A SUMMARY OF THE SOURCES AND QUALITY OF DETECTION PERFORMANCE DATA IN THE NATIONAL SEARCH AND RESCUE MANUAL AND COAST GUARD ADDENDUM

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LIST OF ACRONYMS

CDP	Cumulative detection probability
CPA	Closest point of approach
ELT	Emergency locator transmitter
EPIRB	Emergency position indicating radio beacon
FLAR	Forward-looking airborne radar
FLIR	Forward-looking infrared radar
HHOS	Hand-held orange smoke flare
HHRF	Hand-held red flare
NFOV	Narrow field of view
nmi	Nautical mile
NSARMAN	National Search and Rescue Manual
NVG	Night vision goggles
OEG	Operations Evaluation Group
PFD	Personal flotation device
PIW	Person in the water
POD	Probability of detection
R&D	Research and development
R&DC	Research and Development Center
SAR	Search and rescue
SLAR	Side-looking airborne radar
SQL	Structured query language
SRR	Short range recovery
SRU	Search and rescue unit
SVR	Surface vessel radar
USCG	U.S. Coast Guard
UTB	Utility boat
VDSD	Visual distress signaling device
VSW	Visual sweep width
W	Sweep width
WFOV	Wide field of view
WPB	Patrol boat
WS	On-scene surface winds

EXECUTIVE SUMMARY

1. PURPOSE

The project had several goals, all associated with documenting the source and quality of currently available detection performance information for U.S. Coast Guard (USCG) search and rescue (SAR) operations. The approach taken revolved around a detailed study of the sweep width tables found in the National Search and Rescue Manual (NSARMAN) and its Coast Guard Addendum.

This research was undertaken to document all sources of detection information used directly or indirectly to produce the sweep width tables found in the NSARMAN and its Coast Guard Addendum. A primary goal of this process was to identify which Coast Guard SAR mission detection performance values can be traced directly to field test results and which have been extrapolated from mathematical models. This effort also involved creation of a detection performance data taxonomy structure in ACCESS database format suitable for use on USCG Standard Workstation III computer systems.

A secondary but important goal of this research was to determine which, if any, sweep width tables could eventually be replaced with mathematical models or formulas that could be used to generate lateral range curves. These formulas could be used in SAR mission simulation models to support development of improved search tactics. The lateral range curve models could also be incorporated into future SAR mission planning tools to improve their accuracy, particularly for electronic and multi-sensor searches.

2. SCOPE

All detection performance field experiment reports produced by the USCG Research and Development Center (R&DC) since 1978 were reviewed and analyzed for information content and applicability to the sweep width tables in the SAR manuals. More than 25 formal R&DC reports of field tests conducted since 1978 were reviewed, including all available correspondence files concerning R&DC inputs to the SAR manuals. All SAR manual detection performance tables except for daylight visual sweep width (VSW) are directly traceable to Coast Guard detection performance field tests. The daylight visual detection sweep width tables are produced from a mathematical model based on the inverse cube law of visual detection. The VSW model relies on results of limited R&DC visual detection tests to calibrate its mathematical predictions of visual search performance for all situations covered in the NSARMAN. Special effort was dedicated to comparing the results from this predictive model with the limited amount of statistically generated lateral range curve data available from R&DC daylight visual detection performance field tests. A detection performance taxonomy structure was created in an ACCESS database that contains all sweep width information currently in the SAR manuals in easily accessible form.

3. REPORT ORGANIZATION

Following a brief discussion summarizing the overall results of the investigation and recommendations for areas of continued effort, the report is divided into five sections. Section 1 describes the detection performance database design philosophy and operation. This is followed by sections 2 and 3 detailing the sources of detection performance information in the NSARMAN and the Coast Guard Addendum to the NSARMAN. These sections contain new information concerning formulas and regression model constants never previously published. Section 4 lists all known sources of detection performance information forming the basis of the sweep width tables currently used by the Coast Guard. Section 5 discusses important results and suggestions for additional research.

4. RESULTS AND RECOMMENDATIONS

Database:

A fully operational database was created that contains all the detection performance (sweep width) tables of the SAR manuals. The operator selects the inputs for the search and then applies a preprogrammed filter operation. This causes the sweep width for the selected conditions to appear.

The data structure is robust in the sense that future new tables can be easily inserted without disrupting or redoing the current structure. The design is such that the operator, with very few exceptions, can obtain an answer for each situation presented via the selection lists.

SAR Manual Sources:

All detection performance data in the SAR manuals were traced to original field test sources, original correspondence, and/or original mathematical models. The largest body of sweep width information in the SAR manuals is associated with daytime visual detection of ships, boats, rafts, and persons in the water (PIWs) from fixed-wing aircraft, helicopters, and surface SAR units (three tables). Except for PIW, life raft, and small boat targets, the mathematical model that produced these tables has not been verified with field test data. For most tables, there is a solid record of Coast Guard correspondence recommending the values that appear in the tables. Coast Guard electronic search performance has, for the most part, been estimated from R&DC field test results.

New Search Planning Tools:

This research has important implications concerning the development of new SAR planning methods and tools. The Coast Guard has a significant body of detection performance data based on 20 years of field test results involving targets routinely encountered in real-world SAR operations. All detection performance field test data from these experiments still exist in the interim and final reports of the field tests. Future research and development (R&D) efforts should concentrate on using the available field test data to formulate a consolidated approach to mathematically modeling detection performance for Coast Guard SAR operations. Future search planning tools, detection performance models, and SAR tactical development tools should be based, to the maximum extent possible, on the results of Coast Guard field test detection experiments.

Analysis of field test data provides proven lateral range curves for each situation tested. The lateral range curve has more value in a simulation model than its integral - the sweep width. Mathematical models of these lateral range curves should be directly used as inputs to algorithms in future search planning tools. Current search planning software uses sweep width data to plan search track spacing. This uses a single sweep width number taken from a look-up table. Improved search simulation software could "fly" a lateral range curve model through the simulated search area. The mathematical model of the lateral range curve may have many sensitive parameters that could be optimized for a specific situation. Some of these parameters could include search altitude, search speed, track orientation to the wind, and local weather condition inputs to the model. This method would better account for the effects of the search patterns and tactics used to execute the search when computing search results.

Search asset allocation decisions, SAR asset search tactics, selection of search sensor types, and search pattern planning could all benefit from new search planning tools based on direct use of lateral range curve mathematical models. The new search performance database could be used to more quickly plan searches using current search planning techniques. In addition, the database could easily be extended to store lateral range curve mathematical models for use in search simulation software using the improved computing power available in Coast Guard Standard Workstation III and follow-on workstations.

Future R&D Efforts:

The R&DC obtained substantial amounts of experimental detection performance data before the common usage of the desktop personal computer. Newer, more powerful computers and mathematical analysis tools now exist that can compute, in seconds, problems that took hours using computers of twenty years ago. New analyses of data taken from previous field tests may provide more accurate search performance estimates using cross product statistical techniques that are now available with the most modern statistical analysis packages. It would be prudent to obtain as much information as possible from previously conducted field tests using new analysis techniques. The Coast Guard should place a high priority on taking a new look at selected field tests, especially those involving visual detection (such as the tests conducted from 1978 through 1983).

Every mathematical model of lateral range based on field test data should be cataloged with the limits of the experimental dataset clearly defined. Potentially "safe" regions of model extension outside these limits should also be estimated.

It may be possible to significantly improve the utility of existing models by conducting simple experiments carefully designed to extend the ability to interpolate among existing search performance data. For example, a visual detection model could be extended using a 60-foot sailboat or a 120-foot fishing vessel to collect visual detection performance data on larger targets. By combining small and larger target models, interpolation of lateral range curves for intermediate target sizes could safely fill in gaps in the knowledge base.

Weather conditions strongly affect the shape of lateral range curves. A significant effort should be placed on unifying the effects of weather on detection performance across a wide variety of target types. This is another important area in which to use statistical cross product analysis on previously collected data.

The sweep width tables need another revision. Detection performance information for new search equipment should be added and old information should be revalidated, adjusted, or eliminated from the SAR manuals. For example, Coast Guard surface search radars have been replaced since the field tests conducted in the early 1980s and no information on new radars has been incorporated into the sweep width tables. Future field test work should focus on filling critical gaps in existing search performance models and updating search performance data as Coast Guard sensors are added or replaced with newer equipment.

Saving Money and Lives:

Conducting an efficient and successful search involves knowing where to search and knowing how best to search. Twenty years of field test data collected against commonly encountered SAR targets provide the best proven knowledge base of measurable parameters that affect how to perform successful searches. Parallel R&DC efforts to answer the question of where best to search should reduce the number of SAR assets required for the search. A reduction in the average time to locate a SAR target based on use of better planning tools, including more accurate search performance models, will reduce average SAR mission time, thus reducing average cost per mission while improving the survivor recovery success rate.

SECTION 1.0

AN EXPLANATION OF THE STRUCTURE AND DESIGN OF THE DETECTION PERFORMANCE DATABASE: SWEEP WIDTH INFORMATION FROM THE NATIONAL SEARCH AND RESCUE MANUAL AND COAST GUARD ADDENDUM

1.1 Introduction — Design Issues

The proposed architecture of the detection performance database was designed to meet the following goals:

1. By contractual requirements, the design takes advantage of the features built into the Microsoft ACCESS database program, part of the Microsoft Office Professional program suite, which will be hosted on Coast Guard Workstation III computer systems.

2. Existing sweep width tables from the NSARMAN and its Coast Guard Addendum must be stored and retrieved in such a manner that they are useful to a SAR controller familiar with current sweep width table design.

3. The design allows a SAR controller to easily select information without typing text.

4. The design is flexible enough that new data can be easily added to existing tables and/or entire new tables added as new sweep width and lateral range information becomes available.

5. The design provides a means to assess where sweep width data are missing from the knowledge base.

6. The design reduces database information redundancy to a minimum, thereby reducing database size to exactly what is needed to store the available data.

1.2 Designing and Building the Database

When designing and building a database, the most essential step is careful analysis and planning of its structure based on the intended purpose and functionality. Functionality must work around the programming structures supported by the host program or software. Data organization must avoid duplication to the maximum practical extent. The search performance database is a repository of relatively static information. This is in contrast to databases in which the stored information is constantly changing, such as in inventory control. Databases use search "engines" to sort and select data of interest based on various types of queries. These search engines perform numerical and string search comparisons on data stored in fields. The search engine looks for exact matches between field data in two tables or query inputs from the operator. To avoid spelling errors from causing failures in look-up criteria, this database was designed such that the operator does not have to type when conducting a search for a specific piece of data. All searches are conducted via pull-down menu selections.

The fundamental design constraints for the search performance database are strongly linked to the pull-down menu selection concept. The basic design of the tables requires that only menu selections that belong to a particular table be selectable. This prevents operators from selecting inputs that do not have accompanying output data. Another significant requirement is that tables should be completely or almost completely filled in so that the operator can reasonably anticipate an output from any selectable set of inputs.

The next constraint is ease of use. The operator should be able to use the database without being an expert in database usage. In addition, when retrieving tabulated information, it is helpful for operators to see a structure they are familiar with already. These practical requirements drove the design such that the SAR manual table structures dictated the selection of database field types. In order to satisfy the above constraints within the ACCESS programming structure, a large number of small tables provided an efficient storage of singular primary keys which when properly combined formed the compound primary key entries used in the sweep width tables.

