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FINAL REPORT: RESEARCH
ON A TACTICAL DECISION AID FOR
NEAR-HORIZON EMITTER LOCATION

by

Carl A. Mauro
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Applied Research in Statistics - Mathematics - Operations Research

**FINAL REPORT: RESEARCH
ON A TACTICAL DECISION AID FOR
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**Carl A. Mauro
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TECHNICAL REPORT NO. 120-2

March 1985

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I. INTRODUCTION

This final technical report prepared under Contract No. N00014-83-C-0722 summarizes a research investigation conducted by Desmatics, Inc. under sponsorship of the Office of Naval Research. The Desmatics research focused on the development of an advanced fix computation algorithm for use as a tactical decision aid for near-horizon (i.e., short range) target localization in support of naval battle group offensive cruise missile strike operations.

Under this contract, Desmatics investigated current position location methodology and developed a statistical procedure which combines the lines of bearing and associated error statistics of n ($n \geq 2$) direction finding stations, together with individual station location uncertainty statistics, to yield the best point estimate of the target transmitter and associated confidence regions surrounding the estimated location. In light of the fact that outliers (e.g., wild bearings arising from sources such as ionospheric disturbances or surface wave effects) are a commonly occurring problem in near horizon targeting applications, the emitter location procedure developed by Desmatics is based on a statistical estimation technique that is insensitive to outlier contaminated data. A corresponding computing algorithm, known as HAWKLOC, was also developed by Desmatics during the research program.

In addition to the present report, Desmatics' research findings and accomplishments during the overall research effort have been sum-

marized in three technical documents. The following sections briefly summarize the research accomplished under this contract and provide a reference list of the technical documents resulting from the research effort.

II. PROBLEM BACKGROUND

A problem of great importance to the Navy is target localization based on information obtained from passive bearing measurements. A target localization system consists generally of two or more direction finding (DF) sites in which each site obtains a bearing on the signal of a target transmitter whose location is unknown. These measured bearings are then reported to a command/control station where they are used to estimate the true location of the emitter and construct associated confidence regions surrounding the estimated location.

Emitter location techniques are of significant interest to the Navy and have several important tactical and strategic applications within naval operations and intelligence. For example, location techniques are used to integrate shore-based ocean surveillance data to obtain an HFDF fix (i.e., estimated target location) of the signal source. These techniques are also used in over-the-horizon targeting (OTHT) in support of battle group antisurface warfare (ASUW) operations, e.g., Tomahawk and Harpoon cruise missile targeting. Emitter location techniques are also vital to the search and rescue of downed pilots or aircraft.

If the location of each DF site is known exactly and the target bearings are perfectly accurate, the required coordinates of the signal source can be determined precisely since all bearings would pass through one point. In practical DF applications, however, precise measurements are not possible. Consequently, the target bearings taken

from the DF sites will not, in general, pass through the true location of the target emitter. The resulting statistical problem consists of (1) estimating the most probable position of the target based on the observed data, and (2) estimating the precision of the position indicated by the fix.

The primary objective of the Desmatics research effort was to develop an outlier resistant emitter location procedure suitable for use in near-horizon target localization applications.

III. RESEARCH SUMMARY

In the first phase of the research effort, Desmatics conducted a literature search to become familiar with previous work on location estimation methods. An extensive bibliography of the position finding literature appears in the Appendix. In addition, technical discussions were held with cognizant Navy personnel to discuss key aspects of the near-horizon target localization problem. During these discussions, a set of assumptions was established which would provide a mathematical framework for subsequent research.

The primary assumptions of this research study were as follows:

- (1) Navigation (i.e., longitudinal and latitudinal) errors at each DF station are independent of each other and are normally distributed with zero means and known variances;
- (2) Bearing angle error at each DF station is independent of the navigation errors and has a Von Mises distribution;
- (3) The measured bearing angles are unbiased estimates of the true bearing angles and have known variances;
- (4) Bearing angle and navigation data from one DF station is independent of data from another station;
- (5) Outliers may be present in the reported data;
- and (6) The surveillance area is small enough so that the curvature of the earth's surface can be neglected, thus permitting the use of a "flat earth" geometry.

