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The Journal of Search and Rescue (JSAR) is an open access peer-reviewed electronic journal for the collation and distribution of original scholarly material on search and rescue (SAR).

It is being supported by the in-kind work and contributions of the Editorial Board. There is still the need for a dedicated journal serving those with a direct interest in all disciplines of search and rescue including: rope rescue, water (flat, swift and marine), ice rescue, wilderness search and rescue, structural collapse rescue, trench collapse rescue, cave rescue, dive rescue, motor vehicle extrication, canine search, technical animal rescue, air rescue, search theory, search management, and mines rescue. JSAR exists to fulfil that need.

Article submissions from these and other SAR disciplines are welcome. Launching this journal on the internet offers a relatively cost-effective means of sharing this invaluable content. It affords the prompt publication of articles and the dissemination of information to those with an interest in SAR.

JSAR will provide a forum for the publication of original research, reviews and commentaries which will consolidate and expand the theoretical and professional basis of the area. The Journal is interested in theoretical, strategic, tactical, operational and technical matters.

Advertising within JSAR will be considered in the future to ensure sustainable funding is available to enhance and continue the work of the journal. The publication of an article in the Journal of Search and Rescue does not necessarily imply that JSAR or its Editorial Board accepts or endorses the views or opinions expressed in it.

Cover Image: A Mountain Rescue Team, by Geoff Charles (1952). Llyfrgell Genedlaethol Cymru / National Library of Wales.

Volume 4, Issue 1, April 2020
Pages 1-165
ISSN 2230-5734

Journal of Search & Rescue

Contents

Volume 4, Issue 1, April 2020
Pages 1-165
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Editorial

The Journal of Search & Rescue (JSAR) partnered with the William G Syrotuck Symposium on Search Theory and Practice held in Reykjavik, Iceland to produce this special issue of JSAR. This is the first of a long future of presenting special joint issues. The William G Syrotuck Symposium on Search Theory and Practice is often more simply referred to as the Syrotuck Symposium. It has an impressive history of furthering search theory and advancing the field. Chris Long, the Washington State SAR coordinator, who organized all of Syrotuck Symposiums, provides an overall history in this issue, starting with the first formal Syrotuck Symposium held in 1996 in Denver, Colorado. However, Rick LaValla, in presenting the bio and history of William Syrotuck himself, makes an excellent case that the first formative Symposium took place with "Bill" in attendance back in 1975 as part of a search planning think tank organized by the National Park Service in the Grand Tetons. Much like those early days, Chris Long identified an important gap: how can the information, new knowledge, and experience shared by the Syrotuck Symposium participants have a greater impact than simply reaching those in the room? JSAR exists to disseminate quality information, meeting academic standards, and so a partnership was born. We hope that this is a long and fruitful partnership. We also look forward to putting out another special issue for the next Syrotuck Symposium. A call for papers has recently been made by Chris Long for the next Syrotuck Symposium to be held October 14-15, 2020 again in Reykjavik in conjunction with ICE-SAR Rescue 2020. JSAR is also looking to offer other organizations that are advancing SAR and are looking for a vehicle to disseminate high quality papers. JSAR remains a peer-reviewed, online/digital, open access journal to advance search and rescue.

In looking over all of the presentations made at the Syrotuck Symposium, I'm struck by the wide diversity in the background of the presenters. They represented air, land, and sea disciplines of SAR. They also ranged from full-time employees and volunteers of NGOs, government, military, academics, and industry. However, what everyone present had in common was being a SAR practitioner at some level. Therefore, it isn't surprising that the papers tend to offer practical advice on how to be better. Not everyone who presented provided a paper. However, all of the abstracts of those who presented are provided and those that have an associated paper are marked with an asterisk.

Dagbjartur Brynjarsson of ICE-SAR who also helped organize some of the logistics of the Syrotuck Symposium opened with a presentation on the implementation of formal search theory and land search management in Iceland and how it has been applied. He clearly showed that using search theory is not abstract but can be put into practice. Einar Eysteinsson's paper on Lost Person Behavior – Statistics from Iceland was not presented at the Syrotuck Symposium itself but a few days later at the ICE-SAR Rescue 2018 conference. It has a strong research basis and uses a novel methodology of comparing a more limited database to a larger database. The Washington State SAR Planning Unit with a paper from Mansfield, Carlson, Merrifield, Templin, and Rosenberg also describes a pragmatic approach to applying search theory in the land environment. It became evident from just combining a displacement or ring model and dispersion model that the math can become tedious quickly. Presentations from Frost (who unfortunately couldn't be present so Matthews from the USCG SAR School stepped in) and another by Koester described how computer software can be used as tactical decision aids. They discussed the Search and Rescue Optimal Planning System (SAROPS) being a well-established tool for the maritime environment and FIND being a new tool for the land environment. Koester also discussed how updates in ISRID has improved the Autism Spectrum Disorder category and new spatial models. In a second presentation, Frost wisely pointed out how even with sophisticated tools humans can find novel ways of

Volume 4, Issue 1, April 2020
Pages 1-165
ISSN 2230-5734

making major errors (searching completely the wrong area) with minor mistakes (not entering a negative sign into the flight computer); an important warning and lesson for anyone designing automated systems. Several papers dealt with the management of information and process involved in a search. In fact, it could be argued that a search and rescue incident is one of the most complex information management incidents within public safety. Burke addressed Virtual search planning which involves integrating information from multiple sources and creating an actionable information package for the team actually on the ground managing the incident. Hammond looked at information and process from a SAR team perspective, looking at how they function in chaotic environments with high reliability. He also addressed the importance of team dynamics. Wright and Smith looked at the SAR Planning P process, with a particular emphasis on the transition from initial response to more extended operations. Young went into great depth on the types and need to collect search intelligence and how it should be organized. Two presentations also advanced our understanding of Probability of Detection. Roberts and Hamilton presented Exercise Northumberland which made a meaningful comparison of different resources all searching the same area for the same subjects. The Exercise involved fixed wing aircraft, rotary aircraft, sUAV, ground searchers, and canine. While the full paper is not included here, it can be found on the Centre for Search Research website and the link is provided along with the abstract. Koester described several Probability of Detection experiments involving: day versus night searching; impact of one, two, and three person teams on a linear task; use of FLIR sensors; and additional correction factors. In the end, it is all about instruction and passing on knowledge. To that end, Rockwood presented how the US National Search and Rescue School develops its curriculum, what it teaches and asked what could be improved.

Hopefully, all of us regularly ask ourselves: what can we do better, how can I be safer, how can I find the subject sooner? If you are reading this you are taking an important step. Next, how will you integrate this new knowledge on an actual incident?

Dr Robert Koester

History of the William G. Syrotuck Symposium on Search Theory and Practice

Chris Long
Washington State SAR Coordinator
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The Syrotuck Symposium began in 1996 to: "Foster the intellectual and scientific development of SAR methods and techniques, to promote new ideas, and to encourage development of new techniques and the practical use of technology."

The idea of a symposium focused on search for the lost person has its origins with Bill Wade and the National Park Service (NPS). In 1975, Bill brought together the prominent search function researchers to share information and methods. In addition to Bill, participants included Dennis Kelley, Lee Lucas, Bob Mattson, Bill Syrotuck, and Jon Wartes. Out of that meeting, and concurrent work on the new search management course, came the foundation of what we now recognize as the theory and practice of search for the lost person.

By 1995 a significant body of research on the search function had been conducted by many individuals around the world. A number of people including Paul Anderson, NPS and then-NASAR President; Rick LaValla, ERI International and former NASAR president; Don Cooper, author and trainer; Hugh Dougher, NPS; Skip Stoffel, ERI; and others felt it was again time to assemble the leading experts in the field in order to further the study of the search function and to explore new ideas and concepts. The 1996 NASAR conference in Denver was selected as the venue.

At Rick LaValla's suggestion, the Symposium was named in honor of the late Bill Syrotuck, one of the true pioneers in the field of search for the lost person. The Symposium was open to all who wished to attend. In order to ensure that those known to be active in the study of search theory and practice would be aware of the Symposium and would have the opportunity to make a presentation on their work, some 64 personal invitations were signed by Paul Anderson, NASAR President.

As had been hoped, that first Syrotuck Symposium served as the start of a series of follow on workshops on search theory, practice, and training. Although logistical problems preclude a second Symposium at the 1997 NASAR Conference in Richmond, Virginia, Don Cooper's Special Interest Group meeting, Modern Perspectives in Search Theory, served as a worthy stand-in. While in Richmond, Carol O'Rourke-Elliott from Canada's National SAR Secretariat (NSS) offered to sponsor the second Symposium at SARSCENE 97, Canada's national SAR conference, that fall in Sault Ste. Marie, Ontario.

The third Symposium, co-sponsored by NASAR and ERI, was held at the 1998 NASAR Conference in Portland, Oregon. Due to numerous requests, the NSS sponsored a fourth Symposium that fall at SARSCENE 98 at Banff National Park, Alberta. The fifth Symposium was again sponsored by the NSS at SARSCENE 99 in St. Johns, Newfoundland. The sixth Symposium was scheduled for September 12th, 2001 in conjunction with SARSCENE 2001 in Whitehorse, Yukon Territory. It was canceled as a result of the terrorist attacks on 9/11. The NASAR/MRA conference at Woodcliff Lake, New Jersey in June, 2014 was the site of the revived Symposium.

The most recent Symposium was held October 11-12, 2018 in Reykjavik, Iceland in conjunction with the Icelandic Association for Search and Rescue RESCUE 2018 conference.

William Syrotuck Foreword

Rick LaValla

Washington State SAR Coordinator (Former)
NASAR President (Former)
SAR Historian
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The aim of the Syrotuck Symposium is to foster SAR best practice dialogue and debate. The symposium founder, Chris Long, back in the day was in quest of a name for this event and I suggested it be named for William "Bill" G. Syrotuck who, in the 1960s and 1970s, was a SAR innovator particularly in matters dealing with search management, the training and application of air scent dogs (he also experimented and considered the use of falcons), and use of search theory.

It was late 1971 and I was hired by the State of Washington Civil Defense to work as assistant to Hal Foss the State's SAR Coordinator and founder of the National Association for SAR. Principles of land search planning and SAR management as we know it today were lacking. Law enforcement would often wait 24 hours to determine if someone was indeed missing. "Experienced" individuals (most often older SAR volunteers) would rise to the occasion to serve as the 'search master, mission coordinator, or ring master' (pick a title!). Development of a search plan was inexact and lining searchers "shoulder to shoulder" to move through a search segment was a frequently used tactic.

Bill was promoting the idea that principles of land search planning and management could be taught in a training course environment (much like the US Coast Guard and Air Force mission coordinator schools). He was publishing papers on use of probability theory to establish a search plan and determine probability of detection. He analyzed SAR mission reports and published profiles of lost person behavior with the suggestion that these would be useful in search planning. He stated that the early application of air scent dogs and hasty search resources could be beneficial.

I was told by many of the old "experienced" volunteers that Bill was "nuts" and to stay away from him, and that you only earned the right to be a SAR leader/manager after many years of experience (ignore the fact that you might be doing it wrong).

Meanwhile there were other people emerging who had the same observations as Bill: that land search planning and management needed to come out of the dark ages. People such as Jon Wartes and Explorer Search and Rescue were promoting hasty searching and quantifying probability of detection for search methods. Dennis Kelley published his book *Mountain Search for the Lost Victim* that included use of probability theory. Many other 'thinkers' were emerging as well.

During 1971-1972 Washington State was looking at the National SAR School and the Civil Air Patrol's mission coordinator schools as a framework for inland SAR management training. The National Park Service (NPS) also recognized the need for search management training and were working with Bill to build a training course. NPS conducted a prototype course built around Bill's ideas and publications.

I attended this first NPS course and subsequently began working in collaboration with Bill, the NPS, and other search innovators to continue the development of a best practice search planning course. In 1975 the NPS convened the first search planning think tank in Grand Tetons. Bill and all the innovators of the day were in attendance to debate and further develop inland search planning concepts. In retrospect this was the first "Syrotuck Symposium". NASAR meetings and conferences also provided forums to bring people together to further the development of search management and planning. Until his passing in late 1976, Bill was the center of the "managing the search function" course development, and was the lead instructor (usually 16 hours) for the POA x POD = POS lectures.

Bill was a Canadian living in the USA and married to his lovely wife Jean, an American and a nurse who was involved with hypothermia research. Bill and Jean and their air scenting dogs were deployed to hundreds of lost person missions throughout the country via the US Air Force giving them a national view during the 60's and 70's of how search management was done (or not). Not much is known about his background before coming to the USA. After his passing it was whispered that he had involvement with Canada's "Camp X" and participated in Canada and USA cold war activities. Was his last name really "Syrotuck"?

I was in Bill's company often during these years; rooming with him and debating course content and principles far into the night. I would mention often that he was indeed "nuts" as the old heads in the early days stated; that anyone who would devote their life solely to finding and aiding person is distress must be "certifiable" and should not be allowed to run free. We would have a laugh and then dive back into the "craziness" of course development.

Bill was a mentor and a friend. He would be pleased that the quest for best practices in SAR, and the associated dialogue and debate, continues in his memory.

Syrotuck Symposium

ABSTRACTS

Implementation of Formal Search Theory And Land Search Management In Iceland And How It Has Been Applied.

Dagbjartur Kr. Brynjarsson, ICE-SAR, Iceland

This presentation will discuss the implementation of formal Managing Land Search Operations to the ICE-SAR Rescue school curriculum and how it was adapted to fit the Icelandic SAR system and the natural environment. We will discuss the obstacles we encountered and the situation that exists today. This will include the conduct of search operations in Iceland from pre-planning through extended operations as well as the process for transition from initial response activities to extended operations in which formal search theory must be employed.

Lost Person Behavior - Statistics from Iceland*

Einar Eysteinsson, ICE-SAR, Iceland

To be able to find the missing person you must search in the right place. The sooner you do that the sooner you will find the person. By analysing previous searches, you are able to predict what others will do in similar situation

Since the 2010 the Icelandic Association for Search and Rescue (ICE-SAR) has recorded searches according to ISRID standards. The recording has not been continuous, but the ICE-SAR database has 189 incidents. At the conference Rescue 2018, held by ICE-SAR, statistics from ICE-SAR database was presented.

Virtual Search Planning

Paul Burke, Nevada State SAR Coordinator, USA

Virtual Search Planning is a process, by which relevant elements related to a missing person are examined and analyzed within a fixed period of time, and a solution set related to the subject and their location is developed and delivered to the requesting party. This is done remote from the search base or incident command post and benefits from the removal of emotions and personalities often accompanying the localized, on- site planning effort.

The items contained within the analysis include, but are not limited to, a comprehensive review of the following elements: Subject profile and specific actions; Subject clothing and equipment;

* Denotes that a paper is included in this issue.

Physical, Psychological, and Pharmacology review of the subject; Statistical data related to similar subjects in similar environments; past, present, and future weather related to the search location; terrain and geography; cell phone forensics; social media profile; radar forensics, and vehicle profile and dynamics.

Readily available and common software is used to gather and format the data, and to develop and deliver VSP components to the requesting agency. There is no specific software used to evaluate the data, and there is no computer generated solution. Technology is used only to gather and organize the data for the team of "VSP Analysts" to evaluate the sum total of the information gathered. Information is recorded and verified/annotated to reference the source of all information.

Search and Rescue Optimal Planning System (SAROPS)

J. R. Frost, SAROPS Program Manager, USCG Office of Search and Rescue, USA

The U. S. Coast Guard employs a sophisticated computer-based search planning system called SAROPS to plan searches for persons and craft in distress in the marine environment (although it could, in theory, be adapted for use on/over land). This system provides a robust list of over 80 search object types, including leeway for drift calculations and detection characteristics for estimating effective sweep widths and optimally allocating search effort. Up to four possible search object types may be simulated simultaneously to cover situations where the post-distress state of the craft and survivors is not precisely known. SAROPS provides a number of different scenario types that can be used alone or in combination. These are used to develop scenarios describing what is known or assumed about "originating craft" behavior prior to distress in order to develop thousands of estimates of possible times and corresponding positions where a distress may have occurred. Hazards can be added to Voyage/Flight scenarios to represent regions, such as heavy weather, of increased probability of distress. SAROPS is supported by an Environmental Data Service that provides a catalog of environmental data products from various sources. The search planner selects the sources to be used and SAROPS then computes drift trajectories for each of thousands of simulated search objects to produce a time-series of probability grids on search object location. Once the drift simulation is complete, the search planner enters the planning phase. Inputs include the available search assets, their sensors, the on scene conditions affecting detection, the on scene endurance of each asset, etc. Based on these inputs, SAROPS computes an optimal search plan that maximizes the Probability of Success. This includes simulating the simultaneous motions of simulated search objects and simulated search assets, which means SAROPS does a dynamic optimization. If additional searching is required, SAROPS properly accounts for the negative results of prior searching in order to maximize the cumulative overall POS when developing subsequent search plans.

Issues with Electronic Navigation Systems and Search Patterns

J. R. Frost, SAROPS Program Manager, USCG Office of Search and Rescue, USA

Electronic navigation systems allow both surface and airborne search assets to navigate very precisely. When combined with on-board computing systems and autopilots, search patterns can be computed and followed with the same precision. However, search planners use standard methods for specifying search patterns that have been in place for over 60 years. In addition, the standard methods for computing pattern waypoints also date back more than 60 years. These methods are described in the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual and in the national search and rescue manuals, supplements, and addenda of many countries. On the other hand, the inputs required for most pattern-capable electronic navigation systems do not follow these standards. The result has been a substantial number of different, navigation system-specific, input data sets and pattern waypoint outputs that do not necessarily match the tasking from the search planners. Aircraft and vessel crews must translate the search pattern specifications provided by search planners into the inputs required for their particular navigation system, a process that is susceptible to errors that may not be detected. In addition, even if the translation is done correctly, a single keystroke error or omission during the data entry process into the navigation system can completely alter the area that is searched, rendering the actual search ineffective. Errors of this nature are even more difficult to detect. Finally, even if the translation and data entry are both correct, the methods used by on-board navigation systems for computing waypoints is, in many cases, different from the standard methods used by search planners. These issues have been raised internationally and are illustrated by comparing search pattern plots as planned with those computed by on-board navigation systems of several USCG aircraft types. Formation of an appropriate international standards committee under the auspices of the International Standards Organization (ISO) is advocated so that the difficulties described above may be addressed and eliminated or at least substantially mitigated. A related set of issues is raised in polar regions where the standard methods of the IAMSAR Manual are not usable. Therefore, new standards will be needed to cover situations involving searches close to a pole.

Regulation, Reliability, and Creative Non-Compliance*

Scott C. Hammond, PhD, Utah State University, USA

Highly Reliable Teams (HRT) work in complex and extensively regulated environments where improvisation outside routine processes can be critical to success. Work teams in search and rescue, emergency medicine, surgery, aviation, and military solve complex problems in chaotic environments with high reliability. They must produce successful outcomes under the detailed and conflicting regulations from professional societies, sponsoring agencies, and government.

This research project will identify how HRTs deal with regulation during times of high stress and chaos when solutions fall outside accepted process and regulatory protection. The Principle Investigator (PI) proposes to imbed with six different HRTs, and through observation, interview and participation, explore the relationship, regulation, reliability, and non-compliance.

Land Search and Rescue Probability of Detection: New sweep widths values, correction factors, models, and detection model validation*

Robert Koester PhD, dbS Productions, USA

Search theory allows for correction factors to account for conditions (such as night) that affect the sweep width value. Search theory also predicts that the coverage is proportional to the probability of detection by either the inverse cube curve or exponential function (random search). The objective is to determine the correction factors from night searching, use of IR detection devices and validate the coverage curves.

Effective Sweep Width experiments were conducted in the same location with the same medium visibility adult-sized targets during both the day and the night in a temperate forest. Additional experiments examined the impact of one, two, and three person teams. In addition, high and low visibility clue-sized objects were placed directly on the trail. Low visibility human subjects were used for infrared detection.

We found an effective sweep width of 64 meters during the daytime and 22 meters at night for a correction factor of 0.34 for the adult-sized targets. Both high (100% vs 94%) and low (83% vs 43%) visibility clues were more detectable during the day versus night ($P<0.001$). Searchers with dim flashlights (<200 lux at one meter) resulted in an additional correction factor of 0.5. The use of IR at night increased the sweep width to 68 meters. Two searchers increased the sweep width value by 1.3; however, three searchers didn't see a statistical increase. The probability of detection versus coverage plots of both day and night experiments fell between the inverse cube and exponential curves.

This single experiment for only one visibility class of search target showed that visual searching is significantly degraded by searching at night. The daytime coverage suggest the inverse cube model while the night coverage suggests an interim result. The use of effective sweep width, correction factors, and validated coverage curves can lead to more accurate assessments of the probability of detection.

Enhancements to statistical Probability of Area Models based upon updated ISRID data collection for Autism Spectrum Disorders and Typical Children*

Robert Koester PhD, dbS Productions, USA

The International Search and Rescue Incident Database (ISRID) previously contained 50,000 incidents which was the basis for information found in Lost Person Behavior. A new round of data collection increased the size of ISRID to 145,000 incidents. This latest effort resulted in new data standards and a new data collection tool called Search and Rescue data Collection & Analysis Tool (SARCAT) to improve data quality. A new spatial model called the point model was created which provides the probability that the subject is found within 100 meters of the IPP or the destination. The value of combining different spatial models such as the ring model and distance from IPP as scored by MapScore has been determined to statistically significant. Several new subject categories are defined including multiple scenario based profiles (medical, trauma, investigative, avalanche, etc.). Additional new subject categories will be presented. A more detail analysis of Autism profile is also provided. Significant differences are seen between Autistic Spectrum Disorders and Typical Children. The new ISRID data has also been used to determine enhanced and more detail survivability curves out to the 95%. The integration of multiple models together along with expression of the Probability of Success Rate (PSR) in the FIND tactical decision aid will be discussed.

A Pragmatic Approach to Applied Search Theory*

Guy Mansfield PhD, Joe Carlson BA, Danny Merrifield MS, Peter Templin BS, Eric Rosenberg, Washington State SAR Planning Unit, USA

The Washington State SAR Planning Unit (SSPU) was activated in 2018 with the goal of providing advanced search planning resources to regional incident commands during extended or complex search missions. The SSPU operates under the auspices of the Washington State Emergency Management Department, and is a team of experienced SAR volunteers with extensive training in search management and planning. In addition to providing search planning strategies and technical mapping, one of our primary objectives is to apply modern search theory to challenging search incidents.

Our application of search theory can be parsed into three related planning tasks: (1) Defining initial search regions and segments; (2) Assessing search effectiveness; (3) Prioritizing search segments for subsequent operational periods. A major challenge faced in achieving these objectives, is that the SSPU can be activated by any of the 39 counties in Washington State, all with different search planning approaches, different search data collection practices, and different experience with search theory principles. The SSPU typically engages after the first operational period of a search, and must adapt our search planning methodology to make optimal use of the

data and practices of the requesting jurisdiction.

To this end, the SSPU is developing a pragmatic approach to applied search theory that can be characterized in one phrase: “When objective data are available, use it according to search theory best practices; when only subjective input is available, at least be systematic”.

In our presentation, we will share the decision-tree used to guide our application of search theory under different conditions, along with tools and resources that have been developed to support our work. In addition, we will describe our pragmatic application of components of search theory to recent complex search incidents in Washington State.

Exercise Northumberland[1]

Peter Roberts, Carl Hamilton Center for Search Research, UK

Exercise Northumberland[1] was a major exercise set up to evaluate the performance of aerial and ground-based search assets, based on earlier work, in 1987, by the UK Home Office known as 'The O'Donnell Theory'. It set out to update these historical findings based on current approaches and methodologies for searching on the ground and developments in aerial technology.

Both Initial Response and Intermediate Phase search techniques were employed by both ground searchers and aerial assets including fixed and rotary wing piloted aircraft and fixed and rotary wing drones. An evaluation of the performance of each search asset was made. The challenges and logistics of setting up such an exercise will be discussed; the performance and effectiveness of each asset will be reported on and an outline of future research based on the outcomes of the exercise will be given. Future research will involve the Departments of Computing, Geomatics, Engineering and Neuroscience from the University of Newcastle upon Tyne in a collaboration to better understand this new search asset and to go beyond simply putting 'an eye in the sky'.

The U. S. National Search and Rescue School – Curriculum and Methodology*

Gregory C. Rockwood, Lt Col, USAF, USA

The Inland SAR Planning Course is a 5-day course for experienced SAR decision makers and planners taught free of charge across the United States. It presents a broad understanding of inland search theory and its application for air and ground searches for missing persons and aircraft with a focus on wilderness and rural area searches. The course consists of classroom lessons and practical, tabletop exercises. Emphasis is on the planning necessary for effective area-type search planning during an extended search using Probability of Success (POS), rather

[1] A copy of the full exercise report is available at http://searchresearch.org.uk

than just a few elements of POC (POA), or POD, to predictively allocate limited resources to their best effect. An additional objective of the course is to strengthen the U.S. Federal Government's role in its support to civil SAR through education, including promoting the capabilities of the RCCs, and requesting and coordinating the use of other federal resources with the goal of saving lives.

This presentation will begin with an overview of our curriculum, and an explanation of why we teach the methods of applying search theory for both aeronautical search and ground search to such a broad audience the way we do. Furthermore, in recognizing that there are alternate methods and countless variations used throughout the U.S. and the world, this presentation seeks to encourage dialogue about how the U.S. National SAR School could improve toward its own objectives, and standardize its curriculum with the international community.

The SAR Planning P Process – A Framework for Transitioning from Initial Response to Extended Operations*

Scott Wright PhD, President SARVAC Canada and Richard Smith, SAR Alberta, Canada

The Planning P is a familiar framework to Emergency Management for transitioning from the Initial Response for a more a formalized, structured response. In this presentation a SAR-specific P framework is proposed that retains the simplicity of the OODA Loop and Six Step Response Process in the Initial Response Period, with a critical decision point to continue as is, or activate the Incident Management Team in a more Formalized response for Second Operational Period and beyond. Each step and the associated Goals, Objectives, Strategies and Tactics will be explored through to the Subject being located, or Search Suspended.

The Search Intelligence Process*

Christopher S. Young, Chairman Bay Area Search and Rescue Council (BASARC), USA

The Search Intelligence Process of gathering information regarding the missing subject occurs during every search incident. We recognize intelligence information is used to build a subject profile; gather lists of people with firsthand knowledge of the missing subject that we want to talk to; and task investigators to research and mine information from various sources, like social media or cell phone data, to determine where to look and what to look for.

However, during the initial stage of an active search for a missing person, intelligence gathering can be very daunting, chaotic, haphazard or worse not initiated thus delaying the compiling of crucial information that could shorten the time it takes to locate the subject. In any other aspect of the search operation like ground searching or technical rope rescue we preplan, train and develop processes to be more efficient.

This presentation will discuss the search intelligence process by: defining the various sources of information available to use developing pre-plans for the gathering of intelligent information, developing decision trees, developing lists of reflex tasks, developing algorithms for transitioning between the initial actions into multiple operational periods and eventually to the termination of search operations, and develop ongoing training curricula with the goal of creating efficiencies and hone the necessary skills to perform the intelligence gathering process.

Lost Person Behavior - Statistics from Iceland

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Abstract

To be able to find the missing person you must search in the right place. The faster you can pinpoint the correct search location, the faster you will find the missing person. By analysing previous searches, planners can predict what others will do in similar situation. Since 2010 the Icelandic Association for Search and Rescue (ICE-SAR) has recorded searches according to ISRID standards and though the records are not continuous, the ICE-SAR database has 189 incidents. At the Rescue 2018 conference held by ICE-SAR, the following statistics from ICE-SAR database were presented.

KEY WORDS: *Lost Person Behavior, Iceland, Statistics.*

Introduction

This paper examines Lost person behavior theories from ICE-SAR's perspective and experience. ICE-SAR has used the International Search and Rescue Incident Database (ISRID) data presented in Robert J. Koester's *Lost Person Behavior* (2008) for many years). Since 2010 ICE-SAR has collected its own data, though the data collection has not always been continuous, At the 2010 Rescue conference, the first statistics were presented. Now, eight years later, we have 150 additional incidents in the ICE-SAR database.

Since search is an emergency and every search needs an immediate response. The sooner searchers correctly use the established search theories, the sooner we will accomplish our goal: to search in the right place!

Lost person theories are not new and are not something that ICE-SAR brought to the scene. The first book to be published about lost person behavior was Syrotuck's 1977 *Analysis of Lost Person Behavior: An Aid to Search Planning*. In his book, Syrotuck presented statistics from 229 incidents and categorized them into eight categories. Since then the development has been profound. Robert J. Koester published *Lost Person Behavior* in 2008 with over 50.000 incidents.

As shown by the growing body of literature, lost person behavior is an invaluable tool to search planners. Lost person behaviour is the analysis of past searches which allows us to find patterns in past searches that can be applied to the current search, to help figure out what the lost person was doing and where the search planners should begin their search.

The International Search and Rescue Incident Database, ISRID, was founded in 2002 by Robert J. Koester, with a grant he received from the United States Department of Agriculture, to collect and analyse SAR statistics from around the world (Koester, e.d.). One of the products resulting from that work is the book *Lost Person Behavior*, which includes over 50.000 SAR incidents categorized into 41 subject categories. In 2015 an application was lunched and is available for Android and IOS which allows searchers to take the search data into the field. The next version of the book, Koester's book will contain 150.000 incidents. ICE-SAR has sent 100 incidents and will contribute an additional 90 cases.

Since 2003, attempts have been made to start ICE-SAR database for lost persons. ICE-SAR got a grant to hire a student to collect and analyse cases over the summer, but the student quit before anything of value was produced. Then the "Missing person" form was made by collaboration between ICE-SAR and the National Commissioner, but it was never officially implemented and was therefore never widely used. Soon after when ICE-SAR got a new incident and crisis management software, the form was imported into the software but still remained unused.

At the conference Rescue 2010, Dagbjartur Kr. Brynjarsson and Sigurður Ólafur Sigurðsson gave a lecture of the first statistics from the ICE-SAR database, it contained 30 incidents. They analysed old incidents and recorded new cases during the summer of 2010.

Method

The recording of incidents in the ICE-SAR database is done manually. It has varied between the person in charge of the recording how protocol has been, but always followed ISRID standards.

Current protocol is that when a search mission starts, the person in charge of the database goes on monitoring the incident and crisis management software used by ICE-SAR. If necessary and if circumstances allow, he will contact the incident commander and ask for the missing information.

The incident and crisis management software used by ICE-SAR can't export the necessary data into a convenient format, sot he information is then manually typed into the ICE-SAR database.

Results

One of the main purposes of keeping Icelandic data is to contribute to ISRID because we have been users of and benefitted from that data for years. However, the biggest reason is we want to see how Iceland compares to ISRID. Local data always gives the best picture.

Today we are using the DRY Domain data from ISRID. We don't know how accurate that data is compared to our polar landscape. ISRID 3.0 is expected to publish polar data, and it will collected from Iceland, Canada and Alaska, US.

Significant differences are between the genders in the ICE-SAR database, approximately 64% of lost subjects in Iceland are males and 34% are females. Mixed gender groups are 3%. Solo subjects account for 91% of the incidents compared to 67% in the ISRID (Figs 1 & 2) (Koester, 2008, p 42).

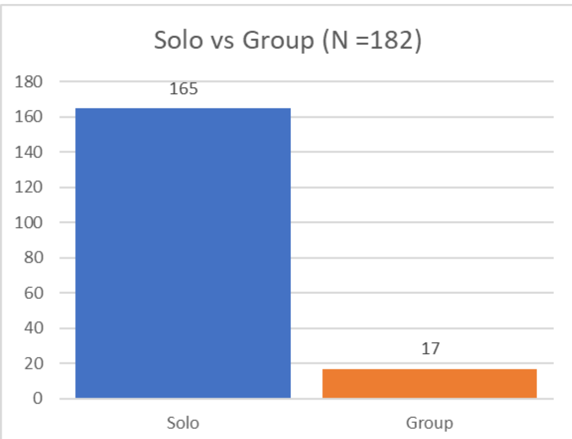

Fig 1: Solo vs Group

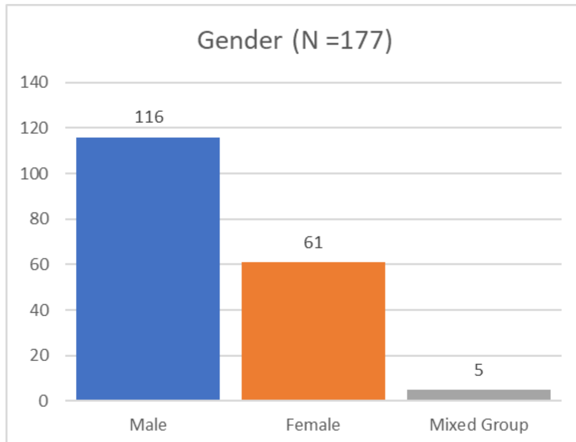

Fig 2: Gender

Fatality rate in the ICE-SAR database show incidents from all searches not just rescues. Subjects found well were 64% of the overall data, which is similar to the ISRID database's report of 62% of subjects found well, though the ISRID database includes both searches and rescues in its calculations (Koester, 2008, page 46). Another difference between the data is that the category hypothermia was added. Although cases of hypothermia could be classified under injured, incidents have been registered as hypothermia, as severe cold is a risk factor in Iceland all year around.

Another difference between the data in ISRID and ICE-SAR is that incidents with no trace of the victim have not been logged into the ICE-SAR database. Since 1970 there have been 43 incidents in Iceland with no trace of the subject („43 óupplýst mannshvörf síðan 1970 - Vísir", e.d.). (Fig 3)

The general find location for most searches matches well to the bicycle wheel model and the reflex tasking. Most of the subjects are found in linear features (spokes) and the reflectors.

Search technique training for ICE-SAR searchers emphasize these areas.

After the presentation at the Rescue conference in 2018, we found four more incidents where the subject was found in the river, those cases will be added into the ICE-SAR database.

The subject strategies graph is in Icelandic alphabetical order. (Fig 4)

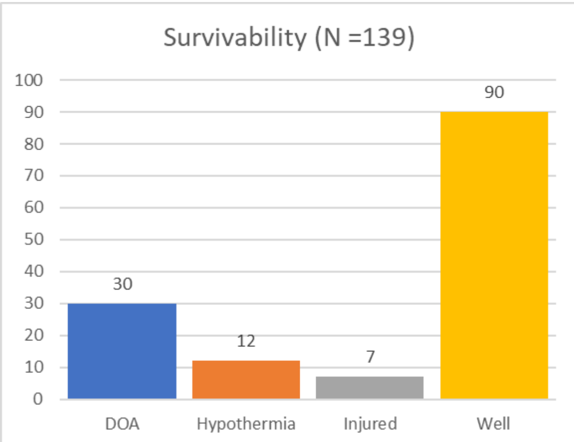

Fig 3: Survivability

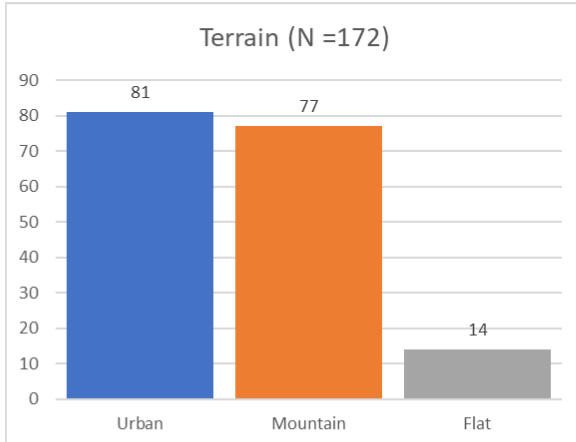

Fig 4:Terrain

The ISRID database contains mostly wilderness incidents (68%) (Koester, 2008, page 40). The ICE-SAR incidents contain 53% wilderness incidents. Although some might conclude that downtown Reykjavik is more difficult to navigate then other cities, it’s not. The reason the percentage of wilderness incidents is lower than ISRID’s is that ICE-SAR has a good working relationship with authorities and ICE-SAR is part of the initial response when someone gets lost in urban environment. Obligations and responsibilities of ICE-SAR and SAR personals for Urban response are bound in law from the Icelandic Parliament („43/2003“, e.d.).

Not many incidents are on flat environment. Those who are familiar with Icelandic wilderness know that in a flat environment you will stand out for kilometres and the lack of vegetation makes it easy to find your way back. But as the data shows, some people do become lost there, most often because of weather conditions, medical issues or substance abuse. (Fig 5)

In terms of knowing who found the subject, only 137 incidents note who found the missing person. We know from experience that the air-scent dogs and tracking dogs have found more than the data shows but it has not been logged. It varies how the information is logged between incident commanders who log into the Sareye Incident and Crisis management software („Proven Incident and Crisis managment software | Sareye“, e.d.). In Iceland we have specialized search techniques teams that have more education and training than regular searchers. They are often called out first or handed special assignments. It’s likely that some of the search team categorization is based on a specialized search technique, but we can’t say for sure because it’s not logged. We hope that recent update to the Incident and Crisis management software will improve this data because know searchers can tag there certifies to their names. (Fig 6)

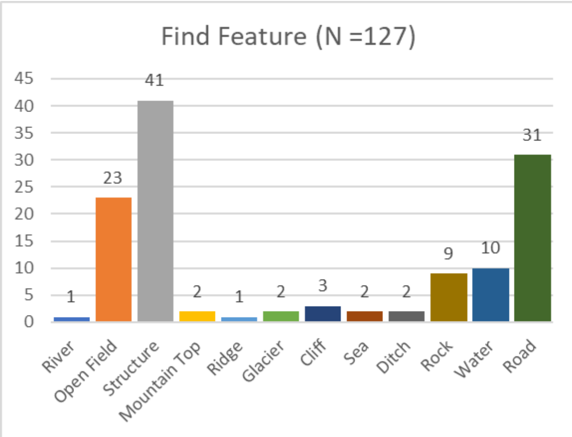

Fig 5:Find Feature

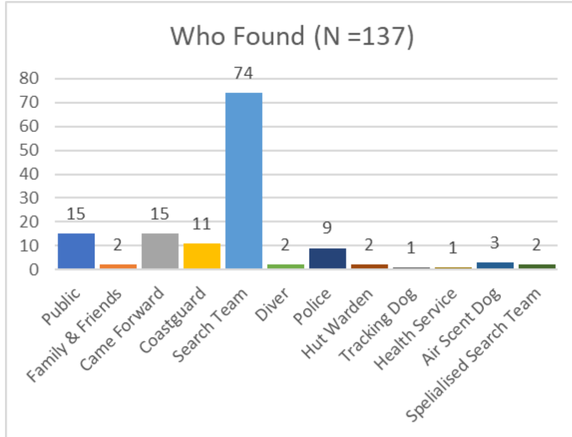

Fig 6: Distribution of finders

The ICE-SAR database contains 19 subject categories unlike the ISRID database that contains 41 categories. The chart below shows three data fields that contain two categories. Although the hierarchy of subject categories would tell you to use the category "vehicle" before you use the category "dementia," it was decided to keep them together as they were logged during search planning, where the categories were deemed equally important.

Until recently, nationality was not part of the ICE-SAR database. It was thought to be necessary to add it because of growing number of lost tourists. In 2017, for example, there were 2.2 million (Ferðaþjónustu, e.d.) who took off from Keflavik airport. The questions arose: who is more likely to get lost, an Icelander or a tourist and do the tourists and Icelanders respond differently when lost?

When we looked more closely at the subject categories and compared them to ISRID we found out that we have fewer incidents involving hikers, hunter and abductions, but more cases of those with dementia, despondency, and mental illness.

We think the reason for lower incident rates for hikers and hunters in Iceland vs ISRID is because Iceland has newer data. In recent years the public's knowledge of hiking and on the outdoors has increased and people are now better equipped, often having smartphones with better signals than previous mobile devices and easy access to GPS and PLB. Therefore, those individuals that would have gotten lost 15 years ago can now find their way back to safety or get in touch with their families without the help of SAR.

Growth in dementia incidents we think is caused by growing life expectancy and larger population.