1.3 Fundamental Structural Difficulties

Loosely described, most sweep width tables list search platforms, search objects, or target types, and conditions or variables that affect the sweep width. These include, but are not limited to, issues such as lighting (day, night, moon, no moon, etc.), contrast and false alarm issues (sea state, visibility, cloud cover, wind, precipitation, etc.), search equipment availability, and equipment operational modes. The primary difficulties to overcome are inconsistencies in spelling, word order, and/or slight variations in the contents of similar data base fields when switching from one table to another.

There is very little exact one-to-one situational agreement between the existing tables in the SAR manuals. For example, the Uncorrected Visual Sweep Width table includes life raft targets for 1, 4, 6, 8, 10, and more people. Boat targets are categorized by type (i.e., sail, power) and by lengths. Other tables split out targets most often as combined sets of the above, such as 1-to-4-person rafts, or boats categorized further by length. The boat lengths do not match between tables and may include overlapping and non-overlapping length conditions. The reasons for this are based on the amount and type of data available from R&DC field tests. Nonvisual-based sweep width tables exist for the target and SAR unit and sensor type combinations from the field tests. These tables reflect broad target classes for which detection performance data have been collected.

There is a Douglas Sea State table with sea states numbered 0 to 9. In the SAR manuals, no sweep width data exist for sea states greater than 4 and normally greater than 3. Sea state is also grouped differently from table to table. While weather conditions affect almost all searches, there is little consistency between tables as to how these conditions are stated. Some tables use wind speed or wave height instead of sea state but could include both with logical “and/or” rules attached. Other tables, due to less robust datasets, use “good” or “fair” to describe typical weather conditions.

Where specialized search equipment such as radar is used, specific operating modes such as range scale become important issues affecting sweep width for specific target types. Search speeds are different for helicopters than for fixed wing aircraft, and these affect corrections to visual sweep widths (VSWs).

R&DC field test results were used to develop the current NSARMAN and NSARMAN CG Addendum sweep width tables. The availability of data dictated the structure and organization of the tables into “book” formats that are not ideal for direct conversion into electronic data base formats. For example, in the case of targets, a solution is needed to an especially troublesome problem that will be referred to as name aliasing in this report. The Uncorrected Visual Sweep Width table lists PIW, 1-Person Raft, and 4-Person Raft as three of many possible targets. The Aircraft Search Speed Correction table lists PIW and Raft - 1-4 Man as two separate target categories. The Weather Correction table lists “Person in Water, or < 30-Ft Length Boat” as one category and “Other Targets” as a second category. There is a relationship between these target types, but additional situations will arise where it may be difficult to correlate targets in one table with targets in another table because of potential overlaps and/or gaps in coverage. An example of this is “Power Boat - 25-40 ft” in the target column of one table and a “36- to 50-foot rec. boat” in the target column of another table. This is a partially overlapping length situation, which also occurs in addition to the variations above in reference to spelling, capitalization, and word order. Fortunately, the tools in ACCESS allow for a solution to these problems.

1.4 Some Details of Database Organization

The elimination of redundancy in databases is partially accomplished through the use of primary key fields in tables that depend on both the software and operator to prevent duplication of identical data. Primary keys to data base tables provide <u>unique</u> searchable criteria to individual records in a table. An automated database search function will not be able to recognize that Raft - 4 Person and 4 Person Raft refer to the same type of target. Spelling differences, even the difference of a single space, appear as totally different items to the database program. The operator loading the database is the only defense for spelling differences in primary key fields. For this reason, field items are selected from a list, rather than typed in by the operator.

There is one master list of all possible ways of referring to targets in a General Target Types table. Other intermediate target tables depend on a subset of these targets. Using a pull-down list from a master table ensures that the spelling, word order, spacing, and capitalization in the intermediate table match those in the master table exactly. This concept is called Referential Integrity. In ACCESS, selecting “Enforce Referential Integrity” rigidly controls the relationships between similar fields in separate tables. The existence of an intermediate target table allows the person filling the database to pull down or select only those targets that should exist in a specific sweep width table. This process greatly increases the chances of obtaining an answer for every sweep width selection possible in any specific sweep width table.

Figure 1-1 is a small piece of the Relationships graphic, the display of the database layout showing table and table field interrelationships. Additional discussion of primary keys, table relationships, and the Relationship graphic follows later. Refer to the block "General_Target_Type" on the far left of Figure 1-1. This represents the table that stores all ways of referring to targets in the database. Relationship lines connect this table to intermediate target tables. Only targets from the master target table can be used in the intermediate target tables. Each intermediate target table only contains target types used in the corresponding specific sweep width table. The same philosophy is duplicated in the main RADAR_Type table. Intermediate radar type tables contain only the radar types used in a specific sweep width table.

1.5 Normalization

The primary purpose of database normalization is to reduce the size of a database to a practical minimum. In a fully relational database, data should only be stored in one physical memory address or location. Theoretically, every other reference to that piece of data should be via pointers to its location. There are tradeoffs to be considered with normalization issues. Too much normalization can force every query of the database to temporarily join two or more tables to recreate the data record or records of interest. In a very large database, this can sometimes increase the time to get the answer out of a query. This is not an important issue in small databases. In addition, ACCESS hides the data join operations in the background so the operator does not need to know about the process of joining tables on a common field.

1.6 Field Relationships

Two proper relationships between similar fields in different tables exist in a normalized database – <u>one-to-one</u> and <u>one-to-many</u>. Improperly normalized tables may contain another relationship, called <u>many-to-many</u>.

1.6.1 One-to-One Relationship

It is useful to limit field data entry by an operator to only the data that should exist in a table while the operator is building the table or filling it with information. For example, for targets, a separate intermediate target table listing only those targets that are used in a specific sweep width table is placed between the master target table and the specific sweep width table. This design prevents a person loading a database from entering a target that was not included on the allowable target list for that specific sweep width table. Since the target type field is selected as the primary key of both target tables and a given target name can only appear once in each list (because it must be unique), the relationship between the two primary key fields in this instance is <u>one-to-one</u>.

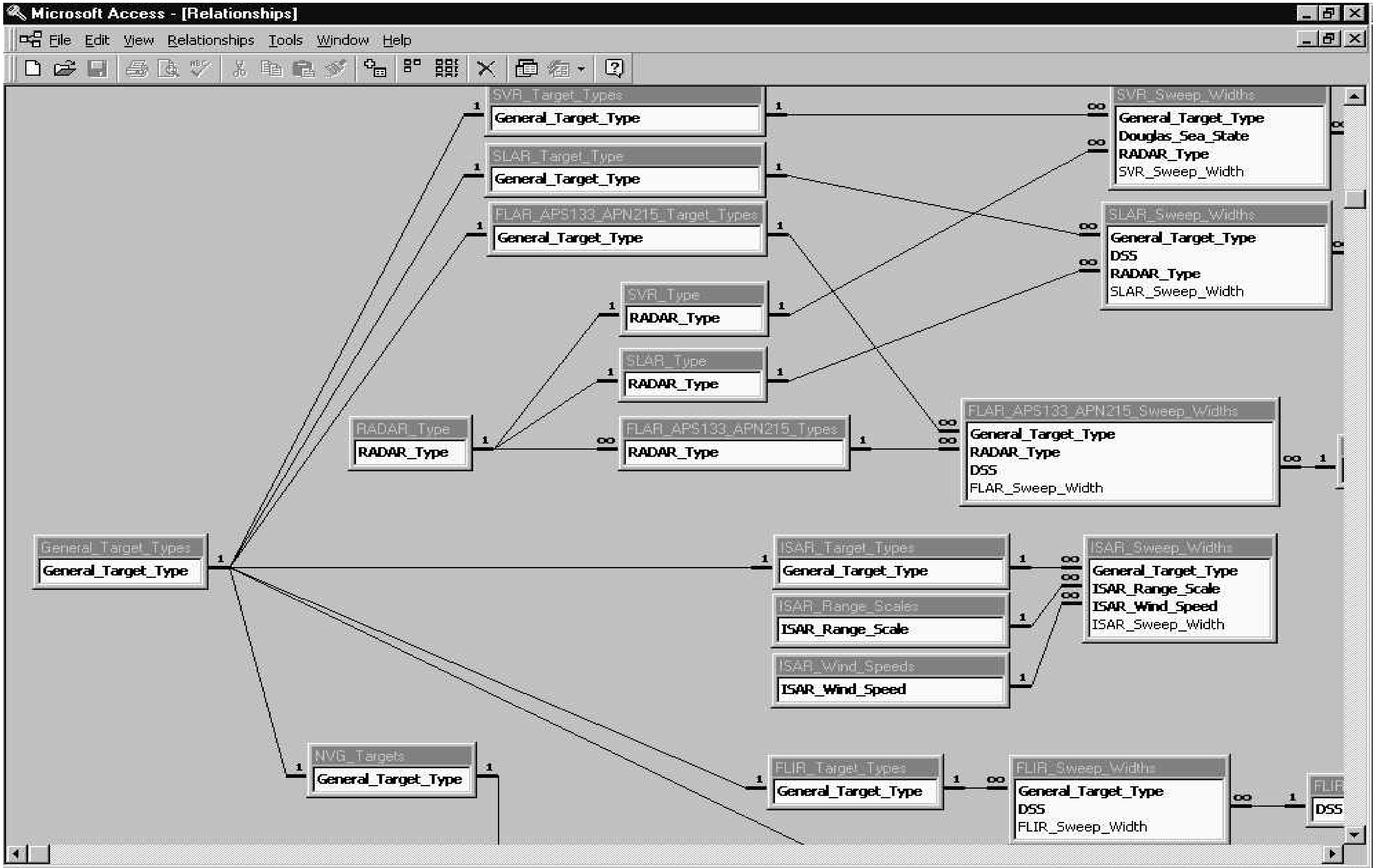

Figure 1-1. ACCESS Relationships Window

1.6.2 One-to-Many Relationship

Suppose the General Target Type table has both “PIW or Raft” and “Other’ as two of a long list of target types. Another table may use a compound primary key which contains target type as one of two or more fields which taken together are unique. Such a table may have several records with instances of “PIW or Raft” and “Other” as target types. This is a one-to-many relationship. When Enforce Referential Integrity has been set between the target fields of these tables, a compound primary key containing a new target cannot be added to the table on the many side of the relationship that does not already exist on the one side (General Target Type table) of the relationship. Using the Enforce Referential Integrity feature protects the database from losing data in records that cannot be located.

1.6.3 Many-to-Many Relationship

An improper relationship exists if several duplicate items in one field of a table match up with several other duplicate items in a different field of the same table. This relationship is called many to many and creates a database that is larger than it needs to be. A familiar example is an address and phone number database with many instances of town or city matching up with many instances of the same phone prefix and/or zip codes. A database design change to form two or more tables, each with a one-to-many relationship can make the storage space smaller. This rule can be violated in very small tables but usually results in design difficulties as the database grows with time. ACCESS has design checking “wizards” to detect these situations and can recommend the corrective action to be taken.

1.7 Relationships Graphic

The Relationships graphic is the ACCESS control tool used to establish and change database relationships. The Tools -> Relationships menu selection illustrates how the various tables in the database are connected on a field-by-field basis (see

Figure). The Relationships graphic is too large to be displayed or printed on one page. In almost all instances, the lines joining tables have either a “1’ at both ends (one-to-one relationship), or a “1” at one end and an infinity symbol at the other (one-to-many relationship). This indicates that referential integrity is enforced between tables for that field type. A line joining tables without these symbols indicates that referential integrity is not set on that field or cannot be set because of the database design.

