THE SAN FRANCISCO EXPERIMENTAL VESSEL TRAFFIC SYSTEM

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The San Francisco Experimental Vessel Traffic System (VTS) is an all-weather marine traffic management complex developed for the U. S. Coast Guard. A unique aspect of VTS is its extensive use of real-time automatic processing technology. Eleven computers and two radar signal processors are combined to automatically detect and track bay shipping, display animated maps with their location and velocity, detect critical situations, respond to operator analysis requests, and maintain a ship information file.

Introduction

Any attempt to minimize maritime accidents in the nation's rivers and harbors must address several facets of the problem. Toward this objective, the United States Coast Guard (USCG) has embarked on a broad program for the development, administration, and operation of Vessel Traffic Systems (VTS) in the U. S. ports and harbors. Responsibility for this function was vested in that agency by the Ports and Waterways Safety Act of 1972 (PL 92-340). The San Francisco Experimental Vessel Traffic System was developed as one aspect of this effort.

This all-weather radar/communications/computer/display complex will be employed to advise mariners of traffic conditions within the area's deep draft waterway system. Two modes of system operation are possible, designated as manual or automatic. Because manual operation is not significantly different from that employed in several other ports,[1, 2, 3] it will be treated only briefly. This will serve to contrast the significantly different capabilities of the automatic mode which constitutes the unique aspect of the San Francisco installation. Thus, the bulk of this paper will treat the design of the two major subsystems, concerned respectively with Automatic Detection and Tracking (ADT) and Traffic Analysis and Display (TAD).

System Concept and Configuration

Because the San Francisco Deep Draft Waterway System encompasses a large geographic area (see Fig. 1), surveillance is maintained through the complementary use of radar coverage and voluntary Vessel Movement Reports (VMR). Radar coverage is confined to the San Francisco Bay and Pacific approach region indicated roughly by the circled portion of the figure. Search radars are located at Pt. Bonita (PTB) and Yerba Buena Island (YBI). Surveillance in the VMR regions of the Waterway, extending as far as Redwood City, Stockton, and Sacramento is achieved via radio reports to VTS from the vessels passing designated sites in that region. All vessels communicating with the VTS receive information on traffic conditions.

Such advisory transmissions constitute a major VTS function and they will be sent to a ship at its request, or when meaningful to that ship, without request. Content of an advisory will vary depending upon circumstances. Typical examples include: traffic beyond an upcoming geographical obstruction; aides-to-navigation irregularities; and weather conditions at various points in the system.

When operated in the manual mode, contacts

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[1] W. A. Krause, "The Hamburg Harbor Shore-Based Radar Chain—An Instrument for Traffic Control," *Symposium Papers RTCM Assembly Meeting,* Vol. I, Radio Technical Commission for Marine Services, Washington, D. C., Apr. 29–May 1, 1970.

[2] P. W. W. Graham, "Operational Aspects of V.H.F. Communication and Radar Surveillance by Port Operations Centres," *Radio and Electronic Engineer* **36,** No. 3, Sept. 1968, 149–152.

[3] A. Harrison, "A Display Centre for Harbor Surveillance and Control," *Radio and Electronic Engineer* **36,** No. 3, Sept. 1968, 161–169.

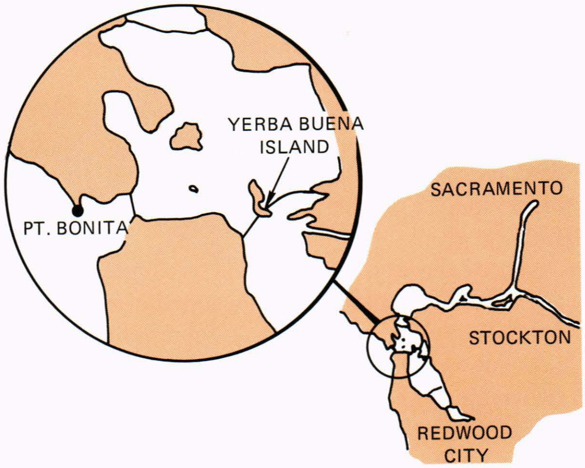

Fig. 1—Vessel traffic system service areas.

in the radar region are detected and tracked visually by operations personnel monitoring PPI radar displays. Characteristics of individual ships (name, pilot ID, destination, etc.) are entered on separate cards which the operator mentally correlates with specific returns on his PPI. For ships in the VMR area, cards and manually updated status boards are employed.

But the automatic mode is of primary interest here and we can begin its description with a review of the major equipment modules in the system—see Fig. 2.

