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NRL Memorandum Report 3625

**Operator-Interactive Signature
Formation for Acoustic Undersea
Surveillance Systems**

[Unclassified Title]

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*Advanced Projects Group
Acoustics Division*

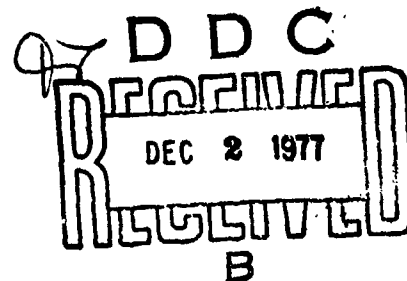
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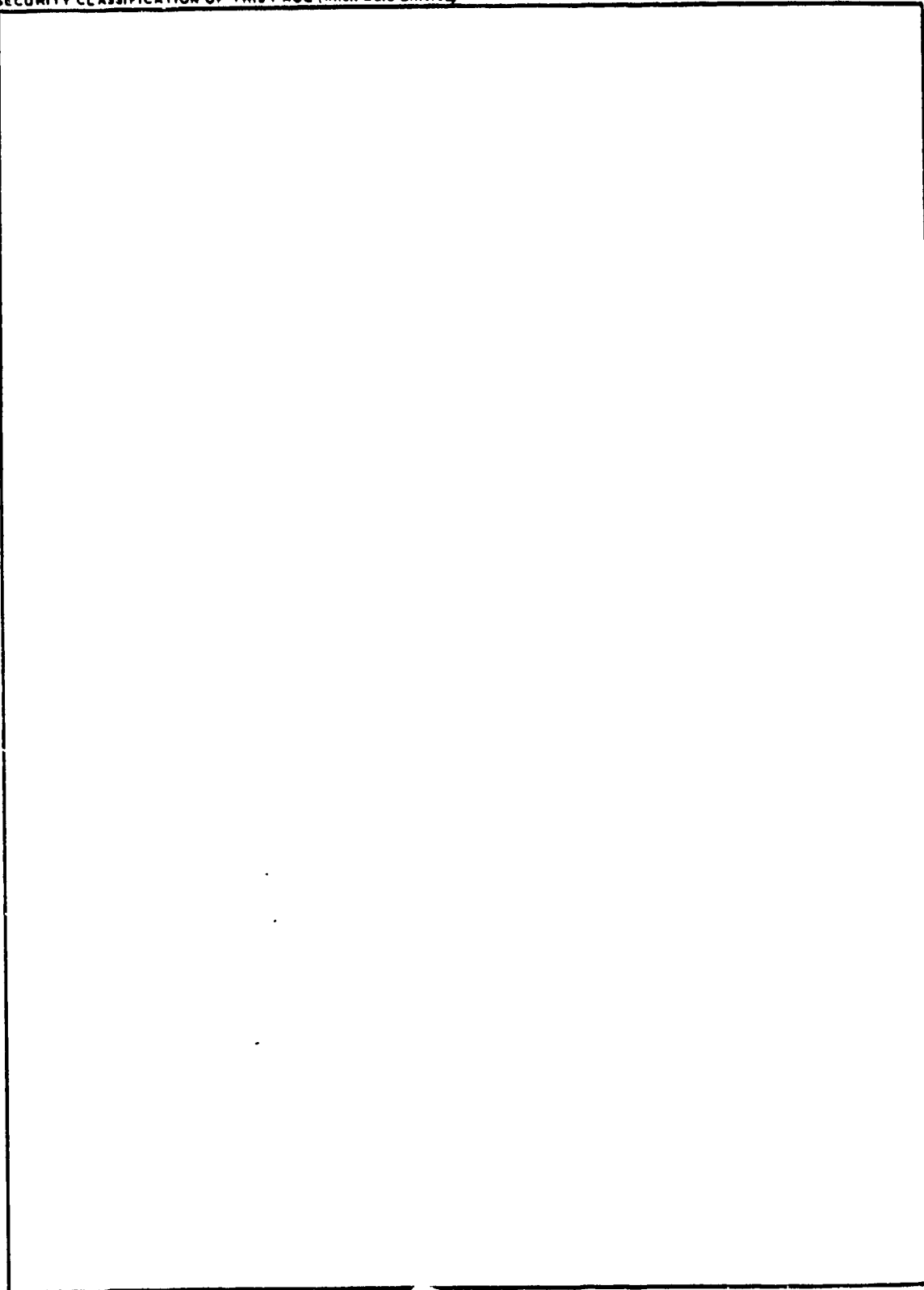
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Table of Contents

Abstract.	.1
Background.	.1
Introduction.	.2
System Overview	.4
Signature Formation Logic	.6
References.	.20
Display System and Interactive Device . . .	.A1
Display System Selection.	.B1

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OPERATOR-INTERACTIVE SIGNATURE FORMATION FOR ACOUSTIC
UNDERSEA SURVEILLANCE SYSTEMS
[Unclassified Title]

(C) ABSTRACT

This report describes an exploratory development for systematic organization of acoustic signals detected by multi-beam Undersea Surveillance Systems into the acoustic signature of ships. The function described is a subset of an NRL concept for an integrated, multi-platform, undersea surveillance system known as ASP - the Advanced Surveillance Processor. The concept, is termed "operator-interactive signature formation", and combines the observational power of a human operator with the storage and computational power of the computer. The interaction consists of a human operator proposing candidate harmonic series by indicating one or more harmonics of that series by means of a cursor or hand-held pointer on an acoustic display on the face of a cathode ray tube. (Signal detection and parameter estimation are accomplished by existing algorithms prior to display.) Subjective interpretations by the operator are not permitted. Ambiguities in the signature formation process are resolved by execution of appropriate signal processing algorithms. Organization of the detected signals is a four-stage process beginning with identification of non-ship interfering signals, proceeding through harmonic set formation to combination of harmonic sets into signatures, and finally to highly automated "steady state" maintenance. The project is currently at the point where signature formation logic has been developed to the third level of complexity, approximately 70 application programs have been identified and initially specified, and display programming for a particular (dark-trace, storage) display has been completed.

a CRT screen.

beginning with identifying

(C) BACKGROUND

This development emerged from a FY'75 study of technology gaps in the area of line relate and clue extraction for the 1980's Undersea Surveillance System, and was sponsored by the Naval Electronic Systems Command (Code 320). The results of the study indicated that major deficiencies exist in our knowledge of target acoustic characteristics, in the methods and procedures used in organizing and interpreting detected signals, in the applicability of various exploratory developments in signal processing, and in the type and quantity of display systems required for effective ocean surveillance. The conclusion of the study, the details of

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which are contained in reference (1), was that the principal obstacle in the path of automating undersea surveillance was the problem of organizing the detected signals into meaningful groupings prior to classification. A three phase development was planned. Phase 1, Concept Definition and Logic Development, is documented by this report. Phase 2, implementation, involves assembling the required hardware/software and coding the application programs. Phase 3, Testing and Evaluation, involves exercising the system with non-inbred acoustic data.

(C) INTRODUCTION

(C) A study of the state-of-the-art of acoustic signature formation in multi-beam undersea surveillance systems, conducted in FY'75, revealed several serious technology gaps.¹

1. As a practical matter, it is seldom, if ever, possible to distinguish, on the basis of acoustics alone, between "threat" and "threat like" detections in general surveillance.
2. Although ambiguities in the signature formation process were known to occur frequently, the acoustic information necessary to resolve these ambiguities was not known.
3. The sequence of procedures in signature formation, even for manual systems, was incomplete and inadequate.
4. Existing man-display interfaces were inadequate and resulted in incomplete and erroneous data being extracted from the display.
5. Measures of operator performance and decision criteria were largely undefined. Critical decisions were frequently made on the basis of operator "experience" or "intuition".

(C) The study considered in detail the four generic approaches to signature formation, namely: manual, totally automatic, threat filtering, and operator-

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machine in combination. The manual, totally automatic, and threat filtering approaches were rejected for the following reasons:

Manual - the complexity of the problem is such that the human's solution is necessarily incomplete. Critical decisions are made on the basis of subjective or intuitive judgments.

Totally Automatic - This approach has consistently resulted in generation of fictitious signatures from fragments of real signatures, and in dismissal of real signatures through false association with other signatures.

Threat Filtering - This approach is not a signature formation technique but merely a discrete frequency detection technique. It was considered as an alternative to the other approaches. In practice, threat filtering results in high false alarm and false dismissal rates, since the acoustic characteristics stated for the threat are not unique to that class, and measures of dispersion are not known.

A more complete discussion of these techniques and their performance is given in reference (2).

(C) If undersea surveillance systems are to perform in the general surveillance mode, it is necessary to reduce the false threat declaration rate drastically, while retaining a false dismissal rate near zero. The study concluded this could be done if the problem is addressed systematically and objectively.

(C) The approach selected as having the best chance of success was a man-machine combination known as "Operator-Interactive Sector Scan". In this approach, the observational and pattern recognition powers of the human operator are utilized early in the signature formation process, not, as in past efforts, where his role was to correct the many errors made by the computer. The man suggests a candidate solution by interaction with the displayed acoustic spectrum. The computer verifies and expands the solution where appropriate, rejects it as incorrect, or in the case of ambiguity, executes the pertinent ambiguity-resolving signal processing algorithm. Subjective interpretations by the man, such as source evaluations, are not permitted.

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Ambiguities, unresolvable by algorithm, are displayed for human interpretation only when the interaction required of the operator can be predefined.

(C) The signature formation process (Fig. 1) proceeds through four stages. First, non-ship "clutter" - station artifacts, projectors, "commas", etc., are identified. Next, candidate independent harmonic series on a particular beam are indicated by the operator. The algorithm makes the required calculations and verifies and expands the solution. The third stage attempts to associate independent harmonic sets to form ships' signatures. Finally, when "steady-state" is reached, the solution is maintained with a high degree of automation, operator interaction being required only when a significant change occurs which presents an ambiguity unresolvable by the steady state algorithm.

(C) The "Sector Scan" above refers to the concept for implementation wherein each operator at an upgraded SOSUS NAVFAC monitors a particular azimuthal sector. Since most beams at most NAVFACS seldom, if ever, hold contact on a genuine threat target, expanded spatial searchlighting is a legitimate technique which permits the number of displays necessary to be monitored simultaneously to be minimized. (Ref. 3).

(C) System Overview

(U) The equipment configuration for the experiment shown in Fig. 2 represents a mix of individual elements adequate for the experiment, but chosen mainly because of no-cost availability or minimum cost to acquire. Particularly in the display area, a refresh CRT with track ball controlled cursors would have been preferable to the DICOMED-SAC (dark trace storage CRT and sonic pen) arrangement. A detailed discussion of DICOMED programming is given in Appendix A. A discussion of an optimum display is given in Appendix B.

(U) Top level signature formation logic is given in Fig. 3. The following illustrates the procedures used.

(C) The operator is required to monitor continually the SOSUS baseband (10-150 hz) in his assigned sector. For purposes of the experiment, the sector is defined as seven, fixed, contiguous beams. The real-world test data consists of seven magnetic tape recorded channels of 4 to 6 hours duration spectrum analyzed data at baseband (0.1 hz), vernier (.03 hz), and supervernier

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(.010 hz) resolutions with accompanying parameter estimation.

(C) The sequence begins with a forty minute duration broadband display (150 hz) of the left-most beam, i.e., channel 1 of the magnetic tape recording. The operator attempts to recognize rather well known non-ship interference in one or more of three general classes - station equipment artifacts, man-made ocean noise, or sea noise. The suspected presence of any of these is indicated by pointing to one or more components with the interactive device, in this case a sonic-pen. A non-ship clutter recognition algorithm, if it confirms the operator's judgment, seeks to identify the interfering signals on the other seven beams as well. (Non-ship clutter is frequently visible on many beams simultaneously). A feature of this stage is that the operator, disagreeing with the algorithm can call for higher resolution displays, and as a result, present additional information to the algorithm. He cannot, however, override the algorithm's classification and force a classification of "clutter". If the algorithm does not call a signal "clutter", it is carried as a ship's signature. The concept here is that this type of interference is so well defined that algorithm performance is expected to be at least as good as the best human. Since it is possible that more than one type of clutter exists on this beam, the operator remains in stage one until he indicates interactively he is ready to proceed to beam two and ultimately, to stage two. All signals identified as non-ship clutter are tagged in the parameter estimation tables for each resolution.

(C) Stage two, harmonic set formation, is the most difficult to accomplish. The operator selects the most visually striking signature on the display, usually one rich in harmonics and signal-to-noise ratio. He indicates interactively some number of harmonics of the series. For multiple line signatures, this means a minimum of two adjacent harmonics. The algorithm calculates a trial fundamental, finds other harmonics of the set in the parameter estimation tables, and determines, on the basis of harmonics present and strength of harmonics, if this or another beam is the main lobe detection. The results are presented to the operator for verification. He is permitted to disagree on the basis of an observation of inconsistency in the solution. For example, a minor dynamic, not resolved by the parameter estimation algorithm, may be clearly visible in some, but not other, candidate harmonics. If the operator concurs, the parameter estimation table is tagged appropriately. Next, a threat potential algorithm is executed. This is merely a conservative "clearly non-threat" vs "possible threat"

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distinguishing algorithm. An attempt is made to localize "Possible threats" by both data processing (maneuvering board solutions) and signal processing, principally inter-array correlation, while "clearly non-threat" are data-processed only from then on. (Note that in this experiment, since the acoustic data base is analyzed data, any large signal processing required is done remotely, at contractor's facilities or the ARC, and not necessarily in real-time.)

(C) The operator then proceeds to the next most visually striking signature and repeats the sequence exactly until every discrete frequency in the parameter estimation table for this beam has been accounted for as either a main-lobe or side-lobe detection. The control algorithm will not permit him to advance to the next beam until he has accounted for every discrete frequency in the beam being analyzed. He continues from left to right until all discrete frequencies on the seven beams for the forty minute period are associated with one or another harmonic series.

(C) In the third stage, he attempts to group individual harmonic sets into ships' signatures. Often this will be done on the basis of observations of similarity of estimated position, direction of movement, or rough bearing rate of change. This kind of information is displayed to the operator for interpretation and trial solution.

(C) Upon completion of the third stage, all signals present have, theoretically, been associated correctly with individual ships detected. A steady state algorithm monitors the static solution for changes, particularly changes which affect the credibility of the current solution. Changes are reported to the operator for confirmation or appropriate action.

(C) Having reached steady state, the operator returns to channel 1 to begin the sequence anew with display of the next time increment. However, his interaction is expected to be minimal since he is required to interact only to the extent that signals detected are not accounted for by the steady state algorithm.

(C) Signature Formation Logic

The paragraph numbers referenced below correspond to the entries in the third level functional logic diagrams, Figs. 4 through 7.

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Non-Ship Clutter (NSC) Removal (Fig. 4)

- 1.0 (C) The operator displays the broadband (10-150 Hz) lofargram on the first beam. At this point he is attempting to recognize interfering signals not generated by ships. The system design philosophy is that these kinds of interfering signals, station artifacts, man-made ocean noise and sea noise are visually recognizable to an operator, usually without even the necessity of making a frequency measurement.
- 1.1 (C) Since many of these kinds of interfering signals appear simultaneously on many or even all beams of an array, the operator reinforces his classification by displaying all seven beams simultaneously on the face of the CRT. The display consists of 5 minute segments of each of the seven beams in beam number order from top to bottom of the screen. Start time for each segment is the time indicated interactively by the operator.
- 2.0 (C) Since it may be desirable to display examples of a particular type of non-ship clutter to allow the operator to make a direct visual comparison between the present interfering signature and a library of similar interfering signals, a photographic information retrieval system was incorporated as an option. In this system, the algorithm not only identifies the type of non-ship clutter, but also displays the address or storage location of examples of that type. The actual display was intended as an "off-line" function. Examples to be displayed were controlled by the operator who decides whether or not to display a particular image. The implementation contemplated was a photographic information retrieval system, perhaps one using microfiche image storage. It is essentially a memory jogger which prompts the operator to the most likely source of non-ship clutter.
- 3.0 (C) The operator indicates on the face of the broadband CRT display, enough components of the candidate NSC so that the algorithm can identify any others and confirm as non-ship clutter. It was anticipated that some non-ship clutter, particularly sea-noise, would require special interactive techniques, for example, multiple indications in the time domain in the case of the sea-noise phenomenon known as "commas", to establish the periodicity of these signals for consideration by the algorithm.

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(C) The form of the interaction is that the operator "points" at the signal or signals on the face of the CRT by touching them with a "sonic pen", a device resembling a ball-point pen which contains a spark gap in the tip across which a hypersonic signal with an extremely short rise time jumps when the tip is depressed on a surface. Two orthogonally mounted pairs of linear microphones, each 14 inches in length, receive the resultant spark. Internal circuitry converts arrival time into X and Y coordinates in the 14" X 14" area to a resolution of as much as 4000 X 4000 points. Sonic pen interaction, thought of as simply an extension of a man's pointing finger is expected to be a natural and convenient method. Parallax problems resulting from curved tube faces, or simply operator inaccuracy were to be handled by the interactive control algorithm. Technical details of the sonic pen are discussed in Appendix A.

3.1/3.2/3.3/3.4(C) System design anticipates that the operator, recognizing non-ship clutter is able to go one step farther to the point that he is able to categorize it tentatively as one of the three generic classes of non-ship clutter. At this point, the operator is heavily interactive with the system. He makes the selection of most likely type of non-ship clutter, and on completion of the algorithm's evaluation, gets the opportunity to concur or not concur. Note that the operator's options at this point are:

1. to accept the algorithm's judgment that the signal is non-ship clutter and continue to the next non-ship clutter signature, (which may be on another beam), or, if there are no others, continue on to harmonic set formation, or,
2. disagreeing with, or being unconvinced by, the algorithm's decision that the signal is not a recognized type of non-ship clutter, he can provide additional signature clues, perhaps from higher resolution displays, or, he can select a search through one or both of the other generic non-ship clutter paths.

The one thing he cannot do, however, is override the algorithm and declare a signal to be non-ship clutter if

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the algorithm decides otherwise. Such signals are carried as if they are ship detections. The reasoning that went into this design feature is that it is more desirable to suffer a temporary (until the algorithm can be updated) increase in false target loading than to permit subjective interpretations (i.e., classifications) at this point to cause false dismissal of a real target signature.

The principal types of non-ship clutter considered in the initial design were those given in Chapter 3 of reference 4.

4.0 (C) All identified non-ship clutter is tagged as accounted for in the parameter estimation table for each resolution, and displayed multi-beam in the format of Section 1.1, above, with the exception that non-ship clutter signals are labeled with a cross stroke on the display. This sequence continues if the operator wishes to test for the presence of other non-ship clutter.

5.0 (C) A high-risk effort designed to eliminate identified non-ship clutter from the display was to be undertaken on a not-to-interfere basis. The intent was to change all intensity words in the time-frequency rectangle enclosing the non-ship clutter to zero intensity, and then substitute pseudo-random noise in that interval. Some of our prior experience in this area indicates that this technique sometimes leads to a more confusing display.

(C) Harmonic Set Formation (Fig. 5)

1.0 (C) Having identified all known non-ship clutter on all beams, the operator next tries to form independent harmonic sets from the remaining discrete frequencies. The approach is to use the pattern recognition powers of the human to reduce the complexity of the organizational problem by attempting to organize the most visually evident harmonic set first, then continue to the next most visually evident, and so forth, until all discrete frequencies are accounted for.

(C) The technique employed is to have the operator point at the minimum number of components necessary to determine the fundamental, normally two adjacent harmonics, although he can indicate more, or less, in the case of a single-line signature. The algorithm makes a frequency determination

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for each operator indication.

- 2.0 (C) The frequency obtained is the value in the parameter estimation table, not the exact value that would be calculated from the position of the interactive device. In cases where the operator indication is not on a displayed frequency, whether through parallax or hasty or inattentive action, the algorithm selects the nearest frequency in the table. In this case, as in the case of an indication which might refer equally well to two frequencies, e.g., one equidistant between two signals, the algorithm's results are displayed to the operator for concurrence. Whenever an uncertainty arises at this stage, the operator can cause displays at vernier and super-vernier resolution to permit observation of minor dynamics or closely spaced signals. A multiple band display permits side by side (time-synchronized) high resolution display of several narrow bands simultaneously. Since the accuracy of the frequency indication is that of the front end signal processor the mean square error characteristic of that particular system will be used initially in testing validity of harmonic set formation.
- 2.1/2.2(U) Calculation of the fundamental frequency is accomplished by subtracting the lower of two frequency entries from the higher, or, if more than two are entered, the minimum difference is calculated. We had given some thought to a procedural requirement that the first two interactive entries must represent the harmonic spacing, but concluded that this was both undesirable and unnecessary. The fewer constraints on their operator's actions, the better.
- 2.2 (C) The algorithm tests that all signals indicated are integral harmonics of the fundamental frequency. If any are not, this information is displayed to the operator, and he is permitted to delete those in error for this particular harmonic set, or return to step 1.0 if the solution is grossly in error. The algorithm attempts to expand the solution by accessing the parameter estimation table for that beam and time interval in search of discrete frequencies which, arithmetically at least, are part of the indicated harmonic series. Candidate harmonics are indicated on the acoustic display by means of a slash (\). Acceptance by the operator results in tagging in the parameter estimation table and completion of the indication on the acoustic display by a superimposed reverse slash (/) - i.e., combination

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/ + \ = X. The operator is permitted to reject candidate harmonics, in which event the parameter estimation table entry is available for consideration as part of another harmonic set.