1.8 Primary and Foreign Key Field Usage

The simplest tables contain one column or field. Each entry is unique and can be used as a natural primary key. Several primary key fields from related tables may be combined to form joint primary key fields or columns in a separate table storing sweep width information. ACCESS calls these foreign keys. Suppose Table A has three values of Target, Table B has four values of Search Platform, and Table C has five values of Weather Situations. Table D can incorporate these three foreign keys as a three-field joint primary key and can have up to 3 x 4 x 5 = 60 possible unique combinations of the joint primary key. As another example, the Uncorrected Visual Sweep Width tables for helicopters and fixed-wing aircraft have four fields, with a three-part foreign key as a primary key combination formed from the primary keys of tables of Target Types, Visibility, and Search Altitudes, with matching Visual Sweep Widths in the fourth column.

Ideally, sweep width data exist for all possible primary key combinations. When this situation exists, a table filter or database query will always have a sweep width lookup answer. However, when the table is only partially filled in (i.e., some primary key possibilities do not have record data), filters and queries can often come up blank, displaying no information. Database design can minimize but not eliminate this problem.

1.9 Explanation of Database Structure

Figures 1-2 through 1-4 duplicate the screens displaying the tables, forms, and macros that exist in the search performance ACCESS database file. In ACCESS all database tables, forms, queries, and macros exist in one large file. Tables store the sweep width information from the SAR manuals. Forms based on the database sweep width tables are intended to be used as "answer machines" in that filters (discussed later) may be applied to rapidly search for specific sweep widths and correction factors of interest. Macros automate sweep width table selection. When the operator selects a macro, the macro opens the form associated with a specific sweep width table and provides the operator with a pulldown (normally compound) primary key field selection list. The names of the macros are keyed to the corresponding SAR manual sweep width and correction factor tables and there is a macro to automatically open every sweep width form in the database, which in turn is tied to its corresponding sweep width table.

Many tables do not contain sweep width or correction factor information. They generally store the primary keys that are selectable in a given sweep width table. Naming conventions for tables usually include the search type first followed by the table information type. For example, FLAR_DSS is the set of Douglas sea state primary keys used in one column of the forward-looking airborne radar (FLAR) sweep width tables.

1.10 Queries versus Filters

After loading a database, the user wants to rapidly find answers to questions about the data using the sophisticated sorting and comparison capabilities of a database search engine. Most relational databases employ a standardized language to accomplish searches, called the Structured Query Language or SQL, often pronounced as "sequel." The language is difficult to learn because of its power and complexity. ACCESS has automated the query process so that the program generates the SQL code for most queries that would be typically generated. It also stores them as permanent database objects. Other permanent ACCESS database objects include Tables, Forms, Reports, Macros, and Modules. Figures 1-2 through 1-4 illustrate what the operator sees with an open database. Figure 1- shows the list of tables that appears when the operator "clicks" the mouse on the Tables tab. Figures 1-3 and 1-4 show what the operator sees when the Forms tab and Macros tab, respectively, are selected. This database has no programmed reports or modules at this time.

At first glance, queries would seem to be the ideal objects for the SAR controller to use in order to look up a specific sweep width for a given situation. However, the real purpose of a query is to poll a database for a set of one <u>or more</u> records that meet a specific set of search criteria. These saved search criteria tend to remain constant over time in a database that is constantly being changed. In the case of the sweep width data in the SAR manuals, the database is very static, but the query changes with every search; a Filter database object serves this purpose.

Filters are automated in ACCESS but cannot be stored as a permanent database object subject to recall. This problem is correctable by using macros and modules. Macros store a frequently used series of keystrokes, and modules store Visual Basic for Applications code, which can be used to provide a user-friendly shell around the database.

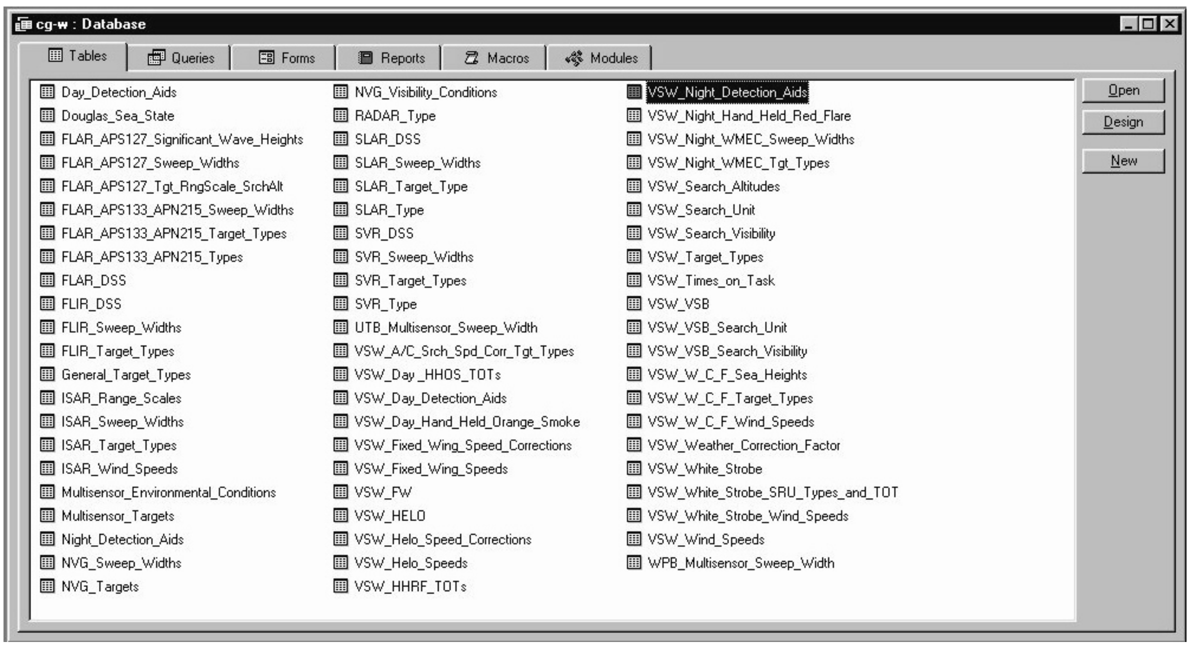

Figure 1-2. ACCESS Table Tab

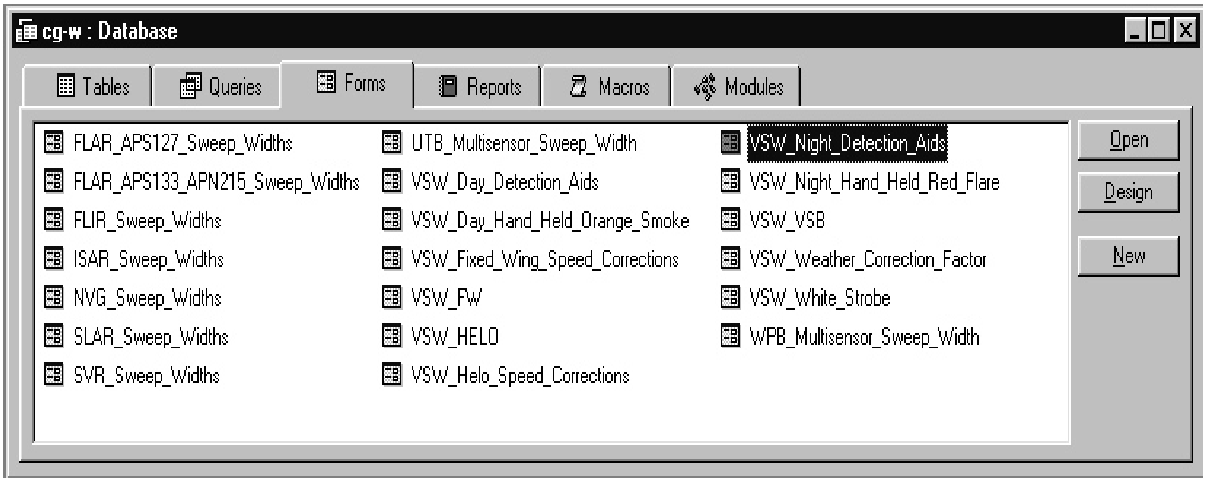

Figure 1-3. ACCESS Forms Tab

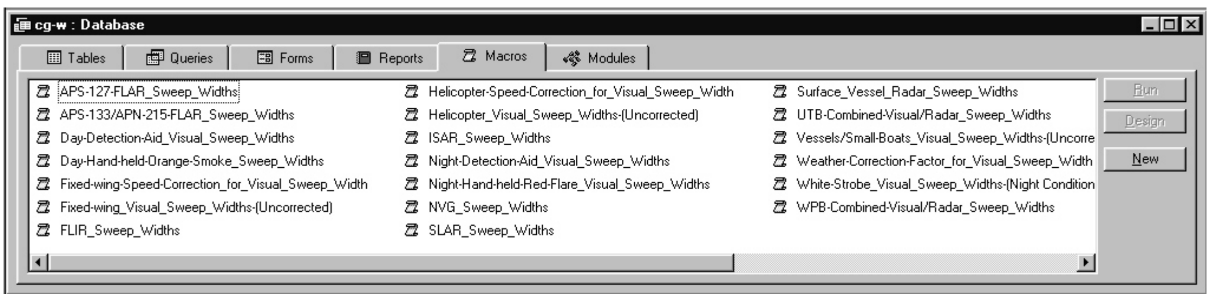

Figure 1-4. ACCESS Macros Tab

1.11 Using Forms

Forms represent a suitable end product for look-up searches. They have the same name as the corresponding table on which they are based. Forms corresponding to all sweep width-related tables of interest in the SAR manuals have been created and stored. The design is such that only selections that actually exist in a particular table appear as pulldown choices. To search for an answer in a form, click on the form and open it as a normal Windows object. A form with the first record filled in appears. Select Record -> Filter -> Filter By Form. A form with a blank record appears. Sequentially select field information using the pulldown menus. Then select Record -> Apply Filter/Sort to see the answer. If a record comes up blank, the operator must select Remove Filter/Sort before changing the filter search criteria and then reselecting Apply Filter/Sort.

1.12 Using Macros

The operator must know how to correctly open a form and activate the search engine to find a sweep width. Macros exist to automate the process of opening the form and preparing it for a sweep width search (form filter operation). Macros relieve most of the burden of the operator in knowing how to operate form filters in ACCESS.

1.13 Database Growth, Change, and Usage Issues

The structure supports the addition of new tables to the database. ACCESS easily supports the addition of extra fields to any table so that, if desired, a pointer to text discussing the source of every sweep width can be entered on a per-record or per-table basis depending on the situation. It is envisioned that the final form of the database will lock the records for data entry and may provide a Visual Basic for Applications shell with standard Windows controls. This will allow SAR operators unfamiliar with ACCESS to use the database as a SAR planning tool without having to know the details of the ACCESS program.

SECTION 2.0

RESEARCH ON THE SWEEP WIDTH ORIGINS OF THE TABLES IN THE NATIONAL SEARCH AND RESCUE MANUAL

2.1 NSARMAN Tables 4-4 through 4-10. Uncorrected Visual Sweep Width for Fixed-Wing Aircraft, Helicopters, and Vessels/Small Boats

Sources of Information:

Source (1):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), paragraph 1.3 - Tables 1-4, 1-5, and 1-6 present the data as shown in the NSARMAN.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Supporting Documentation:

Hover, G.L.; An Evaluation of the U.S. Coast Guard's Physical Detection Model for Visual Search. Report No. CG-D-02-89. Analysis & Technology, Inc., March 1988.

