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JUN 81 J KELLEY, R OUSEY, W ZACHARY   N00014-79-C-0863
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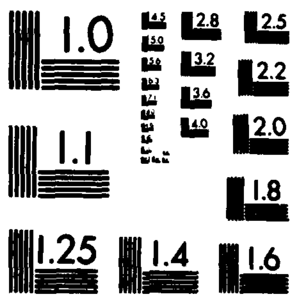

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report explores a modular technique for implementing ASW Decision Aids identified in the air APP program. The P-3C Update II, S-3A, and LAMPS MK III are used as candidate host platforms. Decision aid data modules are synthesized and sized estimates are made of decision aid algorithm size based upon a taxonomy of decision aid techniques.

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EXECUTIVE SUMMARY

This report documents an investigation of the merits and feasibility of implementing decision aids aboard the P-3C Update II, S-3A and LAMPS MK-III. A decision aid package approach was adopted because it accounted for the interrelationship of mission functions and phases which previous piecemeal implementation of decision aids aboard tactical aircraft had not done. Additionally, this approach allows for development of common data modules that can be utilized by multiple decision aids, thus reducing demands on the host processor and facilitating implementation of additional aids or changes to existing ones.

Specific decision aids addressed were:

- Search Pattern Planning
- Processor Mode Selection
- Contact Investigation Pattern Selection
- Signal Correlation
- Threat Assessment and Classification
- Localization and Tracking
- Passive to Active Transition
- Attack Planning

Common data modules for these aids were identified and sized; the decision aid algorithms were established and sized; and, an estimate was made of the impact decision aids had on throughput of the central processor. Table ES-1 summarizes the size requirements of the algorithms and data modules. Use of tape overlay of the decision aid package and integration of a package into

Table ES-1. Summary of Decision Aid Sizing

DATA MODULES	MODULE SIZE IN WORDS	DECISION AIDS: SEARCH PATTERN PLANNING	PROCESSOR MODE SELECTION	CONTACT INVESTIGATION PATTERN SELECTION	SIGNAL CORRELATION	THREAT ASSESSMENT AND CLASSIFICATION	LOCALIZATION AND TRACKING PATTERN SELECTION	PASSIVE TO ACTIVE TRANSITION	ATTACK PLANNING
Search Pattern Inventory	74	X							
Localization and Tracking Pattern Inventory	52						X	X	
Contact Investigation Pattern Inventory	40			X					
Passive to Active Transition Inventory	27							X	
Aircraft Location	10	X		X			X	X	X
Sonobuoy Location	840				X			X	
Sensor Inventory	420	X		X			X	X	
Weapon Inventory	32								X
Operating Area	109	X					X		
Target Characteristics	140	X	X			X			
Target Location	230	X		X	X		X	X	X
Target Capabilities	290	X		X	X	X			X
Oceanographic Conditions	17	X	X	X	X	X	X	X	X
Atmospheric Conditions	15	X		X			X	X	X
Propagation Loss	1030	X	X	X	X	X	X	X	X
Aircraft Dynamics	18	X		X				X	X
ASW Weapon Capability	27						X		X
Acoustic Sensor Capability	48		X		X	X	X		
D.A. Algorithm Size (K Words)		8.3	5.2	8.3	9.0	7.6	9.8	8.2	10.0
Approximate Total Size (K Words)		10.7	6.5	10.4	11.5	9.2	11.8	10.9	11.7

current software with a new executive were both investigated. Results indicated that the P-3 Update II and S-3 implementations are only feasible with the addition of a dedicated decision aid processor. An investigation of the "how" of engineering implementation of the decision aid package with processor, and a cost benefit analysis are recommended.

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1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Acoustic Performance Prediction Program

The Naval Sea Systems Command objective for the Acoustic Performance Prediction (APP) program is to "... develop computer software which provides decision aids to various levels of command to optimize the in-situ performance of undersea warfare ...". The APP system will be capable of providing information pertaining to the overall ASW mission from initial mission planning through post-mission analysis. APP products fall into the following five categories:

- Environmental
- Acoustical
- Target Motion Analysis
- System Configuration Recommendations
- Anti-Submarine Warfare (ASW) Tactical Decision Aids

This report addresses Tactical Decision aids to be used during a mission by ASW aircraft.

1.2 SCOPE

1.2.1 Aircraft Investigation Purpose

The purpose of this document is to report the findings of the investigation to determine the feasibility of implementing decision aids in the P-3C, S-3A, and LAMPS airborne ASW platforms. This effort addresses eight candidate decision aids considered for aircraft implementation and establishes a logical means of implementing decision aids which reduces the amount of computer storage required, eliminates duplication of information, and allows for future expansion. In the past, implementation of decision aids has been performed on an aid-by-aid basis with little regard for integrating new decision aids with those already resident in the aircraft operating programs. This project has been oriented towards an implementation schema which would result in the installation of a decision aid cache. The scheme consists of forming common data modules which can be utilized by multiple decision aids and integrates output of multiple decision aids to augment ASW problem solving.

1.2.2 Platform Selection

The aircraft considered for APP decision aid implementation are the land based P-3C Update II with I-43 operating program; the carrier-based S-3A, with I-4.0.1 version operating program and the LAMPS MK III ship and aircraft system. Since all but the P-3C come in only one variant, only the P-3C required selection of a variant for study. The Update II version of that aircraft was selected for the following reasons.

- The P-3C Update II operational program is the most current version in the fleet.
- Sufficient documentation pertaining to hardware and software is available.
- The P-3C Update II is equipped with an expanded drum memory which provides additional storage.

Other P-3C variants, which were considered but not selected, were the P-3C baseline with tape overlay, P-3C Update I, P-3C Update III, and the C-MOD. The primary rationale for non-selection was:

- P-3C base line does not contain the drum memory and, therefore, has questionable storage and computational space, not including tape overlay functions.

- P-3C Update I aircraft have a slightly different avionics suite than the more current Update II.

- P-3C Update III and C-MOD aircraft are both in the development stage and, as a result, are not totally documented.

1.2.3 Constraints and Assumptions

1.2.3.1 Alternative Processing Configurations. Three alternative processing configurations were considered for integration of decision aids in airborne ASW platforms. The general specifications are:

- Present on board computer capability. This configurations examined integration of decision aids in the platform's current computer system and the present operating program.

- Tape/disc overlay functions to augment current computer capability. This configuration examined storing decision aids on an auxiliary tape or disc drive and later read into the computer for execution when requested by the operator.

- A dedicated decision aiding system, such as an AN/UYK-14. This configuration examined the application of an independent decision aid system which requires installation of a separate computer to be interfaced with existing platform systems.

1.2.3.2 Sensor Input, Display Capability, & Environmental Restrictions. It was established that inputs to the decision aids must be available from current aircraft sensory systems, preflight data insertion program (PDIP) tapes, or provided by personnel via keyboard entry. The display of all decision-aiding output for the P-3C and S-3A is restricted to these aircrafts' present on board equipment. LAMPS MK-III processing and display capabilities are accessed by the present equipment on board the platform and base ship. The selection of decisions aids was based on utilization of acoustic environmental information. Decision aids which do not require acoustic data, such as radar, electronic support equipment (ESM), infrared detection system (IRDS), magnetic anomally detection (MAD), navigation, or communications, were not addressed.

1.2.3.3 Homogeneous Ocean Assumption. For purposes of decision aid specifications, it is assumed that the oceanographic conditions are consistent throughout the aircrafts' operating area. Although this is an over simplification, ASW aircraft are not currently capable of accurately determining the boundaries of different oceanographic areas.

1.2.4 Decision Aids

The decision aids selected for this study were:

- Search Pattern Planning
- Processor Mode Selection
- Contact Investigation Pattern Selection
- Signal Correlation
- Threat Assessment and Classification
- Localization and Tracking
- Passive to Active Transition
- Attack Planning

These aids address the decision situations identified in Analytics Technical Report 1366.A. "Decision Aids for Naval Air ASW", 15 March 1980 which relied on structured fleet interviews, and Naval Sea Systems Command Acoustic Performance Prediction (APP) system information requirements.

2. DECISION AIDS

2.1 DECISION SITUATION IDENTIFICATION

Decision aids, for the purpose of this report, are considered to be automated functions which are capable of integrating information from multiple sources to assist in the determination of solutions to large problems, thereby relieving the operator of some mental and physical tasks and providing the operator with more time to comprehend the overall ASW mission.

Analytics Technical Report, 1366-A, identified decision situations during an airborne ASW mission and identified the means by which decisions aids could be used to assist the aircrew in accomplishment of the mission. This report divided an ASW mission into the following mission segments:

- On Station Search
- Target Identification
- Target Localization
- Target Attack or Target Track

Each mission segment has two possible results based on the goals of the segment. Normally when the segment goal is achieved, the result is the initiation of the next segment. When the segment goal is not achieved, the segment may continue indefinitely. For example, the Search Segment is terminated when a contact is obtained, however, search will continue indefinitely until the goal (contact) is achieved. There is a major exception to this sequence in that localization can proceed prior to target classification. Classification can proceed during localization provided that it is complete prior to attack.

Each segment requires many individual decision functions to be performed in order to achieve one objective event. Because the decisions associated with objective events change from situation to situation, the manner in which these constituent decisions must be coordinated also changes. Certain decisions assume higher priority in some segments than others, and certain criteria become relevant to a decision in some parts of the mission and irrelevant in others. The key to identifying the kinds of decision aids needed is recognizing that it is not the performance of the individual decision functions that poses problems. *Instead, it is the need to coordinate the decisions situations with other ones and relate them to some overall tactical plan for achieving the next goal event in the mission.* Thus, mission segments, do not merely subdivide the mission into temporal slices, but, also provide decision making contexts or situations which define intermediate level problems in need of decision aiding. They are intermediate in that they are *more* detailed than the single high level problem of achieving the overall mission objective (destroy or track the submarine) but *less* detailed than the many low level problems of solving each individual decision function (e.g., determining the spacing for the next sonobuoy pattern) in the mission. These general decision making situations, which can be equated to mission segments transition, were therefore selected as the basis for the analysis of decision aiding.

Specific candidate decision aids were characterized by correlating the decision situations and the proposed product content recommendations of the APP Information Requirements document. Decision aid concepts were formulated utilizing these APP guidelines. The concepts were then viewed by fleet operational TACCOs to determine the validity of the decision aids, aircrew interest and potential application of these concepts. After reviewing these fleet responses, eight decision aids were selected for consideration in this study. The purpose of these eight aids are summarized as follows:

- SEARCH PATTERN PLANNING -- Select the optimal pattern and sonobuoy field for gaining initial contact. Utilize the actual oceanographic conditions, and target intelligence to determine optimal sonobuoy pattern, sonobuoy settings and sonobuoy pattern orientation to compute different search patterns.

- PROCESSOR MODE SELECTION -- Determine the optimal mode for processing acoustic signals for the target(s). This decision aid will correlate both common signals across multiple sensors, and multiple signals across multiple sensors. The output from this decision aid will consist of the sensors holding contact, the specific contact signals associated with each sensor, and a target probability denoting the target location in relation to all sensors.

- CONTACT INVESTIGATION PATTERN SELECTION -- Recommends a sonobuoy pattern which optimizes the probability of establishing direct path contact on the submarine.

- SIGNAL CORRELATION -- Utilizes information from multiple acoustic sensors to refine target uncertainty area and estimate target location.

- THREAT ASSESSMENT AND CLASSIFICATION -- Classifies new contacts, and determines the threat posed by targets classified hostile.

- LOCALIZATION AND TRACKING PATTERN SELECTION -- Recommends optimal localization and tracking patterns, while conserving sensors.

- PASSIVE TO ACTIVE TRANSITION -- Determines when a target has been sufficiently localized to permit effective prosecution with active sensors.

- ATTACK PLANNING -- Used to determine optimal tactics for attack on a hostile submarine.

2.2 DECISION AID GENERIC STRUCTURE

This section provides an overview of the decision aids being investigated for implementation into air ASW platforms. The generic structure of each decision aid is contained in a table which describes input/output features, parameters required for aid calculation, display requirements, and a brief description of what the aid must do. These tables or Decision Aid Characteristics Summaries are used in Section 3 to determine decision aid sizing. The information contained within these tables and definition of the table categories is explained in detail in Appendix A. Table 2-1 through 2-8 summarize the characteristics of each decision aid.

2.3 DECISION AID SOFTWARE DESIGN

The software structures of the P-3C Update II, S-3A, and LAMPS MK-III were investigated and determined to be modular. Table 2-9 lists the software entities of these aircraft, and Appendix B describes them briefly. The APP decision aids share common input data, and some aids require the output of others as input. This phenomenum suggests that a natural modularization of the decision aids software similar to the systems operational software could be achieved. Thus, it was decided that the most cost effective method for implementing decision aids onboard the air platforms with maximum tactical gain was to coordinate the multiple aids with each other to form a complete decision aiding package.

This section identifies and relates the aircraft data modules, data and algorithmic modules used by the candidate decision aids, and establishes a coherent relationship among them. The individual modules and the proposed system software architecture described here provide the input to the sizing analysis documented in Section 3.

2.3.1 Platform Modules Needed for Decision Aid Implementation

The APP program is concerned with providing improved ASW capabilities in the acoustic related performance areas. Therefore, all decision aids contained in this report deal with the impact of improved acoustical information and optimum utilization of the acoustic sensor environment in the ASW mission. Target Management (search, classification, localization, contact reacquisition, and attack of submarines) was investigated. Table 2-10 specifies, by aircraft type, those software system modules which related to target management. Table 2-10 was derived through review of host system documentation.

Table 2-1. Search Pattern Planning Characteristics Summary

Objective: Selection of Optimal Pattern for Gaining Initial Contact Given In-Situ Environmental Conditions.

Task Dynamics: Closed-Loop Iterative.

Underlying Process: Zero or More Submarines Moving In or Through Search Area.

Value Criteria: Coverage Area of Pattern.
Probability of Detection of Submarine from Pattern.

Variables and Parameters

Inputs
Oceanographic Conditions
- PL
- Ambient Noise
- Sea State

Sensors Remaining
Target Contact History

Outputs
Pattern Coverage Area
Probability of Detection (P_d)

Parameters
Sensors: Type
- Capabilities

Available Pattern Geometries
Aircraft Capabilities
Target Capabilities
- Acoustical Emissions
- Movement

Area of Search
- Operating Area
- Restricted Area(s)

Decision Variables
Type of Pattern to be Deployed and Spacing

Relevant Analyses
1. Calculation of In-Situ PL Profiles
2. Exclusion of Patterns Failing to Meet Mission Restrictions.
3. Determination of Pd for a Given Pattern.

Relevant Displays
1. Pattern Geometry and Types and Settings of Sensors Used.
2. Steering Commands, Cueing Sequences, and Fly-to-Points for Pattern Deployment.

Required Human Judgments: Final Choice of Pattern.

Narrative: This decision aid will compute various search patterns and display them to the TACCO to allow the TACCO to select the desired pattern.

Table 2-2. Processor Mode Selection Characteristics Summary

<u>Objective:</u> Select Optimal Mode for Processing Acoustical Signals Given Targets of Interest and In-Situ Environmental Conditions.

<u>Task Dynamics:</u> Uni-dimensional Independent

<u>Underlying Process:</u> None

<u>Value Criteria:</u> Expected Detection Probability

<u>Variables and Parameters</u>

<u>Inputs</u>
<u>Oceanographic Conditions</u>
- PL
- Ambient Noise
- Water Temperature vs Depth
- Layer Depth
- Bottom Type

<u>Parameters</u>
<u>Target Characteristics</u>
- Source Levels
- Frequencies

Acoustic Processor Capabilities
- Recognition Differential
- Resolution
- Band Coverage

<u>Outputs</u>
- Lateral Range Functions
- Detection Ranges

<u>Decision Variables</u>
<u>Processor Mode</u>

<u>Relevant Analyses</u>
1. Calculation of Detection Ranges.
2. Optimization of Processor in Terms of Expected Detection Ranges.

<u>Relevant Displays</u>
<u>Suggested Processing Mode</u>

<u>Required Human Judgments</u>
<u>Acceptance/Final Choice</u> of Processor Mode

<u>Narrative:</u> The Processor Mode Selection decision aid utilizes environmental information, processor mode gain and target intelligence to determine lateral range curves (LATRAN) which denote the probability of passive detection versus range for a target at a specified frequency/source level combination. The LATRAN information is then used to compute a probability of target detection by processor mode. Comparison of mode performance provides the acoustic operator with recommended settings for the acoustic signal processor.

Table 2-3. Contact Investigation Pattern Selection Characteristics Summary

Objective:	Select Pattern which will result in Direct Path Contact with submarines.
Task Dynamics:	Closed-Loop Iterative
Underlying Process:	Movement of one or more hostile submarines through or in search area, possibly attempting to evade or escape detection; movement of ASW aircraft.
Value Criteria:	Probability of Gaining Direct Path Contact with Target.

Variables and Parameters

Inputs
Target Situation
- Location
- Course, Depth, Speed
- Area of Uncertainty

Deployed Sensors
- Location
- Setting Depth
- Remaining Lifespan

Oceanographic Conditions
- PL
- Ambient Noise
- Sea State
- Temperature vs Depth

Sensor Availability
- Number Available
- Type

Parameters
Aircraft Characteristics
Target Characteristics
- Source Levels
- Frequencies

Target Capabilities
- Speed Characteristics
- Maneuvering Capabilities
- Depth Limitations

Sensors Characteristics
Search Area
- Pattern
- Operating Area

Outputs
Coverage Area
Probability of Obtain Direct Path Contact
Probability of Maintaining Contact

Decision Variables
Type of Next Investigation Pattern

Relevant Analyses
Determine Target Uncertainty Area (UA)
Optimize Sensor Pattern Given Target UA and Environmental Conditions

Relevant Displays
Suggested Optimal Pattern, Geometry, and Sensor Types and Settings Cueing Sequences, Fly-to-Points, and Steering Commands to Deploy Suggested Pattern

Table 2-3. Contact Investigation Pattern Selection Characteristics Summary (Continued)

Required Human Judgments
Final Acceptance/Choice of Sensor Pattern

Narrative: The Investigation Pattern decision aid is intended for use after initial contact has been gained and classified from the search pattern where convergence zone contacts are possible. This decision aid will utilize contact information in conjunction with environmental information and provide recommendations relating to the subsequent tactical actions to be employed in order to gain direct path contact. This aid will be used to provide pattern recommendations, sonobuoy locations, and sonobuoy settings for use refining the target area of uncertainty. All information resulting from this decision aid will be displayed to the TACCO.

Table 2-4. Signal Correlation Characteristics Summary

Objective:	Utilize information from multiple sensors to refine target uncertainty area and estimated position.
Task Dynamics:	Multi-dimensional Independent
Underlying Process:	Movement of one or more hostile submarines through search area, possibly taking evasive action.
Value Criteria:	None

Variables and Parameters

Parameters

Target Characteristics
- Source Location
- Frequency

Target Capabilities
- Speed, Depth, Maneuvering Limitations
- Historical Track Data

Search Area
- Operating Area
- Restricted Area

Aircraft Capabilities

Acoustic Processor Capabilities

Outputs

Coverage Area Overlap

Possible Target Locations

Inputs

Target Situation
- Location
- Estimated Course, Depth, Speed, Location
- Uncertainty Area
- History of Contact

Deployed Sensors
- Lifespan Remaining
- Type and Setting
- Location

Oceanographic Conditions
- PL
- Ambient Noise
- Temperature vs Depth
- Operating Area

Decision Variables

Estimated Target Positions

Target Uncertainty Area

Relevant Analyses

1. Calculation of Possible Target Positions from Areas of Overlap.
2. Determination of Probability of Target Being In Each Possible Location.
3. Investigation of Possible Multiple Targets.

Relevant Displays

Location of Deployed Sensors

Sensors and Sensor Types Receiving Signals

Possible Target Locations

Sensor Coverage Area Overlap

Target Area Uncertainty

Table 2-4. Signal Correlation Characteristics Summary (Continued)

Required Human Judgments
Interpretation of Tactical Situation

Narrative: This decision aid will correlate both common signals across multiple sensors, and multiple signals across multiple sensors. The output from this decision aid will consist of the sensors holding contact, the specific contact signals associated with each sensor, and a target probability denoting the target location in relation to all sensors.

Table 2-5. Threat Assessment and Classification Characteristics Summary

<u>Objective:</u> Classification of New Contacts, and Determination of Threat Posed by Each Classified Hostile Target.

<u>Task Dynamics:</u> Multi-dimensional Independent

<u>Underlying Process:</u> None

<u>Value Criteria:</u> Measure of the Uncertainty Remaining in the Classification and Threat Assessment of Each Target.

<u>Variables and Parameters</u>

<u>Parameters</u>

<u>Target Characteristics</u>
- Source Levels
- Frequency

Target Capabilities
- Maneuvering, Depth, Speed, Limitations
- Historical Track Data
- Mission Types (Historical)
- On-Station Time, Transit Time

Sensor Capabilities
- Depths, Settings, Types

<u>Decision Variables</u>

<u>Classification of Each Target</u>

Threat Level of Targets Classified as Hostile

<u>Inputs</u>

<u>Deployed Sensors</u>
- Location, Depth
- Settings
- Remaining Lifespan

Environmental Conditions
- PL
- Ambient Noise
- Temperature vs depth
- Layer Depth

Contact Involved
- Sensor Receiving
- Frequencies
- Frequency Bandwidth

<u>Outputs</u>

<u>Candidate Classifications</u>

Threat Capabilities of Each Candidate Classification

<u>Relevant Analyses</u>

<u>Determination of Possible Classifications from Incoming Frequencies.</u>
Identification of Possible Target Actions from Incoming Signals.
Interference of Threat Level from Capabilities and Inferred Mission.

<u>Relevant Displays</u>

<u>Chosen classification and probability.</u>
Other possible classifications and probabilities.
Movement and attack capabilities of classified targets.
Additional target-related information.
Uncertainty area and estimated location of target.

Table 2-5. Threat Assessment and Classification Characteristics Summary (Continued)

Required Human Judgments

Acceptance/Rejection of classifications.

Determination of which among multiple targets to prosecute first.

Narrative: The Threat Assessment and Classification decisions aid receives the detected signature information from the target and provides the acoustic station operator and TACCO with alpha-numeric listings of the targets classification and capabilities. This information can be used by the TACCO to determine subsequent actions which must be followed in the tactical problem.

Table 2-6. Localization and Tracking Pattern Selection
Characteristics Summary

Objective: Choose optimal localization ands tracking pattern, while conserving sensors for future mission phases.

Task Dynamics: Closed-Loop Iterative

Underlying Process: Movement of target through search area, possibly taking evasive action.

Value Criteria: Probability pattern to be deployed will decrease uncertainty in target location, course, depth, speed.

Variables and Parameters

Parameters

Target Characteristics
- Source Levels
- Frequency

Target Capabilities
- Speed, Depth, Maneuvering Limitations

Search Area
- Operating Area
- Restricted Area(s)

Candidate Sonobuoy

Sonobuoy Capabilities

ASW Aircraft Capabilities

Decision Variables

Pattern and Geometry

Inputs

Target Situation
- Location, Course, Depth, Speed
- History of Contact
- Uncertainty Area

Sonobuoy Inventory

Environmental Conditions
- PL
- Ambient Noise
- Temperature vs depth

Outputs

Coverage Area

Resolution of Candidate Pattern

Relevant Analyses
1. Exclusion Analysis of Patterns which Violate Situational Restrictions.
2. Optimization of Sensor Pattern.
3. Trade-off of Sensor Requirements with Pattern Coverage.
4. Probability of Detection for each Sonobuoy Pattern.

Relevant Displays
1. Pattern Geometry
2. Types and Settings of Sensors
3. Fly-to-Points, Steering Commands, and Cueing Sequences

Required Human Judgments

Final Acceptance/Rejection of Pattern Suggestions.

Table 2-6. Localization and Tracking Pattern Selection Characteristics Summary (Continued)

<u>Narrative</u>: The Localization and Tracking decisions aid will utilize environmental information and target information to determine the target acoustic detection range for the operating area. This will be compared with current target fixing information or target location information to project the target location at a future time. Localization sonobuoy patterns will then be evaluated relative to the target's projected location to select the optimum localization pattern to be used. This decision aid will compute various localization patterns and display them to the TACCO to allow the TACCO to select the desired pattern.

Table 2-7. Passive To Active Transition Characteristics Summary

Objective:	Determine when target has been sufficiently localized so that prosecution with active sensors can effectively begin.
Task Dynamics:	Multidimensional Independent
Underlying Process:	Movement of Hostile Submarine and ASW Aircraft in Search Area.
Value Criteria:	Measure of overall uncertainty in target location, course, speed, and depth, relative to detection capabilities of active sensors.

Variables and Parameters

Parameters

Target Capabilities
- Movement, Depth, Speed Limitations
- Historical Tracks

Target Characteristics
- Source Levels
- Frequencies

Passive Sensor Capabilities

Active Sensor Capabilities

ASW Aircraft Capabilities

Search Area
- Operating Area
- Restricted Area

Active Sensor Patterns

Inputs

Target Situation
- Est. Location, Course, Depth, Speed
- Uncertainty Area
- History of Contact

Sensor Inventory

Deployed Sensors
- Type, Setting, Location
- Remaining Lifespan

Environmental Conditions
- PL Ambient Noise
- Layer Level

Decision Variables

Pattern and Geometry

Type of Active Pattern to Deploy

Outputs

Coverage Area of Active Patterns

Measure of Target Uncertainty Relative to Active Sensor Capabilities

Relevant Analyses

Real Time Calculation of Attainment of Active Sensor Detection Criteria

Optimization of Active Sensor Pattern

Relevant Displays

Attainment of Active Sensor Criteria; Criteria Used

Geometry of Suggested Active Sensor Pattern

Types, Settings of Sensors in Pattern

Cueing Sequences, Steering Commands, Fly-to-Points to Deploy Pattern

Table 2-7. Passive To Active Transition Characteristics Summary (Continued)

Required Human Judgments
Whether or not to attempt Active Prosecution.
Acceptance/Rejection of Suggested Active Pattern

Narrative: This decision aid will provide the TACCO with an indication of when the target has been localized to within active sensor detection ranges, compute and display the active sensor pattern, sensor locations, and sensor setting, provide fly-to-points and steering command for the pilot, and provide the TACCO with the capability to either accept or reject the recommended action.

Table 2-8. Attack Planning Characteristics Summary

Objective:	Determine optimal tactics for attack on a hostile submarine.
Task Dynamics:	Sequential Contingent
Underlying Process:	Attack on Hostile Submarine by ASW Aircraft
Value Criteria:	1. Probability of Weapon Acquiring Target. 2. Probability of Weapon Hitting Target.

Variables and Parameters

Inputs
Oceanographic Conditions
- PL
- Ambient Noise
- Temperature vs Depth

Weapons Remaining
Target Situation
- Location, Course, Depth
- Speed
- Area of Uncertainty

Outputs
Weapon Range Given Environmental Conditions

Parameters
Target Capabilities
- Depth, Speed, Maneuvering Limitations
- Historical Tracks

Target Characteristics
- Source Levels
- Frequencies

Weapon Capabilities
- Types, Settings, and Modes
- Speed, Runtime, Depth
- Search and Homing Frequencies

Aircraft Capabilities

Decision Variables
Plan of Attack
- Weapon, Setting
- Release-Point Time, Flight Path

Relevant Analyses
1. Prediction of Attack Results
2. Optimization of Attack Plan

Relevant Displays
Attack Geography
- o Target Location, Track, Uncertainty Area
- o Weapon Release Point, Aircraft Flight Path

Type and Setting Weapon for Attack
Fly-to-Points, Navigation Commands to Capture Weapon Release Points
Cueing Commands to Set, Arm, Deploy Weapon

Table 2-8. Attack Planning Characteristics Summary (Continued)

Required Human Judgment
Acceptance/Modification of Attack Plan

Narrative: The Attack Planning decision aid utilizes environmental, target location, and weapons characteristics/capabilities data to determine optimum weapon type and weapon placement during attack phase of the ASW mission.