- 2.3 (C) Candidate harmonic sets detected on one beam will frequently be detected on other beams as well. The algorithm, making use of the harmonics identified thus far, attempts to find other beams with more harmonics or the same harmonics with greater relative signal-to-noise values. Algorithm identification of a different beam as best beam satisfies the requirement for accounting for each discrete frequency on one beam before moving on to the next beam. An algorithm decision that this harmonic set is actually on another beam results in a multi-beam lofar display permitting the operator to concur or not concur and to accommodate situations where the pattern recognition capability of the operator can be employed to resolve ambiguities not clearly resolved by the algorithm - e.g., the case where interfering signals temporarily mask the signature on the beam being examined.
- 3.0 (C) When it has been determined that this is the best beam for this harmonic set, the baseband lofargram is displayed with all harmonics identified by the man-machine combination labeled.
- 3.1 (U) The operator has the opportunity to correct or expand the solution, i.e., on the basis of observation of the display either to delete additional harmonics supplied by the algorithm or to add additional harmonics not supplied by the algorithm. (An example of the latter might be discontinuous signals.)
- 3.2 (U) The operator is required to concur in the solution at this point. If he made a correction or expansion, the change must be verified correct by the algorithm.
- 3.3 (C) The pivotal decision point in the signature formation process is the point at which the operator decides that he is, or is not, satisfied with the solution thus far - a solution based largely on measured frequency, observed dynamics, and rough bearing compatibility. In the event an ambiguity or uncertainty arises, he goes to that part of the harmonic series formation sequence that involves the greatest amount of operator interaction and the execution

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of special purpose signal processing algorithms. The percentage of time that the use of signal processing algorithms for ambiguity resolution will be required is not known. However, it seems likely that most harmonic set formation can be done by frequency-based operator interactive techniques alone, particularly in the case of harmonic-rich signatures which comprise the largest part of the interfering clutter.

3.3.1 (C)(Figure 5B) The operator selects that ambiguity resolution path which addresses the specific uncertainty encountered. We anticipate that the most important of these will be in the areas of bearing and minor dynamics, although five other characteristics (amplitude, phase, harmonic emphasis, bandwidth, and stability consistency) will be considered. No signal processing development is being done as part of this experiment. The signal processing algorithms shown in Fig. 5C have been developed by Navy Laboratories or contractors, and are to be available for execution either at the ARPA Research Center or other remote facilities. It is not necessary that they be executed on demand by computer to computer link. Ambiguity resolution by signal processing involves a two-step decision process. The operator first selects one of seven characteristics he wishes to consider. Next, he chooses, consecutively, those signal processing algorithms capable of resolving that particular ambiguity. (In this experimental approach, the intent is to exercise all available algorithms capable of resolving each ambiguity and so evaluate the potential of each.) The objective is to identify the minimum signal processing package required to provide an acceptable confidence level for association of detected signals. In the current experiment, since the signal processing algorithms are, in fact, exploratory developments, whose operational deployment potential is unknown, operator concurrence with the result of a particular algorithm is required.

3.3.1.1(C) Bearing sorting is highly significant in harmonic set formation - if the candidate components have different bearings they are clearly not from the same noise source. The results of execution of the bearing determination algorithms are displayed for operator concurrence. The exact value of the confidence factor assigned is determined by the design of the particular algorithm, within its range of effective operation, until and unless empirical evidence indicates otherwise. In the case where bearings are clearly not compatible, those components cannot be formed into either the same harmonic set or the same ship's signature.

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3.3.1.2() Resolution of time-dynamic ambiguity is the next most important consideration. A clear mismatch on dynamics prevents inclusion of the candidate components in the same harmonic set, but does not necessarily preclude their being linked in the same ship's signature.

3.3.1.3() Although the characteristics tested (amplitude, phase, harmonic emphasis, stability and bandwidth) are thought to have less relative significance than the bearing and dynamics tests, each will be tested to try to establish a maximum confidence score. The technique is, in general, the same as in 3.3.1.1 and 3.3.1.2 except that, since the significance of these measurements is frequently uncertain, a candidate component will not be rejected for either harmonic set or ship signature compatibility on the basis of a "no consistency" result. That is, the significance, if any, will be determined experimentally.

Summarizing the effect of the seven tests:

- a. bearing inconsistency prohibits both harmonic set and signature formation,
- b. dynamic inconsistency prohibits harmonic set but not signature formation, and
- c. all other inconsistencies merely lower confidence in harmonic set or signature formation but prohibit neither.

When the operator has completed a test of all ambiguities, or if no useful purpose would be served by addressing the remaining characteristics, he gets a display with a statement of the degree of confidence with which the candidates have been associated.

3.5 (C) Bandwidth, stability, and harmonic emphasis are determined by accessing the parameter estimation table of the front-end signal processor (spectrum analyzer) utilized. The precise analysis system used is of no particular consequence - several are suitable - provided only that analysis bandwidths approximating SOSUS broadband, vernier, and super vernier are available, and that signal characteristics are estimated and available in tabular format.

3.6 (C) This section represents the simplest kind of classification

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algorithm - i.e., "twenty-questions" or serial logic. In fact it serves, not as a classification algorithm, but as a "negative classifier", or filter for non-interest signatures. Each decision diamond in the diagram represents a comparison of the harmonic set present to known limits in the operating characteristics of targets of interest. The comparisons are objective, based only on the frequency and harmonic emphasis characteristics of the particular harmonic set. Subjective interpretations, for example, estimates of the source, i.e., the rotating machinery producing the signal, are not permitted.

(C) The significance of this test for threat potential is that signals having any threat potential whatsoever are localized, if possible, using both data and signal processing algorithms, while those having no threat potential are not localized, but merely have their best beam identified.

- 3.7 (C) Harmonic sets meeting the minimum threat potential requirements are to be localized. As a practical matter, the initial localization effort with no bearing history available, and simultaneous multi-station contact unlikely, will almost always result in storing the best beam or bearing only. If there is a bearing history, algorithms utilizing bearings, times, and estimated speeds of advance will be executed. If there is multi-station contact, coherent signal processing algorithms will be executed for simultaneous detections meeting the signal input requirements for these algorithms. In all other cases, multi-station localization data processing techniques will be used. Depending on the success of the localization algorithms, the formed sets have either an estimated position or best beam/bearing stored in the threat accounting table.
- 3.8 (C) Upon completion of the localization attempts, the system requires that all discrete frequencies in the parameter estimation table of the beam being processed be accounted for either on that beam or as side lobe detections from another beam. Advancing to the next beam while one or more frequencies are unaccounted for is not permitted. When all frequencies on that beam are accounted for, the operator advances to the next beam and continues to form harmonic sets, unless he has processed the final beam in which event, he goes to the next major phase - combining independent harmonic sets into the signatures of individual ships. Note that the organizational concept employed is that all harmonic

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sets are formed before the first ship's signature is formed.

(C) Ship Signature Formation (Fig. 6)

- 4.0 (C) The objective of this function is to combine separate harmonic series into the signature of a ship, where those series may be dependent, i.e., related by some fixed ratio, or independent. In most cases, we anticipate that combination will be done on the basis of similarity of position or tracking characteristics. In some number of cases, it may be possible to combine harmonic sets on the basis of measurable or observable acoustic similarities.
- 4.1 Three displays are used by the operator in varying combinations and sequences to discover characteristics common to
- 4.2 two or more harmonic series. These displays are:
- 4.3
- 4.4
- a. Geographic - A plot of bearing vs range for harmonic series successfully or tentatively localized. This display also plots harmonic set number vs range.
 - b. Azimuth - a plot of bearings vs series held on that bearing. A more detailed alpha-numeric display accompanies this plot.
 - c. In/Out - a plot of detection intervals for the strongest component for each series on a particular beam or bearing.

An example serves to illustrate a likely sequence. (Fig. 6B)

The operator calls for the azimuth display and notes that harmonic series labeled A, D, and F are on the same bearing. A and D, clearly non-threat signatures, have not been localized, but F, with some threat potential, has been localized for 5, 10, and 15 knot speed estimates. A display of detection intervals for A, D, and F reveals that A and F have similar time histories. The operator attempts to localize the non-threats A and D, using the previously assumed speeds, - vs other appropriate speeds if the situation warrants. A is determined to have a position and general direction of movement similar to F, while D has little track correlation. The logical inference is that A and F combined are candidates for the ship's signature. The more consistencies, of course, the

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greater the probability that the inference is the correct one.

- 4.5 (C) An attempt is made to confirm relationships suggested
4.6 by tracking and localization similarities uncovered in 4.1 through 4.4 through the use of signal processing resources. Specifically, frequency trackers are assigned to the strongest harmonic in each of the two series to try to establish frequency excursion consistency, in terms of direction of excursion, or, better, the existence of a fixed frequency ratio between series. A second signal processing approach seeks to establish constant phase relationships between the two series.
- 4.7 (C) Since the reliability of conclusions based on minor dynamics and phase signal processing is questionable, the operator is given a multi-beam display of the candidate solution and is required to concur or not concur. Until such time as the reliability of these signal processing algorithms is certified, the operator's concurrence is required before candidates for combination are accepted by the system as harmonic series from the same ship.
- 4.8 (C) When two or more harmonic series are combined in a ship's signature, the position assigned to that signature is that which corresponds to the highest confidence localization of any of the series.
- 4.9 (C) The negative classification algorithm applied in the harmonic set formation phase is reapplied. Series which alone have threat potential, when associated with one or more clearly non-threat series, become clearly non-threat ship signatures. Depending on the threat potential of the newly combined series, the signature is stored in either the threat or non-threat file. The significance of this is that when contact is lost on signature components in the non-threat file, no signal processing action is taken, while the same condition (i.e., lost contact, not just loss of a component) in the threat file results in automatic high resolution signal processing in an attempt to regain contact.
- 5.0 (C) An alpha-numeric display of all current potential threats is presented to the operator. Before entering

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the Steady State phase, frequency and geographic trackers, as available, are assigned by the operator to retain contact and refine position and track estimates.

5.0 (C) The Steady State Solution

(U) This phase is characterized by a high degree of automation whose purpose is to maintain and refine the solution developed during the operator-interactive phase with a minimum amount of recourse to the operator interactive mode.

5.1 (C) The Steady State algorithm continually monitors for changes in the Steady State Solution by comparing the most recent formed signatures in the threat and non-threat descriptor tables to the latest output of the front end signal processor in the parameter estimation table. The changes fall into one of four general categories:

- a. loss in harmonic set member(s)
- b. gain in harmonic set member(s)
- c. change in signature characteristics
- d. change in target position, tracking, or maneuvers

5.1.1 Loss in Harmonic Set Member(s)

(C) Loss of one or more components of a non-threat signature is a desirable event in that it reduces non-threat interference. Loss of such components causes the non-threat descriptor table to be updated. Where the loss reflects target movement, i.e., components lost on one beam are now detected on another, a new "best-beam" determination is made and the table so modified. Since the ratio of well-defined, harmonic-rich "clearly non-threat" signatures to "potential threats" is, conservatively about 10 to 1 in the SOSUS and the ratio to actual or "probable" threats is much higher still, it should be possible to account for losses in harmonic sets almost totally automatically without recourse to operator interaction except in rare cases.

Potential threat signatures are handled differently. A loss of one or more harmonics of a potential threat causes an immediate alpha-numeric display advisory to the operator, stating not only the specifics of the loss, but also the processing resources available to

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attempt regaining contact. The operator's action is not determined by algorithm. Loss of a single component may have no special significance except in the unusual case where that component is the only one held simultaneously by another array. An acoustic display allows the operator to note visually the difference in signature appearance before and after the component loss.

(C) Where it is desirable to apply signal processing resources for reacquisition, the operator specifies the type and number of channels to be used and the reacquisition search plan.

(C) A successful reacquisition, e.g., by a frequency tracker or high resolution analyzer, requires operator concurrence and results in either an update of the threat descriptor file for concurrence or return to harmonic set formation for non-concurrence.

(C) The operator, as a result of an unsuccessful reacquisition attempt, can direct the application of other signal processing resources, or the continued application of the previous ones for a fixed period of time.

(C) Loss of components in a high potential signature causes the operator to return to harmonic set formation to maximize the probability of reacquisition. It is likely, however, that in the case where the loss of one or more components still leaves a well-defined signature, the operator will opt to return to steady state as in the case of a low threat potential signature.

5.1.2 Gain in Harmonic Set Member(s)

(C) New detections are compared to existing signatures primarily on the basis of frequency and bearing information. Successful matches result in both an alpha-numeric advisory message, and an acoustic display indicating the harmonic(s) gained and the candidate solution, which requires operator concurrence. Detection of new, unrelated components results in immediate exit from steady state to harmonic set formation. Past experience indicates that most new detections are associated with existing signatures.

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5.1.3(C) Change in Signature Characteristics

(C) A change in signature characteristics noted by comparing the values in the latest parameter estimation table to the previous entries causes execution of the negative classification algorithm. Examples of changes are: a) a change in harmonic emphasis, b) a change in the ratio of the fundamentals of two harmonic sets. These kinds of changes have the effect of converting threats to non-threats and vice versa, or of increasing or decreasing the threat potential, of a possible threat. The operator's concurrence is required to update the target status tables, both threat and non-threat. In the case where the operator disagrees with a non-threat to threat conversion, he is required to examine an acoustic display, and is permitted to call for execution of ambiguity-resolving signal processing resources.

5.1.4(C) Changes in Target Localization, Tracking, Maneuvers

(C) Both threat and non-threat signatures are checked for correctness of the original solution on a continuing basis. Where the signature consists of more than one harmonic series, both are checked for bearing consistency. For threat signatures, changes in the predicted track solution represent a change in the steady state. Abrupt loss of one or more series or frequency shifts indicating maneuvers, are recognized as significant changes. All result in a display to the operator and a requirement for an operator-interactive task - i.e., a decision as to the effect of the change on the particular signature's threat potential - and a modification, if appropriate, of the threat or non-threat file.

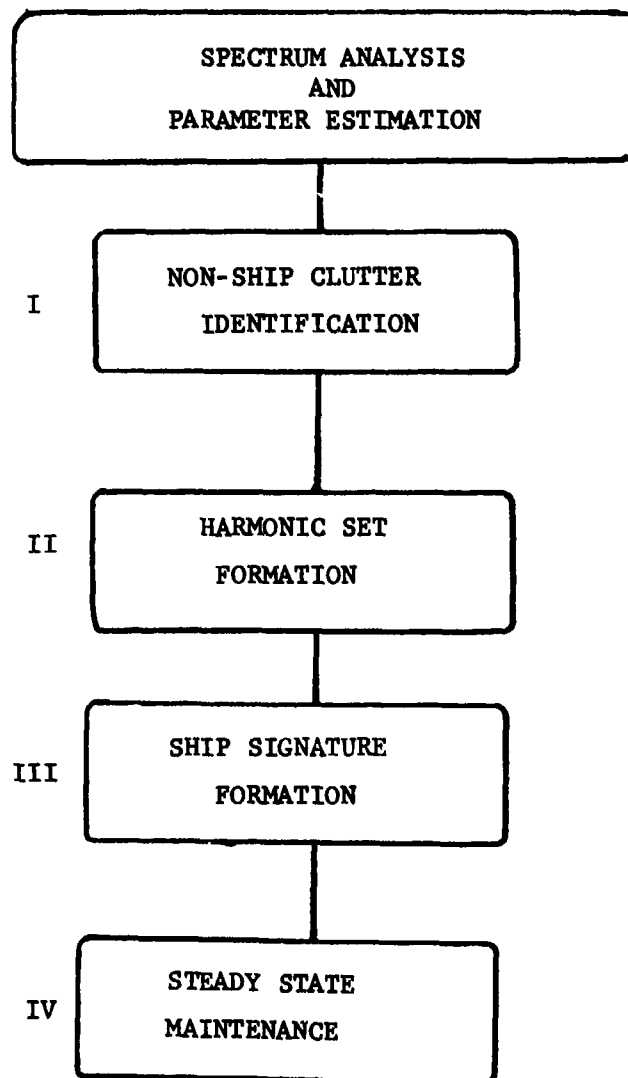
(C) At the point where Steady State has been reached, since change takes place slowly in fixed surveillance systems, and most changes reflect detections or losses of components of signatures currently held, it should be possible to maintain the Steady State Solution with a low operator task rate, where the tasks, options, and action required are objectively defined. A major purpose of this experimental development is to determine empirically, using real-world data, the operator task rate.

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References

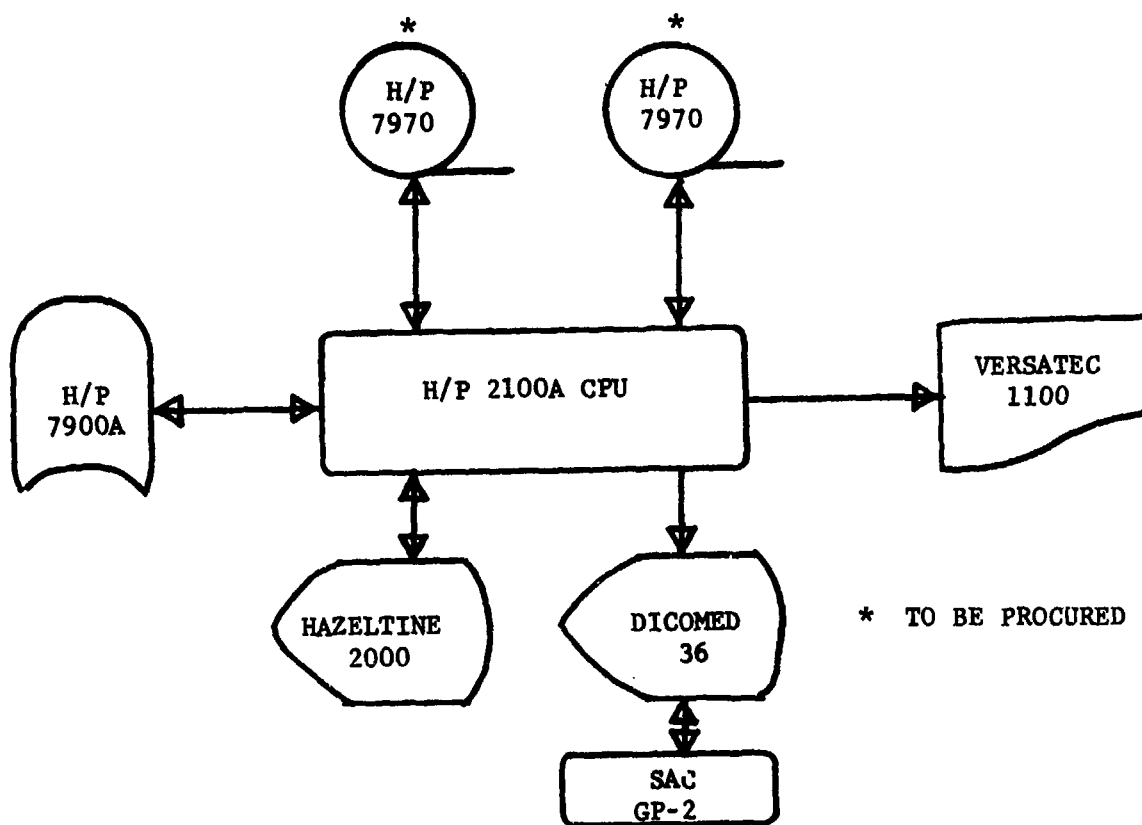
1. Operator/Machine Interactions for Sector Scan in Acoustic Undersea Surveillance^c - NRL Program Plan of 6 June 1975 (S).
2. Automatic Signature Formation and Classification - NRL ltr ser C49 dtd 10 Feb 1977 (C).
3. COMOCEANSYSLANT LIMA Events 1972 and 1973. (George V. Olds, NRL) - Presentation to Automatic Detection/Automatic Classification Committee at NUSC, NLON June 1974.
4. Principles of Lofargram Analysis, NAVSHIPS 0967-340-4010 (S).