Comments:

The uncorrected VSW data presented in NSARMAN Tables 4-4 through 4-10 had their origin in a VSW model produced by Wagner Associates in 1984.

The Wagner model is based on the inverse cube law of visual detection. The model has its roots in work done during World War II by the Operations Evaluation Group (OEG) commissioned by the U.S. Navy to solve Operations Research search theory problems of interest to the military. This group produced report OEG 56, generally attributed to its primary author, Bernard Osgood Koopman. To this day, the OEG 56 report and follow-on texts by Koopman remain a mainstay of basic search theory. It should be noted that the Navy conducted only limited tests of Koopman's model and for many years, critical model "tuning parameters" remained undefined or were limited to specific conditions and target types.

On comparison of the Wagner mathematical model outputs with approximately seven years of field test data collected between 1978 and 1984 by the USCG R&DC, it was decided that several changes to the model output would be required to bring it in line with field test results. On completion of a period of negotiation and technical data exchanges between the SAR School, the Operations Computer Center, the R&D Center, and Coast Guard Headquarters, a revised set of sweep width tables for visual search from aircraft and surface search and rescue units (SRUs) was recommended for inclusion in the next revision to the NSARMAN.

The current tables also come from work prepared in 1985 to be included in the "Commandant Instruction for Probability of Detection in Search and Rescue. COMDTNOTE 16130 series."

The table is first noted in correspondence regarding production of enclosure (1) to COMDTNOTE 16130 for the 1985/86 update to the NSARMAN (Source (2)).

The correspondence shows that there was disagreement concerning the VSW for PIWs. Entries in Tables 4-4 through 4-9 for air search indicate 0.1 or 0.0 nautical miles (nmi) uncorrected VSW. Earlier recommendations from the R&DC during the negotiation phase suggested several 0.3- to 0.5-nmi sweep widths for PIWs. The final sweep width tables submitted by the R&DC did not include these higher values. The reason for the change is related to personal flotation device (PFD) use versus non-PFD use by the PIW. The NSARMAN tables note that for low altitude (<= 500 feet) searches by aircraft, the tabulated values may be increased by a factor of four for PIWs known to be wearing a PFD. The visual detection experiments on PIWs performed by the R&DC have always involved PIWs wearing PFDs.

A closer look at the VSW correspondence also reveals that for air search, the values used for 30-nmi visibility and boat lengths less than 30 feet are the same as for 20-nmi visibility. It was felt that, for small targets, increasing atmospheric clarity from 20- to 30-nmi visibility did not justify the sweep width increases predicted by the inverse cube law of the visual detection model. The final R&DC (source (2)) submittal may also have had some typographical errors that may have gone unnoticed with respect to the sweep width changes made for small targets. Evidence indicates that the analyst originally intended that the 15-nmi visibility sweep width be used for the 20- and 30-nmi visibility sweep width for small targets.

Relating Visual Sweep Width Models:

<u>Logistic Regression Model</u>

All visual detection experiments conducted by the R&DC since 1978 have fit the observed data to a logistic regression model. The model is ideal from the standpoint that it naturally produces probabilities of detection (PODs) versus lateral range that always fall between 1 and 0. The model is also ideal because it is easy to quantify the statistical significance of variables such as wind speed, wave height, visibility, and other factors, controlled or observed, in a particular sweep width experiment. The model can be criticized from the standpoint that the exact physical cause and effect equation is either unknown or not being used. This is a weak criticism, however, since assumptions of exact physical cause and effect will often contain unknown constants, which must be statistically discovered, and may vary or need to be redefined, for each given search situation. For any given visual detection experiment, the integral of the logistic regression POD function with respect to lateral range produces an accurate estimate of sweep width. This is because the sweep width results relate to a real-world controlled experiment.

The logistic regression model was not used to populate the majority of VSW information in the NSARMAN since it only applied to situations where field test data were available. The Coast Guard felt that a model based on the physical aspects of the visual detection process would be a more valid way of populating a large VSW table. The analysis by Hover attempted to evaluate/validate this approach, and found that certain "fudge factor" or model tuning constants based on actual at-sea testing were needed for accuracy except when only limited interpolation/extrapolation was attempted.

The most reasonable approach agreed on was to use the inverse cube law (Wagner) model to populate the VSW tables and then adjust the VSW values where they departed significantly from available field test data or appeared to be unreasonable extrapolations based on the "engineering judgment" of experienced SAR personnel. Examples of this are the previously cited truncation of VSW for small targets as visibility increases to very large values, and the adjustment of the PIW sweep width values.

A thorough analysis of the inverse cube law model used to build the NSARMAN uncorrected VSW tables can be found in:

> Hover, G.L.; An Evaluation of the U.S. Coast Guard's Physical Detection Model for Visual Search. Report No. CG-D-02-89. Analysis & Technology, Inc., March 1988.
>
> Memorandum from Hover, G.L., A&T to LT Bill Reynolds, R&DC; Letter Report of Analysis Results Detailing a Comparison of USCG Physical Detection Model Search Performance Predictions With Canadian Field Test Data., September 22, 1988.

Dangers of Extending the Model Results

The sweep width estimates are normally only valid inside the range of conditions that existed during a particular experiment. Extension of the model results to predict sweep width values significantly outside the bounds of the experiment is tempting but is not necessarily valid. A good example involves wind speed. Suppose that POD at any given range is not a linear function of wind speed. Suppose, instead, POD really falls off proportionally with wind speed to the 1.5 power. Suppose, however, the logistic regression model used fit the data well, as linear with wind speed, over a 5- to 15-knot wind speed interval that existed during a given experiment.

The model results, based on 5- to 15-knot wind conditions, might be incorrectly used later to predict sweep width in 30 knots of wind. The model will predict that POD drops to approximately 50 percent of those for the 15-knot condition as a result of wind speed effects. A more correct POD at any given range would be approximately one half to the 1.5 power or approximately 35 percent of the 15-knot condition. The more universal (but unknown) model would predict lower POD values at all lateral ranges and, when integrated, will result in lower sweep width estimates.

Another example: Suppose sweep widths are measured for 82-foot WPB searches. If one desires sweep width for the larger WMEC and WHEC cutters, there is nothing in the VSW model equation to account for a greater number of lookouts or for the advantages gained from searching from a more stable platform. Only a height of eye factor is incorporated. Only field test data can measure the effects of the unaccounted-for factors.

Lateral Range Curve Comparisons

The lateral range curves produced by the inverse cube law model and the logistic regression model are computed from fundamentally different equations. For this reason, there cannot be a direct conversion of constants or variables between the two models. This presents a fundamental problem when comparing the data contained in NSARMAN tables of uncorrected VSW with sweep widths produced statistically from R&DC experiments. Crude rules, such as "multiply uncorrected VSW by 0.5," are used to adjust the inverse cube law sweep width results for less than ideal weather conditions. This is necessary because weather conditions cannot be quantified exactly in the inverse cube law model. A crude rule to modify a potentially correct estimate of sweep width results in a crude estimate.

2.2 NSARMAN Table 4-11. Weather Correction Factor

Sources of Information:

The table was prepared by the R&DC in 1985 to be included in the "Commandant Instruction for Probability of Detection in Search and Rescue. COMDTNOTE 16130 series."

The table is first noted in correspondence regarding production of enclosure (1) to COMDTNOTE 16130 for the 1985/86 update to the NSARMAN.

The source documented in enclosure (1) to COMDTNOTE 16130 states:

> The following tables were developed by the USCG Research and Development Center, and are based on extensive test data.

The table has the following instructions:

> **Weather Correction.** Weather has an impact on search effectiveness. For small targets the reduction in effectiveness is substantial. Use the table to determine the weather correction factor (if conditions of both columns apply, use the correction factor in the right column).

The second source is Paragraph 1.3.1.2 - Table 1-2 of:

> Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Comments:

The table is meant to provide an approximate correction to the uncorrected sweep widths generated by the VSW model for less than ideal weather conditions. The target type is divided into two categories:

> PIW or Boat < 30 feet
> Other Targets

This is ambiguous. Since small target sweep widths are more adversely affected by worsening weather conditions than large target sweep widths, most life raft targets should appear in the category, PIW or Boat < 30 feet.

The weather correction factors are 1, 0.5, and 0.25. The weather correction factors are used by multiplying a sweep width selected from the Uncorrected VSW table by the listed weather correction factor to obtain the same, or lower, sweep width, depending on local weather conditions. Due to the table organization if either 0.5 or 0.25 could be chosen, the instructions tell one to select 0.25, (the right hand column – see **Weather Correction** above).

2.3 NSARMAN Paragraph 421 c. Fatigue Correction Factor

Sources of Information:

The fatigue correction factor was generated from statistical analysis of field test data which found search "Time on Task," or "Duration," to be a statistically significant variable when determining lateral range curves using the LOGODDS (logistic regression) statistical model. The visual detection field tests conducted by the R&DC from 1979 through 1983 noted a reduction in visual sweep width with increasing time on task, assumed to be due to operator fatigue factors. The table was prepared in 1985 to be included in the "Commandant Instruction for Probability of Detection in Search and Rescue." The table is first noted in correspondence regarding production of enclosure (1) to COMDTNOTE 16130 (date unknown).

The source documented in enclosure (1) to COMDTNOTE 16130 states:

> The following tables were developed by the R&DC and are based on extensive test data.

Fatigue Correction has the following instructions:

> **Fatigue Correction.** These sweep width tables have been adjusted for a "normal" amount of crew fatigue. If feedback from on-scene SRUs indicates that search crews were excessively fatigued, sweep width values should be reduced by 10% (multiplied by 0.9).

2.4 NSARMAN Table 4-12. Search Aircraft Speed Correction Table

Sources of Information:

The table was prepared in 1985 to be included in the "Commandant Instruction for Probability of Detection in Search and Rescue. COMDTNOTE 16130 series."

The table is first noted in correspondence regarding production of enclosure (1) to COMDTNOTE 16130 for the 1985/86 update to the NSARMAN.

The table has the following instructions:

> **Search Aircraft Speed Correction.** Enter the Speed Correction Table with aircraft type (FIXED WING or HELICOPTER) and the speed flown. Read down the column to the target type. This value is the speed correction. Interpolate as required. There is no speed correction for surface SRUs.

The second source is Paragraph 1.3.1.4 - Table 1-3 of:

> Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Comments:

The assumed base search speed for fixed-wing aircraft is 180 knots and for helicopters, 90 knots. Searching at slower speeds tends to improve sweep width but may also reduce sweep rate. The gains and losses tend to offset each other. Changes in search speed cause a bigger change (in percentage) in sweep width when targets are small than when targets are large.

The target types, in this correction table, have minor gaps in terms of length. This situation should be corrected.

2.5 NSARMAN Table 4-13. Visual Sweep Width Estimates for Daylight Detection Aids

Sources of Information:

Source (1):

CO USCG R&DC to Commandant (G-DST) Letter Ser. 3975.4/75101.2 dated 12 March 1985, Enclosure (1) Subject: NATIONAL SEARCH AND RESCUE MANUAL INPUTS.

