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PUGET SOUND VESSEL TRAFFIC SERVICE WATCHSTANDER ANALYSIS

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16. Abstract A team of human factors specialists analyzed the performance of watchstanders in the U.S. Coast Guard's Puget Sound Vessel Traffic Center at Seattle WA. Data collected included copies of the center's forms and logs, records and tapes of watchstander activities for a total of 12 hours of observation, records of 6-in-depth interviews with center personnel, stress questionnaires administered to 14 watchstanders, comments on center services by 6 Puget Sound pilots, and photographs of equipment and workspace layout. Analysis of the data yielded a breakdown of watchstander time utilization, a summary of communications loading, and twenty-three suggestions for improving operations.

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PREFACE

This is an interim report on the analysis of watchstander activities at the Puget Sound Vessel Traffic Service. The study was performed by the Human Factors Branch of the Department of Transportation's Transportation Systems Center (TSC) under the sponsorship of the US Coast Guard's Office of Research and Development.

The authors wish to express their sincere thanks to LCDR C. T. Johnson and LT P. R. Corpuz of the Office of Research and Development and to CAPT N. G. Nelson and all the personnel of the Puget Sound Vessel Traffic Service for the encouragement and support provided by them in every phase of this study. We also gratefully acknowledge the guidance and contributions to the report provided by H. P. Bishop, Program Manager and Chief, Human Factors Branch (DTS-532) at TSC.

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ABBREVIATIONS

COTP	-	Captain of the Port
CRT	-	Cathode Ray Tube
DR	-	Dead Reckoning
ETA	-	Estimated Time of Arrival
ETD	-	Estimated Time of Departure
LOA	-	Length Overall
PPI	-	Plan Position Indicator
PSVTS	-	Puget Sound Vessel Traffic Service
SOA	-	Speed of Advance
SOP	-	Standard Operating Procedure
STC	-	Sensitivity Time Control
TSC	-	Transportation Systems Center
TSS	-	Traffic Separation Scheme
VMRS	-	Vessel Movement Reporting System
VTC	-	Vessel Traffic Center
VTMS	-	Vessel Traffic Management System (Canada)
VTS	-	Vessel Traffic Service

The PSVTS divides watchstander duties by function, each function serving the entire PSVTS area. A Primary Communicator receives all communications from vessels in the system and issues traffic advisories to them. A Plotter prepares a model of each vessel in the system and maintains a current picture of system traffic by moving vessel models on a large, map-based plotting table. Vessel positions are determined by dead reckoning augmented by periodic position reports and radar observations. A Radar Operator monitors the returns from four radar sites, compares indicated vessel positions with model locations on the plotting table, and advises the Plotter of any observed discrepancies.

This "Traffic Team" is supervised by a Watch Supervisor, assisted by an External Communicator.

Duty at the PSVTS is divided into three eight-hour watches, each watch staffed by four enlisted watchstanders and one officer (Watch Supervisor). The enlisted watchstanders rotate through the four duty positions (Primary Communicator, Plotter, External Communicator and Radar Operator) for two-hour periods.

Function	Primary Communicator	Plotter	Radar Operator	Traffic Team	Watch Team
	Percentage of Time				
Communicating					
With Vessels	40	0	0	13	8
With Others	5	7	2	5	7
Monitoring Traffic	43	18	62	41	30
Plotting Traffic					
Plotting Table	2	40	2	15	9
Cards	8	2	0	3	2
Radar	0	0	19	6	4
Miscellaneous	2	33	15	17	40

These observations agree with the comments of the watchstanders that the Primary Communicator has the most strenuous workload. Since routine traffic loads frequently approach the level considered by the watchstanders as uncomfortable for the Primary Communicator to handle, relief for this position is indicated.

Some relief may be obtained by consolidation and rearrangement of equipment at the work station, correction of illumination and noise problems, and simplification of advisory contents, but the only way to achieve a significant reduction of the Primary Communicator's workload is to divide the traffic handled among other watchstanders. This can be accomplished only by dividing the PSVTS area into sectors, with a Primary Communicator for each sector handling a lighter traffic load. However, a necessary condition for sectorization is an improvement in communications capability to prevent overlap and interference of messages, requiring in turn the addition of one or more channels reserved accidents, incidents, heavy traffic, or bad weather) to justify any major changes in duty allocations.

As operations are presently conducted at PSVTS, we estimate that sectorization could require the addition of one person to each Watch Team rather than permit a reduction in staffing. Long-range system developments (particularly improved radar and computer assistance) will eventually permit more consolidation of equipment into standardized work stations and a possible reduction in manpower.

Recommendations

Analysis of all of the data collected at PSVTS has revealed several areas that appear to be amenable to improvements. The feasibility and desirability of implementing these changes can not be determined from this study; however, we do recommend that consideration be given to these recommendations and that their feasibility be given study.

h. Substitute a tinted transparent plastic curtain for the window drapes.

i. Continue efforts to reduce glare spots.

j. Seek ways to improve light-shielding and sound-shielding of radar equipment.

k. Improve sound-shielding of teletype equipment and relocate at External Communicator position.

Recommendations with Improved Communications

l. Divide the Primary Communicator function into two or more Sector Watchstander Positions.

m. Further consolidate the communications console.

t. Design an integrated computer-radar-communications Sector Watchstander console.

Personnel Recommendations

u. Redefine VTS duties to give more responsibility and authority to CPO's.

v. Continue efforts to develop selection criteria for VTS duty.

w. Modify assignment practices to permit overlap of incoming and outgoing personnel for a training period.

1. INTRODUCTION

1.1 Purpose

In order to reduce the probability of vessel collisions and groundings in crowded waterways, and to keep individual vessels apprised of the total traffic situation, the U.S. Coast Guard is operating several Vessel Traffic Services (VTS's). To profit from the experience gained in operating these VTS's, both to improve present services and plan future services, the Coast Guard's Office of Research and Development has undertaken a broad program of analysis of VTS operations.

Human performance is basic to the operation of a VTS. The principal product of a VTS is a traffic advisory communicated by a VTS watchstander to a vessel master or pilot via VHF radio. The value of the advisory is dependent upon the skills of the various watchstanders in acquiring and monitoring traffic data, in integrating the data into a coherent picture of present and anticipated traffic, and in composing and delivering a clear, concise, and accurate traffic advisory. Therefore, the Coast Guard has recognized that any model of VTS operations and productivity must include the influence of watchstander performance on system performance. The Coast Guard's Office of

2. DESCRIPTION OF PUGET SOUND VESSEL TRAFFIC SERVICE

A VTS operation is continually changing. The following section describes the PSVTS as it was at the time of data collection for this study. Even at time of publication, significant changes in staffing, schedules, procedures and equipment have been introduced.

2.1 Purpose of VTS's

The Ports and Waterways Safety Act of 1972 authorizes the Coast Guard to operate vessel traffic services (VTS's) in designated areas to "...prevent collisions and groundings and to protect the navigable waters of the VTS area from environmental harm resulting from collisions and groundings."[1] VTC's meet this objective "...by providing pilots and masters of vessels information on the teletype concerning vessel traffic conditions and navigational hazards that would otherwise not be available to them".[2]

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[1] Code of Federal Regulations, 33CFR161.101.
[2] Puget Sound VTS Traffic Center Manual, #1.1.2

The principal features of the PSVTS area are shown in Figure 2-1.

The PSVTS is comprised of two major components, a Traffic Separation Scheme (TSS), and a communications/surveillance system. The TSS consists of a network of precautionary areas, separation zones, and one-way traffic lanes within the VTS area designed to safely route traffic between the major ports in the Puget Sound area. The traffic lanes are 1,000 yards wide with a minimum depth of 60 ft. and are separated by 500-yard-wide separation zones. A voluntary TSS has been established in the strait of Juan de Fuca by the U.S. and Canada as a "seaward extension" of the Puget Sound VTS.

The communications/surveillance system includes a VHF-FM radio-telephone system, a Vessel Movement Reporting System (VMRS) and a radar surveillance system. The radio communication system permits the VTS to obtain information from vessels and to disseminate traffic information to vessels. The VMRS requires vessels to report their position via VHF-FM radio communications at several specified geographical points as well as when requested by the VTS. The radar surveillance system provides a visual picture of traffic movement in the areas of coverage, which aids in maintaining accurate information on traffic location and movement.

The VTS handles about 540 transits per day, some 16% of which are tug boats, 4% freighters, 1% tankers, 2% government vessels, 69% ferries, 1% miscellaneous vessels, and 7% traffic in the Strait of Juan de Fuca. Plans are underway for an oil transhipment port which, when fully operational, can result in at least one additional tanker movement per day. The presence of large tankers poses a continual threat of a major oil spill.

Ferry and recreational vessels comprise a large proportion of traffic in the area, of which 18 ferries linking waterside communities account for about 69% of the vessels operating in the VTS area. Ferries whose routes cross the Traffic Separation Scheme (TSS) are monitored by the VTS; recreational traffic is not monitored. Radio reports to the VTS are not required of ferry vessels unless the route is unscheduled or visibility is reduced.

2.3 Functions

The PSVTS provides its services through two major functions: monitoring and advising.

transit. Under conditions of traffic congestion or other hazardous circumstances, the VTS is authorized to issue directions to vessels. This authority is used prudently and only when dictated by existing conditions.

2.3.3 Additional VTS Functions

In addition to these basic traffic service functions the Puget Sound VTS will relay messages between Coast Guard units and between vessels and on-shore company installations, when it does not interfere with the basic functions. The VTS also handles and passes information about Marine Events to both VTS participants and recreational vessels. During the fishing season, the Puget Sound VTS prepares two messages hourly, listing the vessels in the traffic system that will transit fishing areas open for that day. These messages are broadcast hourly by Group Seattle and Group Port Angeles.

The Puget Sound VTS and the Vancouver VTMS pass marine information back and forth over a teletype and a direct (hot line) telephone. The teletype is used for notification that a vessel will be entering the other's system within the next 30 - 60 minutes and for less immediate information transfer, such as

3 - QM3 - Watchstanders

3 - RDC - Watchstanders

3 - RD1 - Watchstanders

4 - RD3 - Watchstanders

1 - YN2 - Administration and Supply.

Each watch section included one officer, at least four watchstanders qualified on all positions - Primary Communicator, Plotter, Radar Operator and External Communicator - and one or more day workers and/or trainees.

2.4.2 Selection

Full Lieutenants with seagoing experience as Operations Officer on a High (or Medium) Endurance Cutter, or as Commanding Officer of a Patrol Boat, are needed as Watch Supervisors. Anyone with average or above average proficiency and due for a shore assignment may be selected for VTS duty, although consideration is given to those who volunteer for the assignment. In general, VTS watchstander assignments have been made from Radarman and Quartermaster ratings. A normal tour of duty is three years.

a trainee may fail to qualify. Generally, it takes up to 6 months for a watchstander to become fully proficient.

2.4.4 Work Schedule

There is a regular rotation of watch personnel through the three eight-hour watch shifts and days off so that each watch crew's membership varies according to the schedule. The watch schedule for each individual typically consists of four shifts on and three days off for the three shifts of 0000-0800/0800-1600/1600-2400, with an additional eight-hour watch (dayworker) on the day shift. The watchstander averages 40 hours of watch duty per week (see Table 2-1.) During a watch, the watchstanders rotate through the positions of Plotter, Primary Communicator, External Communicator, and Radar Operator, spending about 2 hours at each position.

2.5 Operating Positions

The Puget Sound VTS operates from a Vessel Traffic Center (VTC) located in Seattle, WA. The VTS provides its services by assigning various activities to the following operating or duty positions: Primary Communicator, Plotter, Radar Operator, and External Communicator. The term "watchstander" will be used to refer to any of these positions. A basic watch section is comprised of one person for each duty position and a Watch Supervisor. In addition, an extra watchstander, a "day worker", may be assigned on a day shift, and one or more trainees may be performing watchstander duties under qualified supervision.

2.5.1 Watch Supervisor

The Watch Supervisor is an officer who is responsible for the total VTS operation during a watch, having the responsibilities of Officer of the Deck (OOD) as defined in USCG Regulations (CG-300). The Watch Supervisor is the direct representative of the Commanding Officer, and for emergency situations has been delegated the traffic control authority of the Captain of the Port (COTP.) The Watch Supervisor stays continually aware of all activities of the VTS during his watch. He assigns his personnel to the various operating positions, supervises their

NAME Margaret Foss

DESTINATION Seattle

ETA 0800 PT.JEFF0400 | TERM

SOA 84.5

DEPART PTS 1845

TUG FRT TKR GOV FY FV
OIL MT HAZ CHEM MISC
LOA/200/13 BG 2RB

NOTES
PT JEFFERSON 0400--SLOW DOWN

78 JAN 24	18:59	PTS
78 JAN 24	20:26	C
78 JAN 24	21:51	1/2N. RB
78 JAN 24	23:22	PART.PT.
78 JAN 25	02:34	PNP c/s4.5
78 JAN 25	05:11	SH
78 JAN 25	07:12	BAY
78 JAN 25	07:49	

OUT EWW *GPO 798-559

FIGURE 2-2. EXAMPLE OF A VESSEL STATUS (TRANSIT) CARD

Each time a required report is made,
when unable to establish communication with a participating vessel,
when a vessel commits a violation,
when special circumstances exist with a participating vessel,
each time, communications load permitting, traffic information is passed to a participating vessel,
when a vessel fails to check out, and
when the final report is made.

The time of the final report is circled, and a line is drawn from the circle to the lower left of the card, where the checkout position is written. The reverse side of the card is punched and annotated on the following occasions:

After notifying Coast Guard authorities of USSR vessel movements,
when vessel movements are reported to the Vancouver VTMS by teletype, and
when a card is made up for the Deep Draft Port Location File.

Anticipated traffic (meeting, overtaking or crossing),
fishing vessel concentrations,
discrepancies in aids to navigation,
channel hazards or obstructions,
weather warnings and information,
traffic controls, and
any other information which may affect vessel traffic safety or the port.

A traffic advisory is provided each vessel as it enters the VTS system, at every movement reporting point, and at any other time when it is apparent that changing conditions warrant it.