Extensive discussion of the Von Mises distribution is given in Mardia [2]. This distribution, which is defined on the circle, is analogous to the normal distribution which is defined on the line. In fact, the Von Mises distribution agrees very closely with a normal dis-

tribution if the bearing angle standard error is small (less than 10°).

The effect of the flat earth assumption on localization error was examined in Desmatics Technical Note No. 120-N1 (30 April 1984). The use of a flat earth geometry was shown to have a negligible effect on localization for those baselines and target ranges typically found in near-horizon DF applications.

In the second phase of the research effort Desmatics developed, based on the set of assumptions listed above, an outlier resistant location estimation procedure and corresponding computing algorithm for near-horizon target localization. The resulting targeting algorithm, known as HAWKLOC, is based on an iterative estimation technique known as M-estimation (See Huber [1]). The objective of this technique is to define a maximum likelihood-type estimator that performs efficiently whether or not outliers are present. In addition, HAWKLOC features a data screening procedure which selects a starting estimate of target location and identifies obvious or gross outliers prior to processing. Methods for obtaining estimated standard errors of the estimated location and constructing associated confidence regions were also developed by Desmatics. A complete description of the HAWKLOC methodology is provided in [3] and [4].

In the final phase of the research effort, Desmatics coded the HAWKLOC algorithm in FORTRAN 77 and implemented the resulting computer program on the Hewlett-Packard Model 9816 microcomputer. A copy of this program was sent to the technical staff at both the Naval Ship Weapon Systems Engineering Station (NSWSES), Port Hueneme, CA, and the Naval Ocean Systems Center (NOSC), San Diego, CA.

IV. DESMATICS DOCUMENTATION

The following pages contain a complete listing of the technical documents prepared under Contract No. N00014-83-C-0722. The corresponding technical abstracts are additionally provided.

Desmatics Technical Note Number: 120-N1 Date: April 1984

Title: EFFECTS OF GEOMETRIC ASSUMPTIONS ON TARGET LOCALIZATION
ERRORS

Authors: Carl A. Mauro, Kevin C. Burns, and Dennis E. Smith

Abstract: This technical note evaluates the target localization errors introduced by the use of a flat earth geometry. In the near horizon naval battle group DF problem, the use of a flat earth geometry is shown to have a negligible effect on target localization. In addition, the long-range DF problem is briefly considered.

Desmatics Technical Report Number: 120-1 Date: September 1984

DTIC Number: AD-A146 603

Title: HAWKLOC: A NEAR HORIZON TARGET LOCALIZATION PROGRAM

Author: Carl A. Mauro

Abstract: This technical report describes the mathematics underlying the HAWKLOC target localization program. HAWKLOC is a new algorithm developed for application to the problem of near-horizon (short-range) target localization in support of Battle Group Operations. HAWKLOC is based on a fix computation algorithm that is resistant to "bad" data. Given two or more estimated lines of bearing and corresponding ship (sensor) positions, HAWKLOC computes the best estimate of target location and the associated areas of uncertainty. HAWKLOC features an adaptive data screening capability and a diagnostic procedure.

Desmatics Technical Note Number: 120-N2

Date: November 1984

Title: NEAR-HORIZON TARGET LOCALIZATION*

Author: Carl A. Mauro

Abstract: Direction Finding (DF) is the estimation of the location of an emitter based on directional readings measured, with *some error*, from two or more observation points. In this paper, I focus on the problem of near-horizon (i.e., short-range) DF in which there are also uncertainties in the locations of the DF stations or platforms. Based on a suitable navigational and bearing error structure, an iterative solution to compute the maximum likelihood location estimate is developed. A robust estimation procedure which is insensitive to outliers is also developed. A method for obtaining estimated standard errors of the estimated location and constructing its associated confidence regions is detailed. An example is provided.

*Submitted for publication in Operations Research.

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tion and rejection of outliers (e.g., wild bearings).

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