Radar, Communications, and Recording Equipment—One of the system's two 50 kW redundant X-band radars is located at Pt. Bonita. From an elevation of 330 feet, coverage extends seaward a distance of 15 nautical miles and the radar design reflects an attempt to enhance ship detection performance in such an environment. A 50 nanosecond pulse, combined with a 0.3 degree azimuth beamwidth, offers both high contact resolution and good detection of ship contacts in the presence of sea clutter. Vertical polarization was selected for the PTB radar to minimize the number of clutter false alarms to be handled by subsequent automatic processing equipment; the antenna polarization can also be switched to circular to improve performance in rain.

A second VTS radar is located 415 feet above the water on Yerba Buena Island, which links the Bay Bridge between San Francisco and Oakland. It employs an identical antenna to that at Pt. Bonita, except that horizontal polarization

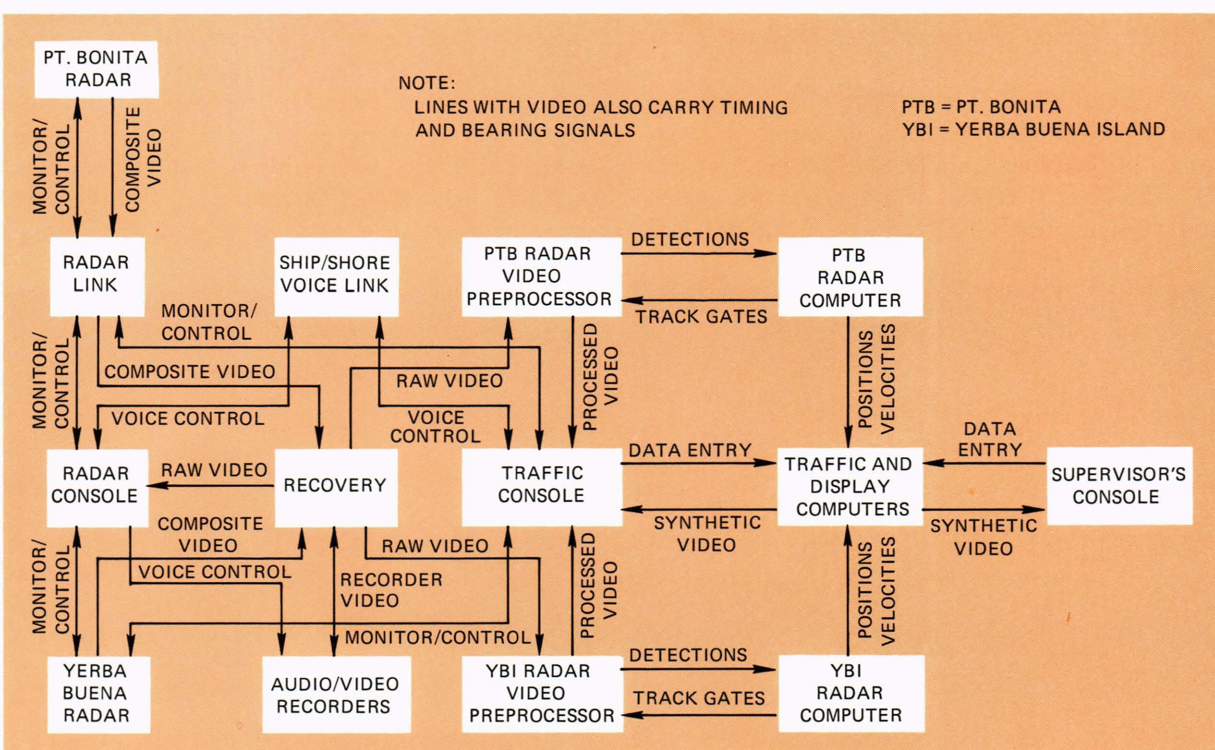

Fig. 2—San Francisco experimental vessel traffic system.

rather than vertical polarization is used. Since sea state within the bay is not as severe as offshore, the false alarm problem associated with the horizontal polarization was not expected to be as severe and so it was selected for its potential detection advantage at the lower sea states. However, experience at the site suggests that selection of vertical polarization might have been more appropriate here also to minimize returns from frequent tide rip activity.

Remote operation of the PTB radar is controlled and monitored from YBI by use of redundant microwave and UHF radio links. A composite video transmission, which combines the received echo signal with trigger and antenna bearing data, is sent from PTB to YBI via a broadband microwave link. Control and monitor signals are transmitted over a narrowband channel. Both radars utilize the composite format since it is required for video recording. The recovery unit processes the composite video signals from both radars in a manner which separates their timing, video, and bearing components.

Communications equipment at YBI, PTB, and a site in the VMR region permit operators to transmit on any of six frequencies. Up to three of these frequencies can be monitored at each site, with the specific choices selectable by the operator.