A typical advisory follows: "HARRY M. this is SEATTLE TRAFFIC; the display shows the PUGET working off the firedocks in the west waterway, the EVCO BREEZE is headed up waterway to Keiser, the THYLENE W. is inbound in the bay, she'll be going up to Lockheed docks and the EXPRESS, light tug inbound, is going to West Anchorage. Over."

FIGURE 2-3. COMPLETED VESSEL MODEL

at the prow. The hulls are color coded to represent various types of vessels. The data tiles are white rectangles about the size of the hull. Some tiles are pre-labelled in black letters; others are blank and are marked by the Plotter with a grease pencil. The order of information on the data tiles from top to bottom is: ETA, SOA, destination, and name. Figure 2-3 shows a typical vessel model.

Models are placed on the plotting table with the prow at the vessel's location on the map. Additional markers can be placed to represent aids to navigation. Figure 2-4 shows several models and markers on the plotting table.

The Plotter's primary responsibility is the maintenance of a complete and up-to-date plot of all vessels participating in the VTS, noting their direction, destination, and estimated time of arrival (ETA) at the next reporting point. Plotting vessel traffic involves a series of vessel entries, exits and updates of the table display. The Plotter advances each vessel model through a dead-reckoning (DR) procedure every 15 minutes. In addition to this scheduled update, he moves the models or corrects their data in response to new vessel information from radio communications and radar surveillance. Thus, the Plotter, like the Primary Communicator, must continually cross-check the displayed traffic against other available information.

2.5.4 Radar Operator

The Radar Operator monitors four radar repeaters (scopes) in order to verify and correct vessel identification and status data through visual inspection of the traffic display or through communications with the Plotter or Primary Communicator. A radar update occurs on an irregular basis and is usually performed by the Plotter. The initiation of such an update is made by either the Radar Operator or the Plotter, involving one or more vessels and the transfer of current radar data to the plot. This transfer can be done in two ways: (a) The Plotter may look at the radar scopes directly and update his plot, or (b) the Radar Operator may compare the plot and his radar and tell the Plotter of any discrepancies, including unidentified vessels. Sometimes the Radar Operator plots radar-observed traffic on a map overlay which he hands to the Plotter. The Radar Operator notifies the Watch Supervisor of any potentially hazardous situations.

Once each watch a Radar Operator makes a calibration check of each of the 4 radar sites, entering data in a log as information for maintenance. Qualified radar technicians may make tuning adjustments at the remote sites from their VTC position.

2.5.5 External Communicator

The External Communicator is responsible for information in and out of the VTS other than the direct radio communications with vessels. He receives incoming telephone calls and operates the teletype between the PSVTS and the Canadian VTMS in Vancouver, BC. The External Communicator records in a vessel transit log the name, destination and ETA for vessels currently in the Puget Sound VTS. The information is tape-recorded every hour. The general public as well as pilots, dispatchers, agents, owners, and U.S. Customs and Immigration, can telephone for this information. The External Communicator assists the Plotter during high vessel traffic periods; during the fishing season, he prepares the Fishing Vessel Traffic Advisory Broadcast, and he files the vessel transit cards accumulated on the previous watch by vessel type and date/time.

2.5.6 Information Flow

Figure 2-6 shows the basic pattern and modes of information flow in the PSVTS. A vessel reports its position by radio to the Primary Communicator, who writes the information on a card, time-stamps it, and hands it to the Plotter, who updates the plot. The Primary Communicator visually reads the traffic situation from the plot, mentally integrates and extrapolates the data, and provides a traffic advisory to the vessel via radio. Additional inputs to the plot include vessel position information sensed by radar and reported to the Plotter by the Radar Operator, advance information from the Vancouver VTMS received by teletype and relayed to the Plotter by the External Communicator, and vessel entry information phoned directly to the Plotter from the Vancouver VTMS. Advisories are also transmitted to Vancouver via telephone and teletype. The Watch Supervisor oversees all operations and intervenes when necessary.

In actual operation, the information flow is usually more complex. Everyone communicates by voice with everyone else, and anyone may assist the Plotter by moving models on nearby areas of the plotting table.

frequently moves around the plotting table to reach vessel models. The External Communicator must cross the room to monitor or use the teletypes, and the Watch Supervisor goes wherever he is needed to resolve problems.

PC = PRIMARY COMMUNICATOR
PL = PLOTTER
RO = RADAR OPERATOR
XC = EXTERNAL COMMUNICATOR
C = COMMUNICATIONS CONSOLE
R = RADAR REPEATER
T = TELETYPE

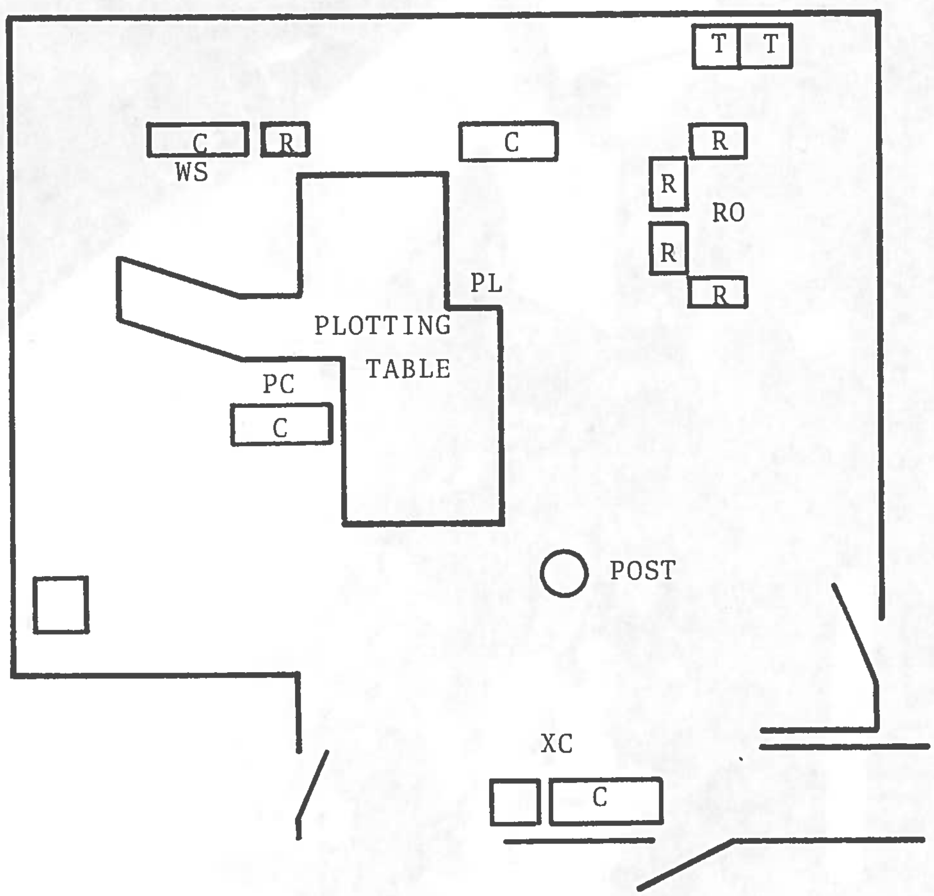

FIGURE 2-7. GENERAL LAYOUT OF THE OPERATIONS ROOM, PUGET SOUND VESSEL TRAFFIC CENTER

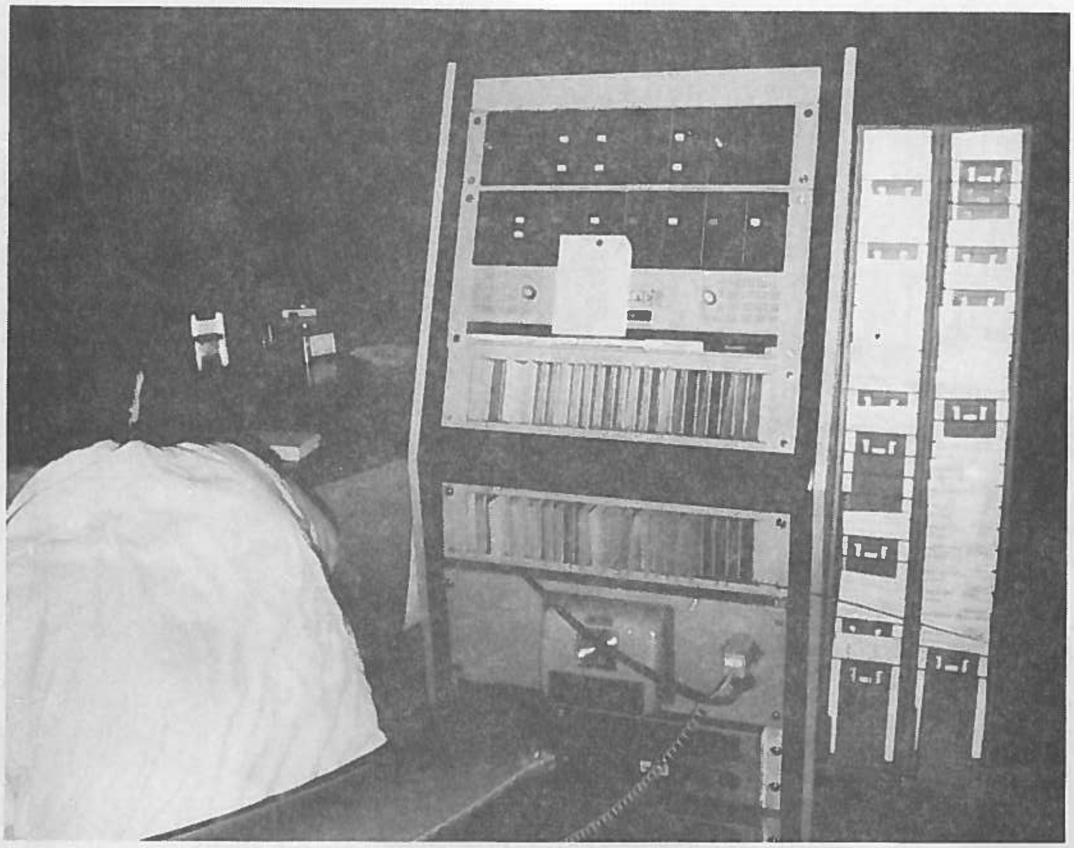

FIGURE 2-9. PRIMARY COMMUNICATOR'S CONSOLE

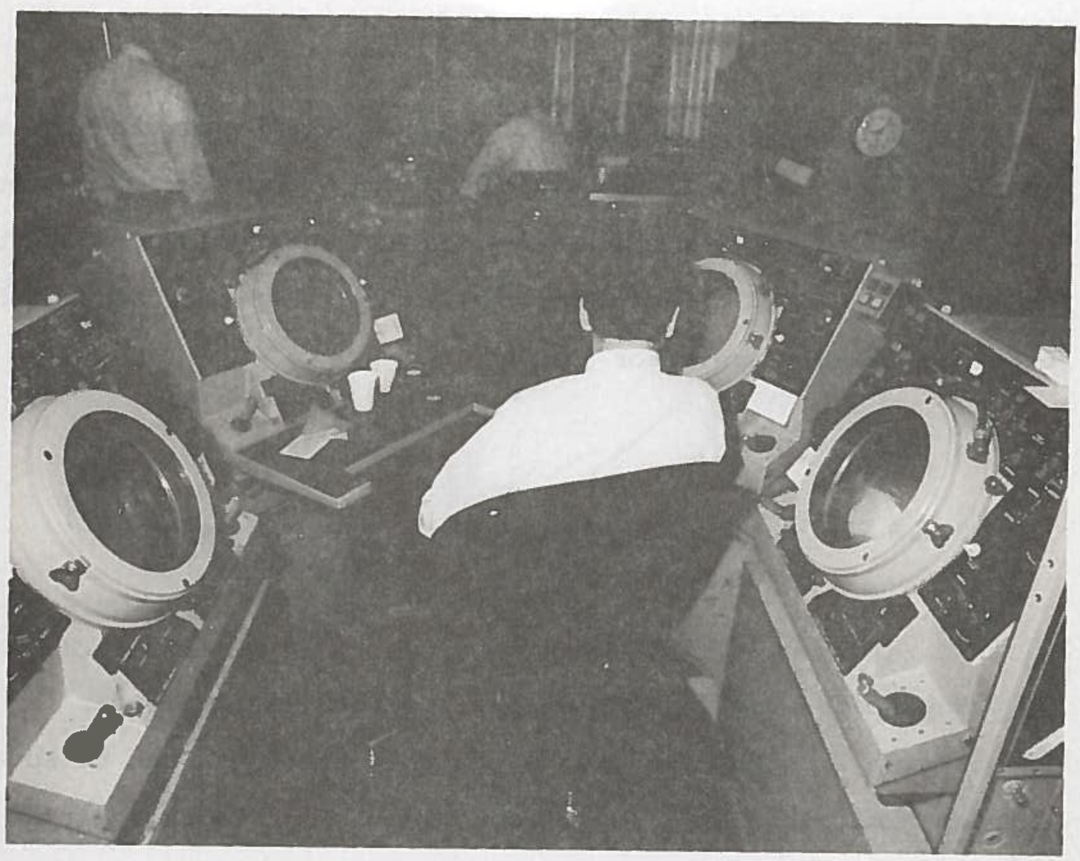

FIGURE 2-11. RADAR OPERATOR'S POSITION

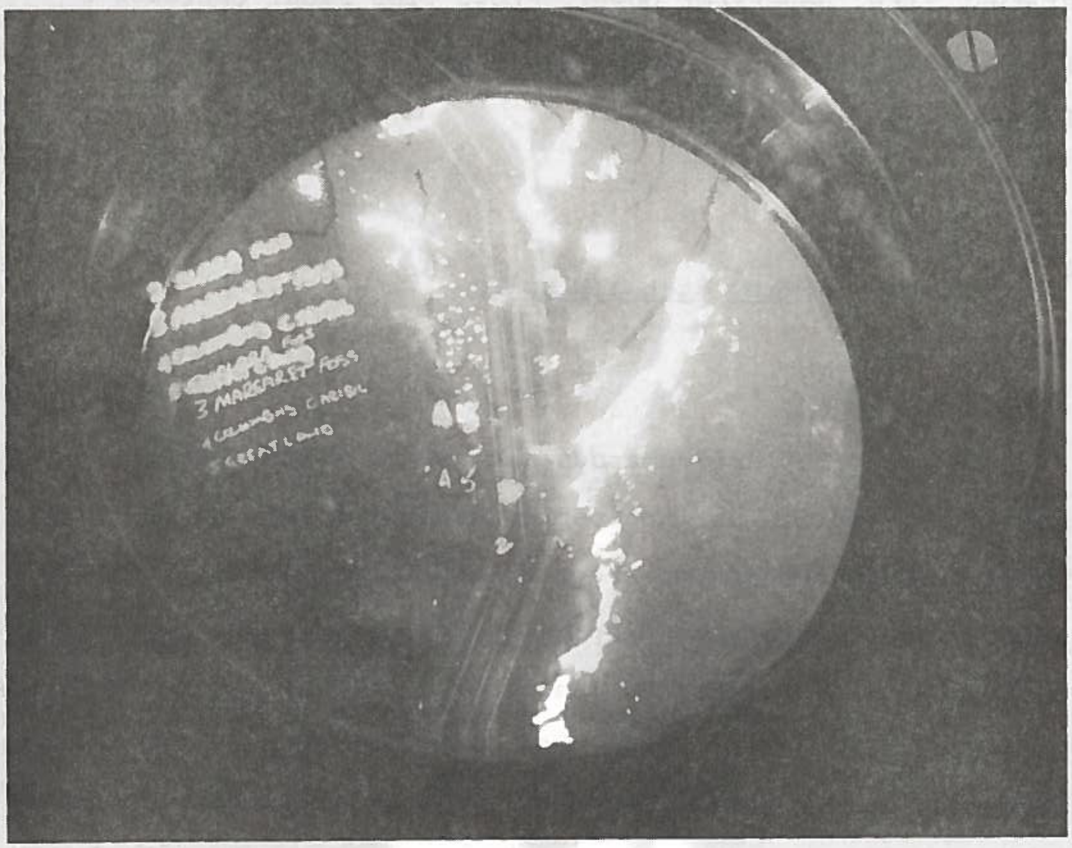

FIGURE 2-12. RADAR DISPLAY

turning off the light; with a westbound departure, he throws the switch to the right illuminating a red light.

