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THE DESCRIPTION OF THE MULTI-MODE DISPLAY SYSTEM,(U)
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DESCRIPTION OF THE MULTI-MODE DISPLAY SYSTEM

by

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D. A. Hanna

Simulation, Analysis and Applications Division (Code 603)

December 1970

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San Diego, California

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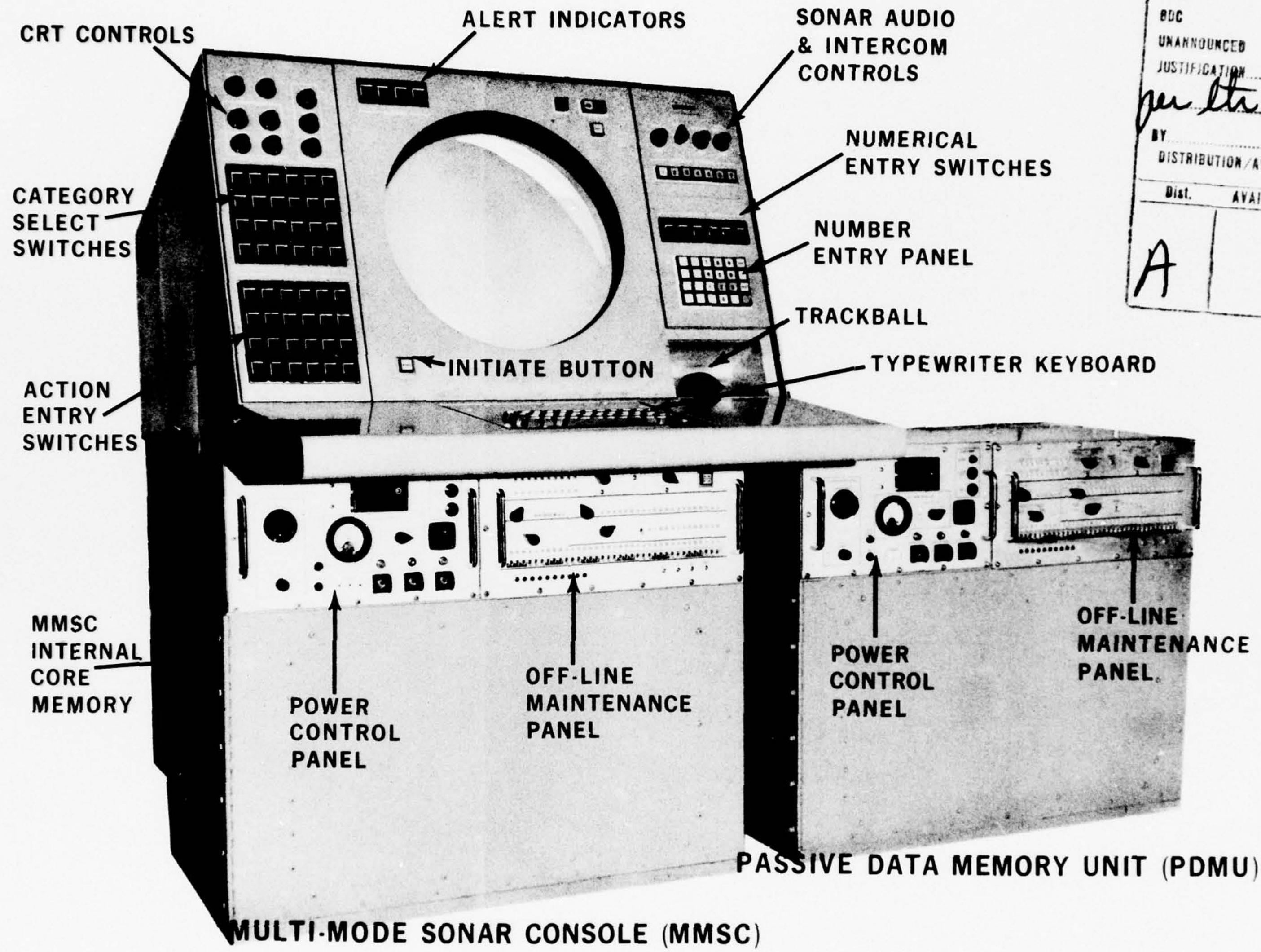

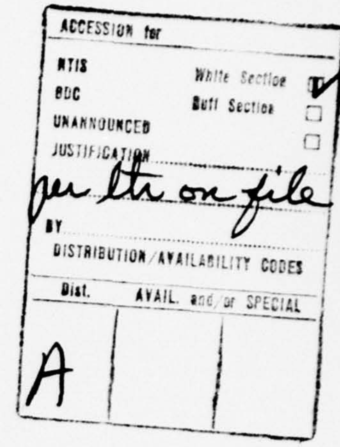

PRIMARY UNITS OF MULTI-MODE DISPLAY SYSTEM

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INTRODUCTION

This technical note describes the equipment and operation of the Multi-Mode Display System (MMDS). The MMDS was designed and developed to evaluate the feasibility of using a single display console hardware configuration to perform all the display functions required for advanced computer-aided ASW systems. A single console configuration is proposed here as an alternative to the present practice of using a special-purpose display design for each system function.