Enclosure (1) to source (1):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Enclosure (1) has the following comments on detection aid effectiveness:

Daylight Detection Aids: The effectiveness of most daylight detection aids is marginal due to the difficulty in achieving high target contrast in a sunlight environment. Lights and pyrotechnics of under 10,000 candlepower are virtually useless during the day except in heavy overcast conditions. Reflective devices, such as smoke, dye, flags, and mirrors, can improve detection over those expected for persons or small craft and vehicles, but only when the environmental conditions are favorable. For example, limited tests conducted by the Coast Guard have shown that orange smoke can be detected reliably by alerted searchers at ranges up to 6 nautical miles in winds under 6 knots; however, as winds increase above 10 knots, detection ranges are reduced to under 2 nautical miles. The signal mirror, or heliograph, can be detected at ranges of several miles, but its effectiveness is extremely sensitive to the relative positions of the sun (when available), searcher, and survivor. ... It is important to note that all sweep widths given assume adequate visibility, open terrain, favorable lighting conditions (requirements vary with device), and an alerted searcher and signaler (i.e., the signal is used when the searcher is looking toward it).

Source (2) is Paragraph 2-3 - Table 2-4 of:

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Comments:

The primary experiment that supports the sweep width data was conducted off the south shore of Long Island, NY, in the fall of 1984. The following reference fully describes the experiment and captures all the relevant detection data:

> Robe, R.Q. and Hover, G.L.; A Static Evaluation of Selected Visual Distress Signaling Devices. Report No. CG-D-15-85. USCG Research and Development Center and Analysis & Technology, Inc., January 1985.

The report does not evaluate lateral range curves nor does it provide sweep width calculations. A very interesting result of the experiment is that many visual distress signaling devices (VDSDs) tend to be more visible in overcast conditions than low cloud cover conditions. Hand-held orange smoke devices (see Table 13a) are much less visible when wind speed equals or exceeds 10 knots.

These tables critically depend on detection range issues, alerted search subjects, and chance (lucky) observations to obtain a successful search.

Short duration VDSDs often depend on the subject of the search to operate a device at precisely the right moment to facilitate detection. In general, short duration VDSDs do not support the sweep width concept. Searches should not be planned based on the assumption of an alert and cooperative search subject in order to provide a detection opportunity.

NSARMAN Tables 4-13a, 4-14a, 4-14b. Visual Sweep Width Estimates for Hand-Held Orange Smoke, Visual Sweep Width Estimates for Hand-Held Red Flare (500 Candlepower), and Visual Sweep Width Estimates for Life Ring/Life Jacket White Strobe (50,000 Peak Candlepower)

Sources of Information:

Robe, R.Q. and Hover, G.L.; Visual Sweep Width Determination for Three Visual Distress Signaling Devices. Report No. CG-D-30-86. USCG Research and Development Center and Analysis & Technology, Inc., September 1986.

Report Table 4 produces NSARMAN Table 4-13a.
Report Table 5 produces NSARMAN Table 4-14a.
Report Tables 6 and 7 produce NSARMAN Table 4-14b.

Report tables include more environmental information that is not included in the NSARMAN. This includes ranges of visibility, wind speed, cloud cover, and significant wave heights that were present during the test. These could be incorporated in the next NSARMAN change as caveats to the data.

Experiment Description:

During April/May 1986, the R&DC conducted a 4-week experiment to study the detectability of three VDSDs. These devices were hand-held orange smoke flares (HHOS), hand-held red flares (HHRF), and white life-ring strobes.

SRUs included utility boats (UTBs), patrol boats (WPBs), and HH-52A helicopters. Environmental conditions for the test included only good visibility and light wind and sea conditions.

Comments:

A major weakness of Tables 4-13a and 4-14a is that, while time on task (searching) proved to be statistically significant when estimating sweep width, the table contains no caveats for weather conditions. This analysis should be performed and included in the next revision to the NSARMAN. It is anticipated that wind effects on daylight use of HHOS will be much more significant than night use of HHRF.

Table 4-14b contains both time on task and wind speed effects on sweep width for white strobes attached to life jackets and life rings. This classification is included only for air search. The surface search table needs a caveat for weather conditions in which the sweep width data are valid. The air search results have been extrapolated outside the experimental dataset for the greater than 15-knot wind speed value. An upper bound, such as 20 or 25 knots, should be specified based on additional analysis.

As previously mentioned, short duration VDSDs do not support the sweep width concept. Searches should not be planned based on the assumption of an alert and cooperative search subject in order to provide a detection opportunity.

A source of corroborating information can be found in:

> Robe, R.Q. and Hover, G.L.; A Static Evaluation of Selected Visual Distress Signaling Devices. Report No. CG-D-15-85. USCG Research and Development Center and Analysis & Technology, Inc., January 1985.

Three interesting evaluations of lateral range are included in:

> Hover, G.L.; An Evaluation of the U.S. Coast Guard's Physical Detection Model for Visual Search. Report No. CG-D-02-89. Analysis & Technology, Inc., March 1988.

NSARMAN Table 4-14. Visual Sweep Width Estimates for Night Detection Aids

Sources of Information:

Source (1):

> CO USCG R&DC to Commandant (G-DST) Letter Ser. 3975.4/75101.2 dated 12 March 1985, Enclosure (1) Subject: NATIONAL SEARCH AND RESCUE MANUAL INPUTS.

Enclosure (1) to source (1):

> Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Enclosure (1) has the following comments on detection aid effectiveness:

> **Night Detection Aids:** Sea conditions, wind, and obscurations to visibility have a less detrimental effect on darkness detection aids. Even a flashlight has a chance of being seen. On clear nights, pyrotechnics have been sighted in excess of 40 nautical miles. For these reasons, night searches for distress signals will often provide the highest probability of detection. ... As with daylight estimates, adequate visibility, open terrain, and alerted searchers/signalers are assumed. A dark environment devoid of background lights or bright moonlight is also assumed. It should be noted further that, in areas where even light surface traffic is present, white lights and non-aerial red signals can easily be mistaken for navigation aids, running lights, warning beacons, or other such non-search objects.

The second source is Paragraph 2-3 - Table 2-5 of:

> Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Comments:

The primary experiment that supports the sweep width data was conducted off the south shore of Long Island, NY, in the fall of 1984. The following reference fully describes the experiment and captures all the relevant detection data:

> Robe, R.Q. and Hover, G.L.; A Static Evaluation of Selected Visual Distress Signaling Devices. Report No. CG-D-15-85. USCG Research and Development Center and Analysis & Technology, Inc., January 1985.

The report does not evaluate lateral range curves nor does it provide sweep width calculations. For long duration VDSDs, additional data analysis from the experiment might lead to generation of sweep width curves as described for Table 4-13.

As previously mentioned, short duration VDSDs do not support the sweep width concept. Searches should not be planned based on the assumption of an alert and cooperative search subject in order to provide a detection opportunity.

2.6 NSARMAN Paragraph 423. EPIRB/ELT Sweep Widths

Sources of Information:

This emergency position indicating radio beacon/emergency locator transmitter (EPIRB/ELT) sweep width information and guidance was provided by analysis conducted at the R&DC for the 1985 change to the NSARMAN.

The forwarding correspondence was CO Coast Guard R&DC letter serial 3975.4/751010.0 dated 12 March 1985. The correspondence forwarded: NATIONAL SEARCH AND RESCUE MANUAL INPUTS, authored by R.Q. Robe, LT L. Nash, and Dr. D.F. Paskausky of the R&D Center and by G.L. Hover and T.J. Mazour of Analysis & Technology, Inc.

The guidance remains unchanged in the current NSARMAN.

2.7 NSARMAN Table 4-15. Sweep Widths for Surface Vessel Radar (NM)

Sources of Information:

Source (1):

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Coast Guard Surface Vessel Radar Detection Performance. Report No. CG-D-18-82. USCG Research and Development Center and Analysis & Technology, Inc., April 1982.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (2) was forwarded by CO USCGR&DC to Commandant (G-DST) letter serial 3975.4/751010.2 dated 12 March 1985, and summarized the results of all sweep width data concerning AN/SPS-64(V) and AN/SPS-66 surface vessel radars (SVRs), and formatted the results for use in the 1985 change to the NSARMAN. The current NSARMAN table remains unchanged from that recommended in 1985.

Paragraphs 3.3.1.1, Table 3-3 and 3.3.1.2, Table 3-4 of source (3) provide the information for the current NSARMAN table.

Comments:

Source (1) contains important lateral range curves regarding AN/SPS-64 and AN/SPS-66 radar usage from 41-foot UTBs and 82-foot cutters. A good discussion of the radar equation and conversion of CDP to lateral range is included in the report.

The AN/SPS-66 radar has been replaced with the AN/SPS-69 radar. The table, while out of date, may underestimate the sweep width generated by a more capable radar. This needs to be confirmed experimentally.

2.8 NSARMAN Table 4-16. Sweep Widths for Forward-Looking Airborne Radar (AN/APS-133, AN/APN-215)

Sources of Information:

Source (1):

Ketchen, H.G.; St. Martin, J.; Hover, G.L.; and Mazour, T.J.; Evaluation of US Coast Guard Forward-Looking Airborne Radars. Report No. CG-D-17-84. USCG Research and Development Center and Analysis & Technology, Inc., March 1984.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1) does not present the sweep width data as listed in Table 4-16. Instead, the report shows the CDP curves from the experiment. Lateral range curves were generated from the CDP curves using a technique described in the report. The generated lateral range curves were integrated to obtain the sweep widths. The notes that document the sweep width calculations are unlocated.

Source (2) was forwarded by CO USCG R&DC to Commandant (G-DST) letter serial 3975.4/751010.2 dated 12 March 1985, and summarized the results of all sweep width data concerning AN/APS-133 and AN/APN-215 airborne radars and formatted the results for use in the 1985 change to the NSARMAN. The current NSARMAN table remains unchanged from that recommended in 1985 except that sweep width data from source (1) for medium and large targets are also included.

Source (3), paragraphs 3.3.2.1 and 3.3.2.2, Tables 3-5 and 3-6, present the data as listed in the current NSARMAN except that AN/APN-215 is incorrectly labeled AN/APN-125.

Experiment Description:

During 1983, the R&DC conducted field experiments off Ft. Pierce, FL, and Oregon Inlet, NC, to evaluate the small target detection capabilities of the AN/APS-127, AN/APS-133, and AN/APN-215 FLARs. The field data were compared to similar West German AN/APS-134 FLAR data to determine the benefits to SAR and ELT missions of using newer technology.

These experiments formed the basis of the current sweep width estimates of the AN/APS-133 and AN/APN-215 FLARs hosted on HC-130 aircraft and listed in NSARMAN Table 4-16.

Comments:

The experiment produced CDP curves, which must be converted into lateral range curves through a special integration process. Sweep widths are not directly obtainable from CDP curves.

2.9 NSARMAN Table 4-16a. Sweep Widths for Forward-Looking Airborne Radar (AN/APS-127)

Sources of Information:

Source (1):

Robe, R.Q.; Lewandowski, M.J.; Hover, G.L.; and Searle, H.S.; Preliminary Sweep Width Determination for HU-25A Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-11-88. USCG Research and Development Center and Analysis & Technology, Inc., December 1987.

Source (2):

Lewandowski, M.J.; Robe, R.Q.; Allen, A.A.; Reynolds, W.H.; Hover, G.L.; Exley, S.A.; Searle, H.S.; and Clark, P.V.; Sweep Width Determination for HU-25B Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-01-90. USCG Research and Development Center and Analysis & Technology, Inc., September 1989.