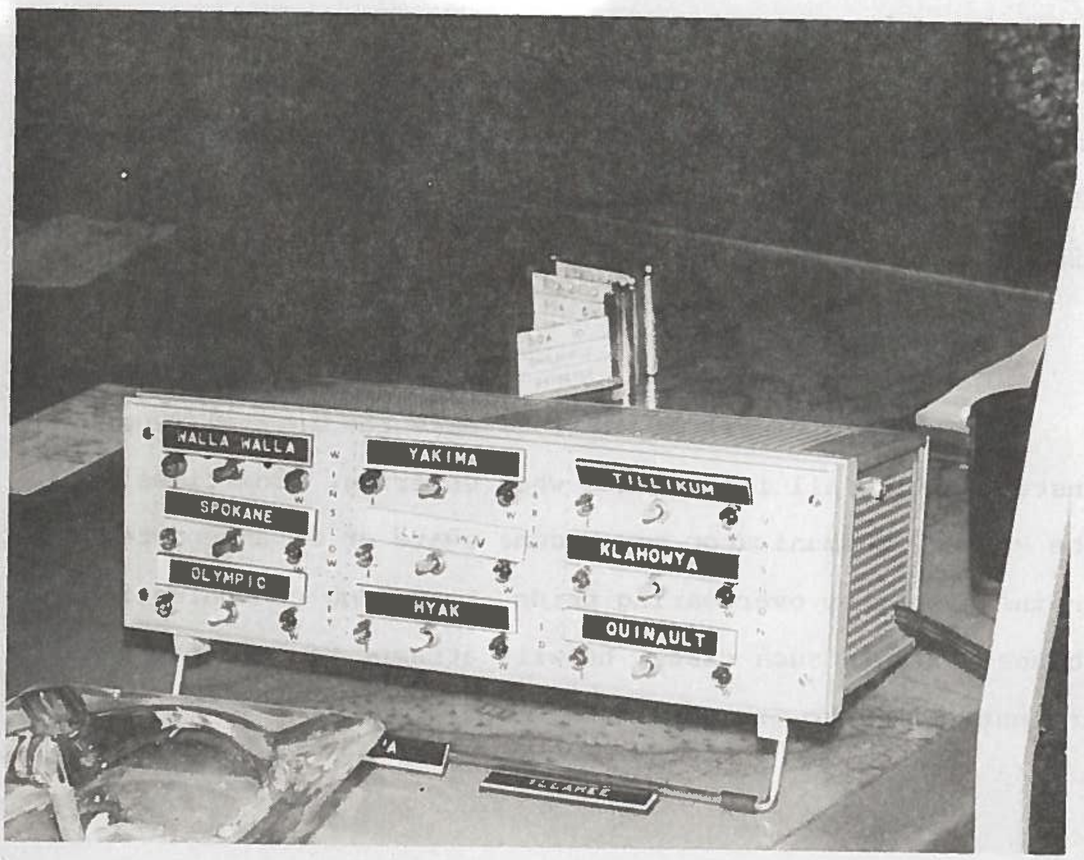

FIGURE 2-13. FERRY STATUS DISPLAY

Primary Communicator of the transit. A model and a vessel transit card are prepared and stored. Likewise, the Puget Sound VTS notifies Vancouver at least 30 minutes before a handoff to Vancouver. When the vessel checks out, the Primary Communicator informs the pilot of the Vancouver radio frequency and reports this event to the Plotter, who notifies Vancouver through a "hot line" telephone.

2.7.2 <u>Transit</u>

While underway in the VTS area, a vessel may report its position under any of the following circumstances:

Vessel requests information from the VTC.

VTC requests information from the vessel.

Vessel routinely reports passing a designated reporting point. (Where there is no radar coverage, or at radar area boundaries, 9 reporting points, shown in Figure 2-1, have been specified. Additional reporting points may be designated by the watchstander if needed.)

Vessel reports changing traffic lanes.

Vessel reports a change in speed of over 1 knot.

Primary Communicator locates the transit card in the card file, time-punches the card, locates the vessel model on the plot and writes the new data on the card. The vessel is then provided a traffic advisory of conditions that he will encounter during

For an inbound deep draft vessel, the Primary Communicator additionally makes up a new status card, time-punches it, and stores it in an in-port location file. The old card is annotated, time-punched, and passed to Plotter to be stored. When a vessel is bound for an anchorage, the card is passed to the Plotter, who removes three tiles from the model, adds an anchorage tile and marks the ETD. The vessel model is stored on the plotting table, and the transit card is reviewed by the Watch Supervisor for recording vessel information in the Anchorage Listing Log.

3. METHOD

3.1 Scope

Watchstander activities at PSVTS were observed for 12 one-hour sessions from January 24 through January 27, 1978. The intervals of data collection were selected in order to provide a representative sample of traffic load and time-of-day activities. The earliest session began at 0500 hours and the latest ended at 2230 hours.

Since the purpose of the VTS is to prevent collisions and groundings and the medium for achieving this end is voice communications via the radio-telephone, it is clear that the information passed between the center and the vessels is the critical element in this process. Therefore, it was decided that the activities of the Primary Communicator, the "Voice" of the center, should be the focus of this investigation. And, since the information conveyed to the vessels and required for making relevant decisions must be stored and readily accessible, the activities surrounding the plotting board were considered to be of comparable importance. Two observers, therefore, were assigned the tasks of monitoring the activities of the Primary Communicator and the Plotter, and, to a lesser degree, activities

Essentially, the Plotter has one basic task; that of maintaining the plot. Based on a variety of input sources he must assure that the models on the board accurately represent the vessels in the system with regard to position, speed, destination, and ETA. This major task was divided into the following six specific aspects of plot maintenance:

1. Vessel Entry
2. Scheduled Board Update
3. Individual Model Update
4. Vessel Tile Update
5. Vessel Exit
6. Radar Update.

These categories are, in the main, mutually exclusive although occasionally there may be coincident occurrences. For example, an individual model update may occur within the period of a scheduled board update.

3.2.2 Channel 14 Communications

The PSVTS maintains a daily 20-channel tape recording of all official communications with the Center. On the day following data gathering a recording of the communications on Channel 14 for the target periods was made from this master tape. The relevant material from this recording included start and stop times of a communication, the name of the vessel involved, who initiated the call, and whether or not contact was made. Transcripts of the communications are not complete at this time, but an analysis of their content is planned for a later supplement.

3.2.3 Primary Communicator

One observer was stationed behind the Primary Communicator to observe communication-related activities. The data were recorded by making a voice narrative into a cassette tape recorder describing the activities of the Primary Communicator. Basically this involved elaboration of the five categories named above.

4. Other Watchstander Communications. Although there was a considerable amount of conversation between watchstanders, only those conversations which were deemed job related were indicated on the tapes.

5. Assisting the Plotter. This category included those activities which were nominally part of the Plotter's tasks but which the Primary Communicator could easily do under conditions of light radio traffic, (for example, aiding with a scheduled board update or an individual model update, and changing ETA, SOA or destination tiles.)

3.2.4 Plotter

A second observer, stationed behind the Plotter, was responsible for making a voice narrative on a cassette recorder of all activities relating to the plotting board. This emphasis concentrated mostly on the Plotter but, tangentially, covered activities of the External Communicator, Watch Supervisor, and Radar Operator as they related to the plot. Elaboration of the six Plotter categories included the following:

5. Vessel Exit. When a vessel reported leaving the system the observer noted the time from removing the model from the board to replacing the model and cleaned tiles in their respective storage places.

6. Radar update. This operation, while usually performed by the Plotter, clearly required the assistance of the Radar Operator to indicate the occurrence of a radar update. The observer noted start and stop times from the Radar Operator's spoken notification concerning the first vessel to the Plotter's position adjustment of the last vessel.

3.2.5 Other Watchstanders

At various times during the sample periods activities of the Watch Supervisor, Radar Operator, and External Communicator were observed by a member of the TSC team in order to get a listing of their indidual activities. Since the activities of these watchstanders were basically in support of the Plotter, a less detailed, yet fairly complete, description was considered adequate.

series. These summaries form the basis for the analyses of Section 4.

3.2.7 Interviews

Six individual interviews were conducted by one interviewer. Each interview generally followed the same format and covered the same topics but was open-ended in nature. The interviewee was assured that he was not being evaluated (rather, that he was helping evaluate the system), and anonymity was assured. The interview, conducted in a comfortable private office, proceeded as a conversation, with the interviewer observing the planned format but freely following up leads and probing interesting topics at his discretion. Interview durations averaged about one hour.

3.2.8 Stress Questionnaires

A questionnaire intended to elicit information on subjective stress was administered to 14 watchstanders. The questionnaire contained 30 items (20 on body functions, 10 on mood) that could be simply checked off by the subject. (A Copy of the questionnaire appears in Appendix C). An experimenter explained

4. RESULTS

4.1 Vessel Traffic

The plan to evaluate PSVTS watchstander performance under routine conditions was apparently successful. During data collection no extraordinary events occurred and the daily traffic load could be considered normal. Table 4-1 contains data on the average daily traffic each month at PSVTS for 1977, along with data for the sample period. The total traffic loads for the four sample days were 542, 526, 537, and 566 vessels per day, respectively. This compares favorably to an average of about 530 per day for the month of January, 1978, and an overall daily average of 540 for 1977.

Table 4-1 also gives the mean daily number of vessels per type in the system. The overwhelming majority of vessels in the system were ferries (i.e., 74 percent of the 1977 total) followed by tugs, 17 percent; freighters, 4 percent; government vessels, 2 percent; and tankers and miscellaneous vessels, 1 percent each.

Although ferries account for 74 percent of the total traffic in the system they do not reflect nearly that proportion of watchstander activity. Because their routes are fixed and scheduled, cards and models are not routinely kept on their movements. During the day the ferries may or may not report their activities to the VTS and at night or at times of reduced visibility ferries report only departures and arrivals to the Primary Communicator who keeps track of their transits on the Ferry Status Display (see 2.6.4).

In the Strait of Juan de Fuca, a voluntary participation section of the VTS area, there was an average of about 42 participating and only 2 non-participating vessels per day over 1977, and comparable traffic during the sample days. Inspection of Table 4-1 reveals an increase in participation in the Strait from 90 percent in January 1977 to 96 percent in January, 1978.

Traffic data for the 4 days of this study taken from the vessel status cards, and presented in Table 4-2, show an average of 37.8 vessels per hour participating in the system with a mean transit time of 5.2 hours. The 12 sample hours are essentially the same with a mean of 38.5 vessels per hour and a range of 30 to 52.

A summary of the mean hourly traffic participating in the system, as determined from the vessel status cards, is shown in Figure 4-1. Using the designations of 0800-1900 as daylight and 2000-0700 as night, the figure indicates distinctly fewer participating vessels at night than during the day.

4.2 Primary Communicator

Almost the entire repertoire of the Primary Communicator's duty activities is reactive. When a vessel initiates a radio communication (which occurred on 70 percent of all radio calls in the sample) the Primary Communicator responds by answering the call, adjusting the console, handling the cards, and/or conversing with other watchstanders, accordingly. His only non-demand activities are those associated with assisting the plotter, adjusting equipment and cards in preparation for a call, and calling vessels not recently heard from.

The various activities of the Primary Communicator were evaluated in two ways: frequency of event occurrences and event durations. The only measures taken were those that could be objectively recognized. Since time spent looking toward the plotting board may have been an evaluation of board status or simply gazing in the direction of the board with other, unrelated intentions, estimates were made of the separate aspects of these activities.

The total number of occurrences for each of the major recorded activities along with their respective percentage of the total recorded events is presented in Table 4-3. Out of a total of 3232 recorded activities during the 12 hours of data collection 54 percent involved handling the cards, 21 percent were associated with adjustments to the radio console, and 17 percent involved radio communications. Verbal, job-related communications with other watchstanders accounted for only 5 percent of the total. From these data it is clear that the majority of the discrete activities performed by the Primary Communicator involved maintaining the vessel status cards. This is not unexpected since many separate operations are required to keep the cards current, and these cards are official records of interactions with the vessels.