The MMDS concepts were developed by NUC in support of the AN/SQS-26 Preselector project, the New Submarine Sonar/Fire Control project and the Conformal/Planar Array Sonar System project.[1] The MMDS hardware was designed and fabricated by the Hughes Aircraft Company of Fullerton, California, according to NUC specifications under Contract N00123-67-C-0833.[2] The equipment was delivered to NUC-San Diego in May 1969 and received final hardware acceptance in April 1970. Total development time from conceptual design studies to hardware acceptance was approximately 5 years.

The major components of the system are the Multi-Mode Sonar Console (MMSC) and the Passive Data Memory Unit (PDMU). This equipment is operational and is presently located in the NUC Display/Simulation Facility at NUC-San Diego. Equipment maintenance and operation are under the direction of the Simulation, Analysis and Applications Division, NUC Code 603.

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[1]Superscript numbers denote references at end of the technical note.

EQUIPMENT AND OPERATION

The Multi-Mode Display System could be configured with up to seven Multi-Mode Sonar Consoles and a single Passive Data Memory Unit. The system is capable of providing a versatile display capability for sonar, fire control, command and control, radar and other computer-aided functions for an advanced ASW system. The MMSC and the PDMU interface with either the militarized UNIVAC CP-642B/USQ-20B or the UNIVAC 1230 computer. All data presented by the system are processed, formatted, and transmitted to the MMDS by computer.

Multi-Mode Display Console

The MMSC is a stored-program general-purpose display console. The programs required to drive the display and the data to be displayed are stored in the console's 8192/36-bit-word random-access memory. Information is displayed on the console CRT by cycling through the memory under control of the stored program. Selectable frame rates of either 35, 39.5 or 50 fps permit a steady-state, nonflickering display.

Considerable flexibility in the operation of the MMSC is realized through the software control of most display functions and through numerous operator interaction capabilities. For example, the following display parameters are defined and controlled by the display software:

- Data display format.
- Legends, labels and other descriptors.
- Switches and indicators enabled.
- Legends shown on each switch.

The software also establishes the link between actions of the operator (via trackball or switches) and the effect produced on the display. Thus, motion of the trackball by the operator can result in motion of a displayed cursor in one case and changes in display marking density in another.

Operator control of the display functions and/or interaction with the displayed data can be exercised through:

- 30 multiple-legend action entry switches.
- 24 multiple-legend category select switches.
- 4 alert indicators.

- An alphanumeric typewriter keyboard.
- A trackball (or a stiffstick)
- A number entry panel.

Each of the multiple-legend switches can illuminate 12 different legends, with the selection of the appropriate legend subject to software control. The film chips which contain the 12 legends for each switch or indicator can be easily modified, thus providing even more operational flexibility. The arrangement of the various control devices is shown in the frontispiece of this note.

The MMSC provides its own computer interface, data transmission, symbol generation, and data refresh independently of the PDMU. The data refresh is accomplished by means of a core memory within the MMSC which stores and recirculates all data needed to refresh the console CRT. Because of the internal refresh memory, transmission from the computer to the MMSC is required only when there is a change in the data presented. Thus, the demands on the computer are minimized, and the computer can simultaneously drive the MMSC and perform other processing functions.

The MMSC can be programmed to display alphanumerics, special symbols and lines as shown in Figure 1, as well as digital raster data. There is no provision for displaying unprocessed analog data on the MMSC. A detailed description of programming characteristics for the MMSC and PDMU is contained in reference 3.

Important features of the MMSC hardware are itemized in Table 1.

FIGURE 1. EXAMPLES OF ALPHANUMERICS, SYMBOLS, AND LINES AS DISPLAYED ON THE MMSC.

TABLE 1. MMSC HARDWARE CHARACTERISTICS

Note: Superscript numbers in parentheses denote paragraphs following the table which contain supplementary explanations.

CRT	
Size (quality viewing circle):	15 in.
Phosphor:	P31
Maximum brightness:	25 ft-Lamberts
Spot size:	17 mils avg
Deflection method:	Electrostatic
Deflection settling time:	4 μsec
Internal Memory	
Type and size:	Core: 8192 words, 36 bits per word(1)
Cycle time:	2 μsec (1 μsec access time)
Uses:	Stores data for several formats; stores symbol codes(2); stores program for current format(3); serves as refresh memory
Features:	Block load/unload
Symbolic Display	
X-Y addresses:	1024 x 1024
Symbol library size:	512 max per console; programmable(2)
Symbol source:	Software(2)
Symbol generation time:	4 μsec(2) (typical)
Symbol/sec:	125,000 (max)
Frame rate:	35 and 50 fps (internal control)
Symbol capacity at	
35 fps:	3500
50 fps:	2500
Individual symbol intensity:	8 levels, computer control
Individual symbol size:	2 sizes, computer control
Lines	
Length:	Up to 2 in.
Writing rate:	0.5 in./μsec (constant)
Accuracy:	±1 spot diam.

