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MEMORANDUM REPORT

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To: Office of Naval Research (LRAPP)
Attn: LCDR K. Evans, Code 6000

Contract No. N00014-75-C-0058

From: D. C. Bossard

Subject: Final Report Under Contract No. N00014-75-C-0058

LEVEL

This is the final report under Contract No. N00014-75-C-0058. The bibliography of work accomplished under this contract is given below in chronological order beginning with the initial proposal dated August 1, 1974, through this final report.

The work accomplished is in five areas:

- (1) ASEPS model validation;
- (2) ambient noise modeling questions;
- (3) second order statistics for ASEPS;
- (4) localization and tracking symposium;
- (5) Kent Beacon analysis and follow-up exercise planning.

Selection of these task areas was at the direction of LRAPP in response to current needs. In addition to this written analysis, Dr. Bossard participated in a number of discussions and planning sessions with LRAPP personnel.

In the following sections each of the major work areas will be summarized.

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1. ASEPS Model Validation

The initial proposal, reference [a], was to devise statistical tests to be used in comparing ASEPS predictions of signal excess with operational data, namely, periods of SOSUS contact with known U. S. SSNs operating along known (or reconstructed) tracks in the SOSUS influence areas, and utilizing calibrated noise projectors. A series of these runs, denoted GNATS I, II, III, etc., were conducted and reconstructed during 1974 and 1975. Most of the data reduction was performed by Mr. Bill Schreiber of Planning Systems, Incorporated, and this phase of our work was done in close cooperation with Mr. Dick Klinkner of PSI.

Bibliography entries related to this task area are references [a] (the proposal), [b] through [f], [h], [m], [p], [s] through [v], [y], [aa] through [pp], [rr], and [ss], and span the time from August 1, 1974 to April 1, 1976. The best general summary of the methodology is reference [y], and the results for GNATS I and II is given in reference [cc].

The net result of this work is that a number of useful tests were designed and implemented on a Wang 2200B programmable calculator for use with data as developed in the GNATS reconstruction and the ASEPS output. These tests are designed to show the regions of signal excess statistics (σ , the instantaneous standard deviation and λ the recurrence rate of independent samples) that are compatible with the observed data (SNR at time of detection and the length of contact, as recorded for individual arrays and propagation paths), and to highlight other anomalies that may arise. By reference to independent analyses that estimate the values of λ and σ , it is possible with these tests to infer the compatibility of the operational results to the observed operational data.

In the initial application of the tests, reported in reference [cc], a number of areas were found where model improvements were needed. It is difficult to say whether these areas were revealed by the tests or by common sense scrutiny of the data, but in either event, the need for further ASEPS model development was indicated and so further application of the tests was suspended.

It should be noted that revision of the ASEPS model has recently been completed, and so it is timely to again consider the use of these tests for comparison of ASEPS output with operational data. In general, it should be noted that the utility of the tests developed for this validation will be greatest if the model is free of obvious prediction errors -- when the errors are obvious there is no need for subtle tests.

It should be noted that Wagner, Associates no longer has a Wang 2200B computer and that the principal analyst for this task, Dr. Bill Barker, is on assignment at Naples, Italy. Thus, revival of these test programs would involve some start-up delays.

2. Ambient Noise Modeling

One of the issues in ASEPS is the way in which ambient noise is modeled -- particularly because of interest in directional (horizontal and vertical) structure in the noise. At the start of the proposed work, PSI under the work of Mr. Lou Solomon was engaged in modeling shipping contributions to ambient noise. In late 1974, NUSC, New London, conducted various directional ambient noise measurements in Bermuda. The task, which was briefly studied as part of our work effort, was to devise appropriate statistical quantities (variance, correlation, etc.) that could be used to evaluate the utility of the directional ambient noise modeling in ASEPS.

References [g], [i], [j], [n], [o], [p], [s] suggest simple measures that can be used to compare directional ambient noise data with predictions. These measures were never implemented because the NUSC data has never (to my knowledge) been reconstructed and made available for such analysis. The basic Poisson spatial process (which is quite capable of handling shipping lanes and other known phenomena) as developed in reference [g] remains of value in ambient noise modeling and has been used in other applications of spatial processes.