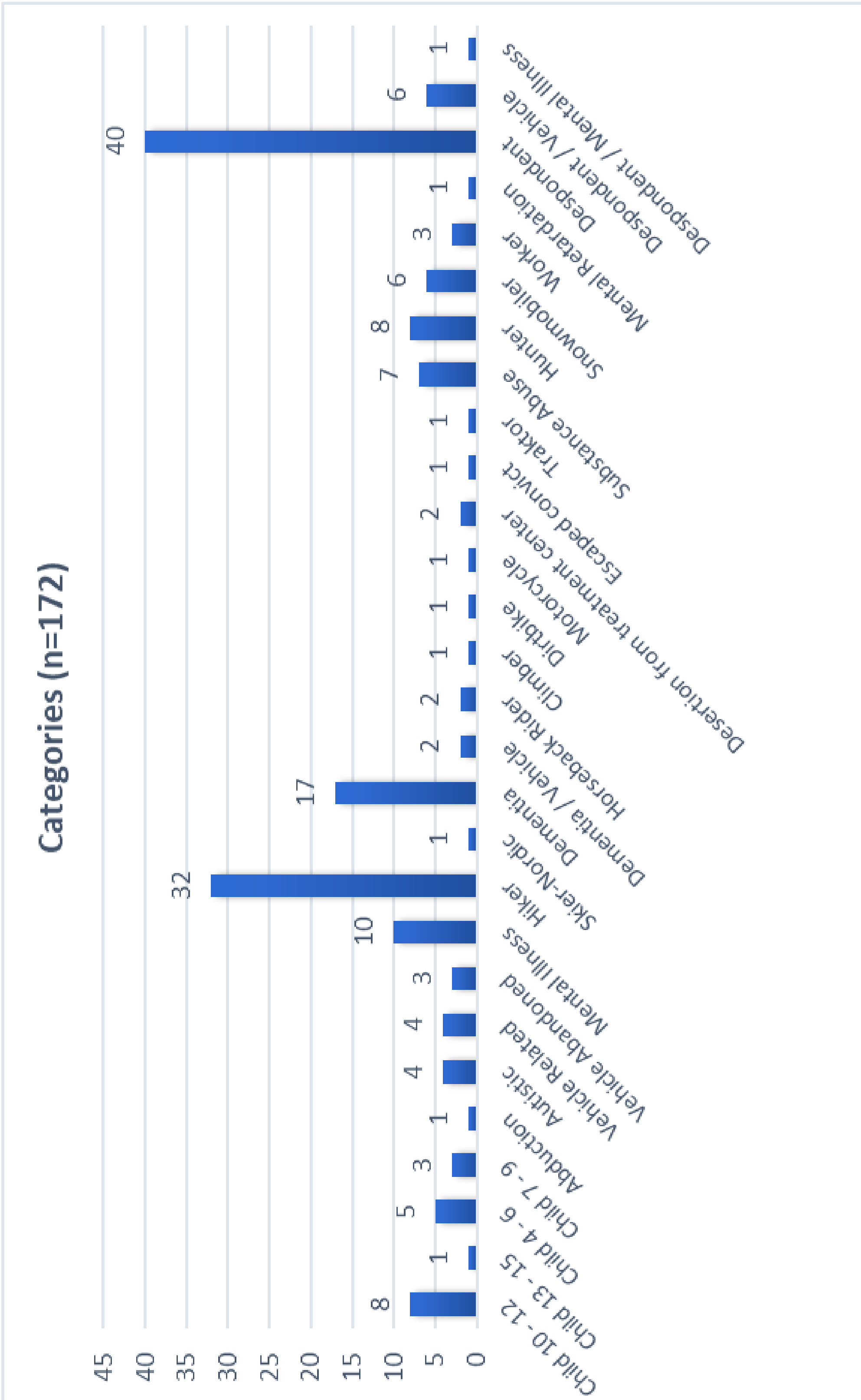

Fig 7: Distribution across categories

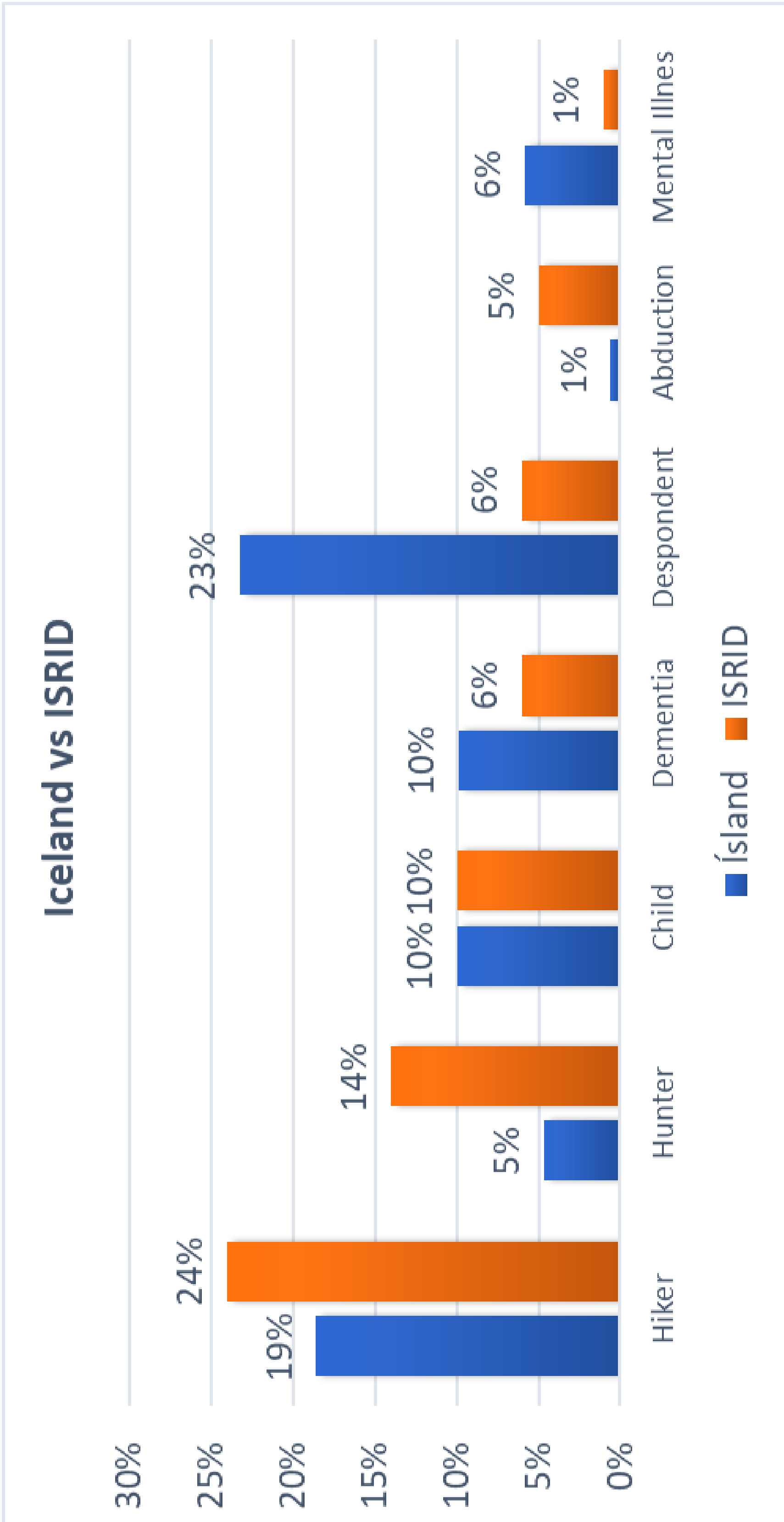

Fig 8: comparison of Iceland and ISRID statistics

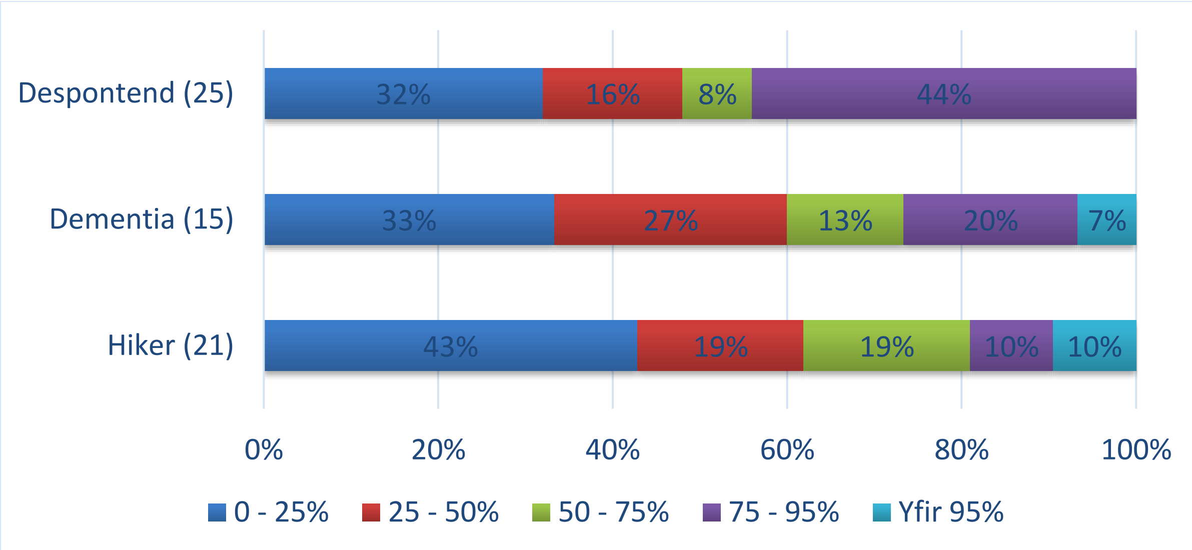

Fig 9: **The most common subject catagories and ther distance from IPP**

We are concerned by the high rate of incidents involving despondents and those with mental illness and are unable to explain why Iceland's rate is higher than its counterpart in ISRID. . It could be because of a Vitamin D deficiency or seasonal depression caused by the limited daylight during the winter, but it is clear that these numbers require deeper analyse. (Fig 8)

The data that we found most interesting was the distance from the Initial planning point (IPP), as it allowed us to finally answer the question of whether The question subjects in Iceland travel farther than those in ISRID. In the pie chart below all the ICE-SAR data is merged together. Cases were analysed individually and compared to corresponding subject categories and the distance from the IPP was marked in the appropriate quartile.

The answer to the question of relative ICE-SAR/ISRID distance travelled is not a clear yes or no, but depends on the cases at hand. The first quartile between 0-25% is bigger which means that a larger number of incidents are found closer to the IPP than ISRID. The middle quartiles from 25-75% are smaller, meaning that fewer subjects are found in those quartiles then ISRID. The last quartile 75-95% is bigger than ISRID, meaning there are more subjects that travel farther than ISRID.

Fortunately, only 5% go farther than "normal." in other words, a perfect match with the ISRID data only 5% of ICE-SAR subjects were found beyond the 95% ring.

When we take a closer look at the distance from the IPP and look at the three most common subject categories we find out that they are not the same as ISRID. Two things particularly stand out: the last quartile for despondent is 44%, which means that subjects in that category go farther away from IPP;

additionally, hikers in Iceland seem to be found closer to the IPP or they go farther away than the 95% quartile. (Fig 9)

Discussion

This data from the ICE-SAR database gives us an idea of the variation between ISRID and ICE-SAR. The importance of local data is significant as it gives us the best and most realistic picture of how far the subject will travel and where he is most likely to be found.

We will continue to use the ISRID database but know we can also use local data, and the the three main categories we have found in ICE-SAR: despondent, dementia, and hikers.

Our goal for the future is to publish data from the database more frequently and apply those data findings to our teaching.

More automation needs to be integrated into the collection and recording of the data into the ICE-SAR database. The best way to do this is to build an export operation into the Incident and Crisis management software ICE-SAR uses. This improvement remains a question of time and money.

The higher proportion of despondent incidents relative to ISRID is concerning. Further research needs to be done. It’s important that we look at the data from our neighbours in the U.K. Questions like what impact of the time of year has on despondency and the suicide rate in Iceland relative to its surrounding countries remain to be answered.

Acknowledgements

The author wish is to express is his gratitude to all of the people of ICE-SAR who have assisted in the collection of the data that makes the ICE-SAR database.

About the Author

Einar Eysteinsson has a general Teacher Education, B.Ed. from the University of Iceland and is an M.I.S. student at the UI. Einar teaches 3rd grade. In 2005, Einar joined the local rescue team, Hjálparsveit skáta í Kópavogi (HSSK). He became certified as a specialized search technician in 2008 and is an instructor. He conducted sweep width estimation for ground search and rescue in Iceland in the summers of 2010 and 2011. In 2015, Einar earned his instructor qualifications in the dbS Productions course *Lost Person Behavior.* Since then he has overseen the registration of data in the ICE-SAR database.

Abbreviations

ICE-SAR	Icelandic Association for Search and rescue
ISRID	International Search & Rescue Incident Database
IPP	Initial planning point

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Constructive Deviance in Search and Rescue Teams: Getting Around Regulations

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Abstract

Highly Reliable Teams (HRT) work in complex and extensively regulated environments where improvisation outside routine processes can be critical to success. Work teams in search and rescue, emergency medicine, surgery, aviation, and military solve complex problems in chaotic environments with high reliability. They must produce successful outcomes under the detailed and conflicting regulations from professional societies, sponsoring agencies, and government.

This research project will identify how HRTs deal with regulation during times of high stress and chaos when solutions fall outside accepted process and regulatory protection. The Principle Investigator (PI) proposes to imbed with six different HRTs, and through observation, interview and participation, explore the relationship, regulation, reliability, and non-compliance.

Key Words: Regulation, Deviance, SAR Teams, Complex Problems,

Introduction

Search and Rescue teams exhibit constructive deviance when regulations are not effectively designed for the current mission. This deviance leads to innovations and improvements in the operating procedures of the team. Though deviant team members act outside of the formal rules, informal constraints continue to guide their actions. Teams also conduct post-mission performance reviews in which the actions of the team are analyzed in a group setting. These discussions are critical to maintaining the integrity of the team while also providing flexibility.

Search and rescue teams undertake physically and mentally challenging missions to come to the aid of lost persons. The mission is to locate and extract the subject(s) to ensure a safe hand-off to the next team for treatment and rehabilitation. Their success is enabled by extensive training to develop technical skills, as well as effective teamwork and communication. A systematic process of problem solving allows them to leverage the talents and expertise of each member of the team and operate effectively. Regulations have been implemented to support the operations of SAR and other emergency response teams. These may be implemented by the team itself or a third-party regulator.

Though regulations are intended to benefit the team, they become problematic because regulators and team leaders possess an imperfect ability to foresee the conditions that will be present in future missions. When team members encounter those unfamiliar situations that could not be anticipated, regulations can become burdensome and obstructive. In some cases, these constraints even increase the risks of a mission or prohibit the team from acting in the best interest of their subjects.

Our findings are supported by participant observation and structured interviews with members from 15 SAR teams.

High Reliability and Complex Problem Solving

Many SAR teams have become dependable and developed the traits of highly reliable teams (HRTs) (see article by Hammond and Taylor in this issue). HRTs are preoccupied with failure, reluctant to blame, and possess a high degree of expertise (Weick and Sutcliffe, 2007). Because failure can result in catastrophic consequences, HRTs prepare and train for future missions. If the desired result is not achieved, team members focus on how they could have acted to improve the situation, rather than pointing a finger at their teammates. This is part of the ongoing process of learning and improvement that these organizations undertake (Beyea, 2005). HRTs are frequently tasked with solving complex problems in high risk environments..

This process allows teams to solve complex problems in an effort to return circumstances to a desired state (Newell and Simon, 1972). The complex problems faced by reliable organizations are difficult to manage due to the potential for catastrophic results in incident of failure, time constraints, and changing characteristics of the mission (Frensch and Funke, 1995). Emotional duress and incomplete information often limit the ability of logic and rational thinking to guide the decision-making process. Complex problem solving is a social process that requires effective communication and a coordinated implementation of technical strategies by multiple individuals.

The performance of these teams does not only require much training and knowledge, but is also heavily regulated. These mechanisms of control are imposed with the intention to modify behavior in a way that reduces risks for team members and the subjects of their missions. These can be imposed through regulations, policies, or organizational mandates called standard operating procedures. They are implemented by regulators or through hierarchical organizational structures and are enforced in cases of noncompliance.

These constraints sometimes add complexity to already complex problems, which are characterized by unfamiliar and uncontrollable elements that make anticipation difficult and sometimes impossible. HRTs, while highly regulated based on previous experiences, must constantly adapt to new situations. However, formal constraints, in order to be restricting, do not include provisions of flexibility. Thus, when unforeseen challenges arise, regulations may impede the ability of team members to respond effectively.

Despite the lack of given flexibility, we have observed that individuals, or the entire team, are willing to bend or break rules to ensure safe completion of the mission. These deviant actions instead conform with informal constraints, such as the culture of the team or individually held values. Though teams prefer an organized and structured course of action that can be implemented in different situations, they find safety and reliability to be of greater importance. Thus, if the optimal response in a given mission is not in compliance with a regulation, the team will disregard that rule to promote safety and success.

In management literature, these behaviors are conceptualized as constructive deviance. Individuals exhibit constructive deviance by acting outside of the constraints of their organization in a way that benefits the organization and is viewed as acceptable (Vadera et al 2013, Warren 2003). Though constructive deviance has been studied extensively, the concept has not been studied in the context of Search and Rescue. These HRTs are justified in straying from the regulations they are subject to when doing so increases the team's chance of success. Constructive deviance benefits the SAR group by reducing risks and improving its processes.

Forms of Constructive Deviance

Constructive deviance can be observed in many different forms within a SAR team. Though this list is not comprehensive, it begins to establish categories that can be used to analyze team behavior. Each of these types of non-compliance share the same objective, which is to benefit the members of the team, the subject, or to more effectively complete the objective and solve the problem.

Deliberately unclear communication: One way that constructive deviance manifests itself within an HRT is through purposeful miscommunication or equivocation. In these instances, team members with complimenting roles overcome the burden of a constraint through the use of understood ambiguity or false pretense. A demonstration of this type of deviance comes from a SAR team in winter conditions in a mountainous location. This search and rescue team had hiked through avalanche-prone terrain over the course of twelve hours to recover a subject lost deep in the mountains. To the team's discouragement, they discovered that the subject had already expired when they were finally able to arrive at his location.

The team was further dismayed when contemplating the twelve-hour return journey ahead of them back through volatile avalanche territory, now carrying a heavy stretcher for their deceased patient. Had they found their patient alive, the team is authorized to call for an extraction via helicopter. But policy did not permit a flight for transporting bodies, regardless of fatigue levels within the team. The pilots, understanding the exhaustion and hazards in front of the team, coordinated a way in which the team could be transported home and avoid the dangerous trek on foot. Over the radio, they instructed the team to begin CPR on the patient so that they could then assist transporting a subject 'in need of urgent medical care.' The team followed instructions, and were taken back to safety. The after-action report states that the subject died during the flight. By using equivocation as to the true situation, the team was able to receive safe transportation through dangerous terrain and avoid potential casualties.

Don't Ask, Don't Tell: The second mode of observed constructive deviance consists of the team's collective agreement to an implausible condition or occurrence in order to overcome regulatory constraints and accompanying penalties that, in their respective instances, take away from their ability to provide assistance to their subject. A team in a coastal area provides an example of this exception method. The team was trained in white water rescues, but was not trained or authorized to conduct rescues in ocean water. On a mission, they began tracking a subject along the beach. At one point, they could see a body in the water, not far off the shore. The team hoped to avoid disciplinary action, but still come to the immediate aid of the individual. Quickly, they made a plan and members of the team waded into the water. Though the patient was out of their jurisdiction, it was critical that the team acted immediately to have a chance at reviving him. Afterwards, the team collectively stated that "the wind brought the body back into shore." By making an exception, the team was able to work around the imperfect regulation.

Finger pointing: This strategy has three different manifestations. The first is to blame the least vulnerable. For example, a senior SAR member used an old rope and a wrong technique to rescue a young woman on a cliff before the SAR team could arrive. The safety violation was ignored because the sheriff's deputy said, "We trusted his experience in determining the urgency of the problem."

The second manifestation is in situations when constraints prevent mission objectives, there can be brief but collective rebellions. Individuals find strength in numbers under the mindset of “they can’t fire us all.” This strategy allows teams to mitigate individual risk by collectively dispersing responsibility and, therefore, potential penalties, across all other team members.

Finally, teams sometimes concentrate full responsibility into one single team member who faces severe penalties while the remainder of the team is not held accountable. This individual may be chosen by the team or might volunteer him/herself in order to help fellow team members avoid disciplinary action, job loss, or even legal liability. Placement within the hierarchical structure may impact the consequences or actions taken against the deviator. Thus, the scapegoat may be a junior or senior member of the team, each with separate reasons to accept full responsibility and its consequences.

Junior members may feel obligated to protect more seasoned members. Penalties for their actions may not be as severe because they are less experienced and, therefore, are not held to the same level of accountability as their leaders. Senior members will receive more leniency due to their past accomplishments and expertise. Some will see it as their duty to leverage this recognition and accept full responsibility.

Conclusion

Constructive deviance plays a critical role in the Search and Rescue community as a process of innovation. Although regulations are created and implemented with the intention of aiding the problem-solving process by positively modifying behaviors, HRTs routinely face complex and unanticipated problems. Inflexible regulations based on prior missions often become burdensome to the team’s ability to accomplish the objective and solve new problems. Unintentionally, they can suffocate the team’s ability to think creatively and implement better methods. Overly stringent regulations hinder the process of problem solving and innovation (Galperin, 2003). Fortunately, teams have found ways to manage these effects and continue operating effectively.

An important way to improve the role of regulations and their effect on team success is to develop an effective feedback loop through a system of after-action reviews. By conducting AARs, the team quickly learns from mistakes and implements new strategies to decrease errors. These reviews can facilitate a connection between regulators and HRTs, who have an interdependent relationship to provide feedback to one another and adjust constraints to more adequately match local circumstances. This will also cultivate an environment where creative thinking and new ideas aimed at innovating and efficiently accomplishing the objective are encouraged. Finally, these post-mission discussions will allow the team to monitor its use of constructive deviance.

The mechanisms of constructive deviance described above demonstrate how teams can successfully innovate. Employing these methods and nonconventional ideas helps Search and Rescue teams to complete their objectives and mitigate risks, despite unforeseen problems and existing regulations that do not support them. Highly Reliable Teams display instances of behavior that conflict with active regulations and norms, but these actions conform with the deeper values of their group culture and lead to innovate solutions in lost-person situations.

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Abbreviations

AAR	After Action Reports
HRT	Highly Reliable Teams
PI	Principle Investigator

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Highly Reliable Teams in Search and Rescue: Seven Characteristics of Excellence

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Abstract

This paper shows how search and rescue (SAR) teams become highly reliable teams (HRTs). It is based on participant observation and interviews over several years, including the SAR experience of the authors. It is also an adaptation and application of the research of Weick and Sutcliffe (2007). We introduce the concept of highly reliable teams by establishing that SAR teams routinely work complex problems. The characteristics of complex problems then drive seven critical characteristics of highly reliable teams which are both descriptive and prescriptive.

Key Words: Teams, Reliability, Complex Problems, SAR Teams, Problem Solving

Introduction

Complex Problems

Complex problems are unique because they require team formation in order to address. (Hammond et al, 2018). In search and rescue, missions are inherently complex. Each mission has elements of familiarity and uniqueness. Failure to resolve a complex problem can cause catastrophic outcomes for teams, subjects, and other stakeholders. While solving complex problems, SAR teams are exposed to uncontrollable environmental circumstances that require an indeterminate number of resources to resolve. When a problem is addressed, solutions may have limited impact and expiration dates, and always lead to new iterations of the problem. Finally, SAR teams addressing complex problems sometimes face unrealistically expectations and high scrutiny in their communities or media.

To address the ever-changing aspects of complex problems, reliable SAR teams create a learning cycle that begins with anticipation and moves to learning, after action review, mission, after action review and is followed by a revision of the anticipation. This cycle has the effect of creating team characteristics that are essential to a team culture of high reliability. Those characteristics are the subject of this paper.

Highly Reliable Teams

In 2007, Weick and Sutcliffe said highly reliable organizations mindfully "track small failures, resist oversimplification, remain sensitive to operations, maintain capabilities for resilience, and take advantage of shifting local expertise (p. 8)." Those characteristics reframed, plus two others we identified through participant observation, describe with some accuracy how SAR teams reach a state of high reliability. In next seven sections, we detail how these are operationalized.

Mission Focus: HRT's are highly mission focused, and the mission defines membership. Likeability, availability and "fit" are important, but expertise in the kinds of problems the team encounters is essential. For example, county based search and rescue teams and K9 Support Search Teams operate very differently. The county SAR teams have a public safety mission. Egos, territorialism, and seniority are often ignored in order to create the highest likelihood of success. K-9 support teams are often more like dog clubs, focusing first on being with and training their K-9 companions.

This does not mean SAR HRTs do not have conflict. Fischer and Boynton (2013) say having team members with egos can generate a rich flow of ideas that create unique and viable solutions. These types of teams had direct dialogue without tip toeing around feelings. One SAR team member was heard telling another, "People hear us talking on the mountain and they think we hate each other. But in a mission, we really need to be direct. The truth is we really love each other." (See KUED "Search and Rescue at https://www.kued.org/whatson/kued-productions/search-rescue).

Preoccupied with failure-Because the consequence of failure can be catastrophic, HRT's spend a great deal of time anticipating what can go wrong. Weick and Sutcliffe[1] identify the preoccupation with failure to include "practices that preclude mistakes (p. 46)." We observed exactly that. HRTs do not try to get the only right answer. They try to not get the wrong answer. Because the problems they address are complex and rarely have a clear positive outcome, they try to hold onto the problem until it can be resolved and transferred without catastrophe. [2]

One SAR member said, "The stabilization and transport of this avalanche victim at night and my concern for team safety was overwhelming. I think focus on the end goal is essential but preoccupation

[1] We have separated and simplified some of the concepts from Weick and Sutcliffe. We have also reordered them.
[2] SAR members often carry this attribute into personal, professional, and family life as a means of situational evaluation and although helpful to being highly effective in a complex mission does not always lead to positive outcomes in more long-term relationships. It is why SAR members like military, may struggle may with personal relationships.

with failure allowed SAR members to avoid an additional avalanche triggered during patient stabilization and extraction due to changing weather conditions."

Reluctant to simplify-SAR commanders are constantly considering problem complexity that includes geographic location, weather, available expertise, available equipment, etc. Each could have a dramatic effect on outcome. The geography includes terrain and boundaries. It may include the number of victims, the nature of any medical issues, jurisdictional issues, etc. While each problem is unique, SAR leadership or membership might be tempted to be driven by history if their last similar mission turned out to be simple. Weick and Sutcliffe say that an essential part of reluctance to simplify is to "carry categories lightly (p. 58)." For SAR HRTs this means that any call can turn into a technical rescue or a medical rescue at any time, even if it was not dispatched as such. Reluctance to simplify may help team members remain ready for a technical rescue involving a victim in swift water or on a cliff; where timeliness and quick reaction can be essential and must be effective. Furthermore, reluctance to simplify can help rescuers remain alert to potential threats from others who may be the original problem for the overdue hiker. Simplification can wrongly ease a rescuer into a false sense of personal security when the reason the overdue hiker is because of the behaviors of others.

Reluctant to blame- When high reliability is expected but not achieve some teams begin to fracture with blame. But for others, they come closer together. Our research suggests that HRTs collectively own all failures, large and small. During a winter, high angle rescue involving the hoist removal of multiple victims from a winter climbing accident on steep terrain involved multiple agencies and air operations, reluctance to blame directly saved lives. Upon extraction of victim one it quickly and dangerously become obvious that the rotor-wash and proximity of the helicopter destabilized the snowpack and safety. The window for adaption and stabilization of the situation was small and only minutes available before catastrophe. Those moments, if they had been filled with blame between agencies, would have led to loss of life. However, reluctance to blame and acceptance of shared responsibility lead to cooperation and solutions that assured a safe extraction of the first patient and further solutions for safer continued operations of the other victims and safe return of the SAR members.

Sensitive to operational complexity- Sensitivity to operational complexity means that a complex problem is beyond the full comprehension of any one individual or team and every team member owns some portion of the problem. Every team member brings something of value into the process. Valued contributions may include special training, expertise, experience, naïve questions, observations, and ideas. No one ever says, "mind your own business" or "that's my problem." It's everyone's business and everyone's problem.

Because there is operational complexity, surprise is inherent in all operations, but the impact of surprise can be reduced by sharing relevant information. Lack of information creates stress, forcing teams to operate without context. Communication processes are every team member's responsibility. A County SAR Team Instructor said, "The first thing everyone learns is how to communicate and when to communication. You will communicate via email, pager, two-way radio, voice and even whistle. We are constantly communicating." Long periods of silence are not tolerated when team members are deployed. "Wellness checks" are initiated every 20 minutes when there is no operational reason to communicate to ensure team members are functioning and attuned to the problem.

Give deference to expertise- Deference to expertise is certainly related to operations complexity, though Weick and Sutcliffe put them in different categories. Because complex problems can be bigger than our collective knowledge, sometimes we go outside the team for ideas and solutions. Timely information related to the problem is welcomed while controlling egocentric interference is shunned.

For example, a hazardous material at the rescue site will warrant a phone call to a local university professor who is a chemist. The team remains responsible for the problem, but they welcome advice and information. Information is never attached to the messenger. One rookie member of an EMS team observed, "They did not even know me, but on the first call when I suggested that we consider something else for the patient, they stopped and listened. I was amazed when they took my suggestion."

Effectively Manage Stress- The Weick and Sutcliffe model says this characteristic is "giving high value to resilience." We observed that HRTs not only value resilience, but they actively promote it. When a new member faced a particularly stressful incident, there was a formal and an informal response. That might involve Critical Incident Stress Management (CISM) support. (Mitchell, 2003). CISM is a peer support driven system that allows those who have been traumatized by an incident to share feelings and fears with others involved in the incident. The process is generally co-managed by a team member and a trained therapist (Brandon and Silke, 2007).

But it is not just individual psychological resilience that is the concern. Team resilience is also tracked as an element or team culture. In the AAR practice or in the fire debrief sessions, teams reported efforts to learn from fast negative feedback (Wildavsky, 1991) so that similar incidents would not have a negative impact. Still active membership in SAR, EMS and Fire create stress beyond the view of the team, family members or the individual (Bonanno, 2004). One former SAR team member told us, "I came down the mountain behind the litter. I had seen this before so many times. Family members were lined up, crying, distraught. I knew at that moment I was done. This would be my last time on the mountain."

Conclusion

The seven characteristics of highly reliable SAR teams are descriptive and prescriptive. We are currently developing a prescriptive instrument that SAR teams can use to assess their commitment to these ideals, but we acknowledge that because of the nature of the complex problems unevenly distributed to SAR teams, connecting reliability (mission success) to these ideas will be difficult.

Because SAR teams tend to be mission focus, they may also focus on rescue techniques and search strategy and neglect learning about and reflecting on their own group processes. The best outcome of this research will be to focus SAR team trainings on better human relations and team processes that will lead to higher reliability in solving the complex problems of SAR. Additional research on how SAR HRTs deal with regulation is provided in another article in this issue by Rhea, Isom and Hammond.

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Land Search and Rescue Probability of Detection: New sweep widths values, correction factors, models, and detection model validation.

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Abstract

Search theory allows for correction factors to account for conditions (such as night) that affect the sweep width value. Search theory also predicts that the coverage is proportional to the probability of detection by either the inverse cube curve or exponential function (random search). The objective is to determine the correction factors from night searching and validate the coverage curves.

An Effective Sweep Width experiment was conducted with the same medium visibility adult-sized targets during both the day and the night in a temperate forest. In addition, high and low visibility clue-sized objects were placed directly on the trail.

We found an effective sweep width of 64 meters during the daytime and 22 meters at night for a correction factor of 0.34 for the adult-sized targets. Both high (100% vs 94%) and low (83% vs 43%) visibility clues were more detectable during the day versus night (P<0.001). Searchers with dim flashlights (<200 lux at one meter) resulted in an additional correction factor of 0.5. The probability of detection versus coverage plots of both day and night experiments fell between the inverse cube and exponential curves.

This single experiment for only one visibility class of search target showed that visual searching is significantly degraded by searching at night. The daytime coverage suggests the inverse cube model while the night coverage suggests an interim result. The use of effective sweep width, correction factors, and validated coverage curves can lead to more accurate assessments of the probability of detection.

Keywords: decision support systems, search theory, search and rescue, model validation, correction factor.

Introduction

Formal search theory was established during World War II in response to the need to detect enemy submarines, but has been applied and adapted to aid aeronautical, maritime and land search and rescue (SAR) incident management (Koopman, 1980)(Kratzhe, Stone, & Frost, 2010)(Stone, 2007)(Cooper, Frost, & Robe, 2003). SAR operations rely on search theory to inform decisions about the search action plan. Search theory generalizes that whether or not something is detected depends on (1) searching in the right area, and (2) being able to detect the subject of the search. Mathematically these principles can be expressed as:

$$\text{OPOS} = \sum POS = \sum (POD * POC) \qquad (1)$$

In other words, the overall probability of success (OPOS) is the product of the Probability of Containment (POC) and the Probability of Detection (POD) (Charnes & Cooper, 1958). The ultimate aim of search theory is to provide an optimal allocation of resources that maximizes the probability of success for each additional increment of effort (Charnes & Cooper, 1958)(Stone, Royset, & Washburn, 2016). In land or wilderness SAR applications the Probability of Containment is often referred to as the Probability of Area (POA), the terms are synonymous (National Search and Rescue Committee, 2011). Thorough discussions on the determination of POC/POA are given in other resources (Cooper, Frost & robe, 2003)(Stone, 1989)(Koester, 2008)(Wysokinski, Marcjan & Dajda, 2014).

Probability of Detection

The Probability of Detection was first described by Koopman as part of his initial work (Koopman, 1946). The key to determining the POD is estimating the coverage of a search area, which relies on the size of the area, the amount of resources put into that area (effort), and the effective sweep width. Several books and papers have detailed how the coverage of a search task is determined (Stone, 2007)(Koester, Chiacchia, et al, 2014)(Koester, Cooper, Frost, Robe, 2004)(Abi-Zeid, Frost, 2005). Once the coverage is either determined or predicted then various detection models (discussed in 1.1.2) can be applied to determine the POD.

Effective Sweep Width (W) or (ESW)

Effective sweep width (W), which is also known as the detection index in land SAR, is determined by considering the searcher (sensor), the search object, and the environment. The W values are derived from field experiments which yield a lateral range curve (LRC) for each search sensor, search object or target, and environment combination. The effective sweep width is a single number measured in units of distance that integrates all of these factors. Theoretically, the sweep width is the area under the lateral range curve p(x) where P is the probability of detecting the object at a distance x. (Abi-Zeid, Frost, 2005).

$$W = \int_{-\infty}^{\infty} p(x)dx \quad (2)$$

Lateral range is the perpendicular distance to the left or right of a searcher at the closest point of approach to the search object. The LRC is a plot of the POD versus the lateral range as the searcher approaches the object (Koopman, 1980). In the land environment where the lateral range distance can be small and the curve can be noisy due to variations in the land the crossover technique described in Robe and Frost is recommended to determine W for each LRC when conducting land-based experiments (Robe and Frost, 2002).

Detection Models

Koopman was the first to describe three possible relationships between coverage and the POD. These are typically referred to as detection models. The Definite Range (parallel track search), Inverse Cube (parallel track search), and Exponential Detection (random search) curve are shown in **Fig. 4** in the results section. A more thorough discussion and derivation of these curves can be found in Koopman (Koopman, 1980)(Koopman, 1946), Stone et. al. (2016), or Washburn (2014). The Definite Range is considered an upper-bound and the Exponential Function a lower-bound with the Inverse Cube in the middle.

Definite Range

The definite range is based upon an ideal sensor that detects everything within a specific range (R) and misses everything outside of that range. Washburn calls this the cookie-cutter search (Washburn, 2014). The effective sweep width value would then be given by W=2R. The relationship between the POD and coverage is linear until the coverage equals 1 and then every part of the search area is covered and every search object detected. The model assumes parallel track searches with a spacing given by S and all effort occurring inside the search area.

$$POD = \mathrm{C} = \frac{\mathrm{W}}{\mathrm{S}} \quad (3)$$

In conditions of coverage less than 1 it is assumed the sensor has perfect parallel tracks with spacing greater than W. The definite range is considered the upper-bound because perfect parallel tracks are unlikely, and more importantly, actual sensors tend to make a certain number of misses even when well inside the operational range.

Inverse Cube

The inverse cube was derived by Koopman based upon the searcher being in an aircraft looking for the wake of a ship (Koopman, 1946). The wake of the ship approximates a rectangle, and the height and range of the aircraft creates a triangle for viewing the ship's wake. Ultimately two angles are formed at the sensor: one measures the length of the wake (β), the second measures the observed width of the wake (α). The shorter the range between the sensor and the search object the larger the αβ angles will become and the greater the instantaneous probability of detection (Koopman, 1946). From these physical factors it was possible to derive the inverse cube equation. It is shown in the format easiest to integrate into spreadsheets.

$$POD = erf\left(\frac{\sqrt{\pi}}{2} * C\right) \quad (4)$$

The inverse cube model is used by the U.S. Coast Guard as one of its standard models for visual search (IMO/ICOA, 2013). Furthermore, the model is integrated into SAROP (Kratzke, Stone, & Frost, 2010) and SARPlan (Abi-Zeid, Frost, 2005) (examples of computer software used in maritime (US Coast Guard) and aeronautical (Canadian forces) search). However, the inverse cube model's use may need to be limited under certain conditions since it is based upon ideal conditions. It assumes perfect parallel and equally spaced tracks. This is often possible from the air with modern navigation equipment, but may be difficult in a land environment. Other factors that may cause deterioration include random movements of search objects (survivors) and adverse environmental conditions (Abi-Zeid, Frost, 2005)(Washburn, 2014). Furthermore, Frost maintains "its validity as a model of visual detection has never been confirmed for any situation."(Frost, 1996).

Searching on land clearly does not involve looking for wakes or from a substantial height above the ocean. However, the actual physics of the two angles are much the same. A search object on the ground can still be characterized by two angles formed at the searchers eyeball. A human being lying on the ground can be represented by a flattened cylinder as shown in **fig.1 A**. The length of the object would be reflected by angle β (**fig. 1B**) and the combination of the height of the object and depth of the object would be viewed by the observer with dimensions represented by line c and reflected by angle α. Thus angle αβ still describes the search object. If the subject is standing instead of lying down the product of αβ remains the same. In the land environment, as the sensor moves, vegetation often hides the search object temporarily much like swells can cause smaller objects to appear and disappear in the ocean.

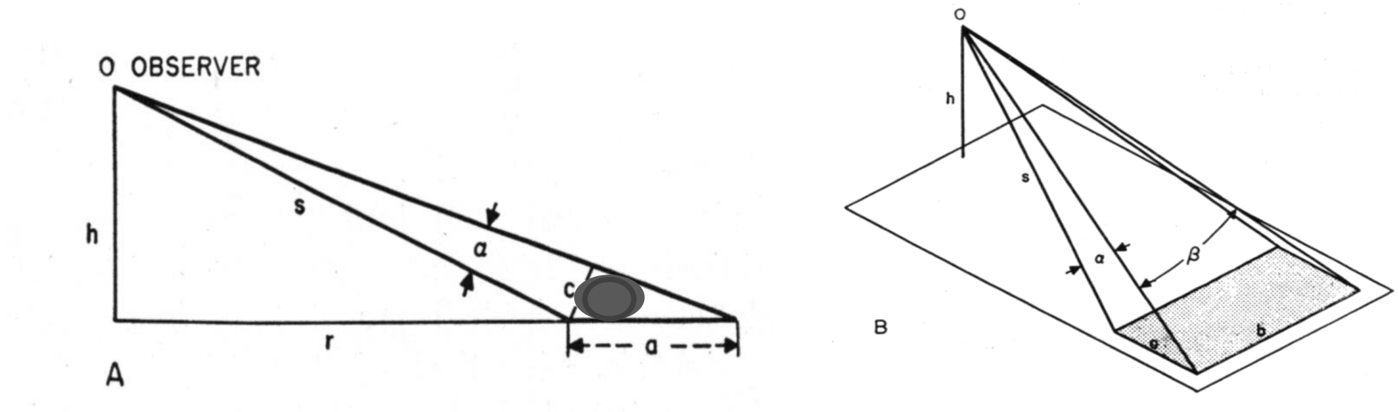


Fig 1 AB. Koopman (1946) originally created the model to describe the angles subtended by a wake of a ship (width a and length b). However, in a land environment, detection of a search object such as a human lying down is described by side c which is also the basis of angle α.

Exponential Model

The final detection model is the exponential model or random model which is considered the lower-bound model. It was also originally derived by Koopman (1946). The model makes two mathematical assumptions: First, each small increment of effort follows a uniform independent distribution over the search area; and second, no effort falls outside the search area. In the first case it is possible that the search sensor will pass over an area it has already searched and will miss an area that hasn't been searched. This is even possible when conducting parallel searching, due to error in navigation, search subject (survivor) motion or factors in a land environment that makes straight line travel impossible to difficult. The formula for the exponential detection model is given below:

$$\text{POD} = 1 - e^{-C} \qquad (5)$$

The exponential detection model has been suggested as the best model for land searching (Cooper, Frost, & robe, 2003)(Koester et al, 2014).. In fact, in most of the land SAR literature it is the only detection model shown (National SAR Committee, 2011)(Frost, 1996)(O'Connor, 2007)(Stoffel, 2006). However, this has not been validated with actual field testing.

Effective Sweep Width Correction Factors

Although W values and correction factors are available for various maritime and aeronautical search conditions, no standardized resource exists for the wide variety of land SAR variables (IMO/ICAO, 2013)(Edward, Osmer, Mazour, & Hover, 1981). Previous land SAR research has focused on different searcher/sensor types (Koester, Gordon, Wells, & Tucker, 2013), search object types (Koester et al, 2014), and environments (Koester, Cooper, Frost, & Robe, 2004)(Chiacchia & Houlahan, 2010). Baseline W values from these experiments could be adjusted with correction factors to account for other variables that may affect POD (and therefore W). Correction factors include target color, searcher fatigue, searcher morale and other aspects of a searcher's ability to locate a target, such as colorblindness and the searcher's height (Koester, Cooper, Frost, & robe, 2004).

Despite the frequency of land SAR operations conducted at night, to date no published W estimates or correction factors exist for land SAR tasks that occur at night. By determining both a daytime and nighttime sweep width value for the same sensor, environment, and search object it is possible to calculate a correction factor. This becomes critical since all baseline land search W values have been determined during the day.

Searching at Night

Searching at night presents numerous challenges to searchers. While human vision has the ability to adapt to low-light conditions, certain aspects of vision such as color and depth perception are more limited than they are in daylight (Barbur & Stockman, 2010). These differences are due to two distinct parts of the retina known as rods and cones. Cones are used for vision when light is readily available, and offer sharp images and color clarity. This is known as photopic vision. In contrast, rods are used when light levels are very low (e.g., starlight), which picks up very low resolution detail and no color. This is known as scotopic vision. In mid- to low-light level conditions (e.g., driving at night using headlights, outdoor lighting, search tasks at night) rods and cones can both be activated for use in what is known as mesopic vision (Barbur & Stockman, 2010)(Khan & Bodrogi, 2015).

In visual-based search tasks, the reduction of color and depth perception that occurs with mesopic vision leads to decreases in object detection and recognition (Kan & Bodrogi, 2015)(Bullough & Rea, 2000). While land SAR tasks conducted at night may involve mostly mesopic vision, measuring human perception in the mesopic range is complicated and beyond the scope of this study. Nonetheless, it is important to account for the effects that decreased visual perception may have on W and POD values for land SAR operations conducted at night.

Handheld flashlights or headlamps are the primary source of light for land SAR operations at night. In wilderness environments, the desire for the brightest light possible is tempered by the need for portability and duration. Recent advancements in small, high-lumen flashlights have resulted in many choices of light sources for searchers. Results of experiments comparing cool white LED sources (LEDs that emit somewhat bluish light) to incandescent or regular white LED suggest that object detection and recognition are improved with the cool white LED sources (Khan & Bodrogi, 2015)(Lewin, 2001). Despite these choices, no standard recommendation exists regarding luminance or spectrum of light that the light source emits. Thus, any experiment that considers W values at night would also need to consider the effect of the searcher's flashlight.

Literature Review

A comprehensive review of search theory was conducted by Benkoski et al. (1991). Since then additional contributions to POD in search theory have been numerous. Washburn has recently addressed detection models, different sensors, LRC, stationary targets, moving targets, multiple targets, and false alarms (Washburn, 2014). In Stone et al. (2016) the focus was on moving targets. Iida (1993) discusses an inverse N^{th} power detection law based upon the lateral range curve. Stone et al. (2014) have also showed how prior POD from different sensors changes the *a priori* in the search for AF447. Frost (1999a, 1999b) has also published a series of articles on general search theory that was directed at a land SAR audience.

The development of formal search theory, especially POD, in the land SAR discipline has not paralleled the aeronautical or maritime discipline or its use in other fields such as archaeology (Stewart, Banning, Edward, Hitchings, & Bikoulis (2015), fishing (Mangel, Marc & Clark, 1983), mining (DeGeoffroy & Wignall, 1985) or weed control (Baxter & Possingham, 2011). Cooper et al. (2003) provide a comprehensive review of the use/non-use of search theory in land SAR. One of the earliest land SAR texts by Bridges makes no mention of search theory (Bridge, 1960). This is not too surprising since Koopman's (1946) work was not declassified until 1956. The first mention of search theory is by Kelley in (1973) who cites Koopman (1956b). Wartes (1974) conducted the first land-based POD experiments during the day and at night. His methodology precludes a direct comparison of results to this experiment since he did not produce a lateral range curve, counted detection opportunities differently, and mixed different types of search objects. However, for a "spacing" of 30.5 meters between searchers a POD of 51% was obtained during the day and 19% at night for an "unconscious" human subject. Wartes (1974) reported that much of his POD results was based upon the spacing of the searchers. While not in his original report, his results were summarized as a formula that gave a POD based upon searcher spacing for all conditions in the land SAR textbooks of the time (LaValla, Stoffel, & Jones, 1981). Bownds et al. (1981) conducted a POD experiment in the Arizona desert using a helicopter search crew as the sensor looking for non-high-visibility people on the ground. The speed, altitude, and spacing was varied and decided on by each helicopter crew. POD values were given for sunny (29%) and overcast days (69%). A similar experiment was conducted in mountainous terrain in Arizona by Bownds & Harlan et al. (1991) with the helicopter flying either a descending contour search or a route search pattern. They reported POD values for three conditions: motionless subject (0%), upright waving (60%), and lying down moving spread eagle (81%). Perkins (1989) described a method of determining POD called "Critical Separation" whereby a spacing between searchers at twice the maximum detection range while moving away from the intended search object results in a POD of 50%. This paper also provides a graph that is linear for critical separation distances less than 1 and then inversely proportion for greater spacings. This was the first technique in land SAR to account for the search object and the environment. However, it did not account for search effort. In the paper Perkins (1989) noted he conducted empirical testing, spacing the searchers at one critical separation but allowing the searchers to wander within their lanes to investigate any features. They reported an actual POD of 80%, which can be accounted for by the extra effort in the trackline which would result in a greater coverage. Colwell (1992) also conducted POD experiments in the Pacific Northwest and reported POD results based upon different spacings. He also reported different curves depending upon the search object or sensor (sound sweep, high visibility sweep, standard sweep, and low visibility sweep). It is somewhat understandable that the land SAR discipline was not aware of formal search theory and how it handled POD since even in 1996 the USAF National Search and Rescue School Inland SAR Coursebook (1996) did not address lateral range curves, sweep width, coverage, or detection models.