TABLE 2-9. ASW Aircraft Software Entities

The P-3C UPDATE II, Fleet Issue I4.3 Operational Software System is composed of the following entities:

- Executive
- Initialization and Control
- Display
- Navigation
- Communications
- Nonacoustic Sensors
- Tactical Control
- Armament
- Ordnance
- Data Extraction
- Recovery
- Data Retrieval
- Apriori
- System Services
- SRS
- IRDS

The S-3A Operational Software System is composed of the following entities:

- Executive
- Initialization and Control
- In Flight Performance Monitor
- Preflight Data Insertion
- Display Control
- Keyset Control
- Navigation and SRS
- Steering
- Search, Localization, Track and Attack
- Ballistics
- Armament Control
- Sensor Control
- RADAR Control
- FLIR Control
- ESM
- MAD
- Acoustic Control (active)
- Acoustic Control (passive)
- Communications
- Data Extraction
- I/O Interface
- System Data & I/O Interface
- System Common Routines

The LAMPS MK-III operational software is identified as the "Avionics Operational Program (AOP)". The AOP consists the following functional entities:

- System Management and Control
  - System Recovery and Initialization
  - Tactical Processing
  - System Status Monitoring
  - Data Extraction
  - Input/Output Control
- Display
- Ordnance
- Sensor Subsystems
  - Radar
  - Electronic Support Measures (ESM)
  - Acoustics
  - Magnetic Anomaly Detector (MAD)
- Data Link
- Navigation

Table 2-10. Aircraft Type Vs Software System Module Affected

AIRCRAFT TYPE	SOFTWARE SYSTEM MODULE AFFECTED
P-3C UPDATE II	EXECUTIVE INITIALIZATION AND CONTROL DISPLAY NAVIGATION COMMUNICATIONS NON-ACOUSTIC SENSORS ACOUSTIC SENSORS TACTICAL CONTROL ORDNANCE A PRIORI SYSTEM SERVICES SRS IRDS ARMAMENT
S-3A	EXECUTIVE INITIALIZATION AND RECOVERY DISPLAY CONTROL KEYSET CONTROL NAVIGATION AND SRS STEERING SEARCH, LOCALIZE, TRACK, ATTACK BALLISTICS ARMAMENT CONTROL SENSOR CONTROL RADAR CONTROL FLIR CONTROL ESM MAD ACTIVE ACOUSTIC CONTROL PASSIVE ACOUSTIC CONTROL COMMUNICATIONS
LAMPS MK-III	SYSTEM MANAGEMENT AND CONTROL SENSOR SUBSYSTEMS DISPLAY ORDNANCE DATA LINK NAVIGATION

Comparing the software system modules specified in Table 2-10 with the total number of software system modules contained in each aircraft, it became apparent that the target management functions affects the majority of each platforms software system modules. In fact, the target management functions utilize 14 of 17 software system modules on the P-3C, 17 of 23 software system modules on the S-3A, and all 6 of the software system modules in the LAMPS MK-III.

2.3.2 Data Modules for Decision Aids

In order to maintain consistency with the aircraft software system design it is necessary to structure decision aid software into modules. These modules include the decision aid and the data modules to support the aid. The latter are shared with the rest of the system software. This design structure envisions the entire decision aid system as a set of special purpose software modules, under the control of a special executive, sharing subsets of mission data with each other and with the platform operating system. These modules become the set of decision aid subprograms which collectively form the preliminary decision aid software system. The executive module in conjunction with the remaining modules constitutes an *operating system* and an *applications subsystem*, respectively. These modules constitute the minimum set estimated to provide meaningful decision aid support to tactical mission improvement.

Because of the modularized structure of the decision aid software, it is possible to identify corresponding sets of data which will be required to perform each decision aid function. These sets of data are categorized functionally and called data modules. The logical subsets called data modules are typically no more than collections of those addresses within the operational software where data required by a decision aid algorithm can be found. When a particular decision aid routine is scheduled the aid executive or platform executive will retrieve the required set of data as defined by the data module. The establishment of data modules which contain the specific inputs needed for the decision aid algorithms was formulated based upon the following factors:

- Subject commonality
- Information update rate
- Number of aids using the information

All the inputs required for each of the candidate decision aids were developed and are specified in the tables of Subsection 2.2. The development of the data modules and their content was based upon the collective input data requirements of all the candidate decision aids. Table 2-11 depicts the data modules and the bases of data subdivision described below.

2.3.2.1 Subject Commonality. The initial sorting of decision aid inputs was by information subject matter. This sort resulted in the following categories of input: environmental related; target information; sonobuoy pattern information; aircraft information; and geographical information. The environmental related category of data modules contain oceanographic and atmospheric condition information as well as propagation loss profile information. The target information category of input data contains target capabilities and characteristics information. The sonobuoy pattern category of input data contains the potential sonobuoy patterns which can be used throughout the ASW mission. The aircraft category of input data contains ASW aircraft capabilities and characteristics, weapons/sensors capabilities, and characteristics and inventories. The geographical category of input data contains locational/positional data on the operating area, aircraft, target, and expended sonobuoys.

2.3.2.2 Information Update Rate. Another factor used to establish the data modules and their content was the update rate of the information. The information used as input to the candidate decision aids will either be static

Table 2-11. Data Module Development

MODULE CATEGORY	UPDATE RATE*	NUMBER OF AIDS USING MODULE
ENVIRONMENTAL		
OCEANOGRAPHIC CONDITIONS	S	8
ATMOSPHERIC CONDITIONS	D	4
PROPAGATION LOSS	S	8
TARGET		
TARGET CAPABILITIES	S	5
TARGET CHARACTERISTICS	S	3
SONOBUOY PATTERN GEOMETRY		
SEARCH PATTERN INVENTORY	S	1
CONTACT INVESTIGATION PATTERN INVENTORY	S	1
LOCALIZATION AND TRACKING PATTERN INVENTORY	S	2
PASSIVE TO ACTIVE TRANSITION INVENTORY	S	1
AIRCRAFT		
AIRCRAFT DYNAMICS	S	5
ASW WEAPON CAPABILITY	S	1
ACOUSTIC SENSOR CAPABILITY**	S	4
WEAPON INVENTORY	D	1
SENSOR INVENTORY	D	4
GEOGRAPHIC		
OPERATING AREA	S	1
AIRCRAFT LOCATION	D	5
TARGET LOCATION	D	6
SONOBUOY LOCATION	D	2

NOTES: * S MEANS STATIC; D MEANS DYNAMIC
** INCLUDES PROCESSOR CAPABILITIES

or dynamic. Static inputs can be described as those items which once obtained remain the same throughout the mission. Examples of static inputs would include propagation loss profile, sensor (sonobuoy) capability or weapon capabilities. Dynamic inputs are those information elements which are updated based upon intelligence or events throughout the mission. Examples of dynamic inputs are sonobuoy inventory, target location, and atmospheric conditions.

Whenever possible it was determined to group data input items into data modules based upon their update rate. Those data input items which remain static throughout the mission are intended to be loaded into the aircraft computer via the preflight data insertion program (PDIP) tape. The PDIP tape and/or operator input would be used to obtain the initial values of the dynamic data input items. These values can then be updated (automatically or manually) in flight. By grouping data input items into static or dynamic data modules, the number of data modules which must be updated inflight is reduced.

2.3.2.3 <u>Number of Aids Using Information</u>. The final qualifier for establishment of data modules was the frequency of occurrence of the data input items. Target, aircraft, sonobuoy pattern and geographical related information subject categories were separated into specific data modules based upon the number of aids which access the data as input. The sonobuoy patterns category contains all patterns which can be used. However, when the aircrew is in the search mission phase, it does not need information relating to investigation, localization or active sonobuoy patterns and vice versa. Therefore, specific data modules were established for each mission phase.

The target related category was subdivided into characteristics and capabilities because the capabilities data items are used as input more frequently than the target characteristics data items. By subdividing this information into separate data modules, the size of the individual decision aids is reduced, since the total size of each decision aid is equal to the size of the data module and the algorithm.

2.3.3 Implementation

This study was directed to look at the following three methods for integrating decision aid software into airborne ASW platforms.

- Modifying the existing operational software
- Tape or disc overlay
- Dedicated processor

The first method (operational software modification) involves using the present equipment capabilities by either adding additional decision aid subprograms to the operational programs; or by integrating the decision aid subprograms into their logical counterparts within the operational programs. Either way involves a presumption of additional storage in memory, additional CPU time and the rewriting of the operational program interface. In the additional subprogram variation, the decision aid software would exist as an autonomous module of the platform operational software. The aid executive would interface with the operational executive to schedule the routine or routines necessary to perform the decision aid and to retrieve the proper set or sets of data from the platform data inventory. In the integration variation, the aid routines would be imbedded into their logical, functional counterparts within the platform operational program. The platform executive would handle the scheduling and data retrieval. The aid executive would exist in this variation only in the form of an interrupt within the platform executive. Figures 2-1 and 2-2 illustrate the software modification method.

The second method (overlay) involves designing the decision aid system as a program, consisting of the modules referred to in Subsection 2.3.2 placing the program on tape or disc, and reserving space in main memory for reading in

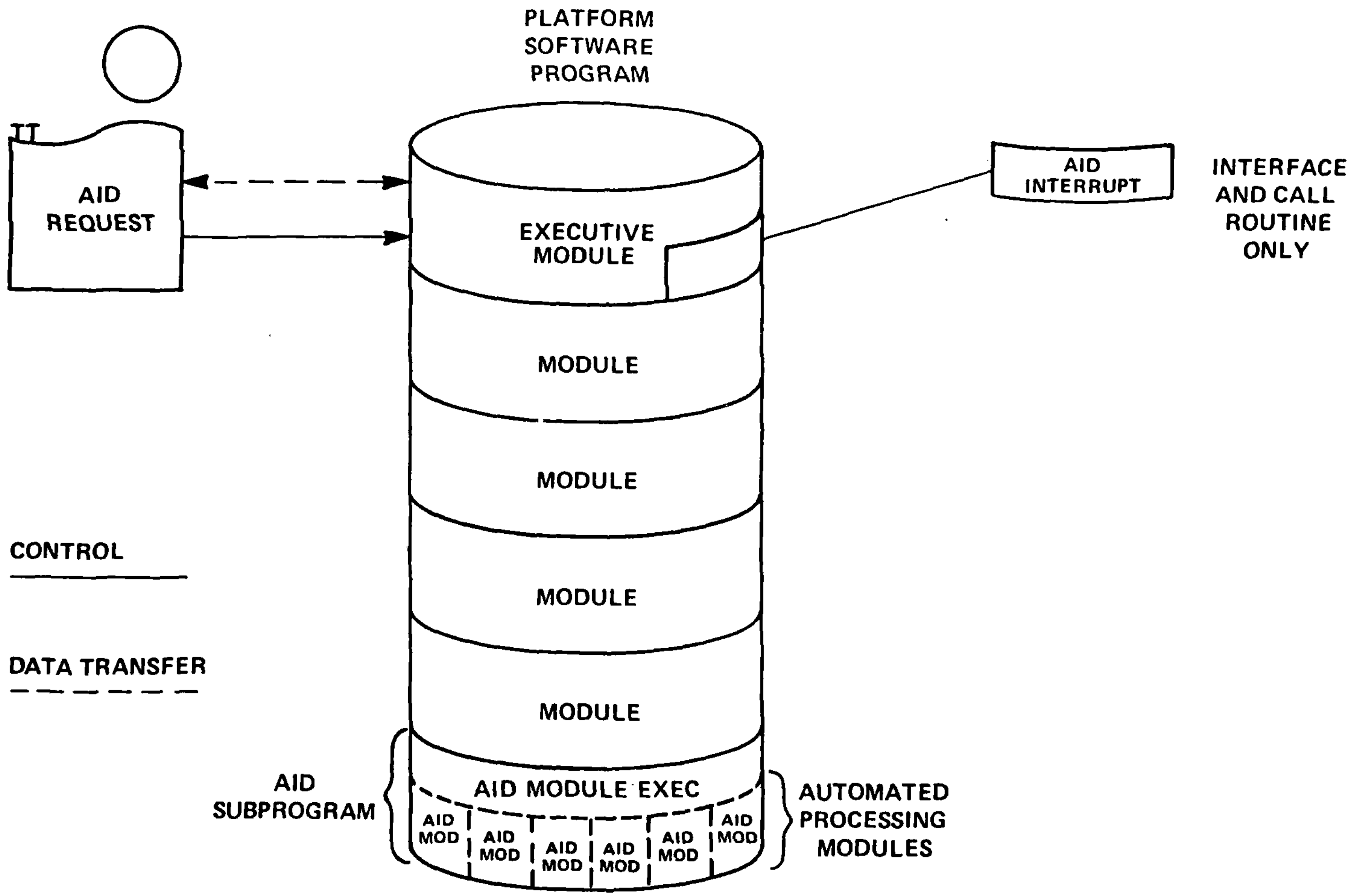

Figure 2-1. Existing Software Modification (Additional Subprogram Module)

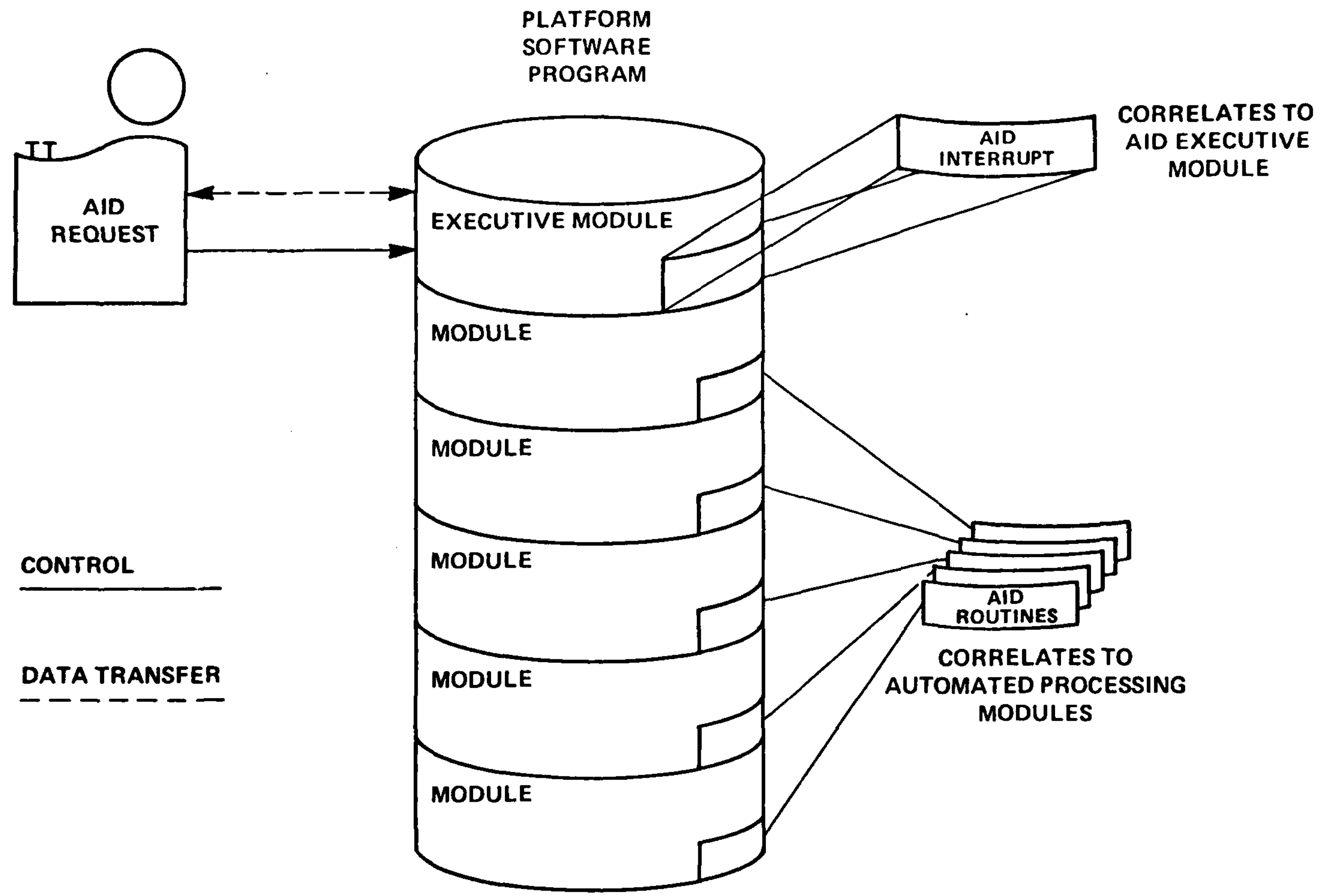

Figure 2-2. Existing Software Modification (Integration Method)

subsets of the decison aid modules*. The platform executive would activate the transfer of the proper subset of decision aid modules (including the aid executive) into the reserved overlay space in core memory. The decision aid subset, then residing in core, would function as one of the platform subprogram modules, interfacing with the platform executive to perform the decision aid. This method would require only the interface modification to existing operational programs, and adequate core memory space for the largest subset of aid modules. It would, like method one, create additional burden for the already beleaguered CPU of the P-3C. Figure 2-3 shows the overlay method.

The third method (dedicated processor) also involves designing the decision aid program as in method two, but places it in a dedicated processor. It then effectively becomes a subsystem. The aid executive would interface with both the platform executive and the peripheral equipment to request the decision aid schedule the proper decision aid modules, retrieve the required data sets, and produce the desired output. This concept would involve a flow of inputs for each of the decision aids from the aircraft central computer to the dedicated decision aid process for calculation and computation when required. All calculation would be performed in the dedicated processor with only the recommendations being transferred to the aircraft central computer for distribution to the appropriate sensor station. Figure 2-4 depicts the dedicated processor method.

In order to provide meaningful capability, a major rewrite of the existing software would probably be necessary if the first method (operational software modification) were adopted. In contrast, the last method (dedicated processor) would cause the least structural impact upon present operational software.

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*Note that the data modules may be pointers to data within the host system.

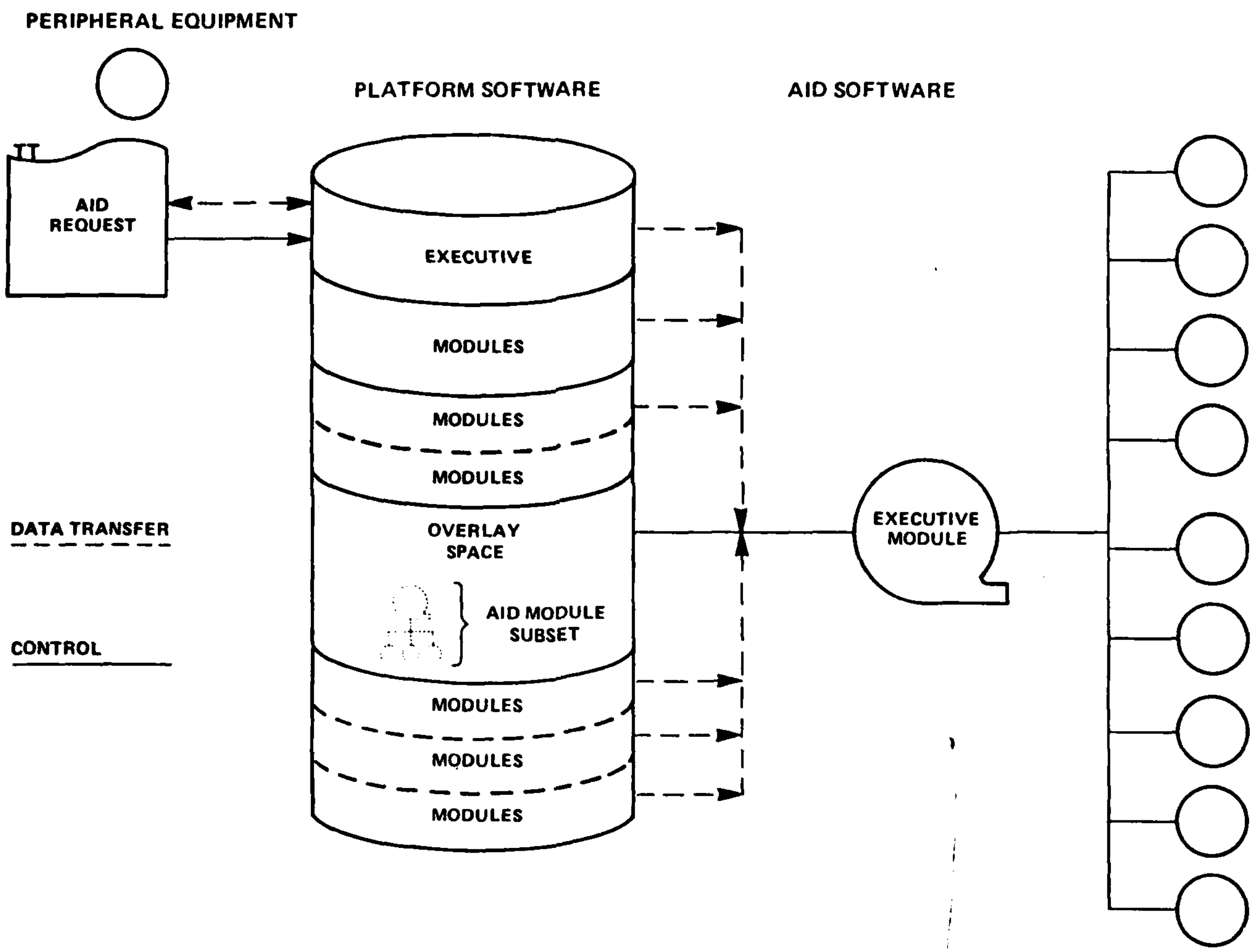

Figure 2-3. Decision Aid Software Package Implementation on a Tape or Disc Overlay

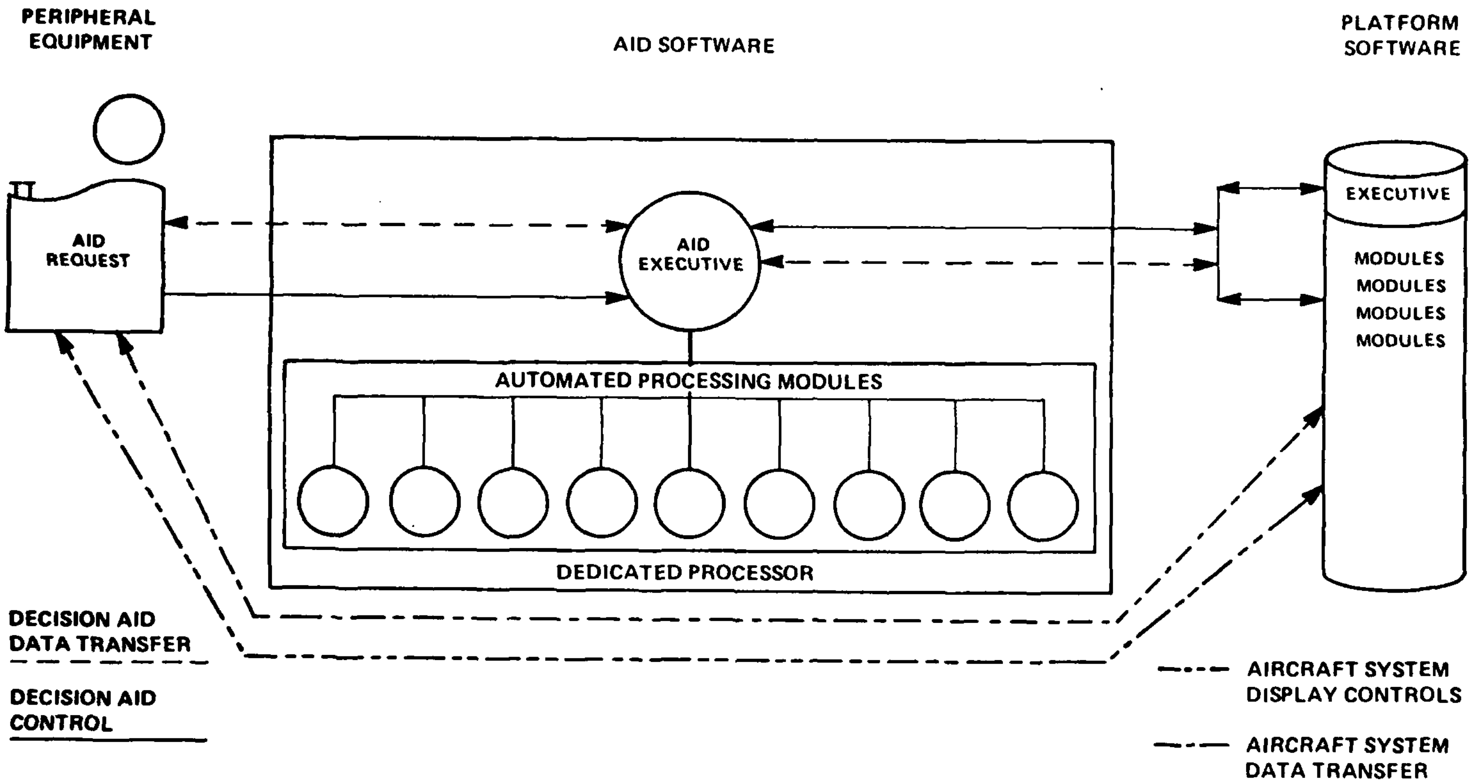

Figure 2-4. Decision Aid Software Package Interface with Use of a Dedicated Processor

The trade-offs are obvious: CPU time and memory space vs equipment space and weight. It is possible to view the overlay and dedicated processor methods as compatible in the sense that the decision aid software design would be identical in both cases; with the decision aid being executed by the operational program in the former case and executing within its own subsystem in the latter.

2.4 DECISION AID DESCRIPTIONS

This section briefly describes eight decision aids and associates them with data modules and display requirements. The aids and the data modules are sized in subsequent sections.

2.4.1 Search Pattern Planning Decision Aid

The search pattern planning decision aid utilizes on station bathothermic data and selected historical environmental data to provide the TACCO recommended sonobuoy patterns, spacing, and pattern orientation. Information to be displayed to the TACCO and pilot as output includes sonobuoy locations, sonobuoy settings, fly-to-points, steering commands, and cueing sequences to select and release the sonobuoys at the appropriate locations.

Data Modules which are utilized by the search pattern planning decision aid include:

- Environmental (Atmospheric, Oceanographic, Propagation Loss)
- Target Location
- Sensor Inventory
- Search Pattern Inventory
- Operating Area
- Aircraft Location
- Aircraft Dynamics

- Target Characteristics
- Target Capabilities

The manner in which these data modules interact to provide the recommended search patterns is depicted in Figure 2-5. The environmental information is compared with the actual BT to determine which stored propagation loss profile most closely approximates the actual conditions. The target characteristics data module contains frequency and source level information which is used to determine the actual target detection ranges. The target location and operating area data modules define the search area boundaries and restrictions. The sensor inventory data module provides input regarding the number, type, and settings of sonobuoy available. The search pattern inventory data module is compared with the detection ranges and search area to determine optimum search patterns. This decision aid can also be expanded to include aircraft location and aircraft dynamics data modules in order to provide time to deploy the pattern information to TACCO.

