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7. Author(s) J. R. Frost (Soza & Co.) L. D. Stone (Metron, Inc.)	8. Performing Organization Report No. R&DC 554
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15. Supplementary Notes

The R&D Center's technical point of contact is Dr. Jennifer Dick O'Donnell, 860-441-2741, email: jodonnell@rdc.uscg.mil.

16. Abstract (MAXIMUM 200 WORDS)

Fundamental limitations inherent in manual search planning methods have severely limited the application of advances in several areas that could improve the efficiency and effectiveness of the U.S. Coast Guard's search and rescue mission. These areas include advances in search theory, environmental data products, knowledge of detection profiles for various sensors, and knowledge of leeway behavior. The U.S. Coast Guard's computerized search planning aids have not kept up with advances in these areas or with technology in general. This report reviews the history and recent advances of search theory and its application to a variety of search problems. It then reviews the history of the U.S. Coast Guard's search planning methods, showing where search theory was initially applied, albeit in a necessarily very limited way, and where later modifications departed from the theoretical basis of the original methodology. Several computerized search planning decision support tools are analyzed and compared, as are the differences between an analytic approach and a simulation approach. The results are summarized in a matrix.

The U.S. Coast Guard needs a new search planning decision support tool for search and rescue and other missions. This tool should use the simulation approach due to its power and flexibility as compared to analytic techniques.

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EXECUTIVE SUMMARY

This report describes the developments in the field of search theory from its origins during World War II to the present day. The completion of this report coincides with the formation of a team to develop the Coast Guard's (CG) new search planning tool, thus providing a perfect opportunity to use this knowledge to develop a search tool that can handle more complex search scenarios with more accurate predictive capabilities. The compromises, simplifications and inaccuracies that have been introduced into the CG search theory over time are described in this report. This report also presents recommendations for the form and functionality of the CG's new search planning tool. These findings can provide the basis for the CG's new search theory tool.

The basic principles of search theory were first applied to SAR planning around 1957 when the U.S. Coast Guard published its search planning doctrine in a search and rescue manual. To apply search theory to practical SAR planning problems, since computers were not then widely available, simplifications to the theory had to be made to develop a method feasible for hand calculations. This became known as the "classical search planning method" (CSPM), and it remains the basis for search planning support tools today.

CSPM was originally a scientifically based, analytic method that was appropriate for the technology and data available when it was implemented in 1957. However, due to the technological limitations, it could address only the simplest of SAR scenarios. Later, attempts were made to extend the methodology to more typical, and more complex, situations. Sometime after 1963, a number of sub-optimal "field modifications" were made that are inconsistent with the underlying theory. The most notorious of these modifications is the Min/Max technique, which violates some of the basic assumptions of the CSPM and the scientific principles on which it was based. Partial attempts to rectify this situation, like the mid-point compromise, were not always improvements.

The Search and Rescue Planning (SARP) system, the first implementation of search planning support on computers, occurred around 1970, well before the microcomputer age. SARP was basically a computerized version of the then current version of the modified CSPM with somewhat improved use of environmental data and drift computations. A few years later SARP was joined by the Computer Assisted Search Planning (CASP) system that took a computer simulation approach to the search planning and evaluation problem. Unfortunately, Coast Guard search planning support tools have not kept pace with technological advances in three important respects. First, they have not kept up with advances in search theory and algorithm development relevant to the practical application of search theory using computer simulation. Secondly, modifications made to the CSPM to make it applicable to typical, complex search scenarios are inconsistent with the basic theory. Third, and most importantly, the tools have generally not kept pace with the significant increases in the amount, level of detail, or accuracy of environmental data products or with new knowledge about drift behavior or detection.

These shortcomings are evident in the four current computerized SAR planning support tools. Their primary difference from SARP is that most run on desktop computers and are supported by

geographic information systems and other interactive tools. However, they all suffer from the limitations of the CSPM. Ironically, the Coast Guard's C2PC/SAR Tools Automated Manual Solution suffers the most in this regard because it is the most faithful to the manual technique. The other three similar tools provide considerable improvement in the availability and use of environmental data for drift computations. CASP 1.x is the most capable search planning tool available today, but only because it is the one tool that uses simulation techniques. CASP's basic framework is more than 25 years old and even then it was severely limited by the obsolete computing environment in which it was forced to operate. In short, CASP 1.x is a primitive implementation of a sophisticated methodology and many key elements are still missing.

In more recent years, the greatly increased availability of inexpensive but powerful microcomputers with high-resolution color geographic information systems has made near-real-time computing support a normal expectation. Programming powerful workstations to emulate the hand calculations of the manual method, a technique developed to get around the lack of computing capability in the 1950's, is unacceptable. Presently, the Coast Guard currently uses more sophisticated techniques to predict oil spill trajectories and perform risk analyses than for matters of life and death, such as SAR.

It is recommended that the Coast Guard's SAR planning theory be corrected and that stochastic analysis be the primary method for executing search plans. The U. S. Coast Guard needs and deserves a new computer simulation-based search planning support tool that takes full advantage of the advances in these areas to ensure efficient, effective use of expensive search resources. Those awaiting rescue deserve the time advantage such a planning support tool can offer.