Robe and Frost (2002) were the first to conduct an effective sweep width experiment on land demonstrating that even in the highly variable land environment distance between the searcher and the search object is the most important factor. They also introduced the use of the cross-over technique to obtain the actual sweep width value from the often highly variable LRC. The methodology was improved and a series of five additional experiments were carried out in different types of terrain and times of the year. These experiments by Koester et al (2004) determined sweep width values for different sizes of search objects, different visibility classes of search objects, and looked at several different potential correction factors. In addition, the study clearly demonstrated that searchers were not able to self-evaluate their individual POD. Chiacchia and Houlahan (2010) collected sweep width values for different search objects and noted some correction factors involving youth in SAR. These experiments also involved improvements to the methodology and the first use of IDEA which automates the experimental design, data collection, and data analysis for land-based sweep width experiments (Koester, Guerra, Frost, & Cooper, 2006a, 2006b). While in most experiments the search sensor was visual detection during the daytime, experiments have been conducted to determine the sweep width value for mounted searchers on horses (Koester et al. 2004), for air-scent dogs representing olfactory search (Chiacchia, Houlahan & Hosterrer, 2015), and for auditory search (Koester, Gordon, Wells, & Tucker, 2013). Koester et al. (2014) reviewed land-based visual effective sweep width experiments. In this review, the authors showed how a simple field procedure called the Range of Detection (Rd) could be used to estimate the sweep width, while accounting for the search object and environment. It also applied a correction factor based upon the search object visibility class to account for the difference between an alerted searcher (during the Rd procedure) and an un-alerted searcher (during an actual search or long-term ESW experiment. All of these experiments were conducted during the daytime. While no previous studies have determined a visual effective sweep width at night, Koester et al.(2013) examined sound and light at night and determined an effective sweep width of 306 meters for the two-way search problem of a subject hearing the searcher's whistle-blast and the searchers hearing the subject's shout. In addition, the ability to spot a flashlight in a heavily forested area produced a sweep width of 277 meters. Land SAR POD research is now consistent with search theory.

Most of the search theory literature talks about the detection models from a theoretical point of view and how Koopman (1980), originally derived the three major models (Stone, 2007). The USCG SAROP and USN NODESTAR certainly use the models in their search software (Wysokinski, Marcjan, Dajda, 2014)(Stone & Corwin, 1995). However, the question remains: what empirical data supports the models in land SAR? Currently no land-based experiments have been conducted to test the detection models. Edwards et al., (1980) using data from USCG R&D Center experiments, plotted the actual coverage against the POD from maritime experiments with 16-foot boats and life rafts as the search objects. They reported that for coverages 0.8 or less the inverse cube law model was a good predictor. For greater coverages the empirical data fell between the inverse cube and exponential curves. A best fit of the empirical data resulted in the following equation.

$$POD = 1 - e^{-1.3C} \qquad (6)$$

They also looked at the empirical curves during good conditions with a peaked LRC curve and poor conditions with a flat LRC. They reported the empirical curve for good conditions was closer to the inverse cube curve than during poor conditions. This paper represents support for the detection models without a clear indication of which one might be the best match.

Methods

The methodology used was similar to visual land based effective sweep width experiments previously described (Koester, Cooper, Frost, & Robe, 2004). An important tool used to set up experiments is the Integrated Detection Experiment Assistant (IDEA) which is built using MS Excel. The calculator determines the total number of targets required, expected length of course, expected time to complete the course, and the random locations to place search objects (representing subjects). In addition to setting up the experiment, IDEA displays the results after inputting raw data (Koester et al, 2006a, 2006b).

Modification to Methodology for Night experiments

In order to conduct the nighttime experiments, a few changes to the previously described methodology were necessary. In addition to collecting Average Maximum Detection Range (AMDR), the Range of Detection (Rd) was also determined using the procedure previously described (Koester et al, 2014). Target placement was based upon the daytime AMDR results and the targets were left in the same location for the nighttime trial (secured with a tent peg). Lateral target placement was measured with a Laser Range Finder (Nikon Aculon AL11) from a well-marked trail which was measured with a measuring wheel (Keson Roadrunner, model RR3M). Medium visibility (blue) adult-sized manikins (stuffed Tyvek coveralls)(**Fig 2**) were used along with both low-visibility (green) and high-visibility (orange) clue-sized objects (gloves and socks that were spray-painted). The clue-sized targets were placed directly on the trail as previously described (Koester et al, 2013).

Fig. 2. Medium-visibility adult sized manikin (Stuffed Tyvek coveralls) placed 6 meters track offset from path. During the day 100% of searchers detected this subject, during the night 70% of searchers detected the subject. Photo taken from path at eye level.

Search Participants and equipment

Search participants were attending a Virginia Department of Emergency Management Ground Search and Rescue College training event. Classes consisted of entry-level search team member, search team leader, introductory tracking, and introductory search management. Both students and instructors participated in the experiment. Searchers participated in either the day or night trial but not both. Participation was voluntary except for those in the search team member class; who are required to go through a clue awareness exercise as part of the class. The collection of individual data however, was still voluntary for this class. Data was collected by the research team and instructors who assisted with the debriefing process. For the nighttime trial, participants used their own flashlights and/or headlights. The lux of the lights were determined at the end of the course using a lux meter app (Lux Meter by Not Quite Them), measured one meter away from the light source in a darkened area outside after the light source had been turned on for 30 seconds. The measurement was taken from the brightest part of the beam with the beam focus set as it had been used during the search trial. The measurement was made at the end of the course. Some participants indicated they had replaced batteries while out on the course. No participants replaced batteries just for the measurement.

Calculation of actual probability of detection

Individual data sheets were scored by the principal investigator to determine if each search target had been detected or missed. This data was entered into IDEA along with the characteristics of each searcher. IDEA was then used to generate the LRC and calculate the half sweep width for both the day and night experiments. IDEA automatically sorts the data by the lateral range distance from shortest to longest distance and also displays the actual percentage of searchers who detected each target. In order to ensure a uniform distribution of potential targets, the LRC was used to interpolate the POD of targets for every meter of lateral range where no actual targets were placed. Since the course was laid out on a linear path with searchers looking both left and right and the sweep width was known, it was possible to change the coverage by simply changing the working definition of the size of the search area. The length of the search area remained fixed; only the width needed to be adjusted for different coverages. With a fixed length and fixed effort the formula for coverage can be simplified as shown below where *w* is the width of the intended search area:

$$Coverage = \frac{\mathrm{W}}{w} \quad (6)$$

For each sized search area the actual POD was calculated using the following formula for both the day and night experiments:

$$POD = \frac{\text{\# of Targets Detected}}{\text{\# potential Targets}} \quad (7)$$

Adjustment for adjacent tracks

Since the experiment was conducted using a single track in the middle of the search area all of the POD values based upon different coverages are based upon the LRC from the single track. However, the inverse cube equation is based upon parallel tracks. Therefore, the adjacent parallel track LRC was simulated based upon the one actual LRC generated for the nighttime experiment for coverages of 0.5, 1, and 2. For each coverage the actual POD determined for the single track, including the adjacent tracks (cumulative value), and the predicted POD from the inverse cube equation [4] are reported. The cumulative curve was calculated in the same manner as calculating additional coverage from multiple tasks (National Search and Rescue Committee, 2011).

Statistics

All statistical measurements consisted of an ANOVA: Single Factor with the *P* value shown in the appropriate table conducted using Excel Data Analysis. Chi-square analysis of fatigue was carried out using GraphPad Software (La Jolla, CA).

Results

The overall experimental conditions and results are summarized in **Table 1**. A total of fifty-four searchers participated in the experiment during what could be described as ideal search conditions. The day and night lateral range curves are shown in **Fig. 3**. Additional night correction factors based upon flashlight brightness (**Table 2**) and searcher experience (**Table 3**) are summarized. The actual percentage of clues detected based upon various coverages are shown in **Fig. 4** for both the day and night experiment.

	General Course Characteristics		
Location	Appomattox 4-H Center, Appomattox, Virginia, USA		
EcoRegion Division	SubTropical		
Season	Winter		
Length of course	1900 meters		
Course type	Road and trail		
Elevation change	43 meters		
Topography	Hilly		
Vegetation	Mixed Deciduous and evergreen. Limited ground cover		
	Day		**Night**
	Environmental		
Temperature (Celsius)	2-7º		-4 – 4.5º
Wind (kph)	0 – 5		0
Light intensity (Lux)	$\bar{x}$ = 35,000 (15,000 – 50,000)		0
Precipitation	0		0
Cloud Cover	$\bar{x}$ = 50% (0 – 80%)		0
Meteorological visibility	unlimited		unlimited
Time (Local)	09:30 – 17:30		20:00 – 00:20
	Demographic		
n	31		23
Age (years)	$\bar{x}$ = 43.4 (23- 64)	*P*=0.47	$\bar{x}$ = 41.0 (20-71)
Years in SAR	$\bar{x}$ = 7.6 (0.25 – 40)	*P*=0.04	$\bar{x}$ = 2.7 (0 – 21)
# Searches in field	$\bar{x}$ = 23.7 (0 – 150)	*P*=0.59	$\bar{x}$ = 17.6 (0 – 200)
Time searching (hours)	$\bar{x}$ = 1.32 (0.45 - 2.25)	*P*=0.06	$\bar{x}$ = 1.47 (1.0 - 2.0)
Speed (kph)	$\bar{x}$ = 1.4 (0.8 - 4.2)	*P*=0.06	$\bar{x}$ = 1.3 (0.95 – 1.9)
Fatigue (% Drowsy)	6%	*P*=0.75	4%
	Outcomes		
Detection % (High Vis clue)	$\bar{x}$ = 100% (92 – 100%)	*P*<0.001	$\bar{x}$ = 94% (67 – 100%)
Detection % (Low Vis clue)	$\bar{x}$ = 80% (50 – 100%)	*P*<0.001	$\bar{x}$ = 42% (0 – 79%)
Detection % (Med Vis adult)	$\bar{x}$ = 74% (47 – 88%)	*P*<0.001	$\bar{x}$ = 32% (6 – 53%)
ESW (Med Vis adult)	64.0 meters		22.0 meters

Table 1 Shows the general course characteristics, environmental, searcher demographics, and outcomes between the day and night experiment. The night time experiment was colder, less windy, and dark. No statistically significant difference was found between the group of searchers participating in the day or night experiment except for the number of years in SAR. Night resulted in significantly less detection of both high and low visibility clues on the path, overall detection of medium visibility targets set away from the path and effective sweep width value. Averages, ranges, and where appropriate *P* values are shown.

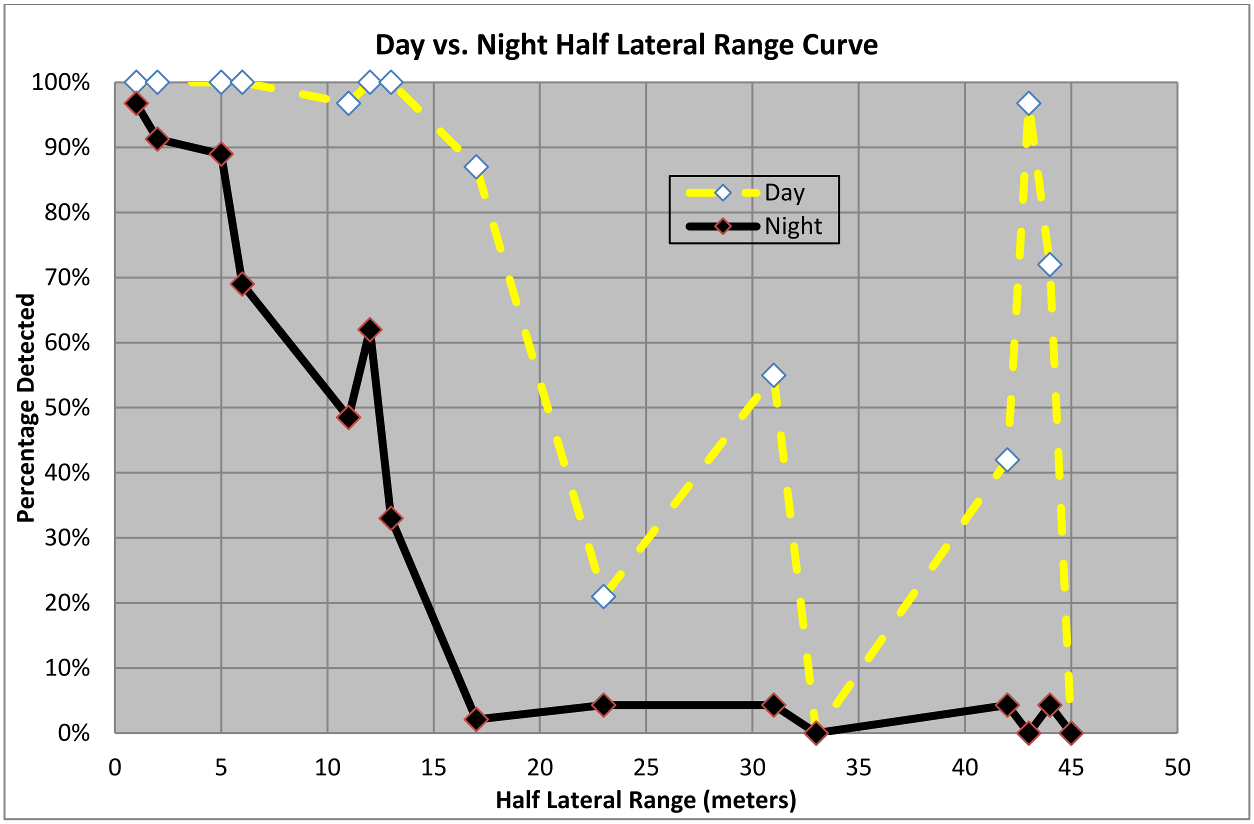


Fig 3. Half Lateral Range Curve (LRC) which combines both left and right of path. Diamonds indicated lateral range of the actual search targets (Blue adult sized manikins). The same targets placement was used for both the day and night experiment. Targets detected at 43 and 44 meters were 20 meters uphill and not obscured by ground vegetation.

Flashlight Lux @ 1 m	ESW (m)	n	% Detected	Correction (*Cf*)
< 200	12	6	21%	0.5
200-500	22	3	33%	0.92
>500	24	14	37%	1.0

Table 2. Flashlight corrections. The table provides the ESW for different lux values of the flashlights used. The ESW of all flashlights over 200 lux was 24 meters which would bring the n value up to 17 and allow correction of 0.5 for only those flashlights less than 200 lux.

	Night				Day			
# Searches	**n**	**ESW (m)**	**% Detected**	***Cf***	**n**	**ESW (m)**	**% Detected**	***Cf***
>10	6	26	43%	1.0	16	64	73%	N/A
≤ 10	17	22	28%	0.85	15	64	75%	
≤ 10 + >200lux	11	22	33%	0.85				

Table 3. Searcher experience at night. Searcher experience had no significant difference during the day. At night searchers with more than ten searches in the field had an ESW = 26m. Night searchers with ten or less field searches had an ESW = 22m even after correcting for weak flashlights. Based upon the total number of targets detected this was statistically significant (*P*=0.04).

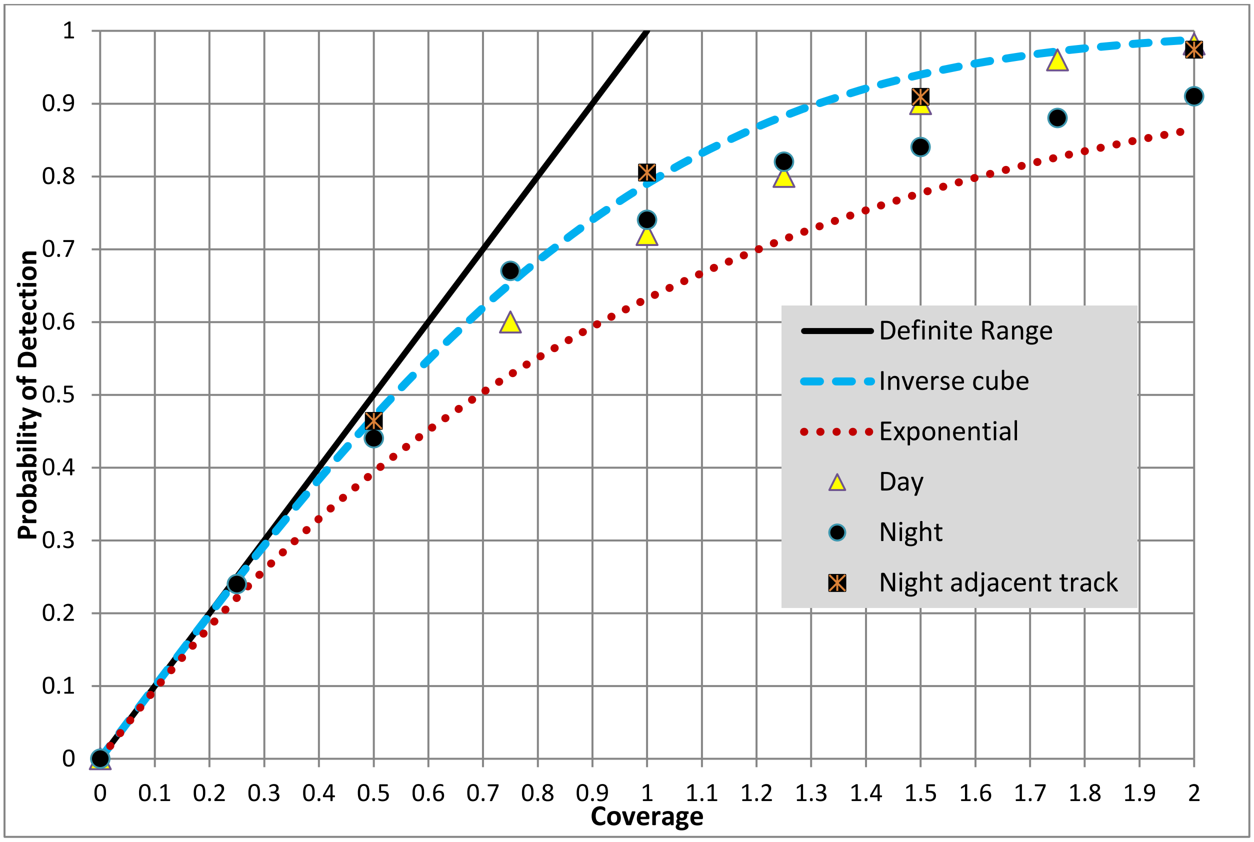
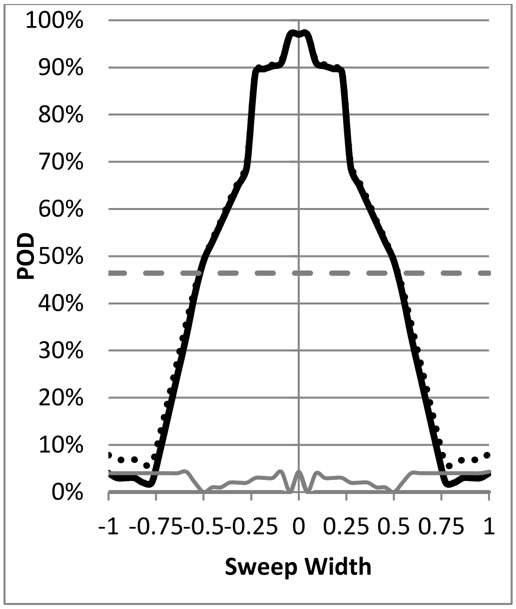
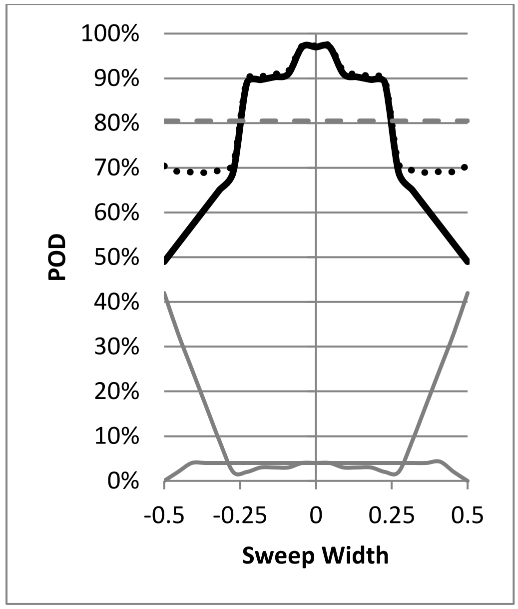


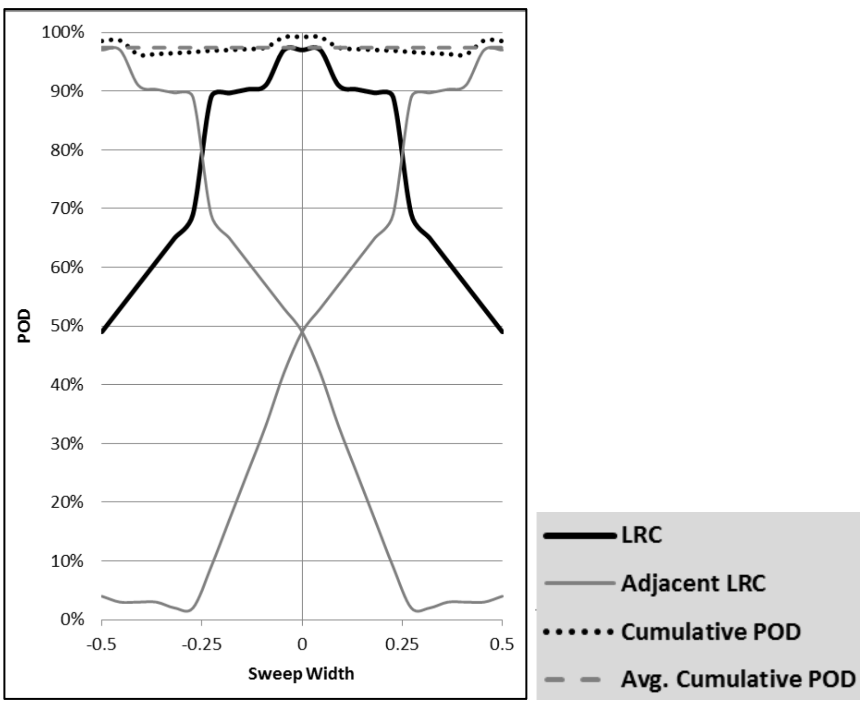
Fig 4. Shows both the three detection functions and the coverage vs POD from the day and night experiments. The Exponential detection curve is also known as the Random Search curve and the Inverse Cube is sometimes referred to as the Inverse Cube Law. Additional points are shown for the night search after adjusting for the presence of an adjacent track based upon parallel track spacing at that coverage (also see Fig 5.).



A. 0.5 Coverage



B. 1.0 Coverage



C. 2.0 Coverage

Fig 5. Each graph is based upon a different coverage using the same LRC from the night experiment. The light gray line shows the LRC from the adjacent track. These are used to determine the cumulative POD curves and the overall average cumulative POD for each particular coverage using empirical data.

Discussion

Searching at night is an essential part of search and rescue. In fact, it represents on average half of the time available for searching. Yet we are not aware of any sweep width or correction factor studies available for night visual searching in the land environment. We are also not aware of any land sweep width experiments specifically carried out to determine correction factor reductions to a sweep width distance based upon secondary factors. The results from the day and night experiments were clear and left little doubt that searching at night is much more difficult. This study determined the sweep width value for a subtropical mixed deciduous and softwood forest during the winter time during both the day and night. The experimentally derived lateral range curves were markedly different. During the nighttime experiments the need for a flashlight brightness correction factor and searcher experience factor was determined. The detection of clues on the actual trail had some similarities and differences to a previous experiment conducted in New Zealand.

Day versus Night Search Participants

Participants for both the day and night trials were recruited from the same pool of instructors and students. Both were given the choice to select the day or night trail. Both the day and night groups were similar in age, level of fatigue and SAR experience. The only statistically significant difference between the two groups was the number of years in SAR. However, no statistical difference existed in the number of searches in the field, which is perhaps a more relevant measure of SAR experience. Previous sweep width experiments (all conducted during the day) have shown that cloud cover, age (once >19), gender, years in SAR or SAR experience do not affect sweep width (Koester et al, 2004). Chiacchia and Houlahan (2010) showed that sweep width values from searchers under the age of 19 are significantly lower than adults. During this experiment no participants were under the age of 20. Therefore, no particular effort was made to control for these factors. However, fatigue levels have been found to have a significant impact on land visual searching, with a correction factor of 10% for high-visibility and 50% for medium and low-visibility search subjects (Koester et al., 2004). While it was hypothesized that searchers at night might be more fatigued than daytime searchers, no significant difference was found between the two groups. Since the experiment took place in January, all of the nighttime searching was conducted between 20:00 and 00:20. Since experiment participants could self-select if they wanted to search during the day, night, or not participant, it is possible that already fatigued participants would decide not to participate in the nighttime trial. Even without any attempt to randomize the day and night cohorts, both groups were essentially the same.

Day versus Night results

While common sense might suggest that daytime searching is more productive than nighttime visual searching, this is the first study to quantify the difference. The daytime effective sweep width for the medium visibility adult was 64 meters; the nighttime value was 22 meters for a day-to-night correction factor of 0.34. Looking at the lateral range curves (**Fig. 3**), it can be observed that all of the search objects that were detected during the day were also detected at least once at night. However, at 18 meters and beyond subject detection never exceeded 5% while many of these same subjects (>18 meters) were detected more than 50% of the time during the day. Therefore, while it was possible to illuminate the more distant search objects to a sufficient level to make the detection, the low illumination associated with mesopic vision made detection much more difficult. The illumination or lux at the search object would also be conditional on the flashlight's throw level. Throw is a measure of how far away a flashlight will "usefully" light an object. Useful is defined by ANSI/NEMA FL 1-2009 standard as being at least 0.25 lux (about a full moon) (ANSI, 2009). The throw distance is not necessarily proportional to the overall lumens generated by the flashlight since it varies with the characteristics of the focused beam (Gawthrop, 2005). Typically, the brighter the illumination, the more cones are activated, and thus more clarity and color vision is achieved (Fotios & Cheal, 2009).

The lateral range curves (**Fig. 3**) also reveal another important difference between the day and night experiments. The day time LRC shows nearly 100% of the targets were detected by the searchers to a distance of 13 meters then the probabilities start dropping off. While for the night experiment some searchers missed a target one meter off the trial and probabilities steeply dropped off immediately beyond even one meter. Targets were not placed directly on the path to test a lateral range of 0, since the path was used by the general public and would have posed a safety hazard. Koopman (1980) describes a LRC that conforms to the inverse cube law as approaching or reaching 100% POD at a lateral range of 0, staying at or near 100% POD for some lateral range, then dropping off. Frost (1996) states that in US Coast Guard experiments with deteriorating search conditions the sweep width becomes both smaller and the peak drops below a POD of 100%. Under these conditions he suggests the exponential curve should be used. This appears to be a good description of the shape of the night experiment's LRC.

The detection of the medium-visibility adult-sized search objects was used to test distance searching and generate a lateral range curve. The placement of clues (glove-sized) along the path required the searchers to shift attention between distant and near searching, as required on actual searches. During the daylight, 100% of the high-visibility clues were detected versus 94% at night (a statistically significant difference). For the low-visibility clues, 80% were detected during the daylight and 42% at night. A similar daytime experiment conducted in New Zealand found 99% of high-visibility clues and 53% of low-visibility clues detected (Koester et al. 2013). The two experiments differed in that Appomattox was conducted on a trail (1 meter in width) with a single searcher and New Zealand had a pair of searchers along a dirt road (3 meters in width). Even with these differences the results are compatible. In searching linear features such as roads or trails it is suggested that these Probability of Detection values for clues can be used directly as a guideline. Low-visibility gloved-sized clues can be missed even when placed directly on the trail and even high-visibility clues can be missed during the night.

The steps required to go from a sweep width value to the actual Probability of Detection (POD) value are well described (Koopman, 1980)(Stone, 1989). The application of a correction factor is a straight-forward adjustment (IMO/ICAO, 2013). If a search segment has a sweep width value derived from a previous daytime ESW experiment or daytime Range of Detection experiment adjustment (Koester et al, 2014), then the night correction factor of 0.34 is multiplied by the daytime sweep width to obtain the corrected night value. If the daytime value was 100m, the area was searched at night (*Cf*=0.34), by a fatigued (*Cf*=0.5), inexperienced team (*Cf*=0.85), and they all had weak flashlights below 200 lux (*Cf*=0.5), then the corrected sweep width would fall to 100m*(0.34)(0.5)(0.85)(0.5) = 7.2m. It is still possible to obtain a high POD, but it would require at least ten times the effort compared to a daytime search with a team that was not fatigued. This begs the question: is night searching even warranted? A lack of any nighttime searching produces a POD of 0%. In addition, we can deploy a non-fatigued experienced team with brighter flashlights and the correction factor becomes 100m*(0.34) = 34m. The team would be expected to detect 94% of high-visibility clues and 42% of low-visibility clues on a trail and potentially hear the subject (night auditory sweep width = 306m) or see a light source (night light detection sweep width = 277m) (Koester et al, 2013). The ultimate tactical decision is up to the planning and operational needs of the incident and types of resources available.

Flashlight illumination effects

In designing the experimental methodology some thought was given to controlling differences in flashlights by issuing a standard flashlight with fresh batteries. However, it was eventually decided to let searchers use the flashlight they currently use on actual searches and measure the light output of the flashlights (night exercises are a regular part of the class curriculum). Searchers used just handheld flashlights or headlamps or a combination of the two. If they used a combination, then the brighter light was recorded. The light output from the flashlights used ranged from 30 lux (LED headlamp) to 8919 lux (tactical flashlight). It was noticed while scoring results that the searchers with the five weakest flashlights (30 – 130 lux) also had the three lowest detection rates (6% - 18%). Looking at the range of flashlight illumination levels, cutoff values of 200 and 500 lux were selected. Searchers with flashlights below 200 lux had a sweep width value half of what bright flashlight (> 500 lux) searchers obtained (12m vs 24m). Only three searchers had flashlights in the intermediate range of 200-500 and they had an intermediate sweep width value of 22m. If the thresholds are changed to simply less than 200 lux or greater than 200 lux then the sweep width values stay at 12m versus 24m. This may be a simpler paradigm to apply in the field. It is hoped all searchers would have a strong flashlight that generates at least 200 lux at one meter; for those that don't have a strong flashlight a correction factor of 0.5 is applied. A better brighter tactical flashlight with a good throw distance is perhaps the quickest, least expensive, and easiest way to improve nighttime searching.

Searcher experience

One of the more surprising and controversial findings from previous daytime sweep width experiments was that experience at SAR (as measured by years in SAR or number of field searches) did not correlate with a higher detection rate (or sweep width value) (Koester, et al, 2014). This was again confirmed during the daytime experiment where those with ten or fewer searches had the identical sweep width value as those with more than ten searches. In fact, the individual with the greatest detection rate had never been on a single SAR incident. Instead, he had led a Marine reconnaissance unit for over twenty years. It has previously been observed that participants with occupations that require daily "searching" out to visual infinity are far more predictive of successful detections than actual SAR experience. However, for the nighttime searching a difference in the sweep width value for those with ten or fewer searches (ESW=22m) versus those with more than ten searches (ESW=26m) was observed, a difference of 15%. The raw number of subjects detected was 43% for the experienced group and 28% for the inexperienced group. A possible confounding factor was the brightness of the flashlights between the two groups. No one in the experienced group had a flashlight that measured below 200 lux while 35% of the inexperienced group had weaker flashlights. In an effort to control for this, if the weak flashlight results are removed from the inexperienced group as shown in **Table 3** the inexperienced group still has an ESW value of 22m. Since the raw number of detections of the experienced group (43%) is still significantly greater than the raw number of detections (33%) of the inexperienced group with brighter flashlights, a correction factor of 0.85 is reported. It is hypothesized that the difference might still be a result of the confounding factor of the flashlight's illumination and/or improper use of flashlights and/or a higher level of anxiety among the inexperienced group of searching alone at night.

Detection models

The working hypothesis of this experiment was that daylight coverage versus POD would follow the inverse cube model while the nighttime experiment would follow the exponential curve. Previous experience with land-based visual LRC for medium-visibility search targets looked similar to LRC associated with the inverse cube model. Searching at night represents an adverse environmental condition that was expected to have a smaller sweep width value and a lower POD at a lateral range of zero, resulting in the exponential curve. Both of the experiments resulted in curves between the inverse cube and exponential curves as shown in **fig. 4**. Between the coverage of one and two the day curve starts approximating the inverse cube curve and the night experiment the exponential curve. The empirical land-based day and night data also closely match the empirical maritime data reported by Edwards et al. (1980). However, clearly more experiments are needed to draw any conclusion other than that the experimental data confirms they are between the inverse cube and exponential.

It is not too surprising that the empirical data fell between the inverse cube and exponential curve. The methodology used to define the search area created by a single track perfectly centered in the search area gives: no navigational errors, no duplication of effort, no large gaps, and no mobile search objects. Therefore, results better than the exponential curve might be expected. However, both the day and night results generally fell below the inverse cube curve. This can also be partially explained by the methodology used by this experiment which placed a single track in the search area. However, the inverse cube formula is based upon integrating an infinite number of parallel tracks within the search area. Washburn (2014) has shown that a search with five parallel tracks that provides coverage of 1.0 would actually have a POD of 67% instead of the predicted 79% from the inverse cube equation [4]. The difference is caused by the lack of overlapping coverage at the two sides of the search area. Looking at the actual empirical data is even more insightful. Using the LRC from the nighttime experiment and the coverage of 0.5 very little overlap of the adjacent track occurs as seen in **fig 5a**.The nighttime single track POD was 44.3% and when the adjacent tracks are added it increases slightly to 46.4%. The inverse cube equation predicts a POD of 46.9% for the coverage of 0.5. The coverage of 1.0 with a single track down the center of the search area results in a POD of 74.7% using the empirical nighttime data. However, when the LRC is added from the adjoining tracks (**fig. 5b**) the cumulative LRC shifts upwards. The new integrated POD then becomes 80.5% which for empirical data is close to the predicted 79.0% of the inverse cube equation. The amount of overlap significantly increases when the coverage is increased to 2.0 as shown in **fig 5c**. The nighttime empirical POD data for a single track at the coverage of 2.0 was 91.0%. When the overlapping adjacent tracks are added the empirical data achieves a POD of 97.4% compared to the predicted POD of 98.8% from the inverse cube equation. Once the correction is made for adjacent tracks, even the nighttime data best matches the inverse cube curve. However, it is important to keep in mind that adjacent tracks would not occur if the land tactic being used was a single linear or hasty task.

Since a single track linear task is perhaps the most common task in land SAR what is the best approach? The conclusion certainly cannot come from a single experiment. The best answer most likely lies between the exponential and inverse cube curves. From a strictly empirical perspective a curve fit of the data would suggest the same empirical equation that Edward et al. reported and is shown in equation 6.

A requirement for the definite range and inverse cube models are searching along perfect parallel paths. Since the experiment was carried out along a linear path and the actual search area was defined by lateral ranges from the linear path, it creates a situation similar to perfect parallel tracks. A fair question: Are perfect parallel paths operationally possible in the land environment? One of the most common search tactics is a linear task (also sometimes called a hasty) along a road, trail, hydrological feature or other linear features. When assigned such a task the team is often not only assigned to search the feature but also a specific distance from the feature. In this circumstance the operational search area would match the experimental setup. It would also mean that the POD would not benefit from an overlapping adjoining search track. Therefore, the POD would always be expected to be less than the inverse cube curve. Another common method used to cover area is the sweep or grid search tactic (National Search and Rescue Committee, 2011). The tactic differs from maritime and aeronautical parallel search in that several searchers typically line up well within visual sight of each other and attempt to maintain uniform spacing. Depending upon training, experience, and terrain it may be easy or difficult to maintain equal spacing during a task. In addition, some searchers may receive tasking instructions to “wander” within their spacing lanes in order to check out obstacles or other points of interest. Therefore, operational reality for land SAR ranges from always being able to maintain a “parallel” path during linear tasks to a situational ability during sweep or grid tasks.

No error bars are shown for the two experiments (**fig. 4.).** The coverage is directly related to the sweep width as shown by equation 6. Combined data from all search participants is required to generate the LRC which involves determining the POD at various lateral ranges. Since the W value is the area under the LRC (equation 2), it therefore also requires all participants to determine the W value. This precludes error bars around the W value even though individual detection rates and total targets detected varied from searcher to searcher since the W value integrates the efforts of all searchers. This also precludes error bars around the plots of the coverage versus POD since it took the entire searcher population to determine the POD. Therefore, any interpretation of the data is limited since it represents only two experiments for a single visibility class of search object in one particular type of terrain and vegetation during the winter.

The furthest a target was placed was a lateral range of 45 meters, therefore the smallest possible coverage was 0.71 for the daytime experiment. The lowest coverage shown for the day experiment is 0.75 and then coverage is shown in increments of 0.25 up to coverage of two. Operationally, coverage of two represents a reasonable upper bound for land SAR. For the night experiment, two additional coverages could be determined since the W value was much lower. At coverages below 0.5 it becomes more difficult to distinguish between the definite range, inverse cube, and exponential models.

Limitations

The chief limitation is that this paper reports two experiments (day and night), in a single environment, with a limited range of search targets. It is unknown if the correction factor of 0.34 applies during summer conditions, in a dry domain, with child or clue-sized objects, or even with different visibilities of subjects. This paper did not discuss illuminated signal devices such as flares, fires, lights, or laser flares that might be detected from kilometers away. Nor does it discuss high visibility retro-reflective material. Searching for these materials along with a flashlight with a good throw distance could result in detections better than daytime results, based upon some preliminary field data. However, the use of retro-reflective material by missing subjects is generally rare for most land-based searches.

This paper suggests a nighttime correction factor for searcher experience. However, these results were confounded by weaker flashlights. While an attempt was made to control for this effect it is still possible that brighter flashlights might have accounted for all of the differences in nighttime searcher experience. Flashlights clearly affect what can be detected at night with the complex relationships of throw distance, total lumens, beam width, lux at fixed distances, battery life, color output, and portability. It would take considerable research to find the best combination. Ultimately, user preferences are a large factor. The methodology calculated values for a single searcher. This is operationally relevant given that when calculating the coverage obtained by a team conducting an area task, it is critical to know the sweep width value for each individual sensor (searcher). However, for a linear task where the interest might be limited to finding clues along a path, the typical minimal tactical deployment would be two people.

This research provides some validation for the use of the inverse cube or exponential search curves. With essentially only two experiments it is impossible to make any definitive statement. As previously stated the results only represent a medium visibility (blue) subject, in a winter forested environment with moderate terrain.

Conclusions

This study, using search and rescue trained resources, provided an objective correction factor of 0.34 for the sweep width between daytime and nighttime searching. It showed that while more distant targets were still illuminated and detectable, mesopic vision makes it difficult to make an actual detection. Clue-sized objects placed directly on the trail were also more difficult to detect at night. Once again it was shown that searcher experience (measured by number of searches) did not affect the sweep width value during the day but resulted in a correction factor of 0.85 at night. The brightness of the flashlight was also significant with flashlights dimmer than 200 lux at one meter resulting in a correction factor of 0.5. The study also validates the use of detection models in the land environment to predict a POD value. Once the empirical data was corrected for adjacent tracks, the inverse cube equation was a good predictor of the POD. However, in situations such as linear or hasty tasks with a single track the POD is expected to fall between the inverse cube and exponential curves.

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About the Author

Robert J. Koester first joined the Appalachian Search & Rescue Conference in 1981 and since then has participated in hundreds of searches, including over a hundred as Incident Commander. He holds a Ph.D. from the University of Portsmouth in search theory and a MS and BA from the University of Virginia in biology (neurobiology). His contributions to search and rescue include seminal research on search theory and lost person behavior along with creating the International Search and Rescue Incident Database (ISRID). He is an instructor for the Virginia Department of Emergency Management since 1988 and past-president (15 years) of the Virginia Search and Rescue Council, Robert has also worked for the USCG (conducting visual sweep width experiments), NASA (conducting missing aircraft radar research), NPS (responding to major searches and writing the draft NPS *SAR Field Manual*), FEMA (as an instructor and disaster reservist), and SAR Institute of New Zealand (conducting sound and light sweep width experiments). He is currently developing SAR software called FIND, for the US DHS S&T directorate. He also developed courses for DCJS and was a Cardiac Technician for twelve years with CARS. He is the CEO of dbS Productions which provides research, software & publications, and training services. He is also a visiting researcher at the University of Portsmouth. Robert has authored dozens of books and research articles on search and rescue, including *Lost Person Behavior,* and is widely cited.

Abbreviations

AMDR	Average Maximum Detection Range
ANOVA	Analysis of Variance
C	Coverage
Cf	Correction Factor
ESW	Effective Sweep Width
IDEA	Integrated Detection Experiment Assistant
LED	Light Emitting Diode
LRC	Lateral Range Curve
M	meters

MS	MicroSoft
OPOS	Overall probability of success
POA	Probability of Area
POC	Probability of Containment
POD	Probability of Detection
R	Range
R&D	Research & Development
Rd	Range of Detection
S	Spacing
SAR	Search and Rescue
USCG	United States Coast Guard
USN	United States Navy
VDEM	Virginia Department of Emergency Management
Vis	Visibility
W	Sweep Width

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Enhancements to Statistical Probability of Area Models based upon updated ISRID data collection for Autistic Spectrum Disorders and Typically Developing Children

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Abstract

Both Autism Spectrum Disorder (ASD) individuals and Typically Developing (TD) children are associated with Search and Rescue incidents. Though they are in the same age range, these two groups are typically placed into different subject categories in lost person behavior profiles. This work compares these two age similar profiles to critically examine what statistical differences do exist. In addition, a new geo-spatial statistical point model is introduced, potentially applicable to all lost person subject profiles. Retrospective data from the updated International Search & Rescue Incident Database (ISRID2) was used to examine both spatial and incident characteristics of individuals with ASD (n=338) and TD children (n=2335) who were reported missing and then were the subject of a search. The updated version of ISRID now contains 145,000 incidents. Those with ASD are 3-4 times more likely to require a search effort ($P << .0001$). ASD children (age 1-15) were not found to be statistically significant than ASD adults. The new point model and watershed model for ASD is introduced. Survivability curves are now reported out to the 5% chance of survival with findings of 7 days for ASD and 11 days for TD Children. Search incidents for missing ASD and TD children demonstrate significant differences but also have some common features. Both adults and children with ASD share the same geo-spatial outcomes.