When the Vessel Traffic System is operated in the manual mode, the VTS operators are stationed at the radar console which consists of five PPI displays, a Radar Monitor/Control panel, and Communications/Recording/Monitor/Control panel. One of these PPI units is automatically photographed at regular intervals with the image alternated between YBI and PTB.

Voice communications are automatically recorded on audio tape units. A video tape recorder can also be activated for brief periods to document specific traffic situations as viewed by the radar.

All of the above equipment is employed when the system is operated in the manual mode. The remaining elements of Fig. 2 come into play during automatic mode operations, which exploit two major subsystems: Automatic Detection and Tracking (ADT) and Traffic Analysis and Display (TAD).

Automatic Detection and Tracking

To establish a motivation for creating an automatic detection and tracking system, consider the time exposure photograph of the PPI display shown in Fig. 3. In the manual mode, the PPI is the major source of surveillance data available to the operator. While this type of display contains much useful information, the photograph does not convey a true picture of the dynamic image from which the data must be extracted.

To the operator the picture is revealed a little at a time as the antenna scans around. Radar echoes appear as bright flashes, which decay rapidly as the sweep continues. The echoes do produce an afterglow which persists for many antenna scans but is faint and can be viewed only at a low ambient light level. Therefore all PPI viewing must be done in a room with subdued lighting

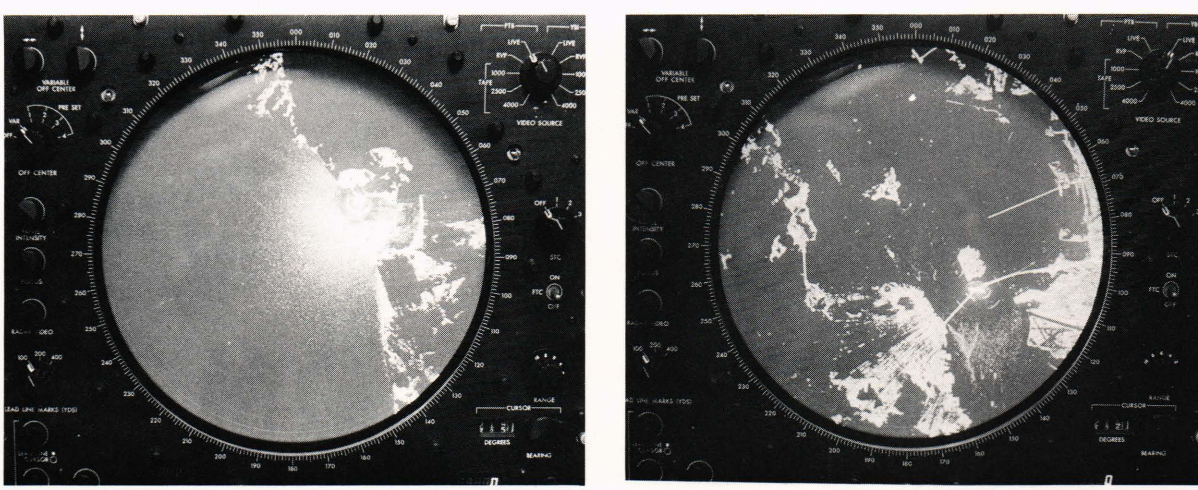

Fig. 3—Pt. Bonita (left) and Yerba Buena Island (right) PPI images.

and care must be taken to avoid undesirable reflections in the PPI faceplate.

Extraction of this routine basic information can be accomplished by a trained operator, but he must remain continually alert in his task if he must, for example, keep track of the three vessels being displayed within the clutter portion of the Pt. Bonita picture as shown in Fig. 3. Such data must be extracted from the PPI and assimilated before an operator can analyze a total traffic picture to uncover those situations which might lead to an accident, such as a potentially close passage between two vessels among many on his screen.

Acquisition of the vessel traffic data is the major function of the ADT system. It examines the signals developed by the radar and without any participation by the operator it will automatically:

1. Detect the presence of vessels, and continually determine their location,
2. Estimate the speed and approximate course of each vessel, and
3. Approximate the size of the vessels.

All of this is accomplished while ignoring those signals created by land and sea clutter. In addition, the system keeps track of buoys within its coverage area and detects excessive drift from their station.

Each radar has its own ADT system, consisting of a Radar Video Preprocessor (RVP) and a Radar Computer which interact with each other to achieve the above performance. An RVP unit contains about 1800 silicon chips, with about 45% of them at the medium scale integration (MSI) level of functional complexity. The computer is a Honeywell DDP-516R with an 8K memory, hardware multiplication, and two direct memory access (DMA) channels.

ADT processing is confined to the significant portions of the radar coverage through use of a video acceptance mask consisting of gating electronics within the RVP unit. These masks include two areas of overlapping coverage which permit one system to track within the others' nominal surveillance region where radar shadow zones obscure vessels.