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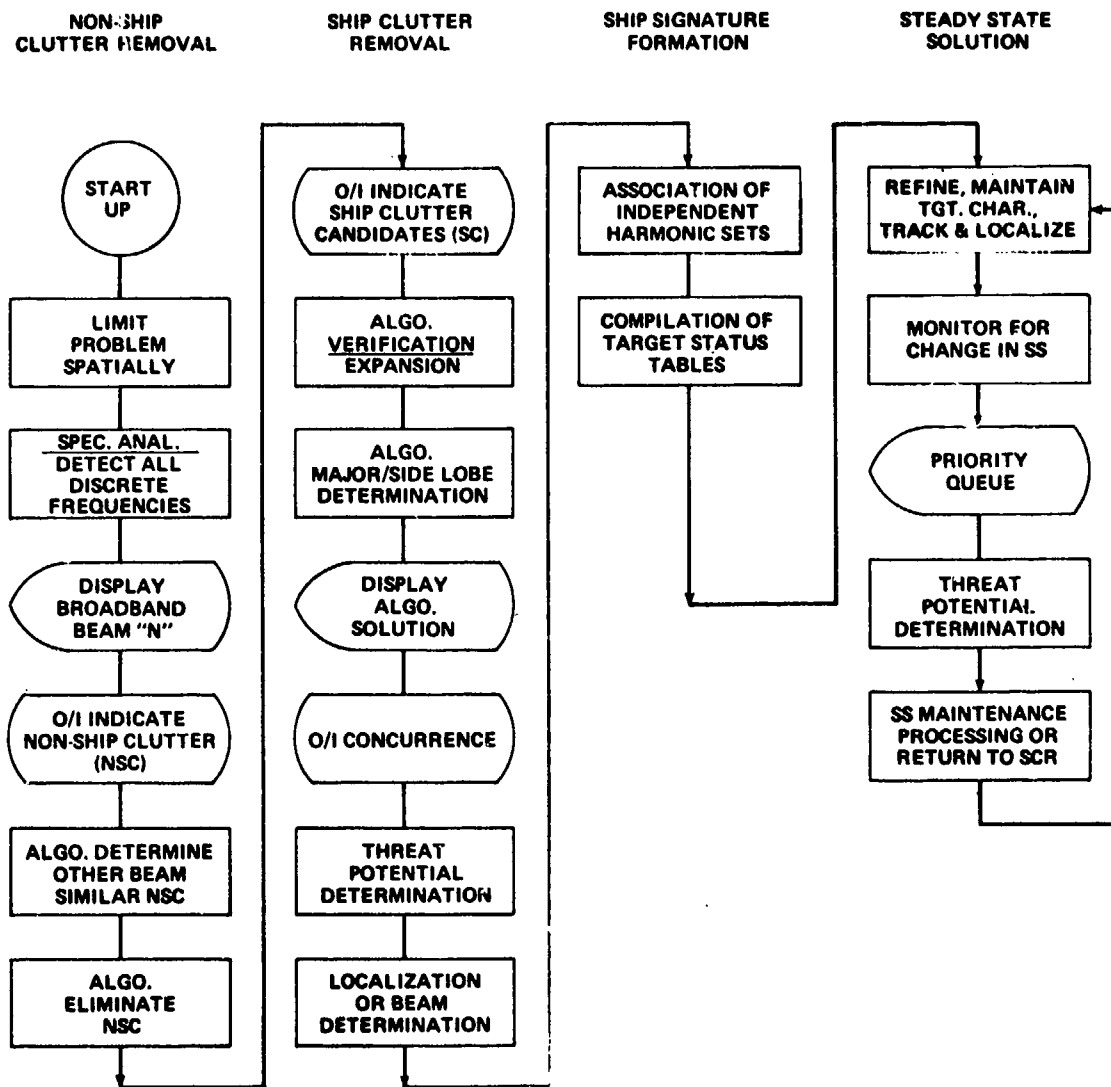
(C) Fig. 1 - Signature formation sequence

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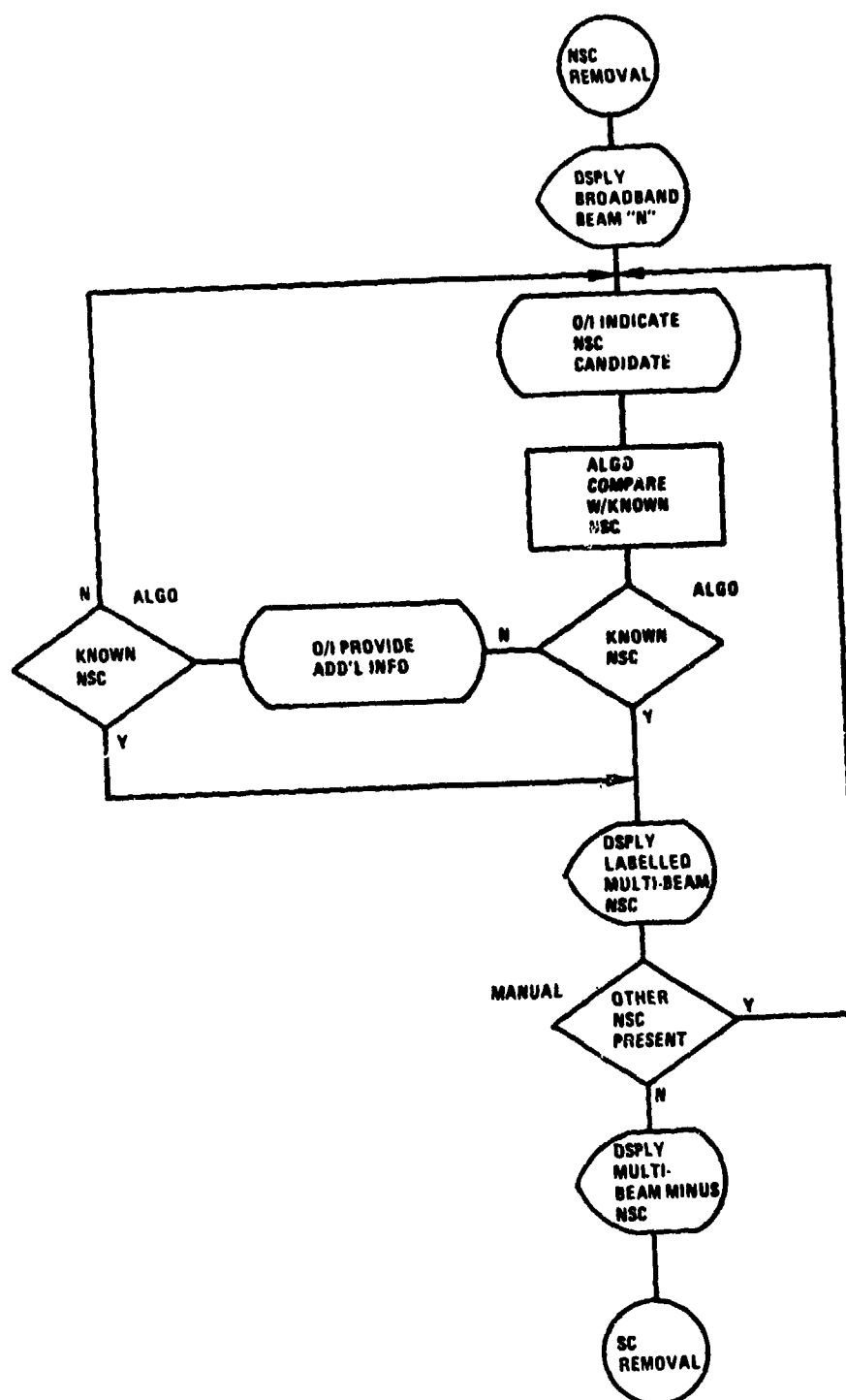
(U) Fig. 2 - Experimental configuration

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(C) Fig. 3 - Operator interactive signature formation overall logic

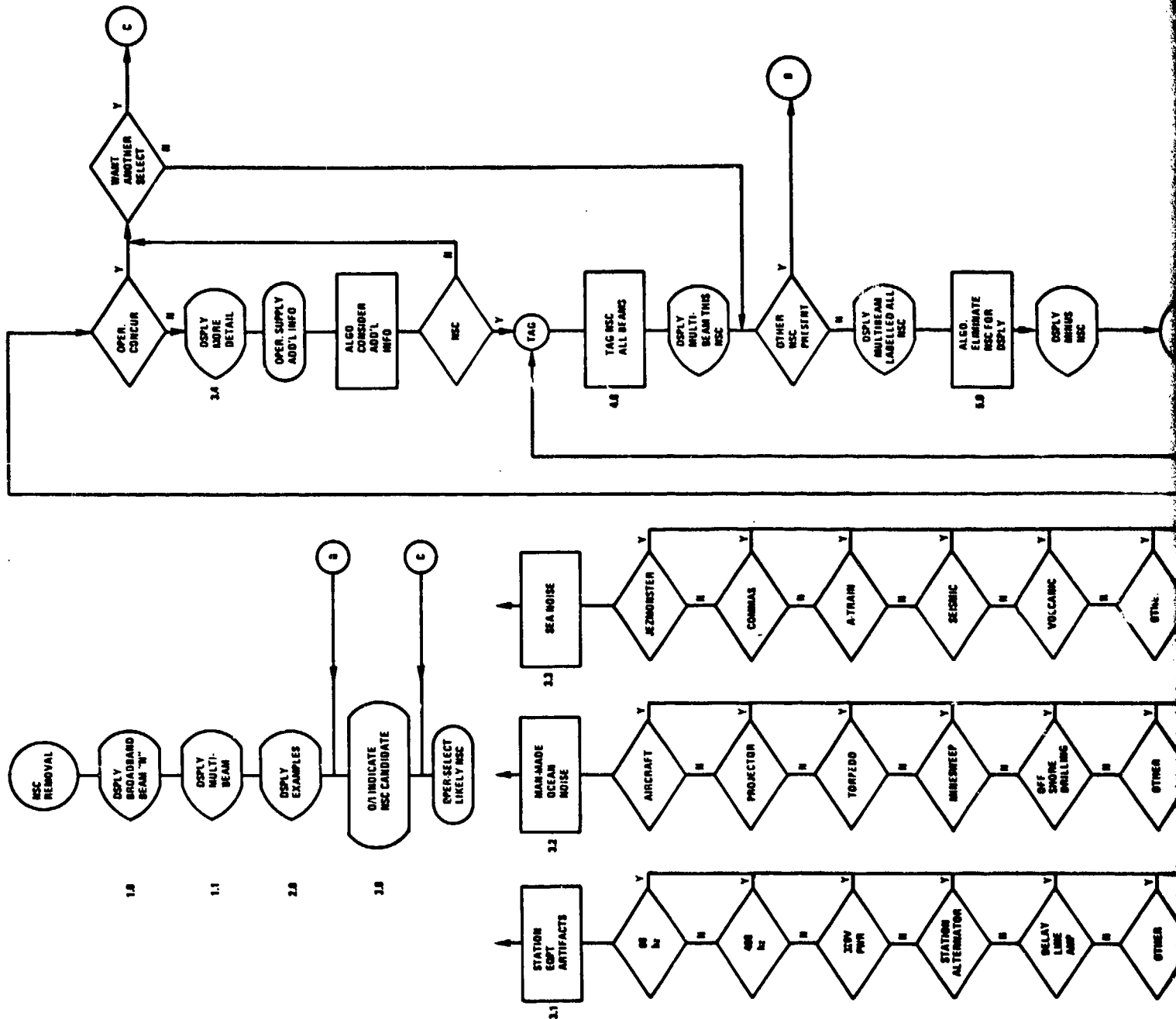
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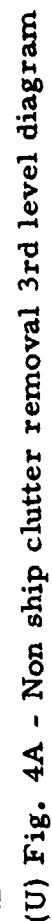


(U) Fig. 4 - Non ship clutter removal 2nd level diagram

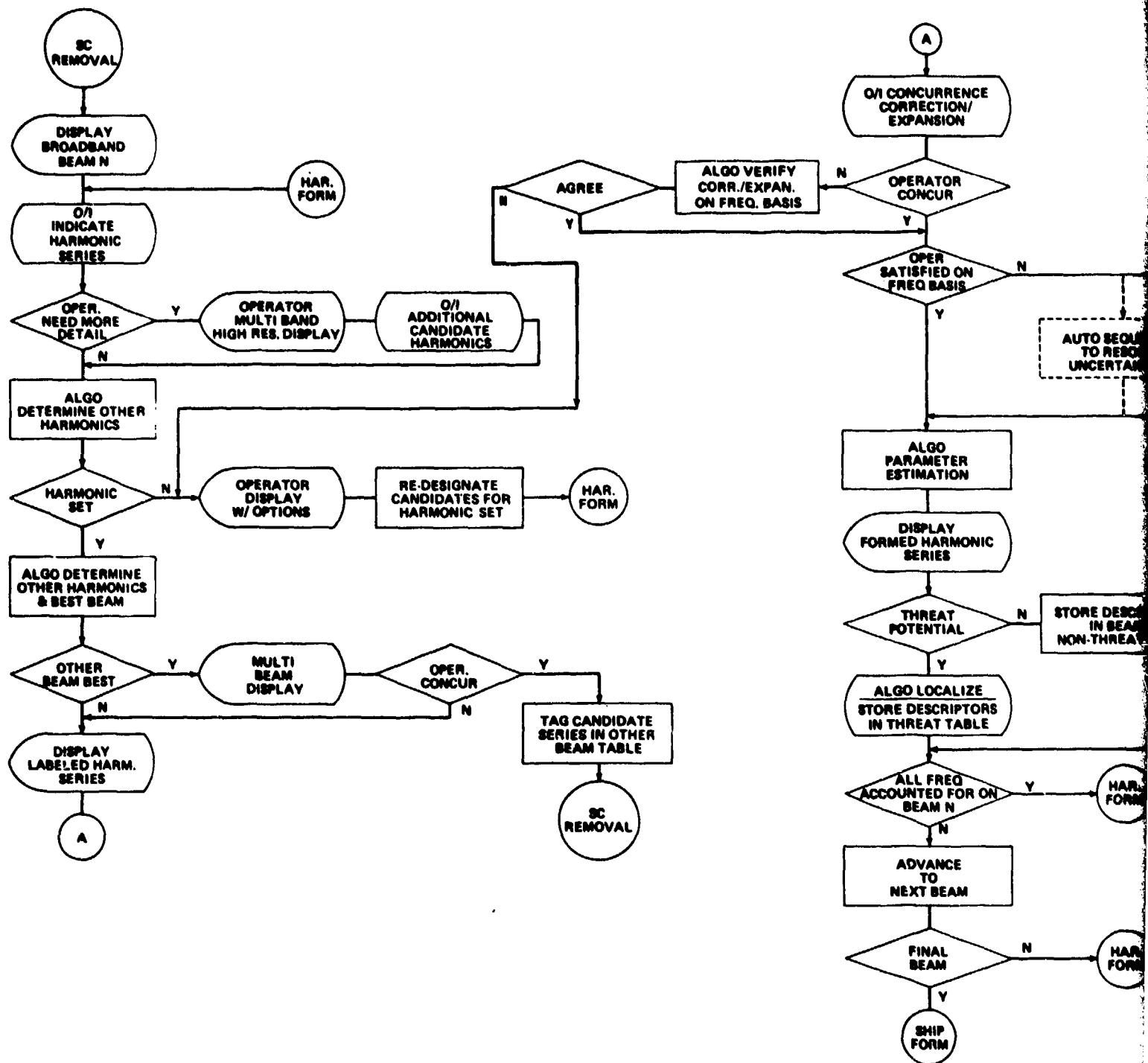
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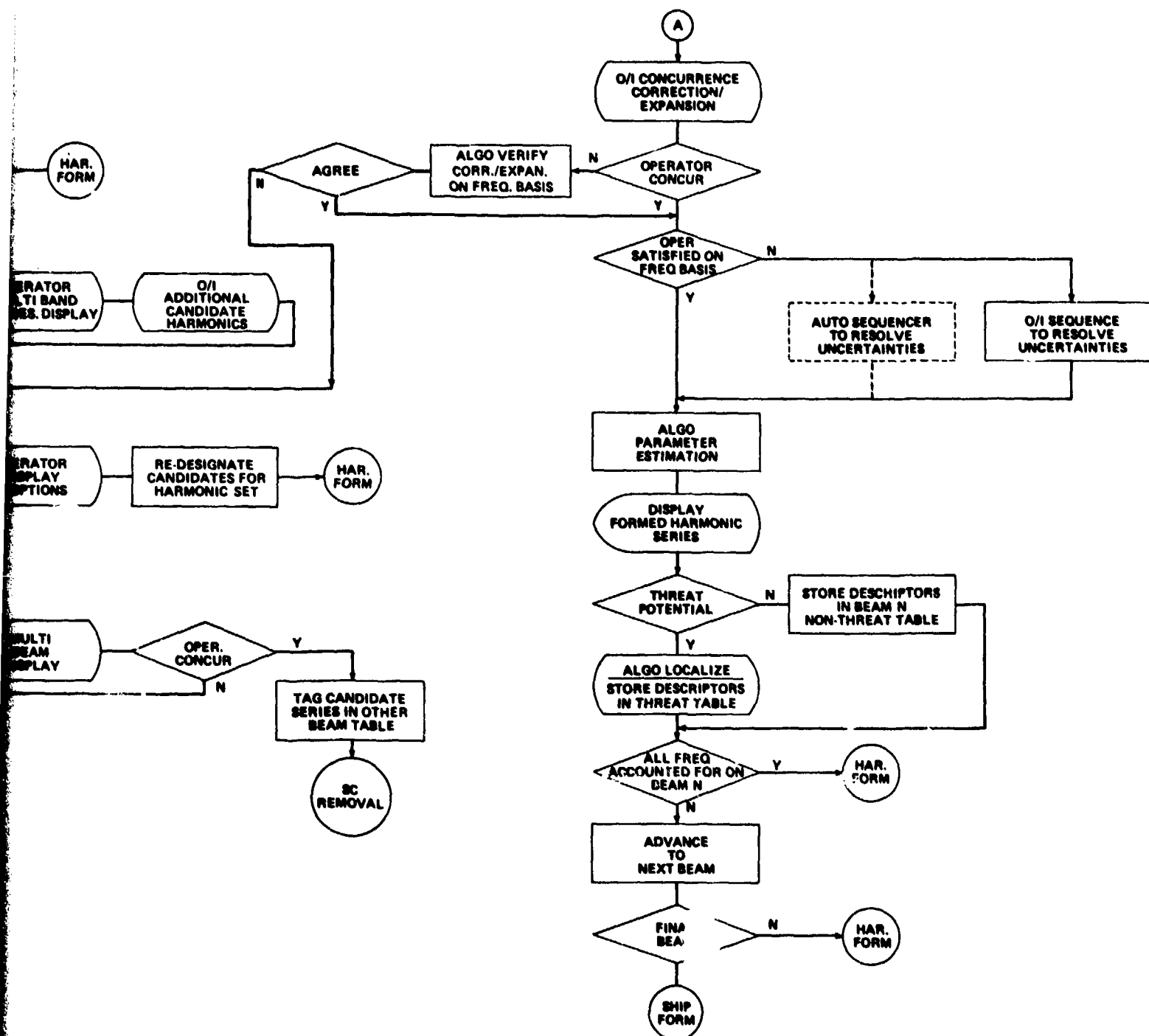




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(U) Fig. 5 - Harmonic set formation 2nd level diagram



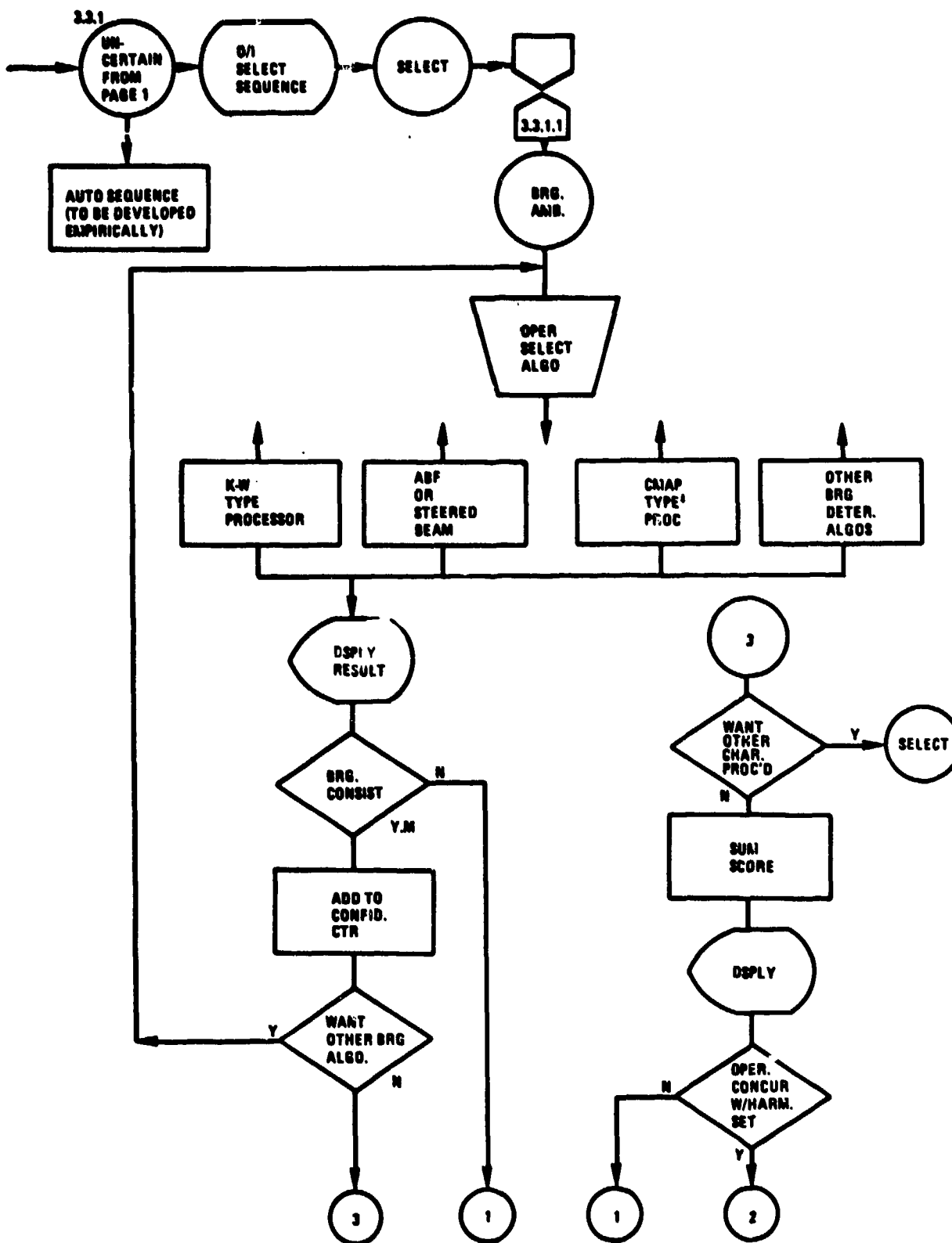
(U) Fig. 5 - Harmonic set formation 2nd level diagram