Keywords: ISRID, Missing Persons, GIS, Lost Person Behavior, Models

Introduction

Spatial navigation is an essential everyday task integrating many sensory and central processes. Getting lost is the ultimate failure of spatial navigation (Dudchenko, 2010). Getting lost and requiring a formal search and rescue response represents a worst-case scenario associated with significant mortality (11.3%) and morbidity (14.3%) (Koester, 2008). We know that behavior when lost depends on both age and cognitive status, but so far there has been no formal field-based comparison between typically developing (TD) children and those with Autism Spectrum Disorder (ASD).

The goal of a search and rescue (SAR) incident is to locate the missing individual as quickly as possible using the tactical resources on hand. A search is ultimately a spatial problem (Doke, 2015). It requires placing resources where the subject is actually located. However, since this is by definition unknown, the various areas within the search area are given probabilities, referred to as Probability of Area (POA), which is also known as Probability of Containment (Charnes and Cooper, 1958). In order to best characterize the POA, three different approaches have been used: a probability map generated by human consensus (Mattson, 1980; Stoffel, 2006); a Monte Carlo simulation of moving particles based upon environmental parameters (Kratzke, Stone, & Frost, 2010; Lin & Goodrich, 2010); or a composite of different fixed spatial models based upon previous incidents (Koester, 2008). It is also possible to combine all three approaches with weighted factors. Central to all three approaches is placing the missing subject into a lost person behavior subject category in order to predict behavior. Syrotuck (1975) was the first to estimate POA by lost person behavior category. He defined several categories by age and activity type (e.g., hiker, hunter, child), and estimated probabilities for distance walked in different terrain. Hill (1998) created the walkaway category which included wandering/elopement of all types. Koester (2008) was the first to establish the SAR ASD profile.

All subjects with ASD are placed into the ASD category unless involved with abduction, water incident, or being transported by a vehicle. The current convention used by Koester for the ASD profile has two basic premises: 1) the classification of ASD is more important than the age of the subject; and the corollary 2) all subjects with ASD will fundamentally behave the same (Koester, 2008). The characterization of spatial behavior involves the horizontal movement (distance) away from the initial planning point, find location, scenario, survivability, and track offset. However, because there were few cases specifically identified as ASD, all of the geographic models typically used in SAR have not been described. Nor has any comparison been made to TD children who are also often the subject of search efforts. Important questions remain: Are searches for TD and ASD children different; are searches for ASD adults different from ASD children searches? As the number of ASD missing cases continues to grow, it is critical that recommendations passed onto SAR providers and law enforcement be based upon sound empirical data.

Literature Review

Children with ASD may be more prone to wander away from caregivers and place themselves at risk for becoming lost. Many of the search and rescue reports involving those with ASD mentioned wandering or elopements. Research into wandering or elopement among those with ASD is still at an early stage. The initial studies looked at treatment of wandering/elopement on an individual basis (Falcomata, Roane, Feeney, & Stephenson, 2010; Lang et al., 2010; Perrin, Perrin, Hill, & DiNovi, 2008). Matson and Rivet (2008) reported a prevalence of 34% for wandering/elopement among adults with severe ASD living in an institution. The most comprehensive research to date is an online survey to members of the Interactive Autism Network (IAN) looking at a sample of 1,218 children with ASD. In their 2012 and 2011 studies, Anderson, et al*.* and Law and Anderson respectively found the following data: 49% of children with ASD have wandered/eloped compared to 13% for TD siblings; the probability increases with severity of ASD; 24% were in danger of drowning; 65% were in danger of a traffic injury; elopement peaked at age 5.4; common last seen locations were the child's home (74%), stores (40%), and schools (29%); children were missing for 41.5 (SD 52.4) minutes on average; and law enforcement was contacted in 35% of cases. McIlwain and Fournier (2012) looked at ASD fatalities as a result of wandering/elopement reported in the media. For 2009-2011 they found accidental drowning accounted for 20 out of 22 (91%) of the fatalities subsequent to wandering/elopement for children (age 14 and below) with ASD. Koester (2008) looked at 62 missing ASD search and rescue (SAR) incidents and reported a 2% fatality rate in the wilderness environment and a 33% fatality rate for those not found in the first 24 hours. Most subjects were located in structures (45% in a wilderness setting and 70% in an urban setting). Distances between the Initial Planning Point and find locations were reported, finding a median of 1.0 km in an urban environment.

The major aim of this study is to identify risk factors that result in those with ASD becoming the subject of a search and rescue incident. It is expected that specific causes, activities, and scenarios will emerge that are unique to the ASD population. Another aim is to characterize the demographic factors. It is expected that a higher prevalence of searches for ASD subjects will exist and the age distribution may be different than the TD population. Search and rescue planners use spatial statistical models to best predict the probable locations of missing persons. It is expected that those with ASD will navigate and behave differently while missing, resulting in different spatial and incident outcomes. Most ASD search incidents are for children. Therefore, the final study aim is to compare ASD searches to those for TD children. It is expected that several differences will exist.

Methods

International Search & Rescue Incident Database (ISRID)

The International Search & Rescue Incident Database (ISRID) has been previously described including inclusion, exclusion, and database participants (Koester, 2008). A second round of data collection was collected from 2013-2014 and obtained data from 18 new sources along with updating previous sources. Data were either considered public domain or provided after a Freedom of Information Act (FOIA) request was made. Access to ISRID is arranged through the corresponding author.

Data Source	#ASD	ASD/TD Child%	# TD Child	Total searches
Project Lifesaver International	202	4040.0%	5	523
Oregon Emergency Management	49	10.9%	448	4529
NCMEC	29	34.1%	85	276
Ontario Provincial Police	19	20.2%	94	810
New Zealand Police	15	13.4%	112	1500
Maryland State Police	15	36.6%	41	470
UK Mountain Rescue	13	18.8%	69	653
Australian Police	9	13.2%	68	446
Georgia DNR	5	15.2%	33	128
Virginia Department of Emergency Management	4	2.2%	178	676
Santa Clara SAR	3	50.0%	6	144
ICE-SAR, Iceland	2	18.2%	11	89
Arizona SAR	2	8.7%	23	290
California	2	4.5%	44	124
NPS Yosemite	2	7.4%	27	213
British Columbia PEP	1	5.0%	20	134
Marin County SAR	1	14.3%	7	64
Colorado SAR Board	1	0.6%	172	1861
Idaho	1	20.0%	5	331
Maine Game	1	4.0%	25	169
New Mexico Public Safety	1	6.7%	15	1200
Pennsylvania DNR	1	1.1%	95	507
Utah	1	1.6%	62	3230
Washington SAR	1	2.4%	41	363
Sources with no ASD	0	0.0%	649	4757
Total	**380**	**7.6%**	**2335**	**23487**

Table 1: Data sources that contributed data with ASD incidents.

Subject Classification Hierarchy

All of the cases reported here fall into either the ASD or TD child (1-16) subject category. However, it is possible that a missing subject might have ASD but be placed into a different subject category based upon the ISRID algorithm used to determine subject categories. The five-step algorithm, new to ISRID2.0, shown in **Fig 1** classifies the subject category based upon external forces, transportation, cognitive condition, age, or activity.

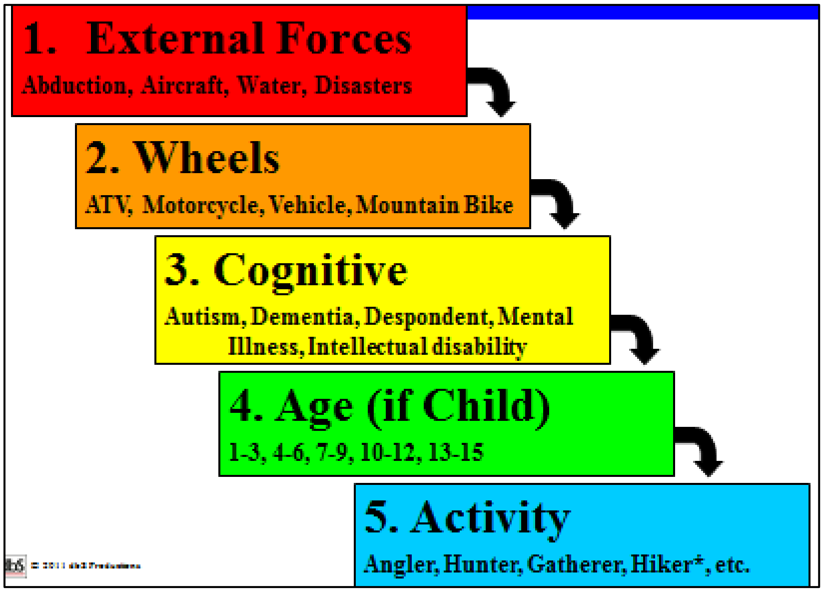

Figure 1 Subject category hierarchy used to classify incidents within ISRID2.0.

ISRID ASD Data

The subject classification of ASD was based solely upon the retrospective search records collected during the incident. The ISRID fields of subject category, sub-category, and comment fields were examined for potential references to ASD. Terms that led to classification as ASD included Autism, Autistic, ASD, Asperger's, and AS. During search incidents initial information is collected from the reporting party. In most cases this is the caregiver, however in some cases it may be a person not familiar with the missing subject. For more protracted searches the investigative process will typically contact the caregivers, medical professionals, and educators. Classification by SAR professionals is based solely upon these contacts. It is possible that the SAR interviewers may have neglected to record any ASD history or for shorter searches the reporting party (or even caregivers) may not disclose any ASD history to SAR. Some caregivers may have also avoided getting a diagnosis for a child who has ASD.

ISRID TD Children Data

ISRID categorizes TD children in the following age groups: Toddler (1-3), Preschool (4-6), School-Age (7-9), Pre-Teenager (10-12), and Adolescent (13-15). Sixteen and older were placed into categories based upon the activity they were participating in. The 2,335 cases of data on TD children reported here comprise the five child age groups (1-15). As previously described in the subject classification hierarchy section, children in missing aircraft, water incidents, ATV, mountain bikes, etc. are not included in the TD Child age brackets.

Notification and Search Times

The standards for notification and search times, Initial Planning Point (IPP) (either the Place Last Seen (PLS) or the Last Known Position (LKP)); incident cause, incident scenarios, and search outcomes can be found in *ISRID data standards* (Koester, 2016)

Geographic Descriptors

Several geographic models are used to describe the find location relative to various geographic features. A detailed description of the methodology for horizontal distance from the Initial Planning Point, use of the Bailey ecoregion domains, track offset, elevation change, find location, and mobility measurements can be found in Koester (2008; Bailey, 1995). The watershed methodology first described by Doke (2015) was modified for this study using the methodology found in Sava et al (2015).

The point model is a new geospatial model for SAR incidents not previously described in the literature. It describes the percentage of subjects who are located at two distinctive and discrete locations--the Initial Planning Point and a known destination. Every search incident has an IPP, but not every incident will have a known destination. IPP, Find, and Destination coordinates are all fields in the ISRID database. In addition, the comment field also allowed classification of the find as occurring at the IPP or destination.

Statistical Analysis

The raw data from ISRID were managed in a Microsoft Excel spreadsheet and exported as necessary to other statistical software. We performed statistical analyses to determine whether apparent differences were statistically significant. Analyses were done in Microsoft Excel 2010, GraphPad QuickCalcs and the Python SciPy suite (Jones et al., 2001; Oliphant, 2007; Perez and Granger, 2007; Hunter, 2007). All tests were 2-tailed.

Categorical comparisons used Chi-Square (χ^2) tests, with Laplace corrections when counts were low (Greenland, 2000). Means of continuous variables were compared using either analysis of variance (ANOVA—when more than 2 variables were being compared) or a parametric *t*-test (when 2 values were being compared) in GraphPad QuickCalcs. In many cases such as distance from IPP, an ANOVA or *t*-test is insufficient for two reasons: first, the distribution is known to be highly skewed; second, a difference in extremes is operationally as important as a difference in means. In these cases, the comparison was made using a nonparametric Kolmogorov-Smirnov (KS) two-sample test to determine if they likely came from the same (unknown) distribution. The KS tests were performed using the SciPy stats module ks_2samp procedure (Jones et al., 2001) Results are considered “significant” if they are less than 5% likely to occur by sampling error alone (P <.05), but actual P values are always reported.

Results

Characteristic	ASD		TD Child		P Value
	n		n		
# Search Incidents	380		2335		
Average Age	338	14.2	2124	8.8	P<0.0001
ASD Children	269/130	5.3%/7.2%	2335/1686		
ASD Adults	87	25.7 (avg age)		10.4	P<0.0001
Male	297	83.2%	1519	70.1%	P<0.0001
Female	60	16.8%	649	29.9%	
Solo while lost	357	100%	1752	89.6%	P<0.0001
Group while lost	0	0%	204	10.4%	
Notification time avg	243	1:34	816	3:43	P=0.15
Search time avg	297	1:43	1589	5:29	P=0.09
Found Well	324	88.5%	1684	88.7%	P=1.000
Found Injured	25	6.8%	103	5.4%	P=0.302
Found DOA	16	4.4%	93	4.9%	P=0.674
Never Found	1	0.3%	19	1.0%	P=0.180

Table 2 reports the overall demographic characteristics of ASD and TD Children who were the subjects of searches in the ISRID database. The age distribution of search incidents is statistically different between ASD and TD Children as seen in **Figure 2**. While ISRID contains 338 ASD adult and children cases, 202 of these came from Project Lifesaver International which specifically enrolls ASD and dementia cases. If both the Project Lifesaver International and adult cases are excluded this leaves 130 child ASD incidents. A total of 2465 ISRID incidents involved children (130 ASD Child + 2335 TD Child) for an ASD child prevalence of 5.3%. Some large data sources reported no ASD incidents. If the data sources that reported no cases of ASD are excluded then the number of TD child searches drops to 1686 and a total of 1816 incidents would involve children (130 + 1686) and the prevalence rate becomes 7.2%. The CDC reports the official prevalence of ASD among 8-year-olds as 1 in 59 for 2014 (1.7%)(Baio, et al., 2018). Using the most recent official CDC estimate of 1.7% and the range of ISRID prevalence of 5.3-7.2%, children with ASD are 3.1 - 4.2 times more likely to become the subject of a formal search. A higher incidence of search incidents occurs for those with ASD than TD children which is statistically significant (χ^2 = 325; P << .0001).

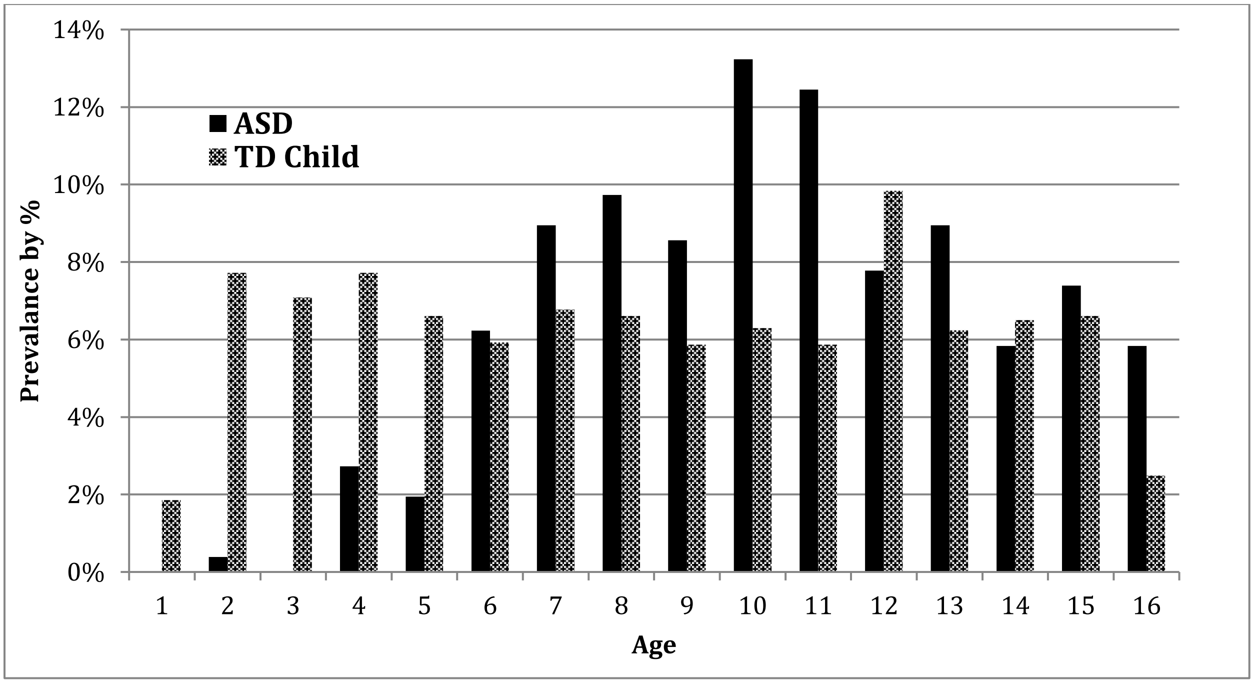

Figure 2. Distribution of prevalence of search incidents by age for 1-16 year-olds. ASD based upon 257 incidents and TD Children based upon 1891 incidents where the age was reported. The two groups are statistically different (F crit = 3.8, P<0.0001).

Search Scenario and Outcome

A general medical outcome was reported in 366 ASD cases and is reported in **table 2**. If the subject was not found in the first 24 hours after being last seen then survivability drops to 62% (n=8). However, when looking at the entire ISRID database, it is clear that the mortality rate among TD children (4.9%) and ASD (4.4%) is significantly lower than the overall ISRID mortality rate of 12% (χ^2=53.12; *P*<<0.0001). The search scenario is reported in **Table 8**. Additional survivability data is displayed in **Figure 3** and summarized in **table 9**.

Child ASD versus Adult ASD

The ISRID database contains 269 children (age 2-16) with ASD and 87 adults (17-75) with ASD. Twenty-four of the ASD subjects had no age reported. Among the spatial models no statistical difference was seen in distance from the IPP (KS; *P*=.429); track offset (Student's *t*-test; *P*=.38); elevation (χ^2 = 2.392; *P*=.302); survivability (χ^2 = 1.118; *P*=.29) or mobility (Student's t-test; *P*=.46).

Geographic Descriptors

Spatial statistics were collected for distance from the IPP, track offset from the nearest linear feature, total time mobile, vertical elevation change between the IPP and find location, point model which measures percentage found at the IPP or the intended destination, type of terrain found in, and the watershed model. The results are shown in **table 2-8**.

	Distance (horizontal) from IPP (km)						Track Offset (m)		Mobility (hours)	
	ASD			TD Child (1-16)			ASD	TD Child	ASD	TD Child
	Temperate	Dry	Urban	Temperate	Dry	Urban				
n	**233**	**10**	**31**	**903**	**115**	**129**	**174**	**55**	**21**	**272**
25%	0.4	0.7	0.4	0.3	0.8	0.2	0	2	1	1
50%	0.9	1.4	1.0	0.9	2.4	0.5	9	14	3	3
75%	2.3	3.0	2.1	2.4	4.0	1.6	46	53	4	5
95%	8.0	7.2	6.4	11.3	9.7	5.2	396	500	7	11
Avg.	2.1	2.4	1.7	2.7	3.2	1.4	81	104	3.2	3.7
SD	3.7	2.8	2.0	5.3	3.7	2.0	232	310	3.0	4.4

Table 3. Quartile and 95% for ASD and TD Children for distance, track offset, and mobility models. No significant difference was seen in the distance models (KS P=0.5) track offset model (K-S p=0.75), or mobility (KS, P=0.8).

		Watershed Model (%)			
Data Source	**n**	0: Same Watershed	1: Adjoining Watershed	2: Two Watersheds away	3: Three+ Watersheds away
ASD	15	67%	27%	7%	0%
Arizona[43]	122	47%	38%	6%	10%
New York[43]	102	70%	24%	3%	4%
Yosemite[3]	184	50%	43%	6%	2%

Table 4. Data for the Watershed model. Data from Arizona and New York from (Sava, Twardy, Koester, & Sonwalker, 2015). Data from Yosemite from Doke (2012)

Point Model (%)						
	ASD			TD Child		
Location	**Potential**	**Actual**	**%**	**Potential**	**Actual**	**%**
IPP	70	3	4%	408	55	13%
Destination	0	0	NA	153	17	11%

Table 5. New Point model based upon subject being found within 100 meters of IPP or destination. Potential means the IPP and/or destination was recorded. Actual means the subject was found at that location. ASD might have had a potential destination but failed to tell anyone.

Elevation Model (%)		
	ASD	**TD Child**
n	**16**	**462**
Uphill	31%	34%
Downhill	31%	37%
Same	38%	29%

Table 6. Elevation model with no significant difference.

	Find Location (%)					
	ASD			**TD Child (1-16)**		
	Temperate	Dry	Urban	Temperate	Dry	Urban
n	**228**	**12**	**29**	**343**	**32**	**128**
Structure	78%	75%	45%	34%	25%	59%
Road	7%	8%	28%	18%	22%	10%
Linear	0%	0%	3%	10%	13%	3%
Drainage	1%	0%	3%	6%	0%	3%
Water	5%	8%	14%	8%	13%	5%
Brush	0%	0%	0%	2%	6%	0%
Scrub	0%	0%	0%	1%	6%	2%
Woods	6%	8%	7%	16%	13%	8%
Field	2%	0%	0%	4%	0%	10%
Rock	0%	0%	0%	1%	3%	0%

Table 7. Data for find location. Note large difference in the find percentage for structures.

Scenario (%)		
	ASD	***TD Child***
n	***106***	***1116***
Avalanche	*0%*	*0.1%*
Criminal	*0%*	*0.4%*
Despondent	*0%*	*0.5%*
Evading	*17.0%*	*5.6%*
Investigative	*20.8%*	*12.8%*
Lost	*54.7%*	*67.7%*
Medical	*1.9%*	*0.4%*
Drowning	*2.8%*	*0.5%*
Overdue	*2.8%*	*9.9%*
Stranded	*0%*	*0.7%*
Trauma	*0%*	*1.4%*

Table 8. Different scenarios involved in cause of incident. Note differences in evading, investigative, drowning, and overdue.

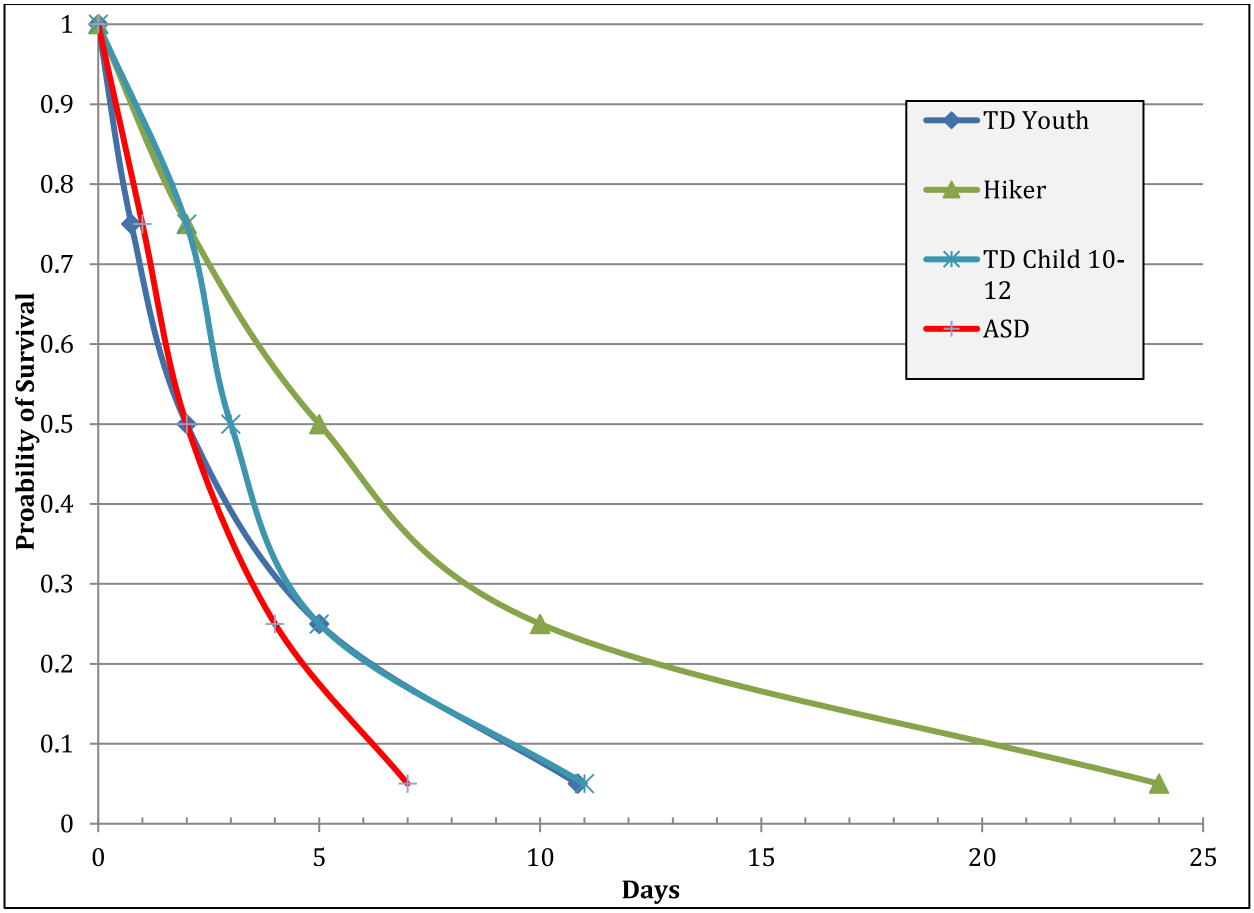

Figure 3: Long-term probability of survival curves. ASD curve is similar to both of the TD Youth (age 13-15) and the TD Child (10-12) curves. Although TD Children have a slightly better chance of long-term survival. The hiker curve (all adults) is provided for reference and has the best long-term survivability. The line provides the probability of finding the subject alive after that number of days have passed since the subject last being seen. For example, at four days, an ASD subject has an 25% chance of being found alive, at seven days, it drops to 5%. All data from searches, recoveries were excluded.

	Probability of Survival (days)			
	ASD	TD Child	TD Youth	Hiker
n	**24**	**73**	**224**	**962**
75%	1	2	0.75	2
50%	2	3	2	5
25%	4	5	5	10
05%	7	11.4	10.9	24

Table 9. Long-term probability of survival curves data that figure 3 is based upon. On the 7th day since the subject was last seen alive, the probability of finding an ASD subject alive would be 5%.

Discussion

Search incidents for missing ASD and TD children demonstrate significant differences but also have some common features. The newly updated ISRID database was able to examine 380 ASD and 2335 TD child search incidents. Based upon the findings of this study, children with ASD are 3.1 – 4.2 times more likely to become the subject of a search than age-matched TD children. This is comparable to the finding by Anderson, et al. (2012) that those with ASD were 3.8 times more likely to elope than their age-matched TD siblings. Furthermore, it is also possible the ISRID-based estimate may underestimate the prevalence of ASD. Within the ISRID database it is possible to have: undiagnosed ASD cases recorded as TD Child, failure of the caregiver to report the ASD diagnosis, or failure of the SAR team to record the ASD information on the data collection forms, all of which would result in the ASD incident being recorded as a TD Child incident. However, it would not be expected to have a TD child reported as an ASD incident. Subsequently, any ASD finding reported is potentially at the lower bound of actual results and any significant findings showing differences was able to rise above this potential obstacle.

The basic premise of lost person behavior is that the subject category can make meaningful predictions and generalizations about the subject of the current search. The algorithm used to determine the subject category implies that categorization as ASD better predicts the find location than age (Koester, 2008). This premise would predict that ASD children and ASD adults are more similar than ASD and TD children. This study is the first to critically examine and support this premise by finding that no statistical differences were seen between ASD adults and ASD children for distance from the Initial Planning Point (IPP), track offset, elevation, mobility, or survivability. However, it is important to note that a thoughtful search planner should use the ASD profile with confidence but should always consider other factors, such as age, in determining the search strategy.

Any search incident is an emergency. Search urgency charts have been developed to measure the need to respond (Stoffel, 2006). Typical ASD incident factors such as a solo subject, age, cognitive condition, experience profile, and equipment profile almost always places an ASD incident into the most urgent category. A search for an ASD child chronicled by King (2012) required 68,936 personnel hours, 5 days, and found the subject alive. The most common search scenario is that the child becomes lost for both ASD (55%) and TD children (68%). However, searchers should be aware that ASD search subjects are three times more likely to be evasive and five times more likely to be involved in a drowning.

This study also describes several different spatial relationships that search planners may use to help model probable locations of a missing subject. The spatial models described in this study include horizontal distance from the IPP, track offset, elevation, mobility, find location, point model, and watershed. This is the first time the track offset, mobility, watershed and point models have been described for ASD. All of the models except the horizontal distance and dispersion model require specific GIS layers in order to display and calculate the probabilities. All of these models may be integrated, with

Sava et al. (2015) and Wysokinski & Marcjan (2015) recently combining some of these models. An integrated model allows search planners to visualize potential locations and then deploy resources while computer programs may further enhance operational decision making by optimizing resources based upon search theory.

The horizontal distance from the IPP model helps to establish the formal search area and define areas of higher probability density. Between ASD and TD Child categories no significant difference was seen. However, the study did find that the environment plays a significant role in distances traveled from the IPP. While Koester (2008) previously reported subject category by ecoregion domains and treated the urban environment as its own domain, this is the first time distance from the IPP has been shown to be statistically significant due to the environment for ASD. TD Child travels significantly farther in the dry ecoregion domain than the humid temperate domain. In addition, for both the ASD and TD Child incidents, subjects traveled farther in urban environments (as measured by “as-the-crow-flies” distances).

While the track offset model was not shown to be significantly different between ASD and TD children, it still holds operational significance for searchers and planners with the ASD 50% quartile track-offset distance of just 9 meters (18 meters total width) versus 14 meters (28 meters total width) for TD Child. This means ASD subjects are much more likely to be found close to a linear feature such as a road, powerline, or hydrological feature. When searchers are assigned to a linear task they should consider searching out to at least the 50% of the track offset. Alternatively, a corridor task may be assigned where the team anchors on the linear feature while the team searches out the 75% track offset distance (46 meters). These may be the only types of tasks possible to search the 75-95% distance annulus.

The find location data indicates a substantial percentage of ASD subjects are found in structures (45-78%), even in more so in urban areas. Search teams should be reminded of the importance of thoroughly searching buildings, out-buildings, yards, and vehicles. In remote areas where no structures are present, subjects have been located in dense foliage, which may represent a proxy for a structure. Searchers, therefore, should also pay particular attention to dense areas that may offer a sense of being enclosed.

Age-specific differences are seen in the prevalence of wandering for both those with ASD and TD children in **Figure 2.** Our findings generally agree with McIlwain and Fournier (2012) who reported ASD three-year-olds as the youngest in their fatality database, even though an early diagnosis of ASD may occur as early as 18 months (Zwaigenbaum et al., 2005). The American Academy of Pediatrics recommends screening all children by age two, yet the median age of Autism diagnosis is 5.7 years (Johnson & Myers, 2007; Shattuck et al., 2009). Therefore, it is both possible that the delayed onset in search incidents among autism may be either a behavioral difference or simply undiagnosed early wandering incorrectly classified as TD children.

Only 7% of the ASD records clearly indicated seeking behavior, although it could be argued that investigative outcomes indicate seeking behavior which would raise the percentage to 27%. This is in contrast to Anderson, et al (2012) who reported that nearly half of all parents reported that the child's wandering/elopement was goal-directed. It is possible that search investigators neglected pursuing possible destinations in ASD incidents

Limitations

This study had several limitations. The ISRID database used a retrospective approach and collected data from numerous different data sources. As a result of the retrospective nature it is quite possible that some of the incidents classified as TD Child may in fact be ASD. Nonetheless, we were able to report statistically significant results even with potentially mislabeled cases. These results are also confounded by different intellectual capabilities within the ASD category. Many of the search records did not mention whether the ASD search subjects were HFA (High Functioning Autism) or LFA (Low Functioning Autism). It is certainly possible that the differences between ASD and TD children seen in this study are more a function of intellectual ability. This distinction may eventually lead to a sub-category within ASD (HFA or LFA) for SAR practitioners based upon future studies. Future studies should compare ASD to children with intellectual disabilities. It would also be appropriate to break ASD into three groups, consisting of of children ages 1-15, unmyelinated young adults ages 16-21, and adults.

Conclusion

The findings of this study have implications for public policy, search and rescue tactics, and a better understanding of the navigational abilities in those who have ASD and TD children. Seven different spatial models provide quantitative data on where those with ASD are located. Those with ASD were 3-4 times more likely to require a search effort, 4.7 times more likely to be involved in a drowning incident, 1.7 times more likely to be evasive, 2.0 times more likely to be found through investigative efforts, and more likely overall to be lost by themselves than TD children (age 1-16).

The study found several statistically significant differences in spatial models used by search and rescue planners. While no differences were seen between the distances traveled by ASD and TD Child in the wilderness, the importance of the ecoregion domain and urban settings was shown. In the urban environment, ASD subjects traveled nearly three times as far as TD Child for all of the quartiles. Differences between ASD and TD Child were shown in decreased distances traveled away from a linear feature (track offset), more likely to be found in the same HUC-12 watershed (67%), and less likely to be found at the IPP (4%) than the TD Child.

This is the first study to look critically at the central premise of lost person behavior categories for ASD and TD Child categories. The data supports the current subject category algorithm of looking at cognitive issues prior to looking at age. The study showed that ASD children and adults are similar while ASD and TD children had several significant differences in spatial models.

Acknowledgements

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Abbreviations

ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorder
ATV	All-Terrain Vehicle
Avg.	Average (mean)
CARS	Charlottesville-Albemarle Rescue Squad
CEO	Chief Executive Officer
DCJS	Department of Criminal Justice Service
DOA	Dead on Arrival
FEMA	Federal Emergency Management Agency
FOIA	Freedom of Information Act
GIS	Geospatial Information System
HFA	High Functioning Autism
IPP	Initial Planning Point
ISRID	International Search & Rescue Incident Database
KS	Kolmogorov-Smirnov
LFA	Low Functioning Autism
LKP	Last Known Point
n	number (count)
NASA	National Aeronautical Space Administration
NPS	National Park Service
PLS	Place Last Seen
POA	Probability of Area
SD	Standard Deviation
S&T	Science & Technology
TD	Typically Developing
USCG	United States Coast Guard
US DHS	United States Department of Homeland Security

About the Author

Robert J. Koester first joined the Appalachian Search & Rescue Conference in 1981 and since then has participated in hundreds of searches, including over a hundred as Incident Commander. He holds a Ph.D. from the University of Portsmouth in search theory and a MS and BA from the University of Virginia in biology (neurobiology). His contributions to search and rescue include seminal research on search theory and lost person behavior along with creating the International Search and Rescue Incident Database (ISRID). He is an instructor for the Virginia Department of Emergency Management since 1988 and past-president (15 years) of the Virginia Search and Rescue Council, Robert has also worked for the USCG (conducting visual sweep width experiments), NASA (conducting missing aircraft radar research), NPS (responding to major searches and writing the draft NPS *SAR Field Manual*), FEMA (as an instructor and disaster reservist), and SAR Institute of New Zealand (conducting sound and light sweep width experiments). He is currently developing SAR software called FIND, for the US DHS S&T directorate. He also developed courses for DCJS and was a Cardiac Technician for twelve years with CARS. He is the CEO of dbS Productions which provides research, software & publications, and training services. He is also a visiting researcher at the University of Portsmouth. Robert has authored dozens of books and research articles on search and rescue, including *Lost Person Behavior,* and is widely cited.

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A Pragmatic Approach to Applied Search Theory

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Abstract

The Washington State SAR Planning Unit (SSPU) was activated in 2018 to provide advanced search planning resources to regional incident commands during extended or complex search missions. The SSPU operates under the auspices of the Washington State Emergency Management Division, and comprises experienced SAR volunteers with specialized training in search management and planning. In addition to providing search planning strategies and technical mapping, one of the primary objectives of the SSPU is to apply modern search theory to challenging search incidents.

Our application of search theory can be parsed into three related planning tasks: (1) Characterizing initial search regions and segments; (2) Assessing search effectiveness; and (3) Prioritizing search assignments for subsequent operational periods. A major challenge faced in achieving these objectives is that the SSPU can be requested by any of the 39 counties in Washington State, all with different search planning approaches, different search data collection practices, and different experience with the principles of modern search theory. For this reason, the SSPU has developed a pragmatic approach to applied search theory that can be characterized in one phrase: "When objective data are available, use it according to search theory best practices; when only subjective input is available, at least be systematic".

KEY WORDS: *Search theory, search planning.*

Introduction

The Washington State SAR Planning Unit (SSPU) was envisioned in 2015 by Chris Long (Washington State SAR Coordinator) and Jon Wartes (King County Search and Rescue) as a team of specially-trained volunteer technicians who would be able to assist Washington State counties with search planning for complex or extended search incidents. They recognized that search theory as applied to land searches, had progressed to the point where it was applicable to real search missions. This new circumstance called for "planning technicians" who were trained in underlying search theory concepts, were familiar with the tactical implications of applying search theory, and who had the ability to use modern software tools to support planning activities. Under the leadership of Long and Wartes, a group of experienced SAR volunteers were selected and trained during 2016-2017, and the SSPU was formally activated in early 2018.

Planning services provided by the SSPU can come in two forms:

1. We can develop and deliver a Remote Search Plan. Remote Search Plans are based on the concept of a Virtual Search Plan, developed by Paul Burke of the Nevada State Sheriff's Department (Burke, 2017). Remote Search Plans comprise an incident overview, detailed subject research, search scenarios, terrain analysis, recommended search objectives, and detailed search maps – all based on search planning best practices where possible. Remote Search Plans are produced via online collaboration of SSPU team members and are delivered electronically to on-site Incident Command.

2. We can provide on-scene planning resources. If requested, SSPU team members will travel to the search incident and provide on-site services that can include: Search theory-based planning, technical mapping, recommended search assignments and priorities, as well as a Planning Section Chief or Situation Unit Leader. Typically, on-scene SSPU staff will integrate and work closely with the command staff of the host county in a unified effort.

Search jurisdictions in Washington State (39 counties and 3 national parks) are diverse in their environments, their search planning experience, and their exposure to modern land search theory. For that reason, when the SSPU is activated, we must adapt our planning methods to make optimal use of local conditions, local data availability, and local expectations. Our approach to this challenge has been to develop a framework that guides decisions about what components of search theory can be applied under what circumstances. Within this framework, we have attempted to create standardized processes, checklists, and tools to facilitate the use of search theory-based best practices.

In this paper, we describe our initial attempt at this framework, divided into three components: (I) Characterizing Search Regions and Segments; (II) Assessing Search Effectiveness; and (III) Prioritizing Search Assignments.

I. Characterizing Search Regions and Segments

A. Defining the Search Area Boundary

As a prelude to defining the Search Area and Search Regions, we generate and formally evaluate Search Scenarios. We use a Proportional Consensus process (supported by a simple spreadsheet tool) to assign relative priorities to Search Scenarios. These prioritized Search Scenarios then drive formation of search objectives, and guide decisions about which objectives to address first. We will sometimes include as a scenario that the subject has traveled outside of the active search area. This scenario (sometimes formalized as “Rest of the World” or ROW), serves to remind search managers of this possibility, but is not defined formally as a Search Region and is not used in quantitative search theory calculations (Cooper et al, 2003).

Our process for defining search regions and segments begins with current best practices for outlining a Search Area Boundary, using (1) theoretical travel distances; (2) historical travel distances based on Lost Person Behavior (LPB) data (Koester, 2008); (3) analysis of terrain features; and (4) subjective inferences (Stoeffel, 2006). In our consideration of the influence of terrain features on subject travel, we have become particularly sensitive to two factors: The value of local knowledge, and the influence of linear features as travel aids. Both of these factors are illustrated by the incident depicted in Figure 1, which shows the travel path of a lost subject in Mount Rainier National Park.

While not a new observation, time and again, the value of obtaining local knowledge of terrain features, old trails or tracks, and past subject behavior in the search area has been demonstrated to us. This was well-illustrated by a 2018 search for a lost backpacker in the Spray Park area of Mount Rainier National Park. Rangers on the planning team were able to recall previous episodes when lost persons in that area worked their way down a narrow creek drainage and ended up wandering to the west down the Mowich River Basin. This detailed local knowledge turned out to be a key in locating the subject.

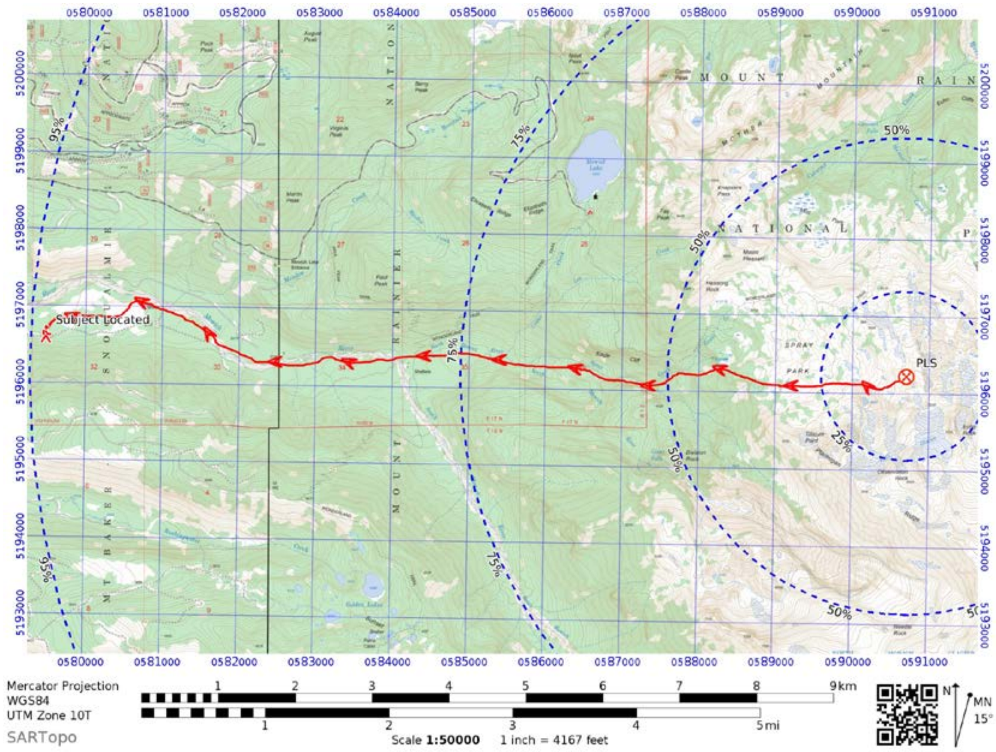

Figure 1: *A Subject's "Linear Escape" of Over 18 km*

As depicted by the red line in Figure 1, once into the river basin, the subject kept moving down this travel aid, performing what we now think of as a "linear escape". After three days of searching, the subject was located in the river basin over 19 km from the Point Last Seen (PLS) -- just at the 95% distance for the Hiker Lost Person Behavior subject category. Search planners (principal author included) had recognized this possibility and had directed a helicopter to search the river basin. What search planners did not do, was to provide specific guidance for <u>how far down the basin</u> to fly (*to the 95% distance would have been a good idea!*), and as a result, the helicopter crew did not fly far enough west. The subject was located (in good condition) by a ranger who had been directed to patrol forest roads in the far western area of the river basin.

