1422	22	Left	White Cap	42
37	1464	12	Left	Orange-White	180
38	1507	17	Right	White Cap	99
39	1559	15	Right	White Cap	307
40	1601	3	Right	White Cap	121
41	1636	7	Left	Orange-White	31

Instructions for Use

1. New values are generated every time new information is entered.
2. While locations for a total of 40 objects is generated (maximum possible), only the number specified by the design worksheet need to be placed into the field.
3. Object type is only needed if placing more than one type of object. If placing two types of objects make sure a minimum of eight objects of each type is choosen. If the minimum is not reached, change the version number to generate a new set of data. Repeat until minimum obtained.
4. Print out worksheet on water-resistant paper.

Object Type # 1
Orange-White

Object Type #2
White Cap

***Color Code Index for Cells**
- BLUE: Numeric data automatically carried over from another worksheet.
- WHITE: Input data in these cells.

Search Object Location Log

This worksheet allows documentation of the actual placement of objects, way points, legs, and other measurements during the actual setup in the field. This worksheet should be printed prior to setting up the experiment and brought into the field to facilitate field recording. Worksheet 3 (object placement) must also be printed out and brought into the field to determine the targeted object locations. Print on waterproof paper.

1. Date	2. Time	3. Location	4. Name

5. Object Type #1	6. Object Type #2	7. Datum	8. Units

Instructions

Log the actual locations based upon the Object Placement Worksheet. Placement along Total Track Distance can be determined by roller wheel or GPS odometer. The lateral range distance should be determined by Laser Range Finder or tape measure.

Object #	Object Type	TTD	LR	L vs. R	UTM E		UTM N		Elevation	Verification
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
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30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										

Waypoint Location Log

This worksheet allows documentation of the actual placement of way points, legs, and other measurements during the actual setup in the field. This worksheet should be printed prior to setting up the experiment and brought into the field to facilitate field recording. Print on waterproof paper.

1. Date	2. Time	3. Location	4. Name
5. Object Type #1	6. Object Type #2	7. Datum	8. Units

Instructions

Log the actual locations based upon the Object Placement Worksheet. Placement along Total Track Distance can be determined by roller wheel or GPS odometer. This form may be printed on the back of the Object Location Log.

WayPoint Type	TTD	UTM E	UTM N	Comments

Searcher/Participant Log

1. Date	2. Location			3. Page of		
Printed Name	Organization	SAR Qualification	Emergency Contact	Arrival Date/Time	Available Until?	Departure Date/Time

Team Sign-Up

Team Sign-Up			1. Location	2. Experiment Date	3. Projected # searchers
4. Sunrise		5. Sunset	6. Estimated Avg Completion		7. Actual Avg

The team sign-up log is used to schedule the departure times for teams (searcher and data logger) participating in the experiment. All attempts should be made to assign teams in the clock-wise direction before sending teams counter-clockwise. Searchers cannot function as a searcher twice. However, they can serve as a searcher then a data logger. Data loggers may be reassigned as often as needed.

Team Number	Time	Clock-wise Searcher	Data Logger	Counter-Clockwise Searcher	Data Logger
	7:00				
	7:15				
	7:30				
	7:45				
	8:00				
	8:15				
	8:30				
	8:45				
	9:00				
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	16:45				
	17:00				
	17:15				
	17:30				
	17:45				
	18:00				

Subject Information Sheet

Subject Information Sheet	**1. Location** Mt. Diablo, CA	**2. Date** 10-Jul-04	**3. Time** 6:00
4. Subject Name Thomas Tema		**5. Gender** Male	**6. Age** 35
7. Name to Call Tom (N/A)	**8. Expected Response** None, subject 100% deaf		

9. Subject's Plans or Intent

Subject departed campground to scout out survey locations. Last seen at the campground last night. Reported missing by employer early this morning. Should have been out of the field early.

10. Physical Description

Height:	5'10"	**Weight**	175
Race	White	**Build**	Avg
Eyes	Hazel	**Hair**	Blond
Complexion	Good	**Facial hair**	Clean

11. Photo Changes: **Date Taken** 2002

Clean-shaven when last seen.

12. Clothing Description

Dark blue pants, dark blue workshirt. May have white overalls with him. May have orange survey vest. Black boots. May have small backpack with assorted gear.

13. Footwear/Track Description

Vibram sole.

14. Incident Summary/Other Pertinent Information

Subject parked at campground. Is a contractor to do survey work. Should have returned Friday night. Contractor informed SAR of overdue report this morning. Subject is an insulin dependent diabetic and is totally deaf.

SIS Worksheet 8 3/4/2004	**15. Prepared by** R. Koester	**16. Date Prepared** 10-Jul-04

Task Assignment Form

Task Assignment Form	7. Task Number	8. Team Identifier	9. Resource Type	10. Task Map	11. Datum
			Ground		

ASSIGNMENT

12. Task Instructions

- Data loggers serves as team leader and will handle navigation, team control, and radio communications
- Start task as indicated on map and follow pink flags data logger indicates
- **Stay on track** marked by pink flags at all times.
- Proceed at a typical search speed for a sweep task. Data logger may ask you to speed up
- Do NOT race through the course, Data logger may ask you to slow down.
- Upon spotting a search object; stop, point at the object, tell data logger what object is, and estimated range
- Data loggers will give guidance to types of valid clues that need to be reported
- Do **NOT** report objects over the radio!
- Keep talking to your data logger to a minimum.
- Data logger is responsible for recording all results.
- If you spot another team moving in the same direction as you, follow your data loggers instructions
- Upon completing assigned task area return to base for debriefing
- You will be asked to estimate sweep width range and 50% vegetation coverage. Please read attached sheet.
- Do not share your results with anyone until the experiment has concluded.

13. Previous Search Effort in Area

Several teams have already walked the track today, do **not** record or report tracks.

14. Transportation to Area

15. Equipment

16. Briefing Checklist

- Expected time frame
- Teams nearby
- Encounter with team
- Terrain/Hazards
- Weather/Safety
- Subject Information
- Rescue/Medical Plan

TEAM

17. Role	Name	Agency	Medical Certification
Data Logger			
Searcher			

COMMO

18. Pertinent Phone Numbers

Base:
Base Cell:
Team Cell #1:
Team Cell #2:

19. Communications Instructions

Report to base when starting task, at each 500 m waypoint and when finishing task. Do **NOT** radio in clues or search objects.

20. Function	Frequency	Channel Description	Comments
Tactical I (Team - Base)			
Tactical II			
Logistics			
Command			

21. Notes/Safety Message

SAR TAF Worksheet 9 3/4/04	22. Prepared by:	23. Briefed by:	24. Time out:

Data Logger Briefing

General Briefing Data Logger	1. Location	2. Date

3. Task Instructions

Data Logger serves as team leader and will handle navigation, team control, and radio communications
Start task as indicated on map, follow flags. Yellow flags serve as start, waypoint, and finish indicators.
Lime Green flags mark every 25 meters. These will help determine your location when a clue is reported.
Hot pink flags assist with navigation and help to mark the course. STAY ON THE TRACK
Stay behind the searcher
Record the starting time on your detection log. If possible radio in your starting and finishing time.
Your searcher should be encouraged to move at a typical sweep task speed. Not racing or moving too slow.
Your team should reach the 100 meter mark (yellow flag) within 6 minutes. If longer, ask your searcher to increase speed. If you reach the 100 meter mark quicker than 2 minutes ask your searcher to slow down.
Keep talking to the searcher to a minimum.
GIVE NO CLUES or HINTS, to the number of clues, types of clues. You may encourage searcher to avoid reporting common trash or items not related to the search scenario.
Do NOT discuss what you found or didn't find if you covered the course as a searcher.
Do NOT report any clues over the radio.
Do NOT allow the searcher to leave the search track. If they think they spot a search object record the sighting
Do NOT record any tracks or sign
Upon searcher spotting an object, record the sighting on the detection log (as instructed)
Record the time you pass a yellow flag (placed every 500 meters or at other waypoints)
PASSING RULES: 1) The first time you spot a team in front, slow down or wait 5 minutes (unless the team has stopped; then pass). 2) If you catch up to the team again, passing is allowed. 3) Initiating passing should be done when within voice contact. 4) Announce you are going to pass, try to ensure team is not in process of recording a sighting. 5) Do not allow searchers to discuss clues spotted. 6) If your team was passed, make sure your searcher stays focused on searching. 7.) USE COMMON SENSE,
The goal is to avoid one searcher watching another searcher making a sighting
Be sure to report back to base for debriefing and collection of your forms.

14. Transportation to Area	15. Equipment	16. Briefing Checklist
	data logging record sheet	Expected time frame Teams nearby Encounter with team Terrain/Hazards Weather/Safety Subject Information Rescue/Medical Plan

Communication Plan

17. Pertinent Phone Numbers	18. Communications Instructions
Base: Base Cell: Team Cell #1: Team Cell #2:	Report to base when starting task, at each 500 m waypoint and when finishing task. Do **NOT** radio in clues or search objects.

19. Function	Frequency	Channel Description	Comments
Tactical I (Team - Base)			
Tactical II			
Logistics			
Command			

20. Notes/Safety Message

Loose rocks, easy to turn ankle, moderate climb in places. Course is cross-country. Some brush.

Data Logger Worksheet 10 3/4/04	21. Prepared by:	22. Briefed by:	23. Time out:

Team Tracking Log

Team Tracking Log			1. Location		2. Date	3. Page _______ of ________ Pages			
Task # Number	Team Identifier	Searcher Name	Data Logger Name	Team Cell Phone Number	Clock or Counterclock wise	Time Out*	Time Start*	Time Done*	Time Back*

* Local Time, 24-hour format. Once a team has returned to base, highlight the entire row.

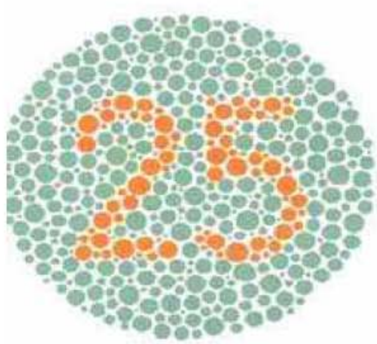
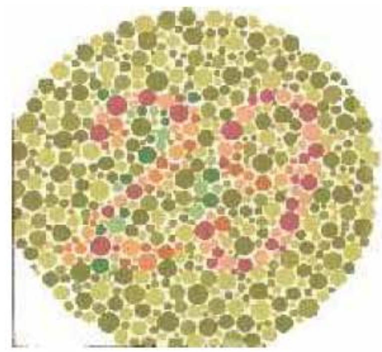
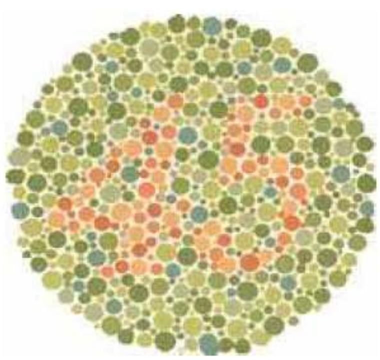
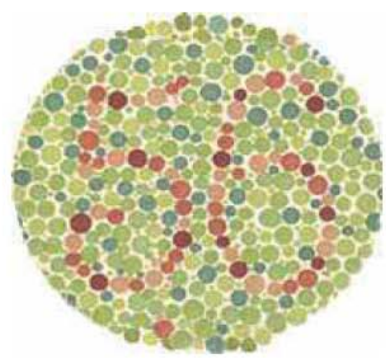
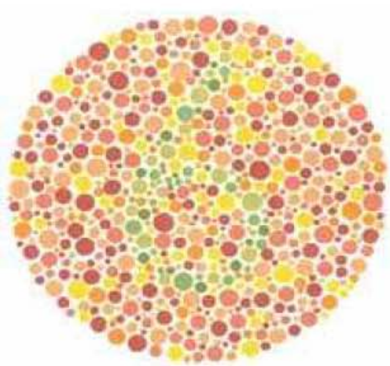
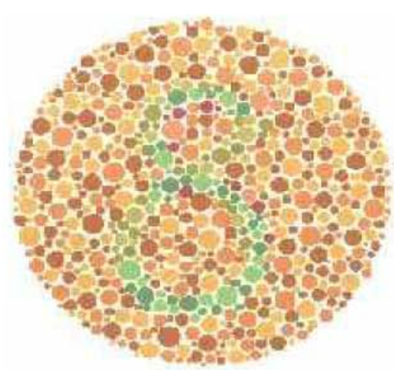
Vision Test – Color Blindness

Two vision tests will be given to search participants. Visual acuity (20/20) and the Ishihara test for color blindness. The tests should be given by the experiment staff as part of the check-in procedure. The results will be recorded on the Searcher Profile Worksheet.

