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Technical Report PTR-1035-77-5/16
Contract N00014-76-C-0864
NR196-141
Report Date May 16, 1977

**STUDIES AND APPLICATION OF ADAPTIVE
DECISION AIDING IN ANTI-SUBMARINE WARFARE:
FUNCTIONAL DESIGN SPECIFICATION**

EFRAIM SHAKET
ANTONIO LEAL

Prepared For:

OFFICE OF NAVAL RESEARCH
Engineering Psychology Programs, Code 455
800 North Quincy Street
Arlington, Virginia 22217

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1. INTRODUCTION

1.1 Review of Program

This program is directed toward the application and demonstration of adaptive decision aiding in airborne anti-submarine warfare (ASW). The approach is based on the adaptive decision aiding methodology, developed by Perceptronics under previous ONR/ARPA contracts, to the decision needs of ASW operations, including target detection, localization, and tracking. Overall program objectives are aimed at improving the effectiveness of sensor deployment and sensor data evaluation in airborne ASW operations and developing a decision aiding prototype simulation demonstration.

To demonstrate the capabilities of adaptive decision aiding, the work focuses on implementation of decision aids for submarine tracking by the Tactical Coordination Officer (TACCO) on the U.S. Navy P-3C ASW aircraft. Accordingly, the program will yield aiding techniques which can be demonstrated immediately in a TACCO crew station and be developed for future operational ASW systems such as LAMPS, new P-3 updates, S-3A, and VPX.

Airborne ASW operations are characterized by a complex decision process consisting of data assimilation, data evaluation, and resource allocation. Operational effectiveness depends heavily on individual decision making performance because the complexity of the ASW decision task, the often severe time constraints, and the inherent limitations of human capabilities combine to tax the ASW decision maker to his fullest. Thus, the proper application of advanced tools for computer decision aiding promises to have a significant impact on ASW performance. Computer aiding can improve performance by allocating the decision functions between man and machine in a way which optimizes the use of their respective strengths.

The major program objectives are:

- (1) Improve Effectiveness of Sensor Deployment in Airborne ASW Operations.
- (2) Contribute to the Design of Updated and Future Airborne ASW Systems by Developing Human Factors Guides for Decision Aids.
- (3) Develop Decision Aiding Prototype Simulation Demonstration.
- (4) Provide a Structure for Assessing System Performance.

The program effort is divided into three main phases:

- (1) Analysis and Design
- (2) Software Implementation and Integration
- (3) Demonstration

The implementation of the adaptive decision aiding algorithms is scheduled to be completed at the Naval Air Development Center (NADC), Warminster, Pa.

1.2 Approach

This document is a detailed description of the functional design specification for the implementation of the decision aiding algorithms. It describes the precise interactions among the three principle components of the ASW system:

- (1) the current P-3 Update System
- (2) the Tactical Coordination Officer
- (3) the ADDAM Decision Aiding System

The detailed step-by-step flow diagram described in this report serves as the basis for the program implementation specification and subsequent integration of the decision aiding methodology into the P-3 update control system.

A full description of the P-3 ASW environment, and the ADDAM model algorithm can be found in Leal, Shaket, Gardiner, and Freedy, "Studies and Application of Adaptive Decision Aiding in Anti-Submarine Warfare", Perceptronics Technical Report PTR-1035-77-2.

2. TACCO DECISION CYCLE

Figure 2-1 shows the overall phases in the TACCO decision cycle. A short description of each phase will be presented, followed by the details of the functional design which deals with each phase separately. The TACCO decision task cycle has seven major steps. The cycle begins when the TACCO receives information from previously deployed sensors (see Figure 2-1, Phase A). The sensor operator (SENSO) returns submarine contact information as directed bearings which appear on the TACCO's main data display.

In Phase B, the TACCO enters his assessment of the situation by choosing significant "fixes" (intersections of bearing lines) he believes to be the possible submarine locations, and associating them with one of several current tracks. He can entertain up to five tracks concurrently and must indicate his level of confidence in each of them. The system calculates (in Phase C) a probability distribution from the TACCO's information and additional general information about submarine behavior. This represents the probability that the submarine will be at certain locations at the time of next sensor deployment. The most likely location is displayed as a "tracking bug" on the screen and is updated in real time. Using this probability distribution, the current environmental conditions, the time required to deploy the sensors, and features of the sensor patterns, the system calculates a vector of attributes for each pattern in the decision space. This includes the probability of submarine detection, false alarms, resource depletion, etc. Each pattern is thus evaluated in its optimal location relative to the progressing submarine.

Phase D is the decision aiding portion of the cycle. From the set of attribute values associated with each pattern in the decision space, the ADDAM system chooses a pattern consistent with the past preferences of the TACCO. The recommended pattern appears on the display screen and is flagged as a recommended strategy. Several less favorable alternatives may be alphanumerically presented upon his request.