While anecdotal, another example of a "linear escape" is the search for a hiker who went missing in 2017 in Olympic National Park. Extensive searching of ground and river terrain near his last known point (LKP) was conducted for months by both official and family resources. In 2018 the hiker's remains were found by park rangers just <u>outside</u> the 95% "lost hiker" radius – 19 linear km from the LKP and 24 km by trail. With these incidents in mind, we extend search area boundaries when appropriate by adding buffer search areas along linear features that might aid subject travel.

Sensitivity to the influence of linear features is also supported by a recent geospatial analysis of find locations with respect to terrain features (Jacobs, 2016). Based on an analysis of 622 ISRID incidents (for Hiker, Hunter, and Gatherer subject categories), Jacobs reported that the probability of find location increased near linear features, such as roads, trails, streams, and drainages. He suggested that terrain-based probability considerations could be applied in some incidents (particularly where terrain is not uniform) to focus search priorities on "*dense searching at the core [near the IPP] surrounded by a web of linear features, with several long-ranging stringers at the periphery*."

B. Characterizing Search Regions

Search Regions are defined and mapped as geographical areas inside which the Probability of Area (POA) is assumed to be uniform. That is, the likelihood of a subject being at any location in the region is the same for all locations within the region. Drawing and characterizing Search Regions yields a "probability map" which illustrates and quantifies the distribution of POA within the Search Area Boundary (IMO/ICAO, 1999b; Cooper and Frost, 2017). The POA of each Search Region is the starting point for applying search theory to evaluate its relative priority in search planning.

Our approach to defining Search Regions depends upon (a) the nature of planning done by the local jurisdiction prior to SSPU involvement, and (b) availability of objective statistical data (e.g., Lost Person Behavior). If the SSPU is activated prior to or during the first operational period, we typically will define search regions using the approaches described below. On the other hand, if SSPU is activated after initial operational periods, we may adopt previously defined search regions if they seem adequate.

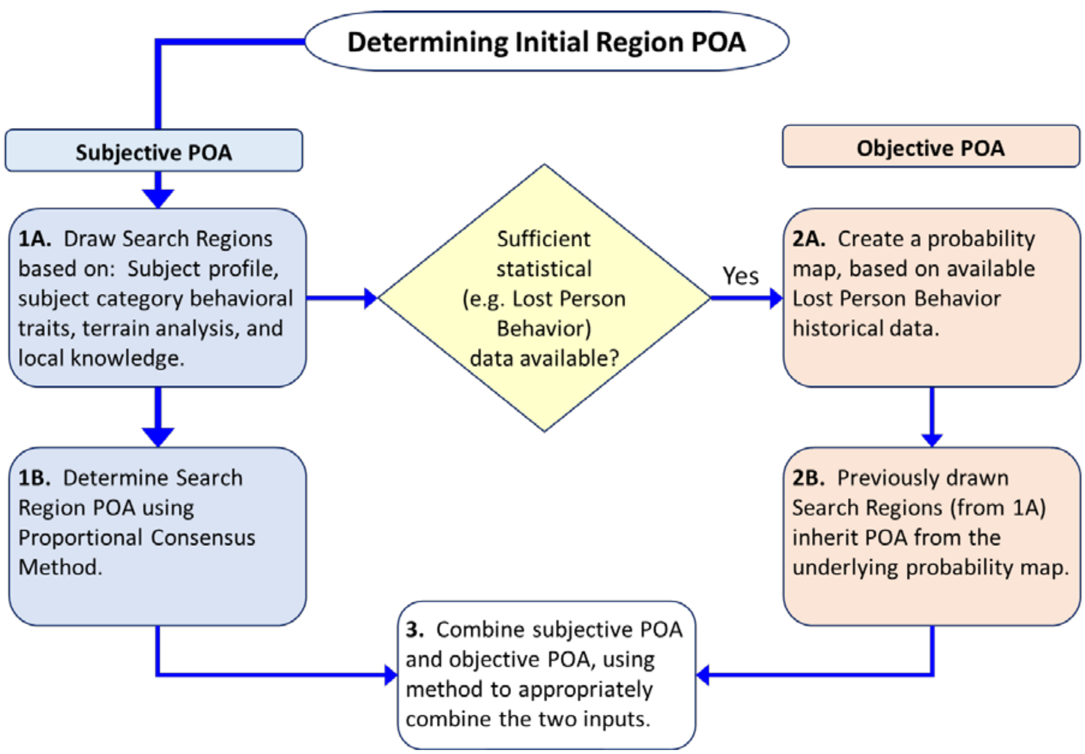

Figure 2: *Decision Guide for Characterizing Search Regions*

As diagrammed in Figure 2 [Step 1A], we begin with a "subjective" approach to defining and mapping Search Regions. Regions are defined using search scenarios, lost person behavior category, the effect of terrain on subject travel, attractions, deterrents, and time elapsed. Physical boundaries, such as terrain or man-made barriers, are also used in defining Search Regions. Once mapped, we use a proportional consensus method [Step 1B] to assign a Subjective POA to each Search Region.

Figure 3 below shows subjectively defined Search Regions (blue-shaded areas) for a missing snowshoer last seen at 8500 feet on the Muir Snowfield in Mount Rainier National Park. For this mission, during planning for Operational Period 2, SSPU members defined Search Regions based on: (a) the likelihood of travel in a given direction; (b) terrain guides (snowfield edges); (c) terrain barriers; and (d) distance from the PLS.

For example, Regions A and C were both within a relatively close distance from the PLS, and both on the Muir Snowfield proper. Region A was judged to have higher relative POA because it was consistent with the subject's presumed direction of travel (downhill to the trailhead). One can also see that the southern boundaries of Regions A, D, I, and F roughly correspond to 25% and 50% Distance from IPP radii (yellow dotted lines).

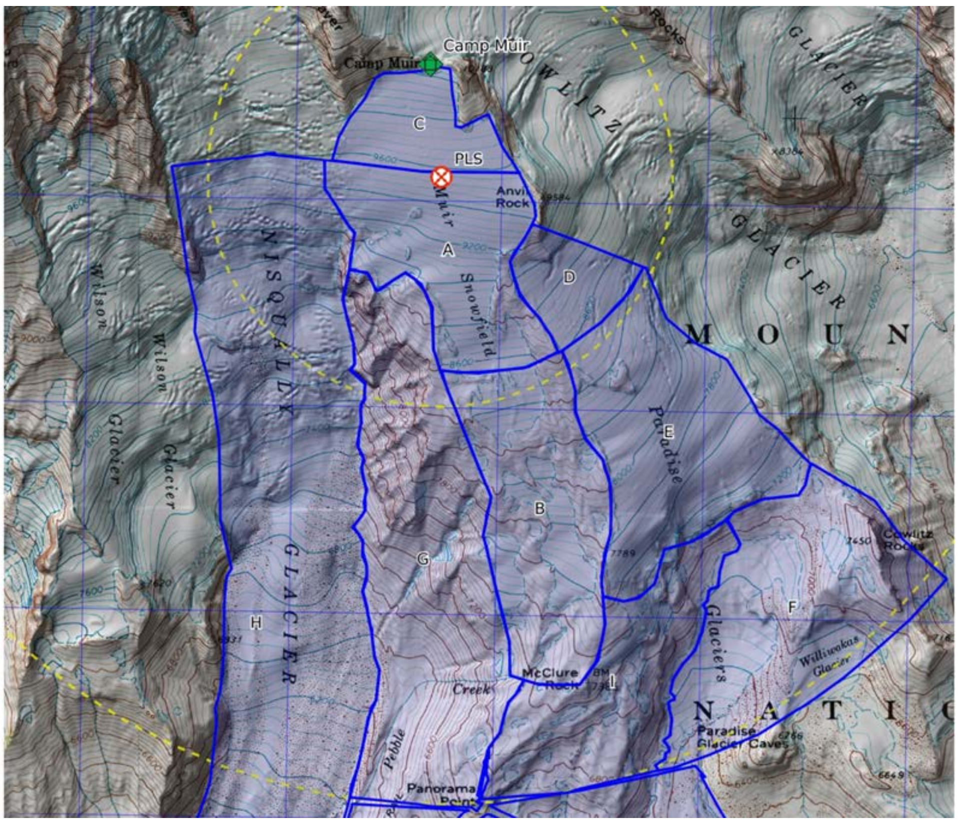

Figure 3: *Subjectively Defined Search Regions for Missing Snowshoer on Mount Rainier*

When multiple LPB factors are available, we attempt to objectively quantify Search Region POA via the approach described by Koester (Koester, 2018). This data-based POA quantification [Step 2A in Figure 2] involves the following general steps:

1. Obtain LPB historical data for at least two (preferably three or more) factors, such as: (1) Distance from IPP, (2) Dispersion Angle, (3) Track Offset, and (4) Elevation Change.

2. The historical percent of finds, as shown for two LPB factors in Table 1 below, form the basis for a probability map used to quantify Objective POA (Koester, 2008).

Lost Person Behavior Factor	**25%**	**50%**	**75%**	**95%**
Distance from IPP	1.1 km	3.1 km	5.8 km	11.3 km
Contribution to Objective POA	25	25	25	20

Lost Person Behavior Factor	**25%**	**50%**	**75%**	**95%**
Dispersion Angle	2^{o}	23^{o}	64^{o}	132^{o}
Contribution to Objective POA	25	25	25	20

Table 1: *Historical Lost Person Behavior Data for Hiker Category (Mountain, Temperate)*

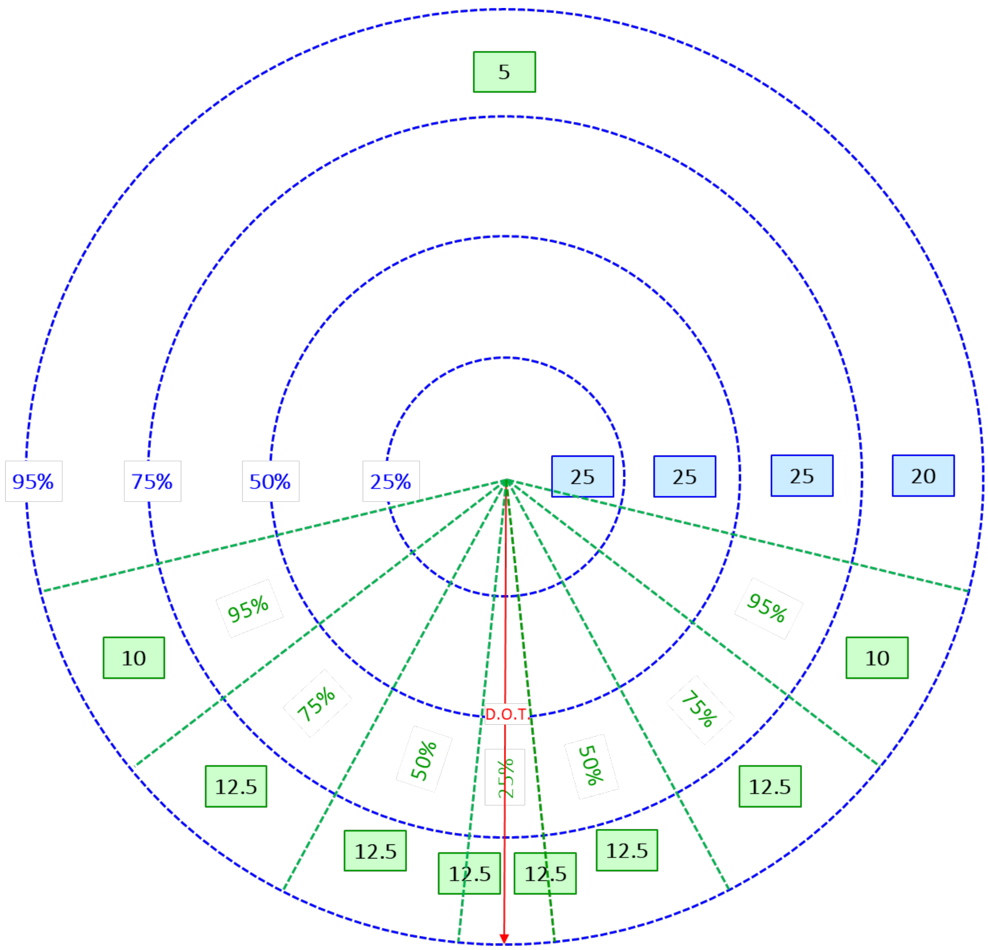

Figure 4: *Underlying LPB Values for Objective POA.*
Dotted blue lines represent Distance from IPP. Dotted green lines represent Dispersion Angle.
In this diagram, dispersion angles and distance radii have been reduced to simplify the exposition.

Figure 4 above, shows how two LPB factors (Distance from IPP and Dispersion Angle) would be combined to create a map of underlying POA values. The Objective POA value for each Distance from IPP ring or annulus comes directly from the historical "percent of finds" data in Table 1 above. Similarly, the Objective POA value for each Dispersion Angle sector derives directly from the LPB data for that factor. (Note that the POA values for each Dispersion Angle sector are halved on each side of the direction of travel, indicated by the red "D.O.T." line).

3. The LPB historical values illustrated in Figure 4 become the basis for a Probability Map in which the historical values are proportionally distributed to each <u>unique intersect</u> of a Distance from IPP ring/annulus with a Dispersion Angle sector. The principal for this is illustrated in Figure 5, where the purple area of the probability map represents the unique intersect of the 95% Distance from IPP annulus and the 95% Dispersion Angle sector. The POA for this area is calculated as follows:
7% of the area of the 95% distance from IPP annulus (20 * .07 = 1.3) plus 44% of the area of the 95% dispersion angle sector (10 * .44 = 4.4), yielding a POA of purple area = (1.3 + 4.4) = 5.7.

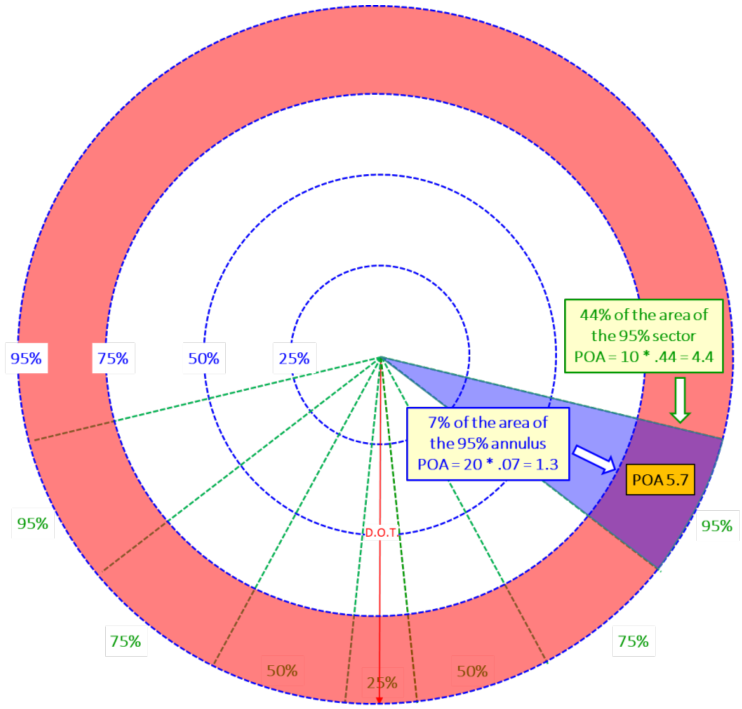

Figure 5: *Probability Map for One Unique Intersect.*

The fully quantified probability map for this two-factor example is shown in Figure 6 below.

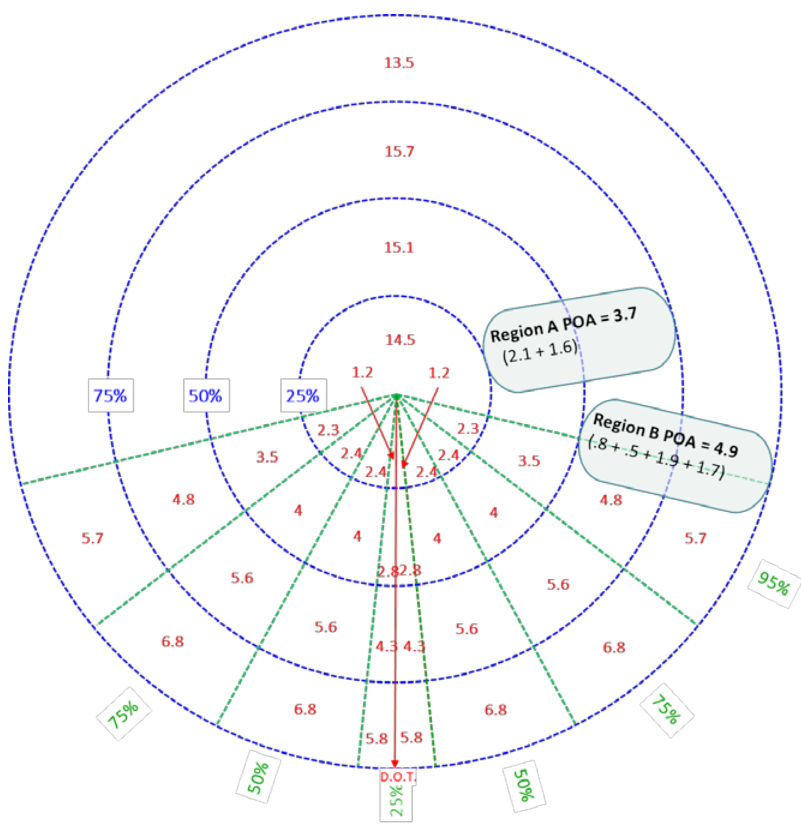

Figure 6: *How Search Regions Inherit Objective POA from an Underlying Probability Map*

4. After a probability map has been created based on historical Lost Person Behavior statistics, previously drawn Search Regions are overlaid on the probability map and "inherit" their Objective POA based the areas of probability covered by each region. Two examples of this are shown in Figure 6 above.

Region A contains two unique intersects, combining to yield a POA of 3.7.

- Region A covers 14% of the portion of the 50% annulus that is not covered by a Dispersion Angle sector. The POA for that intersect is calculated as (15.1 * .14) = 2.1
- Region A also covers 10% the portion of the 75% annulus that is not covered by a Dispersion Angle sector. The POA for that intersect is calculated as (15.7 * .1) = 1.6

Region B contains four unique intersects, combining to yield a POA of 4.9.

- The upper left quadrant covers 5% of the 75% annulus not covered by a Dispersion Angle sector (15.1 * .05 = .8 POA)
- The upper right quadrant covers 4% of the 95% annulus not covered by a Dispersion Angle sector (13.5 * .04 = .5 POA).
- The lower left quadrant covers 40% of the 75% annulus/95% sector intersect (4.8 * .4 = 1.9 POA)
- The lower right quadrant covers 30% of the 95% annulus/95% sector intersect (5.7 * .3 = 1.7 POA).

The examples in Figures 4, 5, and 6 use only two LPB factors and have been artificially simplified to illustrate the basic concepts. (Discussion of modeling nuances -- such as closing the Dispersion Angle POA at the 95% Distance from IPP radius -- are beyond the scope of this paper). Even with the simplification, the probability model is already complex enough so that the human math involved would be tedious as well as unreliable. For this reason, this methodology is best supported using a GIS system, or software specifically designed for this purpose, such as FIND, developed by dbS Productions, LLC (Koester, 2015).

As shown in Figure 2, once Subjective POAs and Objective POAs are obtained, they can be combined appropriately (averaged, then normalized) to derive Initial POAs for each Search Region. In our current approach, Subjective and Objective POAs are weighted equally. Depending upon the quality of information at a particular search incident, planners may choose an unequal weighting.

C. Making Probability Visual

In Washington State counties, the role of Incident Commander is typically filled by a Sheriff's Department deputy. We have learned through experience that the quickest way to lose the interest and "buy-in" from an Incident Commander is to present a 30-minute lecture on the complexities of computing probability based on the principles of modern search theory. For that reason, we rely on visualization of probability to quickly convey the results of our calculations in an easy-to-understand display. Figure 7 shows an example of this for the Muir Snowfield search.

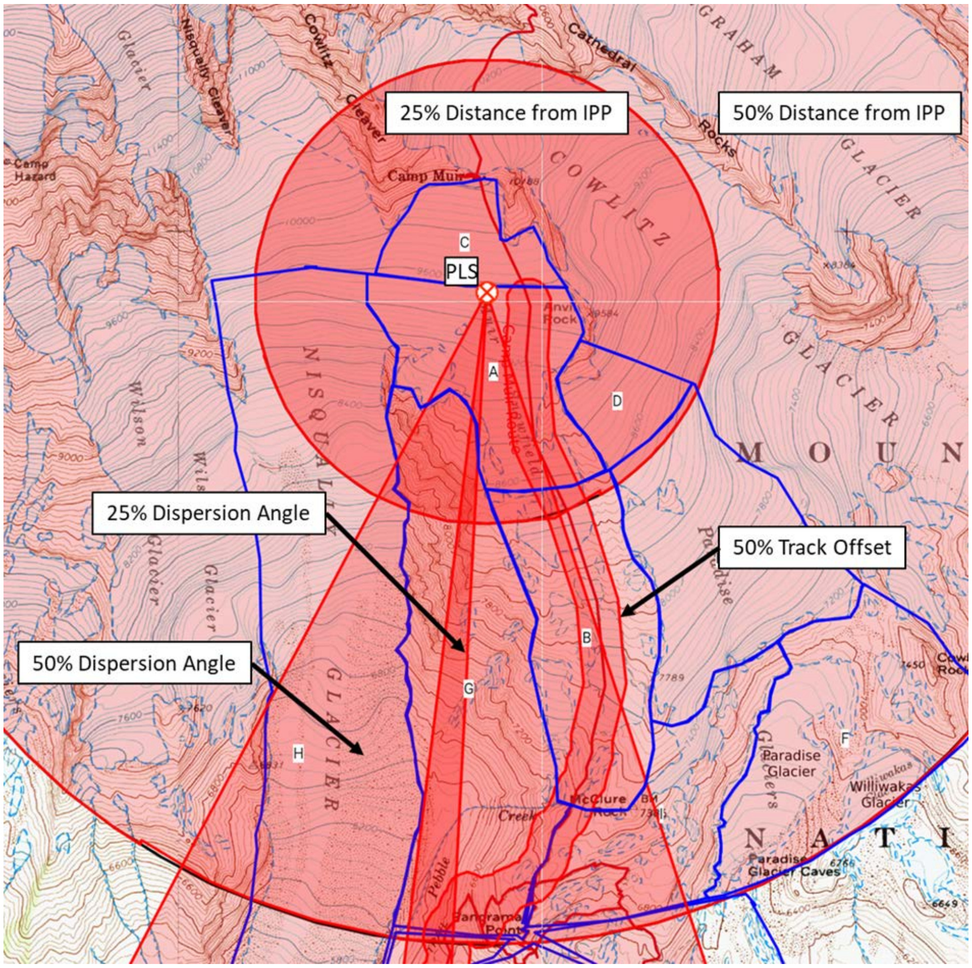

Figure 7: *Search Regions on a Shaded Probability Map*

In Figure 7, Search Regions are outlined in blue over a probability map (based on LPB factors Distance from IPP, Dispersion Angle, and Track Offset). The red shading in this figure represents Probability Density, but can be described to Incident Commanders simply by saying that "*darker areas indicate areas of higher probability*". This approach provides a quickly understandable picture of the logic behind the applied search theory. It also provides a cognitive picture of how probability can be related to statistical (historical) data from Lost Person Behavior.

A different example of visualizing Search Region probability is shown via "thermal color coding" in Figure 8 for the same Muir Snowfield search. To create this representation, Region POAs were divided by region area to derive a Probability Density (Pden) for each Search Region. The range of quantitative Pdens were then grouped into priority categories with an assigned "thermal" color code. This approach allows the Incident Commander and other non-technical search staff to quickly view relative priorities assigned to Search Regions.

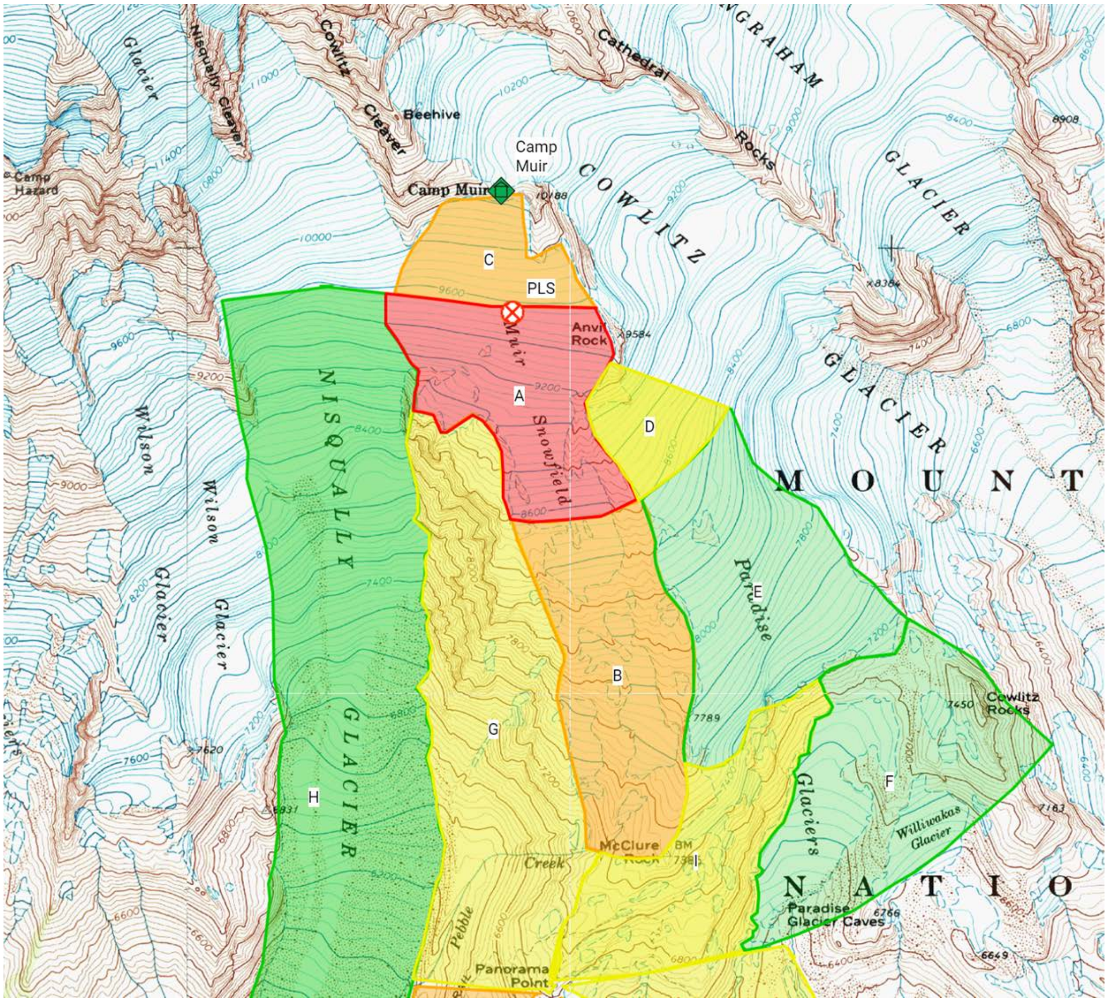

Figure 8: *Thermal Color-Coding of Search Region Priorities*

D. Characterizing Search Segments

Once Search Regions have been characterized, we employ a standard approach to defining and characterizing Search Segments, using terrain analysis and map-reading skills, and following the guidelines below (Hill, 1997; Stoffel, 2006):

- The size of a Search Segment should be such that a search team can reasonably cover their assigned segment in 4-6 hours. Teams should be able to complete their assignment, including travel to and from their assigned area, within one operational period. (Cooper, et al, 2003)

- Where possible, segment boundaries are defined using physical terrain features or manmade features, that are easy for teams to identify both on a map and in the field. Where terrain features are not available, contour lines are sometimes used as segment boundaries. We also use UTM grid boundaries, which are easy to identify on properly marked maps and easy to locate using handheld GPS devices. (In the field, we highly recommend downloading segment boundaries onto team GPS devices as a navigation aid).

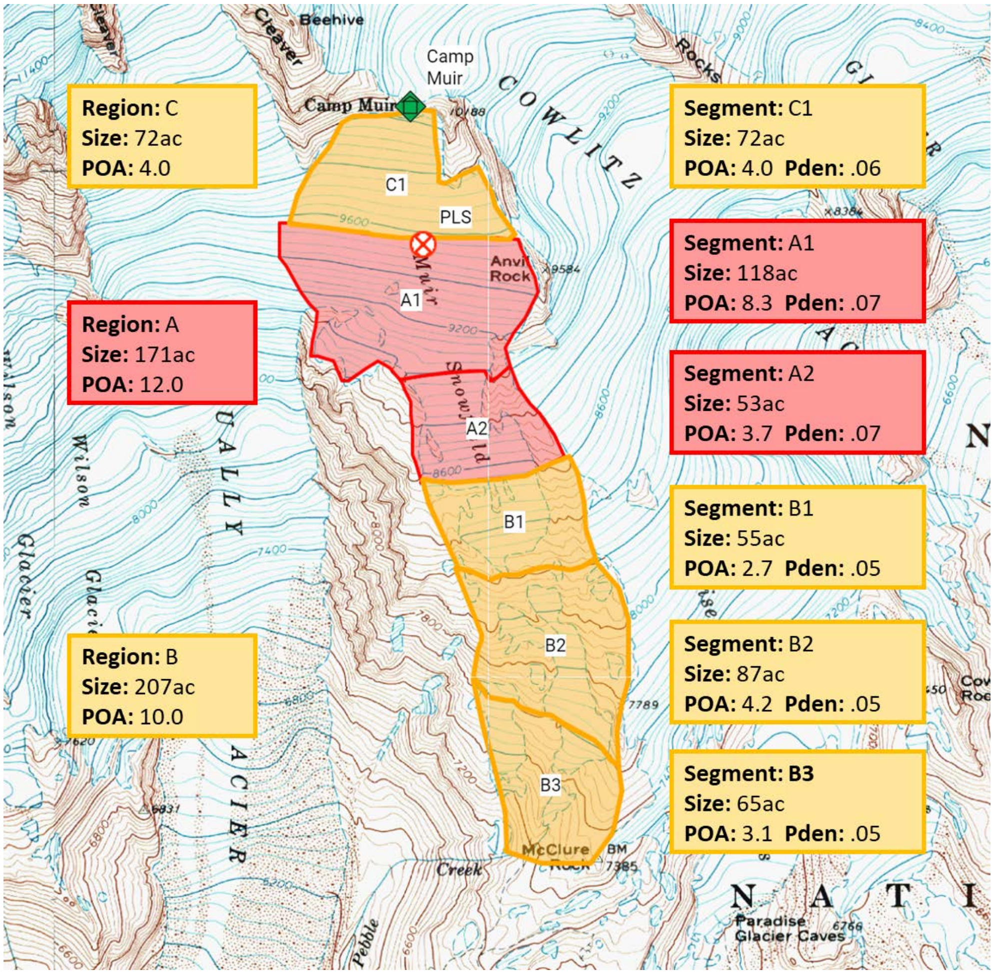

Figure 9: *Three Example Search Segments with Segment POA and Pden*

Figure 9 shows segmentation for three of the Search Regions defined for the Muir Snowfield Missing Snowshoer Search. In this example, Search Segments have been defined using both terrain features and elevation contour lines. After Search Segments have been defined and mapped, they inherit POA from their "parent" region, in proportion to their relative size within the region (Cooper and Frost, 2017). In other words, the POA of a segment is equal to the relative area of the segment (segment area divided by region area) times the POA of the region.

In Figure 9, Search Region sizes and POAs are shown in the left panels. Search Segment sizes, POA and Pden are shown in the right panels. From these, one can see that:

- The sum of segment POAs equals the POA of the parent region.
- Probability density (Pden) is distributed evenly among search segments in a given region.

II. Assessing Search Effectiveness

Our general approach to assessing the effectiveness and coverage of search teams is diagrammed in Figure 10, and is dependent upon the availability of data from earlier searching during the incident. When searchers are debriefed after their assignments, their reported data may be in either graphic form (drawn or recorded team tracks) or verbal form (descriptive information about their search behavior).

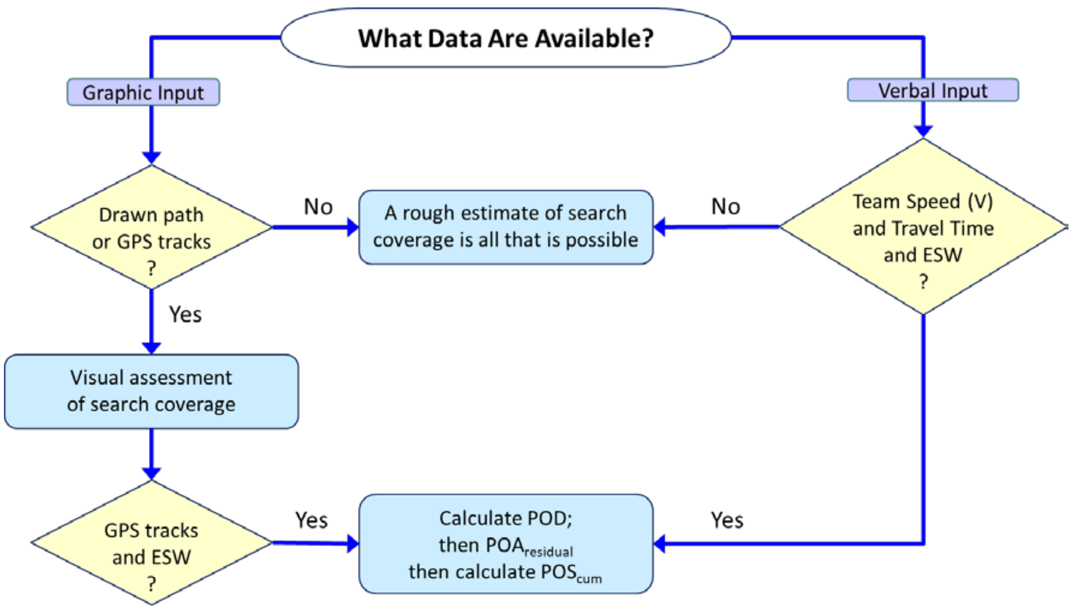

Figure 10: *Decision Guide for Assessing Search Effectiveness*

A. Assessing Search Effectiveness with Minimal Data

When the only search coverage information available is subjective, the choices are: (1) Ignore the information or (2) Use the information in a systematic way. We choose the latter. While it is widely agreed that subjective estimates of POD are considerably less than accurate (Frost, 2000), the following steps may be employed to reduce variability and error in those estimates: (a) Search teams should be debriefed in a structured manner with standardized questions about search conditions, searcher fatigue, distances traveled, areas covered, terrain, weather conditions, visibility, time of day, lighting, and foliage. (b) POD estimates should be based on a consensus of the entire team, rather than the estimate from a single person or the team lead. (Frost, 2000).

Even with the systematic steps described above, these subjective coverage estimates cannot be safely quantified as ratio or interval data. It may be acceptable to treat the results as ordinal data, for example by ranking coverage in search segments on a simple scale such as: High, Medium, Low.

This relative ranking can then be combined with other factors (e.g., new investigative information, found clues, etc.) to provide guidance about future search priorities.

B. Visual Assessment of Search Effectiveness

GPS tracking devices are gradually becoming standard equipment for search teams, and are now available in the form of handheld GPS units, GPS collars for K9s, and cellphone-based applications. With appropriate planning and technology, such tracks can become available in almost real time, to provide search effectiveness information during an operational period.

It is common in our experience that as we engage in a search, we find that GPS tracks from search teams are available (typically for many, but not all teams), but that no estimates of sweep width have been made. It is clear from the literature that it is not possible to calculate an objective POD without a measure of detectability (Frost, 2000). However, even without quantifying POD or coverage, the plotted tracks can provide important planning information. Figure 11 below shows GPS tracks captured via K9 collars (blue lines) and UAVs (yellow-dotted lines) during a search for a missing male in a rural environment, superimposed on an aerial map layer. During the search, this representation was used to understand which search segments had been searched by what search resources. Planners were also able to visualize a rough estimate of the portion of each segment traversed by a search asset.

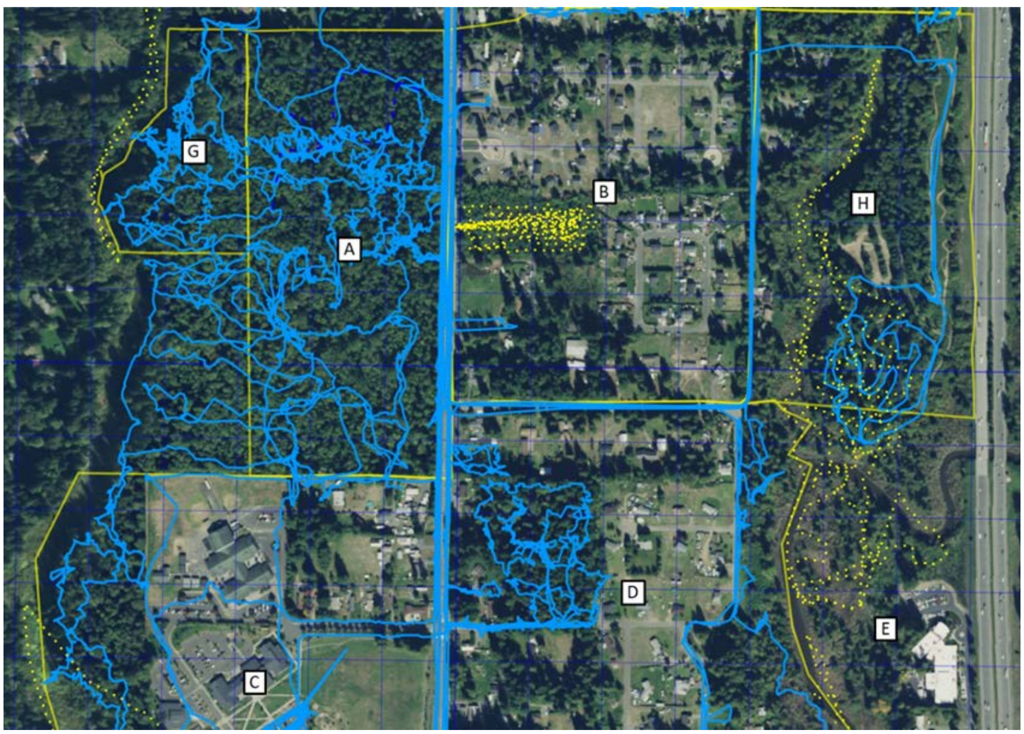

Figure 11: *K9 GPS Tracks (Blue) and UAV GPS Tracks (Yellow) from a Rural Search*

In Figure 11 for example, it can be seen that Segment A (about 40 acres or 0.16 km^2) has been generally well searched by airscent K9 teams. One exception that can be readily seen is the northern section of that segment. Segment A was immediately across the street from the PLS, and for that reason additional K9 resources could have been assigned to the northern section as a priority area. In the adjacent Segment B, it is apparent that there has been almost no K9 searching, and that one wooded lot has been extensively overflown by UAVs.

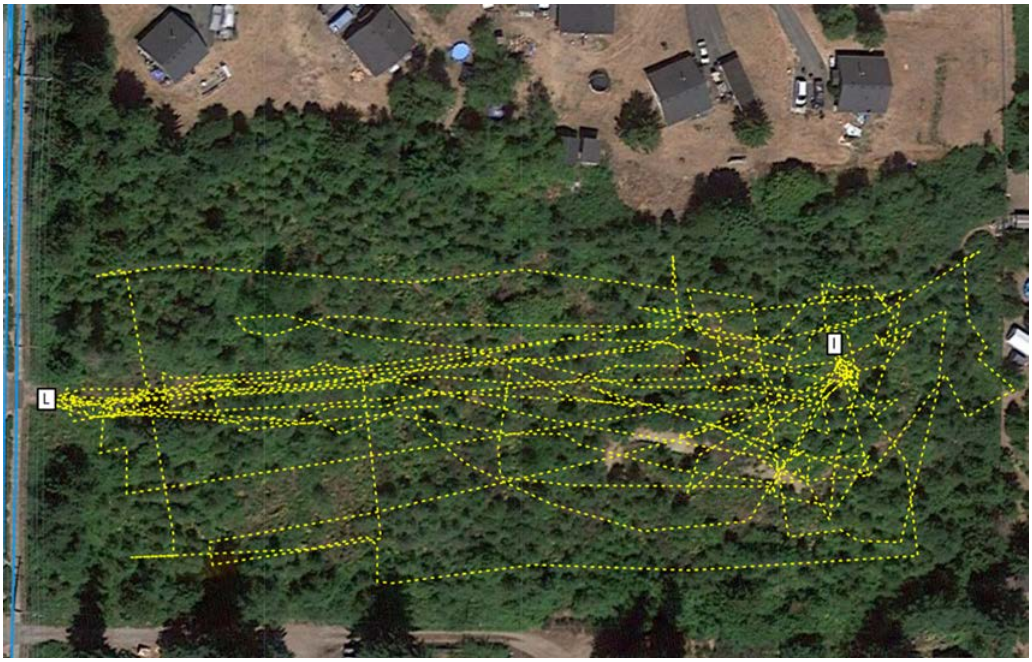

Figure 12: *Detail View of UAV GPS Tracks (Yellow) from a Rural Search*

Figure 12 shows a detail view of the small wooded area (5 ac, 0.02 km^2) in Segment B. In this figure, Point L indicates the UAV launch point and Point I was an object of interest. From this representation, planners could see that the UAVs flew a rough grid pattern, with relatively good "coverage" in central areas, but less "coverage" on the northern and southern edges. When team tracks are collected and plotted as the operational period progresses, teams assigned for future searching can be provided with these maps as an aid to understanding where they might want to focus their efforts.

The hypothetical table below illustrates how subjective, ordinal-scale assessment of coverage can be viewed systematically to help guide decisions about priorities for subsequent operational periods.

	Subjective Coverage Assessment			
Search Segment	**Ground**	**K9**	**UAV**	**Re-search Priority**
1	High	Medium	None	Medium
2	High	High	Medium	Low
3	Low	Medium	None	Medium

4	Low	None	Low	High

Table 2: *Hypothetical Example of Subjective Search Coverage Assessment*

While subjective, visual assessment of search coverage can serve as an important adjunct to relying solely on calculated POD (as described below). Using standard search theory math, POD increases as a factor of Track Line Length (TLL), independent of where the search team has traveled within a segment. As shown in Figure 13 below, the TLL, Estimated Sweep Width (ESW) and calculated POD for each segment is the same; however, a visual assessment reveals important additional information about the effectiveness of the search and considerations for re-search.