Ishihara Test for Color Blindness

Instructions: Print out this page on a color printer. Place under a clear plastic sheet for protection.

Instructions for Searchers:
Please record the numbers you see revealed in the patterns of notes below on your Searcher Profile Sheet under the color blindness test.

A 	**B** 
C 	**D** 
E 	**F** 

Searcher Profile

Searcher Profile	1. Name	2. SAR Organization	3.SAR Sign-In Level	4. Date/Time
FOR OFFICE USE Searcher Number	INSTRUCTIONS: Please complete all the requested information in section A prior to departing on your search task. Your name will not be entered into the final database. The research staff will assist you in completing section B (measurements). After you return from you task, please complete section C (Debriefing). Thank-You!			

Section A - Searcher Demographics

6. Age	7. Gender ☐ Male ☐ Female	9. # of years in SAR	10. # of Searches	11. # of Search in Field	

13. Primary SAR Specialty (Check only one)

				☐ **None**
☐ Ground Searcher	☐ Bike SAR	☐ Helicopter pilot	☐ Ski Patrol	☐ Mountain rescue
☐ Tracking	☐ ATV SAR	☐ Fixed-wing pilot	☐ Swiftwater rescue	☐ USAR
☐ Dog Handler	☐ Snowmobile SAR	☐ Maritime SAR	☐ Cave rescue	☐ SAR mgmt
☐ Mounted (horse)	☐ 4 x 4 SAR	☐ Fire/EMS	☐ Tech. Rescue	☐ Other:________

14. SAR Certifications (Please list)

15. SAR Courses (Please list)

Section B - Physical Characteristics

16. Height w/ boots	17. Wear Glasses? ☐ No ☐ Yes ☐ Sometimes	18. Eyewear in field? ☐ No ☐ Yes	19. Visual Acuity		
				Uncorrected	Corrected
			Right		
			Left		

20. Colorblind? ☐ Yes ☐ No	21. Using the supplied Ishihara colorblindness chart, please record the numbers revealed by the pattern of dots. Leave blank if no numbers seen.		
		A.	B.
		C.	D.
		E.	F.

Section C - Debriefing

22. Hours on Task	23. Morale? ☐ High ☐ Medium ☐ Low	24. Fatigue ☐ Alert ☐ Medium ☐ Drowsy	25. Estimated POD		
				Object	Est. POD
			Object 1		
			Object 2		

26. Estimated AMDR	27. Estimated 50% obscured	28. Estimated half Sweep Width: Estimate the distance where you might miss two targets inside that range and detect two targets beyond that range (two or any equal number)

29. Temp	30. Wind Speed	31. Cloud Cover (%)	32. Precipitation (type and intensity)	33. Meteorological Visibility

34.Problems encountered on Task

35. Suggestions/comments

36. Are you willing to serve as a data logger today?

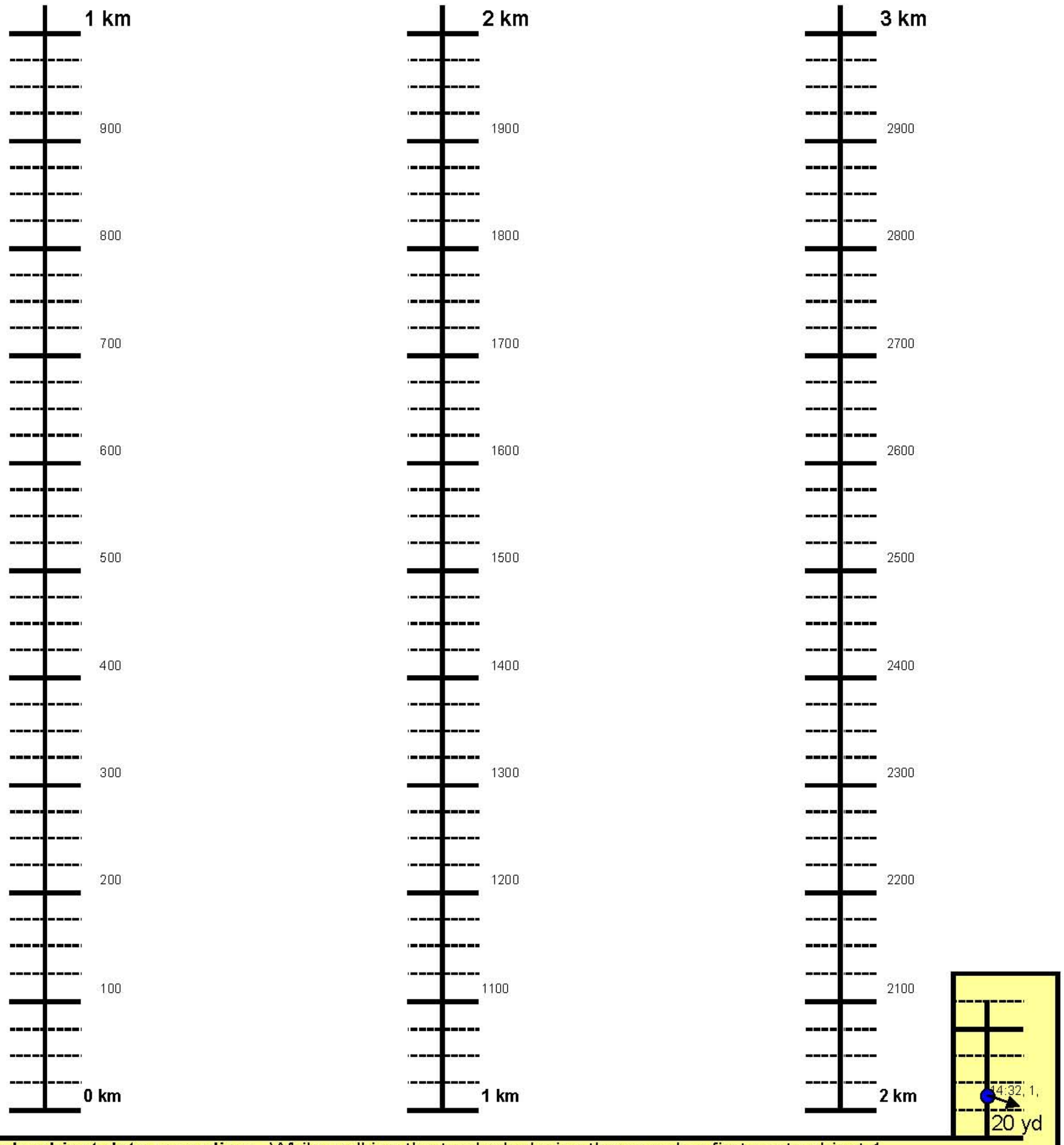
Searcher Profile Worksheet # 13 3/25/2004	37. Debriefed by	38. Time	**PLEASE MAKE SURE THIS FORM TURNED INTO MISSION BASE STAFF! THANK-YOU**

Detection Log

Detection Log	1. Searcher's Name	2. Data Logger's Name	3. Location	4. Date

5. Direction of Movement ☐ Clockwise (#s increasing) ☐ Counterclockwise	6. Search Object 1	7. Search Object 2	8. Way Point Check

Instructions: For each sighting the searcher makes, the data logger should record the following information: The team's location by placing a dot on the track using the wayflags, the time of the sighting, what the searcher sees, the estimated range of the object, and an arrow that gives the relative direction of the object.
All sightings should be recorded even if not matching to a known object. An example sighting record is provided below. Record time at start, finish, and waypoints specified.



Example object data recording: While walking the track clockwise the searcher first spots object 1 at 14:32 halfway between flags 325 and 350, 20 yards away at 4 o'clock.

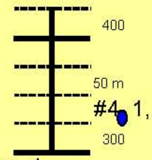
Detection Log Scoring Template

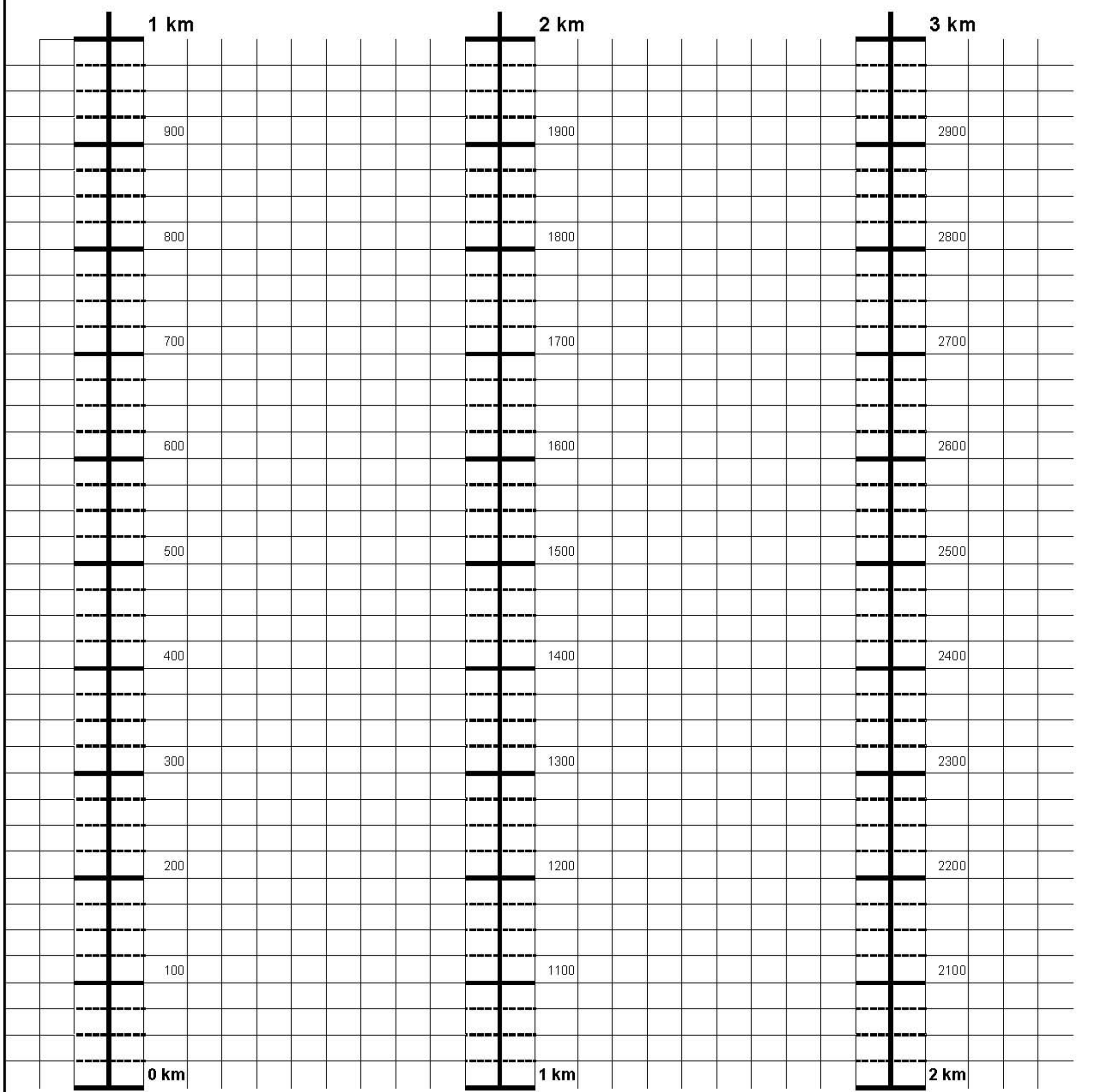
Detection Log Scoring Template	1. Location	2. Search Object 1	3. Search Object 2

Instructions: Print out a copy of this template. Then, using Worksheet 4 (Object Location) plot the known location of the search objects. Plot based upon total track length, lateral range, right or left, and object type. Indicate by 1 or 2 the type of object (if more than one used). Copy/print the template onto acetate. Place the acetate over each searchers Detection Log (Worksheet 14) and determine for each object if a valid detection occurred. For each search object, record on the Detection Summary Form (Worksheet 16) a "1" if a valid detection was made or a "0" if the object was missed.