TABLE 1. MMSC HARDWARE CHARACTERISTICS (Cont)

Digital Raster	
Type:	Rectangular digital sweep
Primary use:	Display of passive sonar data
Data source:	Computer via PDMU
Frame rate:	39.5 fps
Intensity:	8 levels, computer control
Man/Computer Interfaces	
Action entry switches[5]:	30 (6 located above number entry panels; computer controlled legends)
Category select switches:	24 (computer controlled legends)
Alert indicators:	4 (computer controlled legends)
Legends per switch:	12, selectable in software
Numerical entries:	Pushbutton keyboard[6]
General entries:	Typewriter keyboard
"Continuous" entries:	Trackball or stiffstick[7]
Console/Computer Interface	
Input control:	Console interrupts computer on priority basis
Consoles per computer I/O channel:	7 maximum
Reliability and Maintainability	
Mean time between failures:	500 hr predicted. (All solid state components except 1RT)
Accessibility:	Front only
Automatic on-line fault location:	To module level for all digital circuits[8]
Off-line maintenance:	Via integral maintenance panel
Mechanical and Power	
Size:	34" wide x 51" high x 45" deep[9]
Weight:	700 lb
Disassembly:	Disassembles to pass through standard 25" circular submarine hatch
Power (400 cycle):	<2 kW
Cooling:	Water-cooled
Environmental requirements:	Designed to MIL-E-16400 but not tested for compliance
Other Features	
a. Audio:	Intercom and sonar audio

MMSC Hardware Details

The following paragraphs more fully describe or explain the hardware features presented in Table 1. The numbers in parentheses correspond to the superscript numbers of the table.

(1) Words of 36 bits are required only for internal MMSC functions. The MMSC is designed to interface with the UNIVAC USQ-20B and the 1230 30-bit word computers. It could be easily modified to interface with the AN/UYK-7 computer which uses 32-bit words.

(2) Each MMSC symbol (shape) is specified by at least a 36-bit code. A library of up to 512 symbols provides great flexibility, as new symbols can be "invented" and added at any time without hardware changes.

(3) The computer can store up to 256 cells of instructions in the console memory. These instructions specify the format in detail and specify which blocks of data in memory are to be displayed.

(4) The "frame rate" is the number of times per second that the display is refreshed. The MMSC's frame rates are high to permit flicker-free operation at high ambient brightness levels.

(5) The choice of which set of the switches will be illuminated and what legend will be displayed on each switch at any given time is determined by the computer under software control. Each of the 54 switches and 4 alert indicators contains a film chip that allows any of 12 different legends to be displayed (by rear projection) on the front surface of the switch. The film chips can be easily replaced with new chips containing new sets of legends.

(6) The MMSC alphanumeric typewriter keyboard is located in the bullnose. It can be flipped over when not in use, leaving the bullnose completely flat. Typewritten comments can be positioned anywhere on the CRT as desired by the operator.

(7) The MMSC is currently configured with a trackball for providing two dimensions of continuous operator control. A stiffstick to be installed in the near future will offer an alternative form of control.

(8) The MMSC is divided for maintenance reasons into functional modules containing 1 to 7 cards. Automatic diagnostic routines can be periodically initiated by the computer to test all portions of the digital logic. These routines will determine the existence of a fault condition and localize the fault to within a functional module without disturbing normal on-line console operation. This testing requires no initial operator participation and occurs without his knowledge, except when a malfunction is detected. Replacement of any modules can be accomplished in less than 20 minutes with the exception of the CRT module, which requires 30 minutes. Additional manual tests to further isolate the fault may be performed in an off-line mode using the specially designed off-line maintenance panel.

(9) The 45-inch-deep dimension for the MMSC includes a 13-1/2-inch bullnose, which can be folded upward or removed for clearance.

Passive Data Memory Unit

The second major hardware component of the MMDS is the Passive Data Memory Unit. This unit is a programmable 8192, 36-bit word random-access memory for data display formats which require use of the digital raster. The stored raster data are formatted under program control providing considerable format flexibility, as in the MMSC. The PDMU memory module, low-voltage power supply, and many of the digital logic cards and mechanical assemblies are identical to those in the MMSC, and may be directly interchanged between the two components. Primary characteristics of the PDMU hardware are listed in Table 2.

The PDMU is programmable in the sense that the computer stores a 32-word program in the lower portion of the PDMU memory. This program is executed once each frame and produces a format on the MMSC consisting of one to fifteen bands. The number of lines in each band, the number of bands and the width of blank separating bands are specified by the 32-word program. The height of each line is fixed at 15 mils. The total number of lines, the number of horizontal segments per line (beams) and the width of each beam can all be varied through a number of discrete values. The options available are listed in Table 3.

TABLE 2. PDMU HARDWARE CHARACTERISTICS

Memory Parameters	
Type and size:	Core: 8192 words, 36 bits per word (same as MMSC)
Cycle time:	2 μsec (1 μsec access time)
Data source:	Computer
Uses:	Stores passive sonar data for several raster formats; stores program for current format; serves as memory refresh
Features:	Block load/unload
PDMU Interfaces	
PDMU's per computer I/O channel:	1 maximum
PDMU/MMSC I/O capacity:	Up to 7 MMSC's per PDMU
Frame rate:	39.5 fps
Reliability and Maintainability	
Mean time between failures:	800 hr predicted. (Solid state circuitry used throughout)
Accessibility:	Front only
Automatic on-line fault location:	To module level (same as MMSC)
Off-line maintenance:	Via integral maintenance panel
Mechanical and Power	
Size:	34" wide x 27" high x 26" deep
Weight:	500 lb
Disassembly:	Disassembles to pass through standard 25" circular submarine hatch
Power (400 cycle):	<1 kW
Cooling:	Water-cooled
Environmental requirements:	Designed to MIL-E-16400 but not tested for compliance

TABLE 3. RASTER FORMAT OPTIONS

Format No.	No. of Lines (max)	No. of Beams (max)	Beamwidth (mils)
1	680	144	60, 30, 15
2	340	288	30, 15
3	680	144	30, 15
4	680	72	120, 60, 30
5	680	72	120, 60, 30
6	816	120	60, 30, 15
7	408	240	30, 15

Note: Line height = 15 mils.