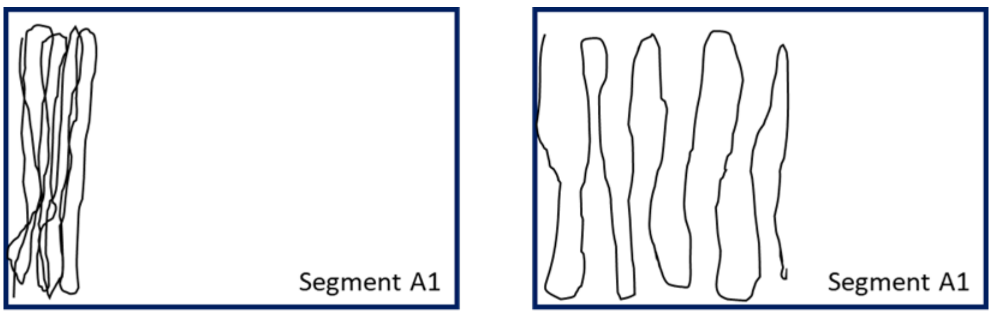

Figure 13: *Two Searches with Equal TLL, ESW, and Calculated POD*

C. Calculating Coverage When Estimated Sweep Width Is Available

In the lower left of Figure 10, we can see that if GPS tracks (which provide TLL) and Estimated Sweep Width are available, standard search theory math can be used to calculate POD, residual POA, and POS values for each search segment. We can also see from the right side of Figure 10 that if search teams can provide travel speed and travel time (used to derive TLL), as well as ESW, then POD calculations can also be done. Based on this, our recommended best practice for search teams is to perform an Average Range of Detection (AROD) exercise prior to initiating their assignment, and to record GPS tracks while performing their search. When this is done, planners have the advantage of being able to both visually assess search patterns and to calculate POD.

III. Prioritizing Search Assignments

Once Search Segments have been defined and characterized (i.e., with POA and Pden), search theory methods should be used to guide applying resources to assignments (Cooper, 2015). This can be done for the first operational period (where sweep width and team speed would be estimated prior to assignment), or for subsequent operational periods (where sweep width would be estimated and team speed and travel may be available via GPS tracks). In either case, the preferred methodology would be to prioritize search assignments based on calculated Probable Success Rate (PSR).

Figure 14 shows a decision guide for using available data to prioritize Search Segments. Where all necessary data (POA, Area, ESW, Team Speed) are available, we calculate PSR and use that to guide prioritization of search assignments. Where only POA and Segment Area are available, Pden can be used to guide assignment priorities; however, consideration should be given to estimating ESW and Team Speed, thereby allowing use of PSR calculations.

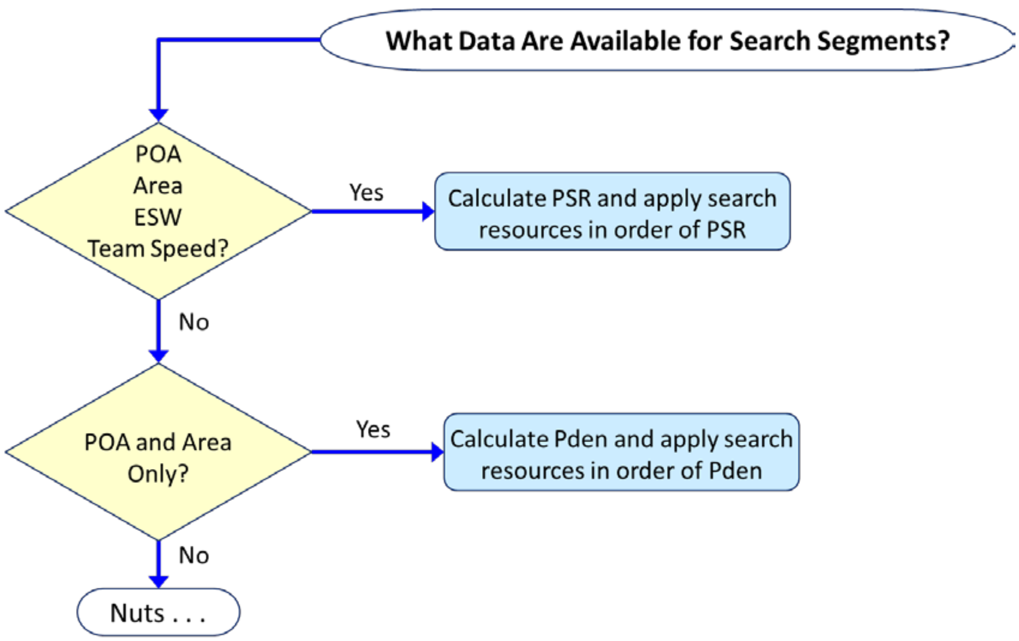

Figure 14: *Decision Guide for Using Available Data to Prioritize Search Segments*

It is important to note that a more holistic approach to prioritizing search assignments would be to systematically consider three factors:

- Probable Success Rate – calculated prior to each operational period.
- Visual assessment of search team tracks in each search segment.
- Quantity and nature of any clues found in each search segment.

IV. Special Considerations

A. Characterizing Search Regions with Multiple Scenarios

In our experience, search planning typically begins with identifying multiple possible scenarios for what has happened to our lost subject. When multiple scenarios are in play, Frost and Cooper, (2014) recommend that consensus-based POAs for each Search Region should first be derived independently, then subsequently combined (using a weighted average) to yield a "composite" subjective POA for each region. This approach imposes additional calculation overhead; however, it should be noted that the National SAR School makes a spreadsheet available for supporting these calculations. In the spirit of full disclosure, we currently do not use these multiple, independent POA estimates. We rely on the knowledge and experience of the individual contributors to subjectively weigh the relative contributions of each scenario.

B. Relocating the IPP, LKP, or PLS Based on New Information

A recent search in the Cascade Mountains of Washington State began with the discovery of the subject's car parked at the trailhead. This location was used as the IPP and LKP. As in many searches, more information became available as the search proceeded – in this case, multiple, reliable sightings of the subject were reported by hikers on the same trail. For the purpose of characterizing Search Regions and Segments as described in Section I above, should the analysis of scenarios, range rings, dispersion angles, subjective and objective POAs be re-positioned and focused around the new (revised) LKP? We believe that based on logic and on discussions at the 2018 Syrotuck Symposium, that the answer is "yes". Koester has suggested (based on limited data) that a repositioned LKP might allow planners to reduce LPB "Distance from IPP" values by as much as 20% (Koester, 2018).

C. Practical Issues Related to Obtaining Estimated Sweep Width

In the ideal search world, AROD estimates are performed by search teams after they have entered their assigned search segment and before they start their search assignment. In a more typical, but less ideal search world, teams do not perform AROD estimates prior to their search. One way to address this would be to send out personnel either during or after the search to perform AROD estimates in representative areas.

When a search is being planned in advance, search personnel can be sent out to get AROD estimates in the search area prior to the operational period. A potentially very useful variant of this approach is to pre-establish AROD estimates for representative search areas within a local jurisdiction. This would yield a table like the example below with pre-assessed AROD values for different types of terrain. This approach is currently being incorporated into the FIND Software Project (Koester, 2018).

Terrain Category	Target Type	Day or Night	AROD (meters)
Second growth forest – light undergrowth	Human Size	Day	5
Second growth forest – light undergrowth	Human Size	Night	3
Second growth forest – moderate undergrowth	Human Size	Day	3
Second growth forest – moderate undergrowth	Human Size	Night	1
Second growth forest – heavy undergrowth	Human Size	Day	1
Second growth forest – heavy undergrowth	Human Size	Night	.5
Second growth forest – light undergrowth	Small Object	Day	2
Second growth forest – light undergrowth	Small Object	Night	.5

Second growth forest – moderate undergrowth	Small Object	Day	.5
Second growth forest – moderate undergrowth	Small Object	Night	.2
Second growth forest – heavy undergrowth	Small Object	Day	.2
Second growth forest – heavy undergrowth	Small Object	Night	.1

Table 3: *Hypothetical Pre-Assessed AROD Values for a Variety of Terrain Categories*

Without going into details, it does need to be pointed out that obtaining useable ESWs for K9 search resources and UAV resources remains largely unaddressed. For UAV resources, it should be theoretically feasible to set up the equivalent of an AROD estimate process, or to pre-estimate ESWs for terrain categories as described above.

On a final, practical note, it seems that one feasible approach would be to estimate AROD (for whatever search resource is applicable), based on a "reasonable guess". The weakness of this approach is that it does not support a calculation of absolute coverage. However, if used consistently across search segment calculations, an estimated ESW will still yield a usable relative coverage value for assessing search effectiveness among search segments in similar terrain.

Discussion

Our goal in documenting a pragmatic approach to applied search theory is to provide the foundation for a step-by-step guide for the Washington State SAR Planning Unit for what components of modern land search theory can be used for planning search incidents in jurisdictions that may vary widely in terrain, data availability, and training. This planning decision guide, along with associated templates, spreadsheets, and computer software, will form the basis of a standardized search planning approach which can be taught to members of SSPU and implemented by them for future incidents.

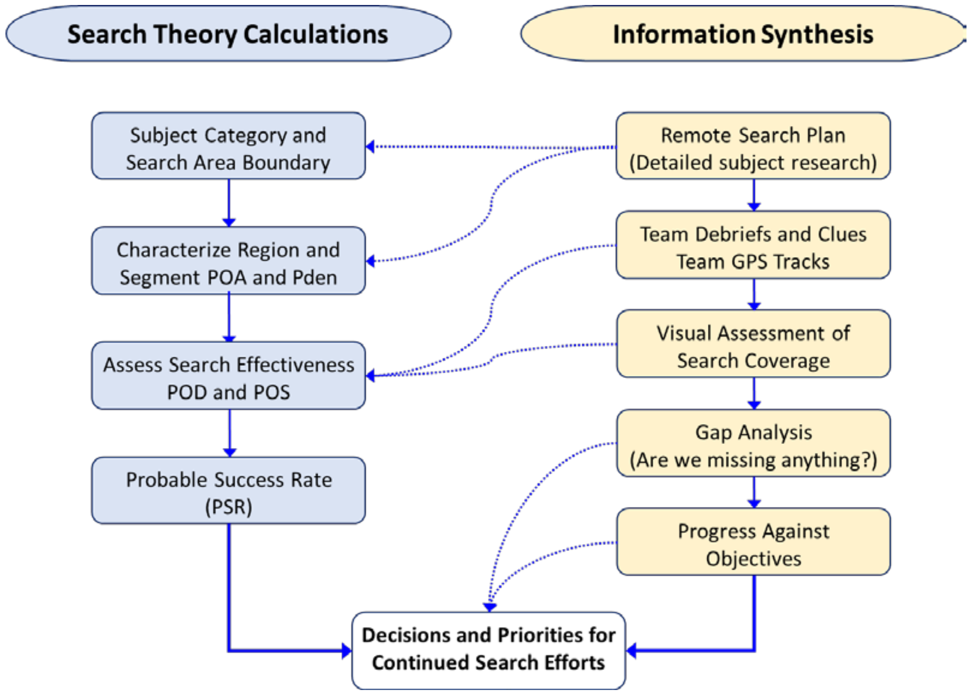

Figure 15: *An Overview of Integrated Search Planning*

Figure 15 above, provides an overview of how components of formal search theory can be combined with information synthesis, research, and situational analysis (Burke, 2019; Wright and Smith, 2019; Young, 2019) to provide a more comprehensive basis for the decisions and priorities used to guide continued search efforts. When data are available, the SSPU will use search theory best practices, concepts, and calculations to provide objective, probability-based input to search planning. These will be augmented in parallel with detailed research (i.e., Remote Search Plans), and systematic collection and analysis of other available information.

Conclusion

Our pragmatic approach to applied search theory, as described above, is in the early stages of being implemented as standard search planning methodology employed by the Washington State SAR Planning Unit. We will be using this approach, supported by the decision guides and associated tools, as a basis for training our members and supporting search incidents. We anticipate gaining practical experience with these methods as they are applied in the real world of land searches, and plan to provide a future report detailing which approaches work well and which would benefit from improvement.

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We would like to acknowledge the invaluable input and feedback provided to us by Dr Donald Cooper and Dr Robert Koester during preparation of our methodology and of this manuscript. In addition, we would like to thank all organizers and participants of the 2018 Syrotuck Symposium, held in Reykjavik, Iceland – your encouragement and support is greatly appreciated. We are indebted to our SAR County Coordinators, Sergeant Danny Wikstrom (Snohomish County Sheriff's Department), and Detective Ed Christian (King County Sheriff's Department), for their years of guidance while we gained experience as Incident Command staff. Lastly, a special thanks to Chris Long of Washington State Emergency Management Division and to Jon Wartes of King County Search and Rescue for their foresight and encouragement. Maps in this paper were created using SARTopo, www.sartopo.com.

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Abbreviations

AROD	Average Range of Detection
ESW	Estimated Sweep Width
GIS	Geographic Information System
GPS	Global Positioning System (can also refer to a handheld GPS device)
IPP	Initial Planning Point
ISRID	International Search and Rescue Incident Database
LKP	Last Known Point
LPB	Lost Person Behavior (Koester, 2008)
Pden	Probability Density
PLS	Point Last Seen
POA	Probability of Area
POD	Probability of Detection
POS	Probability of Success
PSR	Probable Success Rate
ROW	"Rest of the World" (area outside the formal search area boundary)
SSPU	Washington State SAR Planning Unit
TLL	Track Line Length
UAV	Unmanned Aerial Vehicle (a.k.a. "search drone")
UTM	Universal Transverse Mercator

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The U.S. National Search and Rescue School - Inland

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Abstract

The Inland Search and Rescue (SAR) Planning Course is a 5-day course for experienced SAR decision makers and planners taught free of charge across the United States. It presents a broad understanding of inland search theory and its application for air and ground searches for missing persons and aircraft with a focus on wilderness and rural area searches. The course consists of classroom instruction and practical, tabletop exercises. Emphasis is on the planning necessary for effective area-type search planning during an extended search using Probability of Success (POS), rather than just a few elements of Probability of Containment (POC)/Probability of Area (POA), or Probability of Detection (POD), to predictively allocate limited resources to their best effect. An additional objective of the course is to strengthen the U.S. Federal Government's role in its support to civil SAR through education, including promoting the capabilities of the Rescue Coordination Centers (RCCs), and requesting and coordinating the use of other federal resources with the goal of saving lives.

Keywords: Inland SAR School

Introduction

The National SAR School first opened its doors in November 1966 at Governor's Island, New York as the premier maritime and land search and rescue school. For the past 50 years, the SAR School has been providing unparalleled search and rescue training to US Coast Guard, Department of Defense and other government and civilian organizations, as well as international members from over 148 nations. Since its inception, the school's mission has been: "To promote standardization and professionalism within the search and rescue community by providing comprehensive SAR training to selected Coast Guard, Air Force and other personnel."

In 1956, with the publishing of the first National Search and Rescue Plan, the US Coast Guard was designated the federal Search and Rescue (SAR) Coordinator responsible for search and rescue in the maritime regions. Likewise, the US Air Force was designated the federal SAR Coordinator responsible for search and rescue in the aeronautical (inland) regions. Since the inception of the Plan, both services have worked closely together developing procedures and techniques which have increased the efficiency of SAR operations.

Since 1966 the Coast Guard and Air Force have jointly operated the National SAR School, redefining programs as the needs of the services and SAR, in general, have evolved. Each service provides the expertise from its area of responsibility and shares in the instruction across lines of responsibility. However, there are differences between SAR in the Maritime and Inland search environments that go well beyond the obvious characteristics of the physical domains. The USCG has the lead as the designated SAR Coordinator in nearly every SAR situation in the maritime environment, including navigable waterways, and may standardize tactics, techniques, and procedures as they deem appropriate. Similarly, the movements of search objects (vessels, person in water (PIW), etc.) can, and have, been effectively modeled through computer simulations for any number of given conditions (sea states, currents, winds, survivability, visibility, etc.). For some time now, this has allowed maritime search planning to be modeled very quickly by planners entering variables into a computer program, which the USCG calls SAROPS.

Discussion

Until recent developments, nothing comparable to SAROPS has been available to inland search planners due to the complexities of modeling lost person behavior, inland topography and vegetation, and the lack of a single, unified inland SAR responsibility at a national level comparable to that of the US Coast Guard's authority within maritime SAR. Thanks to a project by the Joint Personnel Recovery Agency, and another enabled by a Small Business Innovation Research (SBIR) grant from the Department of Homeland Security's Science and Technology Department, programs have been developed to begin using the advantages of computer modeling to more effectively search for missing people in the inland environment. However, even if these programs are a complete game-changer in saving lives, there is no obligation for the thousands of agencies responsible for search operations within the US to pay for access to this program, often with minuscule budgets for SAR. Additionally, there is no federal funding to sustain either of these programs for widespread national use. For the foreseeable future, a continued study of lost person behavior, and a free class offered by the Inland SAR School may be the only available option for search planners and incident commanders to apply the concepts of search theory to the inland environment.

In the inland environment, every U.S. state does SAR differently and independently, as is their right. Within most states, counties, cities, or tribal areas, authorities may conduct any number of search and/or rescue operations for missing persons or overdue aircraft quite differently than adjacent jurisdictions. Compounding the complexity of inland search operations for missing and overdue aircraft, is that search operations most often begin as a federal problem because of the multi-state nature inherent to many flight operations, and then depending on the situation, are handed off to local authorities.

The majority of inland SAR operations, those for individuals in distress, do not involve the federal government at any level unless the first notification comes through the federal government (often through beacons via satellite).

That is, however, unless the jurisdictional authority requests assistance from the Federal Government in the form of resources to include aircraft or other vehicles and sensors, forensics teams (Cellular, Weather, Radar, etc), or other coordination efforts through a Rescue Coordination Center.

The Air Force element of the National SAR School provides academic instruction on inland search planning and procedures to SAR professionals from all U.S. military branches, various U.S. government, state and local agencies, volunteer SAR organizations, as well as members of the international SAR community in order to make this process more efficient for all parties involved in the interest of saving lives.

The USAF provides two SAR Courses:

Inland SAR Planning Course (ISPC): The ISPC is a five (5) day resident and exportable course designed to teach advanced search theory and its application to land and air searches for missing persons and aircraft. The target audience is SAR leaders in federal, state, and local emergency services and law enforcement, as well as Civil Air Patrol, international, and volunteer SAR agencies -- those few people who are responsible for the planning and overall conduct of inland search missions.

Basic Inland SAR Course (BISC): The BISC is a two day (16 hour) exportable course designed to teach basic federal SAR architecture, resources and mission coordination with an introduction to search theory. This course directly leads the student into the ISPC. The course is designed as an entry level SAR management course for federal, state and local SAR responders.

Anyone involved with SAR, regardless of affiliation, may host or attend these classes on an availability basis. If you are interested, please find additional information on the Inland SAR School and our courses at: http://www.forcecom.uscg.mil/Our-Organization/FORCECOM-UNITS/TraCen-Yorktown/Training/Maritime-Search-Rescue/Inland-SAR/

Abbreviations

BISC	Basic Inland SAR Course
ISPC	Inland SAR Planning Course
POC	Probability of Containment
POD	Probability of Detection
POS	Probability of Success
RCC	Rescue Coordination Center
SBIR	Small Business Innovation Research
USAF	United States Air Force

The SAR Planning 'P' Process

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Abstract

The Planning P is a familiar framework to Emergency Management for transitioning from the Initial Response for a more a formalized, structured response. In this presentation a SAR-specific P framework is proposed that retains the simplicity of the OODA Loop and Six Step Response Process in the Initial Response Period, with a critical decision point to continue as is, or activate the Incident Management Team in a more Formalized response for Second Operational Period and beyond. Each step and the associated Goals, Objectives, Strategies and Tactics will be explored through to the Subject being located, or Search Suspended.

Keywords: Planning P, OODA Loop, Six Step Process, Search Management

Introduction

THE IMPORTANCE OF SEARCH AND RESCUE (SAR) PLANNING.

In typical SAR Missions, the initial response or attack often evolves with limited initial resources targeted through short term decision tools such as the OODA Loop and situational awareness/incident management tools such as the Six Step (SCORPA) Tool. As a search evolves through operational periods there is need to transition from informal to formal planning structures that assure the key steps are addressed, and that documentation is done to ease the transitions between operational periods. Planning models such as the Planning P are a common tool in emergency management literature. In this paper the authors present a SAR Planning P model that is reflective of the specific needs of SAR.

Search is an emergency. While the incident response should be focused on doing everything possible to save life, it cannot ensure the subject(s) will be found: the incident response may not have the capability to detect the subject(s) even if in the search and rescue area, the subject(s) may be somewhere else, or something other than becoming lost/stranded/injured may have occurred. The initial response develops based on the initial objectives.

The tempo and intensity of the response is that which is appropriate to achieve these objectives. There may be periods (or there will come a time) when there are no established objectives related to actual searching. During these periods (or at that time) resources should be assigned against other planned objectives developed through a formal planning process.

All search and rescue operations follow similar patterns presented in Table 1 and there are many well-articulated Initial Response Models that address the urgency and initial tactical response. The initial response and first operational periods are targeted at high probability (and often high risk areas for the subject). As a search moves into the second operation period, there is need to transition to a more formalized strategic planning process, that takes into account the initial flow of information from initial attach resources.

TABLE 1. Common SAR Event patterns

PHASE	TARGET
INITIAL RESPONSE: This phase of the response to a search and rescue mission can be the most difficult. In general, it is:	• Aimed at high probability areas. • Approached with speed as a priority. • The first few hours of the mission, this can last from a couple of hours to 24 hours.
FIRST OPERATIONAL PERIOD: This phase of the mission includes the initial response phase and is generally:	• Aimed at high probability areas that have been determined by the initial response. • Approached with speed and efficiency as priorities. • Considered the first day's search and rescue effort. It usually ends at either 18:00 hrs. (6 p.m.) or 06:00 hrs. (6 a.m.) depending on when the initial SAR response took place. Generally, from 4 to 24 hours.
SECOND OPERATIONAL PERIOD: This phase is normally after the initial response and will start the formal advance **planning process using the Planning P**. From this point on the operational periods usually last 12 hours in duration, until the end of the search and rescue mission. Generally it is:	• Aimed at NEW high probability areas and secondary search areas that have been previously covered. • Approached with efficiency and thoroughness as priorities. • Terminated at either 18:00 hrs. (6 p.m.) or 06:00 hrs. (6 a.m.) depending on when the initial response was started and then continues for 12 hours.

SUBSEQUENT OPERATIONAL PERIODS: This phase of the search mission will probably follow the planning process started during the first full operational period regardless of when it was started. This phase is generally:	• Aimed at high and low probability areas simultaneously • Approached with efficiency and thoroughness. • Involves 12 hour periods of time throughout the rest of the search and rescue mission. • Review, and if necessary, revise the search and rescue objectives, resource needs, subject profile, urgency, etc. • Involves more formal advanced planning.

Planning, both pre-incident and search and rescue action planning, reduces the time needed to conclude the emergency by speeding up the transition from reaction to responsive and proactive management. Planning keeps search and rescue operations responsive to emerging information and data.

Planning is the glue that binds SAR resources together, producing a coordinated, effective emergency response transforming the search and rescue objectives into realistic strategies and tactics (actions) to resolve or control the SAR mission. The use of planning structures ensures effective, efficient use of available and potential SAR resources applied to the problem, reducing redundancy and confusion, evaluating success, and focusing efforts directly on solutions for the event at hand.

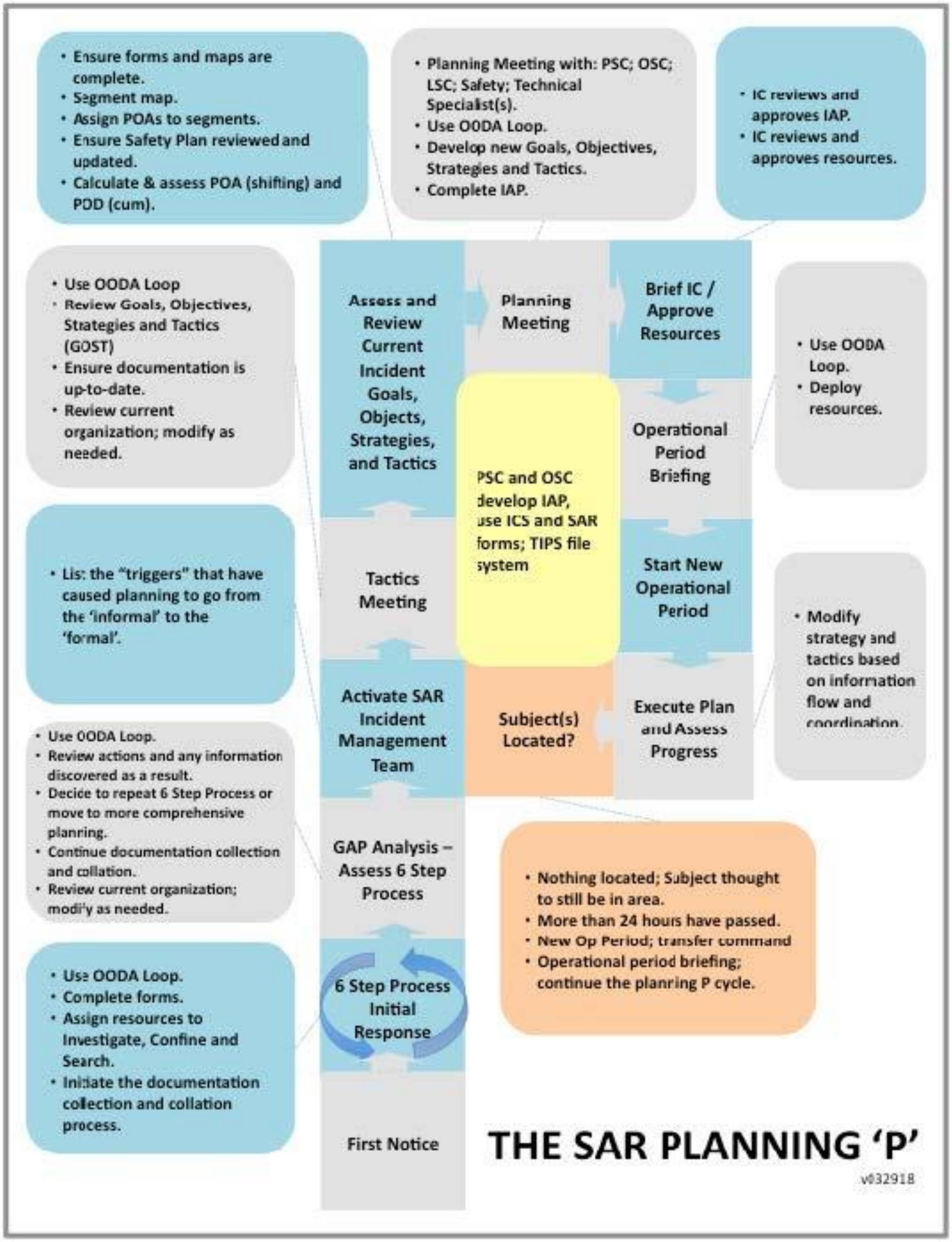
Planning is a key component of operational success. Planning should include a conscious, continuous cyclic process (**The Planning P**) with the flexibility to modify and adjust plans based on information flow and coordination. Situational awareness is generated through the use of the Six Step Process, which then allows for the modification and adjustment of strategy and tactics as the mission unfolds. The Incident Commander and all members of the Overhead Team should continuously use the OODA loop throughout each step of the Planning Cycle and the Planning 'P' for decision making. This will continue to reinforce the decision-making process each step of the planning cycle, and maintain situational awareness for the IC and other members of the planning team. Even though you are using the planning process and the incident response process you must continuously make decisions each step of the way by synthesizing information, correlating and turning it into useful intelligence so you can not only maintain situational awareness but be able to make decisions.

Decision makers are encouraged to utilize the planning P as a guide to fully develop and implement the Incident Action Plan (IAP) including the definition of the incident and impacts, establishment of objectives and processes to address those impacts, dissemination and implementation of the plan, and evaluation and revision of the plan based on the outcomes. The Advance Planning Unit should be activated to prepare for multiple operational periods, with the requirement for producing multiple IAP's.

GAP ANALYSIS - ASSESSING THE INITIAL RESPONSE

Since the inception of search management concepts in the 1970's, curricula have struggled to define an effective process for determining when to significantly de-escalate an incident after sustained efforts fail to locate the subject(s). Over the years, suggestions have included 'Suspending the Mission', 'Limited Continuous Search', and the use of probability estimations such as Probability of Success, Shifting Probability of Area, and Cumulative Probability of Detection all of which have left opportunity for improvement. The terms 'suspending the mission' and 'limited continuous search' have been interpreted by families to infer that the agency having jurisdiction and/or incident personnel are giving up or have lost interest, and are now abandoning their loved one. As for probabilities, the father of one missing woman expressed family perspective very well when he stated before a television camera 'They're figuring their job from the odds, I'm figuring my job from saving my daughter's life'. The gap analysis process described here avoids these perceptions. It is objective ('What else can be done?') rather than opinion ('It's time to suspend') based, and through its methodology cultivates consensus.

A gap analysis is useful for determining and achieving agreement among critical allies and stakeholders for future actions when efforts have failed to locate the missing subject(s). While a gap analysis exercise may result in consensus when to significantly de-escalate, its purpose isn't to convince others the time has come to de-escalate. Because it is an objective process, it facilitates the identification of what has been missed or still needs to be done. One possible result can be identifying additional objectives justifying continued sustained efforts to the degree that the incident's tempo remains the same or even increases. Under such circumstances multiple gap analyses may be necessary over the incident's evolution before a consensus to de-escalate is reached.



• Ensure forms and maps are complete.
• Segment map.
• Assign POAs to segments.
• Ensure Safety Plan reviewed and updated.
• Calculate & assess POA (shifting) and POD (cum).
• Planning Meeting with: PSC; OSC; LSC; Safety; Technical Specialist(s).
• Use OODA Loop.
• Develop new Goals, Objectives, Strategies and Tactics.
• Complete IAP.
• IC reviews and approves IAP.
• IC reviews and approves resources.
• Use OODA Loop
• Review Goals, Objectives, Strategies and Tactics (GOST)
• Ensure documentation is up-to-date.
• Review current organization; modify as needed.
Assess and Review Current Incident Goals, Objects, Strategies, and Tactics
Planning Meeting
Brief IC / Approve Resources
• Use OODA Loop.
• Deploy resources.
Operational Period Briefing
PSC and OSC develop IAP, use ICS and SAR forms; TIPS file system
• List the "triggers" that have caused planning to go from the 'informal' to the 'formal'.
Tactics Meeting
Start New Operational Period
• Modify strategy and tactics based on information flow and coordination.
Activate SAR Incident Management Team
Subject(s) Located?
Execute Plan and Assess Progress
• Use OODA Loop.
• Review actions and any information discovered as a result.
• Decide to repeat 6 Step Process or move to more comprehensive planning.
• Continue documentation collection and collation.
• Review current organization; modify as needed.
GAP Analysis – Assess 6 Step Process
• Nothing located; Subject thought to still be in area.
• More than 24 hours have passed.
• New Op Period; transfer command
• Operational period briefing; continue the planning P cycle.
• Use OODA Loop.
• Complete forms.
• Assign resources to Investigate, Confine and Search.
• Initiate the documentation collection and collation process.
6 Step Process Initial Response
First Notice
THE SAR PLANNING 'P'
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TABLE 2. The Primary Components of the SAR Planning P

SAR Planning 'P' Process *From the Informal to the Formal*		
Planning Step	**Actions**	**Forms/Job Aids**
Six Step Process (Initial Response) (SEE APPENDIX 1 – Decision Making)	• Use OODA Loop • Develop Objectives • Complete forms. • Assign resources to Investigate, Confine, and Search. • Initiate the documentation collection and collation process. • Ensure Safety Plan developed.	• Initial Response Forms 1-8. • **ICS 201**, 203, 204, 205, 206, 207, 208, 211 + Risk Assessment Worksheet (215A). • Maps. • Weather statement/bulletin. • Safety Plan (ICS 208). • Filing system for documents (folders, accordion files etc.).
GAP Analysis - Assess 6 Step Process	• Use OODA Loop. • Review actions and any information discovered as a result. • Decide to repeat 6 Step Process or move to more comprehensive planning. • Continue documentation collection, and collation. – Review current organization; modify as needed.	• Completed forms, maps, and investigative information. • Forms for new 6 Step cycle.
Decide to repeat 6 Step Cycle or move to formalized comprehensive planning. **If formal planning is initiated for multi-operational periods, then proceed to next steps in the SAR Planning P**		
Activate SAR Incident Management Team	• List the 'triggers' that have caused planning to go from the 'informal' to the 'formal'. • Identify formal (unified) Command Structure	• Completed Forms – Incident Action Plan (IAP). • Maps. • Completed ICS 209 (Incident Status Summary).
Tactics Meeting	• Use OODA Loop.	

SAR Planning 'P' Process *From the Informal to the Formal*		
Planning Step	**Actions**	**Forms/Job Aids**
	• Review Goals, Objectives, Strategies, and Tactics (GOST). • Ensure documentation is up-to-date. • Review current organization; modify as needed.	
Assessment Meetings **Assess and Review Current Incident Goals, Objectives, Strategy, and Tactics (GOST)**	• Ensure forms and maps are complete. • Segment map. • Assign POAs to segments. • Ensure Safety Plan reviewed and updated. • Calculate and assess POA (shifting) and POD (cum).	• Maps. • Forms. • Modified Mattson Consensus forms. • Resource Management – sufficient, capable, and effective. • Safety Plan (ICS 208).
Planning Meeting with: PSC; OSC; LSC; Safety; Technical Specialist(s)	• Use OODA Loop. • Develop new Goals, Objectives, Strategies, and Tactics. • Complete IAP.	• SAR Management forms. • ICS forms. • Maps. • Other supporting documentation.
Brief IC on IAP, and Approve Resources	• IC reviews, and approves IAP. • IC reviews, and approves resources.	• IAP. • Supporting documentation.
Operations Briefing	• Review Goals, Objectives, Strategies, and Tactics (GOST).	• IAP. • Supporting documentation
Start New Operational Period		

Execute Plan and Assess Progress	• Use OODA Loop. • Deploy resources. • Modify strategy, and tactics based on information flow, and coordination.	• IAP. • Team assignments. • Manage information, documentation, debriefing reports.
SAR Planning 'P' Process *From the Informal to the Formal*		
Planning Step	**Actions**	**Forms/Job Aids**
Begin a New Planning Cycle?	• Nothing located; Subject thought to still be in area. • More than 24 hours have passed. • New Op Period; transfer command. • Operational period briefing; continue the planning P cycle.	• All information, and documentation reviewed, and 'on the table'.

A gap analysis can be especially useful when elements of critical allies or stakeholders propose the time has come to significantly decrease active search efforts, but where such a decision might be opposed by other elements. Under these circumstances such a decision can cause significant strife and anger between opposing camps if made unilaterally by the incident commander or agency having jurisdiction. The gap analysis process minimizes such conflict by building consensus and ownership in the decision.

The gap analysis process is a broadly used business development and problem solving technique. The method described below has been adapted for search and incorporates techniques successfully used in incidents - especially when it was necessary to achieve the consensus of stakeholders and critical allies.

A key point is that all identified objectives are to be completed. (Remember, objectives are flexible. If the original objectives are unrealistic, modify, adjust, and revise them so they can be achieved. But do not leave objectives uncompleted).

The Gap analysis explores the past, present and future, using the same logical decision making process as SCORPA (See Appendix 1) structured in a formal meeting setting. As used in the search and rescue incident context it explores two questions: 'What has been accomplished?', and 'What else can we do to ensure we've done everything possible to save the subject(s) life?'.

The Gap Analysis Process

Prepare for a Gap Analysis Meeting

- ❑ Determine the key stakeholders and critical allies to be represented.
- ❑ Select a time and location that will maximize attendance of the invitees.
- ❑ Invite the key stakeholders and critical allies, and ensure they understand the purpose and desired product, which is to identify of all reasonable tasks remaining to be completed.
- ❑ Select a facilitator. The default ICS function for this designation is the Plans Section Chief. However, if a level of conflict exists among the stakeholders and critical allies to the degree it could hamper the process; a neutral person may be preferred.
- ❑ Select the persons to make presentations, and ensure each understands what he/she is expected to speak to.
- ❑ Control the presentation of investigative intelligence, and of information that might be *embarrassing* to the subject(s) and family (a family member could be suspect in a criminal investigation). Such information should only be presented as necessary, and in a sensitive manner.
- ❑ Limit attendance to invitees only. Media attendance is normally not appropriate as candid and confidential opinions will be encouraged.

Part I of the Gap Analysis Meeting: What has been accomplished?

- ❑ Following a prepared agenda, a series of speakers with subject matter expertise brief the attendees on all relevant information uncovered since First Notice. This may include subject(s) profile information, possible scenarios that could have caused the subject(s) to become missing, subject(s) known and possible actions, the process by which the search and rescue area boundaries were defined, containment actions, investigative results, search efforts and outcomes including quantitative analysis (cumulative PODs, shifting POAs, etc.), clues found and how resolved, search and rescue resource capabilities, terrain and vegetation, safety concerns, hazards, weather, and psychic reports.

Part II of the Gap Analysis Meeting: What else can we do to ensure we've done everything possible to save the subject(s) life?

- ❑ Establish ground rules:
  - Brainstorming is encouraged.
  - Everyone is expected to listen to ideas with an open mind.
  - Negative criticism and argumentative challenges are inappropriate.
  - Confidentiality is expected. What is said at the meeting stays at the meeting.
- ❑ Facilitate brainstorming. Attendee ideas are listed on a whiteboard or laptop without critical analysis.

Part III of the Gap Analysis Meeting: Develop an action list from the ideas generated through the brainstorming.

- ❑ Review and encourage discussion regarding the items identified in the brainstorming

session. ❑ Establish consensus as to which will be acted upon. ❑ Assure the attendees the selected ideas will be prioritized and completed. ❑ Adjourn the meeting.
Implement the consensus items developed in the Gap Analysis Meeting.
❑ The Planning Section function incorporates the list of consensus items into the SAR Incident Action Plan(s). Objectives are established, resource needs identified, and assignments developed. ❑ As SAR resources become excessive to the need, they are released. For example, once no more flights are needed all remaining aircraft are released. ❑ Discovered clues or other information are investigated and resolved. Additional SAR resources are mobilized if appropriate. ❑ Once the objectives identified by the gap analysis (and any other objectives developed as the result of additional intelligence) near completion, arrange a subsequent gap analysis meeting, or implement a SAR demobilization plan to the significantly decrease active search and rescue efforts. ❑ At some point all identified items will be completed and there will no longer be any search and rescue resources in the field. In effect, active search and rescue efforts will stop. But that doesn't mean that the search and rescue mission is permanently ended. The agency is not 'giving up'. Any information or clues that may be uncovered in the future will be aggressively resolved.

THE SEARCH AND RESCUE INCIDENT ACTION PLAN (IAP).

Every SAR mission must have a written SAR plan as it will aid law enforcement agencies (AHJ) in their missing person investigations. The SAR plan may be shared when:

- Several agencies are involved.
- More than one jurisdiction is involved.
- More than one operational period is involved and it is unified command.

The SAR IAP defined: A plan for successfully resolving the search and rescue incident:

- Must be dynamic (flexible).
- Must be updated for each operational period.
- Must be only one plan for the operational period.

The role of the SAR IAP in Operations is extremely important to the overall SAR management effort. It should provide the operations function with the following:

a. Defined operational periods.
b. Written search and rescue objectives reflecting the policy and needs of all jurisdictions.
c Divisional and area assignment lists (tactical assignments).

d. Organizational chart, based on the Incident Command System.
e. Search and Rescue maps delineating assignment areas.
f. Communications plan.
g. Resource status and availability.
h. Mission situation/status reports.
i. Weather information.
j. Situation predictions.
k. Medical plan.
l. Transportation plan.
m. Subject profile for lost/missing person.
n. Safety considerations for weather, hazards, etc.

> **"A SAR IAP is where the snowshoe meets the snow, and the planning effort gets its report card."**
>
> **- Snowshoe Thompson, 1856**

OVERVIEW OF A SAR INCIDENT ACTION PLAN (IAP) DEVELOPMENT.

a. Developed by the Plans Section in consultation with the general staff.
b. Initially prepared at first planning meeting.
c. The Incident Commander (SAR Manager) establishes information requirements and reporting schedules for all organizational elements.

d. The Incident Commander (SAR Manager) presents general control objectives and alternatives which define legal, policy, resource, and fiscal constraints for the SAR mission in accordance with the preplans and policies of the involved jurisdictions.

e. Operations and objectives are discussed with general staff relative to:

- Resource status and availability.
- Situation status including hazards, risks, work accomplishment.
- Situation predictions. What is the best guess (SWAG) at what is likely to happen?
- Communications capabilities.
- Weather.

f. Plans Section then takes this information and develops the SAR IAP:

- Coordinates strategies and tactics with the Operations Chief.
- Coordinates resource support and service needs with the Logistics Chief.
- Develops the SAR IAP in written form with alternatives.
- Presents plan to the Search and Rescue Manager/IC for approval.

g. Plans Section conducts briefing of general staff.

h. Plans Section makes necessary adjustments to the plan and duplicates and prepares for distribution at field SAR team leader briefing.

> **"The key to making a plan work is the ability to vividly paint clear mental images of the plan and tasks to be done in the minds of the people who need to know and who will have to respond and act."**
>
> ***- Snowshoe Thompson, 1856***

CONSIDERATIONS INVOLVED IN SAR PLANNING.

Avoiding Alligators - As the prophet said: "When you are up to your armpits in alligators, it is difficult to remind yourself that your initial objective was to drain the swamp." Good planning is alligator control. Proper management of information can avoid irritations and distractions, and allow all aspects of the search to focus on draining the swamp.

In some jurisdictions, the Operations Section Chief will be the SAR Manager and the AHJ or police service will be the Incident Commander. The incident commander and the SAR manager may also be one of the same, depending on the jurisdiction and the number of resources available at the start of the initial response phase. Information management - A good deal of search and rescue planning involves the management of information. Properly managed information can reveal guideposts to logical actions (i.e. a plan). Among the items the Plans Section Chief considers when developing strategy includes:

- Investigation results from interviews and deductive reasoning.
- Subject profile compiled from investigation.
- Lost/missing subject behavior data from local and national data bases.
- Search and rescue resources available: types, how many, for how long, and training.
- Terrain and vegetation analysis.
- Weather, both past, present, and predicted.
- Outside political pressures from critical allies or external influences.

This is a lot of information, and it can be overwhelming. But if organized and filtered correctly it provides clear direction and ensures effective use of SAR resources. Some ideas on how to collect and manage this information follow.

Note:	**During the initial response many of these actions are done 'informally' using the 6-step process. Once the decision is made to move from informal to formal planning all of the following formal planning actions need to be considered.**

Assign a SAR Incident Management Team when you transition from informal to formal and include additional ICS functions to manage the information flow and coordination.

SITUATION UNIT. To manage the expected flood of information the Plans Section Chief should immediately assume or assign someone the responsibilities of Situation Unit Leader. This person manages all data through the use of maps, resource status cards, assignment summaries, computer software programs, and other tools discussed in detail below. Delays in establishing a Situation Unit will result in loss of data caused by poor documentation. The Situation Unit Leader is normally a full-time responsibility.