Source (3):

Memorandum: Oceanography Branch, USCG Research and Development Center, R.Q. Robe to LT Schaefer, G-NRS. Change 1, National SAR Manual; comments on. 20 June 1989.

Paragraph 3 of source (3) forwarded the current contents of NSARMAN Table 4-16a.

Experiment Description:

In June of 1987, the R&DC conducted an experiment to determine the detection performance of both AN/APS-131 and AN/APS-127 airborne radars on the HU-25A Falcon aircraft. The experiment was conducted in the coastal waters off Ft. Pierce, FL, with the support of Coast Guard Air Station Miami.

During October and December 1988, the R&DC conducted two experiments to determine sweep widths for airborne radar search by Coast Guard HU-25B aircraft. Search objects were 4- to 10-person life rafts and 23- to 42-foot recreational-type boats. Two radar systems were evaluated in these experiments: the AN/APS-127 FLAR and the AN/APS-131 side-looking airborne radar (SLAR). The experiments were conducted in Block Island Sound and off Nova Scotia, Canada. The sea conditions included 0- to 3.5-foot significant wave heights and 0- to 28-knot winds. Search altitudes varied from 500 to 5700 feet on the 20-nmi range scale and 2000 to 4000 feet on the 40-nmi range scale.

Comments:

Sweep width data based on the 1987 experiment included significant wave heights of < 2 feet and 2 to 3 feet for 6- to 10-person life rafts and < 2 feet and 2 to 5 feet for 23- to 42-foot boats.

Search altitude is included as an important statistical variable in the NSARMAN Table 4-16a, but was not separately analyzed in the report of the 1988 experiment. Many sweep widths included in the NSARMAN Table 4-16a are based on extrapolations of test data.

Sweep widths varied with significant wave heights and target size.

The sweep widths were derived from integration of the following POD as a function of lateral range, Pd(x):

$$Pd(x) = A/((x-B)^2+C)$$

This model is referred to as the "Unimodal Model." Both FLARs and SLARs tend to have a POD peak somewhere in the center region of their detection envelope as a function of lateral range. The above equation does not have the ability to include weather or other effects in the model. The logistic regression model is used to determine the important ways to cut the dataset. Each data subset is statistically fit to the unimodal model.

The following data table was derived from the reports for AN/APS-127 FLAR and includes unpublished regression fit data derived from the graphs in the reports:

From Source (1):

Target	Range Scale (nmi)	Sea Height (ft)	Altitude (ft)	Regression Coefficients A	B	C
Life Rafts	10	< 2	300–500	3.77	4.2	8.39
	10	2–3	300–500	0.72	5.7	3.61
24- to 43-ft Boats	10	< 2	500	26.12	2.6	31.10
	10	< 2	2500–5000	8.39	3.8	13.54
	10	2–5	2500–5000	11.80	3.6	25.11

From Source (2):

Target	Range Scale (nmi)	Sea Height (ft)	Altitude (ft)	Regression Coefficients A	B	C
Rafts	20	< 2	500–5700	5.61	4.5	12.75
	20	2–3	500–5700	2.79	5.0	21.43
	40	2–3.5	2000–4000	26.49	18.5	139.4
23- to 30-ft Boats	20	< 2	500–5700	46.79	9.2	106.3
	20	2–3	500–5700	7.53	7.8	22.82
	40	2–3.5	200–4000	175.1	15.3	795.9
32- to 42-ft Boats	20	< 2	500–5700	96.65	8.8	123.9
	20	2–3	500–5700	64.17	8.0	136.5
	40	2–3.5	2000–4000	91.37	12.0	194.4

The coefficients have the following relationships:

The Pd(x) peaks at x = B.

At x = B, Pd(max) = A/C.

No particular meaning should be attached to the magnitude of A or C.

2.10 NSARMAN Table 4-17. Sweep Widths for Side-Looking Airborne Radar

Sources of Information:

Source (1):

Osmer, S.R.; Edwards, N.C.; Hover, G.L.; and Mazour, T.J.; Evaluation of Two AN/APS-94 Side-Looking Airborne Radar Systems in the Detection of Search and Rescue Targets. Report No. CG-D-64-81. USCG Research and Development Center and Analysis & Technology, Inc., August 1981.

Source (2):

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Utilization of AN/APS-94 Side-Looking Airborne Systems in Search and Rescue. Report No. CG-D-14-82. USCG Research and Development Center and Analysis & Technology, Inc., April 1982.

Source (3):

Robe, R.Q.; Edwards, N.C., Jr.; Murphy, D.L.; Thayer, N.; Hover, G.L.; and Kop, M.E.; Evaluation of Surface Craft and Ice Target Detection Performance by the AN/APS-135 Side-Looking Airborne Radar (SLAR). Report No. CG-D-2-86. USCG Research and Development Center, International Ice Patrol, and Analysis & Technology, Inc., December 1985.

Source (4):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Data from sources (1) and (2) are possibly no longer valid because of upgrades to SLAR systems. The table needs to be reevaluated based on the results of testing the AN/APS-131 SLAR (see Comments section).

Source (4), paragraphs 3.3.1.1 and 3.3.3.2, Tables 3-7 and 3-8, present the data as listed in the current NSARMAN. Sweep width for Douglas Sea State 0-1 - Metal Targets is now 57 vice 54 as listed in source (4).

Experiment Description:

During Fall 1978, Fall 1979, Spring 1980, and Winter 1981, four SLAR detection experiments were conducted in conjunction with visual detection experiments. The system tested was the AN/APS-94 SLAR. In addition, during Spring 1985, the R&DC conducted an open-ocean evaluation of the AN/APS-135 SLAR in cooperation with the International Ice Patrol. Detectability data were collected on surface craft ranging from a 4-person life raft to a 55-meter ship. Target detection performance was affected by target size, lateral range, search altitude, and sea state.

Comments:

When digital processing upgrades to CG SLARs are completed, experiments to verify historical sweep width data should be conducted.

The latest available data for the AN/APS-131 SLAR were collected during October and December 1988. These data are not, however, the basis for the NSARMAN Table 4-17 SLAR sweep widths. The following reference describes the experiment and provides newer detailed information on SLAR sweep widths.

> Lewandowski, M.J.; Robe, R.Q.; Allen, A.A.; Reynolds, W.H.; Hover, G.L.; Exley, S.A.; Searle, H.S.; and Clark, P.V.; Sweep Width Determination for HU-25B Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-01-90. USCG Research and Development Center and Analysis & Technology, Inc., September 1989.

The R&DC conducted two experiments to determine sweep widths for airborne radar search by Coast Guard HU-25B aircraft employing AN/APS-127 FLAR and the AN/APS-131 SLAR. Search objects were 4- to 10-person life rafts and 23- to 42-foot recreational-type boats.

The following data table was derived from the above report for AN/APS-131 SLAR and includes previously unpublished regression fit data derived from the graphs in the reports:

Target	Range Scale (nmi)	Sea Height (ft)	Altitude (ft)	Regression Coefficients A	B	C
Rafts	20	< 2	2000–5000	42.60	12.4	96.81
	20	2–4	2000–5000	68.65	15.8	208.0
	40	1–3.5	2000–4000	55.10	17.0	211.9
23- to 30-ft Boats	20	< 2	2000–5000	20.19	8.3	32.04
32- to 42-ft Boats	20	< 2	2000–5000	276.7	6.8	439.3
	20	2–3	2000–5000	217.9	16.0	435.9
	40	1–3.5	2000–4000	115.7	16.0	282.3

The coefficients have the following relationships:

> The Pd(x) peaks at x = B.
>
> At x = B, Pd(max) = A/C.

No particular meaning should be attached to the magnitude of A or C.

2.11 NSARMAN Table 4-18. Sweep Widths for Forward-Looking Infrared

Sources of Information:

Source (1):

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Preliminary Assessment of US Coast Guard Short Range Recovery (SRR) Forward-Looking Infrared (FLIR) System Small Target Detection Performance. Report No. CG-D-20-82. USCG Research and Development Center and Analysis & Technology, Inc., May 1982.

The sweep widths of Table 4-18 greatly exceed the values noted in source (1) and have their origins in analysis conducted to produce the following reference:

Source (2):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (2), paragraph 4.3, Table 4-2, presents the data listed in the current NSARMAN table.

Experiment Description:

In 1981 the R&DC conducted a detection experiment with an HH-52A helicopter equipped with a prototype (and now obsolete) Northrop SeaHawk FLIR system. Targets for the experiment included 15- to 19-foot fiberglass boats, 4- and 7-man life rafts and simulated PIW targets. The tests were conducted in Block Island Sound during September through November.

The actual data collected were used to generate CDP curves against the targets in wide field of view (WFOV) and narrow field of view (NFOV) FLIR operating modes. From the CDP curves, analysis was conducted to estimate lateral range curves for targets with the closest points of approach (CPAs) of approximately 0.1 to 0.2 nmi.

Comments:

New FLIR lateral range curves need to be produced using the more modern FLIR System 2000 currently in use on USCG HH-60 helicopters. The sweep width data in the NSARMAN are out of date and should be replaced.

2.12 NSARMAN Table 4-19. SLAR/Visual Weather Conditions

Sources of Information:

Source (1):

> Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

The two sets of weather conditions "good" and "fair" characterize the upper and lower bounds represented in the Coast Guard SLAR database taken from experiments using HC-130 aircraft equipped with AN/APS-94D SLAR.

Source (1), paragraph 3.3.1.1, presents the data listed in the current NSARMAN table.

Comments:

The structure of this table is one of the best examples of the difficulty in creating a unified data structure for weather conditions in a database. "Good" and "fair" have different meanings for different sensor types. Therefore, a special table of weather conditions needs to be created for special purposes. This is to be avoided whenever possible in database design.

2.13 NSARMAN Table 4-20. SLAR/Visual Sweep Widths (NM)

Sources of Information:

Source (1):

> Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), Table 5-2, presents the data exactly as listed in the current NSARMAN.

Comments:

AN/APS-131 Sweep Width Source:

> Lewandowski, M.J.; Robe, R.Q.; Allen, A.A.; Reynolds, W.H.; Hover, G.L.; Exley, S.A.; Searle, H.S.; and Clark, P.V.; Sweep Width Determination for HU-25B Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-01-90. USCG Research and Development Center and Analysis & Technology, Inc., September 1989.

The data used for combined visual and AN/APS-94D SLAR search are outdated. New analysis using AN/APS-131 data should be combined with visual data to replace this table. This SLAR and the AN-APS-135 will soon be upgraded to digital systems. Updates of SLAR and SLAR/Visual sweep width tables should be accomplished after the upgrades.

2.14 NSARMAN Table 4-21. UTB SVR/Visual Sweep Width for Targets With Radar Reflectors

Sources of Information:

Source (1):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), paragraph 5.3.2, Table 5-4, is the source of the NSARMAN data.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Nash, L.; Hover, G.L.; and Burns, R.E.; Additional Analyses of Probability of Detection (POD) in Search and Rescue (SAR) Project Data. Report No. CG-D-55-82. USCG Research and Development Center and Analysis & Technology, Inc., September 1982.

Comments:

The original work used to provide the information for sources (1) and (2) was contained in source (3).

The AN/SPS-66 radar on UTBs has been replaced by the AN/SPS-69 radar. Data for this table are now out of date and may not be representative of radars currently in use on 41-foot UTBs.