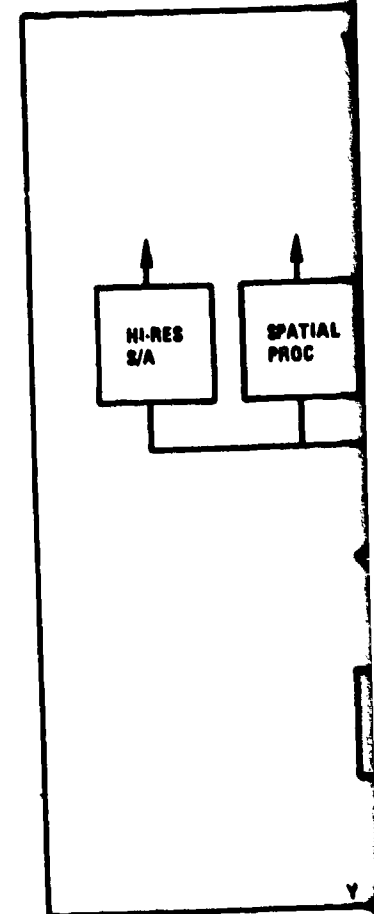
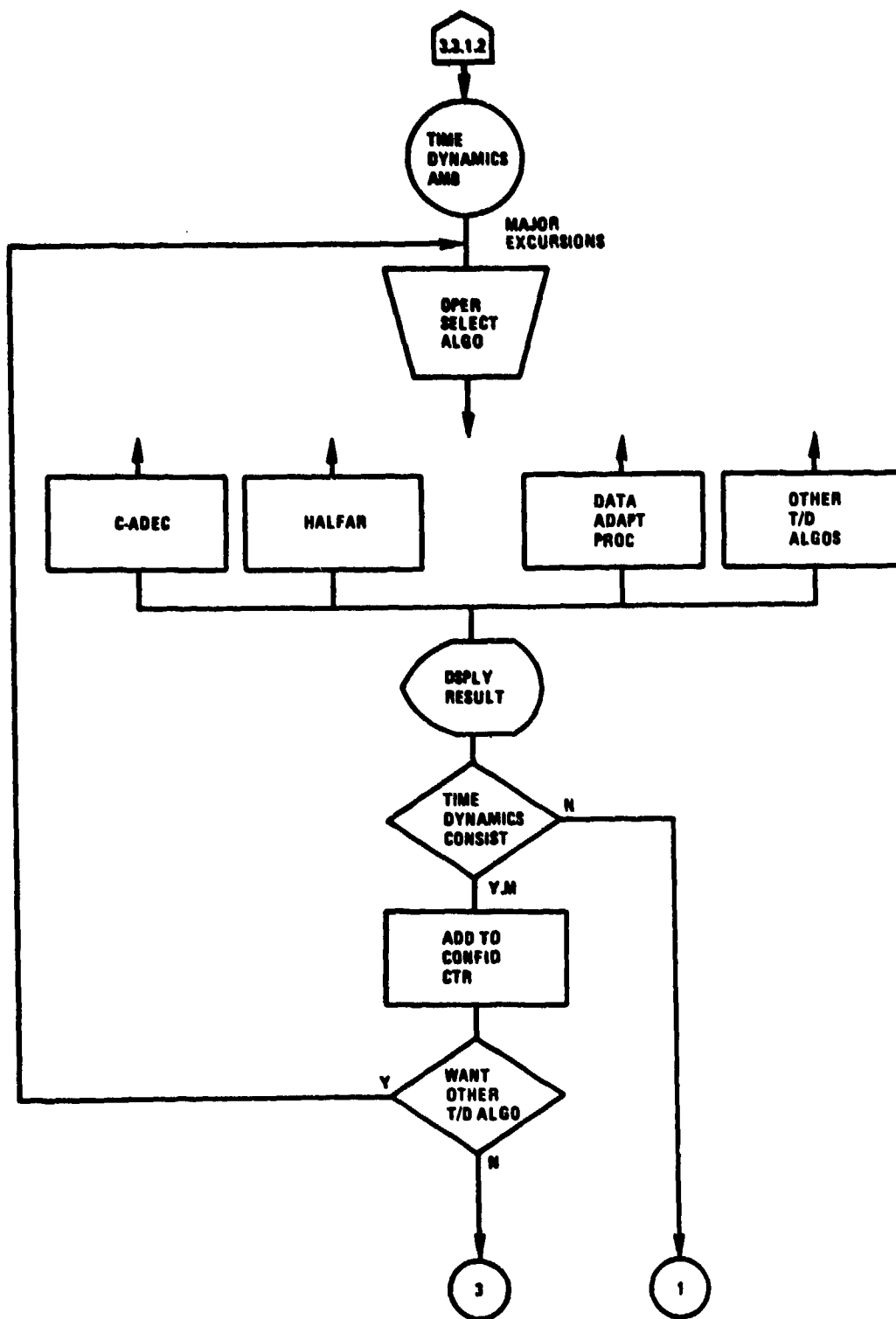
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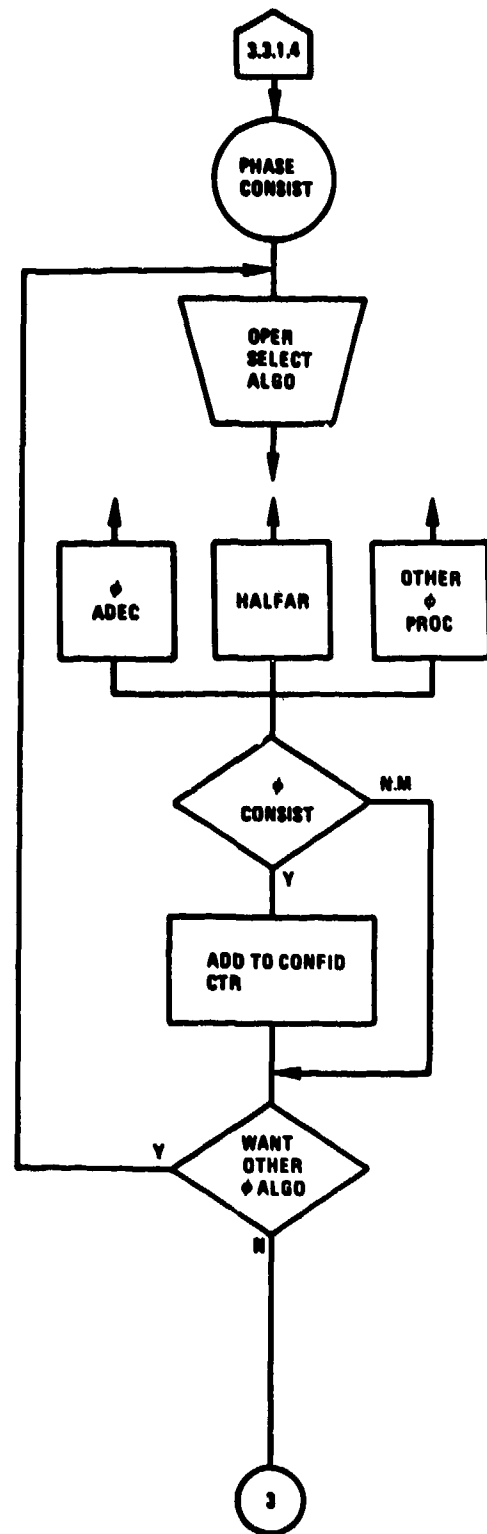
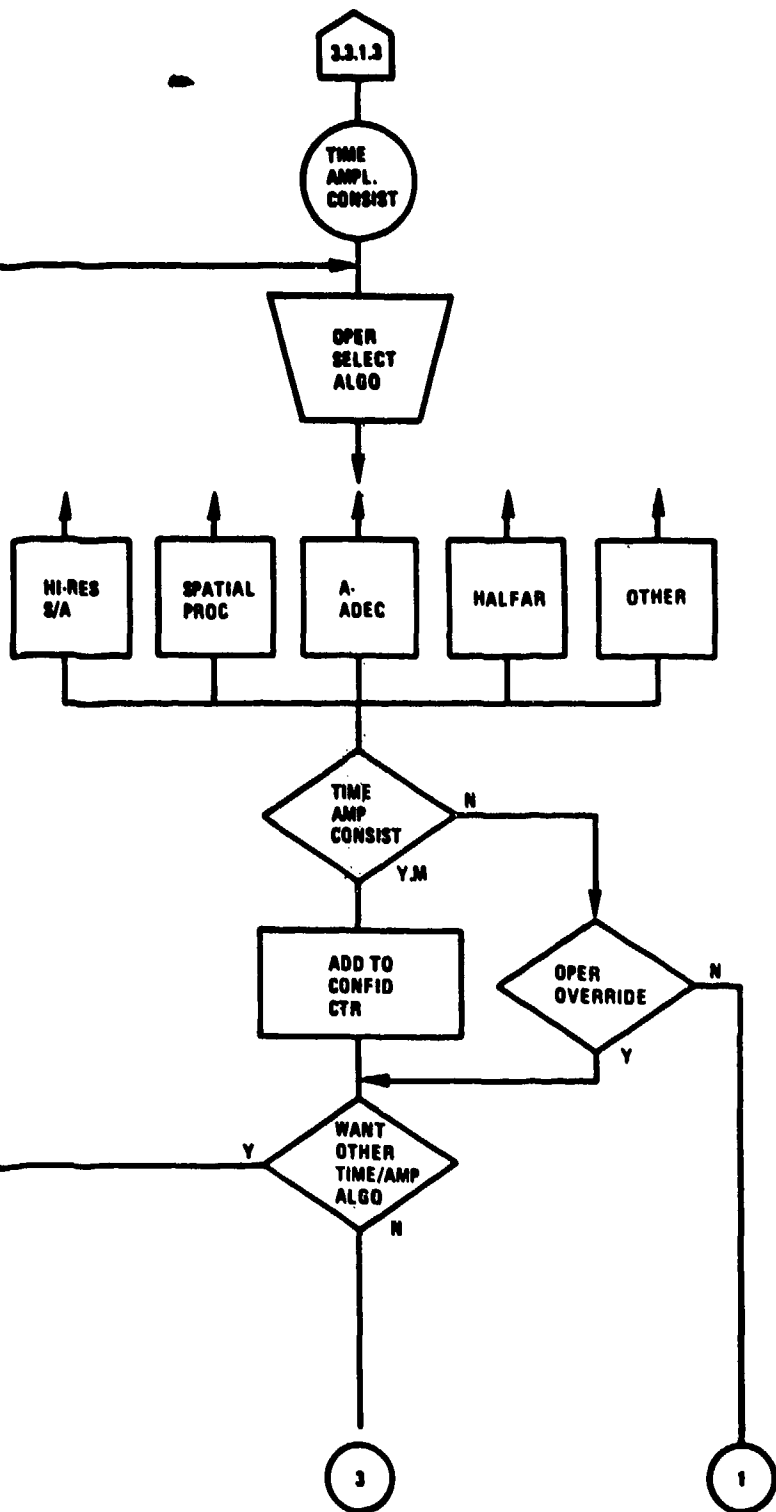
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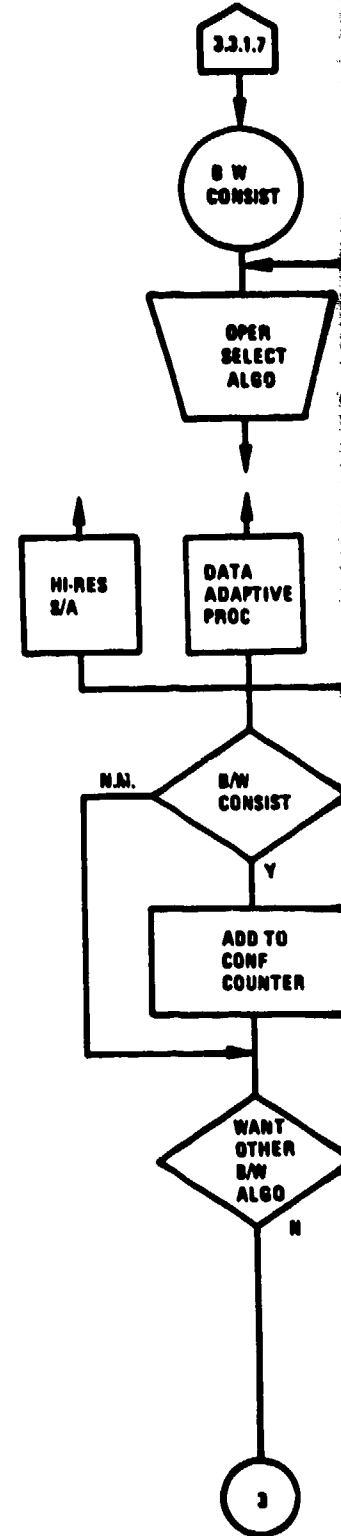
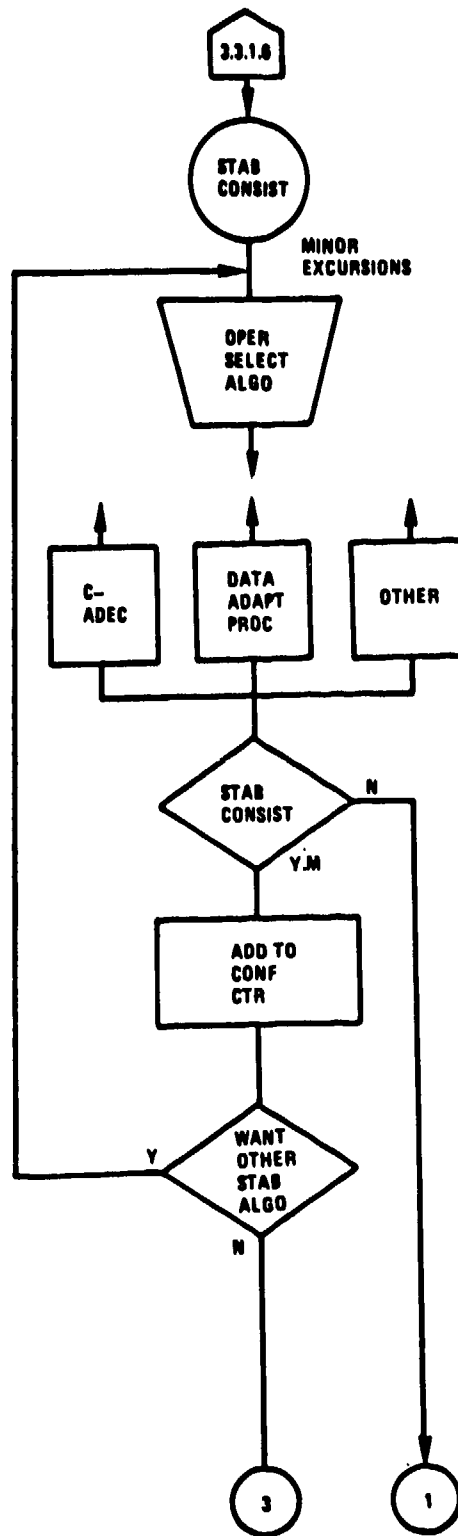
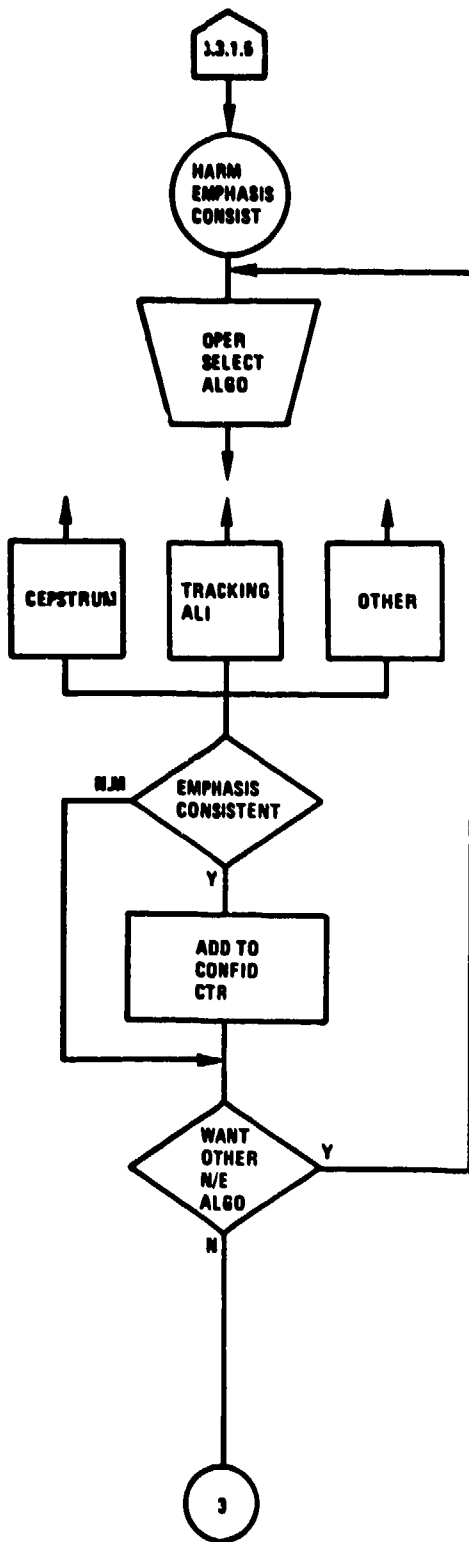


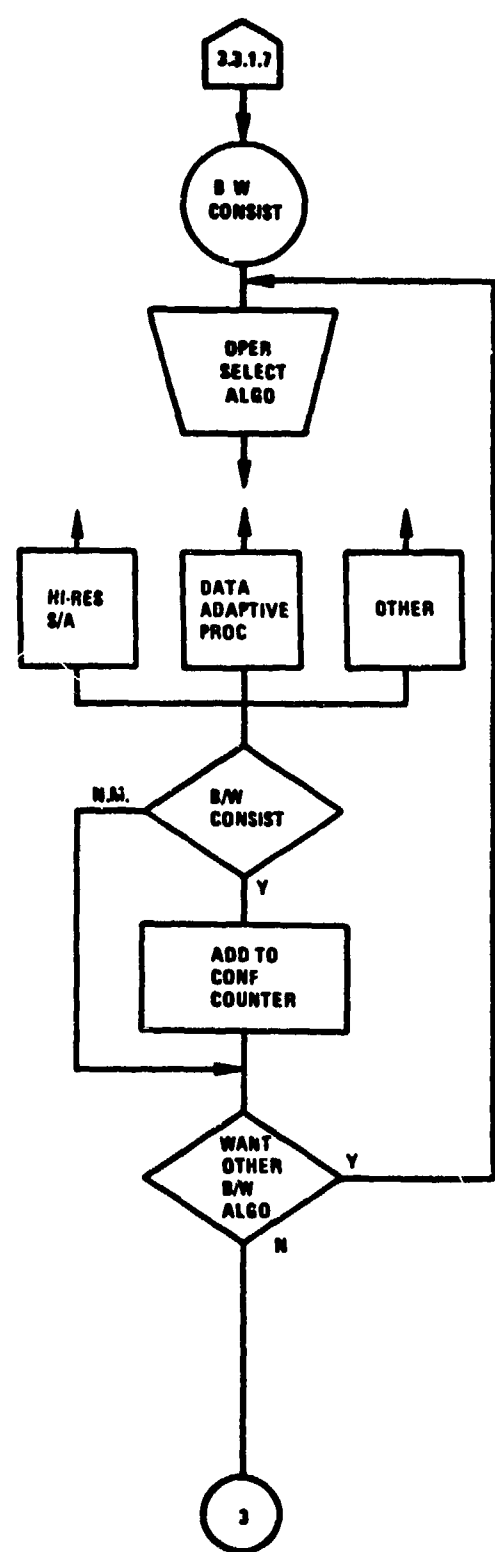
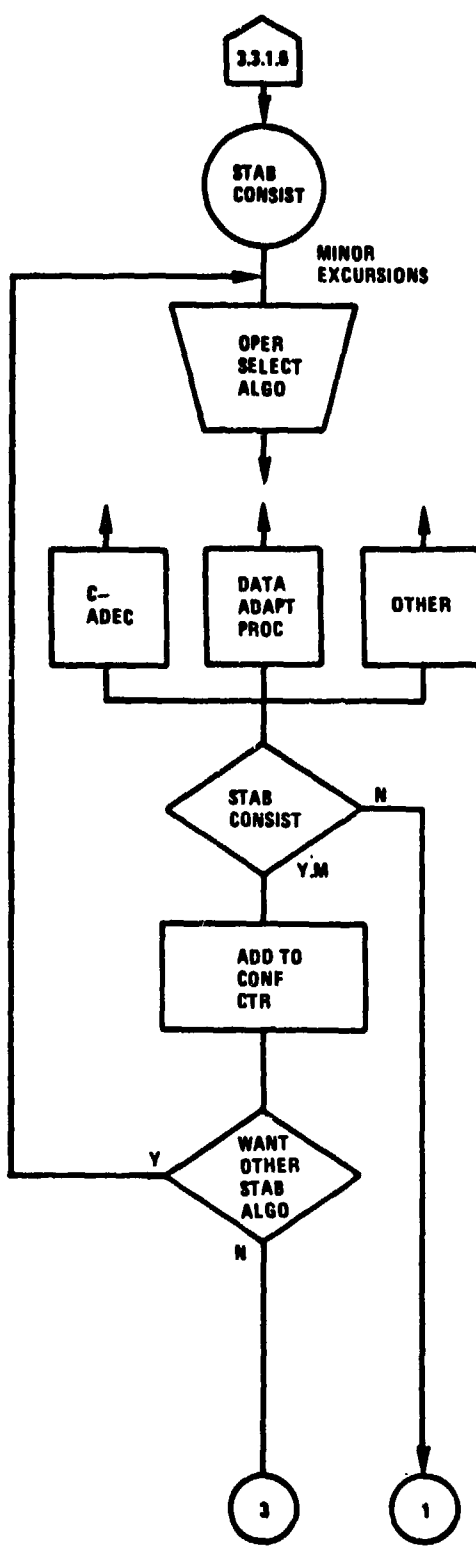
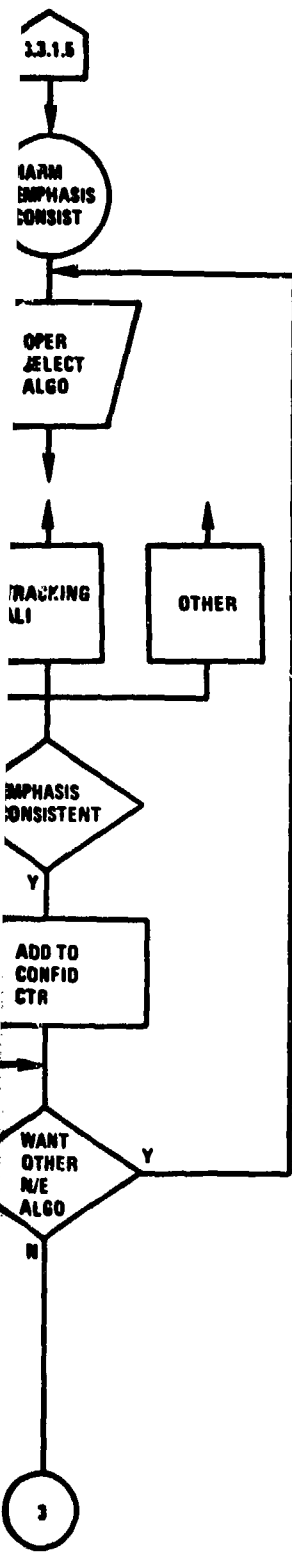
(U) Fig. 5B - Harmonic set f