Example

Object #4
TTL=327
LR=50
Right
Object Type=1





Detection Log Worksheet # 15	

Detection Scoring

Detection Scoring	1. Searcher's Name		2. Searcher Number	3. Data Logger's Name	
4. Date	5. Search Object 1	6. Search Object 2	7. Object 3	8. Object 4	9. Location

Instructions: Using the searcher's **Detection Log** (Worksheet #14) and the **Detection Template** (Worksheet # 15) record below if a valid detection occurred. Record a zero "0" in the appropriate search object column if the search object was missed. Record a one "1" in the appropriate search object column if that search object was detected. Leave the other search object column blank. Staple together the following forms; the **Searcher Profile** (#13), the **Detection log** (#14), and the scored **Detection Scoring** (#16). The results from this paper form will be inputted into the **Data Input Object 1 and 2** Worksheets in order to determine the Sweep Width value for each object.

Location Number	Detections Object 1	Detections Object 2	Detections Object 3	Detections Object 4	Location Number	Detections Object 1	Detections Object 2	Detections Object 3	Detections Object 4
1					41				
2					42				
3					43				
4					44				
5					45				
6					46				
7					47				
8					48				
9					49				
10					50				
11					51				
12					52				
13					53				
14					54				
15					55				
16					56				
17					57				
18					58				
19					59				
20					60				
21					61				
22					62				
23					63				
24					64				
25					65				
26					66				
27					67				
28					68				
29					69				
30					70				
31					71				
32					72				
33					73				
34					74				
35					75				
36					76				
37					77				
38					78				
39					79				
40					80				
Detection Summary Form #16 3/12/2004	Scored by								

Appendix D

Simplified Procedures for Conducting Sweep Width Experiments in Land SAR

Any person or organization considering determining effective sweep width experimentally should be familiar with the full report "Sweep Width Estimation for Ground Search and Rescue" prepared for the U.S. Department of Homeland Security at the request of the National Search and Rescue Committee, and pay particular attention to Part II. The following is a step-by-step procedure. It should be noted that Section 13 (Recommendations for Future Work) recommends that before one undertakes an experiment, that training, consultation, and assistance in the field be provided by the original experimental design team, especially for those unfamiliar with experimental design.

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, during the pass, 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 with labeled surveyor stake flags every 25 meters to aid in determining the searcher's location along the track at any time. Additional flags are placed as needed for ease in following the track.. Objects are placed at randomly selected locations on 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.

This report makes repeated reference to an Experimental Design Calculator. The Calculator is an MS Excel spreadsheet consisting of several worksheets. The Calculator was an invaluable tool that assisted with every phase of the experiment (design, search object location, collection of environmental data, conducting the experiment, forms, data entry, and automatic calculation of effective sweep width). However, it was designed for use by the experimental design team. Prior to its release and use by the general public several modifications are still required.

On the day of the experiment, searchers are sent down the track one at a time, trailed closely by a data logger. 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 logger 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 logger turns in the data sheet and, depending on how many loggers 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 scored, entered, and 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

Designing the Experiment
(Estimated time = 1 hour planning)

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. Estimate the expected number of search teams (searcher and data logger) that will be able to go through the course. Enter this number on the “Design” worksheet of the Experimental Design Calculator.
5. Estimate the average speed of search teams moving through the course. Correct the default speed setting on the “Design” worksheet if required.
6. Estimate the time available for participants to complete the course. Shorter timeframes may limit the number of types of search objects that can be placed.
7. Determine the number of different types of search objects (targets) that will be placed on the course. This number should be between 1-4. Enter this number on the “Setup” page. This number can be changed at a latter time after scouting the area.
   - Select adult, child, or clue sized targets.
   - Select high-visibility (white with orange vest unless snow), medium-visibility (blue), and/or low-visibility (olive green or brown depending upon environment).
   - Use non-responsive target, setting the target on the ground (future work hopes to describe the construction of a “responsive” manikin.)
8. Estimate the AMDR for each type of search object. Enter this number on the Setup page.
9. The Experimental Design Calculator will give you a projected course length based upon all of the variables (AMDR, number of teams, and number of different types of targets). Courses can be longer than the calculated minimum as long as time allows and it is less than 4 hours.
10. The experimental design calculator will also let you know if all your projected values allow the design of an acceptable experiment and if not what factors should be adjusted.
11. If using a projected AMDR values the experimental design calculator must be run again using the actual AMDR values to determine the placement of targets on the course.

Select a Candidate Search Experiment Area
(Estimated time = 3 hours planning)

1. Select an area that is typical, with respect to vegetation and terrain, of the conditions outlined in the search scenario. Avoid steep climbs and descents unless part of 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. The dimensions for a course with an outward-bound leg and return are; half the total course length in length and 7 times the AMDR extinction of the most visible target in width.

3. Select an area that will support a search track laid out along a trail, one that goes cross-country, or one that is mixed.
4. Obtain maps of potential sites to see if they meet size requirements.
5. Select an area that meets the logistical support needs of an experiment such as parking, permission to use the land, staging area, location or building for command and control, water, restrooms, and no unacceptable hazards. If conducting at a conference, locate course adjacent to or as close as possible to conference site.

Prepare for Scouting Site Visit
(Estimated time = 4 hours planning)

1. Prepare for the first visit to a potential site by obtaining good driving directions to the site, topographic map of the site (printed on waterproof paper), aerial photograph of the site, and any other special maps that may be available.
2. If meeting any local resources knowledgeable in the site be sure to have phone contact numbers and alternatives.
3. Be knowledgeable in any hunting activity at the site or any other unique hazards that may impact the experiment.
4. Bring the following equipment with you for the initial site visit:
   - Maps
   - One AMDR form for each target type (printed on waterproof paper)
   - Clipboard
   - GPS unit
   - Lux Meter
   - Laser Range Finder
   - Digital Camera
   - Extra batteries
   - One of each type of search target
   - Flagging tape
   - Vegetative Density Board
   - Typical SAR pack (to carry everything) and contents (to stay safe).

Scouting the Search Area
(Estimated time 3-6 hours in field)

1. Upon arriving confirm driving directions, ownership, hunting, hazards, etc.
2. Drive around borders of area if possible.
3. Walk the area to confirm features on the map, identify features missing from map, general terrain, uniformity of vegetation and terrain, desired type of vegetation, existence of unmarked roads and trails, and get a general feel for the area. Even if familiar with an area it is useful to walk it from the perspective of conducting an experiment.
4. Generally finding an area unacceptable takes little time, determining an area is acceptable takes far more time.

5. If the area is acceptable, obtain environmental measurements and pictures as required on AMDR form (AMDR, Laser Range Finder Maximum distance, Vegetative Density distance, ground cover description). Establishing AMDR is described below.
6. Scout the area from a logistical standpoint, parking, staging, command and control location, start and finish of course, location versus other events/venues, support (restroom, shelter, water, electricity, lighting, radio communications, cell phone coverage, etc).

Establishing Average Maximum Detection Range (AMDR)
(Estimated time 1 hour in field per target)

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 in the area at an initial location (determined by random) representative of the average conditions in the search area.
   b. Walk away from the search object until it is well lost from sight. Turn around and move towards the target. Upon sighting the target record the distance (AMDR detection) on the AMDR form. Continue to look at the target while moving away. At the point it disappears record the distance (AMDR extinction). Turn 90 degrees and travel the same distance just recorded. Turn 45 degrees towards the target and starting moving towards it again. Once again record the distance the target is sighted as the AMDR detection.
   c. Repeat this process around the points of the compass every 45 degrees.
   d. Once out of the field, enter the values on the AMDR form into the Excel Experimental Design Calculator. It will automatically calculate the AMDR extinction, AMDR detection, and AMDR.
2. Repeat steps a to c for each search object type.
3. Take a digital picture of the four cardinal directions from the AMDR location.

Planning to Lay Out the Search Track
(Estimated time 3 hours planning)

1. Enter the AMDR information into the Experimental Design Calculator.
2. The Calculator will give you the minimum acceptable length of the course.
3. The course may be longer (as long as it does not take more than 4 hours). However, the total time to complete the course must be weighed against other factors.
4. Plot onto the topographic map a tentative course.
5. Obtain the following equipment
   - Maps (Grid for use with GPS recommended)
   - GPS
   - Compass
   - Flagging tape (at least 6 rolls)
   - Surveyor’s Flags (Stake Wire Vinyl flags) – Colors may be substituted depending upon availability and natural background.
     - Yellow Flags (one bundle of 100)
     - Lime Green flags (40 per kilometer)

    - Red flags (200 per kilometer if dense)
    - Orange flags (10 per kilometer)
- Stake wire flag carrier (not required but makes carrying flags easier)
- Flagging Dispenser Holster (not required but makes carrying flags easier)
- Roller Wheel
- Permanent Marker
- Search equipment to be safe in the field

Laying out the Search Track
(Estimated time 6 hours in field)

1. With map, GPS, Compass, and flagging tape start flagging the course. Flagging should be sufficient for experimental designer to find trail.
2. Make adjustments as needed. It is common after setting down a segment of flags to find a slightly better route.
3. Walk the course again with Surveyor's flags (Stake wire flags) and roller wheel to measure and mark the track
    - Place a yellow stake wire flag at the start of the course; consider actual signs or flagging tape to make clear.
    - Using the roller wheel measure 25 meters.
    - Place a lime green flag with 25 written on it.
    - Continue with measuring the course with the roller wheel placing a green flag every 25 meters (distance written on flag) with the following color exceptions.
        - Place a yellow flag at start, 100 meters, 500 meters, every 500-meter interval, and end.
        - Place an Orange flag at every 100-meter interval (except where yellow flag).
        - Make sure to write the distance of every 25-meter interval flag.
4. Walk the course again with flagging tape and the red marker stake wire flags.
5. Place red flags along the route to make the route clear and easy to follow. Place additional flagging tape at confusing decision points and course turns.
6. Walk the course with a GPS unit to plot the course. Keep the GPS in the optimal position (for many models it need to be held flat) for receiving satellite signal. Make sure GPS is re-cording route traveled.

Number of Search Objects
(Estimated time 1 hour planning)

1. The number of search object locations is dependent on the track length and AMDR.
2. The Experimental Design Calculator will currently provide random locations for up to 40 search objects. Once redesigned this number may be increased.
3. The number of search objects actually placed will be determined by the number of locations suggested by the Design Calculator coupled to the actual length of the course.
4. A sufficient number of supplies to construct "extra" search objects should be obtained well in advance of the experiment.

Location of Search Objects
(Estimated time 1 hour planning)

1. The location of the search objects is determined using random numbers (with the exception of the first object) by the Experimental Design Calculator on the "Object Placement" worksheet.
2. Follow the instructions on the worksheet
3. Since random numbers are used it is possible to have too many search objects of one type and not enough of another. In this case, enter a new version number and a new set of values will be generated.
4. The next version of the Experimental Design Calculator will ensure a stratified random sample is obtained for lateral range distances. In the event no objects are placed close in or none towards the limit of 1.5 times AMDR then run a new version. Detailed instructions are described in the recommendations for future work section (Section 13) to manually provide a stratified random sample.
5. Print out a copy of the locations onto waterproof paper.
6. If no printer available, transcript locations onto waterproof paper
7. At this time Experimental Design Calculator does not permanently capture the locations.

Placement of Search Objects
(Estimated time 8 hours in field x 4 people)

1. Placement of search objects typically takes 8 hours with two teams. No search objects should be placed the day of the experiment. Therefore, allow an entire day before the experiment for the placement of search objects in the field.
2. Assemble all the required equipment
   - Colored Coveralls
   - Cardboard "stuffing"
   - Tent Stakes (logs or rocks may also be used to prevent objects from blowing away)
   - Clue sized objects
   - Can of appropriate paint to touch up objects if needed
   - Orange vests for search objects (if needed)
   - Orange vests for placement team
   - Laser Range Finder
   - Clipboard
   - Compass
   - Copy of Object Locations on waterproof paper
3. Drive search objects to easy access points on the course. The direction of the course does not have to be followed for the placement of objects.
4. Carry the search objects to general area indicated as Total Track Distance (TTD). Go slightly past the indicated distance (track aware searchers will notice the assembly area).
5. Assemble the search object.