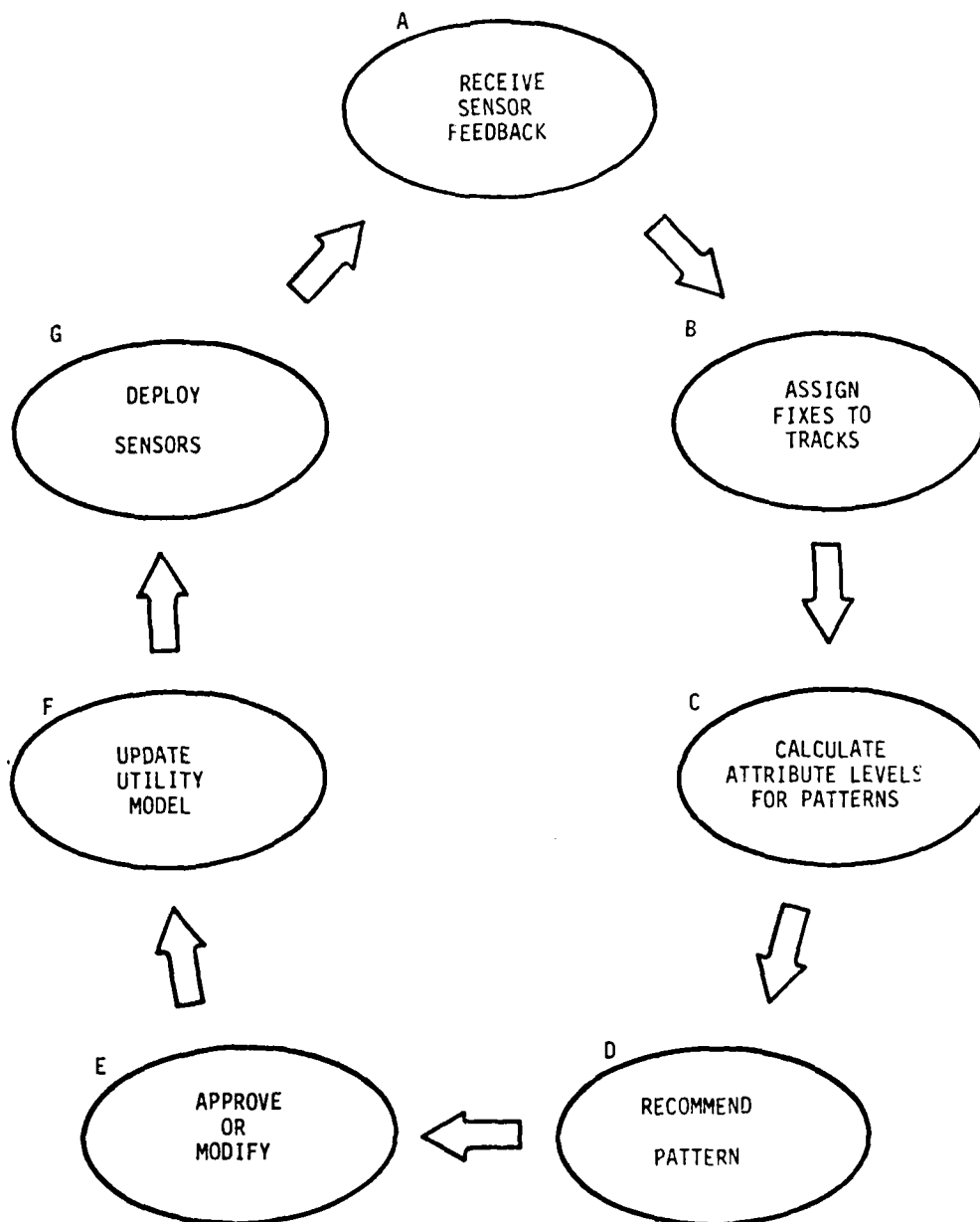


FIGURE 2-1. OVERALL TACCO DECISION CYCLE

It is now incumbent upon the TACCO to approve or reject the recommended pattern (Phase E). If the pattern is approved, orders are automatically issued to deploy the sensors. If the TACCO disapproves of the system's choice, he must specify which pattern in the decision space he prefers so that the system can adapt and make a better choice during the next cycle. If the TACCO rejects all of the patterns in the decision space, he must allocate his own pattern of sensors manually. This manual allocation will, of course, follow established standard procedures as they now exist. (Phase F).

The final Phase G of the decision task cycle is the actual deployment of sensors into the ocean. With the completion of this action, the cycle begins again when new contact information is received.

3. FUNCTIONAL DESIGN

The detailed functional design specification diagram of the TACCO decision cycle appears in Figure 3-1. This flowchart describes the main components of the designed system. An entire cycle corresponds to the dropping of one sonobuoy pattern, the receiving of acoustic information, and the tracking of the submarine as long as the pattern permits. The diagram is a detailed expansion of the overall decision cycle shown in Figure 2-1. The major Phases A-G are shown in Figure 3-1 as large dashed-line boxes. Each internal box is numbered indicating detailed steps in the functional flow. Furthermore, an indication of the communication between various portions of the P-3 update system is included with each box. The following legend shows the possible communication paths among the P-3 update system, ADDAM, the TACCO, and the SENSO.

P	P-3C UPDATE SYSTEM INTERNAL CALCULATION
A	ADDAM INTERNAL CALCULATION
T	TACCO DECISION
S	SENSO ACTION
P-A	INFORMATION FLOWS FROM P-3C ENVIRONMENT TO ADDAM
P-T	TACCO RECEIVES INFORMATION FROM P-3C SYSTEM
A-T	TACCO RECEIVES AIDING FROM ADDAM
T-P	TACCO INPUTS INFORMATION TO P-3C SYSTEM
T-A	TACCO INPUTS INFORMATION TO ADDAM
T-S	TACCO COMMUNICATES WITH SENSO
S-P	SENSO INPUTS INFORMATION TO P-3C SYSTEM

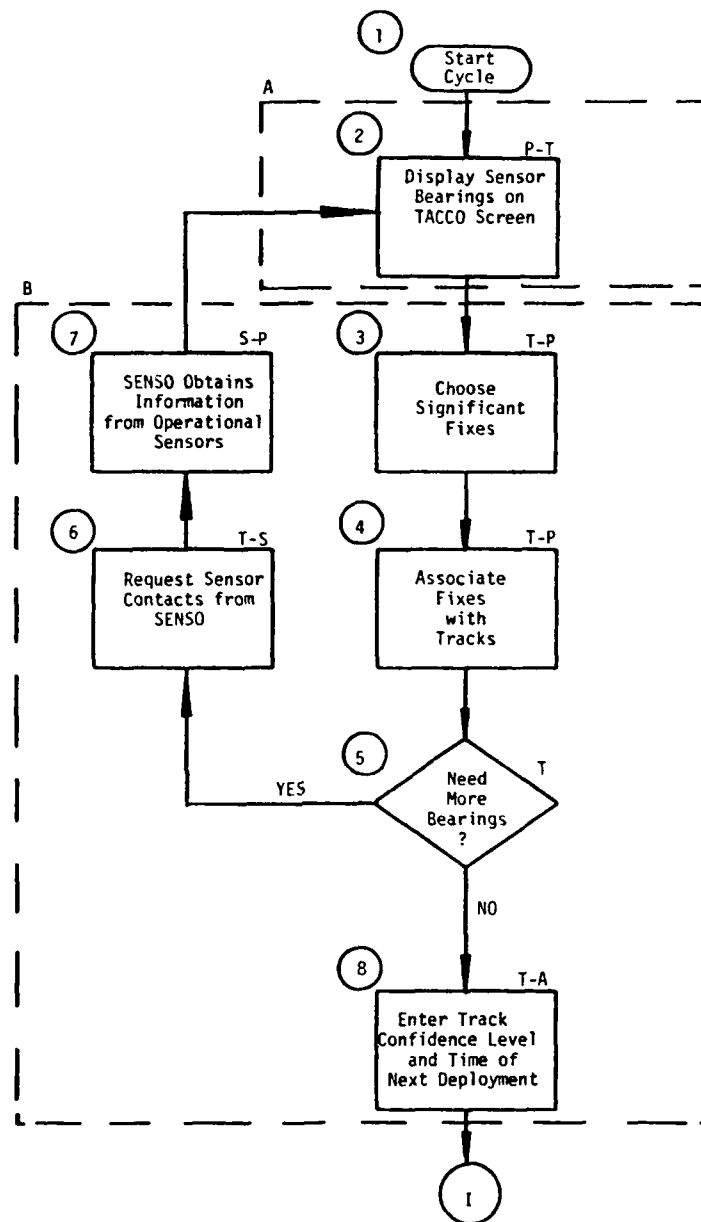


FIGURE 3-1. FUNCTIONAL DESIGN SPECIFICATION

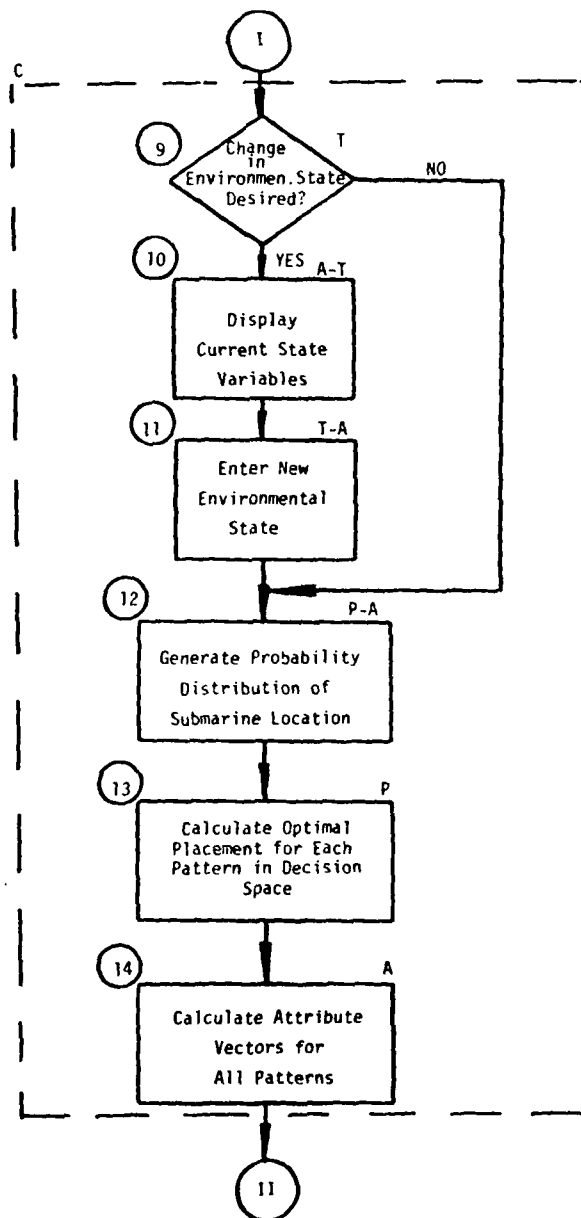


FIGURE 3-1. FUNCTIONAL DESIGN SPECIFICATION (Continued)