Relative frequency of an activity by a watchstander, however, provides only one view of his duties, that of how often he must perform some tasks. Actual time spent in the execution of a task, activity duration, provides another equally, if not more, important and complete description of a watchstander's work load. Primary Communicator activity durations, as measured from the voice narrative tapes, are summarized in Table 4-4.

TABLE 4-4. DURATIONS OF PRIMARY COMMUNICATOR ACTIVITIES

Activity	Total Time (seconds)	Function Support Time	%
Radio Communication	17,276	17,276	40
Bahokus Peak	2,246 (13%)		
Mt. Constitution	5,010 (29%)		
Gold Mountain	8,292 (98%)		
West Point	1,728 (10%)		
Card Manipulation	18,436		
*Independent	3,687 (20%)		
*Concurrent with Radio	14,749 (80%)	3,687	8
Communication with Others	2,166	2,166	5
Plotter	1,157 (53%)		
Watch Supervisor	547 (25%)		
Radar Operator	215 (10%)		
External Communicator	247 (12%)		
Assisting Plotter	765	765	2
*Monitoring Traffic	18,886	18,442	43
Monitoring Plot			
Passive Monitoring			
*Other Activities	864	864	2
Totals		43,200	100

*Estimated Durations

occur and the relative rarety of participation in conversation not related to the job. Since this readiness is a part of the watchstander's reason for being on duty, its time has been credited to the monitoring function as passive monitoring. Only 2 percent of the time was judged to be occupied by activities unrelated to the job.

The largest single category of time spent in an observable activity was radio communications, 40 percent, and since this is the Primary Communicator's major function, all other activities can be said to support this activity or to assist others with their duties.

The communications may be transmitted over any of four transmission sites: Bahokus Peak, Mt. Constitution, Gold Mountain, and West Point. Almost half of all communications were transmitted over the Gold Mountain site, which had the greatest range, covering the area from Port Angeles down to Seattle with little difficulty. Bahokus Peak, accounting for 13 percent of all transmissions, was used almost exclusively for traffic in the Strait of Juan de Fuca and westward into the ocean. Mt. Constitution was used mostly to contact vessels traveling to or from Vancouver via Rosario Strait. The West Point site is designed to handle traffic in the Seattle area and down to Tacoma. In practice, however, Gold Mountain was used for Seattle

Assisting other watchstanders accounted for 2 percent of the Primary Communicator's time. Specifically this involved aiding the Plotter with schduled updates, changing tiles, and removing a model when the vessel checked out of the system. These tasks, while normally being part of the Plotter's job were performed by the Primary Communicator.

4.3 Plotter

Thirty-seven percent of the Plotter's time was directly related to his primary function, maintaining the plot. He performed these duties either at a scheduled board update time (every 15 minutes) or whenever new information on the status of a vessel came in over the radio. So, in a sense, his activities were also the demand type. Unlike the Primary Communicator, however, the Plotter was subject to much less demand on the exact time at which these activities had to be executed. He did not have to respond immediately to new information. In practice, little time elapsed between awareness of a change in a vessel's reported status and the corresponding change in that vessel's model. So the Plotter, like the Primary Communicator, also spent a large proportion of his time waiting for information on the vessel traffic but, perhaps, in a less vigilant state.

Table 4-5 contains both the frequency and duration data for the Plotter's recorded activities. A total of 49 percent of his time is accounted for in directly observable activities which comprised maintaining the plotting board, working with the Radar Operator in a radar update, handling the vessel status cards, and communicating with other watchstanders. Based on inferences drawn from the recorded data and from observer impressions, an estimate of 18 percent of the total time was associated with monitoring the board. Essentially, this monitoring activity included inspecting the position of the models, listening to radio transmissions and verifying any new information with data associated with the corresponding model, and arranging the tiles for future use on new models.

The mean time required to enter a vessel, from the moment the model base was selected until the completed model was placed on the board, was 41.3 seconds. Mean statistics from scheduled, dead-reckoning updates taken from the observer's tapes show that it took 2.05 minutes per update and that these updates occured every 14.04 minutes.

Radar updates, involving both the Radar Operator and the Plotter, took an average of about one minute of the Plotter's time per update. The amount of time required to gather the

Frequently the Plotter had to walk from his designated position to some other part of the plotting table in order to place or move a model, change data on a model, or observe a traffic situation more closely. This mobility was concurrent with the functional activities and thus does not appear as a separate item in the frequency and duration tabulations. The Plotter made some kind of an excursion from 9 to 24 times per hour during the observations, with a mean of 14 excursions per hour, or about once every four minutes.

4.4 Radar Operator

Narrative observation tapes were not made at the Radar Operator's position. However, during five of the hours that Primary Communicator and Plotter tapes were made, a third observer sat with the Radar Operator and marked observed activities on a tally sheet. Activity duration measurements were not feasible. The frequencies of observed activities are summarized in Table 4-6.

TABLE 4-6. OBSERVED FREQUENCIES OF RADAR OPERATOR ACTIVITIES

Activities	A	B	E	G	H	Total	Percent
Console							
Monitor	81	27	37	29	46	220	44
Mark Scope	47	12	17	17	19	112	22
Adjust	1	3	3	10	21	38	8
Site Status Rack							
Monitor	0	1	0	5	1	7	1
Adjust	0	2	1	5	11	19	4
Movement							
In Position	7	3	9	4	12	35	7
Away From Position	1	0	0	1	0	2	1
Communication							
With Plotter							
Job Related	3	3	16	2	4	28	6
(Board Update)	(2)	(1)	(1)	(1)	(0)	(5)	
(Not Job Related)	(0)	(1)	(0)	(0)	(1)	(2)	
With Watch Supervisor							
Job Related	0	0	1	0	4	5	1
(Not Job Related)	(0)	(1)	(0)	(0)	(0)	(1)	
With Others							
Job Related	8	5	2	3	3	21	4
(Not Job Related)	(1)	(3)	(1)	(0)	(3)	(8)	
References To Log	0	0	0	2	10	12	2
Totals	148	56	86	78	131	499	

the second transmitter at a site is kept set for STC, then it can be switched in at the site status rack without the delay and loss of display. Most of the rack activity observed involved using it for switching STC in or out in this way.

4.4.3 Movement

At the time of observation, the Radar Operator was required to stay in position continuously. Only two instances of leaving the position were observed. In one case, the operator stepped over to the plotting table briefly for a closer look at the situation; in the other, the operator took a two-minute break but had another watchstander monitor the position for him. The other observed activity involved standing up and sitting down again in position, either to see the plotting table better or to relieve cramped muscles.

4.4.4 Communication

Communication with other VTC personnel accounted for 11 percent of the observed activities of the Radar Operator. Over half of the communication was with the Plotter. Only five formal updates of the plot were observed, although it is required every

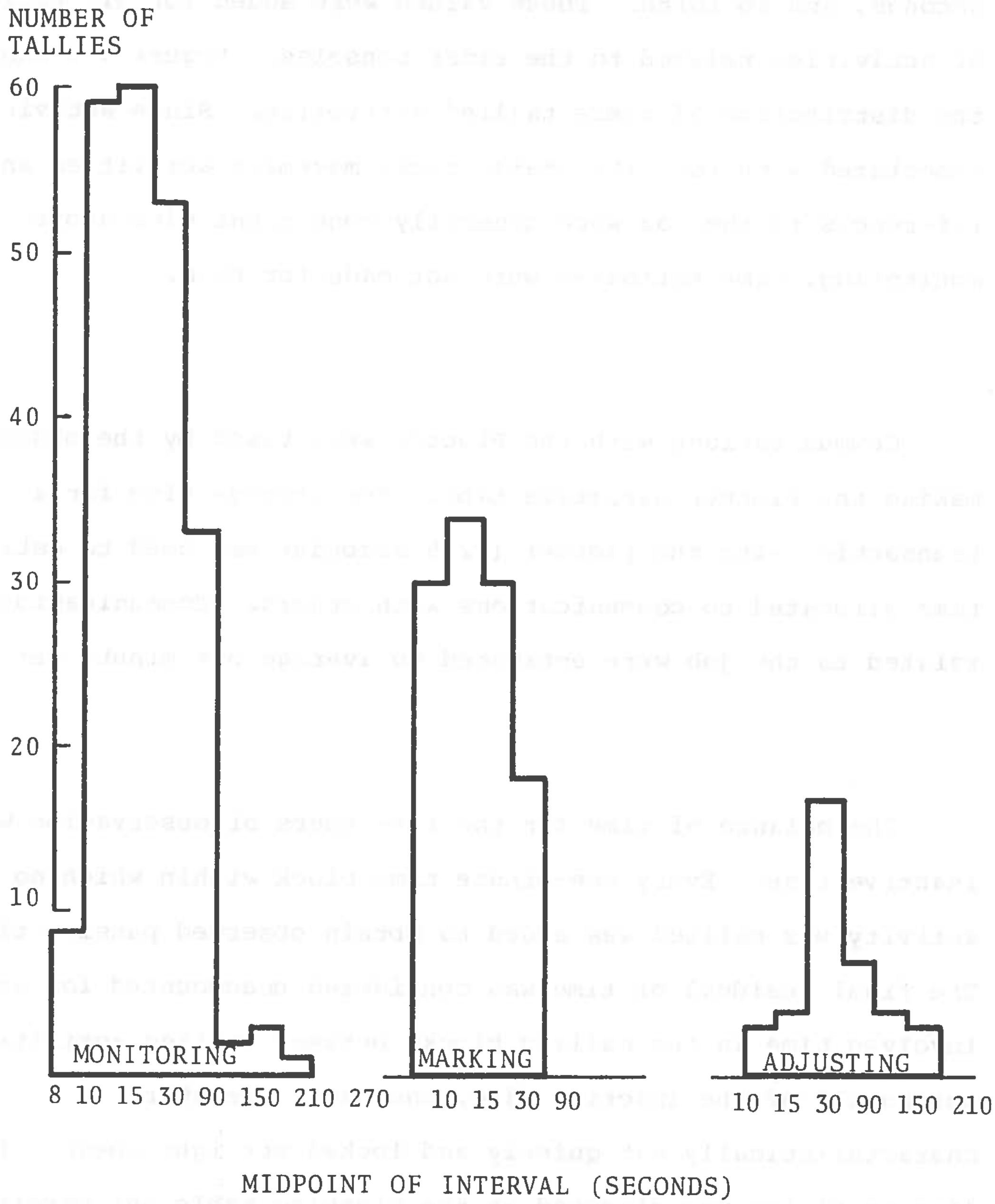

FIGURE 4-2. DISTRIBUTION OF OBSERVED ACTIVITIES AT RADAR CONSOLES

looking at the radar scopes without detectable head movement. Although it was impossible to tell whether the operator was indeed monitoring the plot and his scopes or daydreaming, we have called these inactive periods "inferred monitoring."

The various time estimates were combined and converted to percents of total time. This distribution of the Radar Operator's time over the active and inactive periods is summarized in Table 4-7. Also in the table, the same figures have been combined to show the time contributions to the relevant VTS functions: monitoring traffic, maintaining the plot, and miscellaneous activities. In this accounting, the Radar Operator's tracking activities and communications with other watchstanders were credited to maintaining the plot.

4.4.6 Workload

On the whole, the Radar Operator's job is passive. Only a portion of the traffic in the system is in the area of radar coverage, and that is divided among four scopes. During the periods of observation, the Radar Operator was tracking a maximum of 8 vessels. Characteristically, he sat for long periods doing nothing (inferred monitoring) punctuated with brief flurries of activity, (scope update, plot update, or problem resolution).

Aside from the calibration activity already noted, the only other major activity occurred when the Radar Operator was unable to identify a return on his scope. This resulted in several checks of the plot and verbal interchanges with the Plotter, the Primary Communicator and the Watch Supervisor before the model was located on the plot far behind its true position. Two operators kept busy with job-related tasks -- one tuned and calibrated the radar frequently; the other erased and updated his radar tracking symbols frequently. The other operators simply sat and stared during inactive periods.

4.5 Other Personnel

The activities of the Watch Supervisor and the External Communicator support, but contribute relatively little directly to, the routine functions of monitoring and advising vessel traffic. Each of these positions, however, is discussed below, outlining the significant aspects of their respective contributions to the overall task of the VTS.

TABLE 4-8. FREQUENCY AND DURATION OF EXTERNAL COMMUNICATOR ACTIVITIES OVER 10 HOURS, 12 MINUTES OF OBSERVATION

Activity	Frequency	Duration (in seconds)	Mean Activity Duration (sec.s)	% of Total Time
Outside Communication	39	2335	60	6.4
Entriesin Vessel Transit Log	27	2222	82	6.0
Record Code-A-Phone Message	7	491	70	1.3
TTY/Vancouver	7	579	83	1.6
Communication With Others				
Primary Communicator	23	247	11	0.6
Plotter	13	210	16	0.5
Assist with Plot	25	250	10	0.7
*Other Activities	-	30386	-	83
		36720		100

*Residual Time

TABLE 4-9. FREQUENCY AND DURATION OF WATCH SUPERVISOR ACTIVITIES OVER 2 HOURS OF OBSERVATION

Activity	Frequency	Duration (seconds)	% of Total Time
Monitor			26
Board	18	894	
Radio	17	932	
Radar	3	32	
Communications			13
Vessels (Radio)	3	120	
Outside (Telephone)	8	390	
Watchstanders (Verbal)	14	429	
Handle Written Info			11
Check Ref's	16	575	
Write in Log	3	155	
Handle Cards	4	67	
Assist Others			1
Update Models	7	46	
Adjust Radio	6	34	
Other Activities			49
Social Conversation	18	1890	
Leave Station	9	260	
*Misc.	-	1376	

*Residual Time

TABLE 4-10. LIST OF PSVTS SUPERVISOR'S REFERENCES

List of Juan de Fuca Non-participants
Watch Officer's Information Booklet
PSVTC Manual
VTS Hotword Book - Short term information
VTS Hotword Book - Long term information such as:

- Penitentiary Ferry Schedules
- Private Ferry Schedules
- Emergency Traffic Controls
- Hazardous Traffic Controls
- LNG Regulations
- Telephone Numbers
- Fishing Regulations

Equipment Repair and Maintenance Log
Local Notices to Mariners
PSVTS Seattle Safety Broadcast
Ferry Schedules
List of Merchant Vessels
Lloyd's Shipping Index
List of Lights (USCG)
Violation Letters
Operating Manual

VTS Service. All interviewees agreed that some kind of vessel traffic advisory service is desirable for the Puget Sound area, but their ratings of the effectiveness of the present service ranged from good to poor. Only one interviewee felt that the Coast Guard should be operating the service; the majority favored a Civil Service operation. The interviewees felt that cooperation of pilots and masters is good, although a few are consistently uncooperative. Masters and pilots generally appreciate the traffic advisories but object to being given directions. The VTS has been valuable also in relaying communications, especially in getting assistance for emergency situations. However, the VTS sometimes is a negative influence in giving erroneous or incomplete advisories, in engendering a false reliance on the part of users, in distracting attention of users, and in delaying traffic. The feeling was prevalent that at higher levels the Coast Guard neither understands the purpose nor appreciates the services of the VTS's. Additional comments included: The VTS shouldn't be doing police work. Advisories are too long. Some advisories are unnecessary (for example, passing traffic in a TSS.)