In these formats, the brightness of each beam is set at one of the eight brightness levels by the computer program which defines the format.

The options available as described above can be utilized to generate a variety of passive sonar BTR-like displays.

MMDS SOFTWARE

In this section some of the present applications of the MMDS are discussed, the chief purpose here being to round out the general picture of the system software. More detailed discussion of selected applications will appear in future reports.

As noted, considerable flexibility in utilizing the MMDS stems from the fact that its performance is defined to a large extent in the software developed for it. In essence, the range of functions the system is capable of serving is limited only by the data that can be provided and the computer programs that can be prepared. To date, computer programs have been generated for operation in the following modes: sonar (active and passive), fire control, command and control, maintenance/fault isolation, data analysis, and special purpose. Programs for additional operating modes are being developed.

Each operational mode on the MMDS consists of a variety of data presentation formats and associated legends, labels, and operator control responses. Some examples of formats which have been implemented on the MMDS are illustrated in Figures 2 through 5. The explanatory captions appearing with these photographs of the CRT display are amplified in the next subsection of the regular text. The data displayed in each format are organized and formatted under computer control. The multiple-legend switches, number entry pushbuttons and the trackball provide the means for the operator to select between different operational modes and presentation formats.

At present, more than 30 different formats are operational on the MMDS, many of them with several optional forms. These formats offer such diverse data sets as acoustic intercept data, 3-D presentations, acoustic ray trace, torpedo tracking data, and sonar passive classification data. Much of the sonar data used with the MMDS is real data taken from recordings made at sea on operating ships. A great wealth of such sea data is available from the Data Acquisition, Processing and Analysis Group, NUC Code 6006 in San Diego.