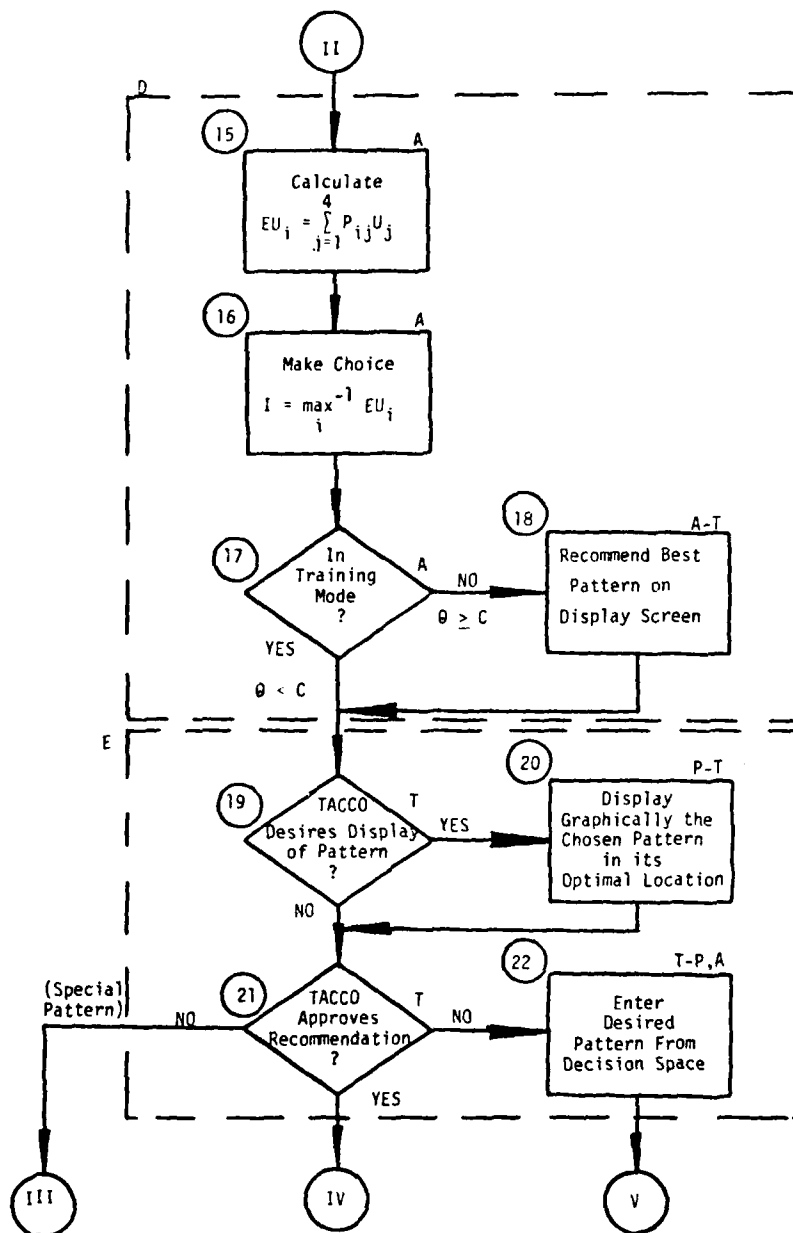


FIGURE 3-1. FUNCTIONAL DESIGN SPECIFICATION (Continued)

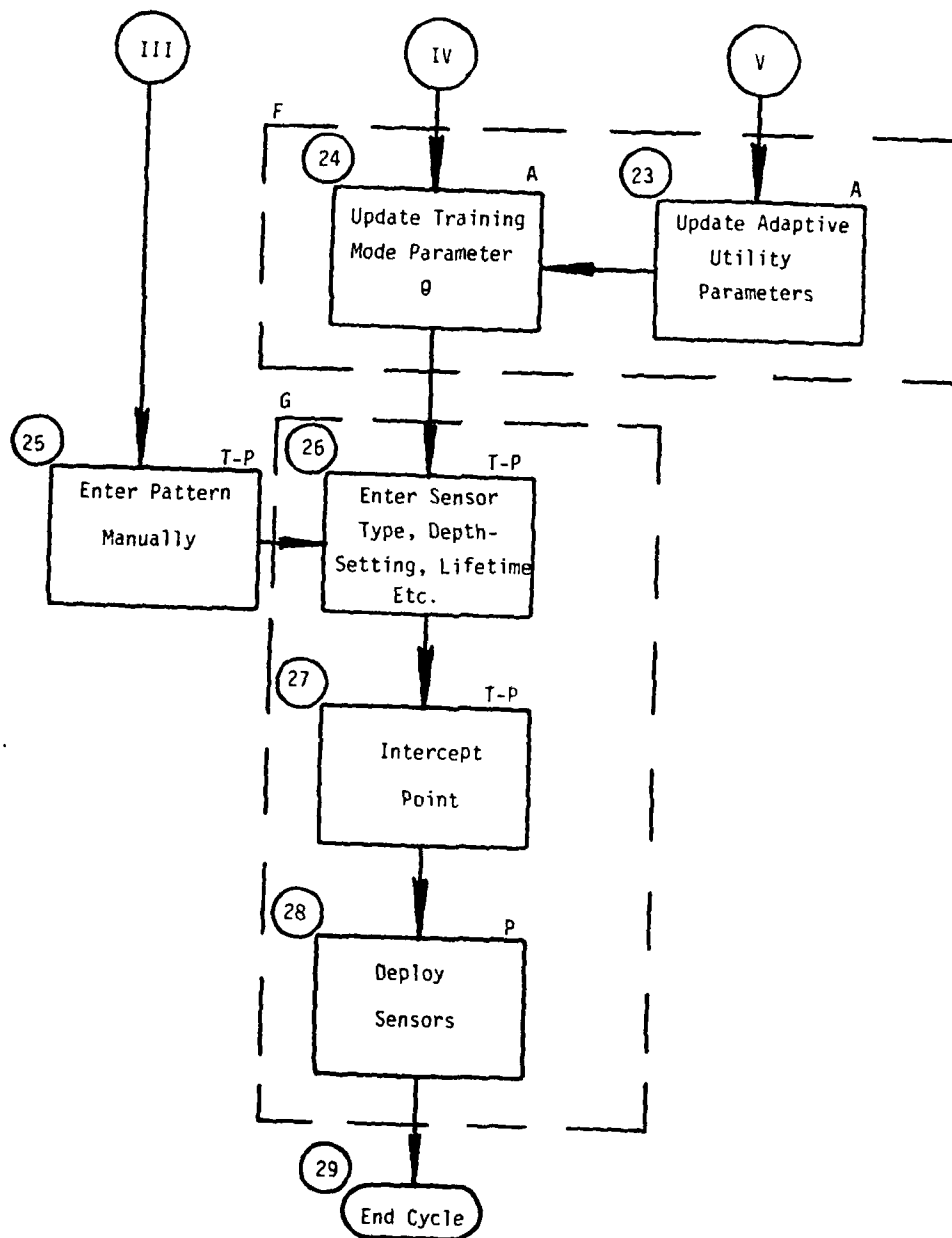


FIGURE 3-1. FUNCTIONAL DESIGN SPECIFICATION (Continued)

4. SENSOR FEEDBACK (PHASE A)

4.1 Start (Step 1)

This is the starting step where all the programs are loaded, the state parameters defined, and the data for the particular set of pretrained TACCO utilities (if any) entered into the system.