Table 2-12. Search Pattern Planning Display Requirements

Display Requirements	Type Display	Primary User	Display*
Sonobuoy Locations	Symbology	TACCO	ASA 70
Sonobuoy Type	Alpha-Numeric	TACCO	ASA 70
Sonobuoy Setting	Alpha-Numeric	TACCO	ASA 70
Fly-to-Points	Symbology	TACCO/Pilot	ASA 70/ASA 66
Steering Commands	Indicator	Pilot	HSI
Area Coverage	Conics	TACCO	ASA 70

*The equipment names used for illustration are those used in the P-3C.

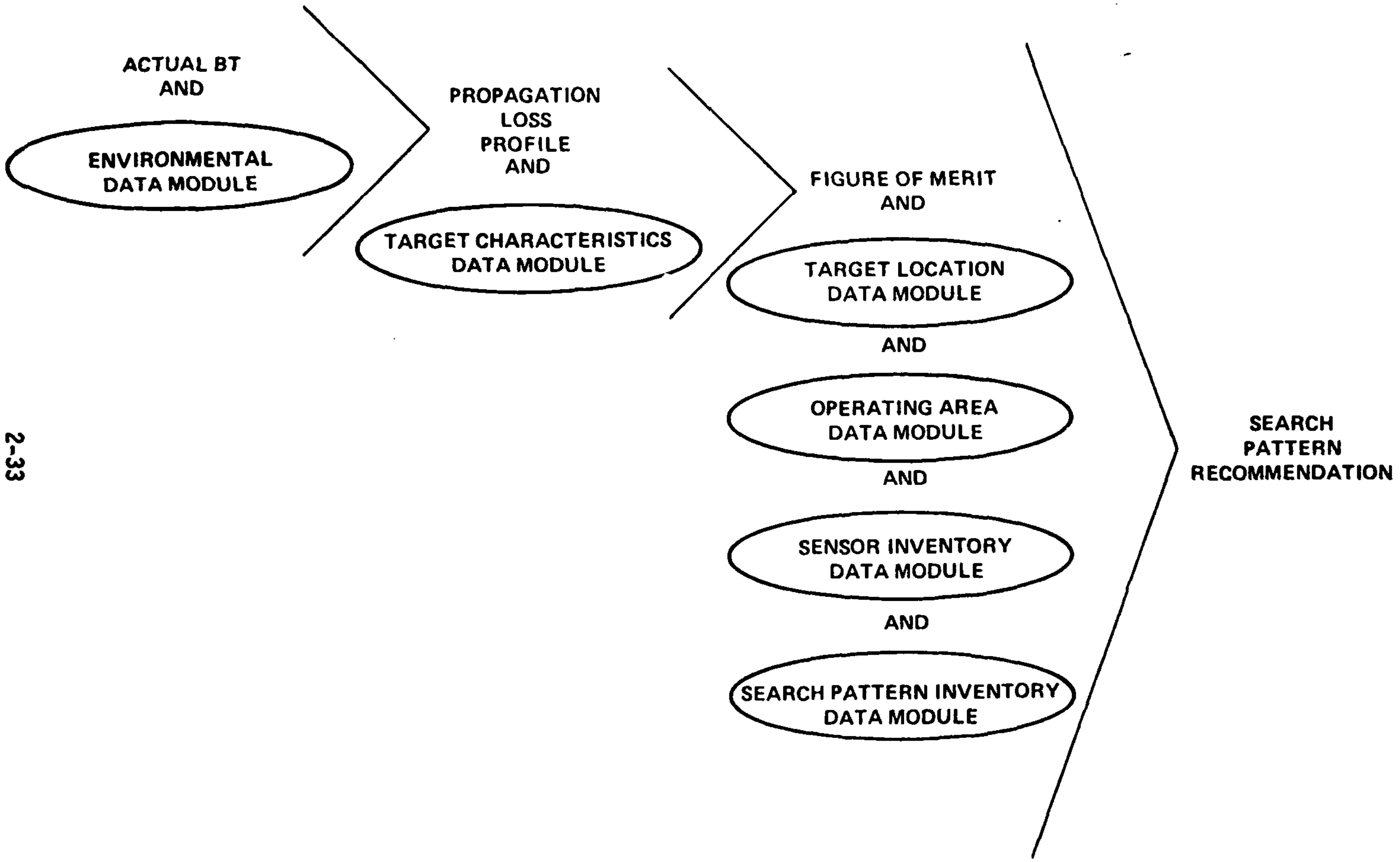

Figure 2-5. Search Pattern Planning Data Module Relationship

2.4.2 Processor Mode Selection Decision Aid

The Processor Mode Selection decision aid utilizes environmental information, acoustic processor capabilities information, and target information to provide recommendations for operating the acoustic processor. The acoustic sensor operator initiates the mode select decision aid which provides the operator alpha-numeric display of recommended acoustic processor mode selections. Recommendations are based upon the environment and the acoustic characteristics of the particular submarine type being tracked. The BT sonobuoy result is first verified and then compared with several BT profiles provided by FNWC during the mission briefing. The stored BT profile which most closely approximates the actual BT is used for all subsequent figure-of-merit and detection range calculations.

The environmental and target capabilities data modules are used to calculate the lateral range (LATRAN) curves for the specific area and target combination. Target information required for the development of the LATRAN curves includes frequency and source level data. Environmental information includes the specific propagation loss profiles for the target frequencies of interest and the ambient noise data of those specified frequencies.

The target figure of merit (FOM) is developed from data pertaining to the acoustic signal processor. The data required consists of the recognition differential (RD) value for each of the modes in which the processor can be operated. From the RD values, line probability of detection (direct path and convergence zone) can be generated for each of the frequencies of interest and each of the acoustic processor modes available. The acoustic processor mode recommendation is based on that mode selection which results in the greatest target probability of detection.

Data Modules which would be utilized by the mode selection decision aid include:

- Environmental (Oceanographic and Propagation Loss)
- Target Characteristics
- Acoustic Sensor Capabilit

The manner in which these data modules interact is illustrated in Figure 2-6. Data from three data modules are used to determine the propagation loss profiles, and the anticipated detection ranges. The detection ranges will vary depending upon the processor mode option. This variation is a function of the gain or loss of recognition differential in the different modes. The propagation loss profiles are generated for each of the anticipated detection frequencies which eminate from the target. This information on target source levels by frequency would be resident in the target characteristics data module. The acoustic sensor data module contains the information on the various mode selection options associated with the acoustic processor.

Table 2-13. Processor Mode Selection Display Requirements

Display Requirements	Type Display	Primary User	Display
Processor Mode	Alpha-Numeric	Acoustic Sensor Update	ASA-66

2.4.3 Contact Investigation Pattern Selection Decision Aid

The Contact Investigation Pattern Selection aid utilizes in-situ BT data to aid in selection of a pattern to transition from initial contact in a sonobuoy search pattern to direct detection (non-convergence zone) on one or more sonobuoys. The aid recommends sonobuoy patterns, settings and spacing for the TACCO's use by presenting this information alpha-numerically and symbolically on his display. Upon acceptance of the pattern by the TACCO, fly-to-points and steering commands become output for the pilot.

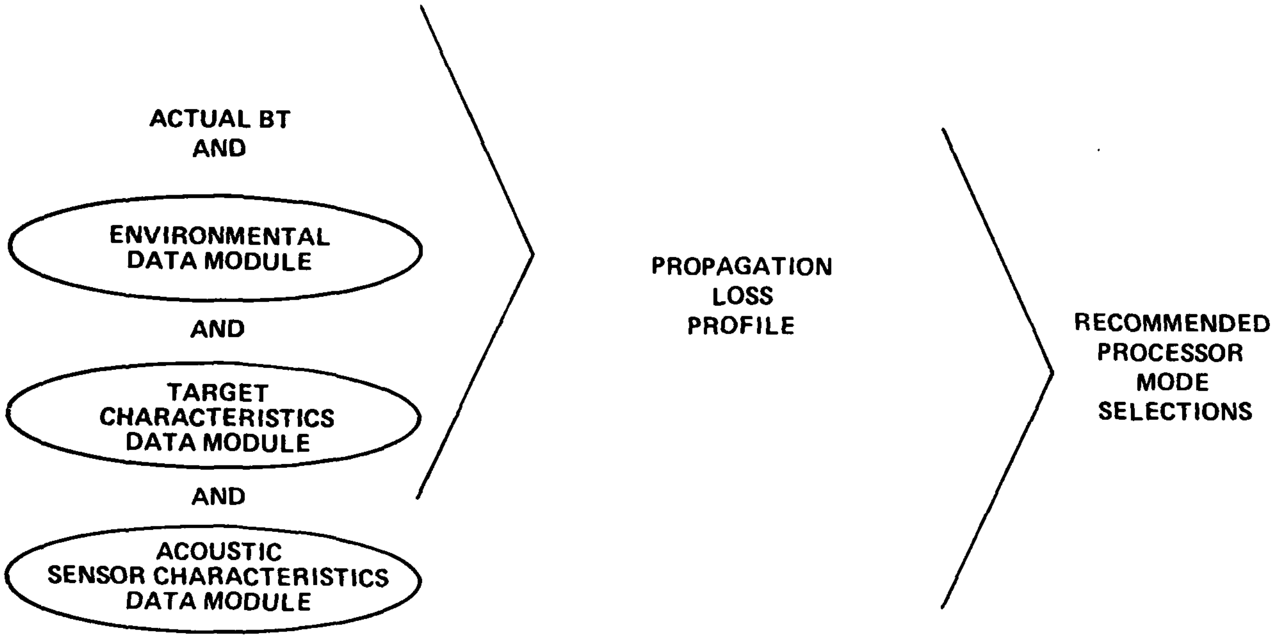

Figure 2-6. Processor Mode Selection Data Module Relationship

Data modules which are utilized by the contact investigation pattern selection decision aid include:

- Environmental (Oceanographic, Atmospheric, Propagation Loss)
- Target Location
- Target Characteristics
- Sensor Inventory
- Aircraft Location
- Aircraft Dynamics
- Investigation Pattern Geometry

The manner in which these data modules interact to provide the recommended investigation patterns is depicted in Figure 2-7. Stored BT's are compared with the in-situ BT to determine which stored propagation loss profile most closely approximates the actual conditions. The target characteristics data module contains frequency and source level information which is used to determine the actual target detection range.

The target location information from the target location data module is updated from the initial briefing information once the acoustic operator informs the central computer and TACCO that contact has been gained. The target location is then expressed in terms of its relationship and uncertainty area about the contact sonobuoy(s). For example, target location may be expressed in terms of direct path (DP) and convergence zone (CZ) annulus about the sonobuoy if only omni-directional data is available, or it may be expressed in terms of limiting arcs within the DP and CZ annulus if directional data is available. Target location based upon single sonobuoy contact while in the search mission phase requires the propagation loss profile as an input. Once the target location has been updated, the sensor inventory is checked to determine the availability of the various types and settings of sonobuoys. The specific

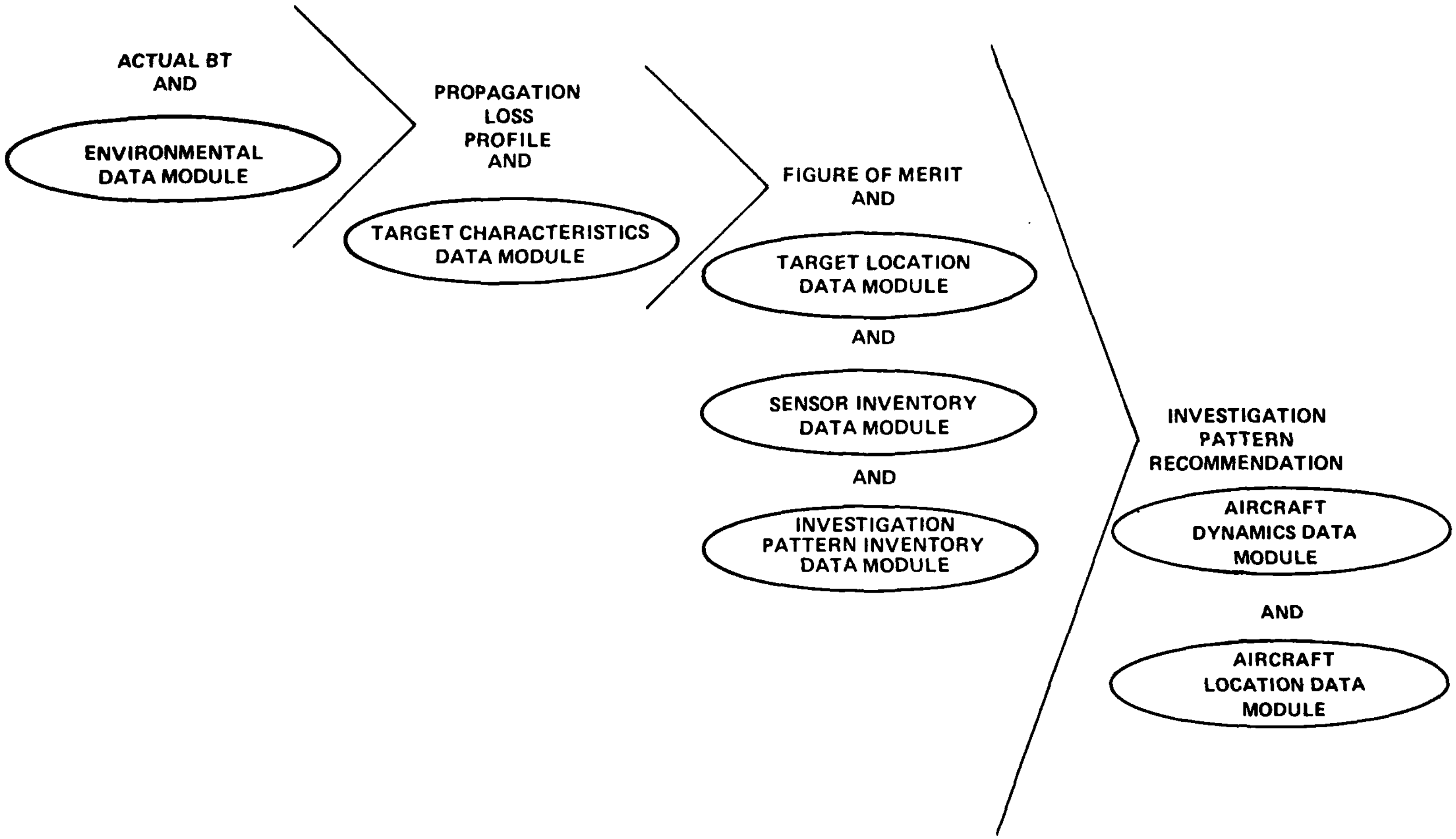

Figure 2-7. Contact Investigation Pattern Selection Data Module Relationship

hydrophone settings of the sonobuoys to be used depend on the environmental information (layer depth) and the target location (target depth). The investigation pattern inventory is used to determine number, type, and location of sonobuoys. The information pertaining to sonobuoy location requires the propagation loss profile results, since pattern orientation and sonobuoy spacing are expressed in terms of oceanographic conditions. If there are insufficient sonobuoys of the desired type and/or setting, the TACCO will be informed and requested to modify his plan accordingly. The aircraft location and aircraft dynamics data modules are used to provide the pilot steering commands, which will allow him to position the aircraft at the desired fly-to-point locations to release sonobuoys. Table 2-14 summarizes the display requirements for this aid.

Table 2-14 Contact Investigation Pattern Selection Display Requirements

Display Requirements	Type Display	Primary User	Display
Sonobuoy Location	Symbology	TACCO	ASA-70
Sonobuoy Type	Alpha-numeric	TACCO	ASA-70
Sonobuoy Setting	Alpha-numeric	TACCO	ASA-70
Fly-to-Points	Symbology	Pilot/TACCO	ASA-66/ASA-70
Steering Commands	Indicator	Pilot	HSI
Contact Sonobuoy	Symbology	TACCO	ASA-70

2.4.4 Signal Correlation Decision Aid

The Signal Correlation decision aid utilizes environmental conditions for determination of actual detection ranges in order to determine if multiple sonobuoy contact is originated from single or multiple targets. This decision aid receives indications of the incoming signals on multiple sonobuoys and compares the sonobuoy locations with the environmental detection ranges to determine the probability that different signals received from multiple sonobuoys eminate from a single target. The signal correlation decision aid provides the TACCO and acoustic sensor operator with cues which verify or reject the possibility of having multiple sonobuoy contact from a single target.

Data modules which would be utilized by the signal correlation decision aid are:

- Environmental (Oceanographic, Propagation Loss)
- Target Location
- Target Characteristics
- Sonobuoy Location
- Acoustic Sensor Capability

The manner in which these data modules interact to provide the signal correlation aid's recommendations is depicted in Figure 2-8. The environmental information is compared with the actual BT to determine which stored propagation loss profile most closely approximates the actual conditions. The propagation loss profiles is used in conjunction with the target characteristics acoustic sensor capabilities module to predict detection ranges and convergence zone activity. The target characteristics module contains frequency and source level information. The acoustic sensor capabilities module provides processing gain and recognition differential data for the buoys and processor modes in use. Thus a figure of merit can be computed for the suspected submarine(s) and by comparison to the PL profile detection ranges predicted. Thus when contact is obtained on more than one buoy a series of possible locations can be estimated based upon the sonobuoy location (from that module) and the detection ranges (direct or CZ). The target location module is used so that recent track data on the target can be used as a weighting factor to eliminate some of the possible submarine locations which result from the intersection of sonobuoy detection ranges and annulii. The TACCO will be presented conic or elliptical displays denoting the target's probability areas. In the event of single sonobuoy contact, a circle with radius equal to direct path detection range and an annulus at detection range are generated about the contact sonobuoy. When multiple sonobuoy contact is obtained either conics or ellipses are generated about the intersection of the

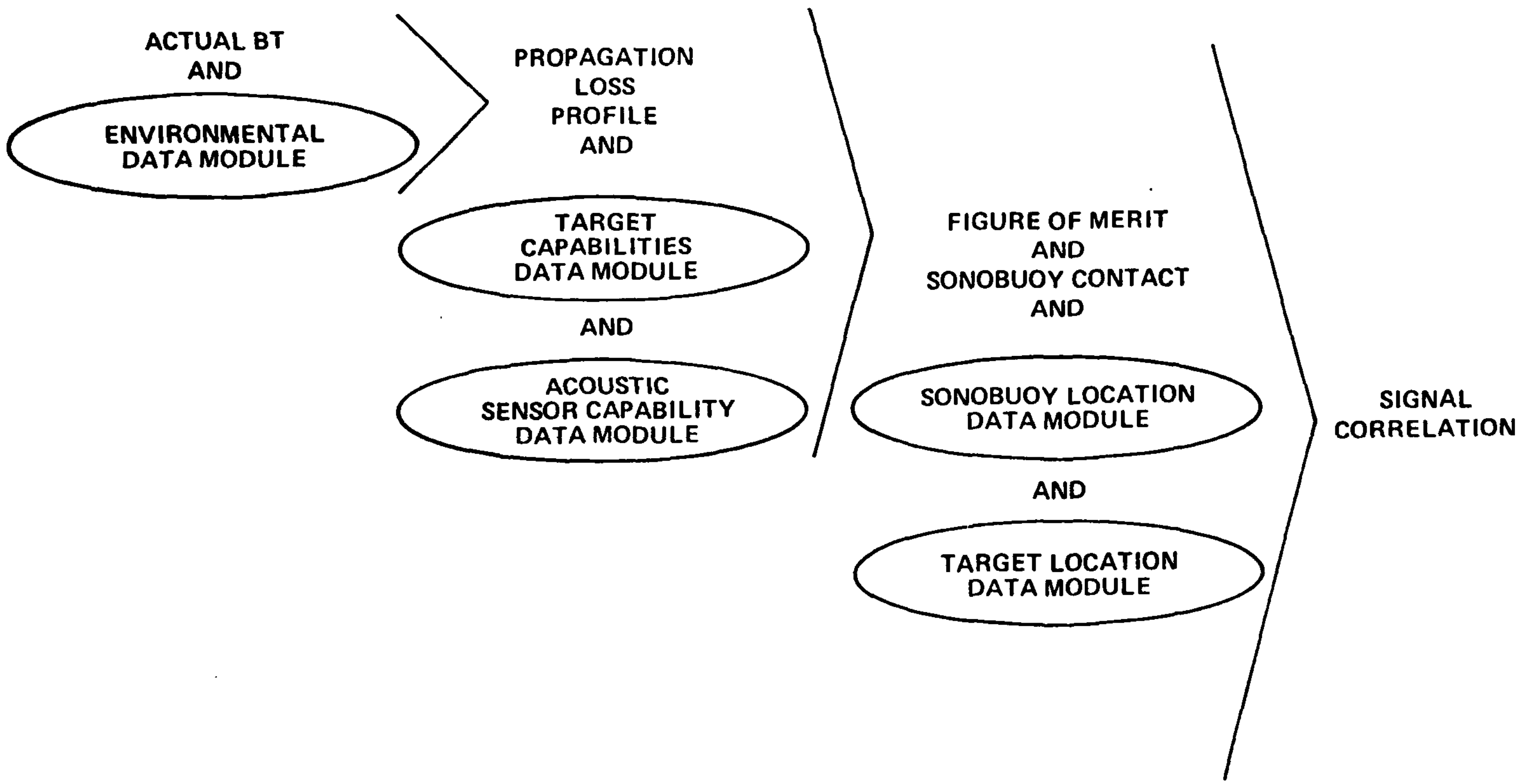

Figure 2-8. Signal Correlation Data Module Relationship

contact sonobuoy detection area. Table 2-15 summarizes the display requirements for this area.

Table 2-15. Signal Correlation Display Requirements

Display Requirements	Type Display	Primary User	Display
Target Probability Area	Conics	TACCO	ASA-70
Target Type	Alpha-numeric	TACCO/Acoustic Sensor Operator	ASA-70
Target Signals	Alpha-numeric	Acoustic Sensor Operator	ASA-66

2.4.5 Threat Assessment and Classification Decision Aid

The Threat Assessment and Classification decision aid is intended to assist the TACCO and acoustic sensor operator in determinng target type, target capabilities, and on some occasions the approximate target location. Target type and target capabilities are displayed to the TACCO and the acoustic sensor operator.

Data modules which would be utilized by the threat assessment and classification decision aid include:

- Environmental (Oceanographic, Propagation Loss)
- Target Characteristics
- Target Capabilities
- Acoustic Sensor Capability

The manner in which these data modules interact to provide the threat assessment and classification output is depicted in Figure 2-9. The stored propagation loss profile which most closely approximates the actual condition is chosen. The target characteristics data module which contains frequency and source level information on the target of interest, is used to determine

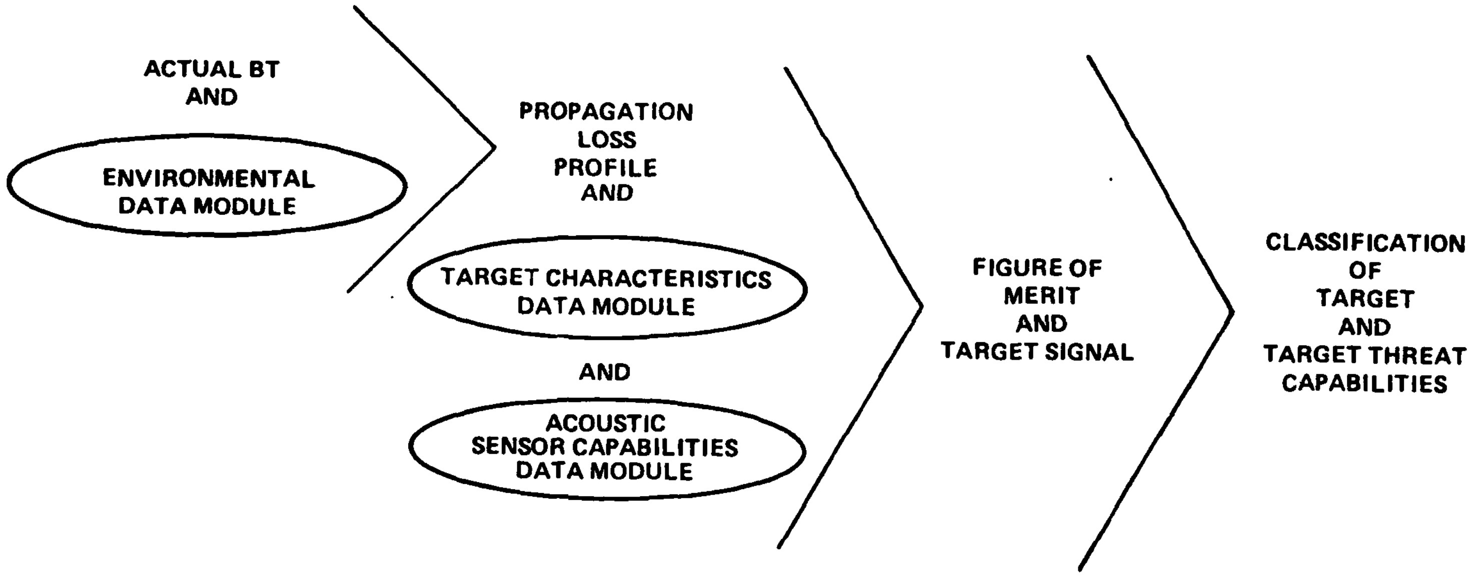

Figure 2-9. Threat Assessment and Classification Data Module Relationship

information on the target of interest, and determine anticipated detection ranges as a function of the signal frequency. The acoustic sensor capabilities module provides input to the determination of the figure of merit and target characteristics data module to determine the target type. After the target type has been determined, the TACCO and acoustic sensor operator will be informed of additional details of the target which may be useful tactically to the current mission. These same data modules can provide the TACCO with warning of an increased threat based upon particular actions which have occurred and been detected. (e.g., the opening of torpedo doors.) Table 2-16 shows aid display requirements.

Table 2-16. Threat Assessment and Classification Aid Display Requirements

Display Requirements	Type Display	Primary User	Display
Target Type	Alpha-numeric	TACCO/Acoustic Sensor Operator	ASA-70 ARO/ASA-66
Target Capabilities	Alpha-numeric	TACCO/Acoustic Sensor Operator	ASA-70 ARO/ASA-66
Target Location	Conics	TACCO	ASA-70

2.4.6 Localization And Pattern Selection Tracking Decision Aid

The Localization and Tracking Pattern Selection decision aid utilizes in-situ gathered environmental data to recommend localization and tracking sonobuoys patterns, spacings, settings, and pattern orientation to the TACCO. Sonobuoy locations, sonobuoy settings, sonobuoy types, fly-to-points, steering commands, and cueing sequences to select and release sonobuoys are displayed to the TACCO and the pilot.

Data Modules which would be utilized by the localization and tracking decision aid include:

- Environmental (Oceanographic, Atmospheric, Propagation Loss)
- Target Location

* Sensor Inventory
* Localization and Tracking Pattern Inventory
* Operating Area
* Aircraft Location
* Aircraft Dynamics
* Acoustic Sensor Capability

The manner in which these modules interact is depicted in Figure 2-10. This aid operates similarly to the contact investigation pattern selection aid but uses the localization and tracking pattern inventory. Table 2-17 lists the display requirements for this area.