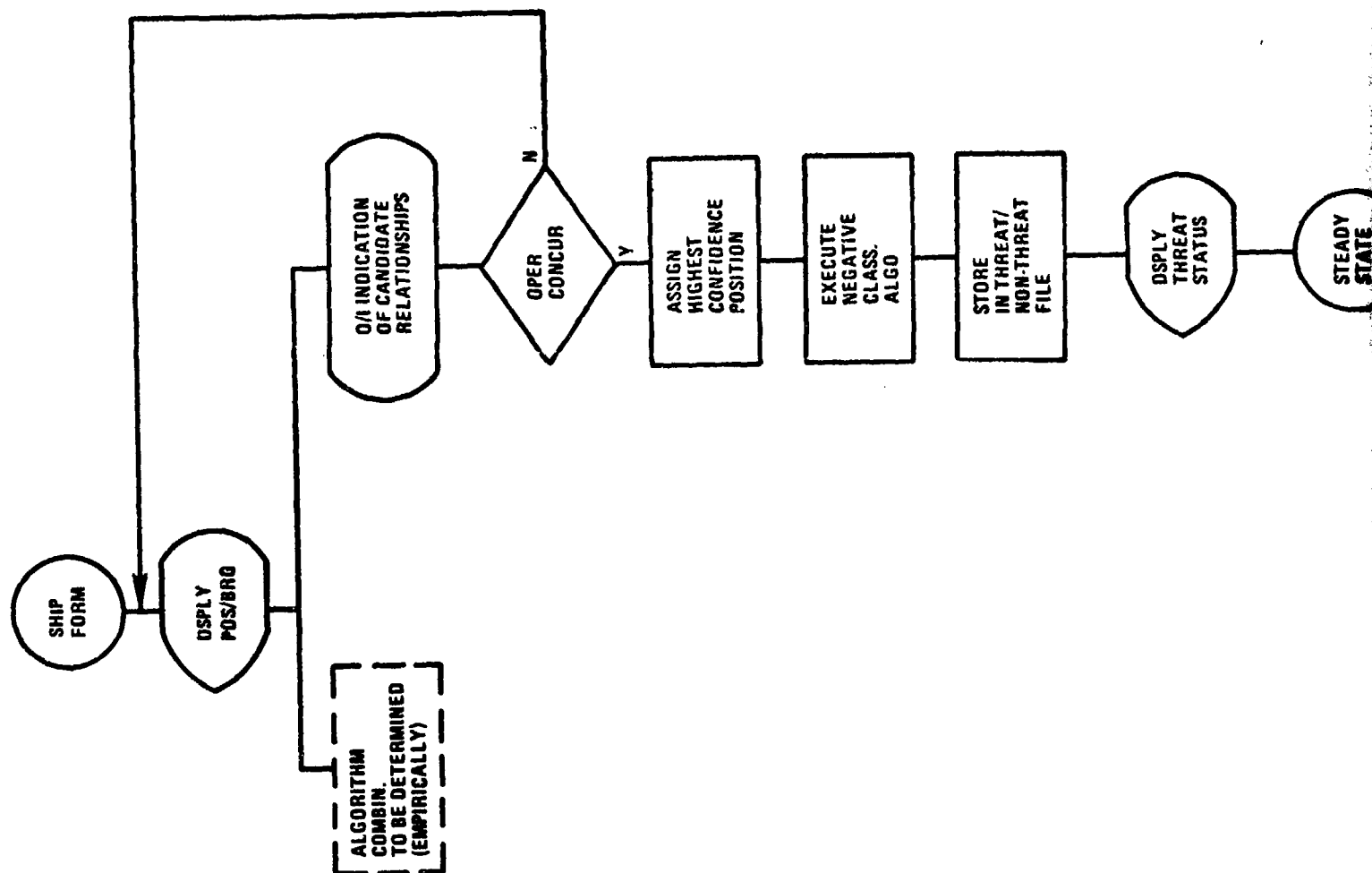
- Harmonic set formation 3rd level diagram (page 2)

3



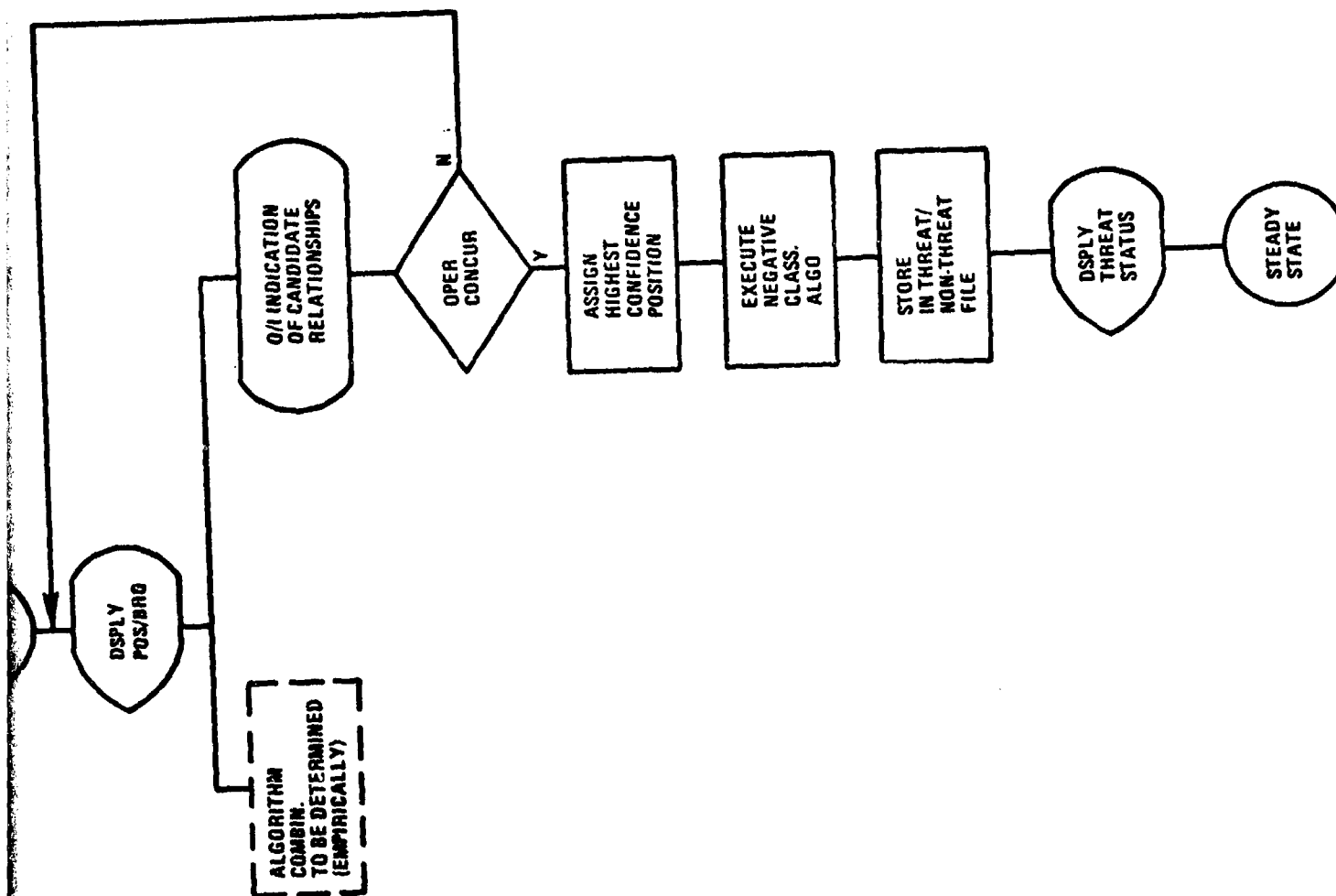


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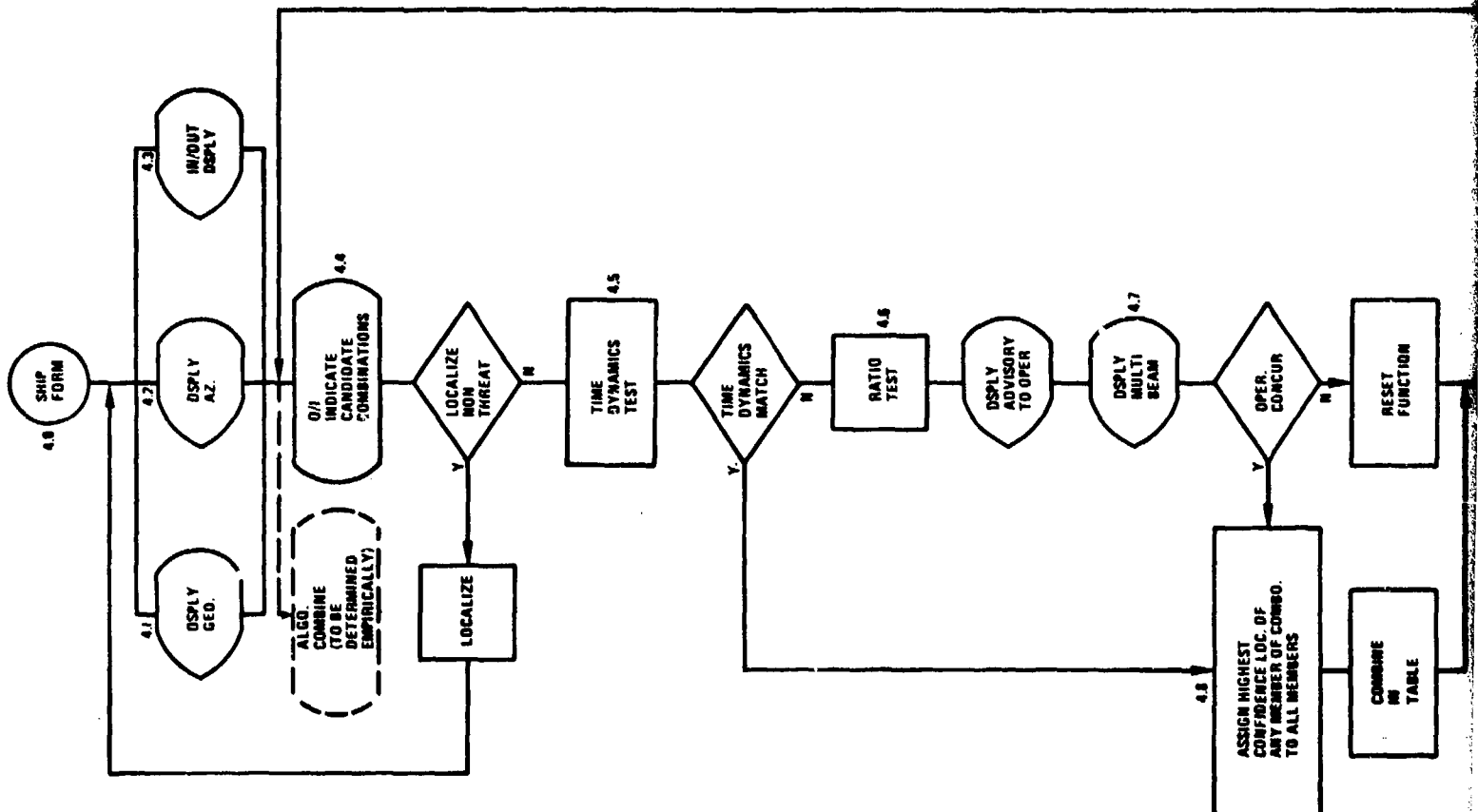
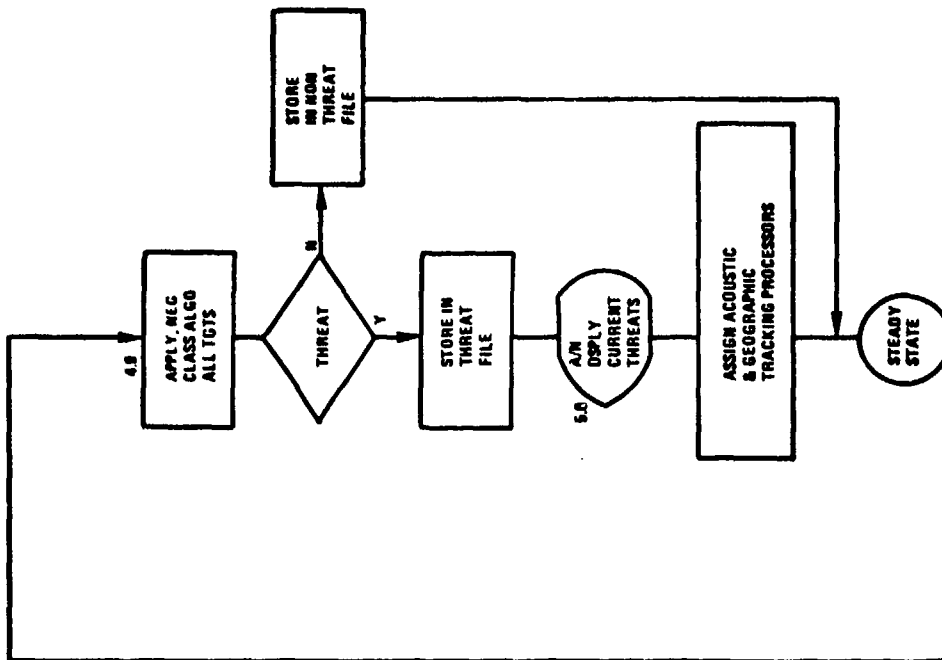
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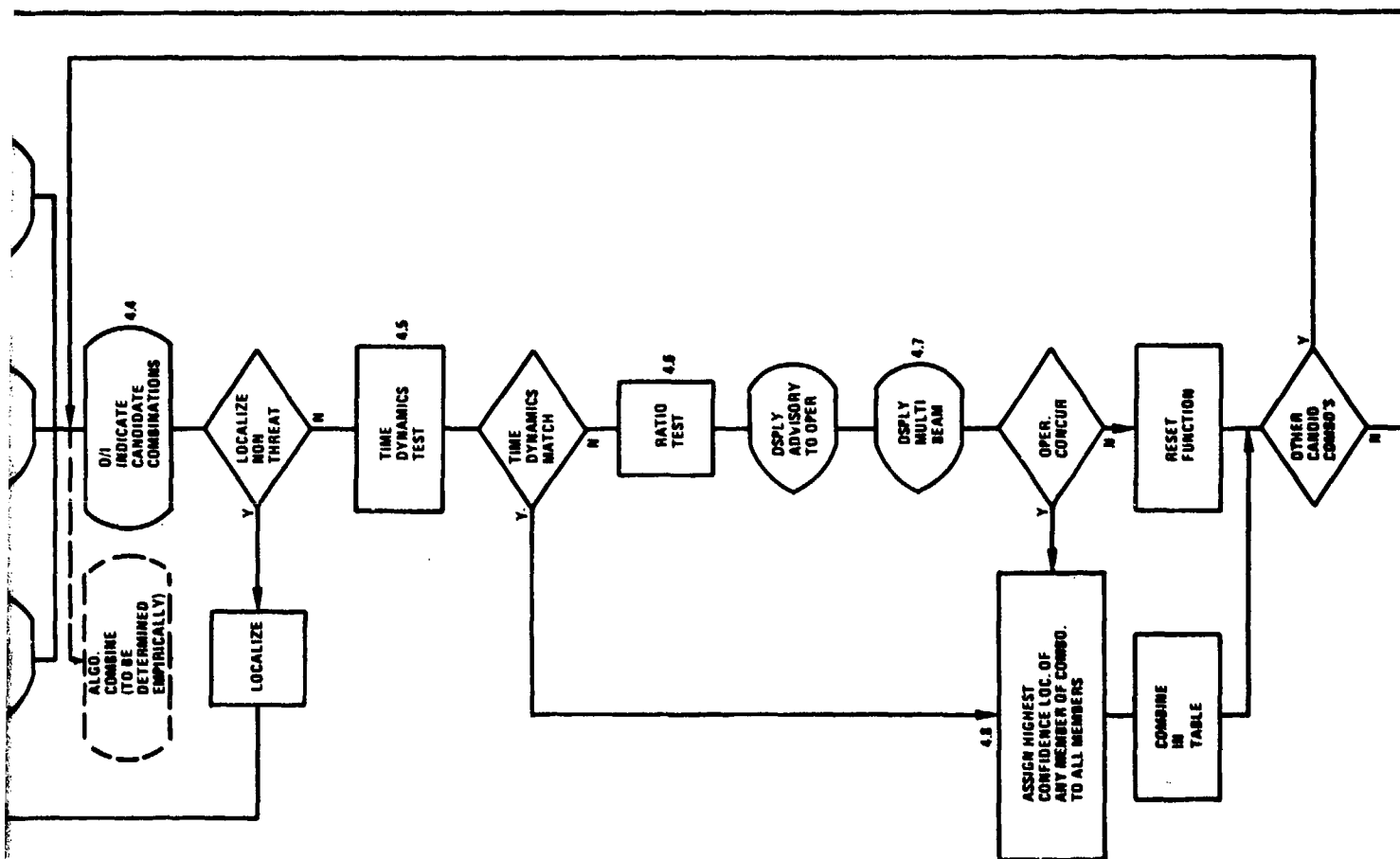
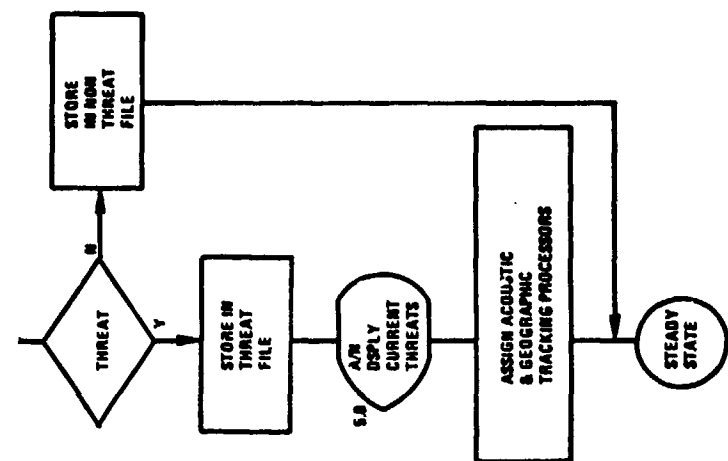
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(U) Fig. 6 - Ship signature formation 2nd level diagram

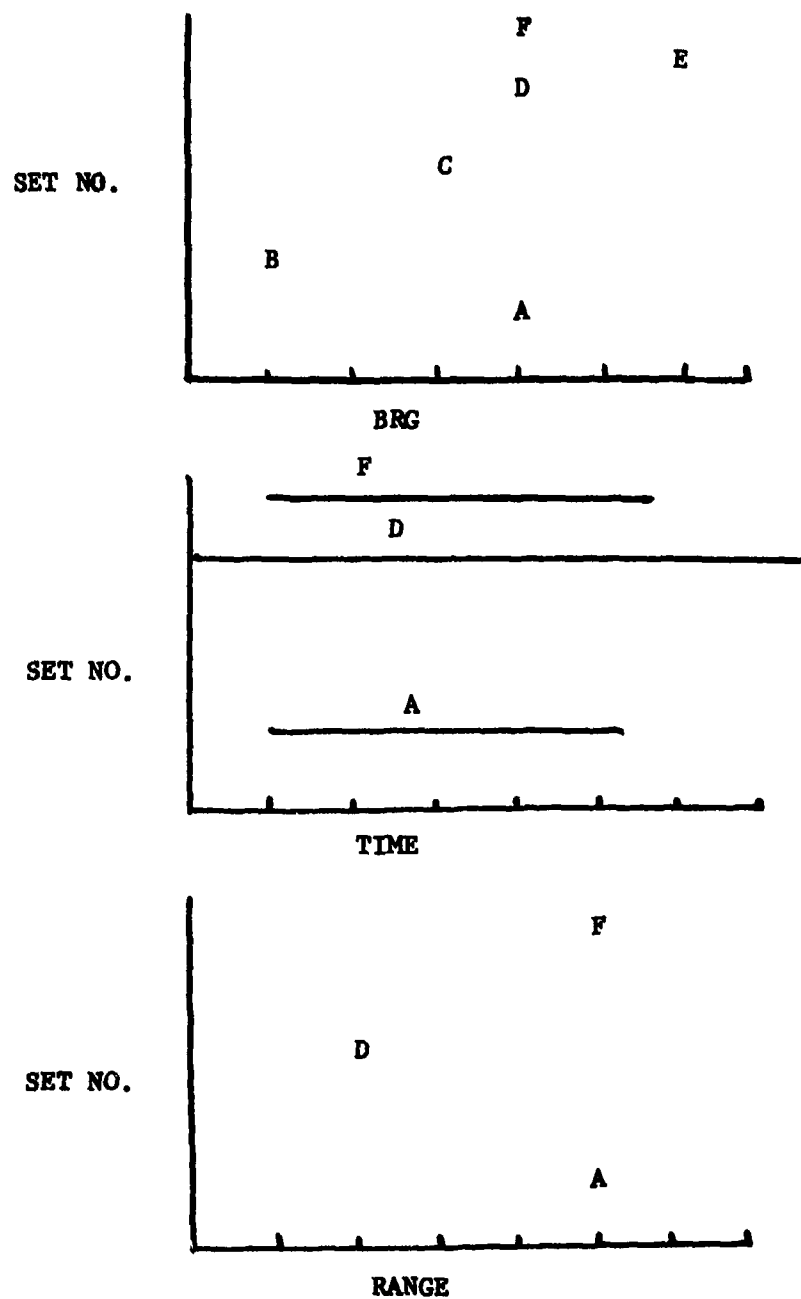
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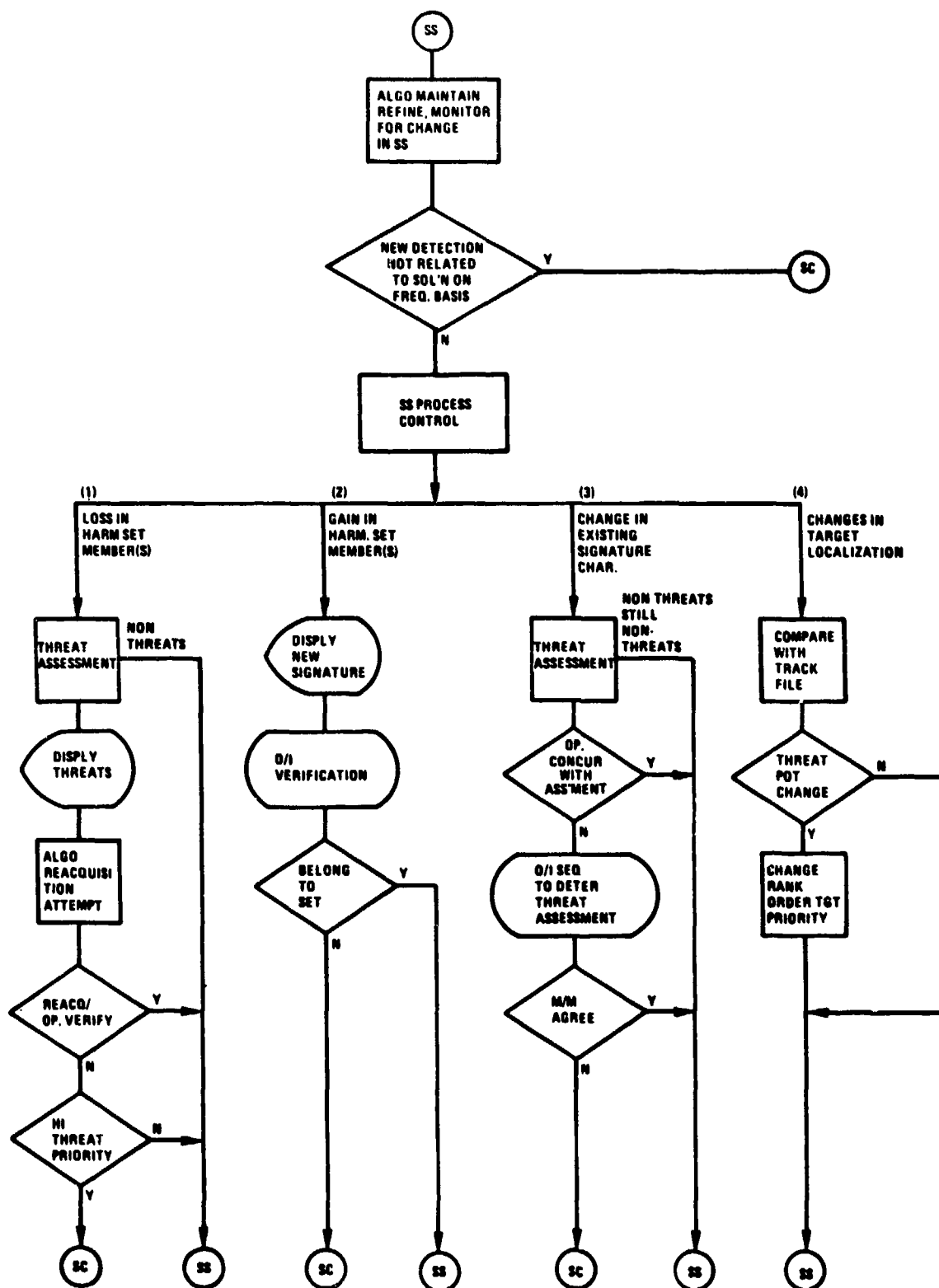
(U) Fig. 6A - Ship signature formation 3rd level diagram