Personnel Matters. Of the six interviewees, three liked VTS duty, two were neutral, and one disliked it. The majority felt that it is not a good career assignment -- that one is not doing what he was trained for and is thus at a disadvantage in his next assignment. Generally, they would not want another VTS

External factors that interviewees felt increase the difficulty of watchstanding include: pleasure boating, fishing fleets, bad weather, accidents, equipment failures on vessels, pilots failing to yield the right-of-way, and lane crossings. Internal factors reported as contributing to difficulties include having visitors in the VTS and having to manipulate vessel status cards.

Equipment. All interviewees agreed that the plotting table is important and gets frequent usage. However, its accuracy was rated moderate to low, especially with regard to exact position. Radar was considered important, but opinions varied considerably about its frequency of usage and accuracy. All interviewees agreed that more radar sites are needed; indeed, half of the interviewees rated radar as the function most badly needing improvement. The difficulty in concentrating on radar for two hours was noted.

Several suggestions were made for rearrangement of equipment, generally aimed at giving the Primary Communicator a better view of the plotting table and the radar.

The PSVTS stress patterns were compared to those obtained in a similar way at the Houston-Galveston VTS. Burning eyes and tiredness were highest also at Houston, but backache and stiffness were much lower (all Houston positions are seated). The general magnitude of stress appeared to be higher at Puget Sound than at Houston, in spite of the fact that Houston runs a 12-hour watch.

4.6.3 Interview with Pilots

Six pilots, members of the Board of Directors of the Puget Sound Pilots Association, were interviewed. (Details of this visit are given in Appendix D.)

The pilots complained of the military aspects of Coast Guard operations, the nature of citations, and the staffing of the VTS by relatively inexperienced personnel. They offered several recommendations, including:

Operate the VTS under civilian authority.
Increase the number of radio channels.
Limit reporting requirements.
Eliminate advisories on routine conditions.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Team Activities

The functions of the PSVTS are accomplished jointly by the combined watch teams. To show the proportion of time allocated to each function by a Watch Team, the estimates for individual duty positions were combined in Table 5-1.

5.1.1 Communicating

Communications with vessels, the primary product of the VTS, account for 8 percent of the Watch Team's time; the rest of the time is spent in support activities or in waiting for the system to require activity. Communicating with vessels is almost exclusively conducted by the Primary Communicator, with the Watch Supervisor occasionally taking over to resolve a problem. Communications outside the VTC, such as routine phone calls, preparation of Code-a-Phone messages, and exchanging information with the Vancouver VTMS, account for about 3 percent of the time, conducted by the External Communicator (2 percent) and the Watch Supervisor (1 percent). General interchange of information among the watchstanders accounts for another 4 percent of the time.

5.1.2 Monitoring

Monitoring the traffic situation occupies nearly a third of the Watch Team's time (30 percent). Everyone except the External Communicator spends a considerable amount of time just keeping an eye on the traffic situation. The External Communicator frequently works at the south end of the plotting table and may also contribute to the monitoring function, but, this function was not directly observed. The Radar Operator spends well over half his time monitoring the situation to assure that the plot accurately reflects the information received by radar. The Watch Supervisor's monitoring time was credited to the monitoring function, although it could just as logically be credited to supervision. The Primary Communicator must base his advisories on his projection of the current traffic situation and thus spends between a half and a third of his time monitoring.

5.1.3 Plotting

The plotting function provides the data for monitoring and advising and required 15 percent of the Watch Team's time, 9 percent going to maintaining the master plot on the board, 4 percent to tracking on the radar scope faces, and 2 percent to up-dating data on the vessel status cards.

a reliable estimate be made as to how much slack time is justifiable under routine conditions.

5.1.5 <u>Traffic Team</u>

In other VTS's, the area is sectorized, with one Sector Watchstander performing all communications, monitoring and plotting functions for his own sector. A Watch Team in these VTS's includes a Sector Watchstander for each sector plus an External Communicator and one or more Supervisors. To make the PSVTS results comparable to Sector Watchstander results in other VTS's, the three positions directly concerned with traffic (Primary Communicator, Plotter, and Radar Operator) were combined and their average time allocations computed for a "Traffic Team." These results (see Table 5-1) show that at PSVTS, for the functional equivalent of a Sector Watchstander, 13 percent of the time is devoted to communication with vessels, 5 percent to other communications, 41 percent to monitoring, 24 percent to plotting, and 17 percent to miscellaneous activities.

radio time, enough closely related activity is added to justify claiming that about 98 percent of his time is occupied with a combination of communication and closely related support activities.

A close look at communications reveals three categories that warrent special attention: communication and traffic load, communication as a function of transmission site, and the actual nature of the vessel advisories.

5.2.1 Communication and Traffic Load

It is to be expected that as the number of vessels participating in the VTS increases, the amount of communications activity would also increase. Figures 5-1 and 5-2 show the relationship between the number of vessels in the system and the number of communications (Fig 5-1) and the total amount of time spent in communication (Fig 5-2) for each of the sample hours. The correlation[5] in the former case is .88 and in the latter,

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[5]A correlation coefficient is an index of the degree to which two sets of measures vary together; 1.00 indicates a perfect relationship, 0.00 indicates no relationship, and a negative value means that one measure increases as the other decreases. Statistical significance is based on an estimate of the likelihood that the value obtained was due to chance alone rather
(Continued)

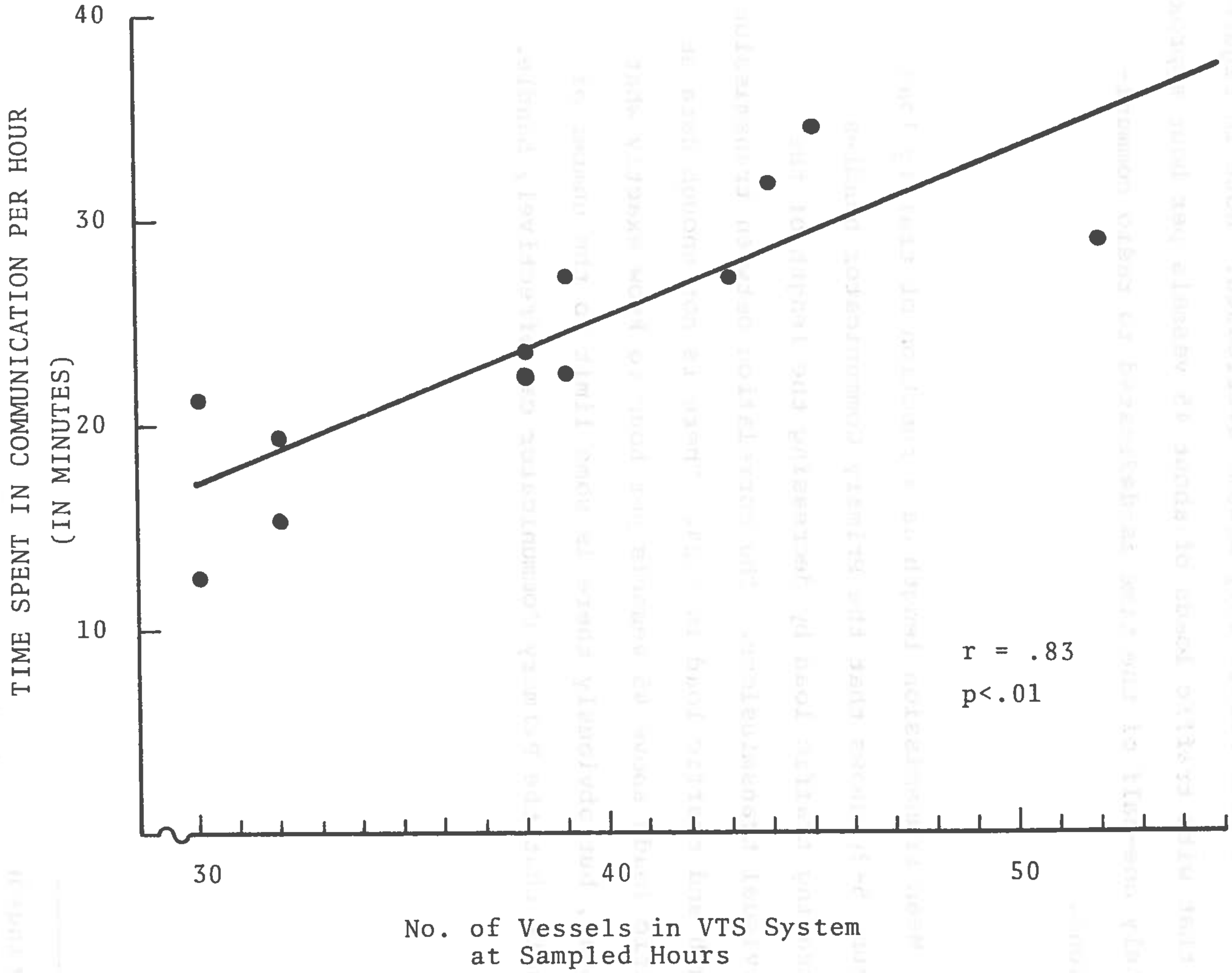

FIGURE 5-2. RELATIONSHIP BETWEEN TIME SPENT IN COMMUNICATIONS AND THE NUMBER OF VESSELS IN THE VTS SYSTEM

5.2.2 Transmission Sites

An analysis of the relative amounts of communication time per transmission site is presented in Table 5-2. When the total communication time per site is divided by the respective number of transactions, the mean transaction time per site results. The significant point here is that the mean transaction time for Bakohus Peak is up to 70 percent larger than for any of the others. The major reason for this is the high proportion of deep-draft vessels entering or leaving the system at the ocean boundary. Although this is a voluntary section of the PSVTS area, most of the vessels do participate (see Table 4-1). These incoming vessels often have foreign masters at the helm who have trouble speaking and understanding English, resulting in delays in the Primary Communicator's obtaining all the pertinent information on the vessels. But even without a language problem, extra time is required to obtain pertinent data on the status of the vessel regarding the condition of onboard radar, communication equipment, and the presence of any mechanical difficulties or oil leakage.

When the Primary Communicator is talking with an entering vessel over the Bahokus Peak site it is difficult for him to interrupt this interaction to deal with other vessels which may be calling from somewhere else in the system. So, to the degree

TABLE 5-2. COMMUNICATION DATA AS A FUNCTION OF TRANSMISSION SITE

	Bahokus Peak	Mt. Constitution	Gold Mountain	West Point
Total Time in Communication (in seconds)	2,246	5,010	8,292	1,728
Number of Radio transactions	44	153	281	55
Mean Time Per Transaction (in seconds)	51.05	32.75	29.51	31.42

Another area deserving study and possible revision concerns the content of the advisories themselves. A typical transaction between a vessel and the VTS includes an initial call, acknowledgment, message and response, followed by an advisory about the traffic condition the vessel should encounter over the next half hour. The pilots interviewed complained that many of the advisories given by the VTS are unnecessary. They felt that responding to a VTS call took a pilot away from other more important tasks simply to respond to a message which was not needed. They also felt that the advisories were too long. That is, sometimes the reported traffic for the next half hour might include 10 or more vessels and there would be no way the pilot could remember all these meetings and overtakings. In conversations with TSC personnel on this topic, some of the watchstanders agreed with the pilots to a degree. Also, they said that when the traffic is heavy the problem is often aggravated by a VTS practice of giving an advisory for the next hour to conserve radio time by reducing the number of advisories.

At this time no specific recommendations seem proper concerning changes in the nature of advisories, but it is suggested that PSVTS look closely at their current procedures. For example, when the visibility is good, how important is it to notify vessels of other approaching vessels within the TSS areas? How far in advance should traffic be described?

One source of error in updating results from careless repositioning by a watchstander. Another source is erroneous information on SOA on the tiles. Although vessels are required to report any change in speed greater than plus or minus one knot, in practice this is often not done, resulting in improper dead-reckoning updates. A third kind of updating error results when the Plotter applies a routine 15-minute advance to a vessel that has been updated within the last 15 minutes.

Measuring position discrepancies was not part of the initial plan of this study but incidental data on discrepancies were recorded. Whenever the Plotter adjusted (corrected) the position of a model on the board, an observer noted the absolute amount of change in terms of model lengths. (Each model had a scale length equivalent to 2 1/4 miles). Over 11 hours of observation, 72 model adjustments were recorded, ranging from 0 (no change) to 3 boat lengths (6.75 miles). The mean adjustment was the equivalent of 1.03 miles. These statistics are only descriptive and all that can be said is that for those models that were recognized as being out of position on the board the average deviation represented about 1 mile off course. Nothing can be said about the proportion of vessels that were off course or what the source of the error was.

In summary, given the present use of the plotting board at PSVTS, the major recommendations resulting from this study would be to increase the radar coverage (presently in the planning state) and begin each scheduled board update with the more precise radar update.

5.4 Operational Factors

5.4.1 Sectorization

There is a second communicator's console in the VTC located near the Plotter's position. In the past, attempts have been made to reduce the Primary Communicator's workload when the traffic load was heavy by dividing the system into two sectors, giving the Plotter the Primary Communicator function for the second sector and having the Radar Operator maintain the plot as well as monitor the radar scopes. These efforts were largely unsuccessful, because the two Communicators' radio messages interfered with one-another.