Table 2-17. Localization and Tracking Pattern Display Requirements

Display Requirements	Type Display	Primary/User	Display
Sonobuoy Location	Symbology	TACCO	ASA-70
Sonobuoy Type	Alpha-numeric	TACCO	ASA-70
Sonobuoy Setting	Alpha-numeric	TACCO	ASA-70
Fly-to-Points	Symbology	TACCO/Pilot	ASA-70/ASA-66
Steering Commands	Indicator	Pilot	HSI
Area Coverage	Conics	TACCO	ASA-70

2.4.7 Passive To Active Transition Decision Aid

The Passive to Active Transition decision aid is intended to notify the TACCO when the target has been localized to within active sensor acquisition ranges. It provides the TACCO with the recommended sonobuoy pattern, location,

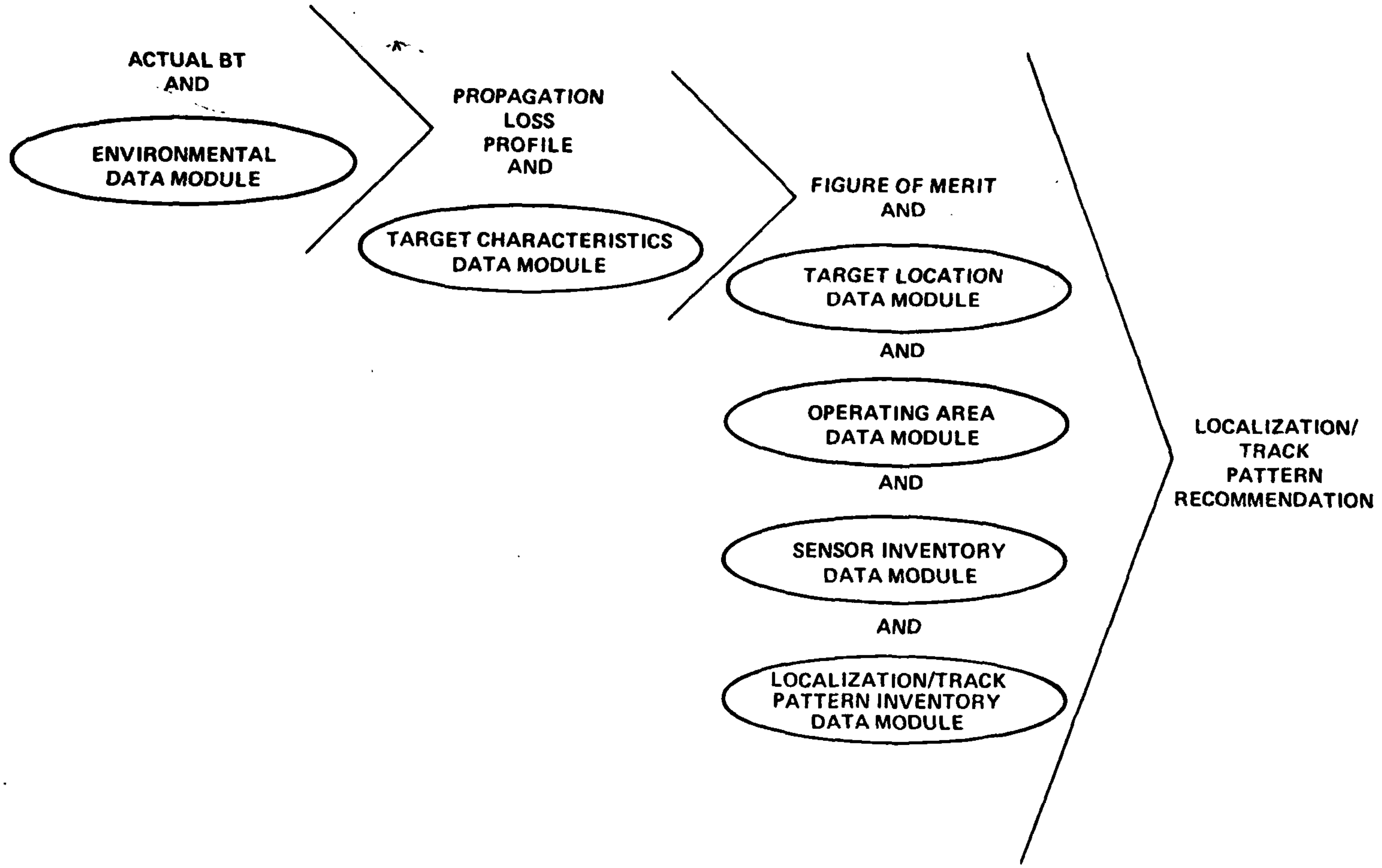

Figure 2-10. Localization and Tracking Data Module Relationship

spacing, and settings for active localization. The environmental information is used to assist in determination of target location and sonobuoy pattern recommendations.

The passive to active transition decision aid can be initiated by the TACCO to monitor the target position and uncertainty area anytime during the missions localization phase. When the target uncertainty area has been reduced to within an active sonobuoy pattern detection range, the decision aid notifies the TACCO, and displays a recommended active sonobuoy pattern. This decision aid is intended to provide a smooth transition from passive to active tactics, thus minimizing the probability of losing the target.

Data Modules which are utilized by the passive to active decision aid include:

- Environmental (Oceanographic, Atmospheric, Propagation Loss)
- Target Location
- Sensor Inventory
- Passive To Active Pattern Inventory
- Localization and Tracking Pattern Inventory
- Aircraft Location
- Aircraft Dynamics
- Sonobuoy Location

The manner in which these data modules interact to provide the passive to active recommendations is depicted in Figure 2-11. The environmental information is compared with the actual BT to determine which stored propagation loss profile most closely approximates the actual conditions. The target characteristics data module contains frequency and source level information which is used to determine the actual target detection ranges. The sensor inventory data module provides input regarding the number, type and settings of sonobuoys available.

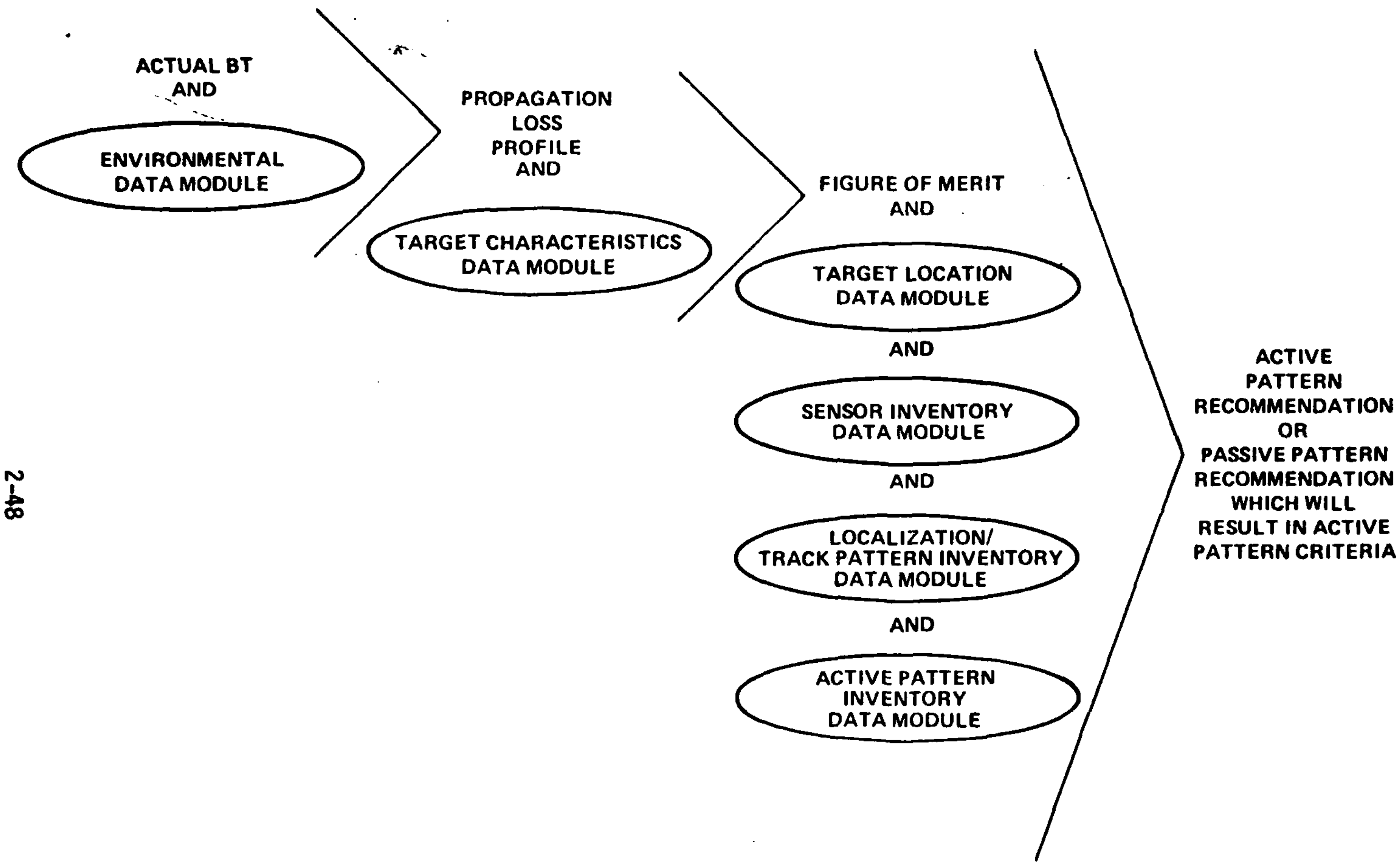

Figure 2-11. Passive to Active Transition Data Module Relationship

The localization and track and active inventory data modules are compared with the detection ranges and to determine pattern coverages. This decision aid can also be expanded to include aircraft location and aircraft dynamics data modules in order to provide information to the TACCO to deploy the pattern. Table 2-18 shows the display requirements for this aid.

Table 2-18. Passive to Active Transition Display Requirements

Display Requirements	Type Display	Primary User	Display
Sonobuoy Location	Symbology	TACCO	ASA-70
Sonobuoy Type	Alpha-numeric	TACCO	ASA-70
Sonobuoy Setting	Alpha-numeric	TACCO	ASA-70
Fly-to-Points	Symbology	TACCO/Pilot	ASA-70/ASA-66
Steering Commands	Indicator	Pilot	HSI
Area Coverage	Conics	TACCO	ASA-70

2.4.8 Attack Planning Decision Aid

The Attack Planning decision aid utilizes environmental data which most closely approximates the actual oceanographic conditions to provide recommendations on the weapon type and setting for an attack, as well as calculating weapon release point and water entry point. This aid is primarily intended for use by the TACCO, but the pilot would also receive some of the aids output. Information to be displayed to the TACCO includes weapon type, weapon setting, weapon location on board the aircraft, weapon release location, and cueing sequences to select, set and arm the appropriate weapon. Information to be displayed to the pilot includes fly-to-point and steering commands needed to position the aircraft at the weapon release point on the optimum heading. Additionally, the pilot will be provided with cues to assist the TACCO in selecting, arming, and releasing the weapon. This decision aid like the others, will provide the TACCO with the ability to override the recommended actions.

Data modules which would be utilized by the attack planning decision aid include:

- Environmental (Oceanographic, Atmospheric, Propagation Loss)
- Target Location
- Target Capabilities
- Weapon Inventory
- Weapon Capabilities
- Aircraft Location
- Aircraft Dynamics

The manner in which these data modules interact and provide the recommended attack placement is depicted in Figure 2-12. Data from the environmental, weapon inventory, and weapon capabilities data modules are all utilized to determine the probable weapon acquisition range. Information from the target location and target capabilities modules are used to compute the position and uncertainty area and the weapons acquisition range are used to determine when the attack criteria are obtained. The aircraft location and aircraft dynamics data modules are used to determine the flight path of the aircraft needed to position it at the weapon release points. Table 2-19 shows the display requirements for this aid.

Table 2-19. Attack Planning Display Requirements

Display Requirements	Type Display	Primary User	Display
Weapon Release Point	Symbology	TACCO/Pilot	ASA-70/ASA-66
Weapon Type	Alpha-numeric	TACCO	ASA-70
Weapon Setting	Alpha-numeric	TACCO	ASA-70
Fly-to-Point	Symbology	TACCO/Pilot	ASA-70/ASA-66
Steering Command	Indicator	Pilot	HSI

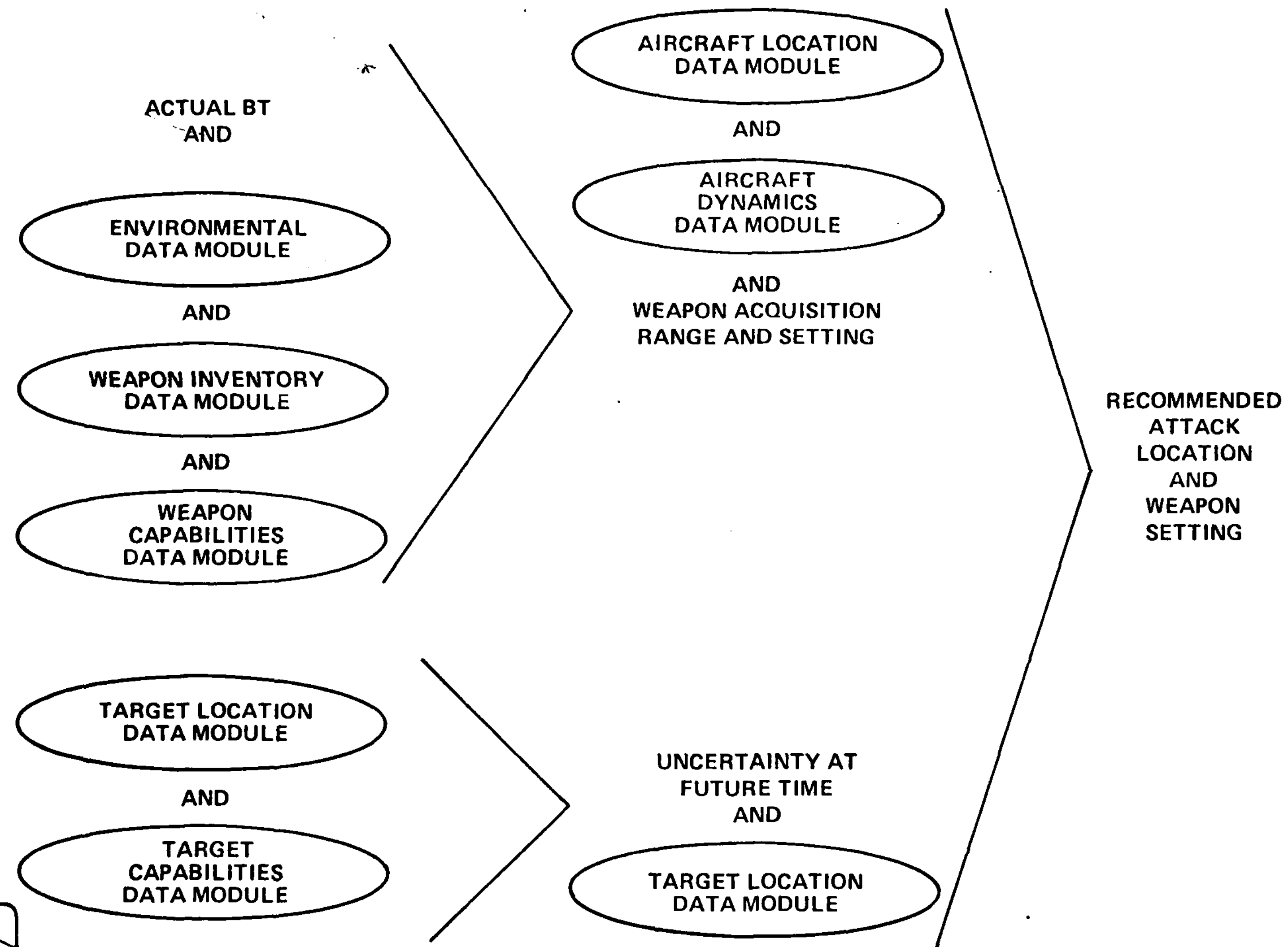

Figure 2-12. Attack Planning Data Module Relationship

3. IMPLEMENTATION ANALYSIS

This section estimates the size of the data modules and algorithms for each decision aid and the decision aids as a package. The feasibility of implementing the decision-aid package is based upon the sizing analysis and a loading analysis of the CPU's associated with the host platform. The loading analysis takes the form of observing the processing delays incurred by the processor in performing present functions as well as that which would be associated with the decision aids. The three methods of decision aid implementation integrated, tape overlay, and associated processor are then assessed for each platform.

3.1 SIZING METHODOLOGY

Calculating the size of each of the decision aid data modules required establishing a number of definitions and ground-rules. First among these was the definition of size. A data module's size was operationally defined as the number of words of memory into which the most concise representation of the variables/information in the data module could be fit. While it appears intuitively obvious, this definition actually embodies several assumptions, and differs from previous approaches. Garon (1977) for example, working with grosser-level structures he termed data files, defined size in terms of Kilobytes or 'K' of memory, and did not worry about the compactness of the data representation. Our definition of size also assumes that computers involved are word-addressable but not byte-addressable, that is, that the word is the smallest directly accessible unit of memory. This assumption is valid for the CP-901 computer currently used on the P-3C and the AN/AYK-10 computer currently used on the S-3A.

The above definition also assumes that the data in the module will be organized so that it occupies as little space as possible. This, in turn, assumes that the modules will be highly structured and employ *positional* information (such as locations in a matrix) rather than *structural* information (such as pointers) to locate individual data items. Implicit in this assumption that the decision and algorithms will be designed to the specifications of the data module's structure (not *vice versa*) and will therefore not employ sophisticated but wasteful-of-space data structures such as 'trees' or 'lists'.

In determining the size of the data module, only the module itself was considered. The amount of space used by the algorithms necessary to move the modules from disc/drum to core and back again was ignored in the calculations, because we assumed that this software already existed as part of the operating systems of the various platforms' computers. Thus, its use to move the decision aid data modules would not affect the space requirements of the APP decision aid concepts considered. In a similar vein, it was assumed that peripheral-to-core and core-to-peripheral data transfers would be transparent in terms of intermediate storage space. Transfer buffers, operating system pointer, etc. were not considered for the same reason as given above -- they already exist in the respective systems under examination and their use by the decision aids would not affect the memory already allocated to them.

Prior to the sizing procedure, each data module was analyzed to determine whether the information contained in the module could be represented more efficiently as a algorithm or function than as a collection of static data points. Data modules for integrated networks of decision aids can sometimes be represented more completely and concisely as algorithms which can *generate* the desired data on demand than they can be as data bases which merely *look-up* precreated data on demand. Analysis showed that the only case where an algorithmic approach offered substantial improvement was the propagation loss module.

3.2 DATA MODULE SIZE ESTIMATES

Several estimating procedures are common to many modules. Four data modules contained sonobuoy pattern inventories. In these modules, each pattern is represented by a number of parameters which indicate how the pattern is applied to a specific tactical situation. Specifically, a pattern is described by:

- the minimum number of sonobuoys required for the pattern,
- the maximum number of sonobuoys usable in the pattern,
- the types of buoys that can be used in the pattern,
- the spacing between buoys, and
- other spacing parameters.

Spacing parameters are always expressed in one of four ways: in terms of mean detection range (MDR), convergence zone width (CZW), convergence zone radius (CZR), or absolute distances. A single representation can be used for all four methods by expressing distance as a weighted sum, as:

$$\text{distance} = \sum_{i=1}^{4} W_i X_i$$

where:

X_1 = MDR	W_1 = multiplier of MDR
X_2 = CZW	W_2 = multiplier of CZW
X_3 = CZR	W_3 = multiplier of CZR
X_4 = 1	W_4 = absolute distance

If any of the four X_i factors is not relevant to the specific distance parameter, then the W_i is set to 0; otherwise the W_i is set to the appropriate value for that pattern. For example, in the BRUSHTAC Pattern, spacing between buoys is 1 CZW, so W_2 is set to a value of 1, and W_1, W_3, and W_4 are set to 0.

An additional spacing parameter of a pattern might identify the distance between the estimated position and some key buoy in the pattern. In the Wedge pattern for example, the Kingpin buoy distance to the submarine is an additional spacing parameter. If this were specified as .5 nm, (an absolute distance), then W_4 for that parameter would be set to .5 and W_1, W_2, and W_3 to 0. Each spacing parameter therefore requires four words of memory (for the four W_i).

Although there are a variety of sonobuoys types carried on board ASW aircraft, the number of different types that will be associated with each pattern is assumed to be limited to six. Thus the buoy types parameter will be considered to require a total of six words of memory for each pattern.

Several of the data modules contain references to geographical locations, expressed in latitude and longitude. It is assumed that each latitude and longitude value will be represented by three components (degrees, minutes, and seconds), and thus will require three words of memory. The directional designator, N/S or E/W, can be appended to the first word in the form of a numerical sign, so that -60 would mean 60°S and +60 would mean 60°N. This directional designator eliminates the need for the fourth memory location, and is therefore consistant with the strategy of determining the most compact representation of each module. Table 3-1 shows the size of each module as derived in subsequent parts of this section.

3.2.1 Search Pattern Inventory Data Module

This data module contains information on five patterns used in the search portion of the mission -- BRUSHTAC, Line, Single Wedge, Double Wedge, and Barrier. Each of these is represented by a maximum and minimum number of buoys

Table 3-1. Summary of Data Module Size Estimates

	Words
Search Pattern Inventory	74
Localization and Tracking Pattern Inventory	52
Contact Investigation Pattern Selection Inventory	40
Passive to Active Transition Inventory	27
Aircraft Location	10
Sonobuoy Location	840
Sensor Inventory	420
Weapon Inventory	32
Operation Area	109
Target Characteristics	140
Target Location	230
Target Capabilities	290
Oceanographic Conditions	17
Atmospheric Conditions	15
Propagation Loss	1030
Aircraft Dynamics	18
ASW Weapon Capability	27
Acoustic Sensor Capability	48

(1 word each), spacing between buoys (4 words), and permitted types of buoys (6 words). Single and Double Wedge also require spacing from the kingpin to the estimated submarine position (4 words each), and the Double Wedge requires spacing between wedges. The barrier also requires the maximum and minimum number of barriers (1 word each). The sizing of the data module is summarized in Table 3-2, the total size is 74 words. If additional search patterns were to be added to this data module, they would require between 12 and 20 words each, depending upon the pattern complexity.

3.2.2 Localization and Tracking Pattern Inventory Data Module

This data module contains information on four patterns used in the localization portion of the mission -- TRITAC, Wedge, Barrier (line), and Circle. Each is represented by the maximum and minimum number of buoys (1 word each), the permissible buoy types (6 words), and the spacing between buoys (4 words). The circle pattern also requires two additional parameters. Buoy spacing in this pattern may be defined by the radius about the specific location (e.g., target fix) as well as by specific spacing values. This radius is expressed in the same manner as other spacing parameters (by the W_i) and this requires 4 additional words of memory.

The sizing of this data module is summarized in Table 3-3; the total size is 52 words. Additional localization patterns to be added to the localization pattern inventory data module would require 12 to 16 words per pattern.

Table 3-2. Search Pattern Inventory Size

Item	Size
Brushtac	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Line	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Single Wedge	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Kingpin Distance to Target	4
Double Wedge	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Kingpin Distance to Target	4
Spacing Between Wedges	4
Barrier	
Maximum Buoys	1
Minimum Buoys	1
Maximum Barriers	1
Minimum Barriers	1
Permitted Buoy Types	6
Kingpin Distance to Target	4
Total	74

Table 3-3. Localization and Tracking Pattern Inventory Size

Item	Size
TRITAC	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Wedge	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Barrier (line)	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Circle	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Radius About Contact	4
Total	52

3.2.3 Contact Investigation Pattern Inventory Data Module

This data module contains information on three patterns used in the contact investigation portion of the mission -- Cadillac, Checker, and TRITAC. Each is represented by the maximum and minimum number of buoys (1 word each) the spacing between buoys (4 words), and the permitted buoy types (6 words). In addition, the Cadillac pattern is represented by a parameter indicating the spacing of the pattern from the previous buoy receiving the contact (4 words). The sizing of this data module is summarized in Table 3-4; the total size is 40 words. Expansion of this data module with other investigation patterns would require 12 to 16 words per pattern.

Table 3-4. Contact Investigation Pattern Selection Inventory Size

Item	Size
Cadillac	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Spacing From Contract Buoy	4
Checker	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
TRITAC	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	6
Spacing Between Buoys	4
Total	40

3.2.4 Passive to Active Transition Inventory Data Module

This data module contains information on three patterns that may be used for prosecution of a contact with active sensors. These patterns are the Entrapment, the Alpha, and the Bravo. As with the passive sensor patterns, each pattern is represented by the maximum and minimum number of buoys (1 word each), and by the allowable types of buoys. Since there are fewer types of active than passive sonobuoys, a maximum of three types will be assumed allowable for each active pattern. In these (active) patterns, the buoy spacing is determined by a radius about the estimated target location. This radius is expressed in terms of the W_i and requires 4 words of memory.

The sizing of this data module is summarized in Table 3-5, the total size is 27 words. Expansion of the active pattern inventory data module to allow for additional active patterns would require 9 words per new pattern.

Table 3-5. Passive to Active Transition Inventory Size

Item	Size
Entrapment	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	3
Radius About Circle	4
Alpha	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	3
Radius About Contact	4
Bravo	
Maximum Buoys	1
Minimum Buoys	1
Permitted Buoy Types	3
Radius About Circle	4
Total	27

3.2.5 Aircraft Location Data Module

This module contains the current (or most recent) information on the ASW Aircraft's location. The latitude and longitude each require three words, while the altitude, heading, speed, and time of fix each require one word. The total size is 10 words.

3.2.6 Sonobuoy Location Data Module

This module contains the location of the current and previous patterns by listing the location and status of each deployed sonobuoy. Each buoy is represented by its RF, type, and hydrophone setting (1 word each), as well as its latitude and longitude (3 words each) and its remaining lifespan (1 word). Ten words are therefore needed to represent each buoy in the pattern, since up to eighty-four buoys may be deployed in a mission, this module must contain information for that many. A total of 840 words are thus needed for this module. The sizing of this data module is summarized in Table 3-6.

Table 3-6. Sonobuoy Location Size

Item	Size
Buoy,	
Latitude	3
Longitude	3
Buoy Type	1
Hydrophone Setting	1
Remaining Lifespan	1
Buoy RF	1
	10 per buoy
Eighty-Four Buoy Total	840

3.2.7 Sensor Inventory Data Module

This module contains information on the acoustic sensors (both passive and active) on board the ASW aircraft. Each sensor will be represented by its type, hydrophone setting, RF and lifespan (1 word each). An additional word will be allocated for the acoustic RF of the sensor, although this word will contain data only if the sensor is an active one. Each acoustic sensor is thus represented by five words of memory, and since there is a maximum of eighty-four sensors on any ASW aircraft, a total of 420 words are required by this data module. The sizing of the module is summarized in Table 3-7.