6. One team member carries the search object to the left or right of track depending upon Search Object Placement Sheet. Make sure when leaving the track not to depart at the straight to the eventual site. Instead, walk well past the site to avoid making detectable track to the target.
7. Use the Laser Range Finder to determine the correct off-track distance (move a meter forward and back to confirm sighting on correct object).
8. Use the compass direction from Object Placement Sheet to determine what direction the search object should face.
9. Place the object and stake it down.
10. Note if a virtual object was placed and the distances of actual object (see 3.3.5.2.3).
11. Note if the location was switched from right to left (see 3.3.5.2.2) on the search object location log.
12. Place the next search object, until all objects have been placed. Document all locations on the object location log.
13. When out of the field, enter the actual object locations into the program.

Conduct the Experiment *(Estimated time 14 hours)*

Record Search Variables

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

Setup Command Center and Logistics

1. Setup Command Center for tracking resources, briefing, debriefing, and making teams.
2. Setup up any logistical support functions.

Instructions to Searchers

1. Have all participants sign-in to the experiment using the Sign-in Form.
2. Pair searchers with data loggers and schedule times (if not done previously) using the team sign-up form.
3. Brief the searchers using the Subject Information Sheet and Task Assignment Form. Explain objectives of the experiment and the experiment scenario.
4. Have searcher fill in Part A of Searcher Profile. Assist searcher in completing Part B. Keep Searcher Profile form at command while searcher in field.
5. Describe the search area and track.
6. Describe the nature of the search objects or instruct searchers to report anything out of the ordinary. All searchers should be given identical instructions.
7. Report as detections all objects in the area that fit the description of the search objects.
8. 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 to the data logger.
9. The searcher should be asked not to discuss the search with volunteers yet to participate.

Instructions to Data Loggers

1. Data recorders should also sign-in on the sign-in form.
2. Data loggers can be scheduled using the team sign-up log. However, since data loggers may go through the course multiple times, their scheduling is often more dynamic.
3. The data recorder will follow the searcher and record all relevant information, comments, and data.
4. The data recorder will be furnished with a map of the search area and search track, data logger instructions, detection log, and clipboard. Depending upon the type of waterproof paper being used (detection log) they should be given two pens or pencils.

5. The briefer will fill out the data sheet header information. Briefer should tell the data logger what the actual items are of interest (this avoids the data logger recording every piece of discarded trash).
6. During the experiment, while following the searcher, the data recorder will record:
   a. Start time
   b. Time at each yellow flag (start, 100 meters, every 500 meters, end)
   c. Time of each announced detection
   d. Place a dot at the appropriate location of the track line distance (using 25 meter flags) where the detection occurred.
   e. Searcher's estimated clock bearing to the detected object as an arrow on the detection log
   f. Searcher's estimated distance to the detected object next to the arrow.
   g. End time
7. Do not tell the searcher the results of the search until the entire experiment is completed.

Debrief Search Team

1. Collect the detection log from the data logger and staple it to the Search Profile
2. Note the team has returned on the team-tracking log.
3. Return any communications equipment that was checked out.
4. Debrief the searcher, completing part C of the Searcher Profile.
5. Examine the rest of the Searcher Profile form and detection log form making sure nothing has been left blank.
6. Ask the searcher if they are willing to serve as a data logger.
7. Store the searcher profile/detection log is a task-completed folder. Keep safe.

Recovery of Search Objects
(Estimated time 4-6 hours x 4 people)

- 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

Scoring Results
(Estimated time 3 hours)

1. Copy the detection log template form onto clear acetate.
2. Using the object location form place a color-coded dot onto the acetate for each search object corresponding to its total track distance, left vs. right, and lateral distance.
3. Place the marked acetate over the searcher's detection log.

5. Use the detection scoring form to score each detection opportunity. For a valid detection place a 1 in the appropriate box, for non-detections use a 0 (the use of 0 vs. 1 must be adhered to since the Excel Design Calculator is programmed to expect only these two scores).
6. Crosscheck each scored sheet carefully, to make sure the correct number of scores exists for each column.

Data Entry
(Estimated time 4 hours)

1. Once all detection logs are scored on the detection scoring form open the Experimental Design Calculator to the "Data Input Object One" worksheet.
2. Enter the results for search object one into the Data input object one using 0 and 1. Leave blank if a detection opportunity was not present.
3. Be sure to include the lateral range (LR)/off track distance for each search object.
4. Enter for every searcher.
5. Repeat for each search object using "Data input object two" etc. Currently the Experimental Design Calculator only as an input one and two. If future development occurs all clues can be inputted into one .xls file. In the meantime, for experiments with more than two clues, two files need to be created.
6. Enter all of the information on the Searcher Profile sheet into the "Searcher Profile Data" worksheet.

Determining Effective Sweep Width
(Estimated time 1 minute)

1. Go to the "Data Summary Sheet Object One".
2. Follow the instruction that causes the Lateral Ranges to sort based upon distances in order for the formulas to work correctly.
3. After the sort, the Effective Sweep Width is calculated and displayed at the bottom of the worksheet.
4. A crossover graph is automatically drawn and can be observed on the "Object 1 Sweep Width estimator" chart.
5. A lateral range graph is automatically drawn and can be observed on the "Object 1 Lateral Range" chart.
6. Several other charts are also automatically created using information provided in the Searcher Profile Data worksheet and results worksheets.
7. All raw data is summarized in the "Raw Data Summary". At this time the entire Excel file is required to provide all summary information for the entire experiment. Future work will place all summary information into the one worksheet.

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Appendix E

Equipment and Materials Sources

One-Time Purchase (Capital equipment needed for experiment)

Required Supplies	Source	Stock #	Web	Phone	Cost	Qty	Total Price
Roller Wheel	Forestry Suppliers	39026	www.forestry-suppliers.com/	800.674.5368	$72.00	1	$72.00
Marker Flag carry-case	Forestry Suppliers	39579	www.forestry-suppliers.com/	800.674.5368	$7.90	1	$7.90
GPS – Civilian Grade	Local Sports store					1	
Laser Range Finder - Civilian	Mosquito Creek	7426	www.mosquitocreekoutdoors.com/	800.250.5191	$299.00	1	$299.00
100 foot tape measure	Local Hardware store					1	
Compass with inclinometer	Local Sport store					1	
Lux Meter	Kaito electronics	fx101	www.multimeterwarehouse.com/FX101f.htm		$40.00	1	$40.00
Digital Camera	Local electronics store					1	

	Comments
Roller Wheel	Used to mark length of course, check with local running club
Marker Flag carry-case	
GPS – Civilian Grade	Used to plot course onto topographic map, generally available
Laser Range Finder - Civilian	Used to measure lateral range distance
100 foot tape measure	less ideal substitute for Laser Range Finder
Compass with inclinometer	Used for target placement, readily available
Lux Meter	Used to measure light intensity
Digital Camera	Used to record terrain, readily available

Disposable equipment needed for each experiment

Required Supplies	Source	Stock #	Web	Phone	Cost/Unit	Unit	Qty	Total Price
Human sized target (Blue coveralls)	GSS	COVWC3584	www.gss-store.com/	888-477-0004	$27.50	box 25	1	$27.50
Human sized target (White coveralls)	GSS	COVHB	www.gss-store.com/	888-477-0004	$24.00	box 25	1	$24.00
Paint (determine color)	Local Hardware store				$4.95	can	0.5/target	$40.00
Orange vest	Local Sporting store				$5.00	each	1/target	
Cardboard Boxes (Body, arms, leg)	Local						4/target	
Selected Clue	Local					each	1/target	
Marker Flags (every 25 meters)	Forestry Suppliers	33507	www.forestry-suppliers.com/	800.674.5368	$4.80	100 flags	2	$10.00
Marker Flags (every 500 meters)	Forestry Suppliers	33507	www.forestry-suppliers.com/	800.674.5368	$4.80	100 flags	1	$5.00
Marker Flags (waypoints)	Forestry Suppliers	33507	www.forestry-suppliers.com/	800.674.5368	$4.80	100 flags	4	$20.00
Marker Flags (every 100 meters)	Forestry Suppliers	33507	www.forestry-suppliers.com/	800.674.5368	$4.80	100 flags	1	$5.00
Permanent Marker	Local office supply					each	2	$4.00
Flagging Tape	Forestry Suppliers	57905	www.forestry-suppliers.com/	800.647.5368	$12.24	dozen rolls	1	$24.50
Various Forms	Laser Printer							
Waterproof paper (for forms)	Rite-in-the-Rain	8511	www.riteintherain.com/copierpaper.html	253.922.5000	$23.95	200 sheets	1	$23.95
Waterproof paper (for maps)	I-Gage		www.igage.com/WeatherP.htm		$19.95	50 sheets	1	$19.95
Extra Pens and Pencils	Local office supply							

	Comments
Human sized target (Blue coveralls)	Used for adult sized target, stuffed with cardboard, able to reuse but easier to replace
Human sized target (White coveralls)	Used for both high and low vis adult target. Painted with spary paint for low vis target. Orange vest placed on for high vis
Paint (determine color)	Used for making low-vis target. One can of spray paint makes two adult targets
Orange vest	For High-vis targets only. Can be reused, also worn when setting out search objects
Cardboard Boxes (Body, arms, leg)	For each adult target need at least one large triangular document box for leg, and two rectangular boxes for chest
Selected Clue	Hat and gloves can be purchased locally, buy white and use spray paint as needed
Marker Flags (every 25 meters)	Need 40 flags for every km of course
Marker Flags (every 500 meters)	Need only one unit (100) to mark start, every 500 meters and end
Marker Flags (waypoints)	Depending upon terrain may need 40-280 flags per km of course
Marker Flags (every 100 meters)	Need only one unit (100) to mark start, every 100 meters
Permanent Marker	Needed to mark flags, carry at least two in case one dropped in field
Flagging Tape	Used to initially mark trial
Various Forms	Forms and numbers needed specified in excel worksheet
Waterproof paper (for forms)	Data logger forms and search profile forms needed to be made on waterproof paper
Waterproof paper (for maps)	If passing out color maps made with a inkjet
Extra Pens and Pencils	

Appendix F

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 Figure 2-7 (also Figs. 9-2 and A1) 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 Section 2 of this report 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 and the detection experiments of 2004 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 C 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 (Figures 2-7, 9-2 and A1) 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 over-simplified 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 Figure 2-7 (also Figs. 9-2 and A1). 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.

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Appendix G

Data Summary

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
Ecoregion	Marine	Subtropical	Hot Continental	Mediterranean	Tropical/ Sub-tropical Steppe
Season	Summer	Summer	Winter	Summer	Spring
Month	May	June	March	July	April
Event	WA SAR conference	NASAR conference	Experiment	Experiment	NM SAR conference
Length	3.5 km	2.8 km	3.9 km	3.6 km	2.1 km
Elevation change	100 ft	80 ft	280 ft	920 ft	480 ft
Layout	trail/ cross-country	cross-country/ road	cross-country	cross-country/ road	trail/cross-country/road
Temp	58 F	75 F	55 F	80 F	59 F
Wind	0 mph	2 mph	4 mph	4 mph	2.2 mph
Cloud cover	96%	20%	99%	0%	2%
Visibility	Unl. - 1 mile	Unlimited	Unlimited	Unlimited	Unlimited
Precipitation	None-heavy	None	None-sprinkle	None	None

Table G1. General course characteristics.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
N	16	31	32	17	20
Avg. Time	2.0 hr	1.6 hr	2.2 hr	2.2 hr	1.38 hr
Avg. Speed	1.75 km/hr	1.75 km/hr	1.77 km/hr	1.63 km/hr	1.40 km/hr
Avg. Age	24.7	43.6	38.7	28.6	46
Avg SAR years	3.9	11.5	9.9	7.1	7.5
Avg # searches	42.6	76.3	31.2	46.1	31.1

Table G2. Participant characteristics.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
N	16[a]	31	32	17	20[a]
# O/W (#DO)	12 (185)	14 (434)	4 (128)	15 (255)	11 (198)
# Blue (#DO)	12 (183)	13 (403)	12 (384)	18 (306)	10 (182)
# Green (#DO)	11 (165)	14 (434)	-	11 (187)	-
# Clue (#DO)	11 (165)	-	-	12 (204)	-
TOTAL Objects	35	41	16	56	21

[a] Some participants followed an abbreviated course resulting in less detection opportunities (DO)

Table G3. Number of search subjects and detection opportunities by course.