Each ADT system can keep track of a maximum of 253 tracks. This total includes buoys and some clutter returns undergoing assessment prior to rejection, so the actual number of ships that can be monitored is less than the track file capacity. Experimental results obtained on the system have shown that at least 150 firm tracks in the YBI system are possible. Sixty-four buoys are monitored in the YBI system and 18 at Pt. Bonita. In the event that traffic exceeds the track file capacity, priority is automatically allocated to large vessels to insure that major shipping commands the system priority.

Traffic Analysis and Display

Each ADT system translates the signals received from its radars into a concise characterization of the traffic within its coverage area, thus extracting the basic position and velocity data for each ship from those signals. The function of the Traffic Analysis and Display (TAD) system is to integrate the information from both ADT systems, present it in meaningful form to Trafffic Center operators, permit them to augment the surveillance data with ship descriptions, and support the operators in the detection and alleviation of problems.

Source Data Integration—Each of the two ADT systems operates independently. They compete with each other for the Traffic Computer's attention, with the YBI system having interrupt response priority. Contact information from these two sources must be integrated into a common Traffic Computer track file which then becomes the core for all subsequent display and analysis. Such integration is straightforward if the contacts are in coverage areas that are not common to both ADT systems.

But the San Francisco system has two areas of overlapping coverage: one west of the Golden Gate Bridge, and the other west of Yerba Buena and Treasure Islands. These overlap areas were deliberately established to try and compensate for coverage weakness of one of the radars. For example, the region northeast of Point Diablo, but west of the Golden Gate is blind to the PTB radar, but there is coverage from YBI although it is obscured by the bridge. Coverage west of the Golden Gate from YBI in the region south of that shadow was also included to aid in the processing of vessels moving between the two ADT coverage areas. Similarly, the overlap zone west of YBI was included to illuminate shadows caused by trees. Thus PTB can achieve a better view of that area than YBI.

In overlapping regions, both ADT systems may be tracking the same contact. Because of radar shadowing, sometimes only one system may have a vessel in track within these regions. The boundaries of such shadow-limited coverage cannot be definitively characterized, because they can be influenced by vessel size, sea clutter return strength, and even variations in propagation during heavy rain squalls. Moreover, since the overlapping coverage areas are not equidistant from the two radar sites, contacts are resolved differently by them. There have even been occasions where wind gusting at PTB has created scan-to-scan shifts of several hundred yards in apparent vessel locations within the YBI overlap zone.

The Traffic Computer must correlate information from both ADT systems in such a way that their independent reports on the same contact are not misinterpreted as data for two different vessels despite all the data corruption described in the previous paragraph.

Presentation of Traffic Conditions—Data received from the two ADT systems must be presented to an operator in a form that aids his assessment of the traffic situation. This is accomplished principally through computer-generated situation map displays on which moving symbols represent individual vessels, and their course and speed.

At any time, there may be up to eight independent map displays which must be maintained by the TAD system. Any of seven possible map area coverage options can be selected by the operators for presentation on each of the eight independent displays. Thus, when the Traffic Computer receives a track record from one of the ADT systems, it must determine whether that location of the vessel is within the coverage window of the active maps, i.e., those currently selected for display. But the vessel data supplied by the ADT system is in polar coordinates, while the map boundaries are defined in rectangular coordinates. Furthermore, each ADT coordinate system has an origin corresponding to the location of its radar site.

Thus, one major task of the TAD system is to convert all incoming data to a common rectangular coordinate system with an origin at the YBI site, before comparison to a map coverage window can be attempted. When a contact has been determined to be within one or more map perimeters, its display coordinates must then be determined for each map to create the computer deflection code for the display list in the equipment which actually creates the electronic map image. This display record must also contain material which indicates the symbol category and size, the length and orientation of the speed-heading leaders, system ID number and other material which is required to create the proper display cues for the operator. For example, symbols blink when a ship track is freshly reported to the Traffic Computer or when it has been lost.

Information Entry, Correlation, and Retrieval—A considerable amount of information that is required for effective VTS operations cannot be developed from the radar/ADT sources. Vessel names, destinations, VMR area movements, departure times, etc. are developed either via operator voice communications to specific ships or telephone communications with local maritime sources. The TAD computer files serve as a central collection/dissemination point for such information. Of greater significance is the utilization of the TAD system to continually maintain the correlation between the ADT supplied data and other information once the operator has established the initial correlation. Thus, after an operator indicates what name should be associated with a particular ship symbol on his map display, that tag remains with the symbol indefinitely, even as the vessel moves from one radar to another.

All mechanisms for entering, editing, and retrieving non-ADT-derived data are provided as part of the TAD system.