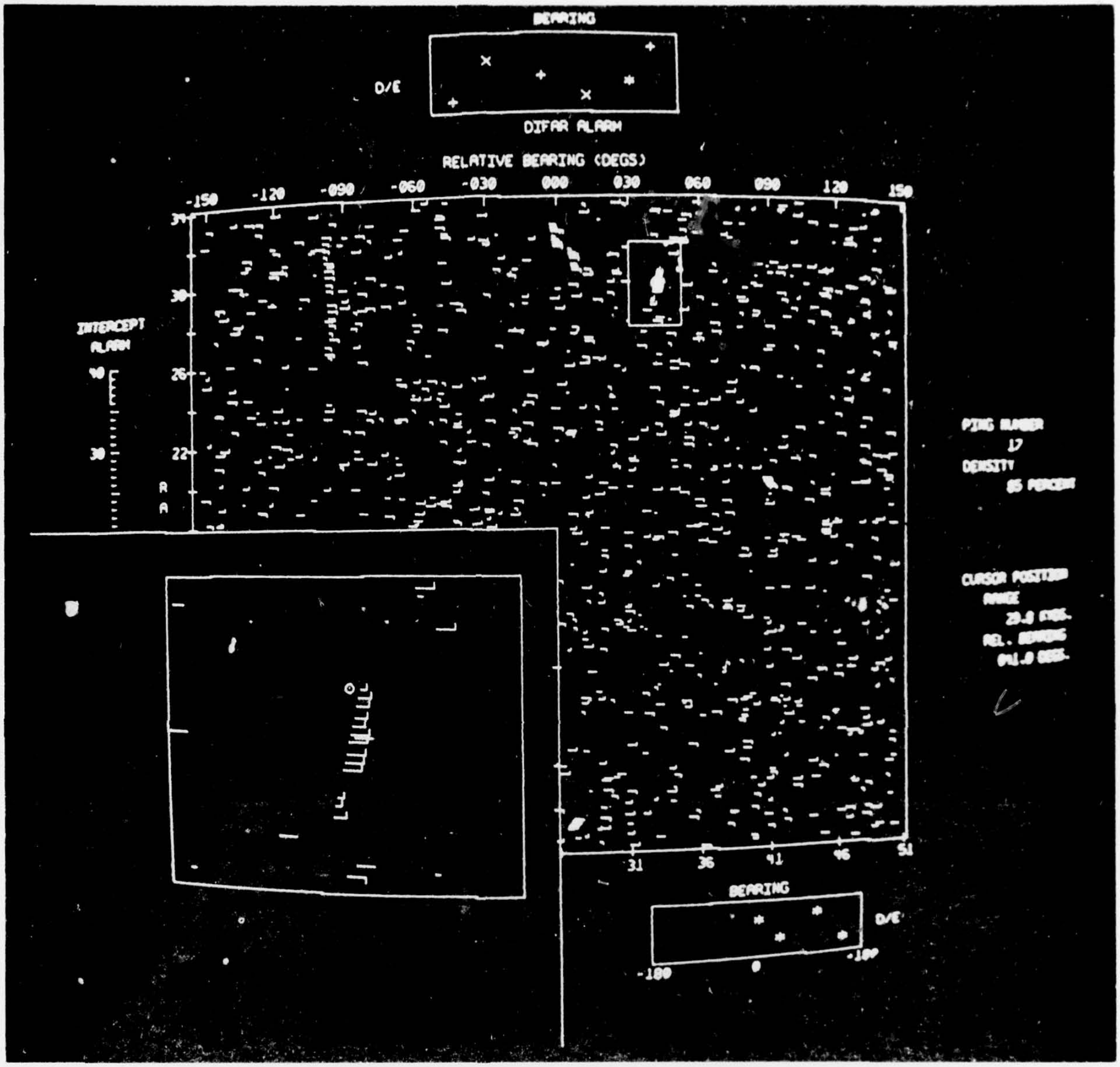

FIGURE 2. ACTIVE SEARCH SONAR FORMAT

Shown here is a simulated active search format presenting a 16-ping history in a range vs bearing plot. The figure illustrates the use of the "expanded area" option which expands the data in the small rectangle and presents it in the diagonally opposite quadrant. In normal operation, the lower-left quadrant would appear much like the other three quadrants shown. (For a more complete description of this format, see main text.)

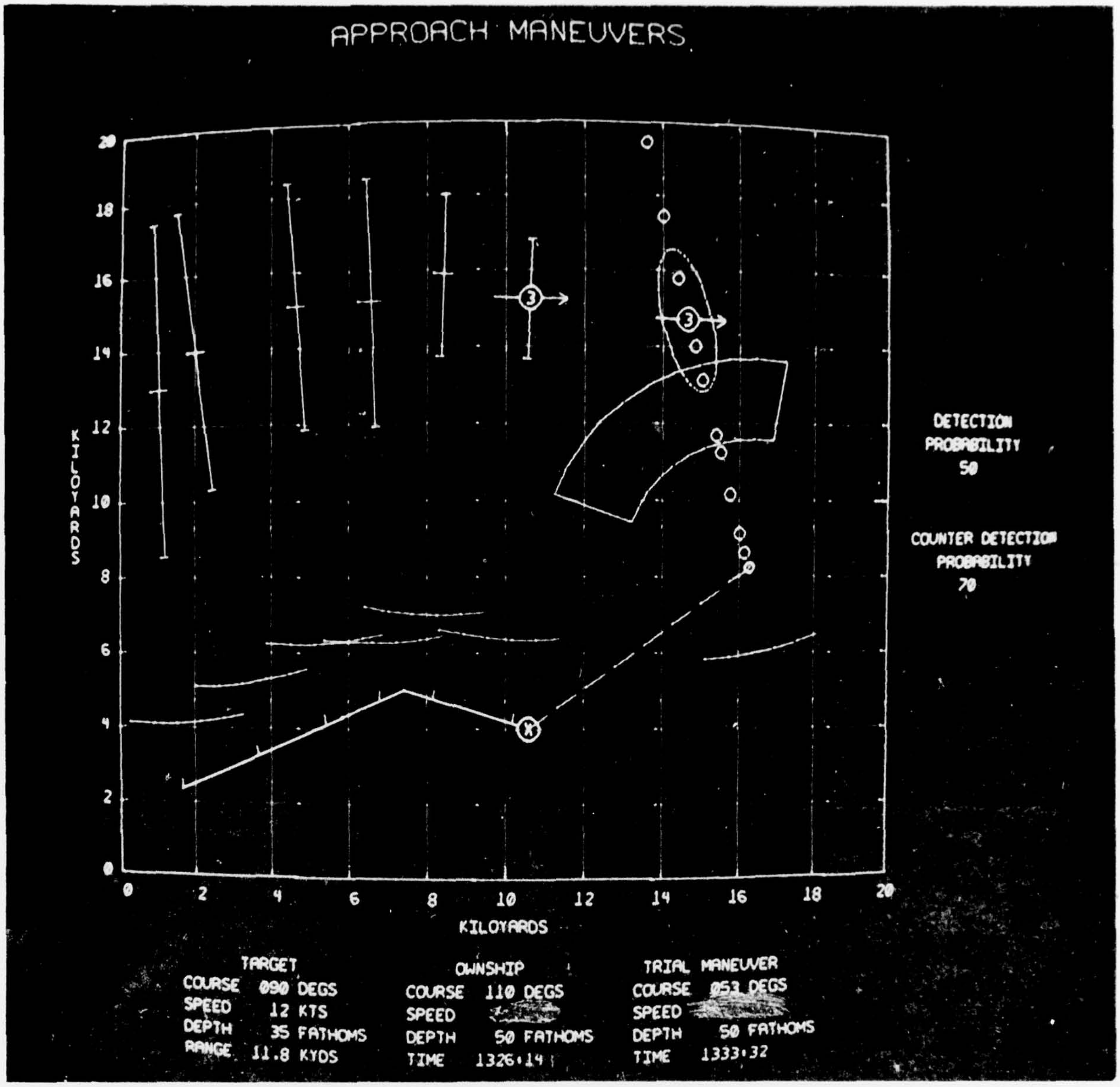

FIGURE 3. COMMAND SUMMARY - APPROACH MANEUVERS FORMAT

This format provides a summary of a tactical encounter between own-ship (shown at the bottom) and target No. 3. It shows the history of past maneuvers of the two ships during a tracking situation, and also the predicted tuture positions based on an assumed trial maneuver by own-ship. The predicted future status includes the target's estimated position, course and speed; estimates of counter-detection probabilities; and weapon kill contours for each weapon in own-ship's arsenal. (See main text for more details.)