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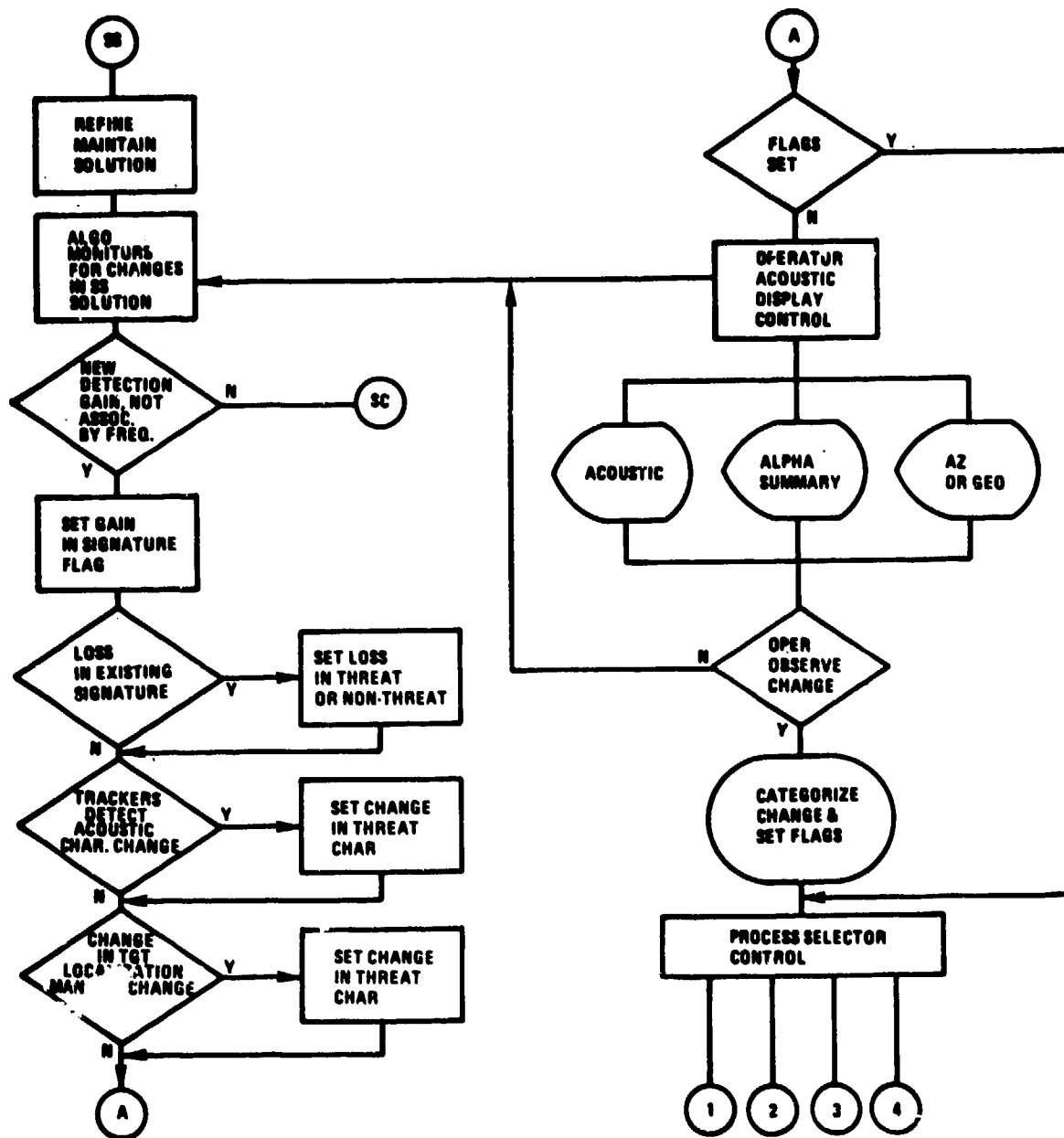
(U) Fig. 6B - Display formats

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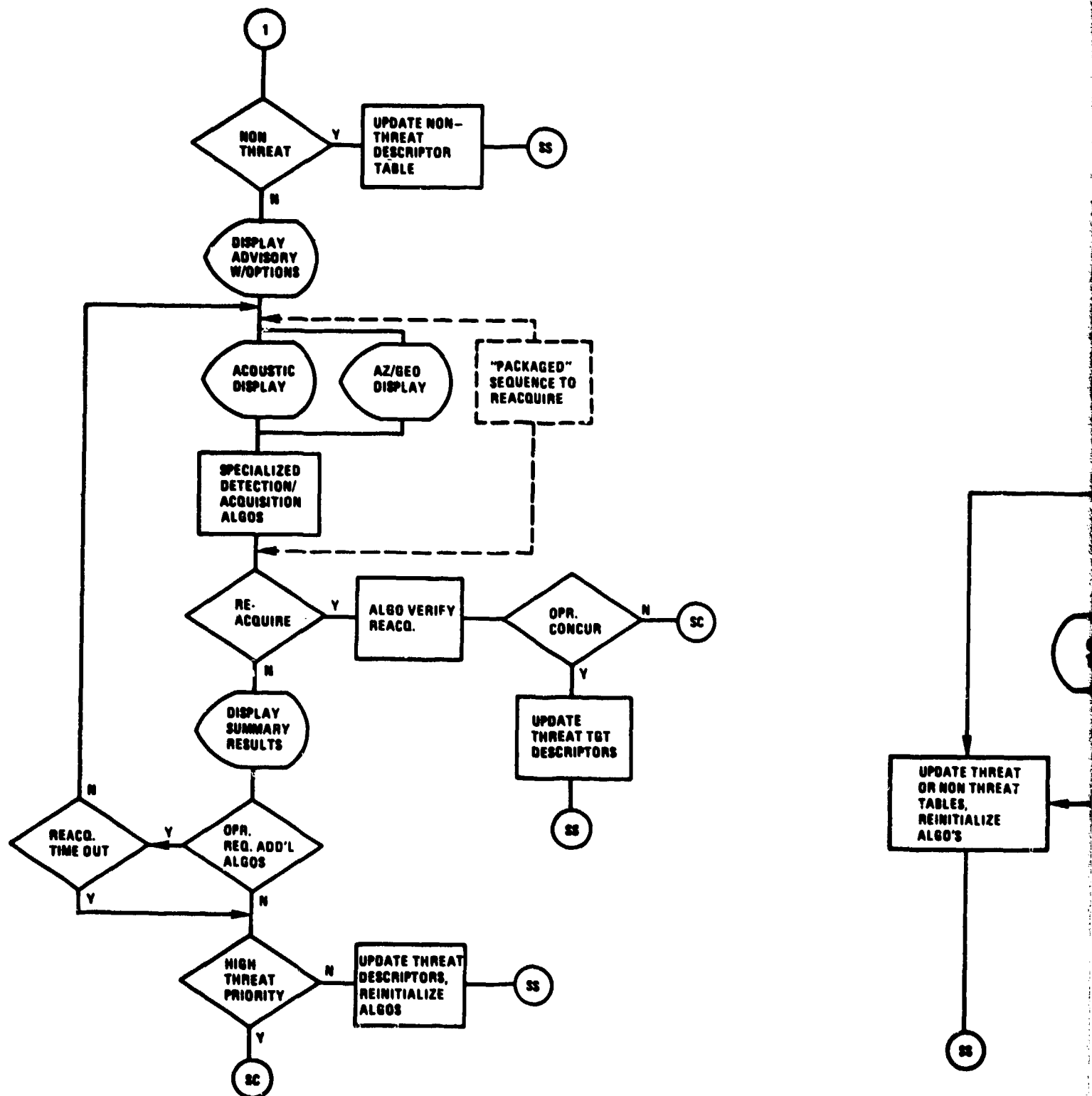
(U) Fig. 7 - Steady state solution 2nd level diagram

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LOSS IN HARMONIC SET MEMBER(S)

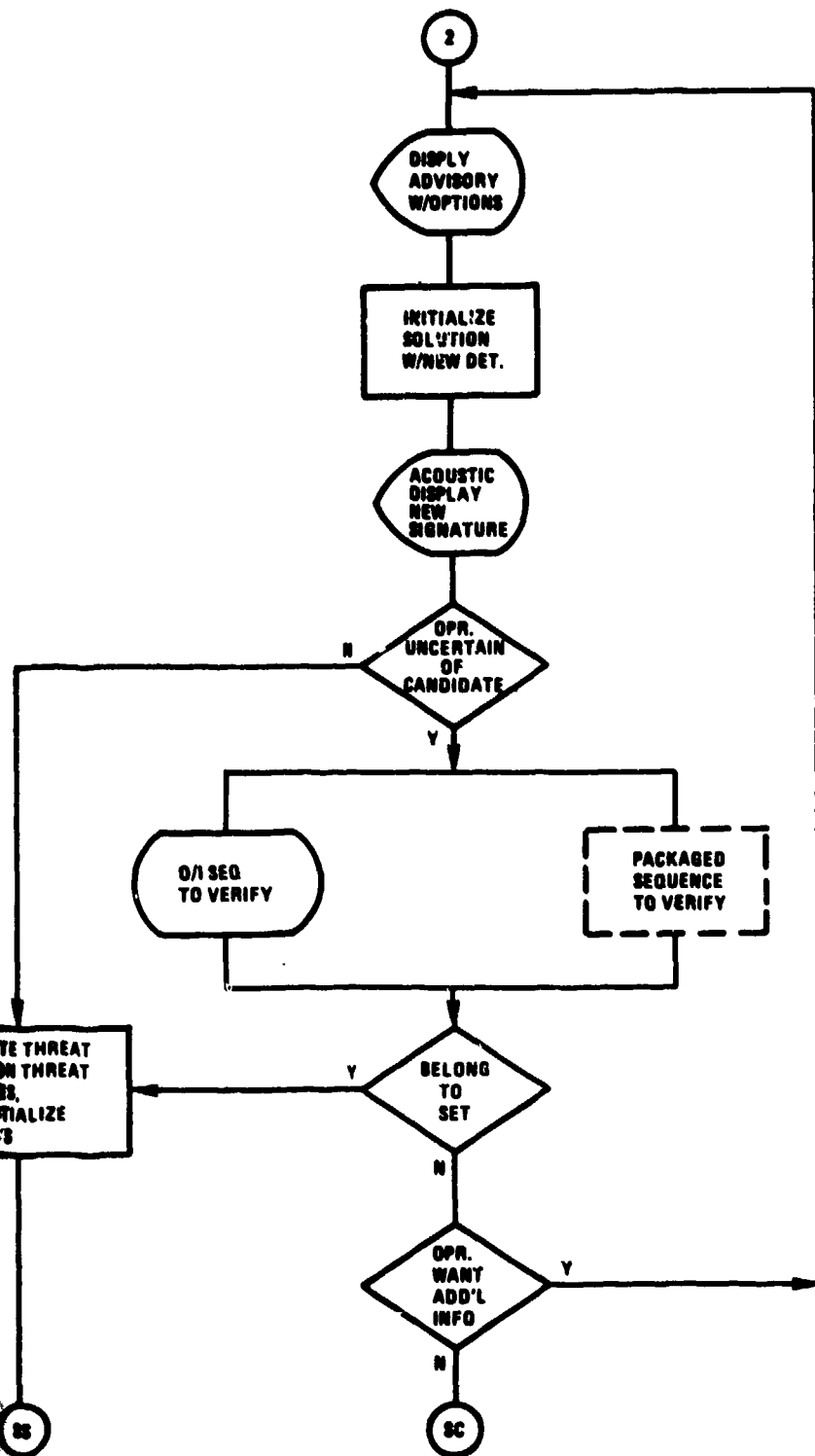
6A10



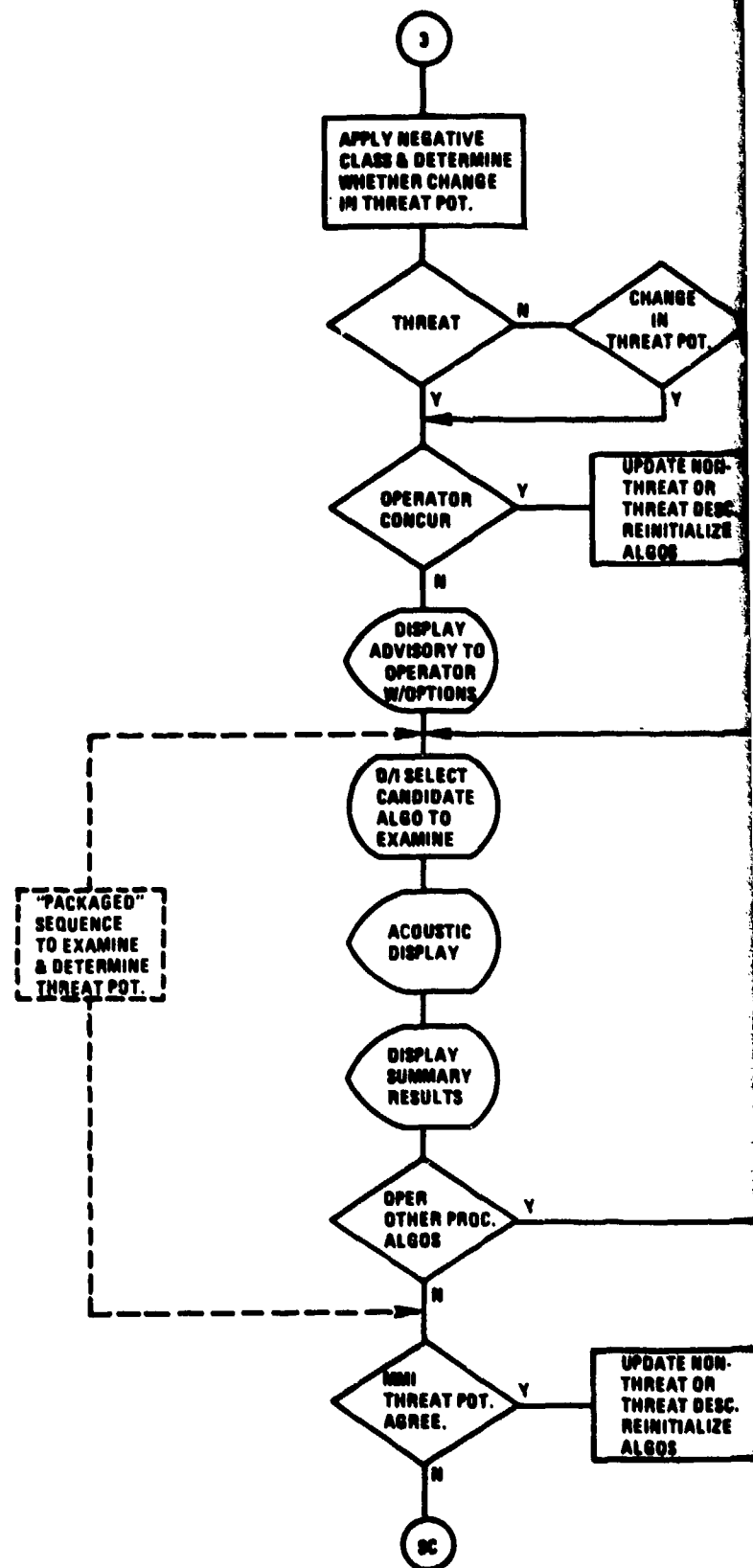
(U) Fig. 7A - Steady state solution 3rd

2

GAIN IN HARM. SET MEMBER(S)



CHANGE IN EXISTING SIGNATURE C

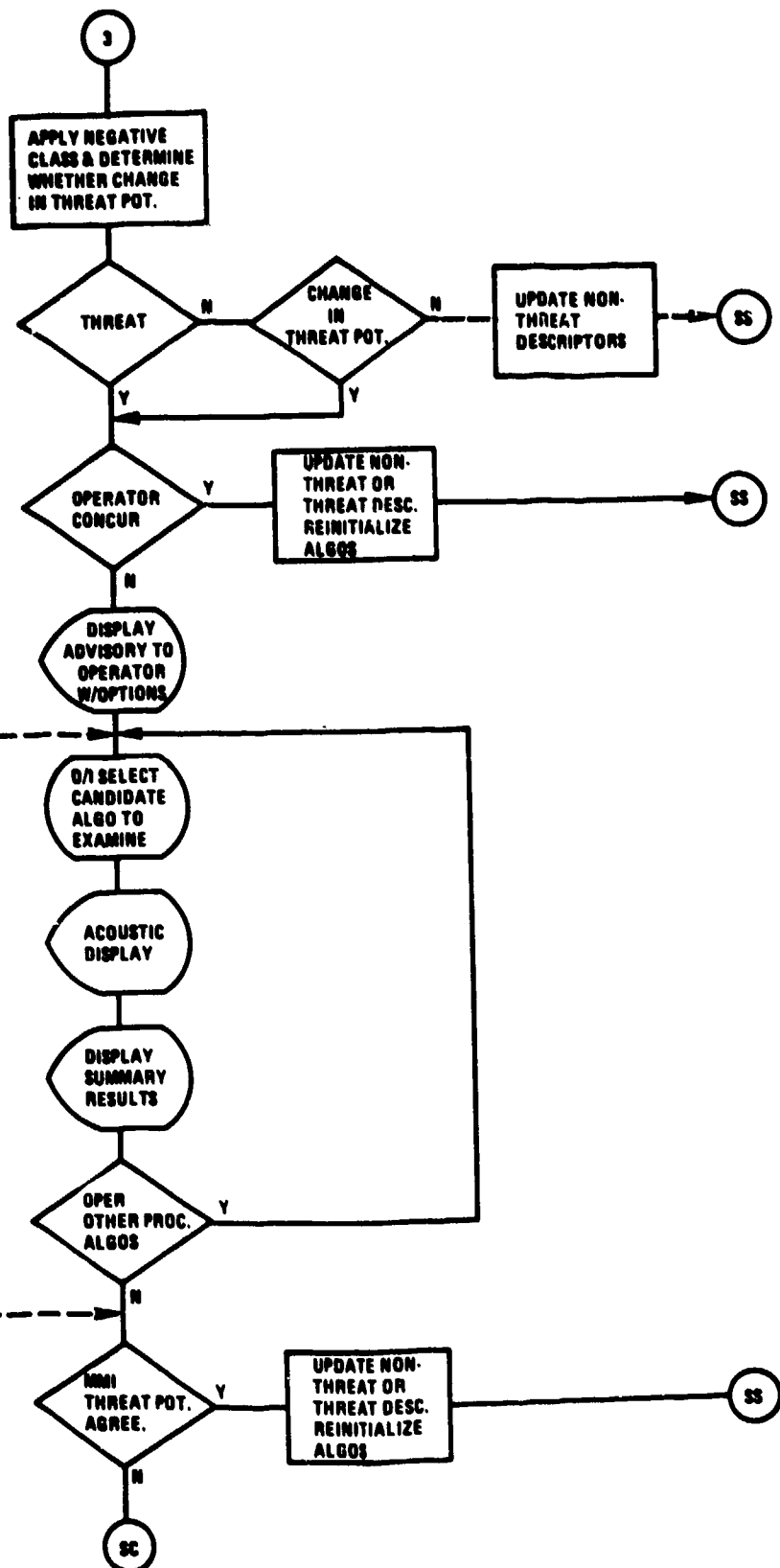


solution 3rd level diagram

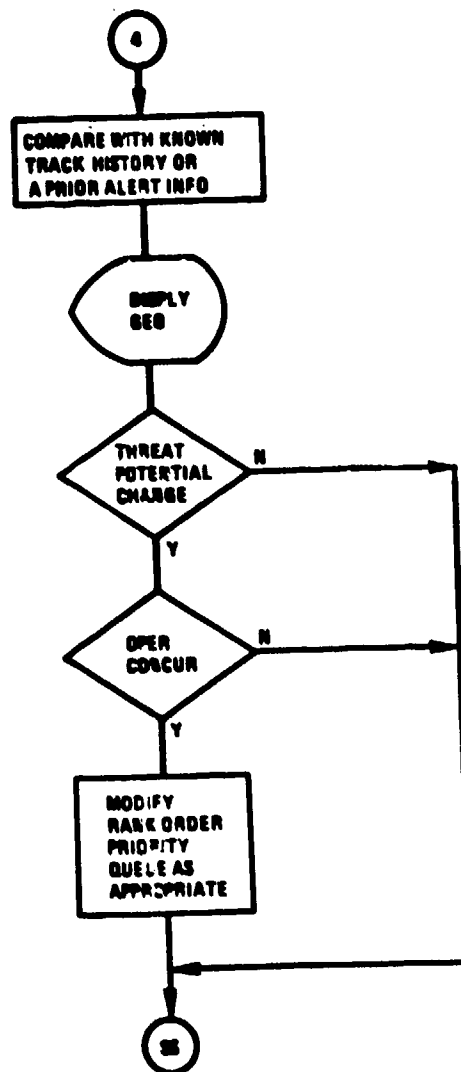
9
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3

CHANGES IN EXISTING SIGNATURE CHARACTERISTICS



CHANGES IN TARGET LOCALIZATION, TRACKING, MANEUVERS



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Appendix A

Display System and Interactive Device

Funding constraints made it necessary to plan to conduct the experiment using an on-board display and interactive device.