RESOURCE UNIT. The other critical Plans Section position is the Resources Unit Leader. This person maintains current records on the status of all SAR resources, including assisting and cooperating agencies. This may be a full-time position, or it might be combined with the responsibilities of Check-In Recorder, Timekeeper, or Situation Unit Leader.

Determine appropriate action. Identify the range of possibilities that might have caused the person to become lost/missing or overdue. Then prioritize response to the potentially most life threatening or serious possibility. For instance, on a lost/missing child report, several high priority possibilities might become apparent, such as a water accident or kidnapping, abduction. Thus a high level of response is warranted to investigate these two possibilities, and less urgent responses aimed at dealing with the others.

- This worst-case concept has applicability in all planning sequences, and is especially useful in the initial response when either available information indicates a low overall urgency, or limited resources force a focusing of efforts.

Develop a lost/missing subject profile. This profile will be useful in:

- Defining search and rescue objectives.
- Estimating SAR resource needs.
- Determining strategy and tactics.
- Mapping the search and rescue area.
- Providing planning data and searching data.
- Briefing search and rescue teams.

Establish Search and Rescue Objectives. These should address the following questions:

- How much time do we have to find the subject alive? (Consider weather, subject profile, statistics and any other subject survivability factors.)
- How large an area will we ultimately search?
- What final POD can we accept (how thoroughly will we search)?

When these objectives are accomplished, the search and rescue mission generally de-escalates. Therefore, the search and rescue objectives usually prescribe a level of thoroughness for searching a large area. However, these objectives must be developed and approved in concert with the SAR Manager/Incident Commander.

Determine and staff the boundaries of the search and rescue area. Consider theoretical, statistical, deductive and subjective methods, search objectives, subject profile, and lost subject behavior data.

- Apply all reasonable and necessary confinement techniques.

Segment the search and rescue area.

- Use features that are visible in the field whenever possible. Features can include ridgelines, streams, fences, roads, vegetation changes, string lines, and streamer lines.
- Make the segments small enough to permit assigned resources to cover entire segments in a 4 to 6 hour period. This will vary depending on terrain and topography.
- Segment boundaries must not be realigned once SAR efforts begin. Any realignment complicates cumulative POD and shifting POA computations. However, combining and subdividing segments can be done if necessary. Erase, add, but do not reroute boundaries. Computer programs are available to assist with this task.

Once the segments have been determined and identified determine the probability of area of each. This is done utilizing the Modified Mattson Consensus Method. Prioritize segments. Consider subjective, statistical, investigative and deductive factors, subject profile, debriefing information, and compare this data with search priority ranking. By now a few segments will begin to appear as having the most likely chance of containing the subject (since he/she/them have not been located in the initial response search areas). Consider the intended destination of the lost missing person. When you have identified the 50% and 95% percentiles based on statistical data, then if the lost missing subject had an intended destination determine the angle of dispersion from that indented destination based on the available data. See Section IX, Chapter H.

Estimate area of the segments. Use a template to determine the size of each segment. Knowing the area of each segment is necessary for determining Probability Density, and is required to calculate the time needed for resources to complete their assignments.

> **Note:** **It is important to determine the size of the area in relation to the POA. SAR resources will have a greater success in a smaller area than a larger one.**

Determine Probability Density. Probability density (PDEN) is the probability that the lost person is in a given segment, divided by the size of that segment (PDEN = POA/Size). The higher the probability density, the greater the chance of finding the subject faster; i.e. a higher POA per square foot (or yards or meters, depending on the measure). Consideration should be given to searching segments with the highest PDEN's first.

Resources. Work up an estimate of the total SAR resources needed to achieve the search and rescue objectives. See Section IX, Chapter 9, Search Tactics and Resources. Consider:

- The type of SAR resources needed or available.
- How long each is available.
- Time available versus area to be covered.
- Estimated POD or POD Tables for each SAR resource.

Encourage Input. Do not plan in a vacuum. SAR personnel, family, and locals will have good ideas, some of which you may not have considered. Obtain their input by methods such as:

a. Directing agency and family liaisons to solicit suggestions and forward these ideas to the Plans Section.

b. Organize a brainstorming session:

   1) Invite key people to participate, including the SAR Manager/IC, Operations Section Chief, selected family members, representatives of participating organizations, individuals with special knowledge of the search area, persons well skilled in strategy and tactics, and free-lance locals (First Nations, hunters and trappers).

   2) Provide a briefing.

   3) Allow each person two to five minutes to make and justify recommendations. List each of these on a flip chart, whiteboard, or laptop.

   4) After everyone has made recommendations, provide a certain amount of time for discussion.

> **These techniques allow everyone the opportunity to provide input, draws the locals into the operation, provides for the family to participate, identifies original ideas while still allowing decisions to be made in a timely manner, and saves time.**

Prepare SAR Assignments. SAR assignments must be written.

a. The use of GIS systems for tactical mapping and planning will greatly aid in this process.
   - Write and display all SAR assignments on Chart paper or use a laptop and projector.
   - Combine all documentation of SAR assignments for one operational period on a map and photocopy, photograph, and use overlays to enhance documentation and presentation for briefings.
   - Additional instructions are written on search and rescue management forms or SAR ICS forms.
   - Date and time stamp each map and instructions.
   - Both the photocopied map and the instructions are prepared as decisions are made.
   - A copy of the map and instructions, together with other information such as subject profile, operational period objectives, communications plan, and debriefing questionnaire serve as the briefing packet to be given to each team leader by Operations.

b. This method minimizes preparation time, provides for fast briefings, serves as documentation, can be carried into the field, minimizes confusion, and lets everyone know what everyone else is doing.

c. Also, list SAR team assignments in large letters on flip chart paper or whiteboard and post for quick reference at Plans. Include columns for status, and accomplishments. These charts allow for quick reference, and comparisons.

Coordinate with Operations for implementation of the SAR plans.

Plan for Operational Periods: Always plan at least 12 hours in advance and use the planning ‘P’. Outline a general plan for the next shift, subject to revision as further information is received. Meet with Operations and Logistics and lay the groundwork for the following phases:

Debrief. Debrief returning SAR team leaders (or teams). Document debriefing information can be placed on transparencies overlaid on a master map.

Crunch Numbers. Prepare a summary (SitRep) of shift efforts:

- Calculate cumulative POD for each segment.
- Calculate shifting POA for each segment.

- Recalculate Search Priority for the next shift.
- List highlights of the shift.

The new cumulative POD's, shifting POA's and Search Priority will indicate new segments to be searched; These are critical to updating strategy. The calculations are not difficult, but they are repetitive. It can take hours to compute by hand cumulative POD's and shifting POA's for a search area having ten segments, and most search areas have more than ten segments. A computer can shorten the time needed to compute the calculations to a few minutes. Programs to accomplish these calculations are available from various sources.

However, it's not always necessary for Plans to be active 24 hours per day. In most search and rescue missions the Plans Section can complete its responsibilities in 15-16 hours. This may be preferred as it allows for greater continuity, avoids the need for time consuming briefings to the relief shift, and releases persons to other tasks.

Termination of a Response

It is critical to preplan the termination of a response process. Inherent in the Planning P is the "subject found" or "response concluded" process. It is recommended that these steps include (but not be limited to); briefing command on the termination activities, establishing demobilization priorities, establishing resource release stages, verifying deactivation procedures, and implementing demobilization processes. It would be a major error to not emphasize the need and values of the debriefing process, ensuring the identification of lessons learned, and application of these learnings to subsequent events.

Discussion

EDITORIAL COMMENTS, SUGGESTIONS AND OBSERVATIONS ON THE PLANNING P

Avoid letting the management of the search and rescue mission generate its own special problems. Troubleshoot early, and encourage everyone to keep sight of the search and rescue objectives.

There is an inverse relationship between level of responsibility and workload; the higher the responsibility, the less the workload. SAR Managers key role is to think forward, not participate in tactical implementation. The SAR Manager, and to a lesser extent, the Plans Section, Operations Section, and other Chiefs are encourages to reserve themselves for the main events and refuse to be drawn into trivia. As Chiefs they need to be available to their subordinates, and have time to evaluate, and think ahead. Effective Chiefs and managers delegate as much as possible so they are prepared to handle the additional problems that are sure to appear.

The only thing worse than a bad decision is indecision. There is no such thing as a 'bad' decision if it is made in good judgment based on available information.

Search and rescue missions are great opportunities to receive on-the-job training in managing large scale incidents. Take advantage of this by assigning inexperienced persons to various overhead operations to learn by 'shadowing' a mentor.

APPENDIX 1

Decision Making adapted from "SEARCH AND RESCUE MANAGEMENT – Initial Response through Extended Operations (Best Practices by Experienced Practitioners) March 2018. Produced published and copyrighted © 2018 by ERI International and SARI – SAR Branch. Reprinted and used by written permission for JSAR.

DECISION MAKING

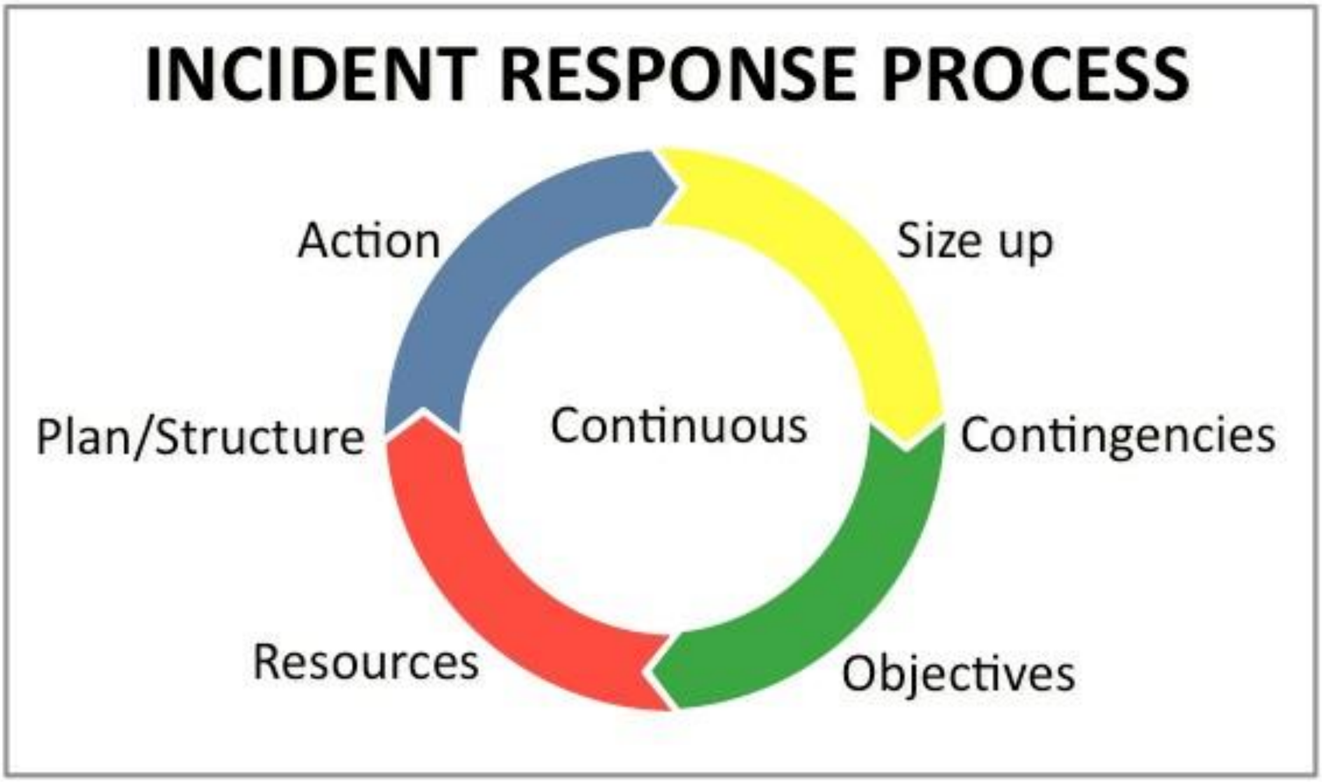
> **"Failure Is Not An Option."**
>
> **- NASA Flight Control, Apollo 13**

1.0 THE SIX STEP PROCESS.

1.1 This 'Six Step Process' (also known as the 'Incident Response Process') was developed by the International Association of Chiefs of Police as an approach for solving an operational problem. It is designed to provide a systematic and logical method whereby incident commanders and managers are able to make rapid decisions on tactics and the application of resources. As the incident evolves and more information becomes available, the Six Steps are repeated. It is a continuous, cyclic process.

1.2 The Six Step Process is extremely versatile; it is just as valuable as a quick mental technique for the individual responder as it is as a means of structuring a more formalized response to a larger incident. As the user gains experience it will become an instinctive process that can be applied automatically and continuously. The generic process:

1. Size–up the Situation	a. What is the nature of the incident? b. What hazards are present? c. What hazards exist for response personnel and the public? d. Do warnings need to be issued? e. Are there injured people who need to be treated or assisted? f. Is evacuation required? g. How large an area is involved? h. Can the area be isolated? i. What location would make a good staging area? j. What entrance and exit routes would be good for the flow of response personnel and equipment?
2. Identify Contingencies	a. What could have happened to cause this situation? b. What could happen to make the situation worse?
3. Determine Goals and Objectives	SMART Objectives developed through, Investigation Objectives, Containment Objectives and Search Objectives.
4. Identify Needed Resources	a. What resources are needed? b. Where will we get them? c. How long will it take them to get here? d. Are there any special resource requirements?
5. Build a Plan and Structure	a. Responsibilities and tasks. b. Chain of command. c. Coordination.
6. Take Action	a. Implement your action plan. b. Supervise/coordinate. c. Continue collecting and analyzing additional information (Step 1 (Size Up) of the next cycle).



1.3 This generic process is adaptable to virtually any incident. It is especially useful in the Initial Response Phase of a SAR mission. For example, a hasty team leader arriving at a trailhead from which a reported lost person departed, quickly runs through the process to determine where to employ available resources: which trails to run, buildings to check, high hazard areas to check, etc. Then the Incident Commander, while the Hasty Team is still in the field, uses the process to plan the first operational period of the search.

1.4 In the event the mission continues into multiple operational periods, the process is useful to organize an expanded, more formalized planning process.

1.5 Section III will detail the Six Step Process from the point where you are notified through to the conclusion of the first Six Step Cycle. For each of the Six Steps it gives you:

- A complete list of all the activities to which you need to attend.
- Any supporting information that you might need, in the form of text or tables.
- A list of 'recommended actions' – these are activities that we think you must deal with.
- References to any documentation that you will need to complete. The documents for this can be found at the back of the workbook.

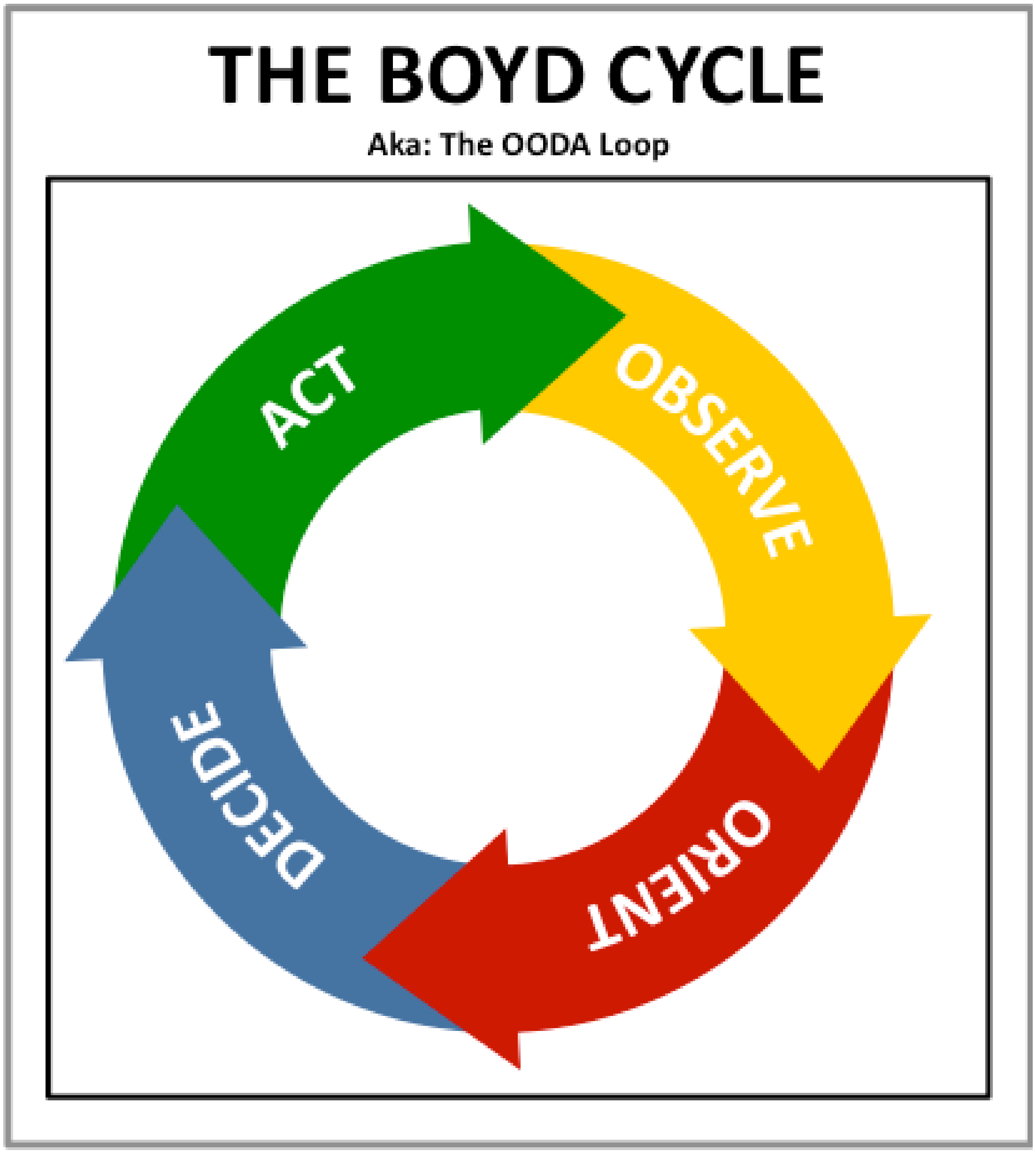
2.0 THE OODA LOOP.

2.1 The study of command and control theory starts with a simple model of the command and control process known as the OODA loop (after Col. John R. Boyd USAF). The OODA loop applies to any two–sided conflict, whether the antagonists are lost, missing persons, wildland fire, or an armed and barricaded individual. OODA is an acronym for observation, orientation, decision, and action, which describes the basic sequence of the command and control process.

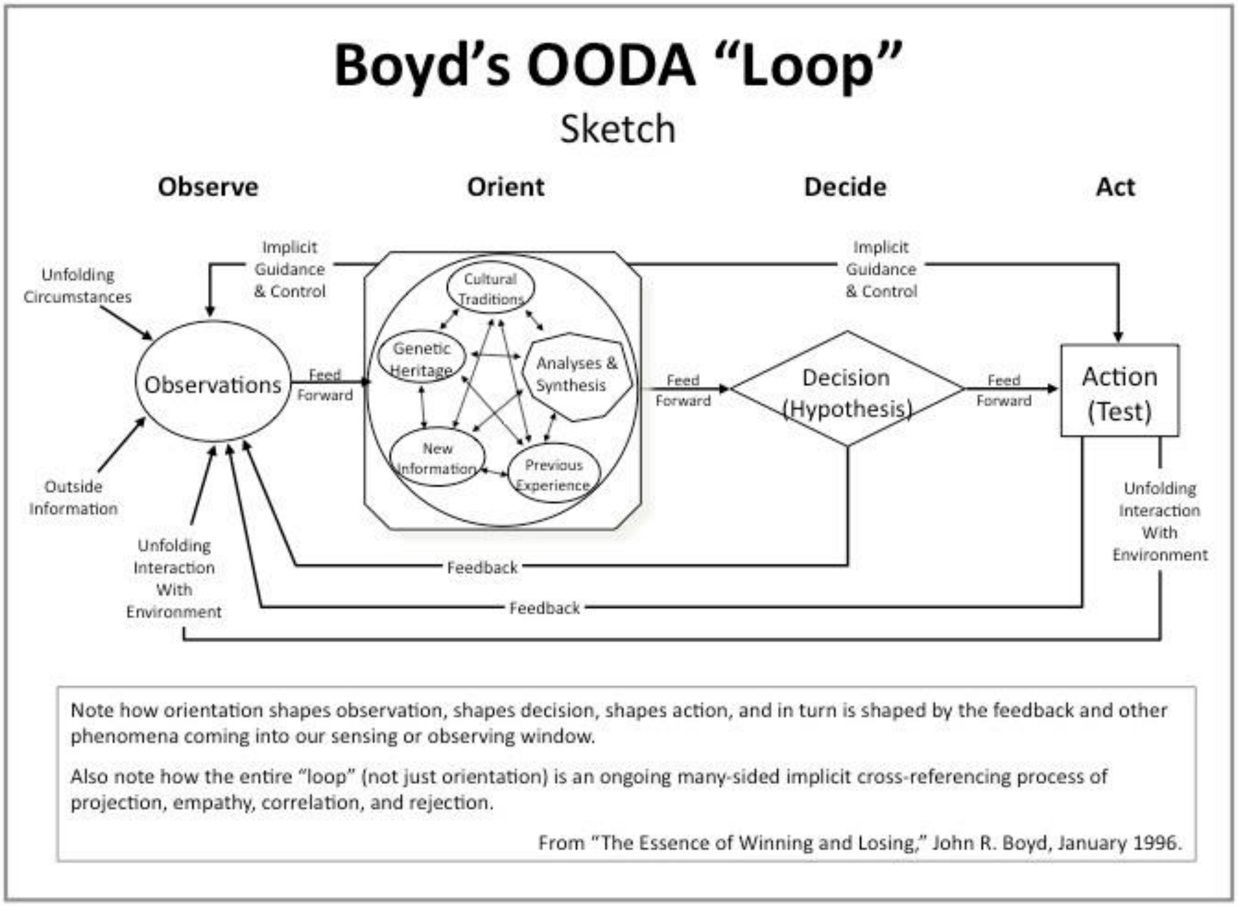
2.2 When engaged in a critical incident, we first observe the situation that is, we take in information about our own status, our surroundings, and our antagonist. Sometimes we actively seek the information; sometimes it is thrust upon us. Having observed the situation, we next orient to it, we make certain estimates, assumptions, analysis, and judgments about the situation in order to create a cohesive mental image. In other words, we try to figure out what the situation means to us. Based on our orientation, we decide what to do, whether that decision takes the form of an immediate reaction or a deliberate plan. Then we put the decision into action.

2.3 This includes disseminating the decision, supervising to ensure proper execution, and monitoring results through feedback, which takes us full circle to the observation phase. Having acted, we have changed the situation, and so the cycle begins again. It is worth noting that, in any organization with multiple decision makers, multiple OODA loops spin simultaneously, although not necessarily at the same speed, as incident commanders exercise command and control at their own level and locale.

2.4 Importantly, the OODA loop reflects how command and control is a continuous, cyclical process. In any critical incident, the antagonist who can consistently and effectively cycle through the OODA loop faster, who can maintain a higher tempo of actions, gains an ever– increasing advantage with each cycle. With each reaction, the slower antagonist falls farther and farther behind and becomes increasingly unable to cope with the deteriorating situation. With each cycle, the slower antagonist's actions become less relevant to the true situation. Command and control itself deteriorates.

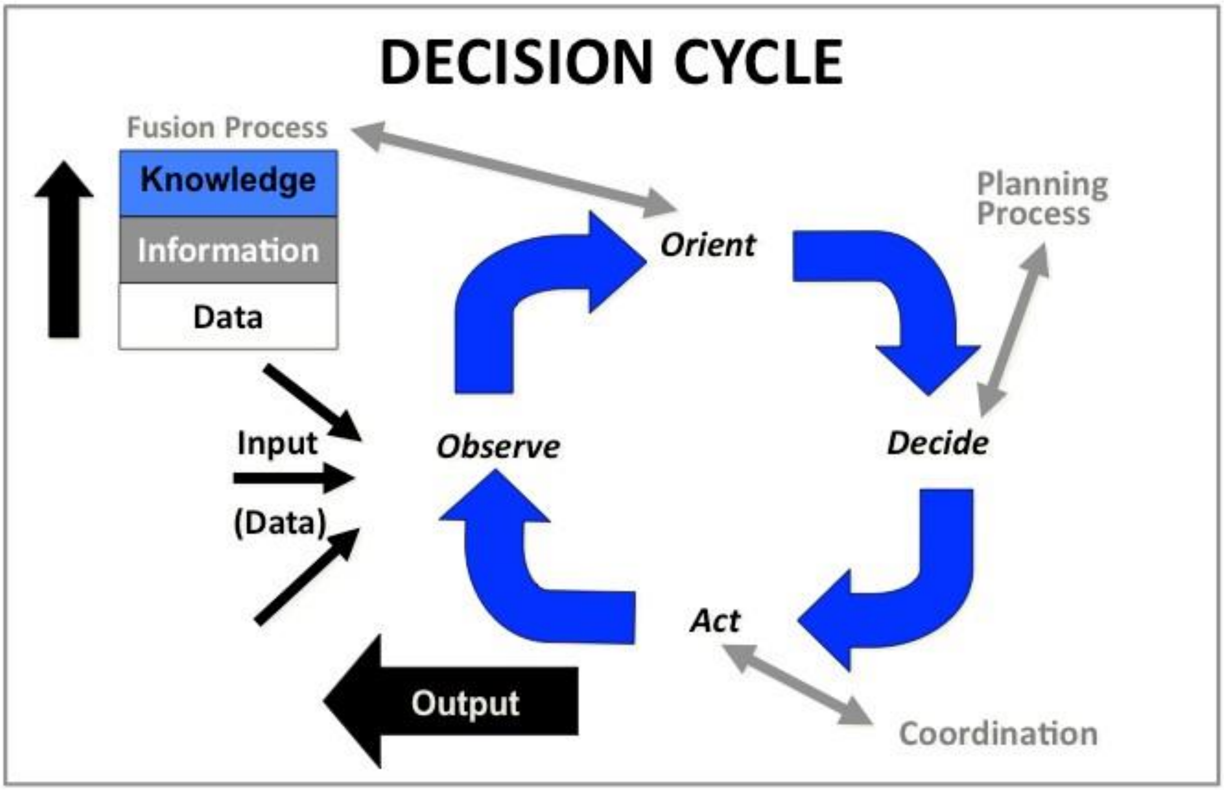


2.5 The lesson of the OODA loop is the importance of generating tempo in command and control. In other words, speed is an essential element of effective command and control. Speed in command and control means shortening the time needed to make decisions, plan, coordinate, and communicate. Since search and rescue missions are dangerous, dynamic, complex, and confusing with the lost missing person being ever evolving and ever changing, it is not absolute speed that matters, but speed relative to the person you are looking for: the aim is to be faster than our antagonist or the person you are working for, which means interfering with the person's command and control as well as streamlining our own processes.



You need to constantly make a decision faster than the other person. The speed differential does not necessarily have to be a large one: a small advantage exploited repeatedly can quickly lead to decisive results. We should recognize that the ability and desire to generate a higher operational tempo does not negate the willingness to bide time when the situation calls for patience. The aim is not merely rapid action, but also meaningful action. The OODA loop principals are based on synthesizing information and the situation, and not analyzing. Under stress during critical incidents you are far better off looking at all of the parts that you have, synthesizing, and then making up the whole, then analyzing the situation, which means you break the whole down into parts. Critical incidents are by their very nature, dangerous, dynamic, complex, and confusing. When speed and process are essential, being a synthesis and not an analysis is a superior process and behavior. To maintain peak situational awareness, you must continue to synthesize, correlate, and turn the information into useful intelligence. The OODA loop gives you this tactical advantage over your adversary, as it is a process of making a decision faster than your opponent.

2.6 The backbone of modern day decision making is situational awareness. Incident commanders and team leaders can increase their decision confidence by maintaining good situational awareness. Incident commanders and SAR leaders can increase their confidence by using time efficiently. In the search and rescue environment, decisions have serious consequences and often have life or death implications for others. With so much at stake, we have a responsibility to understand the decision–making process, the components, the flow, the effect of time, and to develop the skills and confidence that enables us to make the best decision possible with the information and time available.



2.7 From command and control, leadership, and decision making to management requires a more formalized response process. The Six Step Process is extremely versatile; it is just as valuable as a quick mental technique for the individual responder as it is as a means of structuring a more formalized response to larger incidents. The Six Step Process allows the user, once they gain experience to complete the process intuitively, to apply it automatically and continuously.

Abbreviations

ERI	Emergency Response Institute
GOST	Goals, Objectives, Strategies, and Tactics
IAP	Incident Action Plan
ICS	Incident Command System
JSAR	Journal of Search and Rescue
OODA	Observation orientation decision action
PDEN	Probability density
POA	Probability of Area
POD	Probability of detection
SCORPA	Size Contingencies Objectives Resources Plan Action
SWAG	Scientific Wild-Ass Guess

The Search Intelligence Process

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Abstract

The Search Intelligence Process of gathering information regarding the missing subject occurs during every search incident. We recognize intelligence information is used to build a subject profile; gather lists of people with first-hand knowledge of the missing subject that we want to talk to; develop scenarios; and task investigators to research and mine information from various sources, like social media or cell phone data, to determine where to look and what to look for.

However, during the initial stage of an active search for a missing person, intelligence gathering can be very daunting, chaotic, haphazard or worse not initiated thus delaying the compiling of crucial information that could shorten the time it takes to locate the subject. In any other aspect of the search operation like ground searching or technical rope rescue we preplan, train and develop processes to be more efficient.

This presentation will discuss the search intelligence process by: defining the various sources of information available to use developing pre-plans for the gathering of intelligent information, developing decision trees, developing lists of reflex tasks, developing algorithms for transitioning between the initial actions into multiple operational periods and eventually to the termination of search operations, and develop ongoing training curricula with the goal of creating efficiencies and hone the necessary skills to perform the intelligence gathering process.

KEY WORDS: Intelligence Gathering, Missing Person, Interviewing.

Introduction

Sir Author Conan Doyle's Sherlock Holmes is quoted as saying:

> **Data! Data! Data!" he cried impatiently. "I can't make bricks without clay."**
> - *The Adventure of the Copper Beeches*

> **“It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.”**
>
> -A Scandal in Bohemia

> **“It is of the highest importance in the art of detection to be able to recognize, out of a number of facts, which are incidental and which vital. Otherwise your energy and attention must be dissipated instead of being concentrated.”**
>
> -The Reigate Puzzle

Holmes's quotations are perhaps the most famous lines he had ever spoken, and with good reason. For, it points to the tendency that it is all too easy to indulge in: the tendency to do the impossible, to make bricks without their proper material and to create something like a theory, in the absence of anything on which to base it. Further, it speculates what can happen absent any hard facts and/or the misuse of few facts. The intelligent information used to build a profile of a missing person is just as or even more essential than the expected outcome. You need the right data, from the right people, or from the right source before you can expect any type of resolution.

What is intelligence? It is the act of gathering information. But, the other part of intelligence is the analysis of the information. We collect mountains of information about the missing subject both physical and nonphysical like from lost person questionnaires. Who can analyze the intelligence, who is going to go back through it and see if it’s complete, is it accurate, is there other information we need to start looking for that was the result of some comments that were made in the interview.

In a missing person incident intelligent information is the bases of where we are going to start searching (Initial Planning Point (IPP)). Law enforcement will get the call of a missing subject, dispatch a deputy to the residents and talk to the family… “Well he drove off two hours ago” … Is there a place to start? Not really. So, there is need to gather more information perhaps from a more in-depth interview or searching through other sources like social media. This information may lead to favorite hiking trails. Later, the car is found at one of those favorite trailheads. Now we have a place to start.

We are going to use this information to develop a subject type, so we can start using some of Robert Koester’s Lost Person Behavior statistics. Is this a hiker or is it someone who likes to take panoramic pictures? We are going to build a profile, “paint a picture” of who is this missing person. Various scenarios will be developed.

Investigation, as used in a missing person incident, is the continual process of gathering information about the missing person and the circumstances under which they are missing. This process commences with the first report of the missing person and is completed at the end of the missing person incident; concluding were feasible with interviewing the missing person after they are found in order to determine what happened.

Besides usefulness in search planning, investigation gathers historical and statistical information, which can be useful in future searches for similar missing persons. Statistical information compiled in Robert Koester's "Lost Person Behavior" has proven extremely useful in searches for missing subjects throughout the world. The investigation report should include post-search information on the effectiveness of the resources utilized in locating the missing person. This leads to lessons learned and additional training and practice. Further, the complete report of the investigation and the management of the search incident can later be incorporated into management training tabletop exercises.

We have relied on interviews of persons having firsthand knowledge of the missing subject. But, as will be discuss here, there are many more sources of intelligence information.

Historic and Literature Review

Historically: Military Intelligence

Much to the disappointment of many a comedian, **Military Intelligence** is NOT a contradiction of terms or an oxymoron. The origin of the expression was that it was not military personnel that were unintelligent, but that often they were given orders or missions that did not seem to make a lot of sense, especially to those in the lower ranks who had to follow those orders no matter what and without question.

Military intelligence exploits the collection and many sources of information, which are used as approaches to provide guidance and direction to commanders in support of their decisions. This is achieved by providing an assessment of available data from a wide range of sources, directed towards the commanders' mission requirements as part of the operational or campaign planning activity. This could range from looking at and determining the best location to repel an advancing force, to advancing an offensive against the enemy, or to just move a division from one end of the valley to the other.
In order to provide an informed analysis, the commander's information requirements are first identified. These information requirements are then incorporated into a process of intelligence collection, analysis and dissemination.

The most efficient way to locate a missing person while law enforcement and/or search and rescue team personnel are out looking to find clues, is to simultaneously place heavy emphasis on the initial investigations and prepare a search plan that focuses on places the person would likely be found.

Information on where to look comes from good investigation; building a profile of the missing person as if he or she is someone you already know. Getting to know who the missing person's family, friends, business associates or schoolmates are builds a valuable and more detailed picture. This can better predict what the missing person will do in a particular situation. For example, you may find that an initial 911 call about a possible child abduction is determined later, through your investigation, to be a runaway or just a case of the child forgetting to call home.

This is not to say that all search activity should wait until a thorough investigation is completed. In most cases, the initial information collected by the 911 operator and/or subsequent first on scene law enforcement agency representative interviews regarding the missing person will be enough to begin assigning reflex tasks to field personnel and sending them to high probability search areas. As new information comes in, resources can be deployed based on the scenarios that unfold.

Levels of Intelligence:

In the broader definition of the intelligence search for missing persons, there are three levels:

- **Strategic intelligence:** is concerned with broad issues such as number and type of resources to apply to the search effort. Additionally, such intelligence may be scientific (e.g. weather forecasts), technical, tactical or diplomatic (e.g. the family, local politics, or another authority having jurisdiction pressures), but these changes are analyzed in combination with known facts about the area in question, such as geography, or demographics which may be related to safety issues as well as statistical lost person behavior. In search management this is **Planning Data**

- **Operational intelligence:** is focused on support or denial of intelligence at operational level. In search management, this would be managing clues and information as it becomes available in applying that information to affirm or refute the various scenarios being developed. This would be the function of the **Clue Unit Leader** (sometimes referred to as the **Clue Meister** or **Clue Frog** (the person to "jump on it")).

- **Tactical intelligence:** is focused on support of the operations at the tactical level and would include field searchers. At the tactical level, briefings are delivered to teams prior to disbursement which include descriptions of the missing subject, items to look for, potential hazards and other information that would aid the field searcher in locating the missing subject. The teams are then debriefed at the end of their assignment to elicit information for analysis and communication through the reporting chain. This is all classified as **Searching Data**

The Role of Intelligence in a Missing Person Incident

A missing person incident is an emergency. This should go without saying but is not necessarily understood. When a subject is reported missing, the circumstances are unknown. The missing person may be in danger due to the environment, pre-existing health conditions, or due to extremes in age being very young or very old. It is therefore imperative that our actions in gathering intelligence starts immediately as it may mean the difference between life or death. Laws have been established to mandate immediate action without delay by law enforcement. [e.g. California Penal Code 14205]

Law-enforcement investigators are the gatherers of incident clues and facts regarding the missing person. Search and rescue teams (SAR) also provide the same skills but from a slightly different perspective. SAR gathers information to know what to look for, (i.e. searcher data such as footwear, equipment carried by the subject, etc.) which, if found, can be used to identify as belonging to the subject. Facts about the subject like personality can determine their mindset and intent as to why they are missing in the first place (i.e. planning data).

To build a profile of the missing subject or paint that picture in our minds of who is this person, we can approach this concept by saying “we don't know your missing father but we need to know them in the next few hours as if he were our next-door neighbor”. If one lives in the same place for a given length of time you may have gotten to know your next-door neighbor. You may have talked to them over the fence, raised your children together, and may have even gone on vacation together. The point is that you know them well enough that if they went missing you would have an idea what they might do in a various situations and scenarios.

What outside conditions will influences the missing subject (e.g. changes in the weather, the sun going down). Will the subject build a shelter or will they try to macho their way out of the wilderness? Does the subject have a pre-existing medical condition? Do we need to have paramedics standing by to administer life-saving medications? This can make a huge difference in planning for field operations and the application of appropriate resources.

The intelligence information is used to Establish Time Lines. This would include what was happening in their life up to the point of their disappearance going back hours, days, weeks, months, and even years. It also includes putting clues together to establish where the subject has gone and potentially heading. Clues are not always found in the order in which they are left and therefore must be sorted to tell the story. This information will be used to develop scenarios to help distinguish between a subject that is just missing, potentially suicidal, whether there is a crime involved, or distinguish between a kidnapping, runaway or walkaway.

And eventually, intelligent information can be used to create historical and statistical information to aid in searching for missing subjects in the future.

Who should be responsible for SAR Intelligence?

When the Incident Command System was first conceived it was out of the aftermath of a devastating wildfire in 1970 in southern California, USA, that lasted 13 days cost 16 persons their lives, destroyed 700 structures and burned 1.5M acres. As a result, the United States Congress instructed the U.S. Forest Service to design a system. The resultant system was called FIRESCOPE (FIrefighting RESources of California Organized for Potential Emergencies). Through subsequent iterations, FIRESCOPE has morphed into the National Incident Management System (NIMS) the Incident Command System (ICS) has been fine tuned to what we used today to manage the command and control system delineating job responsibilities or functions through an organizational structure for the purpose of dealing with all types of emergency incidents.

In FEMA publications, "ICS allows for organizational flexibility, so the Intelligence/Investigations Function can be embedded in several different places within the organizational structure." [page 15 of ICS Forms Booklet FEMA 502-2, 8/28/2009 file: FEMA-2009-0013-0002 (1)]

And graphically looks like:

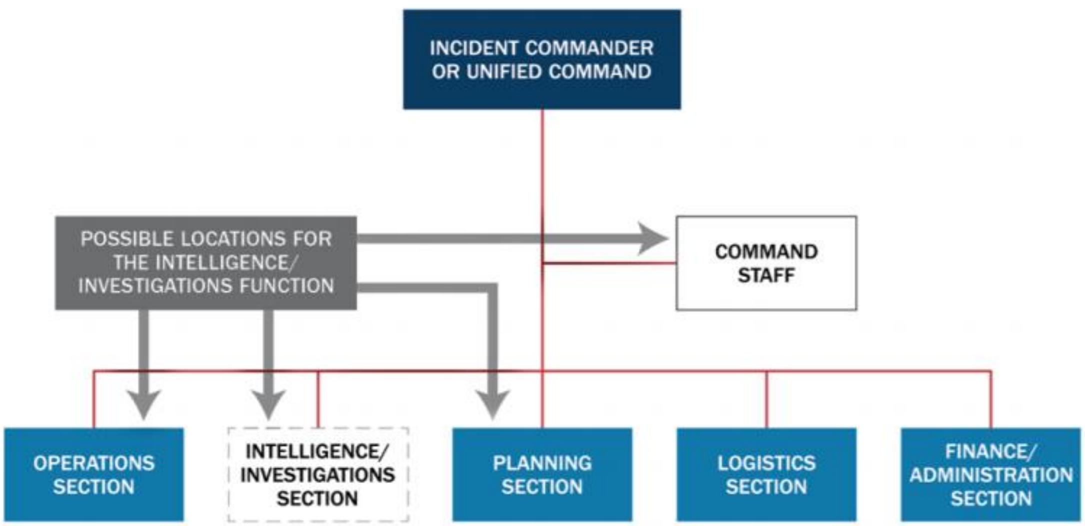


Figure 1 Options for the Placement of the Intelligence/Investigation Function
[National Incident Management System – 3rd Edition October 2017 FEMA]

And under Homeland Security's NATIONAL INCIDENT MANAGEMENT SYSTEM (NIMS) Intelligence/Investigations Function Guidance and Field Operations Guide:

Intelligence/Investigations Function in the Command Staff position: When the incident has an intelligence/investigations dimension but does not currently have active intelligence/investigations operations, the Incident Command or Unified Command may assign intelligence/investigations technical specialists personnel to serve as command advisors.

Intelligence/Investigations Function under the Operations Section: The Operations Section typically integrates resources, capabilities, and activities from multiple organizations with multiple missions. Consolidating the intelligence/investigations activities in the Operations Section unifies all the incident operations (e.g., law enforcement, fire, EMS, hazardous materials response, public health, etc.) in one organization. Within the Operations Section, the intelligence/investigations function may be configured as a new branch or group, integrated into an existing branch or group, or placed under the control of a new Deputy Operations Section Chief for Intelligence/Investigations.

Intelligence/Investigations Function under the Planning Section: Traditionally in a missing person incident the integrating the intelligence/investigations function is in the Planning Section—either as part of the Situation Unit or as a separate Intelligence/Investigations Unit—enhances the section's normal information collection and analysis capabilities. It helps ensure that investigative information and intelligence is integrated into the context of the overall incident management mission.

Intelligence/Investigations Function as a Standalone General Staff Section: The Incident Commander or Unified Command may establish the intelligence/investigations function as a General Staff section when there is a need to manage the intelligence/investigations aspects of the incident separately from the other incident management operations and planning. This may occur when the incident involves an actual or potential criminal, or a missing person incident or when significant investigative resources are involved, such as interviewing, cell phone forensics, mining data from social media, etc.

Establishing the intelligence/investigations (I/I) function as a General Staff section has the potential to create overlaps with the responsibilities of the Planning, Operations, and Logistics Sections. The Intelligence/Investigations Section Chief and other General Staff members should clarify expectations with the Incident Commander or Unified Command and coordinate closely to ensure that requirements are not lost or duplicated between sections.

The use of the I/I Function in a SAR missing person incident allows for the integration of intelligence and information collection, analysis, and sharing, as well as investigations that identify the pertinent historical data leading up to the disappearance regardless of source.