Table 3-7. Sonobuoy Inventory Size

Item	Size
Sensor,	
Sensor Type	1
Hydrophone Depth	1
RF	1
Acoustic RF (if active)	1
Lifespan	1
	5 per sensor
Eighty-Four Sensor Total	420

3.2.8 Weapon Inventory Data Module

This module contains information on the weapons inventory of the ASW aircraft. Each weapon is represented by only two parameters, its type and its location within the aircraft. Each of these requires only one word of memory. Since there is a maximum of 16 weapons on board any ASW aircraft, this module requires 32 words.

3.2.9 Operating Area Data Module

This module contains information on the ASW aircraft's operating area for its current mission. The boundaries of the operating area are stored as the vertices (latitude/longitude) of the polygon which defines the area. Although frequently this area will be defined by only four vertices (a rectangle), provision is made in the module for up to eight. As each vertex requires six words, eight vertices require 48. The area is also defined altitudinally by a maximum and minimum altitude (one word each).

Also contained in this module is the definition of any restricted area. The restricted area, like the operating area, is represented by up to eight vertices of the polygon defining the area. This requires six words for each vertex, or another 48 words of memory. A restricted area may also be defined by a radius about a point, however, so this requires an additional word of memory to store the possible radius, and a word for a flag or switch which indicates whether the first vertex represents the center point for this radius or merely a vertex in the restricted area polygon.

Finally, this data module also contains information on the EMCON restrictions which may apply to the current mission. A single word of memory is required to determine whether each type of emitter on board the aircraft -- radar, HF radio, UHF radio, VHF radio, MAD, lights, and active sonobuoys -- is restricted or not.

The sizing of this data module is summarized in Table 3-8; the total size is 109 words.

Table 3-8. Operating Area Size

Item		Size
Boundaries of Operating Area		
Latitude		3
Longitude		3
	Sub-Total	6
	Total For 8 Vertices	48
Altitude Limits		1
Radius or Semi-Major Axis		1
Semi-Minor Axis		1
	Operating Area Total	51
Boundaries of Restricted Area		
Latitude		3
Longitude		3
	Sub-Total	6
	Total For 8 Vertices	48
Altitude Limits		1
Radius or Semi-Major Axis		1
Semi-Minor Axis		1
	Restricted Area Total	51
EMCON Restrictions		
Radar		1
HF Radio		1
VHF Radio		1
UHF Radio		1
MAD		1
Lights		1
Active Sonobuoys		1
	Sub-Total	7
	TOTAL	109

3.2.10 Target Characteristics Data Module

This data module contains information on the acoustical emitting characteristics of each type of target of interest for the current ASW mission. Information will be stored for a maximum of five targetm. Each target is represented by an ID, and by its source level emissions at several frequencies for a number of different speeds. Three speeds, essentially representing high, medium, and low operating speeds, are used for each target, and require one word of memory each. At each speed, four characteristics frequencies and source levels are used. One word is required for each frequency and source level.

This yields a total of 28 words required for each target, and 140 words for the entire module. The sizing of this data module is summarized in Table 3-9.

Table 3-9. Target Characteristics Size

	Size
Target ID	1
Target Speed	3
Frequency/Speed Combinations(4x3)	12
Source Level Speed Combinations (4x3)	12
	28 per target
Five Target Total	140

3.2.11 Target Location Data Module

This module contains information on the current or latest known location of any target(s) contacted during the current mission. The module allows information on a maximum of five targets to be retained. Each target is represented by a designator, the time of the fix (one word each), the fix itself, the target's uncertainty area, and data on the sensor maintaining the contact.

The target fix is represented by the latitude or longitude of the submarine (three words each), and the estimated course, speed, and depth of the submarine (one word each). The uncertainty area of the target is represented in one of three ways -- as a circular area (radius about a point, an elliptical area (semi-major and semi-minor axes about a point), or a polygon (collection of vertices). One word is allocated to represent each of the radius, semi-major and semi-minor axes. Six words are used to represent each vertex of the polygon (three for latitude, three for longitude). A maximum of four vertices is used to represent a polygonal area of uncertainty. There is also a switch or flag in this portion of the data module which determines whether the first vertex represents the center of circular area, the center of an elliptical area, or the first of a set of points defining a polygon.

Additional data contains the latitude and longitude of the primary sensor maintaining the contact (six words total), the effective radius of that sensor (one word), and the type of that sensor (also one word). The sizing of this data module is summarized in Table 3-10, the total size of the module is 230 words.

3.2.12 Target Capabilities Data Module

This module contains information on the maneuvering, attacking, and sensing capabilities of potential targets of interest on the current mission. Five types of targets are represented in this module. Each type of target is represented by its identifier, its maximum and patrol depth, and its maximum, minimum, surface, patrol, and transit speeds (one word each). It is also represented by turning radius and dive rate at three different speeds. The speeds -- essentially high, medium, and low -- are included. The dive rates and turning radius each require one word of memory.

The attack capability of each target is represented by data on up to six types of weapons. Each weapon type is represented by its identifier, its range, and the number of that type of weapon carried by the target type

Table 3-10. Target Location Size

Item	Size
Target$_1$	
ID	1
Timed Fix	1
Latitude	3
Longitude	3
Target Course	1
Target Speed	1
Target Depth	1
Vertex$_1$	
Latitude	3
Longitude	3
•	
•	
Vertex$_4$	
Latitude	3
Longitude	3
Radius	1
Semi-Major Axis	1
Semi-Minor Axis	1
Circle/Ellipse/Polygon Uncertainty	
Area Flag	1
Sensor detecting	
Latitude	3
Longitude	3
Type	1
Total	46
Total for Five Targets	230

considered. These variables each require one word of memory, so each weapon requires three words total.

The sensing capability of each target type is represented by the predominant characteristics of each of its emitting sensors. A maximum of 2 RF emitting sensors and 2 acoustically emitting sensors are assumed. Each sensor is represented by an identifier and by its predominant frequency, its pulse width, its pulse repetition cycle, and its pulse length (one word each).

The sizing of this data module is summarized in Table 3-11; the total size of the module is 290 words.

Table 3-11. Target Capability Size

Item	Size
Target	
ID	1
Depth	
Maximum	1
Patrol	1
Speed	
Surface	1
Minimum	1
Maximum	1
Patrol	1
Transit	1
Turning (3 Maneuvers)	
Speed	3
Turn Radius	3
Diving (3 Maneuvers)	
Speed	3
Dive Rate	3
Weapon (6 Weapon Types)	
Type	6
Range	6
Number Carried	6
Sensor Type	4
Frequency	4
Pulse Width	4
Pulse Repetition Cycle	4
Pulse Length	4
Total	58
Total for Five Targets	290

3.2.13 Oceanographic Conditions Data Module

This module contains information on the oceanographic conditions in the operating area of the current mission. The oceanographic conditions include the water depth, surface temperature, (one word each), the ambient noise level at four frequencies (eight words, one for each noise level and each frequency), the sea state, the wave height, the wave direction, the bottom topology, the layer depth, the current direction and the current speed (one word each). The total size of the module is 17 words. Additional frequencies would require two additional words per frequency. See Table 3-12.

Table 3-12. Oceanographic Conditions Size

Item	Size
Water Depth	1
Surface Temperature	1
Ambient Noise (4 Levels)	
Level	4
Frequency	4
Sea State	1
Wave Height and Direction	2
Bottom Topology	1
Layer Depth	1
Current	
Direction	1
Speed	1
Total	17

3.2.14 Atmospheric Conditions Data Module

This module contains information on the current or most recently recorded atmospheric conditions in the operating area. The atmospheric conditions are represented by the wind, clouds, and refractivity. Winds are represented by their direction and speed (one word each), both at the aircraft's mission altitude and at the surface. Clouds are represented by their type, base and percent coverage (one word each); refractivity is represented by a single figure in one word of memory. Finally, the latitude and longtitude (three words each) at which the information was collected and the time of collection are recorded.

The sizing of this data module is summarized in Table 3-13. The total size of the module is 15 words.

Table 3-13. Atmospheric Conditions Size

Item	Size
Winds	
At Altitude	
Direction	1
Velocity	1
At Surface	
Direction	1
Velocity	1
Clouds	
Type	1
Bases	1
Percent Coverage	1
Refractivity	1
Latitude	3
Longtitude	3
Time	1
Total	15

3.2.15 Propagation Loss Data Module

This data module contains information on the expected and possible propagation loss (PL) profiles for the current mission. A separate set of expected and possible profiles is necessary for each type acoustic sensor (up to three), using each characteristic frequency (at least 10), operating in either a cross-layer or within layer situation. Thus 24 set of profiles are needed. Each set, to be useful to the in-situ search pattern decision aid, must contain the PL profile for the expected (i.e., predicted) environmental conditions plus several variations (up to three) on either side of the predicted. Thus, at least seven profiles are needed for each of the 24 conditions, for a total of 168. Even if only a portion of each profile were used to represent it (e.g., the portion crossings the expected Figure of Merit $\pm$5dB), each profile would still require at least twenty to fifty words, depending on how crudely it was approximated. This suggests a range of 5040 to 10080 words of memory for this module, for the passive sensors alone.

A more feasible approach is to store an algorithm or function which can generate the needed PL profiles on demand. It is difficult to state the precise size of such an algorithm without creating it, but a good estimation is possible. Several programs are available, for example, for calculating ray tracings, from which PL profiles can be derived in a straight-forward manner. One such program at the Naval Air Development Center, occupies 210 *registers* of memory on a desk top calculator. According to the manufacturer of this machine, each register is roughly equivalent to four words of memory in a standard computer, so this program is roughly 800 words long. Allowing for 25% growth to accomodate calculation of PL profiles from the ray tracing, the algorithmic representation of this data module can be estimated at 1000 words or 1K of memory. This figure is substantially smaller than even the lower bound of the static storage interval given above. Thus, the algorithmic approach is preferred here if run time is short.

A second portion of this data module contains information on the maximum detection rate for the various types of active sonobuoys for up to three ping rates, in either a within-layer or cross-layer situation. One word for memory is required for each range and ping rate, so this portion of the data module requires 30 words. The sizing of this module is summarized in Table 3-14. Additional sensors would require 30 words per sensor space requirement.

Table 3-14. Propagation Loss Size

Item		Size
Algorithm for producing PL profiles		~ 1000
Buoy$_1$ (Active)		
Type		1
Ping-Rate (3 rates)		3
In Layer Range		3
Cross-Layer Range		3
	Total	10
	Total for Three Buoys	30
	Total	≃ 1030

3.2.16 Aircraft Dynamics Data Module

This data module contains information on the flight dynamics of the ASW Aircraft. These dynamics are represented by minimum, maximum altitude; loiter, minimum, maximum airspeed; maximum range; maximum endurance; a constant representing a standard rate turn (3 degrees per second) each at one word (8 words total). A speed and turning radius pair are also stored for three speeds (2 words per pair) for an additional six words. Three engine loiter weight, two engine loiter weight, descent rate and climb rate at one word each account for an additional 4 words. The total size of this data modules is 18 words.* See Table 3-15.

*This module could be made smaller for LAMPS or S-3A since they do not have 3 and 2 engine loiter configurations.

Table 3-15. Aircraft Dynamic Size

ITEM		SIZE
Minimum Altitude		1
Maximum Altitude		1
Loiter Airspeed		1
Maximum Airspeed		1
Minimum Airspeed		1
Maximum Range		1
Minimum Endurance		1
Standard Rate Turn		1
Speed/Turning Radius Pair	2 words x 3	6
Three Engine Loiter Weight		1
Two Engine Loiter Weight		1
Descent Rate		1
Climb Rate		1
	Total	18

3.2.17 ASW Weapon Capability Data Module

This module contains information on the capabilities of the various weapons carried by the ASW aircraft. Each weapon is represented by its type, range, speed, turn radius, run pattern, run time, search mode, (one word each) and by its possible depth settings. Each weapon has a maximum of two settings, each of which requires one word of memory. It is assumed that an aircraft can carry a maximum of three types of weapons, and since each weapon requires nine words of memory, the total size of this module is 27 words. See Table 3-16.

Table 3-16. ASW Weapon Capability Size

ITEM		SIZE
Type		1
Range		1
Speed		1
Turn Radius		1
Run Pattern		1
Run Time		1
Search Mode		1
Depth Settings	1 word x 2	2
	Total	9
	TOTAL FOR THREE WEAPONS	27

3.2.18 Acoustic Sensor Capability Data Module

This data module contains information on the capabilities of the various acoustic sensors carried on-board the ASW aircraft. Each acoustic sensor type is represented by its ID, bearing accuracy, range accuracy, lifespan, (one word each) frequency response range (two words). Each sensor type is also described by up to two hydrophone depth settings (one word each). The module will contain information on up to six different types of acoustic sensors. Since each sensor will require eight words of memory, the total size of this module is 48 words. See Table 3-17.

Table 3-17. Acoustic Sensor Capability Size

ITEM		SIZE
Identification		1
Bearing Accuracy		1
Range Accuracy		1
Lifespan		1
Frequency Response		2
Hydrophone Depth Settings		2
	Total	8
	TOTAL FOR SIX SENSORS	48

3.3 SIZING OF APP DECISION AID ALGORITHMS

This section describes the procedures used to determine the size of the algorithmic components of eight APP decision aids introduced in Section 2 of this report. Subsection 3.3.1 below describes the assumptions utilized in sizing the aid algorithms, and outlines how they differ from those used to size the decision aid data modules above. Subsection 3.3.2 details the algorithm sizing methodology, and Subsection 3.3.3 provides some relative sizing analyses of algorithms which appear in several of the aids. Finally, Subsection 3.4.4 presents the algorithms sizing estimates for each of the eight decision aids considered in this report.

3.3.1 Sizing Algorithms Versus Sizing Modules

Several assumptions made in the preceding sizing analyses for the decision aid data modules also apply to the sizing of the decision aid algorithms. Specifically, it will continue to be assumed that the memory unit of interest is the word, rather than the bit or the byte. It will also continue to be assumed that the software needed to move the aid algorithms from disc/drum to core and vice versa as well as intermediate storage location such as operating system buffers or pointers should not be considered as contributing to the aids' size. The principal difference between the sizing of the algorithms and data modules is that the unit of measurement for sizing algorithms will be a kiloword (K), or one thousand words. This is because there is much less precision possible in the estimation of the size of algorithms than in the size of data modules. The specific items in each of the data modules could be clearly identified, allowing the module sizes to be precisely defined. The specific content of the aiding algorithms cannot be defined until such time as the aids are actually built, thus excluding anything but general estimates of their size. Since the kinds of algorithms generally used in decision aids tend to be large, it is desirable to use a large unit of measurement for these general estimates, such as the kiloword. When appropriate, however, estimates based on tenths of kilowords or .1K are constructed.

3.3.2 Algorithm Sizing Methodology

As discussed in Zachary (1980) decision aids tend to be composed of many, semi-autonomous algorithms rather than single, unified ones. This factor greatly impacts the sizing analyses of candidate decision aids because it suggests that each component algorithm must be identified and sized independently before an overall size assessment of an aid can be made. A methodology for identifying the component algorithms of a decision aid was developed in Zachary (1980), and is applied here as the first step of the algorithm sizing analysis. The methodology, which briefly reviewed in Appendix A, identifies algorithm components by matching type of decision aiding techniques with aspects of the underlying decision problem addressed by the aid. These problems aspects are developed through the analysis of the decision problem in terms of a highly structured descriptive framework. The application of this framework results in the compact problem descriptions known as Characteristics Summaries. These summaries are used in Section 2 and Appendix A.

Each section of the Characteristics Summary Table identifies one or more potential component algorithms of a decision aid for the problem being described. Specific type of algorithms are selected by comparing the problem requirements against the capabilities of each of a group of candidate algorithmic techniques in a Decision Aiding Technique Taxonomy (Table 3-18). Often many techniques are found to be applicable. For the APP problems considered below, the 'smallest' alternative is selected from each set of equivalent approaches, and used in the subsequent analysis.

After all the algorithmic components of an aid have been identified by the Characteristics Summary Table-Taxonomy matching procedure, the size of each component is estimated. These estimates are based on software engineering experience, previous analyses of decision aids, and a consideration of the specific operations performed by the algorithm. Of course, the space required by data that are located in the data modules is not considered in the sizing of the algorithms.

Table 3-18. Taxonomy of Decision Aiding Techniques

1. OUTCOME CALCULATORS 1.1 Closed Form Analytic Models 1.2 Probabilistic Models 1.3 Deterministic Simulations 1.3.1 Mechanical 1.3.2 Differential Equation 1.4 Monte-Carlo Simulations
2. VALUE MODEL 2.1 Multi-Attribute Utility Model (MAUM) 2.2 Adaptively Constructed MAUM 2.3 Direct Assignment of Utilities to Outcomes 2.4 Risk-Incorporating Utility Models 2.5 Non-Linear Utility Model
3. DATA CONTROL TECHNIQUES 3.1 Automatic Data Aggregation 3.2 Data Management Techniques
4. ANALYSIS TECHNIQUES 4.1 Optimization Techniques 4.1.1 Linear Programming 4.1.2 Non-Linear Programming 4.1.3 Dynamic Programming 4.1.4 Fibbonaci Search 4.1.5 Response Surface Methodology 4.2 Artificial Intelligence Techniques 4.2.1 Heuristic Search 4.2.2 Bayesian Pattern Recognition 4.3 Sensitivity Analysis 4.4 Intra-Process Analysis 4.5 Information Processing Algorithms 4.6 Status Monitor and Alert 4.7 Statistical Analysis 4.7.1 Distribution Comparison 4.7.2 Regression-Correlation 4.7.3 Discriminant Analysis 4.7.4 Bayesian Updating
5. DISPLAY/DATA ENTRY TECHNIQUES 5.1 Display Graphics 5.2 Interactive Graphics 5.3 Windowing 5.4 Speech Synthesis/Recognition 5.5 Quickening
6. HUMAN JUDGMENT AMPLIFYING/ REFINING TECHNIQUES 6.1 Operator-Aided Optimization 6.2 Adaptive Predictions 6.3 Bayesian Updating

Finally, after all the component algorithms of each aid are sized, a total-aid algorithmic size is computed. This is estimated to be 140% the sum of the sizes of all the component algorithms. The 40% inflation of the sum is included to provide for the software which interrelates these component algorithms (i.e., an executive or controller algorithm) for immediate storage (i.e., for intermediate, dummy, counter, flag, switch, and pointer program variables) and for dead space (i.e., inefficient machine-language constructions caused by compilation of high-level source code). The value of 40% was selected as an estimate, based on our previous decision aid and software engineering experience. Table 3-19 shows the size of each algorithm as derived in subsequent parts of this section.

Table 3-19. Summary of Decision Aid Algorithm Size

Decision Aid	Words
Search Pattern Planning	8.3K
Processor Mode Selection	5.2K
Contact Investigation Pattern Selection	8.3K
Signal Correlation	9.0K
Threat Assessment and Classification	7.6K
Localization and Tracking	9.8K
Passive to Active Transition	8.2K
Attack Planning	10.0K

3.3.3 Algorithmic Components Present in Multiple Decision Aids

There are certain forms of analyses and/or certain output variables that were found relevant to several of the APP decision problems. Algorithms which perform these analyses and/or compute these output variables will therefore be present in multiple APP decision aids. The discussion of decision aid sizing can be simplified if size estimates of these "repeated" algorithmic components are constructed initially, and then merely referenced in the sizing of each aid. There are five such algorithms that will be present in multiple decision aids. There is a "sonobuoy pattern optimization" algorithm, an "exclusion analysis" algorithm, a "navigational" algorithm, a "sonobuoy pattern coverage area" algorithm, and a "sonobuoy release cueing sequence" algorithm. Each is discussed in more detail below.

3.3.3.1 Sonobuoy Pattern Optimization Algorithm. Four of the decision aids -- Search Pattern Planning, Contact Investigation Pattern Selection, Localization and Tracking Pattern Selection, and Passive to Active Transition --involve the optimization of the next sensor pattern. Thus, each of these aids would contain an algorithm for optimization of sensor patterns. In most circumstances, optimization algorithms are extremely complex, large, and slow, but this is not the case in these four APP cases. The set of options being optimized, i.e., the set of possible or candidate sonobuoy patterns, is always completely known and is small in size. The largest number of candidate patterns is found in the search pattern problem, where only five patterns are considered permissible. Thus, pattern optimization in these four cases can be accomplished by simple enumeration. The criterion function is evaluated for each possible pattern, and the pattern which yields the highest value is selected as optimal.

An optimization algorithm of this form can be very simple. The only complicating factor will be the need to generate the characteristics of each pattern from the information that is stored about it in the respective data module (search pattern inventory, contact investigation pattern inventory, localization/tracking pattern inventory, or active pattern inventory). It is estimated that .2K words will be necessary to generate the pattern characteristics so that the value criterion for the optimization algorithm in each decision aid having one will be given by .2K x N, where N is the number of patterns being considered in that aid.

3.3.3.2 Sonobuoy Pattern Exclusion Analysis. Those decision aids which concern sonobuoy pattern selection were identified as requiring an analysis to determine which (if any) among the candidate patterns would be excluded by situational constraints. In particular, it was seen as necessary to determine whether a candidate pattern, if deployed, would violate the prescribed search area of the mission, or would require more sonobuoys of a particular type than were available at that point in the mission. An "exclusion analysis" algorithm would thus be required by the search pattern selection aid, the contact investigation pattern selection aid, the localization and tracking pattern selection aid, and the passive to active transition aid.

An exclusion analysis algorithm is a simple information processing algorithm with two subcomponents. The first considers the availability of sensors of the pattern, and the second considers the relationship between the placement of the pattern and the search area boundaries of the mission. The first subcomponent requires very little space, as it would merely read the sonobuoy requirements for the pattern from the relevant data module and compare them to the values in the sonobuoy inventory module. Certainly no more than .1K will be needed for this procedure.

The second subcomponent algorithm would be substantially larger. In determining whether a given pattern violates the mission search area, the position of each buoy in the pattern will have to be generated, and then compared with the boundaries of the search area, as defined in the operating area data module. Since the operating area may be defined in any of the number of ways, it will be necessary for the algorithm to make comparison in different manners. This adds to its size. The general operation of the algorithm concerns geometric calculations to determine whether any given point (i.e., projected sonobuoy location) is outside of some closed planar figure -- either a polygon, an ellipse, or a circle. It is estimated that a minimum of .3K will be required for each of these three possibilities, or a total of .9K for all of them. There is also some space required to generate the sonobuoy locations for each different type of pattern, probably on the order of .2K for each pattern. Since the number of patterns considered by each varies, this factor will cause the size of the exclusion analysis algorithm to vary as well. Based on above

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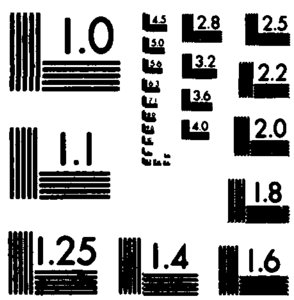

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calculations, the size of each exclusion analysis algorithm will be given by

$$.1K + .9K + (.2K \times N)$$

where N is the number of patterns considered by that aid.

3.3.3.3 Navigational Algorithm. The decision aids that concern sonobuoy pattern selection are all intended to have an option which will generate the fly-to-points and steering commands necessary to deploy the selected pattern. A navigational algorithm is therefore needed by these aids. This algorithm would be an information processing algorithm which determines the sequence of points that should be visited in order to deploy a specific series of sonobuoys, and then generates steering commands to allow the aircraft to capture these points. The algorithm would require extensive formuli representing aircraft motion, and would utilize these in concert with the data contained in the aircraft capabilities module. It is estimated that approximately 1K will be required by each of these navigational algorithms.

3.3.3.4 Sonobuoy Pattern Coverage Area Algorithm. Pattern-construction related decision aids were all found to require the determination of the coverage area of candidate patterns. Thus, a coverage area algorithm would be contained in the Search pattern selection aid, the investigation pattern selection aid, the localization pattern aid, and the passive to active transition aid. There are two separate variants of the coverage area algorithm which require different amounts of memory. In the search pattern selection and the contact investigation pattern selection aids, both direct path and covergence zone contacts are of interest, so coverage area have to be computed in terms of both direct path and CZ areas. In the localization pattern selection and active pattern selection problems, however, CZs are not of interest, or are not meaningful, so the coverage area can be computed on the basis of direct path contact alone.

The calculation of coverage areas poses a considerable computational challenge. Due to the convergence zone phenomema, a given area of ocean may be covered by zero, one, or several sonobuoys in a pattern. The boundaries of the zones of coverage for each sonobuoy are all either circular or annular, so the direct calculation of overlap areas between sonobuoys would involve the solution of complex multiple integrals. Even without considering the difficulty of deriving the necessary equations, it can be seen that the algorithms needed to perform the necessary operations would be large. Alternatively, approximational methods could be used to minimize the algorithmic complexity, but such an approach would introduce noise into the coverage area calculation. It is assumed here that this latter method is preferable, however, because it minimizes the memory requirements of the algorithms.

As a reference point for sizing, an approximational algorithm is envisioned which sequentially examines each element of a relatively fine grid covering the search area. Each grid area is considered to determine if it is covered by at least one sensor. This is done by sequentially examining each sensor in the pattern involved and determining whether any of them can provide coverage for any point on the grid area. The pattern's coverage area is then determined according to the ratio of covered to uncovered grid areas. The size or "mesh" of the grid is crucial to the accuracy of the approach, and also greatly affects the execution time of the algorithm. The finer the grid, the more accurate the approximation but the slower the algorithm. This issue is irrelevant to sizing, however, and is considered in the timing impact subsection at the end of Section 3.

It is estimated that the calculation of whether or not a given grid area was covered could be accomplished with an algorithm using 1K of memory when only direct path coverage is of interest, or with an algorithm using

$$1K + (N \times 1K)$$

of memory when direct path and CZ coverage are both of interest, where N is the number of CZ's in the tactical situation at hand. It will be assumed here that there are never more than 3CZ's present. An additional .5K will be required to generate the patterns from the information contained on them in the relevant data modules and to iterate the testing algorithm overall grid areas. The coverage area algorithm will thus require 4.5K in the cases where direct path and CZ contacts are of interest, and 1.5K in the cases where only direct path contacts are of interest.

There is one additional alternative possible for the coverage area algorithms. The coverage area for each pattern considered by each aid can be precomputed for different generic environmental conditions (no CZ, 1CZ, etc), and stored as a data table. In this form, the algorithm would require only about .5K of memory, but the savings in algorithm size would be lost in the need to store additional data.

3.3.3.5 <u>Cueing Sequence Algorithm</u>. For decision aids which concern sonobuoy pattern selection, a second option (besides the generation of fly-to-points and steering commands) is available -- the automatic controlling of the cueing sequences necessary to select, set, and deploy the sonobuoys in the chosen pattern. Algorithms to accomplish this function are needed by the search pattern selection aid, the contact investigation pattern selection aid, the localization pattern selection aid, and the passive to active transition aid.

It is assumed that, to the extent possible, the cueing sequence algorithm automates the sequence for deploying the sonobuoys, rather than merely guiding the TACCO through a series of button and switch activations. The algorithm would still have to display some information to the TACCO, however, and this requires the storing of the cues as alphanumeric information which is surprisingly costly of space. Even with this in mind, it is doubtful that the cueing sequence algorithm would require more than 1K of memory.