Object Type	Actual Count	Detection Opportunities
Orange/White Body	56	1200
Blue Body	65	1458
Green Body	36	786
Clue	23	369

Table G4. Summary of quantity of detection opportunities by object type.

	WA	VA	VA	CA	NM
Location	Gifford National Forest	Lansdowne	Shenandoah NP	Mt. Diablo State Park	Lincoln National Forest
Ecoregion Code	M241	231	M221	M261	M311
Season	Summer	Summer	Winter	Summer	Spring
ESW O/W	36 m	73 m	142 m	82 m	62 m
ESW Blue	32 m	54 m	106 m	61 m	67 m
ESW Green	17 m	31 m	-	32 m	-
ESW Clue	8 m	-	-	20 m	-

Table G5. Summary of effective sweep widths

Appendix H

Contents of CD

The following electronic files and folders were included on the CD and served as deliverable 3:

DetExpReport_2004.doc	Full report – Microsoft Word format
\Forms	Folder that includes graphic versions (both jpeg and pdf) of all the forms integrated into the report
DetExpReport_2004.pdf	Full report – Adobe Acrobat format
\Photos	Digital photos taken at each course, some of which were used in the report

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Appendix I

Experiment Participant Comments

Shenandoah National Park, Virginia – Winter

- For trackers, flags very distracting
- Maintain terrain consistency
- Reinforce looking for small clues as well as large
- Good mix of course, open woods, hemlock, variable ground cover
- Focus on small objects in beginning.
- Emphasize speed
- Passed five other groups
- Good exercise/training
- Briefed to search for small clues, not enough information at start of course
- Terrain distracting from task
- More data loggers to reduce waiting
- Both blue and white were high contrast in this environment, look for anything need clues as well, flat light reduces contrast of similar colors
- Good exercise
- Need passing rules, no pass doesn't work well.
- Small objects and more of them
- Poor estimator of distance
- Should include thorns for searches in Virginia, searcher annoyed by data logger, better end marker
- More clue sized objects
- Varying clues, place behind trees

New Mexico SAR Conference – Lincoln National Forest

- Make a flatter course
- Would like to see objects in trees
- Enjoyed
- No cowboy boots
- More red trail markers, smaller targets
- Fascinating
- Interesting and entertaining
- Footing problems detracted from searching. No leaves on scrub oak yet.
- Wants to be given hints.
- Well done
- Take water
- Well done
- Medal or badge should be given for completion

<u>NASAR Conference, National Conference Center, Lansdowne, Virginia – Summer</u>

- Laid out very nicely
- Had to retrieve glasses
- Get rid of active bulldozers
- Course real nice
- Great course, Searching here is hard compared to Iceland
- Enjoyed, good pace.
- Nice
- Need water bottle
- Enjoyed, good opportunity, better than expected
- Should comment on search techniques
- Course was fine
- Well laid out, great experiment
- Not as severe undergrowth as usually train in.
- Chased by bulldozer
- Would use 50 meter spacing.
- Vary object size
- Need better sense of distance for ranging. Poison Ivy on course. Would have been lost.
- Start point confusing
- Give more briefing on green search object
- Enjoyed, good practice.
- Warn walkers about poor footing, noticed extremes in shade and sun, how does this affect detection?
- Bulldozer
- Fun, great escape from building
- Construction caused distraction

<u>Washington State SAR Conference, Gifford Pinchot National Forest</u>

- Flat light, saw lots of soda cans, much denser than CA. Thought looking for smaller clues.
- Good course, realistic
- Good fun
- Fun, detour, not enough pink flags at last turn
- Move rocks out of trail
- Make it longer, water bottles needed
- Look both ways
- Kind of boring
- Well laid out course, well prepared, more variety of search objects
- Bring water, be rested
- Better description of task
- Slippery footing
- Logs slick, more information prior to exercise
- Clear trail

Mt. Diablo, California – Summer {Ground}

- Dark sunglasses filter out blue and green targets
- Well set-up (encountered one rattler and loose footing)
- Arrange for fog.
- Nit pick- orange flagging tape slightly confusing with orange vest.
- Good course, do more often
- Great course
- Poison oak same color as some objects, maybe one object was a false positive, water tank in shade of green
- Fun course. That many clues might skew results up due to frequent reinforcement.
- A certain level of fitness should be required
- Excellent course, fun also.
- More smaller things. Bodies too easy, ball caps a reasonable size. Night search would be a good experiment.
- Enjoyed, good idea.
- Document how people look.

Mt. Diablo, California – Summer {Equestrian}

- Good course, well laid out.
- Send horse person to walk trail first
- Consider voice tape recorder to get data versus writing.
- Hard to do on horses. Fell crossing ravine. Hard to fix position.
- Taller stakes for riders to limited dismounts to get distances.
- Had fun! Great job.
- Height helps. Good terrain mix.
- Little confused by multiple instances of same object types.
- Dismount three times for safety. Stayed on trail.
- Need more personal training.

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Appendix J – Raw Data

Here is a summary that describes (1) the number of searchers in each experiment, (2) the length of each course, and (3) the number and types of targets placed in the five experiments:

	Shenandoah NP, VA	New Mexico SAR Conf., Lincoln NF	Washington SAR Conf., Gifford Pinchot NF	NASAR Conf., Lansdowne, VA	Mt. Diablo, California	TOTAL
Number of Searchers (N)	32	20[a]	16[a]	31	17	116
Course Length (km)	3.9	2.1	3.5	2.8	3.6	15.9
Human White-Orange (DO)	4 (128)	11 (198)	12 (185)	14 (434)	15 (255)	56 (1200)
Human Blue (DO)	12 (384)	10 (182)	12 (183)	13 (403)	18 (306)	65 (1458)
Human Green (DO)	-	-	11 (165)	14 (434)	11 (187)	36 (786)
Clue – Orange Glove (DO)	-	-	11 (165)	-	-	11 (165)
Clue – White Hat (DO)	-	-	-	-	12 (204)	12 (204)
Total Targets & Detection Opportunities (DO)	16 (512)	21 (380)	46 (698)	41 (1271)	56 (952)	180 (3813)

Note. “DO” means Detection Opportunity.
[a] Some participants followed an abbreviated course resulting in less detection opportunities.

The data for each detection (detected or not) are included in the raw data tables below. For each object-searcher interaction either a “1” (if a valid detection occurred) or a “0” (if the object was not detected) is recorded. These data were compiled from the Detection Log forms.

Demographic data for each searcher and some observable weather information are also recorded in the raw data tables below. These data were compiled from the Searcher Profile forms submitted by each searcher.

To protect the privacy of searchers, each searcher’s name has been removed from the data that follow.

Shenandoah National Park, Virginia – Winter

Searcher Characteristic	Searcher Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age (in years)	52	40	57	43	33	49	31	30	43	33	47	20	19	59	22
Gender (M or F)	m	m	m	m	m	m	m	m	f	m	f	f	m	f	m
Years in SAR	19	24	6	20	10	0	10	7	5	4	25	0.25	1	9	0.5
# of SAR Searches	50	200	24	75	50	0	100	11	5	5	20	1	2	12	2
# of Field Searches	50	70	20	50	50	0	100	11	5	5	20	1	2	10	2
Avg # of Searches	2.631579	8.333333	4	3.75	5	0	10	1.571429	1	1.25	0.8	4	2	1.333333	4
Primary SAR specialty	tracking	manage	ground	tracking	NPS	ground	tracking	NPS	NPS	NPS	NPS	ground	ground	tracking	ground
Height (in inches)	73	71	68	72	73	67	74	68	67	72	65	63	72	64	72
Glasses in Field	y	y	n	y	no	n	y	y	y	no	no	y	y	y	y
R eye visual acuity	20	20	30	15	20	40	20	25	25	20	25	20	20	25	20
L eye visual acuity	20	20	30	250	20	40	20	20	25	20	25	20	20	25	20
Colorblindness	n	n	n	n	n	n	n	no	NPS	n	n	n	n	n	n
Hours on Task	2	2	1.5	2	1.5	2.75	2.3	1.5	2	2	3.25	2	2.5	3.1	4.5
Speed (kph)	1.9500	1.9500	2.6000	1.9500	2.6000	1.4182	1.6957	2.6000	1.9500	1.9500	1.2000	1.9500	1.5600	1.2581	0.8667
Morale self assessment	h	h	h	h	h	h	h	h	h	h	h	h	h	h	m
Fatigue self assessment	a	a	a	a	a	a	m	a	a	a	d	m	m	a	a
Self POD Object #1	0.1	0.3	0.6	0.5	0.6	0.85	0.3	0.9	1	0.5	0.5	0.3	0.1	0.1	0.5
Self POD Object #2	0	80	70	50	70	85	50	90	100	65	90	40	70	30	60
Estimated AMDR	0	0	100	35		100	50	50	100	75	100	75	100	100	20
Estimated 50%	50	0	0	55		75	35	55	200	50	50	25	50	25	80
Estimated SW	0	30	52	40		50	50	40	50	60	30	30	27	45	7
Temperature (F)	52	54	52	60	50	55	55	60	55	55	55	55	55	55	55
Wind Speed (mph)	5	5	2	5	3	10	10	3	1	5	5	5	5	5	2
Cloud Cover (%)	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100
Precip. (type & intensity)	light rain	light rain	light rain	light rain	light rain	fog	none	mist	mist	mist	none	none	none	none	mist
Meteorological visibility	0	good	7m	0	0	0	0	0	0	0	0	clear	0	0	0

Search Object # 1 — Human Blue

Clue #	LR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	36	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
3	114	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
4	63	0	1	0	1	1	0	1	0	1	0	0	0	1	1	0
5	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	62	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9	53	0	1	0	1	1	1	1	0	1	1	0	1	1	1	0
10	27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	46	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1
12	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	24	0	1	0	0	0	1	0	0	0	1	0	0	1	1	1
Total	12															

Search Object # 2 — Human White-Orange

Clue #	LR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
7	58	1	1	0	0	0	0	1	1	0	1	1	0	1	1	0
8	59	1	0	0	1	1	0	1	0	1	1	1	1	1	0	0
15	65	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
16	71	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	4															