The display is a DICOMED Corporation Model 36 storage display. The general characteristics are as follows:

- a. dark-trace storage type with 10" usable diameter,
- b. up to 1600 resolvable points per horizontal trace,
- c. 16 displayable intensity levels,
- d. full screen image generation in a minimum of 43 seconds, and
- e. full screen erase time of 10 seconds.

The interactive device is a Science Accessories Corporation Graf Pen Model GP-2 sonic digitizer. The GP-2 measures the time required for a sound wave to reach each of two orthogonally-mounted linear microphones located on two sides of the DICOMED. The sound source is a spark, generated by closing the gap in the tip of a device resembling a ball point pen by depressing the tip on the face of the screen. Each time the spark jumps the gap, a hypersonic sound wave with a short rise time is generated. The elapsed time between spark generation and reception at each of the two microphones is a unique measure of the position of the pen relative to some fixed reference, for example f_0 , t_0 on a lofargram, that is, a highly resolved frequency and time coordinate.

The sensor length of the GP-2 is 14 inches, exceeding the usable portion of the DICOMED screen. The resolution over this length is either 2000 or 4000 resolutions depending on whether 11 or 12 bit data words are used, permitting resolution of a displayed lofargram to at least 0.1 hz.

Although the DICOMED-GRAF Pen combination was adequate to permit the experiment to be pursued, there were several shortcomings, principally in the area of support software.

For the DICOMED:

- a. No software, at any level, exists to support image generation. Each instruction and data point must be in machine language. All communications protocol between the display and the computer are the programmer's responsibility.
- b. Display graphics, including alphanumeric characters, must be written in machine language.

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- c. No operator interactive hardware or software was available. Common interactive devices like cursors or light pens are not suitable for use with dark trace storage displays.
- d. It is the nature of storage displays that modifications to already displayed data are limited. Deletion of previously displayed data requires total erasure of the screen and re-generation of the modified image.

For the GRAF-Pen:

- a. A driver to permit GRAF-Pen input-output to the HP-2100A did not exist.
- b. The GRAF-Pen was not compatible with the HP-12566B standard interface. (This was resolved by designing and fabricating a second interface between the GRAF-Pen and the computer interface.)

Experimental Display Program:

In order to test the display system, a stand-alone, core resident program was developed to simulate display of real acoustic data. A self-contained subroutine generated pseudo-random background noise for display. Discrete frequency components were entered by the operator on the TTY. Data entry was limited to two multiple-harmonic series, and one unrelated single discrete frequency. Relative amplitude, bandwidth, start and stop times could be specified by the operator.

The image produced was judged of adequate quality and resolution, with the possible exception that the phosphor was of magenta hue, so that amplitude differences were represented visually by shades of purple, rather than gray to black. The problem seems to be in the novelty of the display compared to a paper writer rather than a quantitative difference in visual detection capability.

Display Program:

The following source listing (Fig. 1) permits operator generation of simulated lofar displays and the DICOMED. The program was designed by J. R. Bouffler, Admiralty Research Laboratory, a British exchange scientist working at NRL during part of this development. The display portion of the program is usable in its entirety. The acoustic data input necessarily needs to be rewritten for use with other than simulated data.

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```

0001 ASMB.A.L
0002 *
0003 *05JAN76/UJ05
0004 *
0005 *
0006 *DEMONSTRATION PROGRAM
0007 *PARAMETERS ENTERED FROM TTY.
0008 *TWO HARMONIC FAMILIES.
0009 *ALTERNATING LINE.
0010 *STABLE LINE>.
0011 *EDITING.
0012 *
0013          ORG 2000B
0014          UNL
0015 STRT  NOP
0016          CLA
0017          STA GCNT
0018          JMP PARD.I
0019          HLT 60B          WAIT
0020 STA   JSB ERA          GO TO ERASE SUB
0021          JMP NEXTD.I
0022 STB   JSB OVT
0023          LDB GCNT
0024          INB
0025          STB GCNT
0026          NOP
0027          JMP INI
0028 STE   JSB OVT
0029          CLB
0030          LDB GCNT
0031          NOP
0032          JMP INI2
0033 STD   JSB PNW2.I
0034          LDA W          FETCH WIGL WORD
0035          ADA H1T
0036          STA H1M
0037          LDA W
0038          ADA H2T
0039          STA H2M
0040          LDA W
0041          ADA H3T
0042          STA H3M
0043          LDA H4T
0044          ADA W2
0045          STA H4M
0046          LDA W3          FETCH WIGL MODR.
0047          ADA H5T          MOD.LINE
0048          STA H5M
0049          LDA W3
0050          ADA H6T
0051          STA H6M
0052          LDA W3

```

Figure 1

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0053	ADA H7T	
0054	STA H7M	
0055	LDA AMP4	
0056	SZA	ALT. LINE ?
0057	JSB ALT	YES-GO TO SUB
0058	LDA AMP8	NO-
0059	SZA	SINGLE LINE ?
0060	JSB SL	YES-GO TO SUB
0061	JSB KZ	NO-GO TO KNEE ROUTINE
0062	JSB FS	GO TO FADE IN LINE SUB
0063	NOISE JSB PNN2,I	
0064	LDB HC	FETCH CELL COUNT
0065	CPB H1M	IS THERE A FUNDL.LINE?
0066	JMP **16	
0067	CPB H2M	
0068	JMP **16	
0069	CPB H3M	
0070	JMP **16	
0071	CPB H4M	
0072	JMP **16	
0073	CPB H5M	
0074	JMP **16	
0075	CPB H6M	
0076	JMP **16	
0077	CPB H7M	
0078	JMP **16	
0079	CPB H8T	
0080	JMP **16	
0081	JMP THRS	
0082	ADA AMP1	ADD SIGNAL TO NOISE
0083	JMP **14	
0084	ADA AMP2	
0085	JMP **12	
0086	ADA AMP3	
0087	JMP **10	
0088	ADA AMP4	
0089	JMP **8	
0090	ADA AMP5M	
0091	JMP **6	
0092	ADA AMP6M	
0093	JMP **4	
0094	ADA AMP7M	
0095	JMP **2	
0096	ADA AMP8M	
0097	RRR 4	BRING 5TH BIT TO END FOR TEST
0098	SLA	IS AMPLITUDE > MAX?
0099	JMP **4	
0100	RRL 4	NO -RETURN TO STATUS QUO
0101	AND MAX	MASK
0102	JMP THRS	
0103	LDA MAX	REPLACE S+H EITH MAX.
0104	THRS LDB THR	
0105	CPB D0	IS THRESHOLDING REQUIRED?
0106	JMP IHT	

Figure 1 (Continued)

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```

0107      JSB T           YES-GO TO THRESH. ROUTINE
0108 INT  JSB OUT        O/P DOT INTENSITY
0109      ISZ HC          ? REACHED END OF LINE
0110      JMP NOISE        NO-GO DO MORE CELLS
0111      LDA EOLX         YEW-FETCH EOL CODE
0112      JSB OUT
0113      LDA HC0          FETCH MAX CELLCOUNT
0114      STA HC           RESET CELL COUNTER
0115      ISZ VC1          INCR. LINE COUNTER
0116      JMP *+2
0117      JMP FIND.I
0118      ISZ VC           ? REACHED END OF FRAME
0119      JMP STD
0120      LDA GCNT
0121      SZA
0122      JMP *+4
0123      ADA D1
0124      STA GCNT
0125      JMP FIND.I
0126      CLA
0127      STA GCNT
0128      JMP FIND.I
0129      JMP FIND.I
0130 OUT  NOP
0131      AND MASK
0132      ADA REQ
0133      OTA 16B.C
0134      SFS 16B
0135      JMP *-1
0136      CLA
0137      OTA 16B.C
0138      JMP OUT.I
0139 *
0140      SPC 5
0141 *DISPLAY INITIALIZATION ROUTINE
0142 *
0143 ERA  NOP
0144      CLA
0145      OTA 16B.C
0146      STC 16B.C
0147      LDA IN
0148      JSB OUT
0149      LDA ERS          FETCH ERASE CODE
0150      JSB OUT
0151      JMP ERA.I
0152 *
0153 INI  NOP
0154      CLA
0155      STA CT1
0156      STA CT2
0157      STA H1M          SET LINES TO ZERO
0158      STA H2M
0159      STA H3M
0160      STA H4M

```

Figure 1 (Continued)

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```

0161      STA H5M
0162      STA H6M
0163      STA H6M
0164      STA H7M
0165      STA H8M
0166      LDA ASD
0167      STA TEMP1
0168      LDA AK
0169      STA TEMP
0170      LDA DM10
0171      STA FM
0172      JSB PNSTD,I
0173      LDA VCO
0174      STA VC
0175      JMP *+2
0176  INI2  NOP
0177      LDA IN
0178      JSB OUT
0179      LDA RPV      FETCH RANDOM POSITION CODE
0180      JSB OUT
0181      LDA VCI1
0182      JSB OUT
0183      LDA VCI2
0184      JSB OUT      FETCH RANDOM POSITION CODE(HORIZ.)
0185      LDA RPH
0186      JSB OUT
0187      LDA HCI1
0188      JSB OUT
0189      LDA HCI2
0190      JSB OUT
0191      LDA VCO1
0192      STA VC1      SET OVERALL COUNTER
0193      LDA HCO
0194      STA HC        SET CSLL COUNT
0195      JMP STD
0196  *
0197      NOP
0198  *
0199  ***CONSTANTS
0200  *
0201  IN      OCT 010000
0202  ERS      OCT 010200
0203  RPV      OCT 010011
0204  RPH      OCT 010010
0205  EOLX     OCT 010002
0206  VCI1     OCT 000304
0207  VCI2     OCT 000002
0208  HCI1     OCT 000373
0209  HCI2     OCT 000000
0210  REQ      OCT 000400
0211  MASK     OCT 070377
0212  *
0213  *KNEE START SUB-ROUTINE
0214  *

```

Figure 1 (Continued)

UNCLASSIFIED

0215	KZ	NOP
0216		LDA VC
0217		ADA KST
0218		SSA
0219		JMP KZA
0220		LDA VC
0221		ADA EK
0222		SSA
0223		JMP KZB
0224		LDA KES
0225		ADA VC
0226		SSA
0227		JMP KZ, I
0228		LDA KSF
0229		ADA VC
0230		SSA
0231		JMP *+2
0232		JMP KZA
0233		LDA TEMP, I
0234		ADA H1M
0235		STA H1M
0236		LDA TEMP, I
0237		ADA H2M
0238		STA H2M
0239		LDA TEMP, I
0240		ADA H3M
0241		STA H3M
0242		LDB TEMP
0243		ADB DM1
0244		STB TEMP
0245		JMP KZ, I
0246		JMP KZB
0247		LDA H1T
0248		STA H1M
0249		LDA H2T
0250		STA H2M
0251		LDA H3T
0252		STA H3M
0253		JMP KZ, I
0254	KZA	CLA
0255		STA H1M
0256		STA H2M
0257		STA H3M
0258		JMP KZ, I
0259	KZB	LDA TEMP, I
0260		ADA H1M
0261		STA H1M
0262		LDA TEMP, I
0263		ADA H2M
0264		STA H2M
0265		LDA TEMP, I
0266		ADA H3M
0267		STA H3M
0268		ISZ TEMP

Figure 1 (Continued)

UNCLASSIFIED

```

0269          JMP *+1
0270          JMP KZ.I
0271      *
0272      *****CONSTANTS
0273      *
0274      TEMP  NOP
0275      AK    DEF K1
0276      K1    DEC -91
0277      K2    DEC -83
0278      K3    DEC -74
0279      K4    DEC -66
0280      K5    DEC -58
0281      K6    DEC -47
0282      K7    DEC -36
0283      K8    DEC -30
0284      K9    DEC -24
0285      K10   DEC -18
0286      K11   DEC -13
0287      K12   DEC -9
0288      K13   DEC -6
0289      K14   DEC -3
0290      K15   DEC -2
0291      K16   DEC -1
0292      K17   DEC 0
0293      K18   DEC 0
0294      K19   DEC 0
0295      *
0296          SPC 5
0297      *
0298      *ALTERNATOR LINE SUB ROUTINE
0299      *
0300      ALT   NOP
0301          LDA VC          FETCH LINE COUNT
0302          ADA AST
0303          SSA          BEFORE / AFTER LINE START
0304          JMP ALTA
0305          LDA VC
0306          ADA AF
0307          SSA
0308          JMP Q
0309          JMP ALTA
0310      Q    NOP
0311          LDA TEMP1.I    FETCH MODIFIER
0312          LDB CT2        FETCH QUADRANT COUNTER
0313          CPB D0        ? IN QUADRANT 0
0314          JMP Q0        YES-GO TO Q0 SECTOR
0315          CPB D1        ? IN QUADRANT 1
0316          JMP Q1        YES-GO TO Q1 SECTOR
0317          CPB D2        ? IN QUADRANT 2
0318          JMP Q2        YES-GO TO Q2 SECTOR
0319          CPB D3        ? IN QUADRANT 3
0320          JMP Q3        YES- GO TO Q3 SECTOR
0321          HLT 70B      NO! FAULT CONDITION!
0322      Q0   LDB CT1      FETCH KNEE MODR POINTER

```

Figure 1 (Continued)

UNCLASSIFIED

0323		CPB D18	REACHED END OF QUADRANT ?
0324		JSB QC	YES-GO UPDATE QUAD COUNTER
0325		CMA, INA	NO-MAKE MODR -VE
0326		ADA H4M	
0327		STA H4M	
0328	UP	ISZ CT1	INC MODR POINTER
0329		JMP *+1	
0330		ISZ TEMP1	INC BUFFER PTR
0331		JMP ALT, I	EXIT
0332	QC	NOP	
0333		ISZ CT2	INCREMENT QUAD CTR
0334		JMP QC, I	
0335		JMP QC, I	RETURN
0336	Q1	LDB CT1	FETCH MODR COUNTER
0337		CPB D0	REACHED END OF QUADRANT ?
0338		JSB QC	YES-GO INC QUAD COUNTER
0339		CMA, INA	NO-MAKE MODR -VE
0340		ADA H4M	
0341		STA H4M	
0342	DOWN	LDB CT1	
0343		ADB DM1	DECREMENT COUNTER
0344		STB CT1	
0345		LDA TEMP1	FETSH MODR BUFFER PTR
0346		ADA DM1	DECREMENT
0347		STA TEMP1	
0348		JMP ALT, I	
0349	Q2	LDB CT1	FETCHNMODR COUNTER
0350		CPB D18	REACHED END OF QUADRANT
0351		JSB QC	YES GO INC QUAD COUNTER
0352		ADA H4M	
0353		STA H4M	
0354		JMP UP	GO INC MODR CTR & PTR
0355	Q3	LDB CT1	FETCH MODR CTR
0356		CPB D0	REACHED END OF QUADRANT ?
0357		JMP *+4	
0358		ADA H4M	
0359		STA H4M	
0360		JMP DOWN	GO DECREMENT MODR CTR & PTR
0361		CLA	GET ZERO & LOAD INTO-
0362		STA CT2	QUAD CTR TO RESET
0363		JMP *-5	
0364	ALTA	CLA	
0365		STA H4M	
0366		JMP ALT, I	
0367		*	
0368		*****CONSTANTS	
0369		*	
0370	TEMP1	NOP	
0371		NOP	
0372		NOP	
0373		NOP	
0374	CT1	NOP	
0375	CT2	NOP	
0376	ASD	DEF L0	

Figure 1 (Continued)

UNCLASSIFIED

0377	L0	DEC 0	
0378	L1	DEC 1	
0379	L2	DEC 2	
0380	L3	DEC 3	
0381	L4	DEC 3	
0382	L5	DEC 4	
0383	L6	DEC 5	
0384	L7	DEC 6	
0385	L8	DEC 6	
0386	L9	DEC 7	
0387	L10	DEC 7	
0388	L11	DEC 8	
0389	L12	DEC 8	
0390	L13	DEC 9	
0391	L14	DEC 9	
0392	L15	DEC 10	
0393	L16	DEC 10	
0394	L17	DEC 10	
0395	L18	DEC 10	
0396	L19	DEC 10	
0397	*		
0398		SPC 5	
0399	*		
0400	*FAMILY 2:FADE IN/OUT		
0401	*		
0402	FS	NOP	
0403		LDA VC	
0404		ADA FST	
0405		SSA	+/-:BEFORE/AFTER FADE START?
0406		JMP FSA	-VE:BEFORE
0407		LDA VC	
0408		ADA FSE	
0409		SSA	+/-:IN/BEYOND ZONE OF FADE START
0410		JMP FSB	-VE:IN ZONE
0411		LDA VC	+VE:BEYOND (NORMAL)
0412		ADA FO	
0413		SSA	+/-:BEFORE/AFTER FADE OUT ZONE?
0414		JMP FS,I	-VE:BEFORE (NORMAL)
0415		LDA VC	+VE:AFTER FADE OUT ZONE
0416		ADA FE	
0417		SSA	+/-:IN/BEYOND FADE OUT ZONE?
0418		JMP FSC	-VE:IN ZONE
0419		SPC 1	
0420	FSA	CLA	+VE:BEYOND:NO LINE
0421		STA H3M	
0422		STA H6M	
0423		STA H7M	
0424		JMP FS,I	
0425		SPC 1	
0426	FSB	JSB FMOD	
0427		ISZ FM	INCREMENT POINTER
0428		JMP FS,I	EXIT
0429		JMP FS,I	EXIT
0430	FSC	JSB FMOD	GO-MODIFY AMPLITUDE

Figure 1 (Continued)

UNCLASSIFIED

```

0431      LDB FM
0432      ADA DM1      DECREMENT MODIFIER
0433      STB FM
0434      JMP FS,I
0435      SPC 1
0436  FMOD  NOP
0437      LDA FM      FETCH FADE MODIFIER
0438      ADA AMP5     MOD. AMPLITUDE OF LINE
0439      SSA,RSS      IS IT -VE?
0440      JMP *+2      NO: +VE: HOLD
0441      CLA          YES:-VE: SET AMPLITUDE
0442      STA AMP5M
0443      LDA FM
0444      ADA AMP6
0445      SSA,RSS
0446      JMP *+2
0447      CLA
0448      STA AMP6M
0449      LDA FM
0450      ADA AMP7
0451      SSA,RSS
0452      JMP *+2
0453      CLA
0454      STA AMP7M
0455      JMP FMOD,I
0456      SPC 5
0457      *
0458      *SINGLE LINE
0459      *
0460  SL      NOP
0461      LDA VC
0462      ADA SS
0463      SSA          BEFORE/AFTER START OF LINE?
0464      JMP *+5      -VE:BEFORE (NO LINE)
0465      LDA VC          +VE:AFTER
0466      ADA SF
0467      SSA          IN/BEYOND LINE ZONE?
0468      JMP *+4
0469      CLB          +VE:BEYOND:NO LINE
0470      STB AMP8M     SET AMPL. TO ZERO
0471      JMP SL,I      EXIT
0472      LDB AMP8
0473      STB AMP8M     SET AMPL. TO NORMAL
0474      JMP SL,I
0475      SPC 5
0476      *
0477      *THRESHOLD SUB-ROUTINE
0478      *
0479      **SET THRESHOLD LEVEL BITS 0-3, IN SWITCH REGISTER
0480      **TO CHANGE DURING 'GRAM GENERATION.
0481      **MAKE SW. REG. BIT 15 = '1'
0482      *
0483      T      NOP
0484      CMB,INB      MAKE -VE

```

Figure 1 (Continued)

UNCLASSIFIED

0485	ADB 0000	ADD TO POINT LEVEL
0486	SSB	-VE ? (ABOVE/BELOW THRESH. LEVEL ?)
0487	JMP *+3	BELOW
0488	LDA MAX	ABOVE - FETCH MAX INTENSITY
0489	JMP T.I	EXIT
0490	LDA MIN	FETCH MIN INTENSITY
0491	JMP T.I	
0492	*	
0493	MIN OCT 000000	
0494	SPC 5	
0495	*	
0496	*FREQUENCY & TIME MARKS	
0497	*	
0498	OVT NOP	
0499	CLA	
0500	OTA 16B.C	
0501	STC 16B	
0502	LDA IN	
0503	JSB OUT	
0504	LDA RPY	
0505	JSB OUT	
0506	LDA VC11	
0507	ADA DM35	
0508	JSB OUT	
0509	LDA VC12	
0510	JSB OUT	
0511	LDA RPH	
0512	JSB OUT	
0513	LDA HC11	
0514	ADA DM66	
0515	JSB OUT	
0516	LDA HC12	
0517	JSB OUT	
0518	LDA DM35	
0519	STA VC1	
0520	FC LDA HC0	
0521	ADA DM66	
0522	STA HC	
0523	LDA HC0	
0524	STA HCC	
0525	FCF LDB HC	
0526	CPB HCC	
0527	JMP *+4	
0528	LDA MIN	
0529	JSB OUT	
0530	JMP *+6	
0531	LDA MAX	
0532	JSB OUT	
0533	LDA HCC	
0534	ADA D100	
0535	STA HCC	
0536	ISZ HC	
0537	JMP FCF	
0538	LDA EOLX	

Figure 1 (Continued)

UNCLASSIFIED