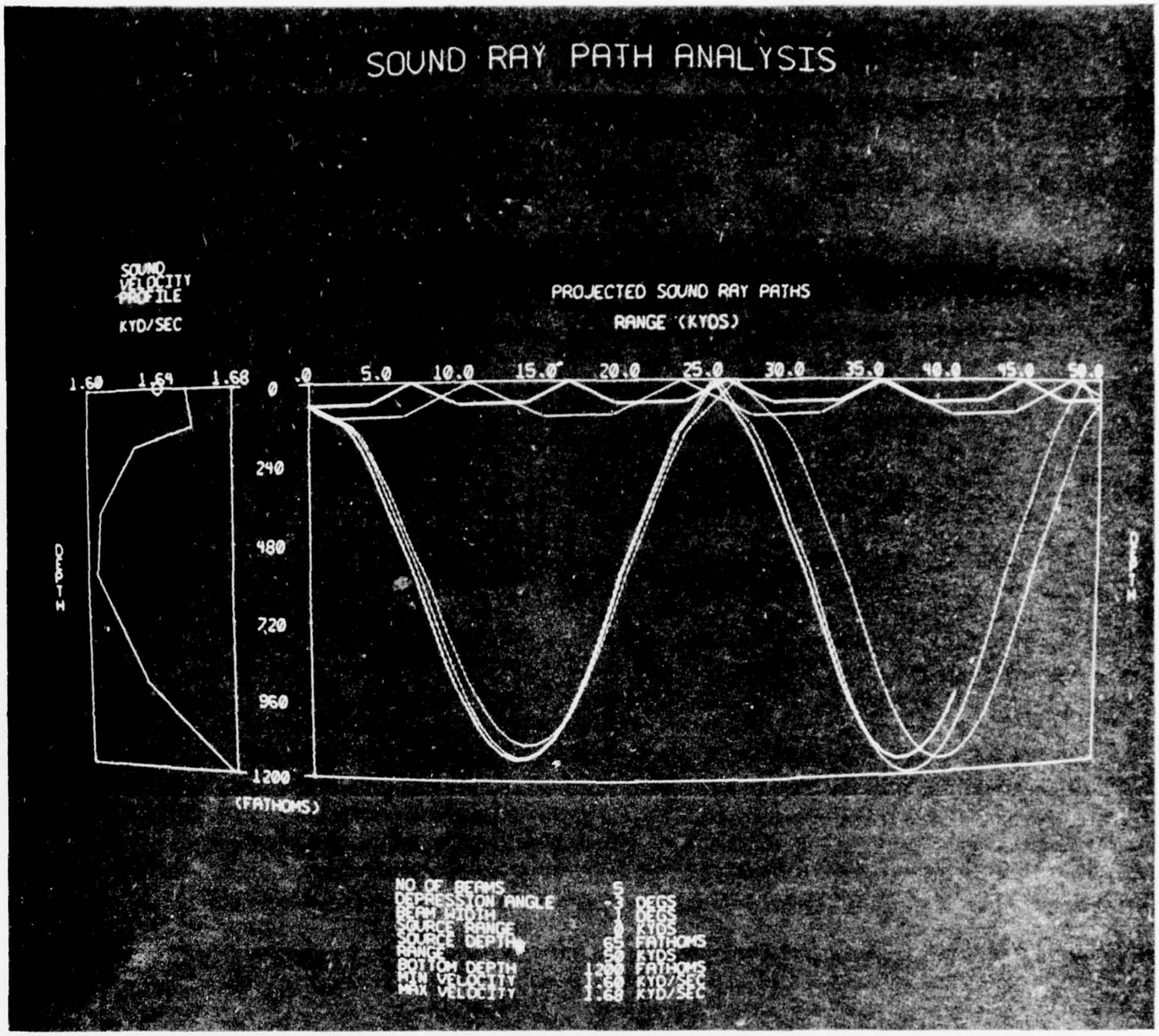

FIGURE 4. SOUND RAY PATH ANALYSIS FORMAT

This format offers a real-time, operator-controlled sound ray path analysis capability that makes it possible to analyze the local acoustic environment of own-ship in real time to determine such important parameters as best operating depth for passive search, ocean areas actually under surveillance during active or passive search, and best depth to avoid detection. (For a detailed description of this format, see main text.)