Searcher Number

Searcher Characteristic	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Age (in years)	21	41	68	71	28	54	46	35	47	46	35	31	44	36	17	25	15
Gender (M or F)	f	m	m	f	m	m	m	m	m	f	m	m	m	f	f	f	m
Years in SAR	0.5	12	53	10	9	10	1	7	8	23	6	3	18	10	3	0.5	1
# of SAR Searches	0	50	20	100	20	15	1	7	50	0	10	12	100	20	4	1	2
# of Field Searches	0	50	15	100	20	12	1	5	50	0	10	11	50	10	3	1	1
Avg # of Searches	0	4.166667	0.377358	10	2.222222	1.5	1	1	6.25	0	1.666667	4	5.555556	2	1.333333	2	2
Primary SAR specialty	ground	NPS	tracking	dog	tracking	tracking	ground	tracking	tracking	NPS	ground	ground	ground	ground	ground	ground	ground
Height (in inches)	73	72	72	65	70	78	71	64	75	64	69	68	74	72	71	67	70
Glasses in Field	y	no	y	n	y	n	n	n	n	no	y	n	n	y	n	n	n
R eye visual acuity	25	20	40	30	20	30	20	20	13	20	20	20	20	20	20	20	20
L eye visual acuity	20	20	40	30	20	30	20	20	13	25	20	20	20	20	20	20	20
Colorblindness	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Hours on Task	2.25	2.1	2.2	2.3	2	2.25	1.9	2.25	3	2.4	2.5	2.25	1.6	1.9	2	2	2
Speed (kph)	1.7333	1.8571	1.7727	1.6957	1.9500	1.7333	2.0526	1.7333	1.3000	1.6250	1.5600	1.7333	2.4375	2.0526	1.9500	1.9500	1.9500
Morale self assessment	m	h	h	h	h	h	m	m	h	h	h	h	h	h	m	h	h
Fatigue self assessment	m	m	a	a	a	a	a	m	a	a	a	a	a	a	m	a	a
Self POD Object #1	0.4	0.55	0.15	0.8	0.3	0.7	0.9	0.45	0.2	0.8	0.6	0.75	0.25	0.6	0.8	0.6	0.65
Self POD Object #2	65	80	40	100	70	90	100	60	25	80	80	75	40	60	90	80	70
Estimated AMDR	200	100	50	33	125	140	150	110	100	300	100	75	125	20	25	33	200
Estimated 50%	75	50	50	50	80	0	0	30	30	500	0	75	33	20	0	50	100
Estimated SW	50	30	40	0	50	40	100	66	40	300	0	40	55	10	0	21	90
Temperature (F)	55	55	55	60	50	53	58	55	56	56	58	56	55	55	60	55	55
Wind Speed (mph)	5	5	5	1	5	2	0	5	5	1	1	1	5	1	1	1	1
Cloud Cover (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Precip. (type & intensity)	none	none	none	sprinkle	none	sprinkle	sprinkle	none	none	none	none	none	none	none	none	none	none
Meteorological visibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Search Object # 1	Human Blue																
Clue #	LR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	63	0	1	1	0	1	1	0	1	1	0	1	0	0	1	0	0	0
5	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	53	1	1	0	0	1	0	1	1	1	1	0	1	1	0	1	1	1
10	27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	46	1	1	0	1	1	0	0	1	1	1	1	1	1	1	0	1	1
12	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	24	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0
Total	12																	
	Search Object # 2	Human White-Orange																
Clue #	LR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
7	58	1	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0
8	59	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0
15	65	1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	1	1
16	71	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	4																	

New Mexico SAR Conference – Lincoln National Forest

	Searcher Number									
Searcher Characteristic	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Age (in years)	65	39	58	41	47	55	28	54	52	39
Gender (M or F)	F	F	M	M	m	m	m	f	f	m
Years in SAR	20	20	3	1	9	14	5	1	5	10
# of SAR Searches	50	15	8	12	36	0	0	1	14	100
# of Field Searches	5	15	8	12	36	0	0	1	14	100
Avg # of Searches	2.5	0.75	2.666667	12	4	0	0	1	2.8	10
Primary SAR specialty	Manageme	Mounted	Ground	Ground	Mounted	Mounted	Ground	Dog	Rescue	Dog
Height (in inches)	0	68	73	68	71	74	69	68	70	74
Glasses in Field	s	y	Y	Y	n	n	y	y	y	y
R eye visual acuity	20/50	20/30	20/20	20/30	20/30	20/25	20/20	20/20	20/50	20/50
L eye visual acuity	20/50	20/30	20/20	20/30	20/30	20/25	20/20	20/20	20/50	20/50
Colorblindness	n	n	n	Y	n	y	n	n	n	y
Hours on Task	1.5	1.75	1.5	1.75	1.6	1.5	1.6	2	1.5	1.6
Speed (kph)	0.7333	1.2000	1.4000	1.2000	1.3125	1.4000	1.3125	1.0500	1.4000	1.3125
Morale self assessment	h	h	h	h	h	m	h	h	h	h
Fatigue self assessment	m	m	a	a	h	m	a	a	a	a
Self POD Object #1	0.85	0.85	1	0.95	0.5	0.7	0.9	0.8	0.8	0.6
Self POD Object #2	0.7	0.7	0.85	0.85	0.4	0.7	0.7	0.7	0.8	0.7
Estimated AMDR	91	15	89	88	100	23	200	50	30	30
Estimated 50%	14	10	30	43	50	23	50	35	18	22
Estimated SW	0	0	0	58	0	0	60	0	0	0
Temperature (F)	55	55	55	60	50	50	50	60	55	60
Wind Speed (mph)	0	0	0	5	5	0	5	5	2	5
Cloud Cover (%)	50	100	12	10	50	60	10	15	0	10
Precip. (type and intensity)	0	0	0	0	0	0	0	0	0	0
Meteorological visibility	UL	ul	ul	ul	ul	ul	ul	ul	ul	ul

	Search Object # 1	Human White-Orange									
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**17**	1	1	1	1	1	1	1	1	1	0
3	**48**	1	0	1	1	1	1	1	0	1	0
7	**29**	0	0	0	0	1	0	1	1	0	0
10	**47**	0	0	0	0	0	0	0	1	0	0
11	**59**	0	0	0	0	0	0	1	0	0	0
13	**18**	1	1	1	1	1	1	1	0	1	1
14	**40**	0	0	1	1	1	0	1	1	0	0
16	**4**	0	1	1	1	1	1	1	1	1	1
18	**15**	0	1	1	1	1	1	1	1	1	1
19	**2**	1	1	1	1	1	1	1	1	1	1
21	**25**	0	1	1	1	1	1	1	1	1	1
Total	11										
	Search Object # 2	Human blue									
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2	**5**	1	1	1	1	1	1	1	1	1	1
4	**27**	1	1	1	1	1	1	1	1	1	1
5	**36**	0	0	0	0	1	0	0	1	0	0
6	**15**	1	1	1	1	1	1	1	1	1	1
8	**45**	0	0	0	0	1	0	0	0	0	0
9	**29**	1	1	0	0	1	1	1	1	1	1
12	**12**	1	1	0	1	1	1	1	1	1	1
15	**32**	0	0	1	1	1	1	1	1	0	0
17	**41**	0	1	0	1	1	1	1	1	1	0
20	**56**	0	0	0	0	0	0	0	0	0	0
Total	10										

Searcher Number

Searcher Characteristic	11	12	13	14	15	16	17	18	19	20
Age (in years)	41	60	27	69	29	35	0	42	45	48
Gender (M or F)	m	M	m	m	m	m	f	m	m	f
Years in SAR	20	4	2	5	1	1	6	3	17	3
# of SAR Searches	0	20	12	52	1	1	25	15	164	3
# of Field Searches	0	20	12	52	1	1	25	15	164	3
Avg # of Searches	0	5	6	10.4	1	1	4.166667	5	9.647059	1
Primary SAR specialty	Ground	ground	Ground	Ground	Ground	Ground	Ground	Ground	Tracker	Mounted
Height (in inches)	76	73	73	75	77	75	63	73	73	64
Glasses in Field	y	y	n	n	n	y	n	y	n	n
R eye visual acuity	20/20	20/20	20/30	20/30	20/30	20/20	0	20/20	20/20	20/40
L eye visual acuity	20/20	20/20	20/30	20/30	20/30	20/15	0	20/20	20/20	20/40
Colorblindness	n	n	n	n	n	n	n	n	n	n
Hours on Task	1.5	1.5	1.3	1.5	1.1	1.2	0.6	0.5	0.5	1.6
Speed (kph)	1.4000	1.4000	1.6154	1.4000	1.9091	1.7500	1.4167	1.7000	1.7000	1.3125
Morale self assessment	h	h	h	h	m	h	h	h	h	h
Fatigue self assessment	a	a	a	a	m	a	a	a	a	a
Self POD Object #1	0.6	0.6	0.35	0.7	0.8	0.3	0.8	0.75	0.89	0.8
Self POD Object #2	0.5	0.8	0.55	0.6	0.65	0.2	0.8	0.65	0.92	0.8
Estimated AMDR	42	30	20	30	60	50	140	50	0	50
Estimated 50%	48	33	30	33	20	20	6	33	0	40
Estimated SW	0	0	0	0	0	0	0	0	0	0
Temperature (F)	60	60	55	60	50	50	60	60	55	50
Wind Speed (mph)	5	5	0	0	0	0	0	0	5	2
Cloud Cover (%)	10	0	0	0	5	5	0	0	0	0
Precip. (type and intensity)	0	0	0	0	0	0	0	0	0	0
Meteorological visibility	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul

	Search Object # 1	Human White-Orange									
Clue #	LR	11	12	13	14	15	16	17	18	19	20
1	17	1	1	1	1	1	1	1	1	1	1
3	48	0	0	0	1	0	0	1	1	0	0
7	29	0	0	0	0	0	0	0	0	0	0
10	47	0	0	0	0	0	0	0	0	0	0
11	59	0	0	0	0	0	0	0	0	0	0
13	18	1	1	1	1	1	1	0	0	0	1
14	40	0	0	0	1	0	0	0	0	0	0
16	4	1	1	1	1	1	1	0	0	0	0
18	15	1	1	1	1	1	1	1	1	1	0
19	2	1	1	1	1	1	1	1	1	1	1
21	25	1	1	1	0	1	1	1	1	1	1
Total	11										
	Search Object # 2	Human Blue									
Clue #	LR	11	12	13	14	15	16	17	18	19	20
2	5	1	1	1	1	1	1	1	1	1	1
4	27	1	1	1	1	1	1	1	1	1	1
5	36	1	1	0	0	0	0	0	0	0	0
6	15	1	1	1	1	1	1	1	1	1	1
8	45	0	0	0	0	0	0	0	0	0	0
9	29	1	1	1	0	0	0	0	0	0	1
12	12	1	1	1	1	1	1	0	0	0	0
15	32	1	1	0	0	1	0	0	0	0	0
17	41	0	0	0	0	1	0	0	0	0	1
20	56	0	0	0	0	0	0	0	0	0	0
Total	10										

Washington State SAR Conference, Gifford Pinchot National Forest

	Searcher Number							
Searcher Characteristic	1	2	3	4	5	6	7	8
Age (in years)	53	18	16	19	17	38	14	14
Gender (M or F)	m	M	m	f	m	m	m	m
Years in SAR	20	1	1	1	1	0	0	0
# of SAR Searches	100	1	1	1	1	0	0	0
# of Field Searches	50	1	1	1	1	0	0	0
Avg # of Searches	5	1	1	1	1	0	0	0
Primary SAR specialty	manage	NONE	ground	ground	ground	law	none	ground
Height (in inches)	73	74	71	68	68	70	57	55
Glasses in Field	y	Y	n	y	n	n	none	n
R eye visual acuity	20	20	20	20	20	20	30	20
L eye visual acuity	20	20	20	20	20	20	30	20
Colorblindness	y	NO	n	n	n	n	none	n
Hours on Task	1.5	1.75	2.3	2.5	2.25	2.25	1.5	2
Speed (kph)	2.3333	2.0000	1.5217	1.4000	1.5556	1.5556	2.3333	1.7500
Morale self assessment	h	h	h	h	h	h	l	h
Fatigue self assessment	a	m	m	1	a	a	d	a
Self POD Object #1	0.75	0.75	1	0.9	0.9	0.95	0.99	0.99
Self POD Object #2	0.8	0.5	0.75	0.8	0.8	0.75	0.5	1
Estimated AMDR	38	48	300	91	182	180	50	150
Estimated 50%	18	50	91	80	9	30	30	100
Estimated SW	0	0	0	0	0	0	0	0
Temperature (F)	55	55	60	60	63	63	66	65
Wind Speed (mph)	0	0	0	0	0	0	3	3
Cloud Cover (%)	100	100	100	100	95	95	95	98
Precip. (type & intensity)	MIST	mist	m	0	none	none	none	n
Meteorological visibility	1	1	ul	5	ul	ul	ul	ul