3. Second Order Statistics for ASEPS

The second proposal, reference [x], extended our analysis into the area of second order statistics for signal excess prediction models. This turn in the work evolved naturally out of the earlier work because of the realization that the utility of ASEPS in the prediction of system performance is closely tied to its ability to predict not only the mean level of signal excess but also the statistical properties of the signal excess about the mean -- to the extent that those properties depend on the environment. It is a fact of life that performance contours for SOSUS are based on assumed second order statistics of the signal excess -- the instantaneous standard deviation of signal excess, σ , and the temporal repetition rate, λ , as much as or more than on the mean level of the signal.

The ASEPS model has a unique potential to correct a universal limitation of all performance prediction schemes, namely that it is assumed that the values of σ and λ are independent of the geographic location and orientation of the arrays, the ambient noise environment, etc. It is well known that these statistical quantities are not universal constants, but until the ASEPS model, there has not been a practical means

to predict variations in these parameters.

To give a simple illustration where second order statistics are important, ASEPS can identify those occasions when the propagation path from source to receiver is "nearly" bottom limited -- that situation in which the critical depth is nearly equal to the ocean depth over a significant segment of the path. In such a circumstance, small changes in the propagation path or in the temperature profile may result in large changes in signal excess over the path; this translates into a large value of σ , and perhaps says something about λ as well. It is particularly interesting to note that the repetition rates generally assumed for performance prediction are on the order of one per hour ($\lambda=1$) to one per three hours ($\lambda=1/3$). In some localities, this may well be influenced by physically identifiable events -- tides, diurnal temperature shifts, etc.

Once the basic capability of ASEPS to predict mean signal excess is reasonably well established, it is desirable from the viewpoint of operations analysis to go into the second order statistics as implied by the propagation path calculations. This was the thrust of references [l], [r], and [w]. The message of the last of these memoranda is that modifications of ASEPS to produce second order statistics is fairly straightforward and should not substantially increase the computation time*.

The work of these references is preliminary, but clearly shows a useful direction in which to move the would greatly increase the value of ASEPS to the performance prediction community. It is our judgment that profitable further analysis remains in this area.

* This assertion has been confirmed in informal discussion with Mr. Chuck Spofford who developed the latest algorithms used in the new ASEPS model.

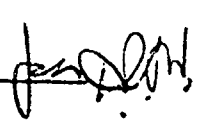
4. Localization and Tracking Symposium

Reference [z] is a summary report of a special task requested by PME-124 and agreed to by LRAPP in which Dr. David Bossard chaired a panel to review the various localization and tracking algorithms in current use within the SOSUS community. This effort involved two or three gatherings at Bell Laboratories, Whippany, NY, and TRW Systems in McClean, VA, to discuss the models presently in use by Bell Laboratories (the SST and MST algorithms), NOSC San Diego (in the advanced signal processing project) and TRW. The reference summarizes the findings, which basically center around the deplorable situation that prevails in the field in which progress is seriously hampered by lack of scientific interchange due to the claim that the information is proprietary. This is particularly true of various Kalman Filter tracking algorithms. As chairman of the session, I was unable to procure a copy of the Bell Laboratory algorithms for purposes of evaluation and comparison with other approaches to target motion analysis, although the information that could be gleaned was enough to confirm certain opinions as to the nature of the algorithms.

5. Kent Beacon Analysis and Follow-up

As the final task under the contract, Wagner Associates was asked to evaluate the contact data obtained during the Kent Beacon exercise conducted during late 1975. Reference [qq] summarizes that analysis. Based on this work, algorithms were developed which duplicate in principle the detection scheme used on that exercise. These algorithms were developed in reference [tt], [vv], and [ww] for implementation during Church Stroke I. The algorithms and subsequent work on this task were taken over by Dr. John Hanna of Systems Analysis, Incorporated and Bunker Ramo. In

our opinion, the algorithms were not properly exercised, so no conclusive information is available for this effort.

David C. Bossard 

David C. Bossard

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