```

0539      JSB OUT
0540      ISZ VC1
0541      JMP FC
0542      LDA DM66
0543      STA HC
0544      LDA VC01
0545      STA VCC
0546      LDA VC01
0547      STA VC1
0548      TCF   LDA VC1
0549      CPA VCC
0550      JMP *+10
0551      LDA MIN
0552      JSB OUT
0553      LDA EOLX
0554      JSB OUT
0555      LDA DM66
0556      STA HC
0557      ISZ VC1
0558      JMP TCF
0559      JMP OVT, I
0560      TC    LDA MAX
0561      JSB OUT
0562      ISZ HC
0563      JMP TC
0564      LDA EOLX
0565      JSB OUT
0566      LDA DM66
0567      STA HC
0568      LDA VCC
0569      ADA D120
0570      STA VCC
0571      ISZ VC1
0572      JMP TCF
0573      JMP OVT, I
0574      *
0575      *CONSTANTS
0576      *
0577      DM35  DEC -35
0578      DM66  DEC -66
0579      D120  DEC 120
0580      HCC   NOP
0581      *
0582      SPC 5
0583      *
0584      *BANDWIDTH SUB-ROUTINE
0585      ORG 12000B
0586      NOP
0587      PNW   NOP
0588      CLB
0589      LDA GEN3
0590      SLA
0591      INB
0592      ARS, ARS

```

Figure 1 (Continued)

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```

0593      SLA
0594      INB
0595      ARS
0596      SLA
0597      INB
0598      ARS,ARS
0599      SLA
0600      INB
0601      SLB
0602      JMP *+3
0603      CLE
0604      JMP *+2
0605      CCE
0606      LDA GEN3
0607      ERA
0608      STA GEN3
0609      LDB MSKB
0610      CPB D3
0611      JMP *+4
0612      CPB D7
0613      JMP *+4
0614      ADA DM1
0615      JMP *+2
0616      ADA DM3
0617      AND MSKB
0618      STA W
0619      LDA GEN3
0620      AND MAX
0621      STA W2
0622      LDA GEN3
0623      RRR 4
0624      AND MSKC
0625      LDB MSKC
0626      CPB D3
0627      JMP *+4
0628      CPB D7
0629      JMP *+4
0630      JMP *+4
0631      ADA DM1
0632      JMP *+2
0633      ADA DM3
0634      STA W3
0635      JMP PNW, I
0636      *
0637      ****CONSTANTS
0638      *
0639      SPC 5
0640      *
0641      *
0642      *10JAN74/JB/19
0643      *
0644      *PN20M = PN20 GENERATOR MODIFIED TO AN
0645      *APPROXIMATE NORMAL DISTRIBUTION
0646      *

```

Figure 1 (Continued)

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0647	PNST	NOP	
0648		CCA	
0649		STA GEN1	SET
0650		STA GEN2	PN
0651		STA GEN3	REGISTERS
0652		CLA	
0653		STA CT15	CLEAR
0654		STA CT14	PN
0655		STA CT13	COUNTERS
0656		STA CT12	
0657		STA CT11	
0658		STA CN10	
0659		STA CT9	
0660		STA CT8	
0661		JMP PNST, I	
0662	PNN	NOP	
0663		CLB	
0664		LDA GEN2	
0665		RRR 3	
0666		XOR GEN2	
0667		SLA	
0668		JMP *+3	
0669		CLE	
0670		JMP *+2	
0671		CCE	
0672		LDA GEN2	
0673		LDB GEN1	
0674		ELB, ELA	
0675		ELB, ELB	
0676		ERA	
0677		STA GEN2	
0678		ERB, ERB	
0679		ERB, ERB	
0680		ERB	
0681		STB GEN1	
0682		LDA GEN2	
0683		AND MAX	MASK OUT ALL BUT REQD. BITS
0684		CPA A15	
0685		JMP *+16	YES - GO SEE IF MODIFICATION REQD.
0686		CPA A14	
0687		JMP *+24	YES
0688		CPA A13	
0689		JMP *+32	
0690		CPA A12	
0691		JMP *+40	
0692		CPA A11	
0693		JMP *+48	
0694		CPA A10	
0695		JMP *+56	
0696		CPA A9	
0697		JMP *+64	
0698		CPA A8	
0699		JMP *+72	YES - GO SEE IF MODN. REQD.
0700		JMP PNN, I	NO - EXIT

Figure 1 (Continued)

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0701	LDB CT15	FETCH "15" COUNTER
0702	CPB D80	IS THE ONE TO BE O/P?
0703	JMP *+5	YES - GO DO IT
0704	INB	UPDATE "15" COUNTER
0705	STB CT15	
0706	LDA A0	
0707	JMP PNN. I	EXIT
0708	CLB	
0709	STB CT15	
0710	JMP PNN. I	
0711	LDB CT14	
0712	CPB D40	
0713	JMP *+5	
0714	INB	
0715	STB CT14	
0716	LDA A1	
0717	JMP PNN. I	
0718	CLB	
0719	STB CT14	
0720	JMP PNN. I	
0721	LDB CT13	
0722	CPB A16	
0723	JMP *+5	
0724	INB	
0725	STB CT13	
0726	LDA A2	
0727	JMP PNN. I	
0728	CLB	
0729	STB CT13	
0730	JMP PNN. I	
0731	LDB CT12	
0732	CPB A8	
0733	JMP *+5	
0734	INB	
0735	STB CT12	
0736	LDA A3	
0737	JMP PNN. I	
0738	CLB	
0739	STB CT12	
0740	JMP PNN. I	
0741	LDB CT11	
0742	CPB A4	
0743	JMP *+5	
0744	INB	
0745	STB CT11	
0746	LDA A4	
0747	JMP PNN. I	
0748	CLB	
0749	STB CT11	
0750	JMP PNN. I	
0751	LDB CN10	
0752	CPB A2	
0753	JMP *+5	
0754	INB	

Figure 1 (Continued)

UNCLASSIFIED

```

0755      STB CN10
0756      LDA A5
0757      JMP PNN.I
0758      CLB
0759      STB CN10
0760      JMP PNN.I
0761      LDB CT9
0762      CPB A3
0763      JMP *+4
0764      INB
0765      STB CT9
0766      JMP PNN.I
0767      CLB
0768      STB CT9
0769      LDA A6
0770      JMP PNN.I
0771      LDB CT8
0772      CPB A5
0773      JMP *+4
0774      INB
0775      STB CT8
0776      JMP PNN.I
0777      CLB
0778      STB CT8
0779      LDA A7
0780      JMP PNN.I
0781      *
0782      *****CONSTANTS ETC.
0783      *
0784      A0      DEC 0
0785      A1      DEC 1
0786      A2      DEC 2
0787      A3      DEC 3
0788      A4      DEC 4
0789      A5      DEC 5
0790      A6      DEC 6
0791      A7      DEC 7
0792      A8      DEC 8
0793      A9      DEC 9
0794      A10     DEC 10
0795      A11     DEC 11
0796      A12     DEC 12
0797      A13     DEC 13
0798      A14     DEC 14
0799      A15     DEC 15
0800      A16     DEC 16
0801      GEN1    NOP
0802      GEN2    NOP
0803      CT15    NOP
0804      CT14    NOP
0805      CT13    NOP
0806      CT12    NOP
0807      CT11    NOP
0808      CN10    NOP

```

Figure 1 (Continued)

UNCLASSIFIED

```

0809 CT9 NOP
0810 CT9 NOP
0811 D40 DEC 40
0812 D80 DEC 80
0813 *
0814 SKP
0815 *
0816 *LINE INTEGRATION ROUTINE
0817 *
0818 ORG 3100B
0819 ED2 NOP
0820 LDA HCO
0821 STA F/HO
0822 LDA EF
0823 STA EF1
0824 CLB
0825 DIV D3
0826 STA EF1/3
0827 CLB
0828 MPY D2 FIND 2ND SUB-HARMONIC
0829 STA EF2/3
0830 LDA EF
0831 CLB
0832 DIV D2 FIND 1ST SUB HARMONIC
0833 STA EF1/2
0834 CLB
0835 MPY D3 FIND HARMONIC
0836 STA EF3/2
0837 LDA EF
0838 CLB
0839 MPY D2
0840 STA EF2
0841 LDA EF
0842 CLB
0843 MPY D3
0844 STA EF3
0845 SPC 1
0846 LDB S1D
0847 STB S1T
0848 LDB S2D
0849 STB S2T
0850 LDB S3D
0851 STB S3T
0852 LDB S4D
0853 STB S4T
0854 LDB S5D
0855 STB S5T
0856 LDA S6D
0857 STB S6T
0858 LDB S7D
0859 STB S7T
0860 SPC 1
0861 LDA FL
0862 INA

```

Figure 1 (Continued)

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0863		CMA, INA	
0864		STA CNT	SET COUNTER
0865	CLR	CLA	
0866		STA S1T, I	
0867		STA S2T, I	
0868		STA S3T, I	
0869		STA S4T, I	
0870		STA S5T, I	
0871		STA S6T, I	
0872		STA S7T, I	
0873		ISZ S1T	
0874		ISZ S2T	
0875		ISZ S3T	
0876		ISZ S4T	
0877		ISZ S5T	
0878		ISZ S6T	
0879		ISZ S7T	
0880		ISZ CNT	INCREMENT CTR.
0881		JMP CLR	RETURN & CLEAR REMAINDER
0882		JSB PNSTD, I	
0883		SPC 1	
0884	STRT3	LDA VCL	
0885		ADA VCO	CONVERT TO LINE COUNT
0886		STA VCL2	=END OF INTEGRATION BLOCK
0887		LDA TL	FETCH BLOCK LENGTH
0888		CMA, INA	
0889		ADA VCL2	
0890		STA VCL1	=START OF INTEGRATION BLOCK
0891		CLB	
0892		LDA FL	FETCH BLOCK WIDTH
0893		DIV D2	
0894		CMA, INA	
0895		STA FL/2	HALF BLOCK WIDTH(-VE)
0896		LDA F/HC	
0897		ADA FL/2	
0898		STA FCON	
0899		LDA EF1/3	FETCH 1/3RD HARM.
0900		ADA FCON	CONVERT TO CELL NUMBER
0901		STA HL1	
0902		LDA EF1/2	FETCH 1/2 HARM.
0903		ADA FCON	
0904		STA HL2	
0905		LDA EF2/3	
0906		ADA FCON	
0907		STA HL3	
0908		LDA EF	
0909		ADA FCON	
0910		STA HL4	
0911		LDA EF3/2	
0912		ADA FCON	
0913		STA HL5	
0914		LDA EF2	
0915		ADA FCON	
0916		STA HL6	

Figure 1 (Continued)

UNCLASSIFIED

0917		LDA EF3	
0918		ADA FCON	
0919		STA HL7	
0920		LDB HC0	
0921		STB HC	
0922		LDB VC0	
0923		STB VC	SET LINE COUNTER
0924		NOP	
0925		NOP	
0926	CV	LDA VC	
0927		CMA, INA	
0928		ADA VCL1	VCL1-VC
0929		SSA, RSS	VCL1>VC ?
0930		JMP NO1	+VE: YES: BEFORE STARTT OF BLOCK
0931		LDA VC	-VE: NO: AFTER STRT OF BLOCK
0932		CMA, INA	
0933		ADA VCL2	VCL2-VC
0934		SSA	VCL2>VC ?
0935		JMP AVD, I	
0936		SPC 1	
0937		LDA EF1/3	
0938		ADA DM120	
0939		SSA	IS EF1/3 < 12HZ ?
0940		JMP *+2	YES - TRY NEXT
0941		JMP CS1A	NO - GO TO SEARCH SUB
0942		LDA EF1/2	
0943		ADA DM120	
0944		SSA	IS EF1/2 < 12HZ ?
0945		JMP *+2	
0946		JMP CS2A	
0947		LDA EF2/3	
0948		ADA DM120	
0949		SSA	
0950		JMP CS4A	YES-GO TO ED.FREQ.SEARCH
0951		JMP CS3A	NO - @GO TO SEARCH SUB
0952		NOP	
0953		SPC 1	
0954	CS1A	LDB S1D	
0955		STB S1T	
0956		LDB FL	
0957		INB	
0958		CMB, INB	
0959		STB CNT	
0960	CS1	LDB HC	FETCH CELL COUNT
0961		CMB, INB	MAKE -VE
0962		ADB HL1	ADD TO FIRST LINE POSITION
0963		SSB, RSS	REACHED THIS POSITION YET ?
0964		JMP *+2	NO: BEFORE START
0965		JMP *+3	YES: INTO BLOCK
0966		JSB NO4	GO TO NOISE ONLY ROUTINE
0967		JMP CS1	RETURN FOR FURTHER TEST
0968		JSB NO2	GO TO INTEGRATING ROUTINE
0969		SPC 1	
0970	CS2A	LDB S2D	

Figure 1 (Continued)

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0971		STB S1T	SET BUFFER POINTER
0972		LDB FL	FETCH BLK WIDTH
0973		INB	
0974		CMB, INB	MAKE -VE
0975		STB CNT	SET COUNTER
0976	CS2	LDB HC	
0977		CMB, INB	
0978		ADB HL2	
0979		SSB, RSS	
0980		JMP *+2	
0981		JMP *+3	
0982		JSB NO4	
0983		JMP CS2	
0984		JSB NO2	
0985		SPC 1	
0986	CS3A	LDB S3D	
0987		STB S1T	
0988		LDB FL	
0989		INB	
0990		CMB, INB	
0991		STB CNT	
0992	CS3	LDB HC	
0993		CMB, INB	
0994		ADB HL3	
0995		SSB, RSS	
0996		JMP *+2	
0997		JMP *+3	
0998		JSB NO4	
0999		JMP CS3	
1000		JSB NO2	

Figure 1 (Continued)

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Appendix B

Display System Selection (U)

Reference: (a) "State-of-the-Art Summary - Candidate Display Systems for the Integrated Undersea Surveillance System" (U) (NRL Background Document Prepared for PME-124, June 1976) (S).

(b) Display Subsystem Recommendations for the Operator/Machine Interaction Program (U) - NRL Report dtd 1 Dec 1976 (S).

I. Background

Although display system selection was determined ultimately by funding constraints, a considerable effort in comparative evaluation and selection of displays was expended and reported on in references (a) and (b). Reference (a) is a comprehensive study of several different display requirements, including large screen tactical displays. Reference (b) focuses on specific requirements for the operator-interactive signature formation effort.

This appendix summarizes the findings and recommendations under reference (b) only. For a detailed understanding of the selection process, refer to references (a) and (b).

II. Overview of Requirements

The general requirements for any candidate display system were:

. Flexibility

Must be capable of displaying:

- a. lofargrams with varying bandwidths and resolutions
- b. automatic line integrations
- c. A scan
- d. stacked A scan
- e. ambiguity functions

. Long Term Viewing Suitability

Factors contributing to operator misinterpretation or fatigue such as flicker, noise, low brightness or contrast, focusing inaccuracies must be minimal.

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- Adequate Resolution/Data Density

Within the limits of human visual acuity, the number of displayable points was to match the frequency resolution of the FFT. A range of between 1000 and 3000 points on both x and y axes was considered. A minimum of 8 levels of intensity were required for any point written.

- Interactive Capability

Any one of a number of interactive devices (e.g., light/sonic pens, potentiometer devices, function keys, etc.) were basically acceptable. The major requirement was that the interactive system be simple in operation and not require extensive manual entry by the operator.

- Self Contained

A complete graphics display system was required, one which could be interfaced directly to the NRL computer. Development of a display subsystem, per se, was never contemplated. Image refresh, interactive peripheral interface, character and vector generation were to be features of the display controller.

- Mature Technology

The display system had to be commercially available with no system hardware or software development required.

III. Specific Display Characteristics

- Raster Scan CRT
- Minimum 512 x 512 resolvable elements
- Monochrome with gray scale
- Local refresh with computer interface
- Local intelligence
- Keyboard, function keys, joystick or trackball
- Minimum 9" horizontal viewing axis

- Raster Scan CRT

Raster scan was determined to be more suitable for the type of high-data density display (principally lofargrams) required. The constant storage requirement of a raster scan system was expected to simplify display programming significantly.

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. Minimum 512 x 512 Resolvable Elements

Although our preference was to match display resolution to analyzer resolution (i.e., about 1500 points in the horizontal direction for lofar displays), the cost constraints on the program forced us to accept a loss in minimum detectable signal of .5 to 1 dB for each halving of resolution.

. Monochrome With Gray Scale

Color as a means of encoding signal amplitude was rejected because of the limited range available before psychophysical problems in recognition are encountered. Amplitude variations with time could be most confusing to an operator. (A detailed study of the relative merits of color vs gray scale was beyond the scope of this study. (References (a) and (b) give considerably more detail and cite other studies). The range of quantizations considered was from six bits (64 levels) to three bits (8 levels). Since work done by several large corporations revealed that there is no significant loss in weak signal detection when quantization is reduced to three bits (8 levels) for a time-frequency display, this bit format was accepted. It may be possible to reduce bit requirements further.

. Local Refresh With Computer Interface

The size of the host computer, (HP-2100A, 32K words) necessitates a large refresh memory associated with the display itself. Computer interface must be of the full-duplex 16-bit parallel register design so as to be compatible with H/P or DEC manufactured computers.

. Local Intelligence Requirements

- . Display related operations can be accomplished at a level above machine language
- . End point vector and conic generator for simple graphics specification
- . A hardware character generator with a minimum of 64 ASCII characters
- . Scaling ability
- . Hardware scrolling
- . Status and control information for peripherals
- . Selective erase
- . Ability to recognize interactive inputs
- . Independent image overlay

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. Keyboard, Function Keys, Joystick

The requirement is that the interaction of the operator with the display must be both simple and minimal. The keyboard must also function in a local mode, not requiring intervention of the host computer.

. Minimum 9" Horizontal Viewing Axis

This allows lofargrams to be displayed without frequency axis compression.

III. Comparison of Candidate Displays

A comparison of four candidate displays is given in Table 3-1. Detailed comparison is made in reference (b).

IV. Implementation Candidate

The system best meeting the technical and cost requirements was the RAMTEK 9300 Graphic Display System. A detailed description of the RAMTEK 9300 is given in reference (b).

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Table 3-

SYSTEM	512 x 512 Resolvable Elements	≤ Gray Lead	Color Available	Local Refresh w/ PDP-11 I/F	LOCAL INTELLIGENCE					CA
					Vector Conics	Char Gen.	Instr. Set	Hardware Scaling	Hard Scro	
Comtal 30SA	X	X	X	X ⁽¹⁾						
Comtal 65SA	X	X		X ⁽¹⁾						
Aydin 5214A	X	X	X	X	X	X	X	(2)		
Ramtek 9300	X	X	X	X	X	X	X	X		

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Table 3-I. Comparison of Candidate Display Systems

CATEGORIES								
INTELLIGENCE							Keyboard	Min. 9" H Viewing A
Hardware Scrolling	Hardware Scrolling	Selective Erase	Access re- fresh memory	Separate over- lay channels	Logical/Arith. functions	Gray level windowing		
(2) X	X X	X	X	X	X(3) X	X	X X	X
		X	X	X		X		X
		X	X			X		X
		X	X	X		X		X

2

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Systems

Over- nnels	Logical/Arith. functions	Gray level windowing	Keyboard	Min. 9" Horiz. Viewing Axis	Est. Cost K\$ (4)	Notes
		X		X	26	(1) Would need separate interface for keyboard since not available by manufacturer. (2) By software (3) Limited to or-ing or erase ones. (4) Estimated cost for system configured with available options and computer interface needed. Computer costs are not included (see text).
		X		X	51	
	X(3)	X	X	X	45	
	X	X	X	X	37	

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3

UNITED STATES GOVERNMENT
Memorandum

7100-032
DATE: 26 February 2004

REPLY TO

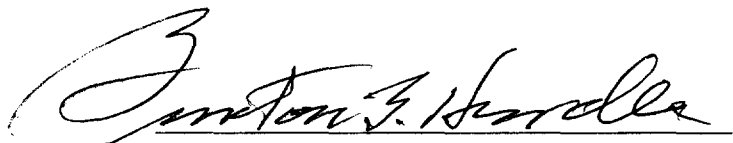
ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Operator-Interactive Signature Formation for Acoustic Undersea Surveillance Systems" (U), William P. Morrogh, Acoustics Division, NRL Memo Report 3625, October 1977 (C)

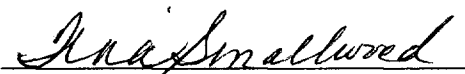
1. Reference (a) describes an exploratory development to systematically organize signals received on Undersea Surveillance Systems (including several reception locations) to identify the signatures of ships and other sources. The method has not been completed or tested.
2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical
3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions


BURTON G. HURDLE
NRL Code 7103

CONCUR:

 3/1/2004
E.R. Franchi Date
Superintendent, Acoustics Division

CONCUR:

 3/3/04
Tina Smallwood Date
NRL Code 1221.1