3.3.4 Sizing Estimates of Individual Aid Algorithms

The analyses given in Appendix A of the eight APP decision problems considered in this report resulted in the Tables shown in Subsection 2.2. Each table identifies certain aspects or portions of the problem which must be treated by a decision aid for that problem or must be utilized in the design of such an aid. The first two descriptive categories, Problem Objective and Problem Task Dynamics, fall into the latter category. They define the problem characteristics which must be preserved in a decision aid design. Categories of Underlying Process and Value Criteria identify portions of the problem which must be addressed by Outcome Calculator and Value Model algorithms respectively. The category of Variables and Parameters identifies the data requirements for a decision aid. Since data considerations were partitioned from algorithmic considerations and covered under the rubric of Data Modules, this category is largely irrelevant to algorithmic considerations. The one exception to this concerns the subcategory of Output Variables, which identifies those relevant variables that must be created or processed from the inputs and parameters. The algorithmic components necessary to obtain the output variables must be considered in sizing the algorithmic component of each aid. The descriptive categories of Relevant Analyses and Relevant Displays identify problem aspects that are addressed by analytic and display/data entry algorithms, respectively. Finally, the category of required human judgments identifies problem aspects which may be addressed by human judgment refinement/amplification algorithms.

3.3.4.1 Search Pattern Planning Decision Aid. A model of the possible movement of submarines in the operating area is necessary to allow calculation of a probability of detection value for preposed search patterns. This model must be capable of dealing with target location uncertainty. Of the two types of outcome calculator algorithms which meet the criterion (Monte-Carlo or probabilistic model), the probabilistic model is more conservative of space, and is thus more appropriate for the Search Pattern Planning Aid. The two value criteria -- coverage area and probability of detection -- are constructed separately through information processing algorithms and then combined via a multi-attribute utility model approach.

The calculation of in-situ PL profiles is actually accomplished by a data module and need not be considered here. The exclusion analysis is conducted by an algorithm of the type discussed in Subsection 3.3.3.2 above as would be the optimization of search pattern (Subsection 3.3.3.1), the calculation of steering commands and fly-to-points, (Subsection 3.3.3.3) and the generation of the cueing sequences for pattern deployment (Subsection 3.3.3.5). The display requirement for the outputs of these algorithms were included in the sizing estimates given above. The single required human judgement does not require any algorithmic support.

The algorithmic components of the Search Pattern Selection Decision Aid, and their estimated sizes are given in Table 3-20. The total algorithmic size of the aid is 8.3K words.

Table 3-20. Algorithmic Size of Search Pattern Planning Decision Aid

Algorithmic Component	Size
Probabilistic Outcome Calculator of Target Movement	2K
Pattern Coverage Area Algorithm	.5K *
Probability of Detection Calculation Algorithm	.7K
Multiattribute Utility Algorithm Combining Separate Value Criteria	.1K
Exclusion Analysis Algorithm	2K **
Search Pattern Optimization	1K **
Navigational Algorithm	1K
Cueing Sequence Generating Algorithm	1K
TOTAL	8.3K

*Smallest Alternative Listed in Subsection 3.3.

**Using 5 Possible Pattern Types

3.3.4.2 Processor Mode Selection Decision Aid. There is no underlying process associated with this decision task so no outcome calculator is required. The value criteria of expected detection range is a nonlinear function, and is calculated through a nonlinear value model algorithm. Each of the two output variables, lateral range functions and detection ranges, are required in the computation of this value criterion and must themselves be calculated by separate information processsing algorithms. The optimization of the processor mode can likely be accomplished through an enumerative algorithm analogous to that used by for pattern optimizatin (see Subsection 3.3.3.1).

The algorithmic components of the Processor Mode Selection Aid, and their estimated sizes are given in Table 3-21. The total algorithmic size of the aid is 5.2K words.

Table 3-21. Algorithmic Sizing of Processor Mode Selection Decision Aid

Algorithmic Component		Size
Nonlinear Value Model Algorithm		2K
Lateral Range Function Algorithm		1.5K
Detection Range Algorithm		.7K
Mode Optimization Algorithm		1.5K
	TOTAL	5.2K

3.3.4.3 Contact Investigation Pattern Selection Decision Aid

Once the ASW platform has gained contact with a hostile submarine, the possible movement of that submarine will play a key role in the selection of future sonobuoy patterns. For this reason, an outcome calculator for predicting these movements is crucial to the Contact Investigation Pattern Selection Aid. The uncertainty in the target's location must be considered in the outcome calculator's predictions, so either a probabilistic or Monte Carlo Algorithm could be employed. The probabilistic form was chosen because this form characteristically uses less space than the other.

The value criterion (probability of gaining a direct path contact) is computed via a nonlinear value model algorithm. This model may interface with the outcome calculator in determining these probabilities, but this interface does not add to the space requirement of either algorithm. The operating area output variable is computed by, and used in, the exclusion analyses algorithm. The probability of maintaining contact is calculated through an information processing algorithm. The algorithm considers possible present target locations and calculates from them future target positions that would not be covered by the proposed pattern. The optimization of the next pattern is accomplished through an enumerative algorithm as discussed in Subsection 3.3.3.1, and a probabilistic information processing algorithm is used to calculate the target uncertainty area.

Navigational algorithms and cueing sequencing algorithms analogous to those used in other pattern selection aids would be used to generate steering commands and fly-to-points and to generate the cueing sequences necessary to deploy the selected pattern. The single required human judgment does not need to be assisted by any algorithmic component.

The algorithmic components of the Contact Investigation Pattern Selection Aid and their sizes are given in Table 3-22. A total of 8.3K words are needed for the algorithmic portion of this aid.

Table 3-22. Algorithmic Sizing of Contact Investigation Pattern Selection Decision Aid

Algorithmic Component	Size
Probabilistic Outcome Calculator of Target Movement	2K
Nonlinear Value Model	1K
Pattern Coverage Area Algorithm	.5K*
Exclusion Analysis Algorithm	1.6K**
Uncertainty Area Calculation Algorithm	.6K
Investigation Pattern Optimization Algorithm	.6 **
Navigational Algorithm	1K
Cueing Sequence Generating Algorithm	1K
TOTAL	8.3K

*Smallest Alternative Listed in Subsection 3.3.

**Assuming 3 Contact Investigation Patterns

3.3.4.4 Signal Correlation Decision Aid. This decision problem is different from the other APP problems considered here because it involves the drawing of complex inferences from multi-sensor signals. An outcome calculator is still needed for this problem, but its purpose is essentially to allow inference about possible target movements to be tested. It may also be used to assign probability values to branches in an inference tree. This latter use would require the outcome calculator to incorporate uncertainty; for the reason cited previously, this suggests a probabilistic outcome calculator algorithm.

A current-pattern coverage area algorithm similar to that used on other aids would be employed by the Signal Correlation Aid. This algorithm interfaces with another algorithm that would determine possible target location based on coverage area overlaps. The "possible target location" algorithm is an artificial intelligence algorithm which uses inferential procedures to determine possible target locations based on coverage area overlaps and the specific sensors receiving signals. This algorithms, in turn, interfaces with yet another information processing algorithm which assigns probabilities to the various possible target locations.

A second artificial intelligence inferential algorithm examines the coverage of the pattern, the sensors receiving contact, and the signals being received in order to infer possible multiple-target scenarios which could give rise to the current tactical situation. The algorithm also assigns probabilities to the various scenarios, to reflect their liklihood vis-a-vis a single-target situation.

The extensive displays relevant to this decision aiding problem will require considerable algorithmic processing. Separate algorithms would be needed to generate the graphic displays and to generate the alphanumeric displays.

The algorithmic components of the Signal Correlation Aid and their sizes are given in Table 3-23. The total algorithmic size of this is estimated at 9K words.

Table 3-23. Algorithmic Sizing of Signal Correlation Decision Aid

Algorithmic Components	Size
Probabilistic Outcome Calculator of Target Movement	2K
Coverage Area Calculation Algorithm	.5K *
Inference Algorithm for Determining Possible Target Locations	2K
Information Processing Algorithm for Determining Target Probability Areas	1K
Inference Algorithm for Assessing Possibilities of Multiple Targets	2K
Graphic Display Generators	1K
Alphanumeric Display Generators	.5K
TOTAL	9K

*Smallest Alternative Listed in Subsection 3.3.

3.3.4.5 Threat Assessment and Classification Decision Aid. There is no underlying process associated with this decision problem, so no outcome calculator algorithm is required by it. The residual uncertainty in the classification will be calculated by a separate information processing algorithm. However since target classification and threat assessment both involve elements of risk, the residual uncertainty value is related to a value function by a risk-incorporating utility algorithm.

The primary output variable is the set of candidate classifications for each signal received. These can be generated in several different ways -- through statistical algorithms, through artificial intelligence algorithms, or through information processing algorithms. Its anticipated that a statistical "template matching" or Pattern Recognition algorithm, which examines data extracted from the gram by the sensor operator and compares them to acoustic profiles of targets of interest will prove to be the most space-efficient approach. This type of algorithm embodies some characteristics of all three generic algorithmic approaches to classification.

Determination of the threat capabilities of each candidate or plausible classification can be accomplished by simple search of the target capabilities data module, and therefore, does not need to be considered here. An artificial intelligence algorithm may be employed in conjunction with the threat capabilities data module to infer possible missions of the targets that can be definitely classified. This algorithm would use these possible missions to determine factors which might increase or decrease the level of threat posed by each target. Finally, the identification of possible target actions would be accomplished by a second template machine algorithm, similar to that used in the classification procedure.

Nearly all of the displays needed for this problem involve the presentation of alphanumeric data, and alphanumeric display generation algorithms are necessary to produce them. An additional graphic display generation algorithm is needed for the (graphic) display of target uncertainty areas.

The algorithmic components of the Threat Assessment and Classification Decision Aid and their sizes are given in Table 3-24. The total algorithmic size of this aid is estimated at 7.6K words.

Table 3-24. Algorithmic Size of Threat Assessment and Classification Decision Aid

Algorithmic Components	Size
Residual Uncertainty Algorithm	1K
Risk-Incorporating Utility Algorithm	.1K
Template-Matching Classification Algorithm	1K
Artificial Intelligence Mission Inference Algorithm	3K
Template-Matching Target-Action Algorithm	1K
Alphanumeric Display Generators	1K
Graphic Display Generation	.5K
TOTAL	7.6K

3.3.4.6 *Localization and Tracking Pattern Selection Decision Aid*. As in other pattern selection aids, an outcome calculator which can be used to model future target movement is vital to the Localization and Tracking Pattern Selection Decision Aid. This outcome calculator must be able to represent the uncertainty in target movement. For the reasons discussed above, this suggests a probabilistic type of outcome calculator algorithm. The value criteria (probability the pattern will further refine the target location) is computed from the output variables -- the coverage area and resolution of the proposed pattern.* Thus, a separate information processing algorithm is needed to calculate each of these variables, and a nonlinear value model algorithm is needed to combine them.

An exclusion analysis algorithm is needed to determine which if any candidate patterns violate the search areas and current sensor inventory. An

*Resolution refers to the expected level of error in target fixes obtained from the pattern.

enumerative optimization algorithm would be used to select the optimal pattern, and algorithms to generate steering commands and fly-to-points, and cueing sequences necessary to deploy the selected pattern, will also be needed.

One final algorithm needed for this aid is one which adjusts the pattern optimization criteria to trade-off pattern coverage and resolution against sensor inventory. The localization and tracking mission phase may extend through the deployment of several sensor patterns. This trade-off algorithm would attempt to maintain sensor inventories for future use while jeopardizing the effectiveness of the patterns deployed as little as possible. The trade-off analyses probably take the form of a sensitivity analysis algorithm.

The algorithmic components of the Localization and Tracking Pattern Selection Decision Aid and their sizes are given in Table 3-25. The total algorithmic size of this aid is estimated at 9.8K words.

Table 3-25. Algorithmic Sizing of Location and Tracking Pattern Selection Decision Aid

Algorithmic Components	Size
Probabilistic Outcome Calculator of Target Movement	2K
Nonlinear Value Model Algorithm	.2K
Pattern Coverage Area Algorithm	.5K *
Pattern Resolution Information Processing Algorithm	1K
Exclusion Analysis Algorithm	1.8K **
Localization and Tracking Pattern Optimization Algorithm	.8K **

*Smallest Alternative Listed in Subsection 3.3.4.3

**Using 4 Possible Pattern Types

Table 3-25. Algorithmic Sizing of Location and Tracking Pattern Selection Decision Aid (Continued)

Algorithmic Components		Size
Navigational Algorithm		1K
Cueing Sequence Algorithm		1K
Sensitivity Analysis Algorithm for Trade-Off Analysis		1.5K
	TOTAL	9.8K

3.3.4.7 Passive to Active Transition Decision Aid

Predictions of the target movement are necessary for the accurate determination of active prosecution criteria attainment. These predictions must incorporate both the uncertainty associated with the current target location as well as the uncertainty involved with future target movements. An outcome calculator is therefore required for this aid, and, as outlined in previous sections, a probabilistic model type of outcome calculator is most appropriate.

The indicated value criteria for this problem is a nonlinear function of two constituent components; i.e., active sensor capabilities and target area uncertainty. The uncertainty information on the target being tracked is computed by a separate target uncertainty algorithm because this information changes continuously during contact with the target. The active sensor detection capabilities, because they vary little for a given environmental condition, need be computed only once and can be calculated as part of a nonlinear value model algorithm. This algorithm also computes the value criterion for the problem as the ratio of these two quantities. The two value-model algorithms (the nonlinear value model algorithm and the target uncertainty algorithm) will interface with a real-time alerting algorithm that will detect and notify the TACCO of the attainment of active sensor criteria.

After the criteria have been attained, the aid determines the best active sensor pattern. An enumerative optimization algorithm is employed to perform this optimization. Navigational and cueing sequence algorithms analogous to those used in other pattern selection aids are incorporated into the passive-to-active transition aid to assist in the deployment of the selected pattern.

The algorithmic components of this aid and their sizes are given in Table 3-26. The total estimated algorithmic size of the aid is 8.2K words.

Table 3-26. Algorithmic Sizing of Passive to Active Transition Decision Aid

Algorithmic Components	Size
Probabilistic Outcome Calculator of Target Movement	2K
Nonlinear Value Model Algorithm	1K
Pattern Coverage Area Algorithm	.5K *
Target Uncertainty Estimation Algorithm	.6K
Active Sensor Criteria Alerting Algorithm	1.5K
Active Pattern Optimization Algorithm	.6K**
Navigation Algorithm	1K
Cueing Sequence Generation For Pattern Deployment	1K
TOTAL	8.2K

* Smallest Alternative Listed In Section 3.4

** Using 3 Possible Pattern Types

3.3.4.8 Attack Planning Decision Aid

Given the objective to optimize the attack plan, it is necessary to utilize an outcome calculator to predict the results of potential attacks on the hostile submarine. There will still be some residual uncertainty in the target's location at this point in the mission, and the outcome calculator should be able to treat this uncertainty, as well as that associated with target acquisition by the weapon. This need to incorporate uncertainty suggests a probabilistic outcome calculator approach.

The twin value criteria of probability of hit and probability of kill is calculated by an information processing algorithm which would interface with the outcome calculator algorithm. The optimization of the attack plan in terms of these two criteria is accomplished by a nonlinear programming optimization algorithm. Because the value-criteria "surface" will likely be monotonic, this optimization algorithm will likely be able to employ the relatively quick gradient search method. If a multiattribute utility approach is used to combine the two value criteria into one, then the optimization could be handled by a simpler hill-climbing method, such as Fibbonacci Search.

As an additional input to the outcome calculator, an information processing algorithm is required to calculate the weapon's target acquisition range given the in-situ environmental conditions. Once an optimal attack plan has been generated and accepted, navigational and cueing sequence algorithms are employed to aid in the implementation of the attack plan. These algorithms would be similar to those used for sonobuoy pattern deployment in the aids concerned with pattern optimization. To assist in the creation of the graphic displays required by the aid, a graphic display generation algorithm is required. The required human judgements do not need any algorithmic support.

The algorithmic components of the attack planning decision aid and their sizes are given in Table 3-27. The total estimated algorithmic size is 10K words.

Table 3-27. Algorithmic Sizing of Attack Planning Decision Aid

Algorithmic Components		Size
Probabilistic Outcome Calculator for Attack Results		2K
Information Processing Algorithm for Calculating Probability of HIT and KILL		1.5K
Nonlinear Programming Algorithm for Attack Optimization		2.5K
Weapon Range Calculation Algorithm		1K
Navigational Algorithm		1K
Cueing Sequence Generator to Deploy Weapon		1K
Graphic Display Generator		1K
	TOTAL	10K

3.4 SIZING SUMMARY

The decision aids and their associated data modules both require memory. This capacity has been estimated separately for the data modules and for each of the decision aids in Sections 3.2 and 3.3 above. The capacity requirements for each decision aid with its data modules are summarized in Table 3-28 below. Should the decision aiding package be implemented as an entity, estimated capacity would be the sum of that required by each decision aid plus that required by the data modules or approximately 69.8K words of memory. If added to the aircraft in a non-integrated fashion, some of the data modules will have to be duplicated and stored with each decision aid.

Table 3-28. Sizing Summary

DATA MODULE	MODULE SIZE IN WORDS	DECISION AIDS: SEARCH PATTERN PLANNING	PROCESSOR MODE SELECTION	CONTACT INVESTIGATION PATTERN SELECTION	SIGNAL CORRELATION	THREAT ASSESSMENT AND CLASSIFICATION	LOCALIZATION AND TRACKING PATTERN SELECTION	PASSIVE TO ACTIVE TRANSITION	ATTACK PLANNING
Search Pattern Inventory	74	X							
Localization and Tracking Pattern Inventory	52						X	X	
Contact Investigation Pattern Inventory	40			X					
Passive to Active Transition Inventory	27							X	
Aircraft Location	10	X		X			X	X	X
Sonobuoy Location	840				X			X	
Sensor Inventory	420	X		X			X	X	
Weapon Inventory	32								X
Operating Area	109	X					X		
Target Characteristics	140	X	X			X			
Target Location	230	X		X	X		X	X	X
Target Capabilities	290	X		X	X	X			X
Oceanographic Conditions	17	X	X	X	X	X	X	X	X
Atmospheric Conditions	15	X		X			X	X	X
Propagation Loss	1030	X	X	X	X	X	X	X	X
Aircraft Dynamics	18	X		X				X	X
ASW Weapon Capability	27						X		X
Acoustic Sensor Capability	48		X		X	X	X		
D.A. Algorithm Size (K Words)		8.3	5.2	8.3	9.0	7.6	9.8	8.2	10.0
Approximate Total Size (K Words)		10.7	6.5	10.4	11.5	9.2	11.8	10.9	11.7

3.5 TIMING IMPACT

The timeliness with which the host platforms computation system can handle a workload including decision aids must be considered in addition to requirement for storage of algorithm and data modules. The issue of timing can pose a very major problem to the overall effectiveness of the mission since it can result in an abnormal delay time in the performance of necessary search/retrieval and calculation routines required to provide the required output. The timing requirements of the aircraft central computer can be related to the mission phase in which the aircraft is involved -- search localization and attack. The search phase imposes the least stress and the attack phase imposes the least.

There is also a relationship of the eight decision aids discussed in this document to the mission phase as summarized below.

- Mission Search Phase
  --Search pattern planning decision aid
  --Processor mode selection decision aid

--Contact investigation pattern selection decision aid
--Signal correlation decision aid
--Threat assessment and classification decision aid

- Mission Localization Phase
  --Signal correlation decision aid
  --Threat assessment and classification decision aid
  --Localization and tracking decision aid
  --Passive to active transition decision aid

- Mission Attack Phase
  --Localization and tracking decision aid
  --Passive to active transition decision aid
  --Attack planning decision aid

Reference to the demand upon the aircraft central computer as used within the content of this section refers to the P-3C and S-3A aircraft computers and the LAMPS MK-III base ship computer. The least amount of impact is anticipated in the LAMPS MK-III base ship computer due to the larger capability and capacity. Impact will also vary dependent upon crew use of the decision aids.

The following discussion of the specific decision aids and their impact upon the central computer timing requirements assumes utilization of a dedicated decision aid processor in which all calculations are performed in a separate computer. The main impact on the central computer would be the exchange of necessary data between the two computers. Application of the tape overlay concept or utilization of the existing aircraft central computer would result in heavily impact upon the central computer. The P-3C NUD aircraft tape overlay function currently requires between seven and ten minutes to roll in and out specific overlay functions prior to the initialization of that function. Therefore, utilization of that function would have to include a similar roll-in/roll-out time allotment. The timing impact on the central computer incorporating the eight decision aids internally is difficult to address, since the central computer would have to be off-loaded of some current functions to allocate space for incorporation of the decision aids.

3.5.1 Search Mission Phase

The search mission phase is the least burdensome on the central computer. Initially, during this mission phase the central computer is concerned primarily with navigation and equipment status. As the mission progressor, such factors as sensors, ordnance, sensor status, sensor signals, and automatic detection/classification is considered as a low priority item. This function does obtain a large amount of computer time because of the relatively low need for the computer while the automatic detection/classification function is active.

The search pattern planning decision aid would be exercised prior to release of any sonobuoys or activation of the automatic detection/classification function. This decision aid would have very little impact upon the overall timing requirements of the central computer since navigation and system status are the major requirements of the computer at the time of activation of the search pattern planning decision aid.

The processor mode selection decision aid would ideally be activated during the execution of sonobuoy search. Since the search pattern planning decision aid would resolve the propagation loss parameters and sonobuoy type and depth variables, this aid could be activated immediately upon conclusion of the search sonobuoy deployment. As with the search pattern planning aid, computer requirements at this portion of the mission are not as demanding as its subsequent mission phases.

The signal correlation and threat assessment and classification decision aids would begin to impact the timing requirements of the central computer. Activation of these aids would occur when the automatic detection/classification functions were active. However, the amount of information being obtained from the sensors during the search phase may not be extensive and the resulting impact on timing could be unnoticed. The burden upon the central conputer could be reduced depending upon the implementation scheme of the dedicated processor. A scheme which duplicated the incoming information for both the central computer and the dedicated processor would not result in an increase on the timing problems.

The contact investigation pattern decision aid would have some impact upon the central computer; however, it would result in a minimal reduction of capability. This decision aid requires very little imput and time to complete, therefore, the overall impact would be negligible. This decision aid would only be required once during the search phase.

3.5.2 Mission Localization Phase

The localization mission phase requires more utilization of the central computer than the search phase since there are more sensors deployed, increased signals being received by the aircraft, potential application of the automatic detection/classification function, and higher utilization of functions available to the TACCO, SS-1/SS-2 and other crew members. During this phase, the crew would be less tolerant of computational delay due to the criticality of time during this mission phase. The major decision aids which are addressed during the localization mission phase are localization and tracking and passive to active transition.

The localization and tracking pattern selection decision aid could result in extensive impact upon the central computer or, at a minimum, a large amount of redundancy of stored data. During the initial portion of the localization mission phase, the automatic detection/classification functions may be activated. As the mission proceeds through this mission phase, the crew members will be activating and requesting more functions, therefore, placing a larger demand on the overall system. Reduction of the loading on the central computer can be accomplished by duplicating all incoming sensor signals to both the central computer and the dedicated processor. This could reduce the amount of interrupts for information being requested of the central computer. However, this may also increase the storage requirements placed upon the dedicated processor and may become unacceptable. The localization and tracking pattern selection decision aid would ultimately be utilized for the majority of the mission phase. As the classification function were accomplished, it could be deactivated and thereby reduce the burden on the central computer.

The passive to active transition decision aid would require high utilization of the central computer. This decision aid would have to receive all incoming sensor data as well as TACCO-generated fixing data to determine target location. Calculations and recommendations would then have to be performed and supplied to the TACCO. This decision aid would be able to incorporate some of the functions currently available to the ASW aircrews and therefore reduce some of the timing requirements.

3.5.3 Mission Attack Phase

The mission attack phase currently places heaviest demand on the central computer. During this portion of the mission, the aircrew is utilizing the greatest portion of the functions available, navigation is utilized, weapons parameters and ballistics are being utilized, more sensors (passive) are used, and additional sensor types (MAD, FLIR, active) may be involved. The attack planning decision aid would be able to incorporate some of the functions currently resident in the central computer (ballistics equation and logic) and therefore eliminate some of the burden on the central computer. Timing delays are critical during this mission phase. Excessive delays in processing could cause failure to achieve a successful attack. However, an analysis of the benefit of this aid would have to be performed to determine the merit of an attack planning decision aid. A decision to incorporate this decision aid would require a need to specify it as a high-priority function and therefore possibly reduce the importance of other aircraft functions currently available to the ASW aircrew.

4. FEASIBILITY OF IMPLEMENTATION

This section summarizes the findings of this report with respect to implementation and recommends future action.

4.1 PLATFORM IMPLEMENTABILITY

The following subsections discuss decision aid package implementability for each aircraft.

4.1.1 P-3C Update II Implementation

The P-3C Update II aircraft have been equipped with an expanded memory capability (MV-9360/AYA-8 logic unit 4) which provides the aircraft with approximately 458K words of storage. In order to install the expanded memory, one of the two magnetic tape drives has been removed from the aircraft. Although there is some available space within the P-3C Update II computer system which could be made available for decision aids, CPU time is currently critical. The addition of new computational requirements will only burden the CPU time to a greater extent. Therefore, it is not feasible to implement the APP decision aid package into the P-3C Update II central computer.

Utilization of the tape overlay approach for the decision aid package implementation into the P-3C Update II aircraft is also impractical. The addition of the logic unit 4 was accomplished by removal of one of the magnetic tape transports. Removal of one tape transport requires the remaining tape transport be used for data extraction/data retrieval. Therefore, the extraction/retrieval tape must be loaded onto the magnetic tape transport for the entire mission. This will not make it feasible to utilize a tape overlay feature in the P-3C Update II aircraft.

The utilization of a federated APP processor for incorporation of the APP decision aids is the most feasible approach for implementation of the decision aid package. This federated systems approach to APP would provide a mechanism which allows for the inclusion of the overall decision aid package. The P-3C Update II aircraft has space available which can hold a federated APP processor, therefore space is not a major issue. The timing and throughput impact upon the aircraft central computer would be a function of the federated processor operating program. Ideally the federated system would be self contained and only the request for the aids and the output of the aids would have to interface with the aircraft central computer. The major drawback of the federated system in the P-3C Update II is the extensive interface design specification requirement and software verification requirements.

4.1.2 S-3A Implementation

Implementation of the decision aids package into the S-3A aircraft is very similar to that of the P-3C Update II aircraft. The central computer on the aircraft provides approximately 16K words of memory for use and storage. There is not enough unused memory available in the aircraft central processor to allow for inclusion of a decision aid package as depicted in this report.

The S-3A is equipped with only one digital magnetic tape unit (DMTU), RD-348/ASH. This DMTU contains the magnetic tape used to load the operational program, record and extract mission events, load the PDIP tape and contain the computer diagnostic tables. This magnetic tape must be installed in the DMTU during the entire mission and cannot be removed. Additionally, there is not enough unused space on the magnetic tape to provide for a tape overlay of the decision aid package. Therefore, the tape overlay feature is not feasible as a means of implementing a decision aid package into the S-3A.

The federated processor may have potential application for the S-3A and the decision aiding package. Currently, there is room to install an AN/AYK-14 type computer in the S-3A. However, this space may be used for installation of a computer processor for use in ESM and acoustic analysis. If space is not available in the S-3A for an APP federated system, the decision aiding package depicted in this report will not be feasible for incorporate into the S-3A aircraft. Therefore, the inclusion of any decision aids into the S-3A would have to be accomplished on an individual aid basis, and at the expense of removal of existing capabilities within the aircraft operating system.