Problem Detection and Alleviation—Several services are available to aid operators in their assessment of various traffic situations, yielding relative position, closest-point-of-approach, and speed/course data. In addition, a number of automatic monitoring activities are performed by the computers leading to messages to the operator advising him of deviations from expected or desired conditions.

For example, an identified contact may disappear from track when the ship passes into a shadow zone or leaves the mask to dock. In the former case, the operator must be alert for the reappearance of an unidentified track when the vessel emerges from the shadow so that previously entered data may be recorrelated with that display symbol. In the latter case, the operator must either exit the ship or change its disposition.

Automatic alerts also advise the operator of projected near miss situations, drifted buoys, or overdue reports from ships in the VMR area.

Operating Stations and Displays—Interaction with the TAD computers is accomplished via two display consoles (Fig. 4) which provide three operating positions. Stations One (Fig. 5) and Two are in the Traffic Console and the third is the Supervisor Console. Within these consoles, four types of display are available: working, satellite, vessel status, and PPI.

Working displays are interactive keyboard-coupled terminals presenting both text and graphics. Screen sizes are 17 inches at each operator station and 21 inches in the supervisor position. Each display and its keyboard is supported by an 8K Imlac PDS-1 display computer which refreshes the displays and manages the interface between the operator and the Traffic Computer.

Fig. 4—Supervisor (foreground) and traffic consoles.

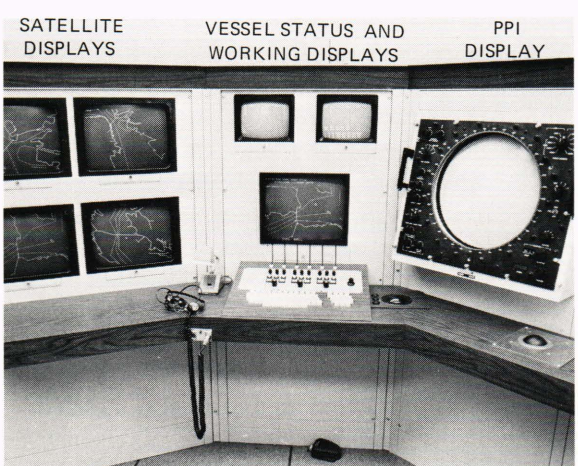

Fig. 5—An operator station.

The image or a working display is partitioned (Fig. 6) into six functionally distinct areas which provide the following information:

Operator Instructions—These are prompting cues which tell the operator what action is expected of him at that point in his activities.

Page Name—This identifies the particular activity being displayed.

Information to Operator—Frequently, the TAD system must respond to an operator action with some type of text message; e.g., the results of an analysis. Such material generally appears in this portion.

Alert Message—When the background management activity of the Traffic Computer reveals a conflict or other event worthy of an operator's attention, a tone sounds at the station and a brief text message appears in this partition.

Main Body—The largest partition on the page will contain either a map like that on the satellite displays or a tabular arrangement of text material which guides the operator in the entry of certain data into the system.

Function Button Labels—This portion has six subportions aligned with pushbuttons in the keyboard area just below the display. The three left-hand labels never change. But the three right-hand labels impart a different meaning to their

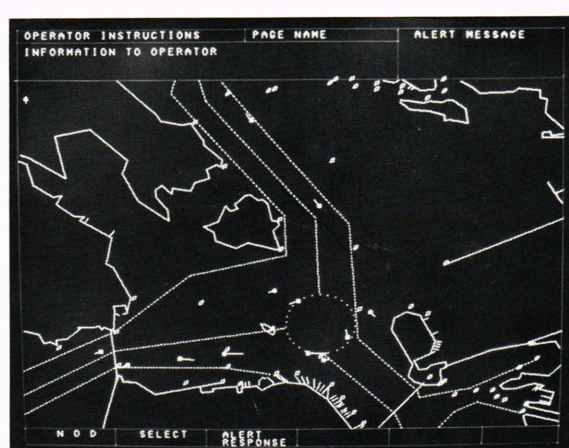

Fig. 6—Working display partitions.

keys depending on which page is currently on display. Time of day is presented at the top center of the display along with the time since the main body map image was last updated.

Zoom controls at each keyboard permit map off-centering and a variable magnification to about 5:1. A switch on the supervisor keyboard permits that screen to function as a working display or as a monitor slaved to either of the two Traffic Console working displays.

Satellite displays are clustered in groups of four within Stations One and Two (see Fig. 5). They can offer either traffic situation maps supplementing those on the working displays or lists of vessels operating outside the radar coverage area, in the VMR region.

Vessel status displays are located above the working displays in the Traffic Console and to the right of the working display in the Supervisor's Console (see Fig. 4).