Staffing the radar position raises problems of fatigue and vigilance. The equipment is noisey, and the need to work at a low level of illumination is visually fatiguing. The Radar Operator must detect the problems he is there to resolve; the system does not call them to his attention. Present requirements for plotting radar targets and adjusting radar equipment occupy only a little over a third of his time -- and some of that may be "busy work" (4.4.6). A procedural change adopted during the observation period relieves Watch Chiefs from radar duty; so the other watchstanders will spend even more time on the scopes. There is considerable risk, then, that the Radar Operator's attention may be distracted from the job.

5.4.3 Procedures

The PSVTS Traffic Center Manual specifies some procedures in considerable detail but is not specific about all procedures. Consequently, each Watch Supervisor has adopted his own preferences for procedures, particularly with regard to updating the plot. Since watch personnel are regularly regrouped rather than being assigned as teams with the same supervisors (2.4.4), there is a degree of uncertainty on any watch as to exactly how things should be done. This problem was recognized and discussed at a supervisors' meeting during the observation period.

In general, it would be advisable for all supervisors to review all procedures, agree on a standard set, state these clearly in a revised manual, and enforce them.

5.4.4 Workspace

Illumination. The most striking characteristic of the operations room at the Puget Sound VTS is its dim level of illumination, maintained to minimize interference with the radar displays. A more subtle feature is the variability in illumination. Overhead fluorescent and spot lights brighten work stations but create glare spots on shiny surfaces. The plotting board is both front-and back-illuminated. During daylight hours, the windows are covered with heavy drapes. None of the interviewees (Appendix B) complained about illumination, yet the highest somatic stress rating (Appendix C) was "Aching or Burning Eyes." Continual readaptation to different light levels may account for some of this visual stress. Other factors may be the necessity to read fine detail (model data and radar returns) at low light levels and to change accommodation for different distances in monitoring the plotting table.

Elevating the Radar Operator's position onto a one-foot-high platform would increase the angle to 4 degrees seated, 7 degrees standing. A better advantage can be gained by moving the Radar Operator closer to the plotting table. A five-foot move toward the table at floor level would yield 6 degrees seated, 10 degrees standing, while elevating the position one foot would give 10 degrees seated, 13.5 degrees standing. Additional advantages would be realized by elevating the Radar Operator's position and moving it closer to the plotting table: the radar consoles could be arranged so that the Plotter could see the scopes; the radar consoles (and their noise) would be farther from the Plotter and Primary Communicator, and the Radar Operator would be closer to the other watchstanders.

Consolidation of the External Communicator's position mainly involves bringing the teletypes closer to the basic position. As it is now, the External Communicator must cross the room each time this equipment requires attention. Sound-shielding would be required because of teletype noise.

Rearrangement of present equipment also merits immediate consideration. Items to be considered include: elevating the Primary Communicator, lowering his communications console and placing it in front of him, elevating the Radar Operator, moving his position closer to the plotting table, rearranging the radar equipment so that the scopes can be seen by the Plotter, and moving the teletype equipment to the External Communicator's position.

Improvements with More Communications Channels. If even one additional channel were reserved for VTS use, the present operation could be sectorized. Equipment is already on hand for a second Communicator's position. Each Communicator would have less traffic to handle, reducing the risks of overload. An additional person would be desirable for each watch section; however, if this were not possible, the Plotter or the External Communicator could monitor the radar. An alternative development that might permit sectorization would be to relocate radio transmitter sites to reduce area overlap.

Improvements with Improved Radar. When the proposed new radar sites and equipment are operational, it may be possible to locate radar repeaters at Sector Watchstander positions, eliminating the Radar Operator function and position. Should equipment permit each sector to be covered on a single scope, then the

5.5 Personnel Factors

5.5.1 Staffing

At the time of the data collection for this study, PSVTS was well staffed. However, past experience at PSVTS as well as experience at other VTS's shows that current USCG staffing procedures permit staffing crises to occur periodically. These crises occur when a number of personnel transfers take place at about the same time. Because (a) replacements generally do not arrive before the transferees depart the VTS and (b) it takes 6 to 8 weeks to prepare a replacement to stand watches, the VTS must run short-handed during the training period, with consequent extra hours of work, fatigue, lowered morale and general lowered performance levels. This situation is occasionally aggravated by the assignment of a person who, for any of a number of reasons, can not qualify as a watchstander. The time lost during training and transfer of such an untrainable can be upwards of a year -- a serious impediment to maintaining a 24-hour service with a limited number of people. The USCG is presently examining selection and placement procedures to alleviate these conditions.

5.6 Recommendations

Analysis of all of the data collected at PSVTS has revealed several areas that appear to be amenable to improvements. The feasibility and desirability of implementing these changes can not be determined from this study; however, we do recommend that consideration be given to these recommendations and that their feasibility be given study. (Note: At the time of publication, PSVTS had taken positive action on recommendations a and d, and the District had established a study group to investigate and act on several others.)

5.6.1 Immediate Recommendations

a. Adopt as standard procedure a complete radar update before each 15-minute dead-reckoning update. (5.4.2, 5.4.4)[6]

b. Review and standardize all operating procedures. (5.4.3)

c. Study ways to reduce the number of advisories

[6]Numbers in parentheses refer to relevant sections of this report.

5.6.2 Recommendations with Improved Communications

l. Divide the Primary Communicator function into two or more Sector Watchstander Positions. (5.2, 5.4.1, 5.4.5)

m. Further consolidate the communications console. (5.4.5)

5.6.3 Recommendations with Improved Radar

n. Provide each Sector Watchstander with a radar display covering his area. (5.4.5)

o. Plot radar traffic at the Sector Watchstander positions; eliminate the Radar Operator position. (5.4.5)

p. Design a consolidated radar-communications console for the Sector Watchstander. (5.4.5) of incoming and outgoing personnel for a training period.

APPENDIX A.