4.2 Feedback Display (Step 2)

From the signals of the sensors deployed in the previous cycle or from other sources of intelligence information, the SENS0 displays on the TACCO's screen his best estimate of sensor bearings by entering the data into the P-3 update system from his operator's console.

5. TRACK FIX (PHASE B)

5.1 Fix Determination (Step 3)

The TACCO chooses and applies various computational aids to derive the needed information for track extensions from the raw data presented to him by the SENS0. The following interactive programs are included in the available computational aids.

5.1.1 Compute Intersection Function. The Compute Intersection Function estimates target position at the intersection of two bearings or circles and calculates the associated uncertainty parameters which are inputs to the generate track and probability contour functions. This function allows computation for two intersecting DIFAR or ESM bearings, or two intersecting range circles from RO or CASS buoys. Details of these functions are available in current system documentation.

5.1.2 Range Rate Aid Function. This function generates a predicted range rate aid circle for an RO or CASS sonobuoy based on the ranges and times of entry of the two previous RO/CASS contacts for that particular buoy or for a single range entry and a doppler value.

When the contact on a specific buoy is lost, this prediction capability permits estimation of target location if range data were available. Buoy placement may be based on the rate aid range. The rate aid circle may be used to fly the aircraft about the circle for MAD contact. This function becomes most effective when there is an absence of updated range data for an active buoy. Only 2 rate aid circles may be active at any one time.

5.1.3 Fix Designate Function. The Fix Designate Function designates any arbitrary display coordinate as a target fix. A target fix is usually designated at the intersection of contact bearings, conics, or both. The program makes no restrictions on designated fix coordinates. Notice that the fix designated can be added by the TACCO to any of the currently active tracks or even be designated as the first fix of a new track.

5.2 Track Association (Step 4)

The TACCO generates new tracks or modifies, adds, and updates existing ones. He can be aided by the options available to him as outlined in Step 3 and can entertain simultaneously up to five live tracks. This procedure is adopted when he is not sure which apparent succession of fixes is the true target. This capability can improve his chances to keep track of the target submarine even when distracting signals are interfering by keeping contact with weak signals that later may turn out to be the true submarine location. The interactive function available to him for this step is the Mark Fix Function.

The Mark Fix Function designates target fixes into the generate track equations to establish and update a track and any associated information. The function is activated by "hooking" (via the display cursor) a valid symbol or fix and depressing the MARK FIX button. Valid symbols include: visual, MAD or radar contact, bearing/bearing fix, circle/circle fix, or fix designate. The MARK FIX TRACK TX alert must be displayed to allow a fix to be marked into a track.

The fix time, converted X, Y coordinates of the hooked position; track identification; and sigma x, sigma y, sigma xy components are recorded for the tracking equations and the target track update initiated.

5.3 Data Acquisition (Steps 5, 6, 7)

If the TACCO feels that he needs more bearings from the sensors in the water to help him decide on the next pattern deployment (Step 5), he can ask the SENSO for more sensor contacts (Step 6). The SENSO will then obtain more data from the operational sensors in the water and after analysis will enter the verified information on the TACCO's screen through the P-3 computational system (Step 7).

5.4 Confidence Level (Step 8)

When there is more than one active track, the TACCO has to enter his estimation of track correctness, that is, his level of confidence of each live track being the "true" submarine location. This data is given as numbers $C_1 \dots C_5$ in the range 0-10 which are then normalized to have a sum of 1:

$$C'_K = \frac{C_K}{\sum_K C_K} \quad K = 1, \dots, 5$$

These estimations will be used as weighting factors when the probability distributions derived from each live track are combined. The system then cues the TACCO for his estimate of the time of the next sensor drop. This information is needed to calculate how far to project the submarine trajectory.

6. ATTRIBUTE LEVELS (PHASE C)

The ADDAM system calculates a vector of attributes for each pattern in the decision space which, when combined with utilities the TACCO has for each attribute, can predict his choice of the next pattern drop.

6.1 Environmental State (Steps 9, 10, 11)

The TACCO defines or modifies interactively the state of the world in the internal model. The state is changed whenever any of the four state variables change. State changes are not done in every cycle. They occur only when weather, sea conditions, or identification of submarine type change. Included in Figure 3-1 is the flow diagram of Phase C in detail.

The state changes are initiated by a computer cue which is only a reminder. If the cue is rejected, the whole step is bypassed. If not, the operator can just review the state or enter changes to the state variables. These state variables have the following sets of alternatives:

- | | |
|----------------------|------------|
| Sea Conditions: | a. rough |
| | b. calm |
| Weather Conditions: | a. stormy |
| | b. clear |
| Submarine Type | a. diesel |
| | b. nuclear |
| Submarine Maneuvers: | a. enroute |
| | b. evasive |

In addition to changes in the set of utilities used in the model, these state variables also define different parameters for the sensors used in coverage calculation.

6.2 Submarine Location (Step 12)

From an a priori model of submarine behavior and parameters derived from past behavior, the computer calculates a probability distribution of submarine location at the time of next sensor drop. Figure 6-1 shows the a priori probability distribution of submarine location at the time of next drop and Figure 6-2 shows an isometric rendering of this distribution. In the current P-3 update system, a simple elliptic distribution is used for projecting the probability of future submarine location. The more complex model adopted here is intended to enable improved evaluation of sensor placement and hence better chances of continuous submarine tracking. Intuitively, there is a high probability that the submarine will continue its motion in the same direction. There is, however, a certain probability that the submarine will change course and even turn completely around. These possibilities are captured by the probability concentration in other directions relative to the main submarine heading. The probability distribution is approximated by several layers of "probability mass" each having a uniform thickness and the shape of a ring with a heavier concentration in the direction of the last observed submarine heading. Figure 6-3 shows the detailed operations performed in this step.

6.2.1 Parameters (Steps 12.1, 12.2). The parameters of the submarine motion probability distribution are calculated from the data in each currently live track (Step 12.1) and from prior knowledge of submarine motions under the prevailing environmental state -- i.e. weather, sea condition, submarine type, etc.