The two 16 inch PPI displays in the Traffic Console offer conventional radar images from either radar with variable off-centering and five discrete magnification options. Picture augmentation options include range rings, a limited number of traffic lane boundaries, and an adjustable range/bearing cursor line. This basic augmentation can be supplemented with an image defining the area of ADT mask coverage, RVP detected video, and track gate symbols.

Computer-Animated Traffic Situation Maps—Various combinations of seven map options can be selected by the operator for presentation on the satellite and working displays. These maps (e.g., Fig. 6) delineate the lane boundaries, along with approximate shore lines, bridges, and key piers. Ship traffic developed by both ADT systems is automatically displayed and updated each radar scan (every three seconds). Different symbols depict unidentified and identified ships in three sizes. Distinct buoy symbols indicate whether the aid is not-in-track, in-track-and-on-station, or in-track-but-adrift.

Leader lines extend from each ship symbol to the projected future ship positions. These look-aheads are one minute for all satellite displays, but the operator can elect to display zero, one, two, three, or six minute leaders on the working display.

Each map can display a maximum of thirty identified contacts. In addition, any combination of buoys and unidentified ships may also be displayed up to a total of 128. Large and medium contacts receive display priority.

ID tags may be displayed by identified ships at the operator's option. These tags follow the symbol automatically as ships cross radar coverage and overlap region boundaries.

Operator Services—Seven services are available at the working display to aid an operator in the performance of his duties. They permit him to select displays, determine relative positions and closest-point-approach, and maintain files on the navigation environment and relevant ship information.

Activating the Select Display function button puts a fixed format data page in the main body partition of the working display. This page indicates which map options are currently present on that working display and the five independent satellite displays. By appropriate movement of the cursor and activation of the control keyboard, the operator can indicate what map changes he requires. This new combination appears alongside the old to confirm his correct entry of the map codes selected from the "menu" at the bottom of the partition. When he is satisfied with his selection, he activates another function key and the maps are changed as required.

A Navigation Advisory Page can be called to the working display and used by the operator to enter and retrieve text information describing various conditions in the navigation area. This might include weather at the offshore pilot boat, locations of regattas, temporary navigation hazards, or malfunctions in navigation aids. It is essentially a status board whose format is flexible. Alphanumeric characters can be entered or deleted anywhere within a matrix of 25 lines each with 51 character positions. Material can be edited character by character and selected lines can be deleted using a single key.

Relative position of any combination of two vessels and/or display points is also available. This yields bearing in degrees and range to the nearest 100 yards as a readout in the Information to Operator partition. On the map, a line appears between the two points of interest. All of this readout information is automatically updated as vessels move. Designation of the arguments for the analysis is accomplished using the trackball and its buttons.

Closest-Point-of-Approach (CPA) is a similar analysis service that yields a projected miss distance in yards and time to this CPA. Lines on the screen show the projected location of the event. Automatic updating takes place and a relative position readout is also supplied.

The remaining operator services all deal with the entry and retrieval of ship information and they are treated as a group in the next section.

Ship Information File (SIF)—Two of the most significant files maintained within the TAD system are the Track File and Ship Information File (SIF). The former is created and maintained automatically by the combined activities of the ADT systems and the Traffic Computer. It includes data on the size, location, and velocity of the traffic. Identities for a subset of those ships, plus others outside the surveillance area of the ADT systems are stored in the SIF along with a variety of supplemental information entered into the system by the operator.

Three categories of these *identified* ships are maintained and designated as Radar (R), Vessel Movement Reporting (V), or Imminent (I). An R vessel is operating within the radar surveillance region (more precisely, within the ADT mask boundaries). Those ships subject to VMR discipline are V, and ships whose entry into the system is anticipated in the near future are labeled I.

Information available from local maritime sources makes it possible to anticipate most ship movements some hours in advance. This information can be supplied to the computer in slack operational periods using the Enter service which presents the Vessel Data Page (VDP) of Fig. 7 to the operator. At this time, only a subset of the information indicated in that figure is available, typically: Name of the ship, its Origin and Destination, and the Vessel Type, which is entered by either typing one of the numbers indicated on the page's menu or supplying a more appropriate designation. The operator would also enter I on the Disposition line. Additional material can be added at a later time through use of the system's updating and editing capabilities.

Portions of the material in the SIF are automatically extracted for presentation in summary form on the Vessel Status Displays or on any Satellite Display which lists ships operating in the VMR region.

Use of the Enter service as just described stores ship information within the computer, but it does not link those data to any of the vessels in the track file. If the vessel is active within the ADT mask area, then the operator can associate the symbol on his working display with the SID data for that vessel. The association is then maintained automatically from that time on and the symbol changes from unidentified to identified. This correlation can be established either when the data are initially entered, or later through use of an Identify service.

Of course, an operator can retrieve any of the SIF material using a Status service.