EVENT SEQUENCE, ROUTINE PASSAGE

○ Information received by an operator or a system component

□ Operator action

◁ Transmission of information or action

◇ Operator decision

⧈ Automatic action

◎ Automatic receipt of information

◀ Automatic transmission of information/data

▽ Manual storage, filing of information

 Automatic data storage

 A communications loop between two operators, talk without aids

 A communications loop between two operators, radio or interphone

A Aurally or Vocally

T Tactually

V Visually

● "Or gate"; follow one path only

FIGURE A-2. OPERATIONAL SEQUENCE DIAGRAM: LEGEND

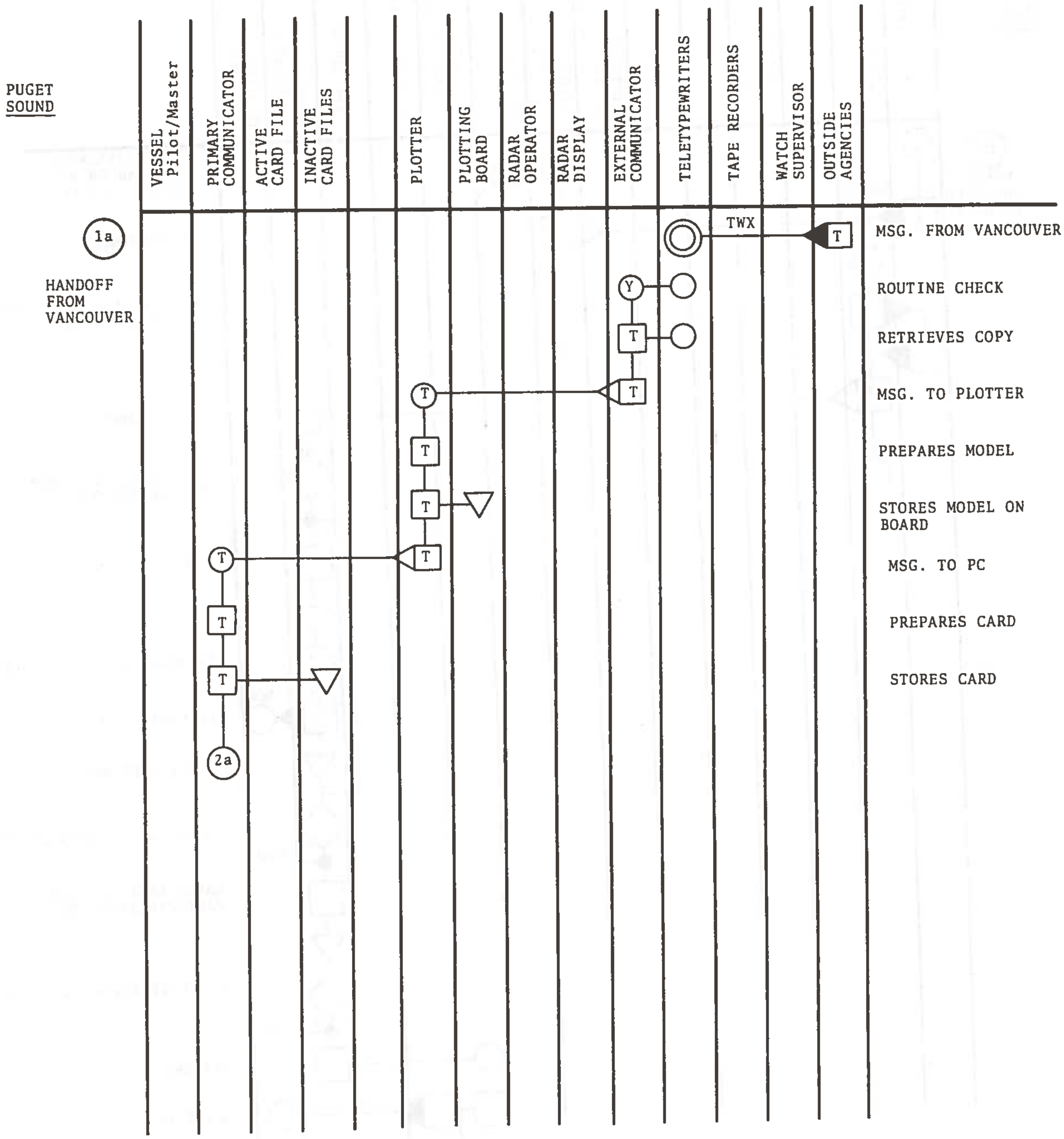

FIGURE A-4. OPERATIONAL SEQUENCE DIAGRAM: HANDOFF FROM VANCOUVER

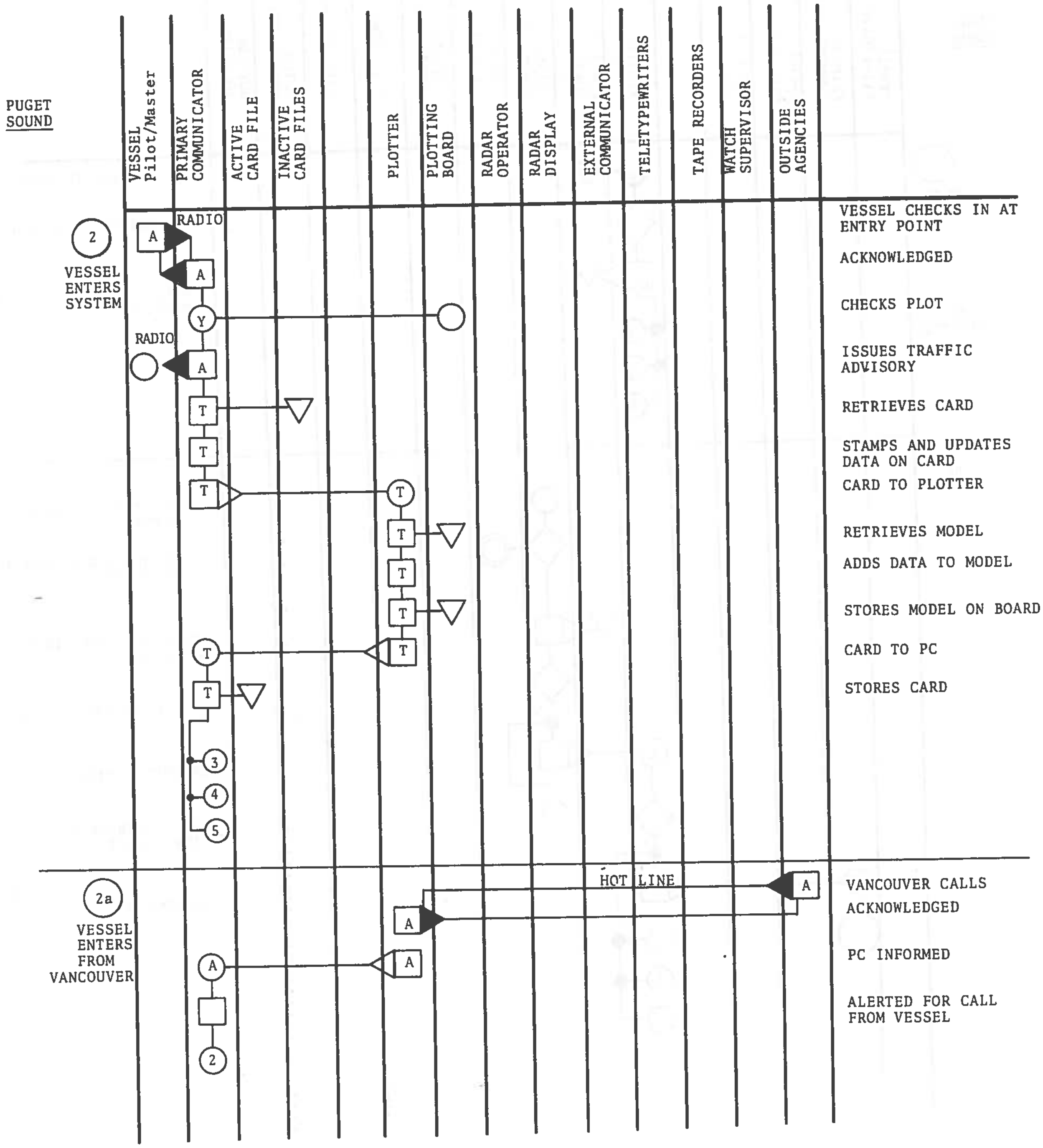

FIGURE A-6. OPERATIONAL SEQUENCE DIAGRAM: VESSEL ENTERS SYSTEM

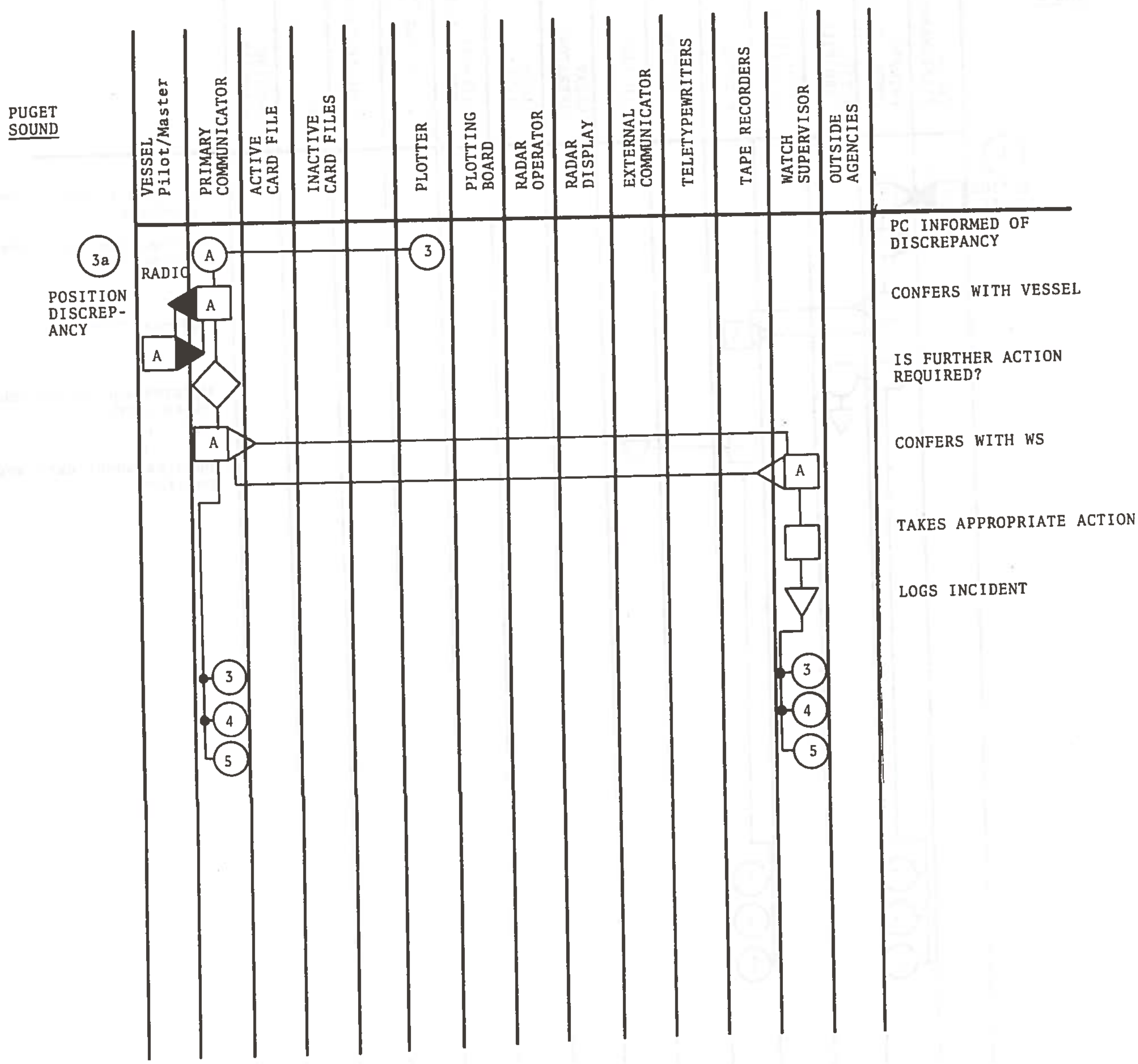

FIGURE A-8. OPERATIONAL SEQUENCE DIAGRAM: POSITION DISCREPANCY

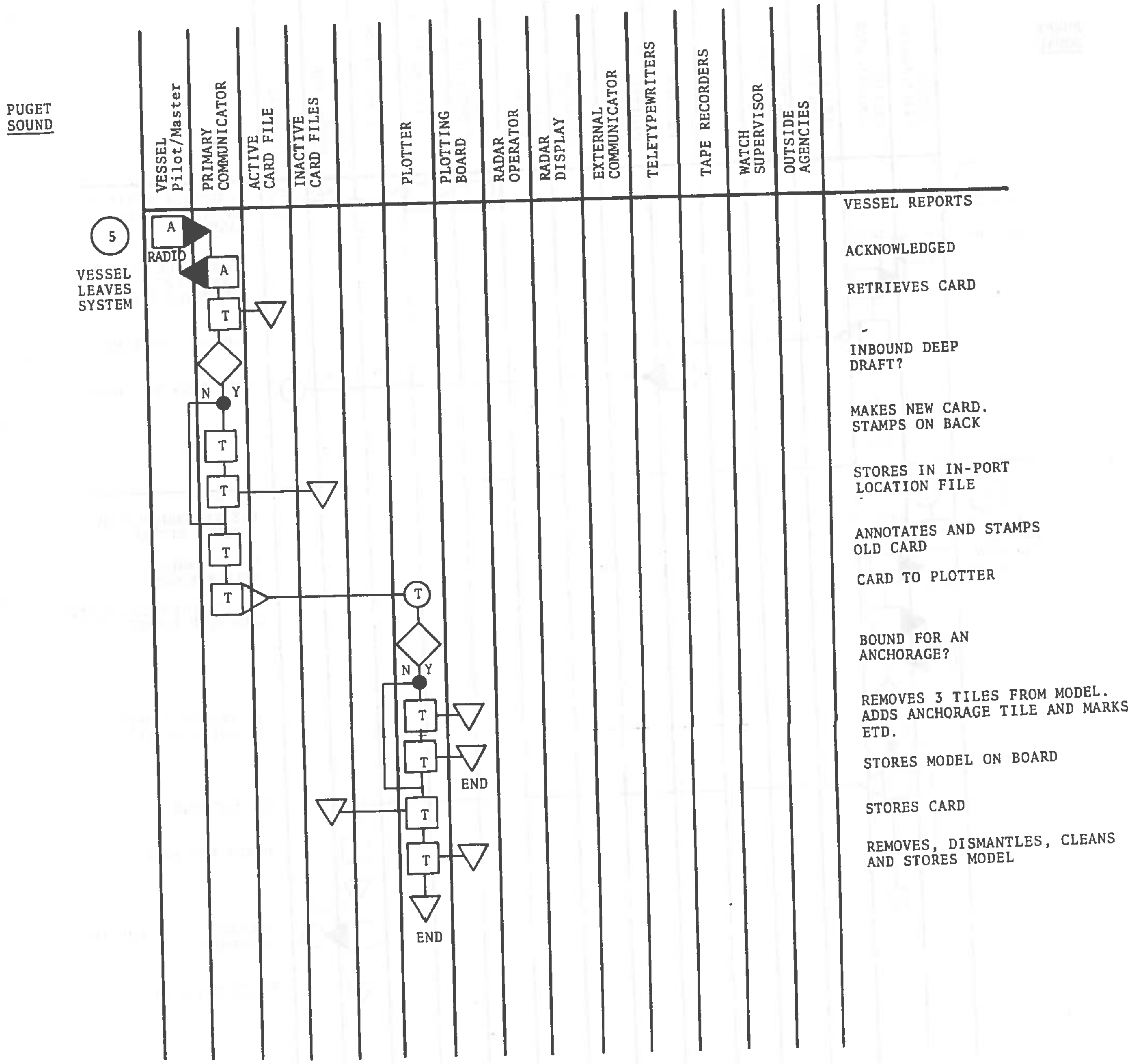

FIGURE A-10. OPERATIONAL SEQUENCE DIAGRAM: VESSEL LEAVES SYSTEM

APPENDIX B.

INTERVIEWS AT PSVTS

Individual interviews were conducted with watchstanders during the same days that observations were made, generally when the interviewee was on day duty. The interviewer and interviewee were seated comfortably in a private office that was quiet and free of interruptions. The interview was conducted as a conversation. The interviewer was guided by a format in order to cover all topics, but the exact wording of questions and order of topics were varied to allow spontaneity in the interviewee's responses.

The interviewer explained the aims of the project and the interview, stressing the fact that the system, not the interviewee, was being evaluated. Then the interviewer asked, and encouraged discussion of, a series of questions. The nature of each question (not necessarily the exact wording used with each interviewee) is given below, followed by a summary of the responses.

TABLE B-1. CHARACTERISTICS OF INTERVIEWEES

Interviewees	Years in Coast Guard	Months at PSVTS	Years of sea duty	Years USCG School	Other Experience
Officer	18	8			
Enlisted					
1	4	18	2	.5	
2	3.7	10	2.3	.3	
3	9	42	4	.3	Navy 5 yr
4	3.5	13	2	.5	
* 5	13	6	10	(1.5)	(ATC Instructor)
Mean (enlisted)	6.6	18	4	.4	(omitting #5)

* Interviewee #5 was given a preliminary interview during development of the interview format. Some questions answered by the other interviewees were added after his interview.

6. <u>Is the VTS properly appreciated</u>? The interviewees split evenly on this question (half yes, half no) regarding masters, pilots and the general boating public, but were 4 to 1 in agreement that the USCG does not appreciate what the VTS does. The consensus was that masters and pilots like the advisories but object to being told what to do (to being policed), although they tolerate it. One comment was that what they don't like makes sense. It was felt that the general public doesn't fully understand the purpose of VTS's--that better public relations are needed. The feeling was prevalent that, at higher levels, the USCG neither understands the purpose nor appreciates the service of VTS's.

7. <u>Is VTS a good career assignment</u>? Four enlisted interviewees answered "No." One of these added that it is a good final assignment---for "settling in." The officer felt that it is a good assignment for enlisted men, "...but they don't think so." The main complaint was that, at a VTS, you're not doing what you chose to do; you're at a disadvantage on your next assignment, and, thus, your career is jeopardized. One bitter comment was that a VTS is "...a good place to send people if you want them out of the service."

12. Have you any ideas for improving training? Two interviewees suggested less pressure on beginners, while one proposed being stricter with regard to procedures. Other suggestions were: Assign trainee to work with the same person for two weeks--then with someone else. Try to teach how the service is perceived by pilots and masters. Simulate operations in a training laboratory.

13. Have you any ideas for selecting personnel for VTS duty? Three interviewees indicated that experience in radio communications should be required. Two specified a hearing test (one commented that he had gone twelve years without having a test of his hearing). One interviewee each suggested experience in navigation and general sea duty. Other comments were that VTS shouldn't be manned by USCG personnel, that career personnel should not be selected, that radarman and quartermaster ratings are appropriate, and that VTS assignments should start with a probationary period.

14. How do you like the present watch schedule? No interviewee expressed dislike of the present schedule. One considered it a reward for the 120-hour weeks of sea duty. One complained of the 40-hour requirement, noting that 72 hours is inadequate for a weekend--96 would be better. One preferred 12 hours for 4 days rather than 8 hours for 5 days.

lot as Plotter, and boredom plus high ambient noise as Radar Operator.

18. Would it help to break the VTS area into sectors? Three interviees felt that sectorization would be helpful. Two specified four sectors: southern end, Elliott Bay, northern end, and Strait of Juan de Fuca, with each Primary Communicator on a radar terminal. Two interviewees felt that sectorization is not necessary. One said the traffic load doesn't warrant it; the other said that if a person is on the ball, he can handle it--"you earn your pay check."

19. Would you add radar sites? All interviewees agreed on the desirability of more radar sites. Two specifically noted that the present Seattle radar is in a poor location. Other specific suggestions included: Get the radar information directly to the Primary Communicator. Use a larger scope in a smaller console - like the 25 Alpha. One interviewee noted that nobody asks the watchstanders where the radar should be.

20. Might other aids improve the VTS? Five interviewees felt that computers might be useful. Although expressing lack of knowledge about computers, they suggested such uses as replacing the plotting board and assisting in televising the radar data.

22. <u>Rate the plotting board for importance, usage and accuracy</u>. Using a 4-point rating scale---High, Medium Low and Very Low---the interviewees rated the plotting board as follows:

	H	M	L	VL
Importance	5	0	0	0
Usage	5	0	0	0
Accuracy	1	2	2	1

Everyone agreed that the plotting board is important and gets high usage. Most rated the board as moderate to low in accuracy. One interviewee rated it high in accuracy for general position but very low for exact position and identification. It was noted that better radar would reduce the importance of the plotting board.

23. <u>Would you like a different arrangement of equipment</u>? Five interviewees had one or more ideas for rearrangement. Two involved moving the radar closer to the Primary Communicator, while one would put Radar Operator in the corner farthest from other activities. One interviewee suggested raising the Primary Communicator position higher above the board and moving his communications console closer and in front of him. Two suggested consolidation of External Communicator equipment at one position.

26. <u>What situations increase the difficulty of operations for watchstanders?</u> Answers to this question distributed as follows:

Cause	Number Citing
General Public (pleasure sailing, racing)	5
Fishing	4
Weather	3
Incidents (accidents, groundings)	3
Other	4

Among "other" causes, interviewees cited equipment failures on vessels, pilots failing to yield right-of-way, and lane crossings (especially between plot updates).

27. <u>Do some VTS tasks interfere with the primary duties of watchstanders?</u> The general response to this question was negative. Having visitors in the center was cited as distracting as well as taking a man off the job. Manipulating Simplex Time Cards was mentioned by two interviewees as interfering with communications, but necessary.

said he doesn't like to be a cop. Another interviewee felt that stricter training is required to achieve more accurate advisories.

30. Can you cite instances from your own experience in which the VTS was a significant aid in resolving an incident? One interviewee cited two incidents in which the VTS was able to direct other vessels to aid at an accident scene before the arrival of the SAR vessel. Another noted an occasion in which three vessels were overheard getting crossing signals mixed; by advising them, the VTS was able to avert an incident. Generalized examples included helping ferries meet schedules by giving advance information on log tows, relaying information (such as an injured man on a tug), and generally aiding in communications.