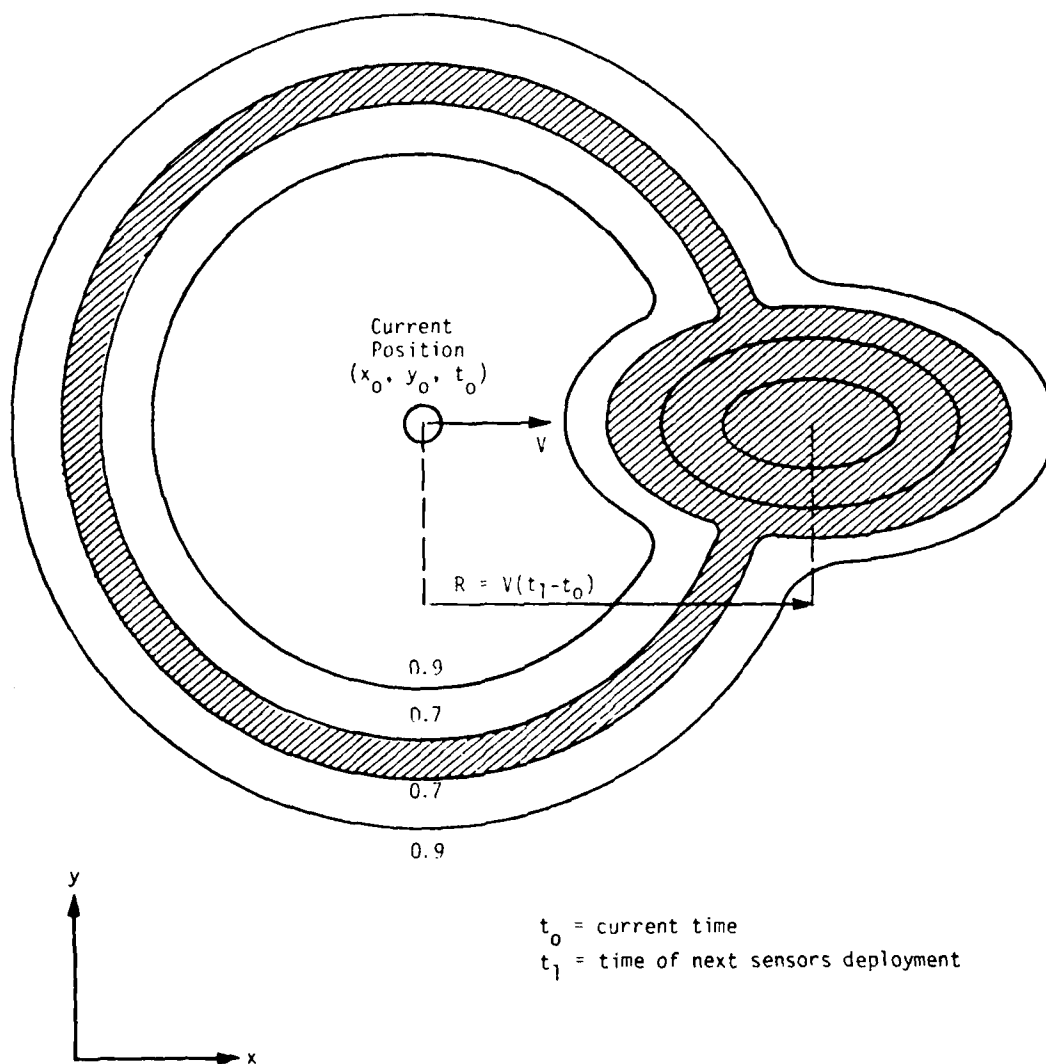


FIGURE 6-1. A PRIORI DISTRIBUTION OF SUBMARINE LOCATION AT TIME $t = t_1$

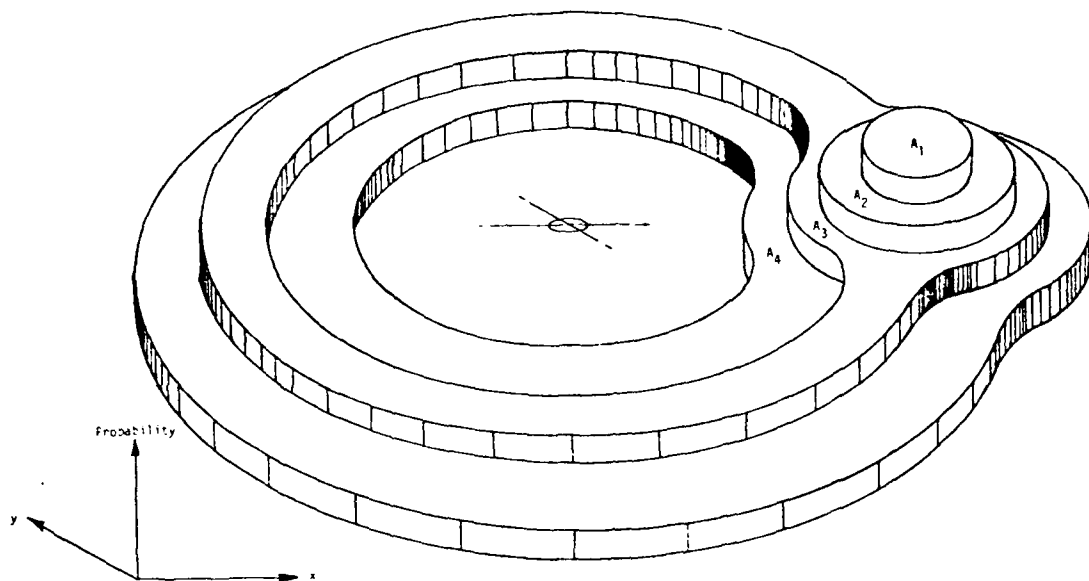


FIGURE 6-2. ISOMETRIC VIEW OF PROBABILITY DISTRIBUTION OF SUBMARINE MOTION

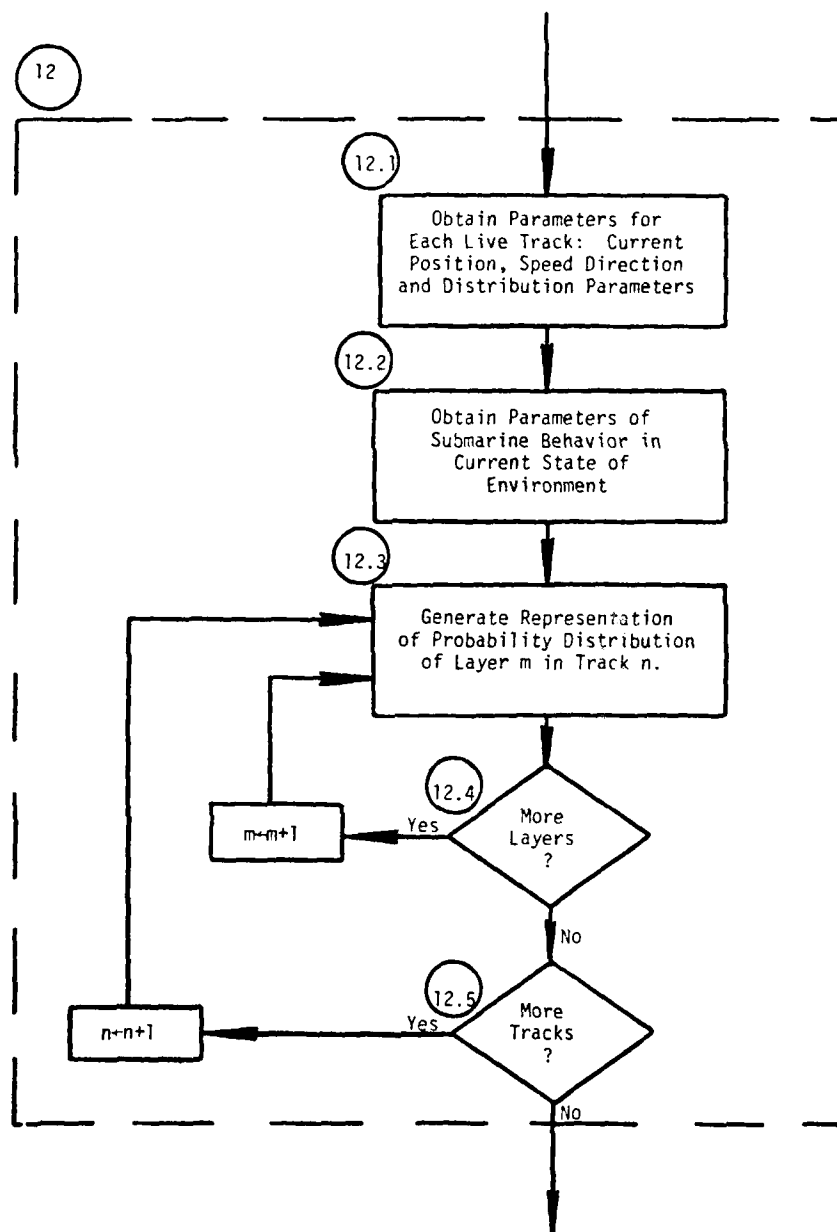


FIGURE 6-3. DETAILS OF STEP 12

6.2.2 Distribution (Steps 12.3, 12.4). The probability distribution is generated layer by layer. Each layer represents a fixed amount of "probability mass" distributed evenly. Thus, 0.3 of the total mass is distributed over the area A_1 as shown in Figures 6-1 and 6-2; 0.5 is concentrated within A_2 or smaller. In other words, the thickness of the top layer is $0.3/A_1$ and that of the second one is $0.2/A_2$, and so forth. This leads to a simple additive calculation of submarine detection probability. In Step 12.3, a single layer is calculated. Step 12.4 loops through all the layers of a given active track as shown in Figure 6-3.