2.15 NSARMAN Table 4-22. UTB SVR/Visual Sweep Width for Targets Without Radar Reflectors

Sources of Information:

Source (1):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), paragraph 5.3.2, Table 5-5, is the source of the NSARMAN data.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Nash, L.; Hover, G.L.; and Burns, R.E.; Additional Analyses of Probability of Detection (POD) in Search and Rescue (SAR) Project Data. Report No. CG-D-55-82. USCG Research and Development Center and Analysis & Technology, Inc., September 1982.

Comments:

The original work used to provide the information for sources (1) and (2) was contained in source (3).

The AN/SPS-66 radar on UTBs has been replaced by the AN/SPS-69 radar. Data for this table are now out of date and may not be representative of radars currently in use on 41-foot UTBs.

2.16 NSARMAN Table 4-23. WPB SVR/Visual Sweep Width for Targets With Radar Reflectors

Sources of Information:

Source (1):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), paragraph 5.3.2, Table 5-6, is the source of the NSARMAN data.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Nash, L.; Hover, G.L.; and Burns, R.E.; Additional Analyses of Probability of Detection (POD) in Search and Rescue (SAR) Project Data. Report No. CG-D-55-82. USCG Research and Development Center and Analysis & Technology, Inc., September 1982.

Comments:

The original work used to provide the information for sources (1) and (2) was contained in source (3).

2.17 NSARMAN Table 4-24. WPB SVR/Visual Sweep Width for Targets Without Radar Reflectors

Sources of Information:

Source (1):

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Source (1), paragraph 5.3.2, Table 5-7, is the source of the NSARMAN data.

Source (2):

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Source (3):

Nash, L.; Hover, G.L.; and Burns, R.E.; Additional Analyses of Probability of Detection (POD) in Search and Rescue (SAR) Project Data. Report No. CG-D-55-82. USCG Research and Development Center and Analysis & Technology, Inc., September 1982.

Comments:

The original work used to provide the information for sources (1) and (2) was contained in source (3).

SECTION 3.0

RESEARCH ON THE SWEEP WIDTH ORIGINS OF THE TABLES IN THE COAST GUARD ADDENDUM TO THE NATIONAL SEARCH AND RESCUE MANUAL

3.1 Coast Guard Addendum to NSARMAN Tables 2-8 and 2-9. AN/APS-137 Radar (Aircraft) Sweep Widths

Sources of Information:

Source (1):

The letter reference is:

Commanding Officer, USCG Research and Development Center
To: Commandant, US Coast Guard (G-NRS)
Via: Commandant, US Coast Guard (G-ER)
Serial: 3900/741012.4.1 dated: 9 December 1994.

The following final report contains data that formed the basis for the referenced letter. The letter includes analysis using wind speeds that greatly extend beyond the data taken in the experiments reported on in the reference below. The Coast Guard Addendum to the NSARMAN Tables 2-8 and 2-9 may need a caveat warning the user of analysis that extends outside the experimental dataset.

Source (2):

Robe, R.Q.; Raunig, D.L.; and Marsee, R.L.; AN/APS-137 Forward Looking Airborne Radar (FLAR) Evaluation Final Report. Report No. CG-D-18-94. USCG Research and Development Center and Analysis & Technology, Inc., May 1994.

Experiment Description:

During April 1992, September and October 1992, and May 1993, the R&DC conducted experiments to determine the sweep width for the AN/APS-137 FLAR when searching for 4-, 6-, and 10-person life rafts and small recreational boats. Workboats used to deploy the rafts during the Fall 1992 and Spring 1993 experiments were used as targets of opportunity.

Experiments were conducted in the coastal waters off the west coast of Florida from Wacussa Bay to Gasparilla Island and on Lake Erie. The dataset included 0.3- to 3.6-foot sea heights and 1.0- to 15.2-knot winds.

Statistically sensitive parameters included radar range scale, lateral range, and wind speed for life rafts. Small boat sweep widths were also sensitive to boat size.

Comments:

The fitting equation is the "Unimodal Model," where POD is a function of lateral range (x), Pd(x) = A/((x-B)^2+C). The report contains a complete summary, in Appendix B, of A, B, C constants for APS-127 and APS-137 experiments against the targets noted. These equations are not the values reported in the referenced letter.

Reconstruction of the fitted equations in the letter follows:

W = Sweep Width
WS = On-scene Surface Winds (knots)
nil in the table implies that the model has a predicted W less than zero.

16-nmi range scale:

4- to 10-person life raft:
W = 12.30 - 0.5963 WS^2

17- to 25-foot recreational boat
W = 13.85 - 0.3606 WS^2

26- to 35-foot recreational boat
W = 16.67 - 0.7984 WS^2

36- to 50-foot recreational boat
W = 21.05 - 0.7026 WS^2

32-nmi range scale:

17- to 25-foot recreational boat
W = 17.67 - 0.3615 WS^2

26- to 35-foot recreational boat
W = 22.05 - 0.8025 WS^2

36- to 50-foot recreational boat
W = 29.04 - 0.7015 WS^2

The referenced letter claims that sweep width is proportional to both length squared and wind speed squared. The data in the table support proportionality with wind speed squared. The data support a first power fit with length at high wind speeds and a second power fit with length at low wind speed. Since this is inconsistent, there appear to be calculation errors in the table. According to the letter, the data in the table should fit a model such as W = K1+ K2*L^2 + K3*WS^2, but do not.

3.2 Coast Guard Addendum to NSARMAN Tables 2-10 and 2-11. Sweep Widths for Night Vision Goggles (NVG) Searches

Sources of Information:

Source (1):

Reynolds, W.H.E.; Robe, R.Q.; Hover, G.L.; and Plourde, J.V.; Evaluation of Night Vision Goggles for Maritime Search and Rescue, Interim Report. Report No. CG-D-14-90. USCG Research and Development Center and Analysis & Technology, Inc., April 1990.

Source (2):

Reynolds, W.H.E.; Robe, R.Q.; Hover, G.L.; and Plourde, J.V.; Evaluation of Night Vision Goggles for Maritime Search and Rescue, Interim Report. Report No. CG-D-01-91. USCG Research and Development Center and Analysis & Technology, Inc., August 1990.

Source (3):

Robe, R.Q.; Plourde, J.V.; and Hover, G.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (Third NVG Report). Report No. CG-D-03-92. USCG Research and Development Center and Analysis & Technology, Inc., June 1991.

Source (4):

Robe, R.Q.; Plourde, J.V.; and Marsee, R.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (Joint Canadian/U.S. Coast Guard Experiment), Interim Report. Report No. CG-D-13-92. USCG Research and Development Center and Analysis & Technology, Inc., November 1991.

Source (5):

Robe, R.Q.; Raunig, D.L.; Plourde, J.V.; and Marsee, R.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue, (Summary NVG Report). Report No. CG-D-16-92. USCG Research and Development Center and Analysis & Technology, Inc., February 1992.

Source (6):

Robe, R.Q. and Plourde, J.V.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (HH-3/HH-60 Comparison Report), Final Report. Report No. CG-D-09-93. USCG Research and Development Center and Analysis & Technology, Inc., January 1993.

Comments:

The correspondence that forwarded the current values of sweep width found in the Coast Guard Addendum to the NSARMAN has not been located. Tables 2-10 and 2-11 are dated 19 May 1995. Sources (5) and (6) both contain information similar, but not identical, to the data in Table 2-11. Additional analysis was accomplished to provide the information for Tables 2-10 and 2-11.

SECTION 4.0

SWEEP WIDTH INFORMATION SOURCES FOR THE NATIONAL SEARCH AND RESCUE MANUAL AND THE COAST GUARD ADDENDUM

4.1 Primary Sources

Robe, R.Q.; Nash, L.; Paskausky, D.F., Ph.D.; Hover, G.L.; and Mazour, T.J.; National Search and Rescue Manual Inputs. USCG Research and Development Center and Analysis & Technology, Inc., March 1985.

Hover, G.L. and Mazour, T.J.; Guide for Visual and Electronic Search. USCG Research and Development Center and Analysis & Technology, Inc., August 1985.

Memorandum: Oceanography Branch, USCG Research and Development Center, R.Q. Robe to LT Schaefer, G-NRS. Change 1, National SAR Manual; comments on. 20 June 1989.

Letter report sent by R.Q. Robe.

Commanding Officer, USCG Research and Development Center
To: Commandant, US Coast Guard (G-NRS)
Via: Commandant, US Coast Guard (G-ER)
Serial: 3900/741012.4.1 dated: 9 December 1994.

4.2 Supporting Sources

Edwards, N.C.; Osmer, S.R.; Mazour, T.J.; and Bouthilette, D.B.; Analysis of Visual Detection Performance (Fall 1978 Experiment). Report No. CG-D-03-79. USCG Research and Development Center and Analysis & Technology, Inc., December 1978.

Edwards, N.C.; Osmer, S.R.; Mazour, T.J.; and Hover, G.L.; Analysis of Visual Detection Performance for 16-Foot Boat and Life Raft Targets. Report No. CG-D-20-80. USCG Research and Development Center and Analysis & Technology, Inc., February 1980.

Edwards, N.C.; Osmer, S.R.; Mazour, T.J.; and Bemont, R.A.; Evaluation of National SAR Manual Probability of Detection Curves. Report No. CG-D-41-80. USCG Research and Development Center and Analysis & Technology, Inc., September 1980.

Osmer, S.R.; Edwards, N.C.; Hover, G.L.; and Mazour, T.J.; Evaluation of Two AN/APS-94 Side-Looking Airborne Radar Systems in the Detection of Search and Rescue Targets. Report No. CG-D-64-81. USCG Research and Development Center and Analysis & Technology, Inc., August 1981.

Edwards, N.C.; Osmer, S.R.; Mazour, T.J.; and Hover, G.L.; Factors Affecting Coast Guard SAR Unit Visual Detection Performance. Report No. CG-D-09-82. USCG Research and Development Center and Analysis & Technology, Inc., August 1981.

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Utilization of AN/APS-94 Side-Looking Airborne Systems in Search and Rescue. Report No. CG-D-14-82. USCG Research and Development Center and Analysis & Technology, Inc., April 1982.

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Coast Guard Surface Vessel Radar Detection Performance. Report No. CG-D-18-82. USCG Research and Development Center and Analysis & Technology, Inc., April 1982.

Osmer, S.R.; Nash, L.; Hover, G.L.; and Mazour, T.J.; Preliminary Assessment of US Coast Guard Short Range Recovery (SRR) Forward-Looking Infrared (FLIR) System Small Target Detection Performance. Report No. CG-D-20-82. USCG Research and Development Center and Analysis & Technology, Inc., May 1982.

Nash, L.; Hover, G.L.; and Burns, R.E.; Additional Analyses of Probability of Detection (POD) in Search and Rescue (SAR) Project Data. Report No. CG-D-55-82. USCG Research and Development Center and Analysis & Technology, Inc., September 1982.

Ketchen, H.G.; Nash, L.; and Hover, G.L.; Analysis of U.S. Coast Guard HU-25A Visual and Radar Detection Performance. Report No. CG-D-29-83. USCG Research and Development Center and Analysis & Technology, Inc., June 1983.

Ketchen, H.G.; St. Martin, J.; Hover, G.L.; and Mazour, T.J.; Evaluation of US Coast Guard Forward-Looking Airborne Radars. Report No. CG-D-17-84. USCG Research and Development Center and Analysis & Technology, Inc., March 1984.

Robe, R.Q. and Hover, G.L.; A Static Evaluation of Selected Visual Distress Signaling Devices. Report No. CG-D-15-85. USCG Research and Development Center and Analysis & Technology, Inc., January 1985.