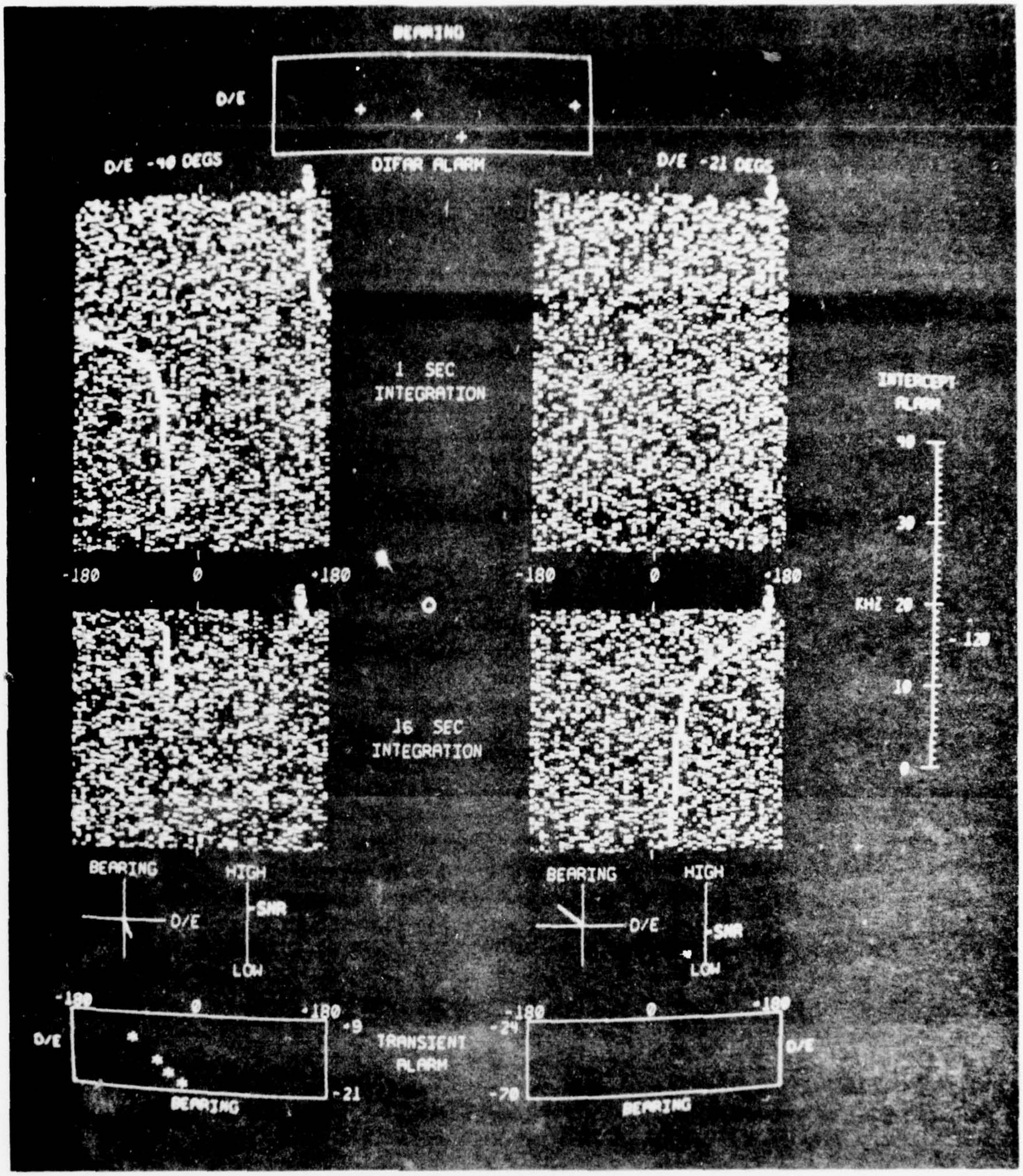

FIGURE 5. PASSIVE SEARCH/TRACK SONAR FORMAT

This format consists of sets of BTR-like data displays (simulated data used) to represent a passive search/track mode operating at two different D/E angles and two different integration times. (For a fuller description of this format, see main text.)

Description of Illustrated Formats

The following paragraphs describe the formats pictured in Figures 2 through 5 more fully than the captions appearing with these photographs.

Active Search Sonar Format (See Fig.2)

General Format: The format presents a 16-ping history of active search data in a range vs bearing plot. Each data point is encoded with both amplitude information shown by the horizontal length of the symbol and doppler shown by the hook orientation. An upward-directed hook signifies opening doppler, no hook means zero doppler, and a downward-directed hook denotes closing doppler.

Format Variations: (1) The same data can also be shown in a time-compressed mode during which each of the echoes of the 16-ping history is brightened in chronolgoical order but much faster than real-time. This cycle is repeated at a rate of approximately once per second. (2) The range scale can be compressed (at the touch of an action entry switch) to one-half or one-quarter of the full scale shown. (3) Any one or any two of the doppler categories can be suppressed and not shown. This greatly reduces the clutter for the doppler categories which remain. (4) The display of various amplitude categories of events can be suppressed. This reduces the clutter for the remaining categories. (5) The marking density of the display can be varied continuously under trackball control. The current marking density is displayed to the operator to the right of the data block.

Cursor Control and Tracking Aids (Expanded Area Capability): The operator can position a cursor consisting of a rectangular box so as to center a set of data points within the box. Once the cursor is positioned, the size and shape of the box can be varied to permit enclosing within its perimeter all the data points that might be associated with a target track. The operator can then expand the area defined by the box into the quadrant of the displayed data which is diagonally opposite the box position, as shown in Figure 2. With the area expanded, the cursor can be positioned within the enlarged area. Thus the range of the most recent return can be accurately determined and "handed off" as an input to a tracking procedure. At the same time the track of interest is labeled with a number to uniquely identify it.

It should be possible to provide more detailed information in the expanded area than is shown in the general format. This information could assist the operator in the detection, tracking or classification functions. This option has not yet been implemented but will be studied in the future.

Auxiliary Alarms: A number of different alarm indicators are shown in Figure 2 around the perimeter of the main data block. These alarms are suggestive of one way that such auxiliary information could be provided to the operator. They do not, however, represent an optimized solution to the auxiliary information problem.