A similar representation for the distribution of future submarine location is generated for each live track (loop through Step 12.5). The distribution for each track is calculated independently from the available parameters of each track. The layered "probability mass" representation makes it possible to have a composite probability distribution without considering overlaps. The combined collection of layered distributions represents the overall distribution of future submarine location and is shown in Figure 6-4. This composite distribution is a first step in calculating the probability of hit of the various sensor patterns.

6.3 Optimal Pattern Position (Step 13)

The computer finds the optimal placement of each pattern in the decision space. The optimal position is calculated either by existing placement algorithms specific for each type of sensor pattern or by a hill climbing process. This process puts the pattern at some plausible position in front of the moving submarine and calculates the probability of detection. It then shifts the pattern to a different, but nearby position and recalculates this probability. This is repeated until a local maximum is obtained and the associated pattern location is considered the optimal one. Figure 6-5 depicts the detailed operations in this step and is described in detail below.

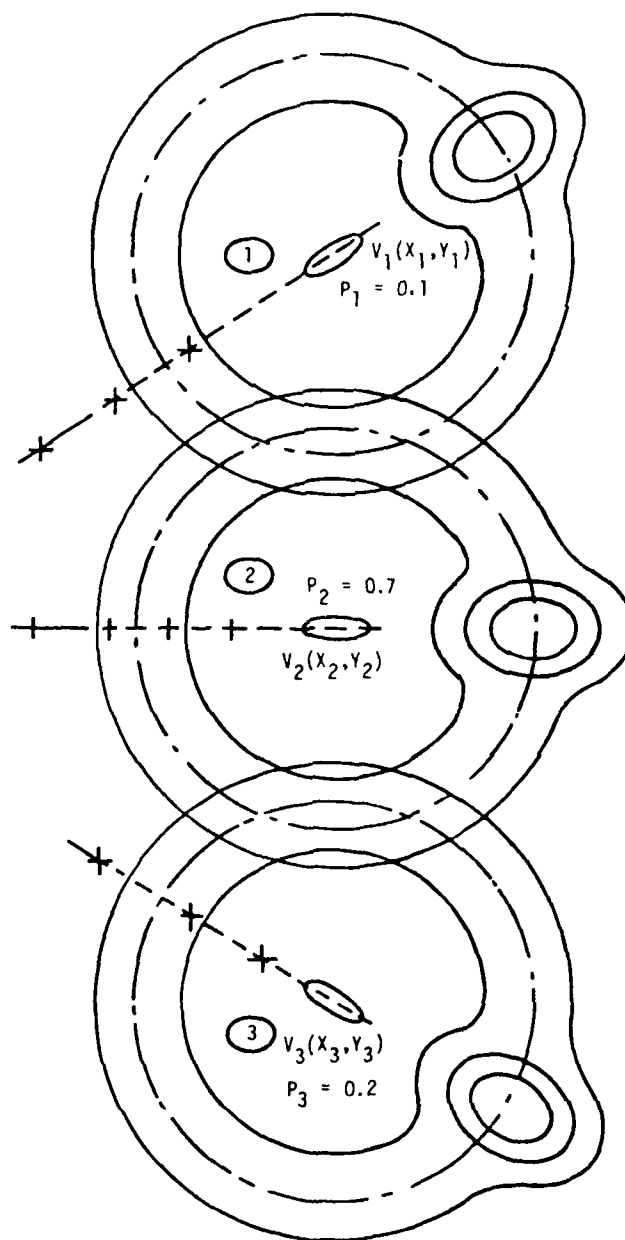


FIGURE 6-4. A COMPOSITE PROBABILITY DISTRIBUTION

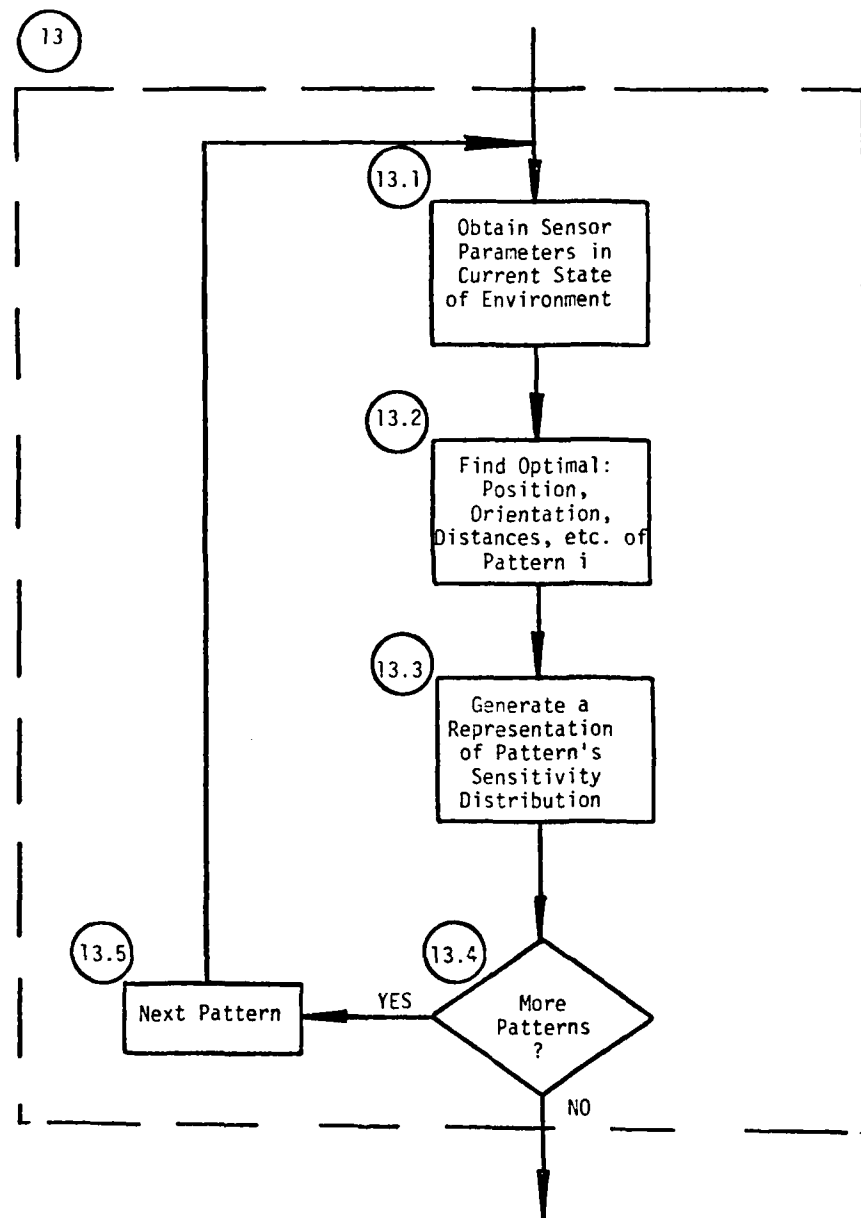


FIGURE 6-5. DETAILS OF STEP 13

6.3.1 Initial Parameters (Step 13.1). In different weather and sea conditions, the sensitivity and error parameters of the sensors will vary. In this step, the parameters are obtained for the current state of the environment.