The activities and information I/I Function are viewed as the primary responsibilities of "traditional" law enforcement departments and agencies having jurisdiction (AHJ). The I/I Function has aspects that cross disciplines and levels of government. "Non-traditional" forms of intelligence/investigations activities (i.e., non-law enforcement) might include but not limited to:

- Interviewing those having first-hand knowledge of the missing subject
- Searching and mining information from Social Media
- Using current Cell Phone technologies like “find my phone” tracking, geolocation services, phone pinging, etc.
- Door to door neighborhood canvassing
- Crowd sourcing – Security Camera analysis, game camera set up and usage, small unmanned aerial vehicles (sUAV)

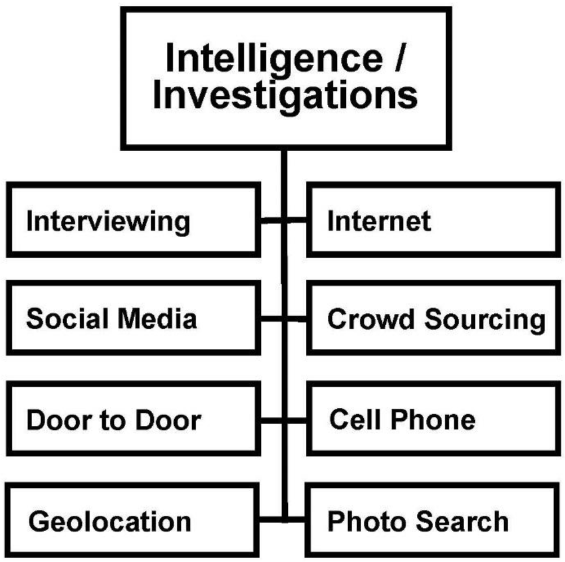


Figure 2 Intelligence/Investigation Function in Missing Person Incident

A word of caution/disclaimer: Controversies have surrounded law enforcement intelligence do to instances where the police departments maintained records of citizens' activities that were viewed as suspicious or subversive though no crimes were being committed. Therefore, intelligence and investigations practitioners must protect constitutional, victim, and privacy rights, civil rights, and civil liberties; restrict the dissemination of sensitive/classified information; and honor legally imposed restrictions on investigative behavior that affect the admissibility of evidence and the credibility of witnesses.

Discussion

As noted in the ***Introduction***, in a missing person incident, Intelligence gathering is the continual process of gathering information about the missing person and the circumstances under which they are missing. Information gathering includes interviewing people who have pertinent knowledge of the person. This process commences with the first report of the missing person and is completed at the end of the missing person case; concluding with interviewing the person after they are found in order to determine what happened.

The information gathered must be verifiable. Take for example one piece of information “he hasn’t been sleeping well for the last couple days”. Does it set off your “Spidey senses”? Maybe despondent? But that’s the only thing you have. In further investigation of their office you find the insurance policy, the will, the car keys and their wedding ring sitting in a row on the desk. Along with disrupted sleep now what can we conclude? Despondent, possibly? We are looking for clusters of information. It may turn out later that asking the wife about the items on the desk. “Oh, he had an appointment tomorrow with the family lawyer to revise his will, as we have grandchildren as well as make sure the insurance policy includes the grandkids. His habit is to lay out the stuff he needs to do for the next day including setting his keys and wedding ring nest to the papers”. This changes the whole dynamics and scenarios.

What are we trying to establish?

To establish what is really going on here, the possible scenarios and determine if a physical search is warranted or further investigation is needed prior to deployment of resources there is a need to collect data. The basic components of intelligence/investigation data are to answer the questions: who, what, when, where, why and how. The questions can be grouped and focused on establishing the missing subject’s:

- Description
- Intent
- Survivability
- Ability to travel
- Ability respond and to what

Description

The basic attributes of who we are looking for to be able to spot them from a distance whether searching in the wilderness or in an urban setting would include but not limited to examples:

Searching data:

- The full name of the missing subject including nicknames and aliases
- Date of birth (age)
- Race and Gender
- Physical characteristics (height, weight, hair and eye color, and other physical attributes):
- Clothing description missing person is believed to be wearing (from head to foot and outer to inner garments):
- Notable items that may be carrying or using such as purse, cane, walker, or backpack

- Recent photograph.

Additional descriptive attributes may include:

Planning data:

- Mental, emotional and physical condition
- Any medications, alcohol or drugs involved

Intent

Probably one of the most important set of questions relates to the subject's mind set and/or their intent. What are they trying to accomplish? What are they trying to get to or away from? Answering any of these simple questions can move the search effort in the right direction and eliminate wasted efforts.

For example, is the missing person suffering from dementia? Knowing that the urge to wander can be strong and is usually based on

- Fear: fear of their new surroundings at a care home, where nothing is familiar and thus they wish to find that which is normal and familiar.
- Frustration: they are frustrated that they can't do what they want to do and therefore will seek to do so
- Food: the basic drive to seek sustenance wherever it may be
- Obligation: obligation or the strong need to perform a duty like go to work though they've been retired for years.

How does this look in practice? If a vehicle is found at trailhead and you find camera equipment in the back seat and you know that the missing subject likes to take panoramic pictures, then where would you send the search teams? Obviously, where there are scenic overlooks at the edge of a cliff (or at the bottom of the cliff).

Survivability

Survival in any environment is challenging whether urban or wilderness. However, some missing persons may be unable to recognize or utilize the facilities, services or resources that are required for basic survival, (e.g., food or shelter). They may be unwilling, afraid or too independent to ask for help. These attitudes could affect their chances of survival and increase the urgency of the search effort.

Another line of questioning is the subject's **ability to communicate**. Do they have access to a Personnel Locator Beacon (PLB), SPOT™, cell phone or sat phone? Do they know how to call home or dial 911 for help? Is there an answering machine back home or access to voicemail? Are they familiar with the international emergency sign for distress which is three of any signal: three shots, three blasts on a whistle, three flashes with a mirror, or three fires evenly spaced?

Ability to Travel

Depending on the environment the missing person could meander or, in the case of an urban environment, move in a straight line. If there are no impediments or restraints on pathways, the subject could travel great distances eventually ending up out of the local area. This will expand the search area quickly. This could lead to a complete rethinking of where and how to search for the missing person.

How mobile is the subject? Are they:

- Walking?
- Riding in a vehicle, on a horse, on a mountain bike?
- Are they on the water in a boat or other flotation device?
- In the air in a commercial or private aircraft or glider, “flying squirrel suit”?
- Are they familiar with public transportation, such as bus, train, taxi or rideshare services

Ability to respond and to what

The tendency of the person to respond to attraction techniques, such as calling the missing persons name, may be very normal when they are in a normal situation or state of mind. However, circumstances in their environment or life may preclude them from doing so. For example, someone who does not want to be found (e.g., runaway, throwaway or despondent) may avoid searchers or not respond to any attraction techniques.

The missing person may have a fondness for a specific activity, a place to “hang out”, a special pet or animal that they enjoy being around. The converse should also be asked: What would cause them to turn away, shun or hide if they were exposed to an unpleasant activity, crowded environment or specific type of person or thing? What would cause them to have a catastrophic reaction to become violent or potentially hurt themselves or other like load noises, flashing lights, or searchers running toward them.

Sources of Intelligence

Frequently, after collecting intelligence/information from one source, a list of additional sources of information is developed, including names of all the people who know and have firsthand knowledge the missing person including friends, family, teachers, relatives and clergy. The information could include lists places and attractions. More information may be available from outside agencies and jurisdictions frequented by the missing person. Searches for information may be looking at institutions such as hospitals, domestic violence shelters, homeless shelters and jails should be contacted. The remainder of the discussion will follow the example list from Figure 2,

The Interview

In a missing person incident, whether involving law enforcement and/or search and rescue personnel, there is a specific definition of “interview”: A Search Interview is

- A structured, yet informal questioning process to obtain useful information from someone who has firsthand and/or relevant knowledge of the missing person.
- The tone of the interview is such that there are no accusations and there is no condoning or condemning of the actions of the missing person, the interviewee or the circumstances surrounding the person’s disappearance.
- Questions are structured to aid the interviewee in recalling specific details and events leading up to the disappearance of the missing person.
- The information gathered is used to develop a missing person profile, to collect lists of other persons to interview and to aid in planning where to look for the missing person.

To expand further, the structured but informal interview means that you have a prepared list of questions (Missing Person (MP) Questionnaire/Interview Form/Guideline) but the environment of the interview is intended to be more relaxing in order to reduce stress. We are speaking to those who can really tell us who this person is because they have known the missing subject and can best describe them as well as help predict their reactions in various scenarios.

In this type of missing person interview, the questions are nearly the same for all types of searches and missing persons. In an interrogation type interview, it can take many hours to build rapport. However, in the Search Interview a rapport is developed almost instantaneously because of the common goal between the interviewer and interviewee that is to find the missing person and bring them home safely. This is sometimes referred to as **“compressed intimacy”** (Lois, 2003). This compressed intimacy is something to be cherished as it is quite fragile and can be destroyed at any time by the words that are used or even body language perceived. It is important to understand what the differences are between non-condoning, non-condemning and non-accusatory questioning and the need to remain neutral. We therefore must be cautious and conscious of our statements to prevent negative reactions from our interviewee.

Who should we interview? The most informed people we can find who have first-hand knowledge of the missing subject. Usually we are talking about family and/or friends. But, interacting with those that have firsthand knowledge of the missing subject brings on many responsibilities and problems for the interviewer. For example, the interviewer will need to deal with stress and emotional ties to the missing subject which can be distracting and difficult to stay focused.

The person (or persons) who first reported the subject missing (the Reporting Party or RP), the last person to see the missing subject and/or the missing subject's family are usually the best place to start. These could all be one in the same. But, anyone with recent firsthand knowledge or potentially important knowledge of the missing person can provide the investigator the best information to help develop the missing person profile.

The Internet

The following example best illustrates the use of the Internet as a source of intelligence:

During Yosemite National Park's annual maintenance, a trail crew came upon an empty campsite that looked perfectly normal. Sleeping bag stuffed loosely in the tent, camp stove sitting out and the like. The backpack was missing. Nothing unusual for someone who set up a base camp and went out for a day hike. It wasn't until several days later when the same trail crew came back though the campsite when they noticed that nothing had changed or been disturbed. This created suspicions that the owner of the campsite might be in trouble. Yosemite Search and Rescue (YOSAR) was notified and a search was initiated.

A search through the campsite belongings revealed a backcountry permit taken out by a British citizen. YOSAR management decided to do a Google search of the subject's name and came up with information that he was a Professor at a university in the UK. Investigators then went to the university website, located the missing subject's department, found his picture and a contact number for the department. A phone call was made and investigators we able to talk to a colleague. The colleague stated that the missing subject was on sabbatical in the United States visiting several national parks including Yosemite. The colleague last had contact with the subject only a few weeks before via email noting that he was very excited to spend some time in Yosemite. There did not appear to be any physical or mental problems.

YOSAR investigations decided on a long shot and sent an email out to the missing subject stating they were concerned for his welfare and wanted to know his location. They were surprised to receive a return email from the missing subject that stated, he had lost track of time and didn't realize till it was almost too late that he had a meeting with a professor at a university just outside the park. He decided to just leave his camp, pack out as quickly as he could hike to his vehicle and make his meeting. He felt that no one would disturb his camp that he intended on returning to finish his visit to Yosemite.

Social media

In incident in an urban city in California, a teenage girl was believed to have headed out to high school on a normal day using public transportation, but she never arrived. Investigations interviewing the family indicated that the teenager was very depressed the last several months to the point that she had to change high schools. Interviews with new and old classmates indicated the same. Classmates also pointed out that her postings on Facebook were disturbing as well. Through the help of friends, investigators could gain access to the Facebook account. Postings indicated she was depressed and that she liked to take solitude at a special place in an open space regional park that backed up to her home. Search efforts up until then were focused in the urban areas from her home to access the public transportation. However, with this new information from Facebook teams were dispatched to the subject's favorite spot where she was found alive after jumping off a 30-foot cliff.

Crowdsourcing

We have often heard the term crowdsourcing with relationship to business and the acquisition of funding for a particular project, cause or start up. The actual usage of the word crowdsourcing is a portmanteau of "crowd" and "outsourcing" coined by Prof. of Journalism at Northeastern University Jeff Howe (2006) in a June 2006 Wired Magazine article "The Rise of Crowdsourcing". In that article Howe defines crowdsourcing as "… The act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an unidentified, generally large group of people in the form of an open call." To put it simply, it is taking a large and daunting task, breaking it up into smaller elements, then distributing those elements to several individuals, a direct reflection of the saying "many hands make light work". It is the further defined as the coordinated use of human intelligence to perform tasks that computers are currently unable to do.

One of the earliest forms of crowdsourcing was in the late 19th century when Prof. James Murray led a project to draw on the knowledge and expertise of tens of thousands of volunteers to create the Oxford English Dictionary. Prof. Murray received hundreds of thousands of slips of paper over the course of 70 years each of which contain the definition of English words. The modern-day equivalent is Wikipedia, which draws on the knowledge and experience of hundreds of thousands of volunteers to create the largest body of knowledge on almost every subject conceivable.

Crowdsourcing can further be defined as explicit or implicit. **Explicit** focuses on individuals consciously working to resolve a problem. An example of explicit crowdsourcing would be taking a large geographic area and segmenting it into smaller pieces of real estate and asking small groups of individuals to walk through those smaller pieces of real estate looking for evidence that a single individual may reside there. We call this search and rescue. **Implicit** focuses on individuals performing a task that indirectly solves a problem. For example, when using software to scan and digitize an old book, words and phrases that are unrecognizable are tagged (referred to as captcha validation). This unrecognizable tagged information must rely on a live human to translate. This human is actually helping digitize the old book one word at a time. There is third form of crowdsourcing called Piggybacking, which is seen most frequently by websites such as Google that mine one's search history and websites to discover keywords for ads

Surveillance or Sentinel devices provide a need to crowd source. In another example, a young 15-year-old female, from California went missing while on her way to school. The missing teen had been diagnosed with what was then defined as Asperger's under the autistic spectrum. Her profile showed that she was very focused on specific tasks. Through investigations it was suspected that she was heading to San Francisco with the intent of jumping off the Golden Gate Bridge. Suspicions were confirmed when investigators could obtain video surveillance camera footage from one of the San Francisco Bay Area Rapid Transit (BART) stations. The videos were from more than a dozen different cameras located in and around the station and exit points. In order to expedite the review of the many camera locations, each video was separated and viewed by family members and friends. It was felt that who would be better to spot her in an image, than those who have had first-hand knowledge and therefore would be able to recognize her quickly. A photo was quickly found of the missing teen coming up an escalator with her bicycle. Further review of other surveillance videos confirmed that she had jumped from the bridge.

We can increase our odds by setting up a form of containment. In Wisconsin a search was conducted for a Mexican native visiting the area. Authorities received a phone call from a nearby resident who stated that while reviewing photos from one of his game cameras, the caller found several pictures of the missing subject. Based on the time stamp on the photo and the location the camera, search efforts were shifted. Sheriff's officials urged all sportsmen, hunters and landowners in the area to check their game cameras for any other possible sightings of the missing subject.

Figure 3 Typical Game Camera

Using airborne platforms like fixed or roto-wing aircraft to record video images is not new. However, with the proliferation of small Unmanned Aerial Vehicles (sUAV) both commercially available to law enforcement and those privately owned it is possible to create video images on the fly (pun intended). There are recorded cases where ground search efforts have been futile which were followed by the launch of a UAV and the subject was located within minutes. Some of this is pure luck but in most cases, it still requires analysis of several minutes to hours of recorded video. It should be noted that those analyzing UAV video need to be experienced viewers to be able to identify what does a human form look like either standing, sitting, or lying down from different camera angles and various environments (i.e. urban versus wilderness).

Neighborhood Door-to-Door Canvassing and Interviewing

An often-used technique in the search for missing subjects in the urban environment it can be just as productive in a trailer or tent campground. Discussed in greater detail in the book "Urban Search – Managing Missing Person Searches in the Urban Environment" co-authored by Christopher Young and John Wehbring, teams are tasked to collect information from the public and the "unknown witnesses".

The "unknown witness" is someone who might have seen or heard something but may not have recognized the importance of the occurrence until it is brought to their intention that there is an effort to find a missing subject in the area. So, it is equally important to consider what is NOT out of the ordinary, or what is normal for the neighborhood. This would include interviewing such persons as:

- Mail carriers
- FedEx™ and UPS™ drivers
- Newspaper delivery persons
- Utility workers, trash collectors, city workers
- Familiar walkers, joggers, neighbors in the area
- Neighborhood Watch Program participants
- Bus drivers, taxi drivers, ridesharing drivers

In management of a missing person search in the urban environment, it is important to saturate the area around the point last seen (PLS) or last known point (LKP) out to a radius of ¼ mile (300 m) with field teams. The technique of door-to-door canvassing and interviewing in residential neighborhoods generates many clues. Door-to-door interviews may help answer the question "Did the missing subject pass by this way?"

Cell phones mapping

Cell phones or mobile technology has been around for decades. Initially called car phones they were bulky cumbersome and expensive. Today they are slim, contain a massive amount of computing power, and affordable enough for everyone to carry in their pocket. While we accept this technology for granted it is only been in recent years that the technology has been exploited for the use of locating missing persons. The most famous of which was the search for the James Kim family in 2006

On Saturday, November 25, 2006 the San Francisco high-tech executive James Kim and his family were visiting the Portland, Oregon area over the Thanksgiving holiday weekend. The family left heading south with the intent of reaching Gold Beach on the coast of Oregon. The Kim's missed the main route turnoff from Interstate 5 to Oregon Route 42 and instead of backtracking they consulted a highway map and decided on a secondary route that near the Wild Rogue Wilderness and entered a remote area of southwestern Oregon. Unfortunately, the map they consulted, did not indicate the road was closed to through traffic during the winter months. The family drove till they got stuck. The family was reported overdue to authorities when James Kim did not report to work. A massive search was conducted between Portland Oregon and San Francisco California not knowing where the family had disappeared.

Two enterprising Edge Wireless (the Kim's cell phone carrier) engineers, Eric Fuqua and Noah Pugsley, contacted search and rescue authorities offering their help in the search. On Saturday, December 2, the pair began searching through the data logs of cell sites, trying to find records of repeaters to which the Kims' cellphone may have connected. They discovered that on November 26, 2006 at around 1:30 a.m., the Kims' cellphone made a brief automatic connection "ping" with a cell site near Glendale, Oregon, and were able to retrieved two text messages. Through the data logs, the engineers determined that the cell phone was in a specific area west of the cellular tower roughly in a 35 mile arc. They then used a computer program to determine which areas in the mountains were within a line-of-sight to the cellular tower. This narrowed the search area tremendously, and finally focused rescue efforts on Bear Camp Road. At first the search base was reluctant to accept the engineer's findings once they did the family was located. Unfortunately, James Kim perished due to exposure when he set off on his own to try to locate help.

From the after-action review of the Kim family search it became apparent that the data collected by cell phone providers had been underutilized in the search for missing persons. Since then it has become commonplace and more complicated due to privacy laws.

Data can now be mapped showing the overlapping of cell signals and pings form various towers to locate the cell device (see **Figure 4**).

Figure 4 Mapping from Cell Phone Data

International Mobile Subscriber Identity (IMSI) Catchers

An International Mobile Subscriber Identity or IMSI catcher is a device used to act as a “fake” mobile tower to either interrupt the connection between the cell phone and the service provider’s real tower or in the absence of a provider’s tower provide a cell phone connection. Originally developed as a cell phone ease dropping or listening device to intercept conversations/texting and to track the movements of the device it has proven successful in the location of missing persons in remote or desolate locations where no cell service towers are available. IMSI catchers go under many commercial names like “Stingrays”, “Triggerfish”, and “Dirtbox”.

Figure 5 shows the difference in cell coverage between a fixed tower and an IMSI devise mounted on the underside of a helicopter.

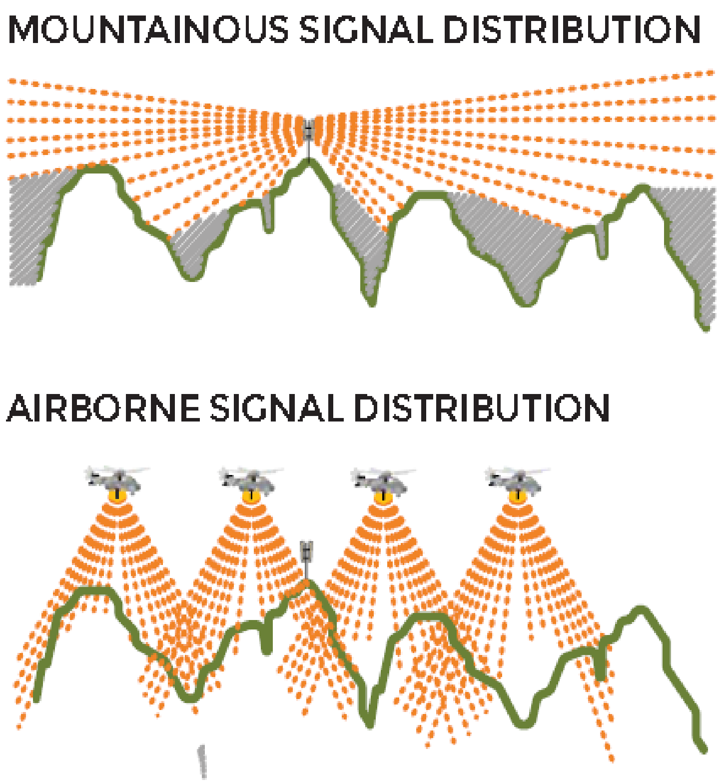


Figure 5 Example How the IMSI Signal Works Mounted an Aircraft Over Mountainous Terrain
[NORRIS Brochure A4 20141204]

Geo Location Services – Web Based Browser Apps

Because of today's technologies, the expectation/assumption of the public is that they can pick up their cell phone and call 911 (or 112) to attain help, especially if they find themselves lost in an urban, rural or wilderness environment. The behavior patterns would be to:

- See if they have any bars (signal strength) indicating a connection to a cell tower
- If they see no bars then they will either move around or climb to higher elevations until they do.
- Make a direct voice call to 911
- Try texting to 911
- Try texting to someone that can relay a message to 911

The problem with all these attempts is that the caller/sender must be able to tell 911 their location somewhere on the earth. The burden is placed on the sender to either provide a street address or a description of their location (i.e. next to the north entrance of the parking lot).

But what happens when the caller has no idea where they are? They may try to send a photograph showing their location, but that will only work if the 911 system will allow them to receive that type of data.

However, there are ways of extracting location information and display it in latitude/longitude if the person in distress knows where to look within their cell phone. (Like opening the Compass app on their iPhone and looking at displayed latitude/longitude)

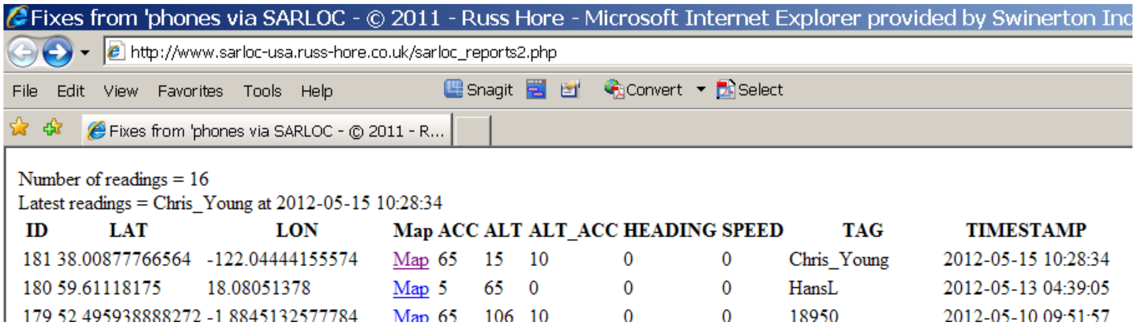
Browser-based Geolocation Services: There are simple browser based location finding services using Short Message Service (SMS) and Global Positioning System (GPS) technologies that already exist within cell phones

These services are the outcropping of the frustration felt by Search and Rescue practitioners to be able to use current technologies available on cell phones to locate a missing subject. It is believed that the first to experiment with technology to extract location data automatically from cell phones was Russell Hore, then with the Ogwen Valley Mountain Rescue Organization of the North Wales Mountain Rescue Association in 2011. By combining MRMap, a real-time tracking program for managing the location of search and rescue teams in the field via the GPS in the radio handset and SARLOC a geo-location Application Program Interface (API) using the phones own web browser system without having to install any software on the cell phone.

All cell phones today are required by law, in most countries, to include GPS chips that can transmit and display the cell phone’s current location. However, most people are unaware that this feature exists or if they do, don’t know how to access this information to be able to transmit the information via a short SMS text message. Many times, a lost person doesn’t know or realize that SAR personnel are out looking for them. In remote locations, the ability to use a cell phone to call for help is limited by weak signal acquisition by cell towers, cold weather and/or low batteries.

These browser based service applications are meant to solve this problem by automatically acquiring the cell phones GPS location and allowing the subject to email, SMS text, or just read the coordinates out over the phone.

In more detail, the services work using open source HTML5 Geolocation JavaScript API to find a cell phone location via the internal GPS and display it. A message is prepared that should include a URL address and either emailed or text to the target cell phone with a request of the user to click on the URL or respond to the text. Embedded within the response is the extracted GPS coordinates. The return information is then collected via a web based application and plotted on a map.



ID	LAT	LON	Map	ACC	ALT	ALT_ACC	HEADING	SPEED	TAG	TIMESTAMP
181	38.00877766564	-122.04444155574	Map	65	15	10	0	0	Chris_Young	2012-05-15 10:28:34
180	59.61118175	18.08051378	Map	5	65	0	0	0	HansL	2012-05-13 04:39:05
179	52.495938888272	-1.8845132577784	Map	65	106	10	0	0	18950	2012-05-10 09:51:57

Figure 6 Geolocation Information form Web Base application

[Source: http://www.sarloc-usa.russ-hore.co.uk/sarloc_reports2.php]

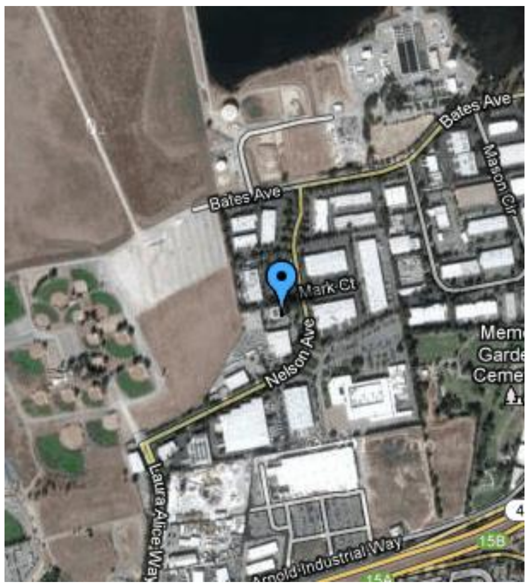


Figure 7 Example of Geolocation Source Information Plotted on a Map

Photo Search – Meta Data EXIF

The advent of digital photography and the demise of the photographic film industry, there have been many changes in the way we view the world as well as well as cultural changes in the field of photography. There is no longer the need in traditional photography to have dark rooms or deal with hazardous materials to produce a post-production image. Images can now be processed, enhanced and edited on a computer screen in the home, which allows for more creativity.

Certainly, the camera feature on most cell phones has also helped popularize digital photography, largely due to the strong need for recording every day events, photos of friends and loved ones and the “Selfie” (a self-portrait form of self-expression), and posting of all to the internet and social media.

Mining information from photograph images has always been useful tool in building a profile of a missing subject. This would include such things as the subject’s:

- Favorite places
- List of friends
- Favorite activities
- Emotional status
- Physical status
- Other interests

What has also become useful in the search for missing persons is the mining of hidden data within a digital image. When taking a digital photograph using a cell phone or a GPS enabled digital camera, besides recording the image there is also additional information hidden within the digital file. This hidden digital information referred to as “Metadata” is information regarding the image taken and stored in what is called the **Exchangeable Image File Format (EXIF)**. The EXIF is a standard that specifies formats and “tags” used by digital cameras including smart phones.

So how does this EXIF information help us in locating missing persons? If you can see the metadata contained within photos, you would find information such as, but not limited to:

- the date and time the photograph was taken
- the file source
- the Camera make and model or Cell Phone used
- the size of the file
- the focal length
- the exposure time
- the f-stop

But one of the main key pieces of data is that it also contains the **GPS latitude, longitude, altitude and image direction** (assuming the GPS feature on the phone is turned on).

If we can download a digital image the extraction of the GPS information of course is extremely useful. If we know something about the origin of the image from other investigated sources such as:

- who took it
- the subject matter or scene
- when it was taken
- those depicted in the photograph

This all combines to paint a picture of where the missing subject might be. If we have an image sent directly form the subject in real time, our search work may be close to accomplished. The right image could also tell us the local terrain and provide information on access to the missing subject and possible extraction routes.

However, there is a caveat that must be noted. Some social media sites such as Facebook, Twitter and Instagram will strip away the metadata when an image is uploaded. This is being done as a privacy security policy and data compression. The only way to determine where a photo was taken is if the user associated the image with a place when they uploaded to the social media site.

So, what is the process to extract this information? The first task is to download the image. Once this is done, there are couple of options.

There is a simple quick option for an iPhone (from an iPhone image sent by the subject). Saving a texted image to "Photos", opening the image and slide it up:

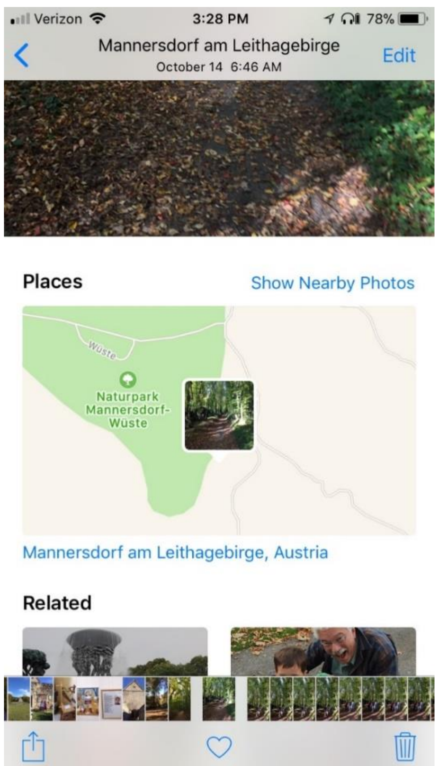
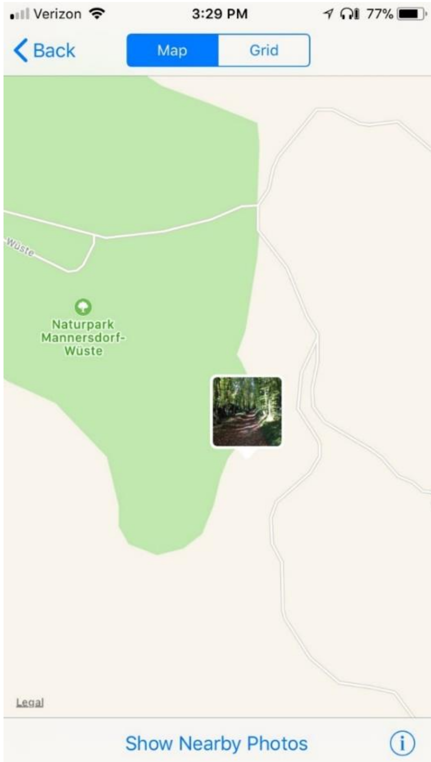


Figure 8 iPhone Photo Image Slid up to Reveal Map

Tap the photo in the center will bring up the Map app which can be viewed as a Map, Hybrid or Satellite.



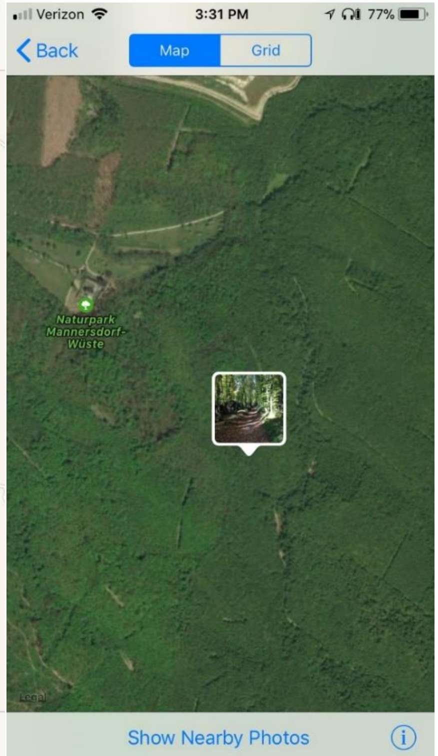


Figure 9 iPhone "Map" Image ***Figure 10 iPhone "Satellite" Image***

A Second Option is to save the picture to a computer running Windows. Right "Click" on the image, select "Properties" and click the "Detail" tab. Scroll down to "GPS". On a Mac "Click" on the image, select "Get Info" and look under "More Info" section

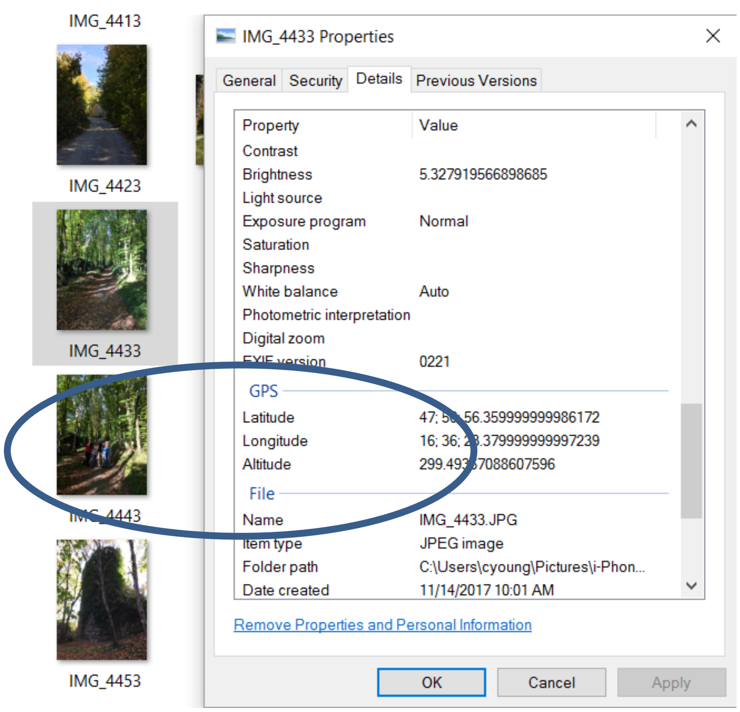


Figure 11 Windows Image of "Properties/Details" Showing GPS Metadata

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Results

Intelligence preplanning:

Looking at all the management functions we need to process prior to missing person incident requires thought and preparation. This is referred to as preplanning. This can be summarized based on the review of intelligence and information process and the many sources of information

For Intelligence/Investigations Sections

- Look at Lessons Learned from various types of missing person incidents and locations. What were the sources of information made these incidents successful or could have been improved with the right information

- Seek out candidates that have search management experience as well as the appropriate aptitude, demeaner and passion to be a good investigator

- Conduct courses on:
  - Intelligence gathering and Interviewing
  - Sensitively in dealing with families
  - Technical skills for internet & social media mining
  - Technical skills in extracting videos & photo data
  - Technical skills in extracting cellphone & ISMI data

- Establish lists of Geolocation Services

- Establish lists of outside services to cover services not available to the authority having jurisdiction (AHJ)

Coordination with Plans/Operations Sections

- Review and be familiar with the output of the Intelligence/Investigations Section.

Coordination with Logistics

- Review and be familiar with the technical support and equipment for the Intelligence/Investigations Section.

In addition, look at the workflow process and intelligence gathering from individual sources and plot out decision trees. Example:

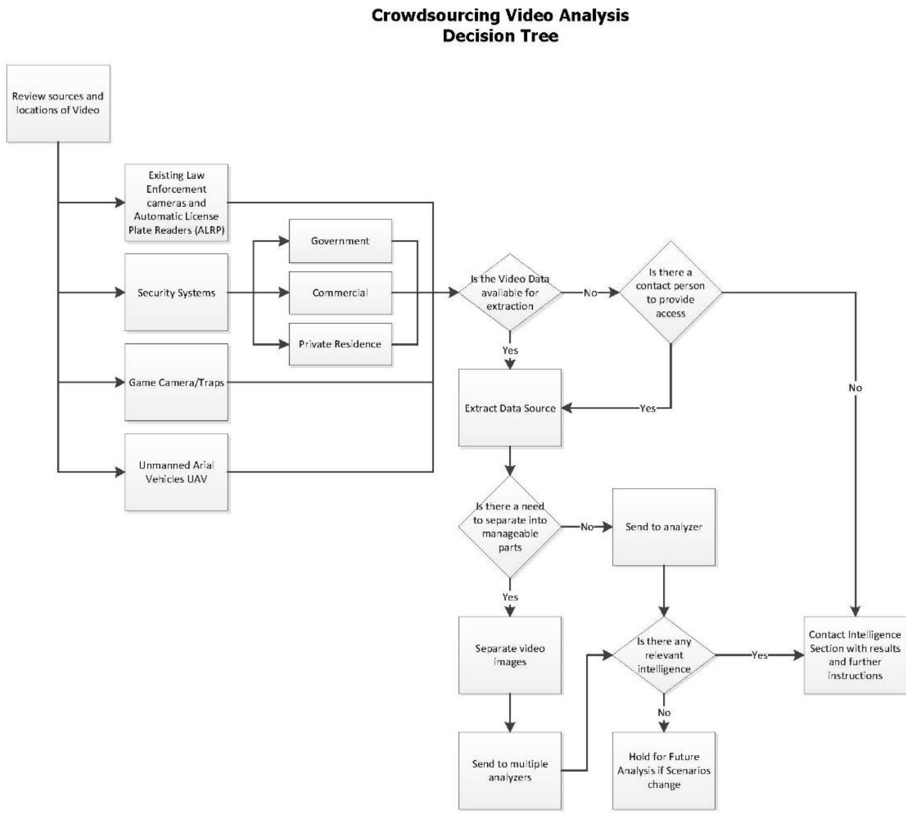

Figure 12 Crowdsourcing Video Analysis Decision Tree

Intelligence Reflex Tasking

Reflex tasks are those initiated as soon as possible from the commencement of a missing person incident. These assignments are assigned as qualified personnel become available. These include:

Incident Commander:

- Assign Intelligence Section Chief

Intelligence Section Chief

- Assign teams to the various disciplines to be investigated

Plans/Operations

- Set up the pre-established procedures to react to output of the Intelligence Section.

Coordination with Logistics

- Set up the technical support and equipment for the Intelligence Section.

Training Curriculum, Practice and Discussions

In incident management courses there is a component that puts all of the tenants learned and applies them to a practical exercise, and often referred to as a map or tabletop problem. For the intelligence/investigations process to be successful, there must be curricula developed as well as practical exercises to hone the skills necessary to be successful in a missing's person incident. A course curriculum has been developed by this author and is available upon request.

As part of the course there is a breakout session where students are broken up into teams of three and given a simple scenario. One of the team members will act as the person reporting the incident (PRI). This scenario is that the PRI has a relative that came to stay with them for the weekend. The PRI leaves in the morning to go shopping and upon their return at noon they find their relative missing. The person acting as the PRI is asked to describe a real life relative. It is up to the two remaining members of the team to act as the investigators to build a profile of the missing subject as well as develop scenarios. They can use whatever investigative sources of information they feel necessary. The exercise can run from 45 minutes to a few hours. It is not expected that the investigation will be completed in this period of time. At the conclusion of the exercise the teams brought back together to review the following:

- Note how much investigation was completed in the time given?
- What did you learn? Describe the facts of the case, the summaries, the scenarios developed?
- How would you do it differently?

Conclusion

So, what does this all mean? During a missing person search the organization and function of the Intelligence/Investigation Section has often been overlooked or not applied at all. The goal of this paper is to provide a better understanding on the utilization by defining its use in developing subject profiles and scenarios. There are lots of sources of information out there if we know where to look and think out of the box. Experience tells us that this can make or break an incident. The process is very labor-intensive and is up to the individual agencies having jurisdiction to plan ahead to train resources to perform the functions necessary for a successful outcome.

Acknowledgements

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About the author

Christopher S Young has been active in Search and Rescue since 1981, managed searches since 1986, is the past reserve Captain for the Contra Costa County Sheriff's Search and Rescue Team and serves as chairman of the Bay Area Search and Rescue Council, Inc. (BASARC). Chris is a retired Instructor for the POST "Direction and Control of the Search Function Course" for the State of California Office of Emergency Service for 25 years, is currently an Instructor Trainer for the "Managing the Lost Person Incident" and "Urban Search Management" (developed by Chris) for the National Association for Search and Rescue (NASAR), he is also an Instructor Trainer in Emergency Medical Response and first aid for the American Red Cross since 1972, as well as specialized topics in Search Management, including Search Management in the Urban Environment, and Investigation and Interviewing in SAR. Chris has also written, published and presented search management papers at the National Association for Search and Rescue conferences, the Canadian National Search and Rescue Secretariat SARSCENE conferences, the William Syrotuck Symposiums on Search Theory and Practice, the Canadian Coast Guard College, the Provincial Sûreté Du Québec Police, the Ontario Provincial Police, the New Zealand National SAR Conference, the Icelandic International Search and Rescue Conference, Norwegian Frivillige Organisasjoners Redningsfaglige Forum (FORF) Seminar and several State Search and Rescue conferences. He is also co-author of the book **"Urban Search – Managing Missing Person Searches in the Urban Environment"**, published 2007 by dbS Publications as well as a contributing author on several other books for search and rescue. Additionally, Chris is a Level 1 law enforcement reserve with the Sheriff's Dept and the City of Danville and is an EMT 1 Instructor. Chris holds a Master of Science Degree in Construction Management and works as a Senior Project Manager for a large general contractor based in San Francisco and is responsible for overall management of multi-million dollar ground up commercial, high rise, hospital, educational and hotel projects.

Abbreviations

AHJ	Authorities Having Jurisdiction
API	Application Program Interface
BART	Bay Area Rapid Transit
BASARC	Bay Area Search and Rescue Council
EXIF	Exchangeable Image File Format
FEMA	Federal Emergency Management Agency (US)
GPS	Global Positioning System
I/I	Intelligence/Investigations
ICS	Incident Command System
IMSI	International Mobile Subscriber Identity
IPP	Initial Planning Point
LKP	Last Known Point
MP	Missing Person
NASAR	National Association for Search and Rescue
NIMS	National Incident Management System
PLB	Personal Locator Beacon
PLS	Place Last Seen
PRI	Person Reporting Incident
RP	Reporting Party
SAR	Search and Rescue
SMS	Short Message Service
sUAV	Small Unmanned Aerial Vehicles
YOSAR	Yosemite Search and Rescue

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William G. Syrotuck Symposium on Search Theory and Practice Participants

Reykjavik, Iceland
October 11-12, 2018

Top (L to R): Scott Hammond, Hugh Dougher, Chris Long, Rick LaValla, Eric Rosenberg, Chris Young, Guy Mansfield, Robert Koester, Erik Swanson, Peter Roberts, Carl Hamilton, Dan Merrifield.

Bottom (L to R): Earl Matthews, Scott Wright, Gregory Rockwood, Dagbjartur Kr Brynjarsson, Lárus Steindór Björnsson, Richard Smith.