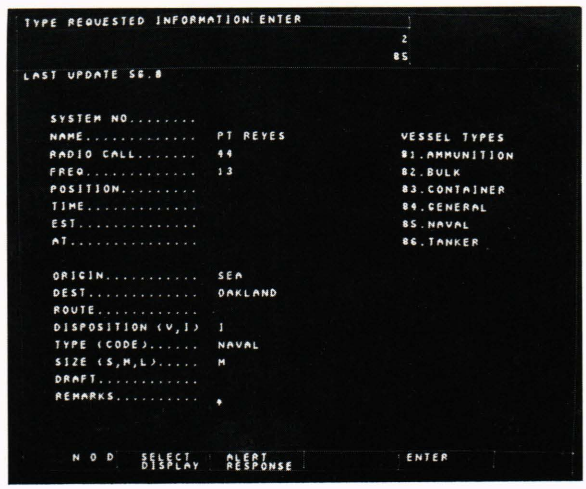

Fig. 7—Vessel data page.

Automatic Alerts—The services described above must all be initiated by the operator. However, certain aspects of the VTS operation are monitored by the system computers to detect and notify the operator of events worthy of his attention.

One of these automatically generated alerts is the Collision Warning. CPA calculations are periodically carried out for each identified contact with all other identified contacts and large and medium unidentified contacts. When the projected CPA is less than 1000 feet within five minutes, an audio tone is triggered and information appears within the Alert Message partition on the Working Displays. Activating the "Alert Response" function button presents the critical situation to the operator, changing his current map if necessary. Information is both text (information to operator partition) and CPA graphics (on the map). The data will be automatically updated as the situation develops and it includes the pilot call sign, radio channel, and time to CPA.

As noted earlier, buoy positions are monitored by the ADT system and deviations from their intended stations are detected. These deviations are conveyed to the operator in terms of symbol changes on the map displays. Thus, a different symbol depicts each of the following conditions: (a) in-track-and-on-station, (b) not-in-track, and (c) in-track-but-off-station.

Status of ships in the VMR region is monitored to generate the VMR overdue alert. If an expected report from such a vessel is more than 15 minutes overdue, an audio tone briefly sounds and the category symbol (V) blinks on the Vessel Status Display. Blinking will stop when the operator edits the reporting point information.

There are a number of normal conditions in which tracking of an identified ship will cease. For example, when a vessel berths it usually leaves the coverage area defined by the ADT mask. Or a vessel may pass into a radar shadow zone (e.g., behind Alcatraz or Angel Islands). A Lost Identified Contact alert brings such conditions to an operator's attention. This alert may be cancelled, in a situation like the first example, by changing the ship category or exiting it from the system. In the second case, the operator can wait for its reappearance and employ the Identify service to recorrelate the ship data with the new ADT track. This alert is manifested as a brief audio tone, coupled with a continual blinking of the particular ship's R symbol on the Vessel Status Display. In addition, at the last position of the ship on the screen, the symbol and its leader will blink until the data are either correlated with another track, or until the ship is exited or has its category changed.

System Performance to Date

When this article was being prepared, the evaluation of the automatic mode system was still underway and scheduled for completion in the late spring of 1974. However, from results to date, it is already apparent that use of computer technology offers significant advantages over a manual mode system.

For example, consider Fig. 8. It pictures the same Pt. Bonita area shown in Fig. 3 at approximately the same time. Note how the automatic system clearly indicates the active ships and buoys, while eliminating the distracting clutter. It should be stressed that these ships were automatically acquired, placed on display, and updated without any operator participation. Thus the system clearly demonstrates that automatic detection and tracking can be successfully accomplished. A similar comparison is indicated for the Yerba Buena Island area.

All traffic analyses and display capabilities described in this article are functioning successfully. Thus, when the system is placed in use, an operator will benefit from a substantial extension