6.3.2 Optimal Placement (Step 13.2). The optimal set of placement parameters are calculated for the currently evaluated sensor pattern. It includes the following:

1. pattern position
2. pattern orientation
3. intra-sensor distances
4. other special parameters (such as the angle between the wings of a wedge)

6.3.3 Sensor Sensitivity (Step 13.3). A layered disk representation of sensor sensitivity is generated for the pattern found in the optimization step. This sensitivity is represented as a distribution of conditional probability of submarine detection given that the submarine is at location (x,y) . The distribution is approximated by a set of layered disks isometrically shown in Figure 6-6. The radii of different sensitivity levels r_1 , r_2 , and r_3 , are a function of sensor type and weather conditions.

Separating the distribution into independent disks makes it additive similar to the distribution of submarine location. Thus, the disk of radius r_1 is 0.4 units thick, etc. The conditional probability of detection is the sum of the thicknesses of the disks at that point. For example, at point (x_1, y_1) , two disks are present resulting in a probability of detection of 0.5. The sensitivity of complete pattern is the additive collection of disks from all the individual sensors making up the pattern. Steps 13.4 and 13.5 are for loop testing.

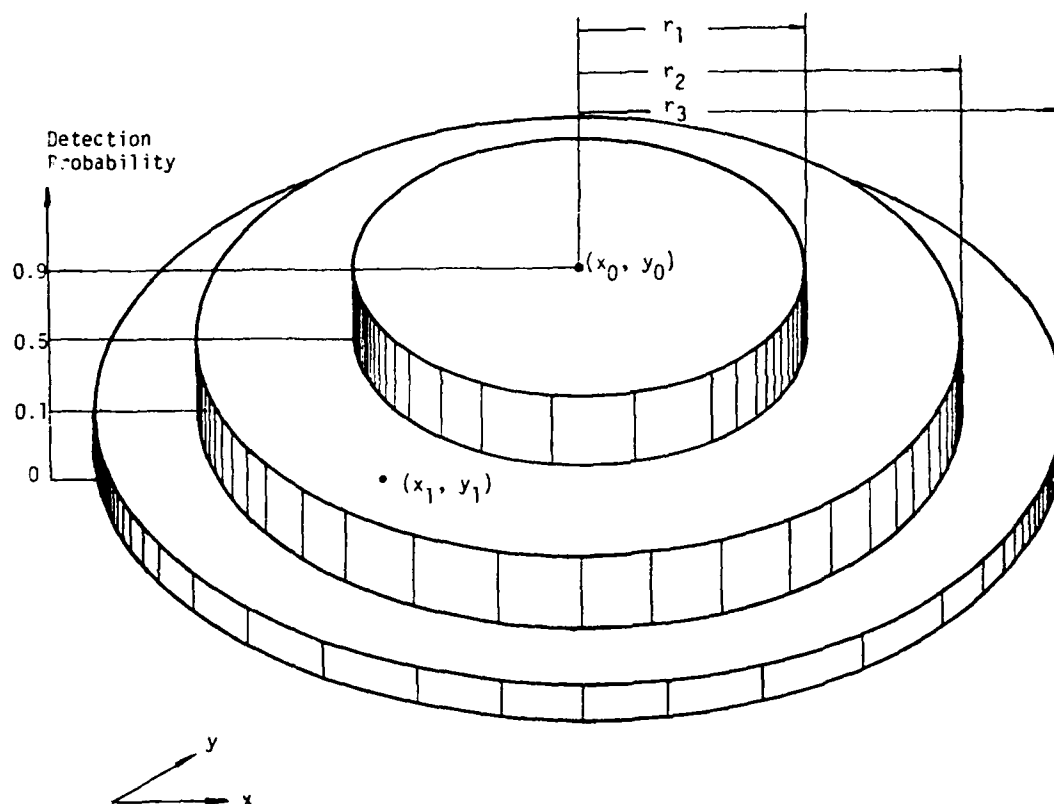


FIGURE 6-6. DETECTION SENSITIVITY DISTRIBUTION OF A SINGLE SENSOR

6.4 Attribute Vectors (Step 14)

The vectors of attributes are calculated for each choice in the decision space (see Figure 6-7). The attributes are the following:

6.4.1 Submarine Detection (Step 14.1). Probability of detection of the submarine by the pattern given the distribution of submarine location and the conditional probability of pattern sensitivity. The formula for the calculation is:

$$P_{i1} = \int_{xy} P_s(x,y) [1 - \beta_i(x,y)] dx dy$$

where the integration is done over the entire relevant area.

$P_s(x,y)$ is the probability distribution of the submarine being at point (x,y) at the time of next pattern drop and

$\beta_i(x,y)$ is the conditional probability that the sensor pattern i will fail to detect a submarine present at point (x,y) .

6.4.2 Detection Failure (Step 14.2). The probability of failure to detect a submarine present in the pattern's coverage area is calculated by:

$$P_{i2} = 1 - P_{i1}$$

6.4.3 False Alarm (Step 14.3). The probability of false alarms is calculated by:

$$P_{\text{false alarm}} = n [P_\alpha + \delta_{sc} P_{sc} + \delta_{ac} P_{ac}]$$

where: P_α is the probability of positive sensor error,

P_{sc} is the added probability of error due to a rough sea,

P_{ac} is the added probability of error due to a storm,

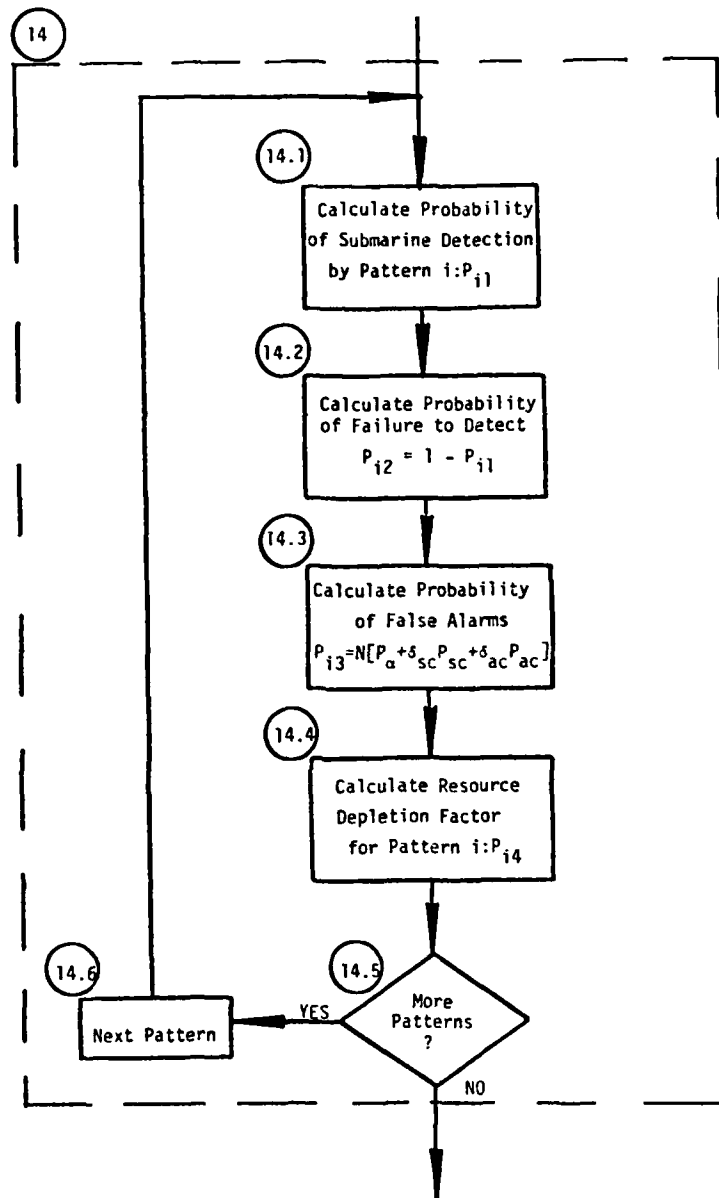


FIGURE 6-7. DETAILS OF STEP 14. CALCULATION OF ATTRIBUTE VECTORS

$$\delta_{sc} = \begin{cases} 0 & \text{when the sea is calm} \\ 1 & \text{when the sea is rough} \end{cases}$$

and $\delta_{sc} = \begin{cases} 0 & \text{when the atmosphere is quiet} \\ 1 & \text{when there is a storm} \end{cases}$