Command Summary - Approach Maneuvers Format (See Fig. 3)

Track Summary: This format presents a summary of the history of a tactical encounter between own-ship (shown at the bottom of the photograph) and a target (shown at the tope as target 3). Own-ship's past positions are indicated by two straight-line tracks, their divergence revealing that own-ship executed a change in direction in order to enhance the passive "bearings only" tracking solution on the target. Own-ship's present position is shown as a circled X.

Immediately above own-ship's track is a family of arcs. These arcs represent the best estimate of the range from the target at which the counter-detection probability equals 70 percent. Thus, own-ship normally maneuvers to stay below the arcs to minimize the chance that the target will detect her.

The past positions of the target are shown as the intersection of a relatively short horizontal line and a longer vertical line. The lengths of these lines indicate the uncertainty in the estimates of the target's position. Thus, initially, bearing is well resolved and range poorly resolved. The range estimate improves considerably after own-ship executes a maneuver. The target's present position is denoted by a 3. The vector shown indicates estimated target speed and direction.

Simulated Maneuver: At any time in the tracking process it is possible to simulate an own-ship maneuver (shown by the dashed line extending from own-ship's present position to the circle). Once this maneuver is placed on the display by the operator, the projected position of the target also appears (shown by the ellipse which represents the uncertainty about the target's projected position.) A curved area is displayed in the format which partially overlaps the target. This represents the envelope of weapon A and, in this case, discloses that for this choice of maneuver and weapon, own-ship would not be in a good position to launch weapon A. The envelopes of other weapons are also available to the operator and can also be displayed. If all weapons are found wanting, it would be necessary to evaluate other prospective maneuvers.

A variety of supporting information is presented at the bottom of the format.

Sound Ray Path Analysis Format (See Fig.4)

A real-time, operator-controlled sound ray path analysis capability is represented by this format. All the key parameters shown can be varied by the operator. Once a parameter is changed, a new set of ray paths consistent with the new value is presented. Thus, the source depth, bottom depth, number of beams (rays), beamwidth (which determines ray spacing) and other parameters can all be varied. The sound velocity profile (SVP) can be entered by the operator and changed as required. In an operational system the option of automatically inserting a SVP from a bathythermograph reading would also be provided

Sonar Passive Search/Track Format (See Fig. 5)

The following paragraphs describe the passive search/track mode of operation illustrated in Figure 5.

Generated with the use of simulated data, the BTR-like displays shown in the photograph of the CRT represent two different D/E angles and two different integration times for each D/E. The data exemplify a passive preformed beam sonar with the outputs of 50 beams shown for each D/E angle. Each horizontal line presents the data from the various beams integrated for the time indicated. The format presents time vs bearing, with new data appearing at the top and the oldest data shown at the bottom of each data block. Each data cell (beam) is shown at one of eight brightness levels, the degree of brightness being proportional to the appropriate energy level.

There are 300 lines shown in each of the upper blocks of data with a 1-second integration time for each line for a total history of 5 minutes. The lower blocks of data each show 200 lines with 16 seconds per line for a total history of over 53 minutes for each data block.

Estimates of bearing error and signal-to-noise ratio (SNR) are presented below the data as an aid to the operator in determining the quality of tracking solutions.

NUC DISPLAY/SIMULATION FACILITY

The current configuration for the MMDS, consisting of a single MMSC and a PDMU, is housed in the NUC Display/Simulation Facility in Building 133 at NUC-San Diego. The Facility is presently being utilized by NUC Code 603 personnel in the conduct of advanced display studies. It can be made available to both government and contractor activities for system concept studies and detailed display format design and evaluation.

While the primary component of the Display/Simulation Facility is the MMDS, auxiliary equipment includes a special-purpose TV monitor, a high-speed electrostatic printer, still photographic equipment and a rotating-disc viewing device which provides either 3-D or a multi-color capability. The Facility has provisions for reasonable control of environmental conditions, including ambient lighting.

All equipment in the Display/Simulation Facility has direct access to the NUC-SD Computer Center's UNIVAC 1230 computer, which features 32K of core storage, fast I/O channels and high-speed (approximately 2 μsec/instruction) operation. A UNIVAC 490 computer will also be available soon. Among the peripheral equipment on hand are 8 tape drives, on-line printers, card-handling devices, an off-line plotter and a 600,000-word drum. Extensive FORTRAN IV and CS-1 library routines are available, including special-purpose routines developed exclusively for use with the MMDS.[4] As mentioned earlier, a large library of recorded sea data is available nearby through NUC Code 6006.

SUMMARY

The present configuration of the MMDS consists of a stored-program, general-purpose, multi-mode display console and a passive data memory unit. The system, together with an associated computer, provides an advanced capability for the display and storage of sonar and other data and for subsequent operator interaction.

The MMDS, as described in this technical note, embodies the following principal features:

1. Flexibility through software control.
2. An Advanced data display capability.
3. Significant operator interaction capabilities.
4. A flexible raster display capability.
5. Modular maintainability with automatic fault detection and localization.

The Multi-Mode Display System provides the Naval Undersea Research and Development Center with a unique and versatile display and interactive data processing tool. The MMDS is being applied in the design and evaluation of operationally realistic tactical and data analysis formats, using both simulated and actual sea data. Additionally, it is serving as an invaluable device for conducting experiments with advanced computerized data presentation techniques, and for the evaluation of new display system requirements in advanced ASW systems.

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