4.1.3 LAMPS MK-III Implementation

The overall LAMPS MK-III system is composed of two separate yet connected subsystems; the base ship and the LAMPS MK-III helicopter. The LAMPS MK-III helicopter system is not capable of providing a means for implementation of the decision aid package, although this platform has some onboard computer processing capability. Tape overlay capabilities are not feasible in the LAMPS MK-III helicopter nor is the federated APP processor approach. The LAMPS MK-III helicopter is extremely space critical and does not contain the necessary space.

The LAMPS MK-III helicopter does have a separate computer for processing ESM information. Although this computer appears to have insufficient capacity to house individual decision aids, it is the only means by which decision aids might be implemented into the LAMPS MK-III helicopter.

The LAMPS MK-III baseship is equipped with onboard computers which are capable of storing and utilizing the decision aid package. Utilization of the base ship as the location of the decision aiding package would provide the LAMPS MK-III helicopter with the APP decision aid package through utilization of the dedicated data communications link between the helicopter and the ship. This link provides the two way flow of information between the two platforms. As the helicopter acquires sensor information it is forwarded to the baseship for processing. The results of baseship processing are returned to the helicopter. This same exchange of information could be used for the APP decision aid package. The helicopter crew could request a decision aid, have the decision aid processed onboard the ship, and have the output displayed in the helicopter via the data communications link.

The location of the decision aid onboard the ship is the most attractive means of implementing the decision aid package in the LAMPS MK-III. This approach would not require the utilization of tape overlay or federated processor technique, but rather utilize the existing baseship central processor.

4.2 RECOMMENDATIONS

4.2.1 Aircraft Investigation

Investigation should be made into the installation of an APP decision aid package using a federated system for the P-3 and S-3. This investigation should determine interface (hardware and software) requirements as well as will cost-effectiveness, cost and weight and balance problems associated with the federated processor.

4.2.2 Antisubmarine Warfare Operational Center and Carrier Based Antisubmarine Warfare Module

Investigation into the land based antisubmarine warfare operational center (ASWOC) and the carrier based antisubmarine warfare module (CV-ASWM) should be initiated to determine the feasibility and applicability of the data modular concept for APP decision aids. Since these facilities are going to interact directly with the various ASW aircraft, the computer systems should be compatible and able to freely exchange the information.

4.2.3 Desk Top Calculator Application

Prior to implementing the decision aid package depicted in this report, it should be implemented on a minicomputer in order to perform testing and evaluation.

4.2.4 Decision Aid Package Expansion

The current decision aid package is limited only to acoustic related decision aids. This decision aid package should be expanded to include all decision aids relating to the ASW aircraft. Areas of investigation for decision aiding should include all non-acoustic sensor related tasks, navigation, communications and flight planning/routing.

APPENDIX A

DECISION TASK ANALYSIS

The generic and detailed structures given for each of the eight decision aids considered in this report have been developed from analyses of the specific decision tasks they address. These analyses are applications of a methodology for defining the decision-aiding requirements of a given decision situation or problem. The method was developed (and is fully documented) in Zachary (1980), Detwiler, Fitzkee, and Zachary (1980). It is therefore only summarized here.

The identification of the decision aiding requirements for any decision problem or decision situation involves three steps. First, the functional aspects of the problem must be identified. Second, the functional categories of decision aiding techniques must be identified. And third, the specific technique or techniques capable of aiding each problem aspect must be chosen. Obviously, the second step in the process, categorization of aiding techniques, is a one-time task. Once accomplished, the same categorization can be applied to each new decision situation or decision task encountered.

The first step in the process of functional analysis of a decision involves the application of a descriptive framework designed to focus attention on appropriate functional problem aspects. "Appropriate" aspects are defined as those which relate directly to the highest-level categories of decision aiding techniques in the technique categorization. The application of this descriptive framework identifies the parts of the problem which relate directly to categories of aiding techniques. This allows the third step in the process (selection of appropriate techniques) to be accomplished by merely matching of the content of the problem (as expressed in each part of the functional description) with the decision aiding techniques in the corresponding category that may perform the identified decision function.

The descriptive framework contains eight "frames" for describing specific portions of a decision task. These are:

- *Objective* -- What is the decision maker trying to accomplish? Is there a specific event or events that will fulfill the objective and move the decision maker further toward his overall goal?
- *Task Dynamics* -- How is this decision actually performed? Is it independent of future/past decisions or part of a sequential series of decisions which are contingent upon one another? Is it performed only once or is it embedded in an iterative procedure where it is made repeatedly?
- *Underlying Process Involved* -- What is the process, if any, for which the decision maker is attempting to plan? What are the interactions with the enemy?
- *Value Criteria* -- On what kind of scale could a decision be evaluated? Are there one or more measures by which one choice can be seen as better than another?
- *Variables and Parameters* -- What are the inputs to the decision? What are the (fixed) parameters of the situation which affect the decision? What is the decision maker specifically trying to decide? What outputs (processed data) would be useful in making that decision?
- *Relevant Analyses* -- What kinds of analysis of the input and/or output data would help in making the decision?
- *Relevant Displays* -- What information should be displayed? How?
- *Required Human Judgments* -- Are there any judgmental assessments which the human must make? What are they?

In this appendix, the descriptive framework is applied to the problems of search pattern selection, contact investigation pattern selection, acoustic processor mode selection, multiple sensor correlation, weapon placement determination, contact threat assessment and classification, contact localization and tracking, and timing of changeover from passive to active prosectuion. A standard format for summarizing the information generated through application of the framework, called the Characteristics Summary, is included in each problem description.

A.1 SEARCH PATTERN SELECTION

A.1.1 Objective

During the ASW mission, the aircrew attempts to optimize utilization of the sensors available to them. The initial use of the sensors is to gain contact with the threat target. Although the crew receives information on the search area and on suggested initial sonobuoy patterns at its briefing, this data is based upon predictions of environmental conditions which may or may not be present at the actual time of the mission. Because of this reliance on predicted conditions, the suggested sonobuoy pattern may turn out to be suboptimal when a variation exists between the actual and predicted conditions. The objective of the search pattern selection task is the choice of a search pattern which is optimal given the in-situ environmental conditions.

A.1.2 Task Dynamics

The search pattern selection task is first undertaken after the aircraft arrives on station and obtains a bathythermal recording of the operating area oceanographic conditions. However, this task may be repeated numerous times during the search portion of the mission, as the aircrew desires to deploy new search patterns. The search portion of the mission normally ends with the gaining of a contact on one or more deployed sonobuoys. Thus, the task has a closed-loop iteratives task dynamic, in which it may be successively performed in nearly identical fashion many times.

A.1.3 Underlying Process

In the search pattern decision task, zero or more target submarines are either transiting to an assigned operating area, patrolling in the operating area, or in the vicinity of a friendly force. The aircrew is preparing to employ its sensors to gain contact with a target submarine. If the target submarine anticipates or detects the presence of the ASW aircraft, it may attempt to utilize the environment to avoid detection.

A.1.4 Value Criteria

The value criteria relevant to this task are the measure by which one candidate pattern may be seen as better than another. Since the goal of the search portion of the mission is gaining contact, criteria which relates to this goal must be used. Two key criteria of this type are the coverage area of a candidate search pattern, and the probability of gaining contact with a target within the operating area through use of a candidate pattern. It may be necessary to combine these two criteria into a single value measure for candidate patterns.

A.1.5 Variables and Parameters

A.1.5.1 Parameters. There are several kinds of fixed values or parameters which are relevant to this decision task. The first includes information on the sensors available to construct the pattern: their type, quantity, and capabilities. The second type of parameter includes the specific pattern geometries which can be used in constructing search patterns. The third type of parameter concerns the capabilities of the ASW aircraft. The fourth type of relevant parameter concerns the characteristics of the various targets of interest to the current mission, particularly their characteristic emitting frequencies and source levels, but also their historical tracks and their movement capabilities. Finally, the fifth type of parameter includes the search area definition of the current mission -- the operating area and any restricted areas.

A.1.5.2 Inputs. The inputs, or dynamic values, which are relevant to the search pattern construction decision task fall into three categories. The first group of inputs are the in-situ oceanographic conditions, such as ambient noise level, sea state, layer level, and propagation loss profile. The second set of inputs concerns any target contact the ASW platform has had while on station, and the third set of inputs concerns the remaining sensors available for deployment.

A.1.5.3 Outputs. The only outputs, or processed information, which are relevant to performing this decision task are the areas of coverage and the probability of detection for each candidate search pattern.

A.1.5.4 Decision Variables. There is only one value or variable whose value is being decided in the search pattern selection decision task, and this is the specific pattern to be employed.

A.1.6 Relevant Analyses

There are three forms of analyses which are relevant to this decision task. The first is the calculation of the exact or approximate in-situ propagation loss (PL) profiles. Sensor performance is dependent on PL, so in order to optimize sensor utilization the PL profile considered must reflect the actual one as closely as possible. The second analysis is the calculation of 'excluded' possibilities. This analysis would determine those patterns which are not practical because their use would violate certain constraints of the current mission, for example requiring buoy placement outside the operating area, or requiring more than the available number of certain type of sonobuoy. The third relevant form of analysis would be calculation of the probability of detection (P_d) and the coverage area for each non-excluded candidate pattern.

A.1.7 Relevant Displays

The information which it would be useful to display is the optimal pattern type and geometry, and the cueing sequences, steering commands, and fly-to-points necessary to deploy it. The values of the output variables (P_d and coverage area) could be made displayable on demand.

A.1.8 Required Human Judgment

The human operator, in this case the TACCO, must ultimately accept or reject the pattern suggested by an aid. This judgement may require reference to the TACCOs experience, intuition, and special features of the current mission not considered by the aid, and thus cannot be left totally to the decision aiding algorithm.

The description aiding requirements for this task, as identified from this description, are summarized in Table A-1.

A.2 PROCESSOR MODE SELECTION

A.2.1 Objective

All ASW platforms have available a wide variety of acoustic sensors, which can be employed in a number of different ways. The targets that may be sought have widely differing acoustical characteristics, and the oceanographic conditions may impact on acoustical detection capabilities in a variety of ways. To accomodate this wide range of operational situations, the acoustic signal processing equipment has available many different operating modes, each of which is optimal for a certain mix of conditions. The selection of a processing mode for this equipment thus has a far-reaching impact on the remainder of the mission. The objectives of this decision task is to select the optimal mode of acoustical signal processing.

Table A-1. Search Pattern Planning Characteristics Summary

Objective: Selection of Optimal Pattern for Gaining Initial Contact Given In-Situ Environmental Conditions.

Task Dynamics: Closed-Loop Iterative.

Underlying Process: Zero or More Submarines Moving In or Through Search Area.

Value Criteria: Coverage Area of Pattern.
Probability of Detection of Submarine from Pattern.

Variables and Parameters

Inputs
Oceanographic Conditions
- PL
- Ambient Noise
- Sea State

Sensors Remaining
Target Contact History

Outputs
Pattern Coverage Area
Probability of Detection (P_d)

Parameters
Sensors: Type
- Capabilities

Available Pattern Geometries
Aircraft Capabilities
Target Capabilities
- Acoustical Emissions
- Movement

Area of Search
- Operating Area
- Restricted Area(s)

Decision Variables
Type of Pattern to be Deployed and Spacing

Relevant Analyses
1. Calculation of In-Situ PL Profiles
2. Exclusion of Patterns Failing to Meet Mission Restrictions.
3. Determination of Pd for a Given Pattern.

Relevant Displays
1. Pattern Geometry and Types and Settings of Sensors Used.
2. Steering Commands, Cueing Sequences, and Fly-to-Points for Pattern Deployment.

Required Human Judgments Final Choice of Pattern.

Narrative: This decision aid will compute various search patterns and display them to the TACCO to allow the TACCO to select the desired pattern.

A.2.2 Task Dynamics

This decision may be made once or more during the course of a normal mission. The number of times this task is performed is dependent upon acoustic sensor usage and actions performed by the target submarine.

A.2.3 Underlying Process

The TACCO and acoustic sensor operator who make the decision are not trying to do so in the context of any encompassing process. The decision is unaffected by the actions of the ASW platform. However, it can be affected by the actions of the target submarine in the search area.

A.2.4 Value Criteria

The optimal mode will be that which maximizes the detection range of targets within the search area. In general, each mode will have a different detection range for every target/frequency combination so an expected or mean detection range will have to be aggregated for all targets and frequencies as the criteria value for each processing mode.

A.2.5 Variables and Parameters

A.2.5.1 Parameters. The parameters relevant to the mode selection decision task fall into two groups. The first group contains the acoustic characteristics of the targets of interest -- the emitting frequencies and source levels for each. The second group contains the characteristics of the ASW platform's acoustic signal processor, including the recognition differential in each mode, the resolution (in Hz), and the band coverage and number of bands examined.

A.2.5.2. Inputs. The only dynamic variables relevant as inputs to this decision task are the in-situ oceanographic conditions, which condition the operating capabilities of the sensors and signal processing equipment. The specific inputs of interest are the ambient noise levels at all relevant frequencies, the water temperature vs depth profile, the layer depth, and the bottom type.

A.2.5.3 Outputs. The outputs which are relevant to the processor mode selection are indicators of the effectivenss of different processor mode. Such output variables include the lateral range functions, and the (mode-specific) detection ranges.

A.2.6 Relevant Analyses

There are two relevant analyses for this decision task. The first is the calculation of the detection range over all target/frequency combinations for any given processor mode or combination of modes. The second is the optimization of expected detection range value over all possible modes and mode combinations.

A.2.7 Relevant Displays

There is very little information which needs to be displayed to the decision maker in the mode selection task. In particular, only the suggested (i.e. optimal) processing mode needs to be presented.

A.2.8 Required Human Judgments

The human operator is ultimately required either to accept the optimal mode suggested by the aid, or to reject it on the basis of experience and situational factors not considered by the aid algorithm.

The decision aiding requirements of this task, as identified from the preceding description, are summarized in Table A-2.

Table A-2. Processor Mode Selection Characteristics Summary

Objective: Select Optimal Mode for Processing Acoustical Signals Given Targets of Interest and In-Situ Environmental Conditions.

Task Dynamics: Uni-dimensional Independent

Underlying Process: None

Value Criteria: Expected Detection Probability

Variables and Parameters

Inputs
Oceanographic Conditions
- PL
- Ambient Noise
- Water Temperature vs Depth
- Layer Depth
- Bottom Type

Parameters
Target Characteristics
- Source Levels
- Frequencies

Acoustic Processor Capabilities
- Recognition Differential
- Resolution
- Band Coverage

Outputs
- Lateral Range Functions
- Detection Ranges

Decision Variables
Processor Mode

Relevant Analyses
1. Calculation of Detection Ranges.
2. Optimization of Processor in Terms of Expected Detection Ranges.

Relevant Displays
Suggested Processing Mode

Required Human Judgments
Acceptance/Final Choice of Processor Mode

Narrative: The Processor Mode Selection decision aid utilizes environmental information, processor mode gain and target intelligence to determine lateral range curves (LATRAN) which denote the probability of passive detection versus range for a target at a specified frequency/source level combination. The LATRAN information is then used to compute a probability of target detection by processor mode. Comparison of mode performance provides the acoustic operator with recommended settings for the acoustic signal processor.

A.3 CONTACT INVESTIGATION PATTERN SELECTION

A.3.1 Objective

Once a signal has been detected and has been classified as originating from a target of interest, the ASW aircrew will begin to investigate the contact, by repeatedly selecting and deploying investigation sensor patterns. The objective of deploying these patterns is to reduce the target area of uncertainty to that of a direct path contact.

A.3.2 Task Dynamics

Investigation patterns will continue to be deployed until their objective is met or the contact is lost. Each successive pattern will draw and build upon the information gained from the last, but the decision as to which pattern to deploy next remains essentially unchanged throughout the investigation process. Thus, the task dynamics of this situation are closed-loop and iterative.

A.3.3 Underlying Process

Since this decision task begins after contact has been gained, there must be at least one submarine moving in or through the search area. The process which underlies the investigation pattern selection decision task is the movement of any submarine in the search area, any possible attempts on the part of the submarine(s) to evade or escape detection, and the movement of the ASW aircraft to deploy and/or monitor its sensors.

A.3.4 Value Criteria

The objective of this decision task, gaining a direct path contact with the target, is obviously an all-or-nothing situation, so it is not possible to evaluate candidate patterns on the basis of their 'degree' of attainment of this goal. It is possible, however, to assess the probability of gaining a direct path contact from a potential pattern, and this would be the most straight-forward means of comparatively assessing those patterns vis-a-vis each other.

A.3.5 Variables and Parameters

A.3.5.1 Parameters. The parameters which are relevant to this decision task fall into four basic groups. The first group includes the capabilities of the ASW aircraft itself. The next two groups consider the target being prosecuted. One of these includes the acoustical characteristics of the target (or set of potential targets, if classification is incomplete), primarily the frequency and source levels of acoustic emissions. The other target-related group of parameters covers the motion capabilities of the target. These include its speed and depth limitations, its maneuvering limitations, and any historical track information. The fourth group of parameters concerns the search area, as defined by the restricted and operating areas of the current mission.

A.3.5.2 Inputs. The input variables for this situation also fall into four groups. The first group of inputs concerns the current situations of the target -- its estimated location, course, depth, speed, and uncertainty area. The second group indentifies the deployed (functioning) sensors. Relevant information here includes their location, type, depth, setting, and remaining life.

The third group of inputs to the task concerns the in-situ oceanographic conditions. This includes the PL profile, the ambient noise levels, the sea-state, and water temperature versus depth profile. The final group of relevant inputs identifies the type and number of available sensors remaining on-board the ASW platform for deployment.

A.3.5.3 Outputs. As with the search pattern selection task, this decision task is facilitated by calculation of the coverage area. Rather than a probability of gaining contact, however, it is more useful in this case to consider the probability of maintaining contact.

A.3.5.4 Decision Variables. The only decision variable for this decision task is the type of the next investigation pattern to be deployed.

A.3.6 Relevant Analyses

There are two relevant analyses of the variable and parameters for this task. The first is the determination of the (projected) target uncertainty area that would remain after the deployment of a selected pattern. The second form of analysis is the optimization of the sensor pattern type, given the current target uncertainty area and in-situ environmental conditions.

A.3.7 Relevant Displays

The information that is necessary to display in this decision task concerns the suggested optimal investigation pattern and the procedures needed to deploy it. The pattern and its geometry should be displayed, as should be the type and settings for the sensors to be used in the pattern. Also displayed should be the cueing sequences, the steering commands, and the fly-to points needed to deploy this pattern.

A.3.8 Required Human Judgments

In this, as in other decision tasks considered here, the final acceptance/choice of the next contact investigation pattern must be left to the TACCO, who may wish to incorporate other situation-specific or experiential information into this judgment.

The decision aiding requirement for this task, as defined by the preceding description, are summarized in Table A-3.

Table A-3. Contact Investigation Pattern Selection Characteristics Summary

Objective: Select Pattern which will result in Direct Path Contact with submarines.

Task Dynamics: Closed-Loop Iterative

Underlying Process: Movement of one or more hostile submarines through or in search area, possibly attempting to evade or escape detection; movement of ASW aircraft.

Value Criteria: Probability of Gaining Direct Path Contact with Target.

Variables and Parameters

Inputs
Target Situation
- Location
- Course, Depth, Speed
- Area of Uncertainty

Deployed Sensors
- Location
- Setting Depth
- Remaining Lifespan

Oceanographic Conditions
- PL
- Ambient Noise
- Sea State
- Temperature vs Depth

Sensor Availability
- Number Available
- Type

Parameters
Aircraft Characteristics
Target Characteristics
- Source Levels
- Frequencies

Target Capabilities
- Speed Characteristics
- Maneuvering Capabilities
- Depth Limitations

Sensors Characteristics
Search Area
- Pattern
- Operating Area

Outputs
Coverage Area
Probability of Obtain Direct Path Contact
Probability of Maintaining Contact

Decision Variables
Type of Next Investigation Pattern

Relevant Analyses
Determine Target Uncertainty Area (UA)
Optimize Sensor Pattern Given Target UA and Environmental Conditions

Relevant Displays
Suggested Optimal Pattern, Geometry, and Sensor Types and Settings Cueing Sequences, Fly-to-Points, and Steering Commands to Deploy Suggested Pattern

Required Human Judgment
Final Acceptance/Choice of Sensor Pattern

A.4 SIGNAL CORRELATION

A.4.1 Objective

After initial contact has been gained with a target, and then throughout the prosecution of that target, the problem of multi-sensor signal correlation may arise. The ASW platform will normally have multiple acoustic sensors deployed at any given time. When several sensors receive signals simultaneously, a problem arises as to the interpretation of these signals. The signals may be originating from multiple targets, or from a single target. If from a single target, the relative locations of the receiving sensors (and their CZs) theoretically provides information that can be used to further reduce the area of uncertainty of the target involved. The objective of this decision task, then, is to interpret and utilize the cross-sensor information contained in a multi-sensor contact situation.

A.4.2 Task Dynamics

Although the decision may arise at numerous points within a single mission, each occurrence is essentially different from and independent of each other occurrence. Thus each decision of this type can be considered as having multi-dimensional independent task dynamics.

A.4.3 Underlying Process

The process involved in this task is similar to that which underlies other acoustic-related decision tasks. One or more hostile submarines are moving in or through the search area, possibly attempting to escape or evade detection by the ASW aircraft.

A.4.4 Value Criteria

Since there are no true alternatives being compared in this decision task, there can be no true value criteria for comparing alternatives.

A.4.5 Variables and Parmeters

A.4.5.1 Parameters. Four sets of parameters apply to this decision task. The first two -- target characteristics and target capabilities -- concern the submarine(s) in the operating area. Target characteristics refer to the acoustic features of the submarine, i.e., their source levels at various characteristic frequencies, while the target capabilities refer to the speed, maneuvering, and depth limitations. This set of parameters also includes any historical track information on the target. The third set of parameters identifies the search area of the mission, as defined by the operating and restricted area(s). The fourth set of parameters concerns the capabilities of the acoustic signal processor on the ASW aircraft, e.g., available processing modes, frequency response. The fifth set of parameters involves the capabilities of the ASW aircraft itself.

A.4.5.2 Inputs. The inputs to the signal correlation decision task fall into three groups. The first group concerns the in-situ information on the target(s) contacted. This includes the estimated location, course, depth, speed, and uncertainty area, as well as the history of the contact(s) in the current mission. The second input set concerns the location, type, setting, and remaining lifespan of all deployed sensors. The third set involves the in-situ oceanographic condition, such as the PL, ambient noise, temperature vs depth profile, etc.

A.4.5.3 Outputs

Possible outputs useful in performing the multi-sensor correlation decision task are the determination of the areas of coverage overlap between or among multiple sensors gaining simultaneous contact, and the possible locations (and associated probabilities) where a single target causing the multiple contact could be located.

A.4.5.4 Decision Variables. There are two decision variables in this task. The first is the estimated position of the target(s) involved, and the second is the uncertainty area associated with the target(s).

A.4.6 Relevant Analyses

The analyses that are relevant to this task all involve extraction of the possible redundant information presented by the sensors maintaining contact. One aspect to the procedure is the calculation of possible target positions based on the areas of coverage overlap. Another is the estimation of the probability that a target is actually located in each of these areas or locations. A third potential form of analysis is the examination of the sensor information to determine if multiple target may be the sources of the multiple signals.

A.4.7 Relevant Displays

The information that would be useful to display for this task involves the relative geometry of the tactical situations. The locations of all deployed sensors should be shown, with those receiving signals highlighted. The areas of coverage overlapped should be shown, as well as the possible location of a single target causing the mustiple contacts. The overall target uncertainty should also be displayed.

A.4.8 Required Human Judgment

In this decision, the integration of all the available information into a single assessment of the true underlying tactical situation must be made by the human operator, in particular the TACCO.

The decision aiding requirements of the multi-sensor signal correlation task as defined by the above description are summarized in Table A-4.

Table A-4. Signal Correlation Characteristics Summary

Objective: Utilize information from multiple sensors to refine target uncertainty area and estimated position.

Task Dynamics: Multi-dimensional Independent

Underlying Process: Movement of one or more hostile submarines through search area, possibly taking evasive action.

Value Criteria: None

Variables and Parameters

Parameters

Target Characteristics
- Source Location
- Frequency

Target Capabilities
- Speed, Depth, Maneuvering Limitations
- Historical Track Data

Search Area
- Operating Area
- Restricted Area

Aircraft Capabilities

Acoustic Processor Capabilities

Outputs

Coverage Area Overlap

Possible Target Locations

Inputs

Target Situation
- Location
- Estimated Course, Depth, Speed, Location
- Uncertainty Area
- History of Contact

Deployed Sensors
- Lifespan Remaining
- Type and Setting
- Location

Oceanographic Conditions
- PL
- Ambient Noise
- Temperature vs Depth
- Operating Area

Decision Variables

Estimated Target Positions

Target Uncertainty Area

Relevant Analyses
1. Calculation of Possible Target Positions from Areas of Overlap.
2. Determination of Probability of Target Being In Each Possible Location.
3. Investigation of Possible Multiple Targets.

Relevant Displays

Location of Deployed Sensors

Sensors and Sensor Types Receiving Signals

Possible Target Locations

Sensor Coverage Area Overlap

Target Area Uncertainty

Required Human Judgments

Interpretation of Tactical Situation

A.5 Threat Assessment and Classification

A.5.1 Objective

After one or more sensor patterns have been deployed during the search phase of the mission, contact may be gained with one (or more) targets. These contacts may represent hostile submarines in the search area, but they also represent non-hostile or even friendly targets. The TACCO and acoustic sensor operator must interpret the signals originating from the contacts and determine whether or not they represent targets-of-interest (i.e. hostile submarines). In a situation where multiple targets-of-interest are identified, the relative threat posed by each must be determined so that prosecution can initially proceed on the most threatening target. Thus, there are two objectives in this situation: the classification of the contacts gained, and the determination of the threat they pose.

A.5.2 Task Dynamics

The classification and threat assessment decisions are made only one time for each target, and are basically independent of the preceeding tactical decisions. Thus, this decision task has a multidimensional independent task dynamics.

A.5.3 Underlying Process

Since the classification and assessment procedure is essentially one of extracting the desired information from the incoming sensor signals there is no real-word process associated with the decision task.

A.5.4 Value Criteria

When only a single contact is involved, it must be definitely classified as either hostile or non-hostile, and when there is more than one hostile target, they must be ranked in terms of their potential threat. There are both all-or-nothing decisions, and cannot convey any uncertainty. Thus, value criteria for these decisions can be assessments of the residual uncertainty in the classification or threat ranking. Such measures of classification or assessment uncertainty will be a function of the number of alternative conclusions (i.e., classifications or rankings) that have not yet been excluded, and the degree to which each of these is probable.

A.5.5 Variables and Parameters

A.5.5.1 Parameters. There are only three types of parameters for the threat assessment and classification decision. The first two relate to the targets-of-interest for the ASW mission. The target characteristics are of prime importance. These include the acoustic source level and frequency characteristics of the various targets, and also the historical information on the targets i.e., their historical tracks, their possible missions, their transit times, and their times on station. A second target-related parameter considers the capabilities of the various target types, such as their movement limitations, their depth limitations, and their speed limitations. The third parameter relevant to this decision task includes the capabilities of the various acoustic sensors carried by the ASW platform.