Robe, R.Q.; Edwards, N.C., Jr.; Murphy, D.L.; Thayer, N.; Hover, G.L.; and Kop, M.E.; Evaluation of Surface Craft and Ice Target Detection Performance by the AN/APS-135 Side-Looking Airborne Radar (SLAR). Report No. CG-D-2-86. USCG Research and Development Center, International Ice Patrol, and Analysis & Technology, Inc., December 1985.

Robe, R.Q. and Hover, G.L.; Visual Sweep Width Determination for Three Visual Distress Signaling Devices. Report No. CG-D-30-86. USCG Research and Development Center and Analysis & Technology, Inc., September 1986.

Robe, R.Q.; Lewandowski, M.J.; Hover, G.L.; and Searle, H.S.; Preliminary Sweep Width Determination for HU-25A Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-11-88. USCG Research and Development Center and Analysis & Technology, Inc., December 1987.

Hover, G.L.; An Evaluation of the U.S. Coast Guard's Physical Detection Model for Visual Search. Report No. CG-D-02-89. Analysis & Technology, Inc., March 1988.

Memorandum: From Hover, G.L., A&T, To: LT Bill Reynolds, R&DC; Letter Report of Analysis Results Detailing a Comparison of USCG Physical Detection Model Search Performance Predictions With Canadian Field Test Data., September 22, 1988.

Lewandowski, M.J.; Robe, R.Q.; Allen, A.A.; Reynolds, W.H.; Hover, G.L.; Exley, S.A.; Searle, H.S.; and Clark, P.V.; Sweep Width Determination for HU-25B Airborne Radars: Life Raft and Recreational Boat Targets. Report No. CG-D-01-90. USCG Research and Development Center and Analysis & Technology, Inc., September 1989.

Reynolds, W.H.E.; Robe, R.Q.; Hover, G.L.; and Plourde, J.V.; Evaluation of Night Vision Goggles for Maritime Search and Rescue, Interim Report. Report No. CG-D-14-90. USCG Research and Development Center and Analysis & Technology, Inc., April 1990.

Reynolds, W.H.E.; Robe, R.Q.; Hover, G.L.; and Plourde, J.V.; Evaluation of Night Vision Goggles for Maritime Search and Rescue, Interim Report. Report No. CG-D-01-91. USCG Research and Development Center and Analysis & Technology, Inc., August 1990.

Robe, R.Q.; Plourde, J.V.; and Hover, G.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (Third NVG Report). Report No. CG-D-03-92. USCG Research and Development Center and Analysis & Technology, Inc., June 1991.

Robe, R.Q.; Plourde, J.V.; and Marsee, R.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (Joint Canadian / U.S. Coast Guard Experiment), Interim Report. Report No. CG-D-13-92. USCG Research and Development Center and Analysis & Technology, Inc., November 1991.

Robe, R.Q.; Raunig, D.L.; Plourde, J.V.; and Marsee, R.L.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (Summary NVG Report). Report No. CG-D-16-92. USCG Research and Development Center and Analysis & Technology, Inc., February 1992.

Robe, R.Q. and Plourde, J.V.; Evaluation of Night Vision Goggles (NVG) for Maritime Search and Rescue (HH-3/HH-60 Comparison Report), Final Report. Report No. CG-D-09-93. USCG Research and Development Center and Analysis & Technology, Inc., January 1993.

Robe, R.Q.; Raunig, D.L.; and Marsee, R.L.; AN/APS-137 Forward Looking Airborne Radar (FLAR) Evaluation Final Report. Report No. CG-D-18-94. USCG Research and Development Center and Analysis & Technology, Inc., May 1994.

SECTION 5.0

RESULTS, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

5.1 Detection Performance Database

A fully operational database was created that contained all the detection performance information in the sweep width tables of the SAR manuals. The operator selects the search type from a list of clearly named macros. The macro opens the form, which is related to the appropriate sweep width table. A pulldown list of search input selections appears. The operator selects the inputs for the search and then applies the "filter by form" operation. This causes the sweep width for the selected conditions to appear.

The data structure is robust in the sense that future new tables can easily be inserted without disrupting or redoing the current structure. Each table of sweep widths contains only those pulldown selections that are applicable to a particular table. Thus, the operator, with very few exceptions, can obtain an answer for each situation presented via the selection lists. No operator typing is desired or required.

The effort in creating the data structure pointed out many deficiencies in categorizing information that were not immediately obvious. These were most pronounced in the areas of characterizing weather conditions and naming SAR targets.

5.2 Pedigree of Sweep Width Information

The sweep width data in every SAR manual table were traceable to one or more primary sources. Except for significant sections of the NSARMAN Uncorrected Visual Sweep Width tables, each primary source was supported by R&DC reports documenting field test results of POD in SAR experiments or sweep width experiments measuring lateral range. For tables based on field test data, a block of information is generally missing on medium-to-large-size search targets (30 feet or greater in length) and also for poor-to-very poor weather conditions. As a result, some sweep width extrapolations based on analysis may be invalid.

For most tables, there is a solid record of R&DC correspondence recommending the values that appear in the tables. In a few cases, correspondence made minor changes in sweep width values from those values noted in supporting field test reports. In some cases, these decisions are no longer traceable.

It was originally planned to attach a database field to every sweep width number in every table to document the pedigree of all data. This was found to be unnecessary since each table was traceable to a given set of experiments and forwarded as a whole by R&DC correspondence. Therefore, this aspect of the database may be completed in a future effort.

5.3 Secondary Numerical Research

A preliminary and abbreviated study of the relationship between the sweep widths produced by the Visual Sweep Width - Physical Detection Model (inverse cube law of visual detection) and the Logistic Regression Lateral Range Model yielded surprising results. The physical detection model was previously "tuned" using actual field test results to increase the accuracy of the predicted sweep widths. The current tables for uncorrected VSW are based on corrections to the physical detection model recommended by the R&DC in 1985.

The Uncorrected Visual Sweep Width tables are the longest tables in the NSARMAN. The helicopter and fixed-wing aircraft VSW tables have 1,400 entries each. It was discovered that sections of the uncorrected VSW table can be replaced with a logistic regression sweep width model that uses a single formula to predict sweep width. This discovery requires further investigation. Conversion of sweep width tables from one model type to another does not improve sweep width accuracy. It may be possible, however, through analysis, to improve those portions of the VSW tables that are validated with field test results by adding selected weather-related variables to the logistic regression model in order to eliminate crude correction factors based on weather.

The VSW experiments performed by the R&DC from 1978 through 1983 were re-investigated from the standpoint of sweep width formulas using the logistic regression model. A technique may be available to make the model more general so that one model could be used for more than one search platform type searching for one of several target types. The technique was made possible through the use of improved statistical software not available in 1980. This analysis is not complete but is another example of the ability to replace tables or sections of tables with formulas in a future search planning tool.

5.4 Weather Conditions

All statistical analysis discovered to date has analyzed the first power of observables. It is known intuitively that as wind speed increases there is a corresponding nonlinear decrease in sweep width. On several models, a significantly better statistical fit was provided with a regression model of wind speed to the 3/2 power. More research into the relationship of wind speed to lateral range curve shape needs to be conducted. If there is a strong theoretical basis for such a model, it would be possible to extend sweep width estimates beyond those normally encountered during experimental conditions.

The analysis work with the VSW tables indicated a strong interaction term between target length and visibility. This is also intuitively appealing because, when visibility is very high, large targets can be seen at long distances. Small target sweep width does not benefit nearly as much from excellent visibility conditions. Additional cross product analysis should be accomplished with respect to target length to help obtain a more unified approach to sweep width estimation.

Weather conditions strongly affect the shape of lateral range curves. A significant effort should be placed on unifying the effects of weather on detection performance across a wide variety of target types. This is another important area in which to use statistical cross product analysis on previously collected data.

5.5 Cataloging of Models

A complete list of all logistic regression lateral range curve mathematical models produced since 1978 should be compiled. These models, based on field test data, should be cataloged with the limits of the experimental dataset clearly defined. Potentially “safe” regions of model extension outside these limits should also be estimated.

It may also be possible to replace the unimodal model used for generating lateral range curves for airborne radars with a quadratic form of the logistic regression model.

5.6 Tuning and Extension of Existing Models

It may be possible to significantly improve the utility of existing models by conducting simple experiments carefully designed to extend the ability to interpolate among existing search performance data. For example, a visual detection model could be extended using a 60-foot sailboat or a 120-foot fishing vessel to collect visual detection performance data on larger targets. By combining small and larger target models, interpolation of lateral range curves for intermediate target sizes could safely fill in gaps in the knowledge base.

5.7 Elimination of Outdated Information

Some sweep width tables need another revision. Detection performance information for new search equipment should be added and old information should be either revalidated, adjusted, or eliminated from the SAR manuals. For example, Coast Guard surface search radars have been replaced since the field tests conducted in the early 1980s.

5.8 New Search Planning Tools

This research has important implications concerning the development of new SAR planning methods and tools. The Coast Guard has a significant body of detection performance data based on 20 years of field test results involving targets routinely encountered in real-world SAR operations. All detection performance field test data from these experiments still exist in the interim and final reports of the field tests. Future R&D efforts should concentrate on using the available field test data to formulate a consolidated approach to mathematically modeling detection performance for Coast Guard SAR operations. Future search planning tools, detection performance models, and SAR tactical development tools should be based, to the maximum extent possible, on the results of Coast Guard field test detection experiments.

Analysis of field test data provides proven lateral range curves for each situation tested. The lateral range curve has more value in a simulation model than its integral - the sweep width. Mathematical models of these lateral range curves should be directly used as inputs to algorithms in future search planning tools. Current search planning software uses sweep width data to plan search track spacing. This uses a single sweep width number taken from a look-up table. Improved search simulation software could "fly" a lateral range curve model through the simulated search area. The mathematical model of the lateral range curve may have many sensitive parameters that could be optimized for a specific situation. Some of these parameters could include search altitude, search speed, track orientation to the wind, and local weather condition inputs to the model.

Search asset allocation decisions, SAR asset search tactics, selection of search sensor types, and search pattern planning could all benefit from new search planning tools based on direct use of lateral range curve mathematical models. The new search performance database could be used to more quickly plan searches using current search planning techniques. In addition, the database could easily be extended to store lateral range curve mathematical models for use in search simulation software using the improved computing power available in Coast Guard Standard Workstation III and follow-on workstations.

5.9 Future R&D Efforts

The R&DC obtained substantial amounts of experimental detection performance data before the common usage of the desktop personal computer. Newer, more powerful computers and mathematical analysis tools now exist that can compute, in seconds, problems that took hours using computers of twenty years ago. New analyses of data taken from previous field tests may provide more accurate search performance estimates using cross product statistical techniques that are now available with the most modern statistical analysis packages. It would be prudent to obtain as much information as possible from previously conducted field tests using new analysis techniques. The Coast Guard should place a high priority on taking a new look at selected field tests, especially those involving visual detection (such as the tests conducted from 1978 through 1983).

Conducting an efficient search involves knowing where to search and knowing how best to search. Twenty years of field test data collected against SAR targets commonly encountered provide the best proven knowledge base of measurable parameters that affect how to perform successful searches. Parallel R&DC efforts to answer the question of where best to search should reduce the number of SAR assets required for the search. A reduction in the average time to locate a SAR target based on use of better planning tools, including more accurate search performance models, will reduce average SAR mission time, thus reducing average cost per mission while improving the survivor recovery success rate.