6.4.4 Resource Depletion (Step 14.4). The resource depletion factor is calculated by:

$$P_{i4} = 1 - k \left| \frac{n_{ti} - n_{opt}(t)}{n_{opt}(t)} \right| = 1 - k \frac{T}{N_0(T-t)} \left| n_{ti} - N_0 \frac{(T-t)}{T} \right|$$

where: $N_{opt}(t) = N_0 \cdot \frac{T-t}{T}$

and: N_0 = the initial number of sensors on board

T = the total length of the mission in minutes

t = the time passed into the mission in minutes

n_{ti} = the number of sensors left on the plane after dropping sensor pattern i

k = a constant of proportionality which varies the acuteness of the parameter R_i .

The substeps 14.1, 14.2, 14.3, and 14.4 in Figure 6-7 calculate each of these parameters for each choice according to the indicated formula.

7. PATTERN RECOMMENDATION (PHASE D)

The ADDAM model is applied to choose the pattern which would best fit the TACCO's utilities. The chosen pattern will be recommended for the TACCO as a pattern with the number of buoys in it to be used in the next drop.

7.1 Utility Values (Step 15)

For each pattern of sensors i , the expected utility is calculated according to the formula:

$$EU_i = \sum_{j=1}^4 P_{ij} U_j$$

where

P_{ij} are the attribute levels of attribute j for pattern i ,

U_j are the personal utility values the TACCO has for attribute j .

7.2 ADDAM Recommendation (Step 16)

The pattern with the maximum total expected utility is chosen and will be the system recommendation.

7.3 Training Mode (Steps 17, 18)

The ADDAM system gives a recommendation only if it is confident enough in its own prediction. θ is the level of system confidence and is calculated from the number of successful predictions in the 10 most recent cycles.

$$\theta = \frac{n}{10}$$

where n is the number of successful system predictions of TACCO choices. The confidence level θ is compared to a threshold t_c determined experimentally. If $0 < t_c$, the system is still training its parameters and will not recommend a pattern to the TACCO. If $0 > t_c$, the system will display the recommended pattern. This recommendation will appear at the bottom of the display. For example, a typical recommendation would be:

"PLACE A BARRIER OF 5 SONOBUOYS"

8. TACCO DECISION (PHASE E)

The TACCO can now ask to see the actual layout of the chosen pattern or any other pattern in the decision space on his main display. His requested pattern will be displayed in its optimal location relative to the submarine motion. It is then incumbent upon the TACCO to decide whether he wants to approve the system's choice or to modify it. The system will adapt its parameters according to his decision.

8.1 Recommendation Display (Steps 19, 20)

If the description of the chosen pattern is not sufficient, the TACCO can ask and receive a graphical presentation of the pattern shown in the optimal position calculated for it.

8.2 TACCO Choice (Steps 21, 22)

The TACCO has three alternatives for approving a recommendation.

- a. Approve the recommendation given (Step 24).
- b. Disapprove and choose another alternative from the decision space (Step 22).
- c. Define an altogether new pattern (Step 25).

In Step 22 he must also indicate which other choice in the decision space he prefers.

9. UTILITY UPDATE (PHASE F)

9.1 Adaptive Utility Parameters (Step 23)

If the TACCO decides to choose another element of the decision space, the model made a wrong prediction and must be updated. This is accomplished by changing the vector of utilities $\bar{U}$ associated with the current state of the environment according to the difference in the attribute vectors associated with the recommended pattern P_R and that of the chosen pattern P_C :

$$\hat{U} = U + \lambda(P_C - P_R)$$

where:

λ is a parameter determining the speed of convergence,

P_R is the attribute vector of the pattern the system recommended,

P_C is the attribute vector of the pattern chosen by the TACCO.

9.2 Adaptive Training Parameter (Step 24)

If the TACCO chose to accept the systems choice (Step 24) only the confidence level θ must be updated to account for the successful prediction of his decision. The utility parameters of the ADDAM model are not changed since it proved itself correct by making the right prediction.

9.3 Special Patterns (Step 25)

When the TACCO rejects the system's choice and even does not find any element in the decision space applicable (Step 21), he must resort to the manual steps for pattern definition as they are used in the current P-3 procedures.

10. SENSOR DEPLOYMENT (PHASE G)

This is the final phase in the cycle. The TACCO must define parameters of the pattern such as buoy type, depth setting, etc. Then, he must calculate the trajectory needed to deploy this pattern and finally give commands to the pilot for commencing the action.

10.1 Modify Tactics Function (Step 26)

Even when accepting a recommended pattern, the TACCO can go through a modification phase, changing small aspects of the pattern construction. The modification phase of pattern construction gives the option to:

- (1) Change the buoy type. (If the requested buoy type is not available, the LIFE-DEPTH UNAVAIL alert is presented and the MODIFY cue redisplayed.)
- (2) Specify depth setting and lifetime for each buoy in the pattern.
- (3) Resolve unassigned RFs. Automatic sequencing occurs unless a hook verify is performed. Hooking a specific buoy designator presents the option of changing an already assigned RF or making an initial assignment. Available nonconflicting RFs are displayed in the AVAILABILITY cue. Buoy type and life/depth are maintained. If there are no available RFs, the CONFLICT cue is presented. Undisplayed available and conflicting RFs are allowable entries.
- (4) Modify the pattern geometry. The SELECT INPUT cue allows modification of the spacing and radius of the circle.
- (5) Accept the pattern as constructed and displayed.

After each change is entered, the MODIFY cue is redisplayed. The process continues until the pattern is accepted. Each modification is reflected on the pattern display and any buoy selection or deselection is shown in the Pattern Construct tableau.

10.2 Intercept Point Function (Step 27)

The intercept point function computes the shortest distance the aircraft must travel to intercept a designated point. This command is used to calculate the best trajectory the P3-C should take to come to the starting point for dropping the pattern decided on through the cycle.

10.3 Sensor Deployment Function (Step 28)

"Execute" initiates steering commands directing the pilot to fly over each buoy drop position of a constructed pattern. At the CPA (Closest Point of Approach) to the drop point, the appropriate sonobuoy is released. Pattern execution is a combination of steering and ordnance interfacing to automatically carry out previously specified TACCO decisions. Through the MDD display and switch illumination, the TACCO can follow pattern progress. The automatic execution of a preconstructed pattern releases the TACCO from the burden of tactical manipulation and gives him time to monitor and evaluate the tactical situation. The TACCO retains control of all phases of the execution.

10.4 End Cycle (Step 29)

After execution of the chosen pattern is finished, the cycle is repeated over again for the next drop as shown in the global loop of Figure 3-1.