A.5.5.2 Inputs. The inputs to this task fall into three basic groups. The first group deals with the in-situ environmental conditions, including the exact (or approximated) in-situ PL profile, the ambient noise levels, the temperature versus depth profile, the sea state, and the layer depth. The second group of inputs concerns the contact itself -- the sensor or sensors which have contact, the frequency or frequencies which are being received, and the bandwidths involved. The third group of inputs concerns the still-active sonobuoys that the ASW aircraft has deployed. Included in this group are location, type, setting, and depth of each deployed sonobuoy, as well as its remaining lifespan.

A.5.5.3 Outputs. Output variables which may aid in the classification and threat assessment decision are the target types which may match the signals received, and the threat capabilities of each of the possible classifications.

A.5.5.4 Decision Variables. The primary decision variable in this task is the classification of each contact gained. A second decision variable is the assessed threat level of each classified target.

A.5.6 Relevant Analyses

Several analyses are relevant to this decision task. First, the incoming signals can be analyzed to exclude certain types of targets, and to assign likelihoods of each of these possible classifications. Second, the incoming signals can be analyzed to determine whether additional information on the target's current actions can be gained. For example, the signal could be examined for resemblances to the noises known to be made by the opening of torpedo doors. Third, the capabilities and inferred intents of each target of interest could be analyzed to assess the level of threat posed by it.

A.5.7 Relevant Displays

The chosen classification for each target, as well as any other possible classifications that could not be dismissed with certainty, should be displayed to the TACCO and acoustic sensor operator, along with the probability of each classification being correct. The movement and attack capabilities posed by each classified target should also be displayed, along with any additional information that could be extracted from the incoming signals. Finally, the initial uncertainty area and estimated location of the target should be displayed to the TACCO.

A.5.8 Required Human Judgments

The final acceptance or rejection or the classification of each target must ultimately be left to the human operator. The determination of which target should be prosecuted first, in a multiple-target environment, must be left to the human operator as well.

The decision aiding requirements of the threat assessment and classification decision task, as identified from the preceding description, are summarized in Table A-5.

A.6 Localization and Tracking Pattern Selection Decision Task

A.6.1 Objective

This decision task begins after contact with a target has been gained, classified as a hostile submarine, and investigated. If investigation proceeded successfully, a direct path contact with the target was gained. At this point the localization and tracking process begins. The ASW platform attempts to reduce systematically the remaining uncertainty in the estimated course, speed, depth, and location of the submarine, either for prolonged tracking or subsequent attack. This is done through the deployment of sensors and sensor patterns, but since the localization and tracking process may continue for a prolonged period of time, the judicious utilization of the limited number of available sensors is also necessary. Thus, the objective of this decision task is to reduce or maintain the current level of target uncertainty while ensuring the availability of sensors for subsequent phases of the mission.

A.6.2 Task Dynamics

This decision task is performed each time a new localization or tracking pattern is deployed. This decision is virtually identical fashion each time, even though the tactical details will change from occurrence to occurrence. Localization and tracking is thus a closed-loop iterative decision task.

Table A-5. Threat Assessment and Classification Characteristics Summary

Objective: Classification of New Contacts, and Determination of Threat Posed by Each Classified Hostile Target.

Task Dynamics: Multi-dimensional Independent

Underlying Process: None

Value Criteria: Measure of the Uncertainty Remaining in the Classification and Threat Assessment of Each Target.

Variables and Parameters

Parameters
Target Characteristics
- Source Levels
- Frequency

Target Capabilities
- Maneuvering, Depth, Speed, Limitations
- Historical Track Data
- Mission Types (Historical)
- On-Station Time, Transit Time

Sensor Capabilities
- Depths, Settings, Types

Decision Variables
Classification of Each Target
Threat Level of Targets Classified as Hostile

Inputs
Deployed Sensors
- Location, Depth
- Settings
- Remaining Lifespan

Environmental Conditions
- PL
- Ambient Noise
- Temperature vs depth
- Layer Depth

Contact Involved
- Sensor Receiving
- Frequencies
- Frequency Bandwidth

Outputs
Candidate Classifications
Threat Capabilities of Each Candidate Classification

Relevant Analyses
Determination of Possible Classifications from Incoming Frequencies.
Identification of Possible Target Actions from Incoming Signals.
Interference of Threat Level from Capabilities and Inferred Mission.

Relevant Displays
Chosen classification and probability.
Other possible classifications and probabilities.
Movement and attack capabilities of classified targets.
Additional target-related information.
Uncertainty area and estimated location of target.

Required Human Judgments
Acceptance/Rejection of classifications
Determination of which among multiple targets to prosecute first.

A.6.3 Underlying Process

During the localization and tracking sequences, the principle action involved is the movement of the hostile submarine through or within the search area. The submarine may also be taking evasive action.

A.6.4 Value Criteria

The value criterion for selecting one sensor pattern over another in this decision task must relate the pattern to the overall objective of the mission. The most general criterion of this sort is an overall measure of the probability that the pattern will further reduce or (at least) maintain the present uncertainty in the target's location, course, speed,and depth. Such a value criterion will necessarily be a function of the in-situ environmental conditions, the target type, and the coverage and geometry of the pattern involved. Given the need to manage sensors, this criterion should also consider the number of sensors remaining onboard the aircraft.

A.6.5 Variables and Parameters

A.6.5.1 Parameters. Six types of parameters are relevant to this decision task. The first two involve the target submarine. Target capabilities, such as speed, depth, and maneuvering limitations are necessary to predict possible target movements. Target characteristics, such as acoustical frequencies and source level emanation, are needed to determine the acoustic signature of the vehicle being tracked. The search area, as defined by the operating area and restricted area(s), constitutes a third type of parameter for this task. The possible or candidate sonobuoy pattern geometries for localization and tracking frequencies -- of the sensors availabe on the ASW aircraft are the fifth type of parameter. Finally, the movement capabilities of the ASW aircraft itself represent the sixth type of parameters.

A.6.5.2 Inputs. There are three kinds of inputs to the localization and tracking task. The first is the current situation ofthe target. This includes the estimated course, speed, depth, and location as well as the area of uncertainty and the history of the contact with the target. The second input is the status of the ASW aircraft's sonobuoy inventory -- the number of each type of sensors remaining available for deployment. The third input is the insitu environmental condition. The actual (or approximated) in-situ PL profile, the layer depth, the ambient noise,and the temperature versus depth profile are all included in this category of input.

A.6.5.3 Outputs. The outputs that would be meaningful in the decision task are evaulative indicators of candidate localization and tracking patterns. In particular, the coverage area, and estimated resolution of the targets' position, course, speed, and depth that a proposed pattern would yield are useful outputs.

A.6.5.4 Decision Variables. There is only one decision variable in this task, the next localization and tracking sensor pattern to be deployed.

A.6.6 Relevant Analyses

Some of the types of analyses relevant to the other pattern selection tasks (search pattern selection and investigation pattern selection) are also relevant to this decision task. An 'exclusion' analysis is needed to determine which among the candidate patterns violate the search area definition and/or current sonobuoy inventory. An optimization of the sensor patterns not so excluded is also needed. An analysis that is relevant to this task but not the other pattern selection decision tasks is a "trade-off" analysis which adjusts the value (i.e., utility) of a candidate pattern according to its demands on the current sensor inventory. Such an analysis might greatly penalize a pattern requiring many sensors if it were used late in the mission, when sensor inventories were low, but might penalize it much less early in the mission when sensor inventories are higher.

A.6.7 Relevant Displays

The displays required for this decision task are the same as for the other pattern selection tasks. First, the geometry of the suggested pattern must be displayed. Second, the types and settings of each sensor in this pattern must be displayed. And third, the fly-to-points, steering commands, and cueing sequences necessary to deploy the suggested pattern must be displayed.

A.6.8 Required Human Judgments

As in many other decision tasks, the ultimate acceptance or rejection of the aids suggestion must be left to the human operator.

The decision aiding requirements of the localization/tracking pattern selection decision task, as defined by the preceding description, are summarized in Table A-6.

A.7 TRANSITION FROM PASSIVE TO ACTIVE PROSECUTION

A.7.1 Objective

Initial search for targets and the early stages of the prosecution of the contacts gained are conducted with the used of passive acoustic sensors. As contact prosecution proceeds toward the attack phase of the mission increasingly detailed information on the submarine's location, course, speed, and depth, is needed. Although this information can be obtained from continued judicious use of passive sonobuoys, it can be obtained much more quickly and reliably from active sonobuoys. Unfortunately, however, active sensors have more restricted detection ranges, and will alert the submarine to the ASW aircraft's presence, even when the target is beyond the active sensor's detection range. Thus, transition from passive to active prosecution is desireable only when the target is definitely localized to within the active-sensor detection range. The objective of this

Table A-6. Localization and Tracking Characteristics Summary

Objective: Choose optimal localization ands tracking pattern, while conserving sensors for future mission phases.

Task Dynamics: Closed-Loop Iterative

Underlying Process: Movement of target through search area, possibly taking evasive action.

Value Criteria: Probability pattern to be deployed will decrease uncertainty in target location, course, depth, speed.

Variables and Parameters

Parameters

Target Characteristics
- Source Levels
- Frequency

Target Capabilities
- Speed, Depth, Maneuvering Limitations

Search Area
- Operating Area
- Restricted Area(s)

Candidate Sonobuoy

Sonobuoy Capabilities

ASW Aircraft Capabilities

Decision Variables

Pattern and Geometry

Inputs

Target Situation
- Location, Course, Depth, Speed
- History of Contact
- Uncertainty Area

Sonobuoy Inventory

Environmental Conditions
- PL
- Ambient Noise
- Temperature vs depth

Outputs

Coverage Area

Resolution of Candidate Pattern

Relevant Analyses
1. Exclusion Analysis of Patterns which Violate Situational Restrictions.
2. Optimization of Sensor Pattern.
3. Trade-off of Sensor Requirements with Pattern Coverage.
4. Probability of Detection for each Sonobuoy Pattern.

Relevant Displays
1. Pattern Geometry
2. Types and Settings of Sensors
3. Fly-to-Points, Steering Commands, and Cueing Sequences

Required Human Judgments

Final Acceptance/Rejection of Pattern Suggestions.

decision task is the determination of the earliest time at which effective transition between passive and active prosecution is warranted.

A.7.2 Task Dynamics

Once transition to active prosecution has occurred, the submarine will be alerted to its prosecution and begin evasive action. Prosecution must therefore culminate, shortly after this transition, or the contact will likely be lost. This decision function then is made only once in a prosecution sequence, and is independent of the preceeding or subsequent decisions.

A.7.3 Underlying Process

The process which unfolds during the decision task involves the movement of the submarine in or through the search area, (including any attempts at evasion on its part), and the movement of the ASW platform.

A.7.4 Value Criteria

The value criterion for this decision task will have to relate the present degree of uncertainty in the target's location, course, depth, and speed, to the amount required for a successful transition to active prosecution. The degree of uncertainty in each of these four components may not be the same, and each component may not weight equally or the desirability of transition to active prosecution at that time. Thus the value criteria must be a measure of target uncertainty relative to active sensor criteria which is explicitly sensitive to the differential importance of the various components of target uncertainty.

A.7.5 Variables and Parameters

A.7.5.1 Parameters. There are seven types of parameters which are relevant to this decision task. Two of them relate to the target being tracked. These are the target capabilities (speed, depth, maneuvering limitations, historical tracks), and the target characteristics (source levels and emitting frequencies). Two other types of parameters related to the acoustical sensors carried on board the ASW aircraft. The passive sensors' characteristics must be considered (e.g., type, settings, frequencies covered), as must be the active sensors' capabilities (frequency versus detection range). The fifth type of parameter considered in this decision task is the search area of the current mission, as defined by the operating area and any restricted areas. The sixth type of parameter is the capabilities of the ASW aircraft such as the speed and maneuvering limitations. Finally, the seventh type of parameter relevant to this decision task involves the various active sensor patterns that could be deployed, when active prosecution is considered appropriate.

A.7.5.2 Inputs. There are four sets of inputs which are used on this decision task. The first set of inputs covers the in-situ environmental conditions, such as the PL profile, the ambient noise levels, and the temperature vs depth profile. The second set includes the current information on the target being tracked -- its estimated location, course, speed, and depth, as well as the uncertainty in each estimate and the overall history of the contact. The remaining two types of inputs concern the ASW aircraft's sensors. The remaining number of each type of active and passive sensor on board the aircraft is one important input, and the location, type, setting, and remaining lifespan of each sensor already deployed are also important inputs to this decision task.

A.7.5.3 Outputs. Output variables in this decision task are quantities which relate sensor capabilities to the tactical situation at hand. The actual coverage area of each possible active sensor pattern (given the in-situ environmental conditions) is one such output. Another is the calculation of the uncertainty measure used as the value criterion.

A.7.5.4 Decision Variables. There are two decision variables within the passive-to-active transition decision task. First, the exact time at which to transition to active prosecution must be decided. Second, the type of active pattern to be used, once active prosecution has been decided upon, must be selected.

A.7.6 Relevant Analyses

There are two forms of analyses which are relevant to this decision task. The first is the (real-time) calculation of the attainment of the criteria for active prosecution i.e. determination of when the target is within active-sensor detection range. The second is the optimization of the type of active sensor pattern to be deployed.

A.7.7 Relevant Displays

The fact that active sensor criteria have been gained must be displayed to the TACCO as soon after it has been determined as possible. If multiple criteria for active prosecution exist, the specific set of criteria met should also be displayed. The geometry of the suggested active pattern must be displayed, along with the type and settings of the sensors to be deployed. Finally, the cueing sequences, steering commands, and fly-to-points relevant to deploying the suggested pattern should be presented.

A.7.8 Required Human Judgment

There are two judgements which must be left to the human decision-maker. First, the TACCO must decide whether or not to transition at all to active prosecution. While active prosecution may greatly increase the speed at which attack criteria are gained, it also greatly increases the likelihood of alerting the submarine to the ASW aircraft's presence and allowing it to escape the contact. An experienced TACCO who is unconstrained with regard to passive sensors or on-station time may prefer to take the slower but surer route of all-passive prosecution, and thus may opt to ignore any recommendation that a transition to active prosecution is possible. However, should the TACCO decide to begin active prosecution, he must also be responsible for the final acceptance/rejection of any suggested active sensor pattern.

The decision aiding requirements of the transition from passive-to-active prosecution decision task, as identified by the preceding description, are summarized in Table A-7.

A.8 ATTACK PLANNING

A.8.1 Objective

After gaining contact with a hostile submarine, the ASW aircraft will attempt to determine the precise location, course, speed and depth of the target. All of these will always be subject to some uncertainty, but when the uncertainties have been reduced to a certain level an attack may be placed on the target. The objective of the attack planning decision function is to determine the optimal tactics for such an attack.

A.8.2 Value Criteria

In theory this decision function is performed only once, but there is always a chance that the attack will fail and another required. The tactics associated with each subsequent attack will be affected by the outcome of each preceeding one. Thus, this attack planning decision dynamics are sequentially contingent.

A.8.3 Underlying Process

The attack planning decision task concerns the process of attacking the hostile submarine. This process includes the submarine's movement and possible evasive efforts, the motion of the ASW aircraft itself, and the actions of any weapon that is deployed by the ASW aircraft.

Table A-7. Passive to Active Transition Characteristics Summary

Objective: Determine when target has been sufficiently localized so that prosecution with active sensors can effectively begin.

Task Dynamics: Multidimensional Independent

Underlying Process: Movement of Hostile Submarine and ASW Aircraft in Search Area.

Value Criteria: Measure of overall uncertainty in target location, course, speed, and depth, relative to detection capabilities of active sensors.

Variables and Parameters

Parameters

Target Capabilities
- Movement, Depth, Speed Limitations
- Historical Tracks

Target Characteristics
- Source Levels
- Frequencies

Passive Sensor Capabilities
Active Sensor Capabilities
ASW Aircraft Capabilities
Search Area
- Operating Area
- Restricted Area

Active Sensor Patterns

Decision Variables

Pattern and Geometry
Type of Active Pattern to Deploy

Inputs

Target Situation
- Est. Location, Course, Depth, Speed
- Uncertainty Area
- History of Contact

Sensor Inventory
Deployed Sensors
- Type, Setting, Location
- Remaining Lifespan

Environmental Conditions
- PL Ambient Noise
- Layer Level

Outputs

Coverage Area of Active Patterns
Measure of Target Uncertainty Relative to Active Sensor Capabilities

Relevant Analyses

Real Time Calculation of Attainment of Active Sensor Detection Criteria
Optimization of Active Sensor Pattern

Relevant Displays

Attainment of Active Sensor Criteria; Criteria Used
Geometry of Suggested Active Sensor Pattern
Types, Settings of Sensors in Pattern
Cueing Sequences, Steering Commands, Fly-to-Points to Deploy Pattern

Required Human Judgments

Whether or not to attempt Active Prosecution
Acceptance/Rejection of Suggested Active Pattern

A.8.4 Value Criteria

There are two separate but related value criteria for this decision task, both of which are probabilities. The first probability is the probability that the ASW weapon system is able to acquire the target subsequent to the weapon's deployment. The second probability is the probability that the weapon will hit the target. The second probability is obviously lower than, and dependent upon, the first, but it also provides a criterion more relevant to the decision task objective.

A.8.5 Variables and Parameters

A.8.5.1 Parameters. This decision task involves many of the same parameters as to the preceeding one. That target acoustic characteristics are relevant specifically source levels and frequencies, as are the target capabilities, in terms of speed, depth, and maneuvering limitations. Target historical tracks are also parameters unique to the attack planning task is the capabilities of the weapons carried by the ASW weapon. The capabilities of interest include the types of weapons available, and the settings, speed, run-time, operating modes, search frequencies, and homing frequencies of each weapon type.

A.8.5.2 Inputs. Inputs to this task are two basic types. First are the in-situ oceanographic conditions -- the PL, ambient noise, temperature vs depth profile, etc. Second, are the variables which describe the history of the contact with the target being attacked. Prime among these are the current or most recent target position, course, depth, and speed, as well as its area of uncertainty.

A.8.5.3 Outputs. Since oceanographic conditions can have such a major impact on weapon system effectiveness, one useful output would be the effective range of each type weapon in the current environment.

A.8.5.4 Decision Variables. The decision variables for this task comprise an overall attack plan. The weapon to be used and the setting must be selected, as must the time to deploy the weapon, and the location to deploy the weapon. The aircraft's course, altitude, and speed at the time of deployment must also be decided.

A.8.6 Relevant Analyses

There are two forms of analysis which are relevant to this task. First, the results of any possible attack on the submarine by the ASW platform must be predicted in some manner. Second, the results of the potential attack must be optimized (in terms of the task's value criteria) overall possible attack plans in light of the in-situ environmental conditions, to determine the optimal way of attacking the submarine.

A.8.7 Relevant Displays

The information which should be displayed in the attack planning decision function concerns the details of the selected optimal attack plan. The projected target position, track and uncertainty area should be displayed, along with the weapons release point and time. The path of the ASW aircraft to the weapons release point from its current position should also be displayed. The fly-to-points and steering commands necessary to capture the weapon release point should be presented, as should the cueing sequences necessary to select, set, and deploy the weapon.

A.8.8 Required Human Judgments

The acceptance of the suggested attack plan, or its modification because of situation or experiential information must ultimately lie with the human operator.

The decision aiding requirements for the attack planning decision task, as defined by the preceding description, are summarized in Table A-8.

Table A-8. Attack Planning Characteristics Summary

Objective:	Determine optimal tactics for attack on a hostile submarine.
Task Dynamics:	Sequential Contingent
Underlying Process:	Attack on Hostile Submarine by ASW Aircraft
Value Criteria:	1. Probability of Weapon Acquiring Target. 2. Probability of Weapon Hitting Target.

Variables and Parameters

Inputs

Oceanographic Conditions
- PL
- Ambient Noise
- Temperature vs Depth

Weapons Remaining

Target Situation
- Location, Course, Depth
- Speed
- Area of Uncertainty

Outputs

Weapon Range Given Environmental Conditions

Parameters

Target Capabilities
- Depth, Speed, Maneuvering Limitations
- Historical Tracks

Target Characteristics
- Source Levels
- Frequencies

Weapon Capabilities
- Types, Settings, and Modes
- Speed, Runtime, Depth
- Search and Homing Frequencies

Aircraft Capabilities

Decision Variables

Plan of Attack
- Weapon, Setting
- Release-Point
  Time, Flight Path

Relevant Analyses

1. Prediction of Attack Results
2. Optimization of Attack Plan

Relevant Displays

Attack Geography
- Target Location, Track, Uncertainty Area
- Weapon Release Point, Aircraft Flight Path

Type and Setting Weapon for Attack

Fly-to-Points, Navigation Commands to Capture Weapon Release Points

Cueing Commands to Set, Arm, Deploy Weapon

Required Human Judgment

Acceptance/Rejection of Attack Plan

APPENDIX B

AIRCRAFT SYSTEM SOFTWARE MODULE DESCRIPTIONS

B.1 P-3C MODULES

B.1.1 Executive

This activity consists of a closely associated group of modular elements designed to provide the P-3C UPDATE Operational Software System with the necessary control and overall resouce management for the applications tasks. The main processing accomplished by the Executive is as follows:

- Loading of the operational program into core and drum.
- Initializing of Executive Control Tables and queues.
- Scheduling, dispatching, and termination of demand or periodic applications tasks.
- Managing of core and drum resources as related to applications transient tasks and files.
- Controlling of all I/O channels and their associated interrupts and specific handlers for the magnetic tape transport and drum.
- Processing of the power up, power down, program fault, memory protect fault and count down clock interrups.
- Providing sufficient analysis and debug aids to develop a program.

B.1.2 Initialization and Control

This function controls the initialization of the applications data base prior to the addition of apriori or recovery data. It also controls the initialization of all P-3C UPDATE II peripherals connected to the 16 I/O channels of the CP-901.

B.1.3 Display

This activity is composed of four functions:

- Manual Entry - Supports the use of cues, alerts, switch illumination, the hook and switch depression.
- Display Control - Supports the operation and control of the MDDs. This support includes: mode changes, buffer control, peripheral data update, single item and data set symbology maintenance, scale and center changes and the amplify and recall functions.
- Display Aids - Provides various manipulative aids to the operator which include functions such as the deisgnation of a symbol to another station (display line, circle), mark, various insert LAT/LONG and various position support processes.
- Tableau Control - Provides the support for line select and line modification, provides a generalized and standardized interface for tableau control and service function, and supports the Index tableaux at NAV/COMM, TACCO, SS-1/2, and SS-3.

B.1.4 Navigation

This activity is responsible for maintaining present aircraft position and its relative position to all aircraft deployed search stores (buoys), contacts and fixes. The Navigation activity includes the OMEGA and Steering subsystems.

B.1.5 Communications

This activity provides the means to transfer data between the P-3C UPDATE Operational Software System and other operational units, including aircraft, the Tactical Support Center, and surface ships, via Data Link or teletype.

B.1.6 Nonacoustic Sensors

This function provides the equipment interface control, display control, and the data management services necessary to employ the radar, ESM and MAD sensors to detect, record, localize and track contacts of interest.

B.1.7 Acoustic Sensors

This activity is responsible for RF management and acoustic contact entry either through operator evaluation or Passive Acoustic Detection and Classification (PADs).

B.1.8 Tactical Control

This activity is responsible for the arrangement and interpretation of the aircraft's position in coordination with total sensor information. This activity is composed of the following four functions:

- Tracking - Provides for tracking of the target.
- Pattern Tactics - Provides for the establishment of buoy patterns for tactical use.
- Contact Management - Provides for the maintenance of an accurate information system on contacts.
- FTP Control - Provides for the control of the flight path and destination of the aircraft.

B.1.9 Armament

This function is responsible for the control processes, status checks and computations involved in the selection and launch of weapons. It also has the responsibility of maintaining inventory, establishing FTPs for preselected drop points, issuing release commands and checking for store releases.

B.1.10 Ordnance

This function is responsible for the control processes, status checks, and computation involved in the selection and release of search stores. It also enables TACCO to select standard or nonstandard search inventories and maintains the inventory status throughout the flight.

B.1.11 Recovery

The Recovery function is responsible for recording and retrieving the data necessary to reinstate the system to an operational condition following a system failure.

B.1.12 Data Retrieval

This activity provides the functional capabilities necessary to analyze and selectively print records of the extraction tape. It also enables the operator to initiate the retrieval operation and specify the reporting requirements.

B.1.13 Apriori

This function provides for the retrieval of the apriori data from a preestablished data file of the P-3C UPDATE II system load tape and for the insertion of the data into the Operational Program data base.

B.1.14 System Services

This subsystem provides for common service routines used through the system. The mathematical trigonometric functions, DCD to octal conversions, etc., are handled by this subsystem.

B.1.15 SRS

This subsystem provides for the management of the Sonobuoy Reference System. RF phase measruements are converted to sonobuoy positions which more accurately described the tactical situation.

B.1.16 IRDS

This subsystem provides for the management of the infrared camera aboard UPDATE II aircraft.

B.2 LAMPS ENTITIES

B.2.1 System Management and Control

1. System Initialization and Recovery - assures orderly and proper initial startup and/or restart of the avionic system hardware and software including system mode control - provides software data recovery capability.

2. Tactical Processing - provides, in response to operator keyset inputs, display symbol control functions relating to the tactical situation display - provides symbol track management to enable the operators to record contact detections, and to implement speed, course, and predicted position computations.

3. System Status Monitoring - acknowledges and verifys bit responses - determines operational status of avionic system equipment - generates operator alert and equipment failure indication messages as a result of detected system failures - performs system operational readiness tests.

4. Data Extraction - gathers specified computer system data and statistics - gathers specified mission profile and LAMPS system status data at specified intervals as a function of system state - stores the gathered data in an appropriate buffer area - outputs the data to the mission profile data tape.

5. Input/Output Control - performs I/O operations in response to demands of the computer program - performs I/O operations in response to demands imposed on the computer program by external equipment.

B.2.2 Sensor Subsystems

1. Radar - enables the ship or helicopter operators to control the helicopter radar - supplies data to the SDC for radar display stabilization and orientation - processes IFF interrogation data from the ship.

2. ESM - initializes ESM set - displays priority contacts to airborne operators - transfers ESM data to ship.

3. Acoustics - controls commands for CASS and DICASS sonobuoys - tunes sonobuoy receivers - controls the processing of acoustic data in the Analyzer - Detecting set - controls the display of acoustic data.

4. MAD - provides the display of MAD contact data - controls interface for manual entry of MAD data.

B.2.3 Display

Controls keyset processing logic as a function of the Airborne Tactical Officer (ATO) and Sensor Operator (SO) keyset inputs - performs legality checks on keyset inputs - generates control and display of the tactical situation geometry, sensor data, and tabular data - processes and displays cues and alerts - controls display modes.

B.2.4 Ordnance

Maintains an up-to-date inventory of all sonobuoys - selects stores for release during mission - calculates the weapon release points for torpedoes - calculates the water entry points for sonobuoys and torpedoes - launches selected sonobuoys automatically.

B.2.5 Data Link

Provides an interchange of commands and data between the airborne and shipboard computers - provides data link control - determines functions to be scheduled to process received data - provides a validity check on received data and insert validity parameters in transmitted data - informs the status monitor function when the data link is not operational.

B.2.6 Navigation

Maintains a helicopter and ship position in and X and Y coordinate system, referenced to a common point - provides helicopter/sonobuoy field stabilization through buoy overflight techniques and subsequent computation and incorporation of bias velocity - provides navigational parameters for sensor processing and equipment operation - computes bearing and range to designated fly-to-points.

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