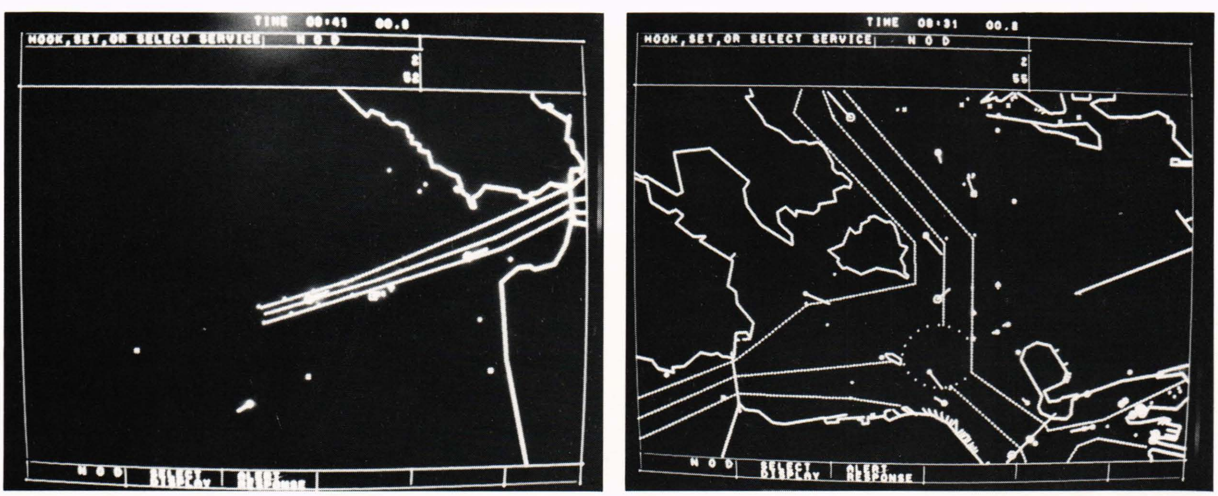

Fig. 8.—Pt. Bonita (left) and Yerba Buena Island (right) working display images taken at approximately the same time as the PPI images of Fig. 3.

of his ability to maintain ship identities and evaluate traffic conditions within the bay area. Among the benefits are:

1. Continual automatic correlation of vessel identities with radar returns once identity is established. (In the manual mode system, operators place cards with vessel names adjacent to the screen and attempt to maintain the correlation mentally.)

2. Immediate availability of approximate course and speed of any vessel and projected future positions. (In the manual mode, an operator must observe a ship's movement over several scans, before he can deduce the same information.)

3. Automatically-generated warning of probable close passage between two vessels. (An operator using the manual mode must extract similar information from observations of PPI images like those in Fig. 3.)

The San Francisco Experimental Vessel Traffic System is currently employed only in the manual mode. Those skeptical of the benefits of an automatic system might ponder the implications of the following incident.

An off-duty operator was monitoring one of the computer-generated working displays and observed the velocity-indicating leader on one of the vessels shrink to zero. He called the condition to the attention of an on-duty operator who had been observing a PPI display, but had not detected any anomaly. Radio contact with the ship in question then established that it had just run aground!

The automatic system, as currently configured, could not have averted that grounding. But that vessel's progress was being effortlessly and continually monitored by the computers. If knowledge of the intended course had been inserted into the computer for comparison with the actual course, could the deviation have been detected and called to an operator's attention in time to avert the grounding?

Advocates of automatic systems clearly believe the answer to be Yes. San Francisco demonstrates that the necessary automatic monitoring and analysis required for automatic hazard alerting can be accomplished.

Acknowledgment

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This Bibliography lists source material on various aspects of the San Francisco Vessel Traffic System discussed in this issue of the *Digest*.

1. A. J. Cote, Jr., *Antenna Design Considerations for Harbor Surveillance Radar,* DOT USCG Office of R & D, CG–D–58–74, Nov. 1973.
2. A. J. Cote, Jr., *APL/JHU Project Report: Computer Technology for Harbor Traffic Systems,* DOT USCG Office of R & D, CG–D–84–74, Dec. 1973
3. R. G. King and F. S. Gregorski, *Software Architecture for the Traffic Analysis and Display System of the San Francisco Vessel Traffic System,* DOT USCG Office of R & D, CG–D–83–74, Dec. 1973.
4. J. L. MacArthur, J. M. Davis, and S. F. Oden, *Automatic Detection and Tracking for the San Francisco Vessel Traffic System,* DOT USCG Office of R & D, CG–D–67–74, Nov. 1973.
5. J. L. MacArthur, *Some Advantages of Display Automation in Vessel Traffic System,* DOT USCG Office of R & D, CG–D–68–74, Dec. 1973.
6. D. C. Schleher, "Harbor Surveillance Radar," *Proc. Ocean* 73, 579–582, IEEE International Conference, Seattle, Sept. 25–28, 1973.
7. *Sea Clutter Data Collection and Analysis for the Design of Harbor Surveillance Radar Systems,* DOT USCG Office of R & D, CG–D–38–74, Oct. 1973.
8. *VTS Operation and Maintenance Manual* (7 volumes)
   Volume I "Functional System Description" CG–D–37–74, Dec. 1973.
   Volume II "Console Operation" APL/JHU MSC–73–292, Dec. 1973.
   Volume III "System Operation" APL/JHU MSC–73–293, Dec. 1973.
   Volume IV "ADT Maintenance" APL/JHU MSC–73–294, Dec. 1973.
   Volume V "TAD Maintenance" APL/JHU MSC–73–295, Dec. 1973.
   Volume VI "Schematics and Wire Lists" APL/JHU MSC–73–348, Dec. 1973.
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