31. Can you cite instances from your own experience in which the VTS caused an incident or made one worse? Specific incidents included telling a ferry "no traffic" when a tanker (showing zero SOA on the board) was getting under way; directing a ferry into the path of a freighter because of mixed radar identification, and confusing a vessel by giving it the wrong direction of movement of ferries. A recent incident, mentioned several times, involved a tug going aground while the Radar Operator was getting a cup of coffee. Although it was claimed

APPENDIX C.

STRESS LEVELS AT PSVTS

Introduction

In staffing a Vessel Traffic Service care must be taken not to overly stress any individual watchstander. Excessive stress leads to poor morale, degenerative health, and accidents.[1] Except for comments and observations, no indications of stress present at Vessel Traffic Centers (VTS's) have been recorded. However, the Federal Aviation Administration[2] has successfully established the presence of stress in air traffic controllers, a position similar to watchstanders, using a paper-and-pencil questionnaire.

A modified version of the FAA questionnaire was administered to nine watchstanders at the Houston-Galveston VTS. The results of this survey established the presence of measurable stress at a VTS. A detailed description and results are presented in Reference 3. This same stress questionnaire was administered to 14 watchstanders at the Puget Sound VTS.

TABLE C-1. INSTRUCTIONS FOR STRESS QUESTIONNAIRE

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, MA 02142

This survey is designed to assess the physical and psychological effects you experience in connection with your work as a U.S. Coast Guard Vessel Traffic Services watchstander. Under no circumstances will your answers become a part of your personnel file or in any way affect your status in vessel traffic services work. You will be assigned an identification number so that all responses from each individual can be kept together. These data will be stored at the Transportation Systems Center until summarized. At that point there will be no further need to identify an individual's data and all forms will be destroyed.

Your task is to rate the degree of physical or psychological effects your are experiencing at the time you fill-out the rating form. You are to complete the rating form four times each working day: Just before beginning a shift, during a break or lull about half way through a shift, at the end of the shift, and at home at least three hours after a shift. You are to do this for one week.

Your specific task on each form is to rate the degree of physical or psychological effects you are presently experiencing for each item from none through severe by marking an X anywhere along the line as illustrated in the examples below. Suppose at the time you are completing the form you do not have a headache, then mark the item as shown:

1. Headache: |X________________________________|
None Moderate Severe

Suppose you do have a headache at the time you are completing the form, then depending upon its degree you might mark the item as shown:

1. Headache: |____________________X___________|
None Moderate Severe

Your cooperation is greatly appreciated. Thank you.

TABLE C-2. STRESS QUESTIONNAIRE (CONT.)

12.	Indigestion or heartburn:	None	Moderate	Severe
13.	Difficulty in staying awake.	None	Moderate	Severe
14.	Stiffness or body tenseness:	None	Moderate	Severe
15.	Bothered by distracting noise;	None	Moderate	Severe
16.	Nausea or sick to your stomach:	None	Moderate	Severe
17.	Asthma:	None	Moderate	Severe
18.	Insomnia:	None	Moderate	Severe
19.	Backache:	None	Moderate	Severe

Each line below represents a scale of moods you might feel ranging from none to severe. For each item below please mark an (X) anywhere along the line corresponding to the degree of mood you feel at the present moment. (You may go beyond the ends of the line if you wish.)

1.	Worry:	None	Moderate	Severe
2.	Uncomfortable:	None	Moderate	Severe
3.	Tense:	None	Moderate	Severe
4.	On edge:	None	Moderate	Severe
5.	Irritable:	None	Moderate	Severe
6.	Fidgety:	None	Moderate	Severe
7.	Depressed:	None	Moderate	Severe

assure that it complied with the instructions. The questionnaire required about 2 minutes to complete.

Watchstanders then received a packet of 16 questionnaires to be completed according to the following schedule. For each of four days, watchstanders were to complete one questionnaire just prior to a shift (PRE), one about halfway through (DUR), one immediately upon ending the shift (POST), and one at least three hours later at home (HOME). Four days were specified because watchstanders work one shift for four days before taking a break. The questionnaires were then returned to the experimenter through the mail.

Results

Nine watchstanders completed and returned their packets of 16 questionnaires. The results from the Puget Sound VTC are presented in Table C-3 in terms of median[7] ratings made for the (PRE), (DUR), (POST) and (HOME) periods. For the highest rated somatic item and mood item, the medians, together with the values below which 25 percent and 75 percent of the ratings fell, have been graphed in Figures C-1 and C-2. The numbers on the vertical

---

[7]Median: The middlemost rating; half the ratings fall above the median, half below.

axis indicate the distance (in centimeters) along the scale from None (0 to 0.85 cm) through Moderate (3.50 to 5.25 cm) to Severe (8.0 to 9.5 cm) at which watchstanders marked each item. These items are typical in that every item exhibited a worsening trend throughout the watch, with partial recovery later at home. The spread of ratings about the medians is also typical of the spread in the other items.

Tables C-4 and C-5 present these results ordered by the magnitude of the post-shift median scores for those items in which the median rating exceeded 0.85. Seven of the 19 somatic items and eight out of the 11 mood items indicated appreciable stress. The most sensitive items were "Aching or Burning Eyes" and "Tiredness".

Ratings tended to be essentially the same for all four days of the watch period.

The results of the original FAA survey are also presented in Table C-4 in rank order. Although not perfect, the two rankings agreed fairly well (Spearman rank-order correlation = 0.81, $p<0.0005$), lending support to the validity of the survey.

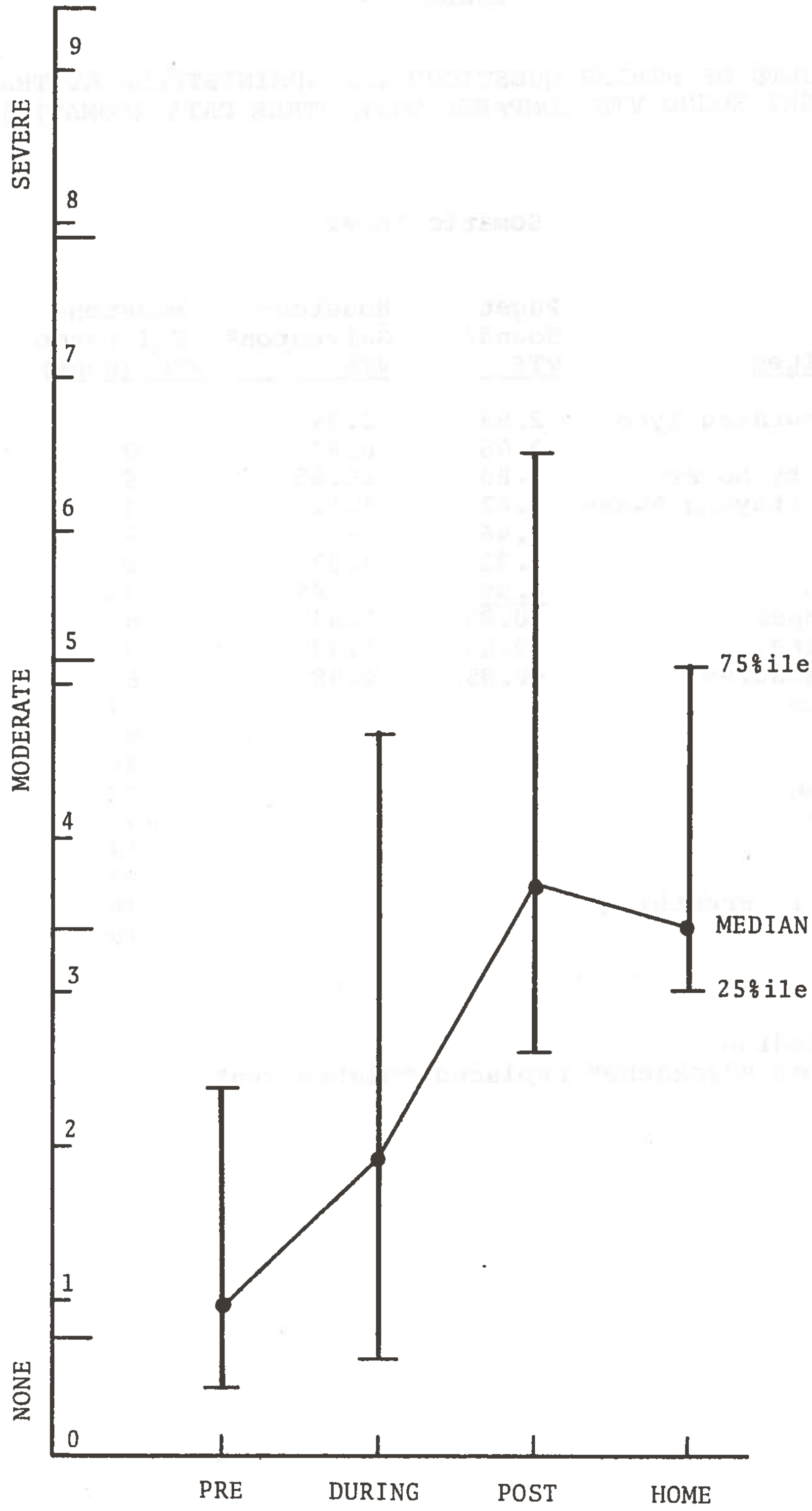

FIGURE C-2. TIRED. PUGET SOUND VTS.
NINE SUBJECTS. FOUR DAYS EACH.

TABLE C-5

RESULTS OF STRESS QUESTIONNAIRE ADMINISTERED AT THE PUGET SOUND VTS COMPARED WITH OTHER DATA (MOOD)

Mood Index

Item	Puget Sound VTS	Houston-Galveston VTS	Houston-Galveston VTS (Rank)
Tired	3.76	3.09	1
Drowsy	2.33	1.12	7
Irritable	1.36	1.46	5
Tense	1.24	1.64	2
On Edge	1.12	1.55	4
Uncomfortable	1.02	0.90	8
Anxious	1.00	1.35	6
Fidgety	0.88	1.57	3
Depressed			11
Upset			10
Worry			9

For those items rated above None, the magnitude or level of stress reported at Puget Sound exceeded that from the Houston-Galveston VTS Center. For instance, on the leading item "Aching or Burning Eyes", the median response for watchstanders at Puget Sound was 2.93 compared to 2.39 for those at the Houston-Galveston center.

Comparison of the results on the Mood index (Table C-5) again revealed a) a different order or pattern of items between each center and, b) greater levels of reported stress on some items, less on others. "Tired" ranked highest at both centers. "Depressed", "Upset", and "Worry" were not rated above None at either center. The items in between were distributed somewhat differently between two centers; however, the two rankings agreed fairly well (Spearman rank-order correlation = 0.67, $p<.005$).

Higher levels of stress were reported at the Puget Sound VTS for the items: "Tired", "Drowsy", and "Uncomfortable". Houston-Glaveston VTS watchstanders reported higher levels on the other five items: "Irritable", "Tense", "On edge", "Anxious", and "Fidgety".

long radar watches in very low illumination, and difficulty in reading radar displays. Vessels are not split among several watchstanders at Puget Sound, whereas they are at Houston. Some of the "Headache" response may thus be due to the pressures of feeling responsible for all vessels at Puget Sound rather than for a defined set of vessels. The fact that the Puget Sound service is mandatory may contribute to these pressures.

Watchstanders at both centers reported about the same level of "Difficulty in Staying Awake". However, "Backache" and "Stiffness" were reported at Puget Sound, where watchstanders must stand next to, lean over, and reach across a large, waist-high map table. It is interesting that "Indigestion" is present at Puget Sound even though watchstanders eat comfortably at the External Communications position and prepare their meals in an adjacent room.

The ratings on the Mood index reveal watchstanders at Puget Sound to feel more "Tired", "Drowsy", and "Uncomfortable" possibly from having to stand, lean, and reach often. On the other hand, they reported being less "Irritable", "Tense", "On edge", "Anxious" and "Fidgety" than did watchstanders at Houston. Perhaps, this difference exists because watchstanders at Puget Sound are not restricted to sitting in one place, unable to interact with other watchstanders, as are those at Houston.

References

1. Caplan, R.D., Cobb, S., French, J.R.P., Van Harrison, R., & Pinneau, S.R., HEW Publ. No. (N10SH) 75-160, April 1975.

2. Hauty, G.T., Trites, D.K., & Berkley, W.J., Biomedical Survey of ATC Facilities: Incidence of Self Reported Symptoms. Report (AD689806) March 1965.

3. Devoe, D.B., Abernethy C.N., & Kearns, K.S., Houston-Galveston Vessel Traffic Service Watchstander Analysis. U.S. Coast Guard Report No. CG-D-24-78, May 1978.

APPENDIX D.

VISIT TO PUGET SOUND PILOTS ASSOCIATION

D.1 Introduction

During the week of data collection at the PSVTS, the opportunity arose for the TSC research team to visit the offices of the Puget Sound Pilots Association and converse with members of the Association's Board of Directors. Four TSC representatives talked to six of the pilots, including the Association President, Captain Soriano. The discussion was informal. Each pilot expressed his feelings about the PSVTS and answered questions raised by the TSC visitors.

The discussion was generally limited to complaints about VTS policies and services and suggestions for improving the service. Highlights of these remarks are summarized below. They are presented essentially as given, without any attempt to judge or evaluate them.

Another consequence of operation of the PSVTS by the USCG that is particularly objectionable to the pilots is the staffing of the operation by personnel far less skilled in the problems of handling vessels in Puget Sound than the pilots and masters on the vessels. Coast Guard watchstanders are generally young, have limited experience with large vessels--and that mostly in open waters, are not local people, and are at the PSVTS for only two-to-three years before being reassigned. The pilots stated that watchstanders appear to replace judgment with rote responses.

D.2.2 Complaints about Services

The pilots present complained that the PSVTS both requests and imparts too much information. They feel that VTS personnel ask for unnecessary information, have irrelevant conversations, and don't address their real problems. In addition, the pilots indicate that they can't assimilate, remember and use all of the information given in advisories. They also claim that sometimes the information is wrong, particularly in the waterways.

A second major complaint is that the radio channels are overloaded--that they can incur delays of 5-to-10 minutes in getting into a channel.