	Search Object # 1	Human White-Orange						
Clue #	LR	1	2	3	4	5	6	7	8
1	4	1	1	1	1	1	1	1	1
2	17	0	1	1	1	0	1	1	0
4	13	1	1	1	1	1	1	1	1
5	33	0	0	0	0	0	0	0	0
7	6	1	1	1	1	1	1	1	1
11	38	0	0	0	0	0	0	0	0
15	22	0	0	0	0	0	0	0	0
16	17	0	0	0	0	0	0	0	0
17	34	0	0	1	0	0	0	0	0
19	29	0	0	0	0	0	0	0	0
20	45	1	0	0	0	0	0	0	0
23	54	0	1	1	0	1	1	1	0
Total	12								
	Search Object # 2	Human Blue							
Clue #	LR	1	2	3	4	5	6	7	8
3	3	1	1	1	0	0	1	1	1
6	37	1	0	0	0	0	0	0	0
8	15	0	0	0	0	0	0	0	0
9	9	1	1	1	1	1	1	1	1
10	16	0	1	1	0	1	1	0	0
12	29	0	0	0	0	0	0	0	1
13	15	1	1	1	1	0	1	1	1
14	8	1	1	0	0	0	1	0	0
18	46	0	0	0	0	0	0	0	0
21	23	1	1	1	1	1	1	1	1
22	34	0	0	0	0	0	0	0	0
24	24	1	1	1	0	0	1	0	0
Total	12								
	Search Object # 3	Human Green							
Clue #	LR	1	2	3	4	5	6	7	8
1	15	0	0	0	0	0	0	0	0
3	2	1	1	1	0	1	1	0	1
5	17	0	0	0	0	0	1	0	0
6	12	0	1	0	0	0	0	0	0
8	10	0	1	0	0	0	0	0	0
9	30	1	1	0	0	1	1	0	0
11	3	1	1	0	1	1	1	0	1
14	20	0	0	0	0	0	0	0	0
15	27	0	0	0	0	0	0	0	0
16	5	0	1	0	0	1	1	0	0
17	9	1	1	0	0	1	1	0	0
Total	11								
	Search Object # 4	Clue - Orange Glove							
Clue #	LR	1	2	3	4	5	6	7	8
2	1	0	1	1	1	1	1	1	1
4	22	0	0	0	0	0	0	0	0
7	9	0	1	0	0	1	1	1	0
10	3	0	0	0	0	1	1	1	1
12	10	0	0	0	0	0	0	0	0
13	8	0	0	0	0	0	0	0	0
18	4	0	1	1	1	1	1	0	0
19	11	0	1	0	0	0	0	0	0
20	0.5	0	1	1	1	1	1	0	1
21	4	0	0	0	0	0	0	0	0
22	8	0	0	0	0	0	0	0	1
Total	11								

	Searcher Number							
Searcher Characteristic	9	10	11	12	13	14	15	16
Age (in years)	12	12	17	12	35	32	30	56
Gender (M or F)	m	m	m	m	m	m	f	m
Years in SAR	0	0	1.5	0	3	2	2	30
# of SAR Searches	0	0	8	0	30	10	30	500
# of Field Searches	0	0	8	0	28	10	28	200
Avg # of Searches	0	0	5.333333	0	10	5	15	16.66667
Primary SAR specialty	ground	ground	ground	ground	ground	tracking	ground	ground
Height (in inches)	63	64	72	61	74	71	64	70
Glasses in Field	n	n	y	n	y	y	n	n
R eye visual acuity	20	20	20	20	20	0	20	20
L eye visual acuity	20	20	20	20	20	0	20	20
Colorblindness	n	n	n	n	n	n	n	n
Hours on Task	1.75	1.1	1.6	2	2.5	2.5	2.5	0
Speed (kph)	2.0000	3.1818	2.1875	1.7500	1.4000	1.4000	1.4000	0.0000
Morale self assessment	h	h	h	h	h	m	m	h
Fatigue self assessment	a	a	m	a	m	a	a	a
Self POD Object #1	0.9	0.5	1	0.9	0.6	0.9	1	0.8
Self POD Object #2	0.5	0.8	0.9	1	0.3	0.65	0.9	0.6
Estimated AMDR	50	20	48	20	600	50	45	35
Estimated 50%	40	20	30	45	350	15	22	30
Estimated SW	0	0	0	0	0	0	0	0
Temperature (F)	60	60	65	60	55	50	50	50
Wind Speed (mph)	0	0	0	0	0	0	0	0
Cloud Cover (%)	90	90	90	90	100	100	100	100
Precip. (type & intensity)	0	0	0	0	0	100	100	100
Meteorological visibility	3	ul	ul	ul	2	1	1	1

	Search Object # 1	Human White-Orange							
Clue #	10	9	10	11	12	13	14	15	16
1	4	1	1	1	1	1	1	1	1
2	17	0	0	1	1	1	1	1	1
4	13	1	1	1	1	1	1	1	1
5	33	0	0	0	0	0	0	0	0
7	6	1	1	1	1	1	1	1	1
11	38	0	0	0	0	1	1	0	0
15	22	0	0	0	0	1	0	0	0
16	17	0	0	0	0	0	0	0	0
17	34	0	0	0	1	1	0	0	0
19	29	0	0	0	0	0	0	0	0
20	45	0	0	0	0	0	0	0	0
23	54	0	0	0	1	1	1	1	0
Total	12								
	Search Object # 2	Human Blue							
Clue #	LR	9	10	11	12	13	14	15	16
3	3	1	0	1	1	1	1	1	1
6	37	0	0	0	0	0	1	0	0
8	15	0	0	0	0	0	0	0	0
9	9	1	1	1	1	1	1	1	0
10	16	0	0	0	1	1	1	1	0
12	29	0	0	0	0	0	0	0	0
13	15	1	0	1	1	1	1	1	0
14	8	1	0	0	0	1	1	1	0
18	46	0	0	0	0	0	0	0	0
21	23	1	1	0	0	1	1	1	0
22	34	0	0	0	0	0	0	0	0
24	24	1	0	1	0	1	1	1	0
Total	12								
	Search Object # 3	Human Green							
Clue #	LR	9	10	11	12	13	14	15	16
1	15	0	0	0	0	0	0	0	0
3	2	1	0	0	0	1	1	0	0
5	17	0	0	0	0	0	0	1	0
6	12	0	0	0	0	0	0	1	0
8	10	0	0	0	0	1	1	0	0
9	30	0	0	0	0	1	1	1	0
11	3	0	1	0	1	1	1	1	0
14	20	0	0	0	0	0	0	0	0
15	27	0	0	0	0	0	0	0	0
16	5	1	0	0	1	1	1	1	0
17	9	1	0	0	1	1	0	1	0
Total	11								
	Search Object # 4	Clue - Orange Glove							
Clue #	LR	9	10	11	12	13	14	15	16
2	1	1	1	1	1	1	1	1	0
4	22	0	0	0	0	0	0	0	0
7	9	0	0	0	1	0	0	0	0
10	3	1	1	1	0	1	0	1	0
12	10	0	0	0	0	0	0	0	0
13	8	0	0	0	1	1	1	0	0
18	4	1	0	1	1	1	1	1	0
19	11	0	0	0	1	1	0	0	0
20	0.5	0	1	1	1	0	1	1	0
21	4	0	0	0	0	1	0	0	0
22	8	0	0	0	0	0	0	0	0
Total	11								

NASAR Conference - National Conference Center, Lansdowne, VA – Summer

Searcher Number

Searcher Characteristic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age (in years)	45	52	31	44	57	32	54	28	34	40	52	26	49	46	30
Gender (M or F)	m	m	m	m	m	m	m	m	m	m	m	m	f	f	f
Years in SAR	6	20	10	20	26	15	3	11	18	15	15	2	15	5	9
# of SAR Searches	0	30	100	500	100	55	9	80	100	100	100	1500	130	1	30
# of Field Searches	0	20	100	500	100	40	3	40	100	100	100	0	130	1	30
Avg # of Searches	0	1.5	10	25	3.846154	3.666667	3	7.272727	5.555556	6.666667	6.666667	750	8.666667	0.2	3.333333
Primary SAR specialty	pilot	tracking	tracking	dog handle	mgmt	mgmt	air	mgmt	tracking	mgmt	ground	mgmt	dog handle	dog handle	ground
Height (in inches)	73	72	75	68	71	0	71	74	72	72	68	71	67	65	65
Glasses in Field	n	n	y	n	n	n	y	n	n	n	y	n	y	y	n
R eye visual acuity	15	20	20	30	30	30	20	20	30	20	30	20	20	20	30
L eye visual acuity	15	20	20	30	30	30	20	20	30	20	30	20	20	20	30
Colorblindness	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Hours on Task	2	1.75	1.5	1.75	1.1	1.6	1.5	1.5	1.5	1.7	2.1	1.5	2.2	1.5	1.6
Speed (kph)	1.4000	1.6000	1.8667	1.6000	2.5455	1.7500	1.8667	1.8667	1.8667	1.6471	1.3333	1.8667	1.2727	1.8667	1.7500
Morale self assessment	h	h	h	h	h	h	h	h	h	h	h	h	h	h	h
Fatigue self assessment	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Self POD Object #1	0.15	0.6	0.2	0.6	0.6	0.5	0.2	0.4	0.6	0.1	0.35	0.7	0.1	0.3	0.2
Self POD Object #2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estimated AMDR	46	30	25	100	200	150	70	100	50	75	40	40	72	50	40
Estimated 50%	23	15	14	25	200	30	35	35	25	20	25	25	50	25	20
Estimated SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (F)	72	75	70	70	65	68	68	72	73	75	75	75	75	75	80
Wind Speed (mph)	5	5	2	2	0	2	3	2	2	2	2	2	2	2	2
Cloud Cover (%)	0.15	15	0	10	10	10	10	10	25	10	20	0	5	90	50
Precip. (type & intensity)	none	none	none	0	0	0	0	0	0	0	0	0	0	0	0
Meteorological visibility	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul

Search Object # 1 Human White-Orange

Clue #	LR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	12	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1
3	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	47	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
10	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	11	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
15	21	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
20	34	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
21	47	0	1	1	1	0	1	1	1	0	0	1	0	0	1	1
22	22	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
23	62	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
25	44	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
26	18	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Total	14															

Search Object # 2 Human Blue

Clue #	LR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
8	38	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
9	35	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
11	10	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
13	13	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
14	17	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
16	25	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
17	53	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0
18	22	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
19	4	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
24	25	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1
27	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	13															

Search Object # 3 Human Green

Clue #	LR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	25	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
2	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	30	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
5	2	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0
6	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	16	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1
8	18	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
9	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	30	0	0	1	1	0	0	1	1	0	1	1	0	0	0	1
11	15	1	1	1	1	0	1	0	0	0	0	0	0	0	1	1
12	29	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
13	14	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
14	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	14															

Searcher Number

Searcher Characteristic	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Age (in years)	46	56	50	50	56	45	41	50	30	38	45	42	34	51	46	53
Gender (M or F)	m	m	f	f	m	m	m	f	m	f	m	m	f	m	m	m
Years in SAR	5	1	0	13	20	15	8	8	6	4	20	7	5	18	23	13
# of SAR Searches	50	1	0	35	100	25	25	6	50	20	300	202	8	60	100	50
# of Field Searches	20	1	0	25	100	20	10	6	50	20	300	202	6	40	50	30
Avg # of Searches	10	1	#DIV/0!	2.692308	5	1.666667	3.125	0.75	8.333333	5	15	28.85714	1.6	3.333333	4.347826	3.846154
Primary SAR specialty	mgmt	ground	fire	swiftwater	mgmt	dog handle	dog handle	dog handle	ground	dog handle	mgmt	dog handle	pilot	ground	mgmt	ground
Height (in inches)	71	75	63	67	71	73	70	0	71	69	71	78	69	73	65	64
Glasses in Field	y	n	y	y	n	y	y	y	y	y	n	n	y	y	n	y
R eye visual acuity	30	30	30	30	20	20	20	20	20	30	40	30	20	30	20	40
L eye visual acuity	30	30	30	30	20	30	30	20	20	30	40	30	20	30	20	40
Colorblindness	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Hours on Task	1.6	1.6	1.5	2	1.8	1.8	1.8	1.5	1.25	1.12	1.5	1.3	1.5	1.6	1.5	2
Speed (kph)	1.7500	1.7500	1.8667	1.4000	1.5556	1.5556	1.5556	1.8667	2.2400	2.5000	1.8667	2.1538	1.8667	1.7500	1.8667	1.4000
Morale self assessment	h	h	h	m	h	h	h	m	h	h	h	h	h	h	h	h
Fatigue self assessment	a	a	a	m	a	a	a	m	a	a	a	a	a	a	a	a
Self POD Object #1	0.2	0.6	0.1	0.15	0.5	0.4	0.1	0.2	0.08	0.5	0.2	0.5	0.02	0.1	0.2	0.25
Self POD Object #2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estimated AMDR	50	25	100	0	0	0	70	0	20	30	20	40	40	25	30	0
Estimated 50%	30	15	100	40	50	25	30	0	50	15	0	40	20	30	15	14
Estimated SW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (F)	80	76	80	85	83	80	80	70	77	76	70	82	75	75	85	80
Wind Speed (mph)	5	3	2	2	0	2	2	0	2	2	2	0	1	0	0	2
Cloud Cover (%)	25	58	0	30	0	20	40	50	10	30	10	50	5	30	0	15
Precip. (type & intensity)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meteorological visibility	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul	ul

Search Object # 1 Human White-Orange

Clue #	LR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	12	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
3	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	47	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0
10	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	34	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	0
21	47	0	1	0	0	0	1	1	0	1	1	1	1	1	1	1	0
22	22	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0
23	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	18	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Total	14																

Search Object # 2 Human Blue

Clue #	LR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
5	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	28	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0
8	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	35	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
11	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	53	0	0	0	0	0	1	0	1	1	1	1	1	0	0	1	0
18	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	25	1	1	0	0	1	1	0	0	0	1	0	1	1	1	1	0
27	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	13																

Search Object # 3 Human Green

Clue #	LR	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	25	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
2	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	16	0	0	0	1	1	1	1	0	1	1	1	1	1	0	1	0
8	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
10	30	0	1	0	1	1	0	0	0	0	0	1	1	1	0	1	0
11	15	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0
12	29	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0
13	14	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	14																

Mt. Diablo, California – Summer

Searcher Number

Searcher Characteristic	1	2	3	4	5	6	7	8
Age (in years)	37	48	49	33	18	33	27	48
Gender (M or F)	m	m	m	f	f	m	m	m
Years in SAR	9	3	24	10	2.5	5	0	0
# of SAR Searches	75	4	200	0	1	25	0	0
# of Field Searches	45	0	200	0	1	25	0	0
Avg # of Searches	8.333333	1.333333	8.333333	0	0.4	5	0	0
Primary SAR specialty	tracking	comm	tracking	ground	dog handle	Bike	ground	ground
Height (in inches)	67	74	72	69	65	71	74	71
Glasses in Field	y	y	y	n	y	y	n	y
R eye visual acuity	0	20	20	0	20	20	20	20
L eye visual acuity	0	20	20	0	20	20	20	20
Colorblindness	n	n	n	n	n	n	Y	n
Hours on Task	2	2.3	2	3.5	2.5	1.8	2	2.5
Speed (kph)	1.8000	1.5652	1.8000	1.0286	1.4400	2.0000	1.8000	1.4400
Morale self assessment	high	high	high	high	medium	high	high	high
Fatigue self assessment	alert	alert	alert	medium	drowsy	alert	alert	alert
Self POD Object #1	0.25	0.45	0.65	0.75	0.6	0.6	0.2	0.4
Self POD Object #2	0.6	0.55	0.9	0.75	0.75	0.75	0.5	0.25
Estimated AMDR	50	200	70	200	60	200	50	200
Estimated 50%	33	50	25	0	60	50	50	50
Estimated SW	0	0	0	0	0	0	0	0
Temperature (F)	0	0	0	0	0	0	0	0
Wind Speed (mph)	0	0	0	0	0	0	0	0
Cloud Cover (%)	0	0	0	0	0	0	0	0
Precip. (type & intensity)	0	0	0	0	0	0	0	0
Meteorological visibility	ul	ul	ul	ul	ul	ul	ul	ul

	Search Object # 1	Human White-Orange							
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	4	1	1	1	1	1	1	1	1
4	45	0	0	0	0	0	0	1	1
5	14	1	1	1	1	1	1	1	1
10	33	1	1	1	1	0	1	1	1
13	130	0	0	0	0	0	0	0	0
15	20	0	1	1	0	0	1	1	0
22	91	0	0	0	0	0	0	1	1
23	37	0	1	1	1	0	0	0	1
24	56	1	0	0	0	0	1	0	0
31	6	1	1	1	1	1	1	1	1
33	6	1	1	1	1	1	1	1	1
34	26	1	1	0	0	0	1	1	1
35	41	1	1	1	1	1	1	0	1
52v	29	0	0	0	0	0	0	0	0
56v	48	0	0	0	0	0	0	0	0
Total	15								
	Search Object # 2	Human Blue							
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
2	9	1	1	1	1	1	1	1	1
3	16	1	1	1	1	0	1	0	1
11	35	0	0	0	0	0	0	0	0
12	64	1	0	0	1	0	1	0	1
14	23	1	1	0	0	0	0	0	1
16	26	1	1	1	1	0	0	1	1
17	42	0	1	1	1	0	1	1	0
19	48	1	1	1	1	0	0	1	1
20	12	1	1	1	1	0	1	0	1
25	6	1	1	1	1	0	1	1	1
27	10	1	1	1	1	0	1	1	0
29	40	1	0	0	0	0	0	1	0
30	35	0	0	1	0	0	0	0	0
32	17	1	0	1	0	0	0	0	0
51v	47	0	0	0	0	0	0	0	0
53v	62	0	0	0	0	0	0	0	0
54v	58	0	0	0	0	0	0	0	0
55v	57	0	0	0	0	0	0	0	0
Total	18								
	Search Object # 3	Human Green							
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
6	68	0	1	0	0	0	0	0	0
7	146	0	0	0	0	0	0	0	0
36	2	1	1	1	1	1	1	1	1
38	15	1	1	1	0	0	0	0	0
39	20	0	0	0	0	0	0	0	0
40	4	1	1	1	1	1	1	1	1
42	3	0	0	0	0	0	0	0	0
45	5	1	1	1	1	0	1	0	1
47	19	0	0	0	0	0	0	0	0
48	21	1	1	1	0	0	1	0	1
49	10	0	1	0	0	0	0	0	0
Total	11								
	Search Object # 4	Clue - White Hat							
Clue #	**LR**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
8	106	0	0	0	0	0	0	0	0
9	10	0	1	0	0	0	0	0	0
18	5	1	1	1	1	1	1	1	1
21	8	1	1	1	1	0	0	1	1
26	20	1	1	1	1	0	0	1	1
28	15	0	1	0	1	0	0	1	1
37	9	1	1	1	1	1	1	1	1
41	2	0	1	1	0	0	1	0	0
43	5	0	1	0	0	0	0	1	1
44	10	1	1	1	1	0	1	1	1
46	11	0	0	0	0	0	0	0	0
50	1	1	1	1	1	0	1	1	1
Total	12								

Searcher Number

Searcher Characteristic	9	10	11	12	13	14	15	16	17
Age (in years)	50	37	31	32	57	50	20	42	44
Gender (M or F)	m	m	f	m	f	m	f	m	m
Years in SAR	25	3	2	0	5	22	1	1	9
# of SAR Searches	100	30	20	0	15	150	1	17	100
# of Field Searches	100	20	15	0	14	100	1	14	100
Avg # of Searches	4	10	10	0	3	6.818182	1	17	11.11111
Primary SAR specialty	ground	tracking	tracking	ground	tracking	tracking	ground	ground	mgmt
Height (in inches)	73	72	65	72	69	69	65	0	67
Glasses in Field	y	y	n	n	y	n	n	y	y
R eye visual acuity	20	20	30	30	0	20	20	0	20
L eye visual acuity	20	20	30	30	0	20	20	0	20
Colorblindness	n	n	n	n	n	n	n	n	Y
Hours on Task	2.75	2.5	2.6	1.8	2.6	2.6	1.5	1.5	1.75
Speed (kph)	1.3091	1.4400	1.3846	2.0000	1.3846	1.3846	2.4000	2.4000	2.0571
Morale self assessment	high	high	high	high	high	high	high	high	high
Fatigue self assessment	alert	alert	medium	alert	alert	alert	alert	alert	alert
Self POD Object #1	0.6	0.3	0.15	0	0.8	0.65	0.05	0.4	0.4
Self POD Object #2	0.8	0.6	0.4	0	1	0.8	0.2	0.75	0.7
Estimated AMDR	200	50	80	30	70	150	70	100	0
Estimated 50%	75	15	7	0	50	75	15	20	0
Estimated SW	0	0	0	0	0	0	0	0	0
Temperature (F)	0	0	0	80	80	80	80	80	0
Wind Speed (mph)	0	0	0	4	4	4	4	4	0
Cloud Cover (%)	0	0	0	0	0	0	0	0	0
Precip. (type & intensity)	0	0	0	0	0	0	0	0	0
Meteorological visibility	ul	ul	ul	ul	ul	ul	ul	ul	0

Search Object # 1 — Human White-Orange

Clue #	LR	9	10	11	12	13	14	15	16	17
1	4	1	1	1	1	1	1	1	1	1
4	45	1	1	1	0	0	1	0	0	0
5	14	1	1	1	1	1	1	1	1	1
10	33	1	1	1	1	1	1	1	1	1
13	130	1	0	0	0	0	0	0	0	0
15	20	1	0	0	0	1	1	1	1	1
22	91	1	1	1	0	1	0	0	1	1
23	37	1	1	0	1	1	1	1	1	1
24	56	0	0	0	1	0	1	1	0	1
31	6	1	1	1	1	1	0	1	1	1
33	6	1	1	1	1	1	1	1	1	1
34	26	1	1	1	0	0	1	1	1	1
35	41	1	1	1	1	1	1	1	1	1
52 v	29	0	0	0	0	0	0	0	0	0
56 v	48	0	0	0	0	0	0	0	0	0
Total	15									

Search Object # 2 — Human Blue

Clue #	LR	9	10	11	12	13	14	15	16	17
2	9	1	1	1	1	1	1	1	1	1
3	16	1	1	0	1	1	1	0	1	1
11	35	0	0	0	0	0	0	0	0	0
12	64	1	0	1	0	1	1	0	0	0
14	23	1	0	1	0	0	0	1	1	1
16	26	1	1	1	1	1	0	1	1	1
17	42	1	1	0	0	1	1	1	1	0
19	48	1	1	1	1	0	1	1	0	1
20	12	1	1	1	1	0	1	1	1	1
25	6	1	1	1	1	1	1	1	1	1
27	10	1	1	1	1	0	1	1	1	1
29	40	1	0	0	0	0	1	0	0	0
30	35	0	0	0	0	0	0	0	0	0
32	17	0	0	0	0	1	0	0	0	1
51 v	47	0	0	0	0	0	0	0	0	0
53 v	62	0	0	0	0	0	0	0	0	0
54 v	58	0	0	0	0	0	0	0	0	0
55 v	57	0	0	0	0	0	0	0	0	0
Total	18									

Search Object # 3 — Human Green

Clue #	LR	9	10	11	12	13	14	15	16	17
6	68	0	1	0	0	0	0	0	0	0
7	146	0	0	0	0	0	0	0	0	0
36	2	1	1	1	1	0	1	1	1	0
38	15	0	0	0	0	0	0	0	0	0
39	20	0	0	0	0	0	0	0	0	0
40	4	1	1	1	1	1	1	1	1	1
42	3	1	1	0	0	0	1	1	0	0
45	5	1	1	1	1	1	1	1	1	1
47	19	0	0	0	1	0	1	0	0	0
48	21	1	0	0	1	1	0	0	1	0
49	10	1	1	0	0	0	0	0	0	0
Total	11									

Search Object # 4 — Clue - White Hat

Clue #	LR	9	10	11	12	13	14	15	16	17
8	106	0	0	0	0	0	0	0	0	0
9	10	0	1	0	0	0	1	0	1	0
18	5	1	1	1	1	1	1	1	1	1
21	8	1	1	1	1	1	1	1	1	1
26	20	1	1	1	1	1	1	1	1	1
28	15	0	1	0	1	1	1	1	1	1
37	9	1	1	1	1	1	1	1	1	1
41	2	0	1	0	1	0	1	0	0	0
43	5	0	1	1	1	0	0	1	1	0
44	10	1	1	1	1	1	1	1	1	1
46	11	0	0	0	0	0	0	0	0	0
50	1	1	1	1	1	1	1	1	1	0
Total	12									