UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
G-WWM-1/11
16470
LTJG OCKEN, x61940

DATE: 16 September 1980

SUBJECT: ACTION: Transmittal to Congress of the report on the "Vessel Monitoring Systems Study" (September 1980)

FROM: Admiral John B. Hayes
Commandant, U.S. Coast Guard

TO: The Secretary
THRU: The Deputy Secretary

BACKGROUND:

Enclosed is a copy of the final report on the "Vessel Monitoring Systems Study". Section 3 of the Port and Tanker Safety Act of 1978 requires the delivery of this report to Congress by 17 October 1980. The purpose of the study, in accordance with the Section 3 mandate, was to evaluate monitoring system alternatives and recommend a system with qualities outlined in Section 3. Those qualities include the ability to monitor vessels in the Fishery Conservation Zone (FCZ), to give the identity of those vessels, and to give the position of those vessels (as well as course and speed). The system also must be a single, comprehensive, and cost effective system.

DISCUSSION:

The study indicates that wide-area monitoring of the FCZ may be cost effective. However, this study was preliminary in nature and does not possess sufficient detail to thoroughly justify a commitment to full, immediate implementation of the recommended system.

In this study an attempt was made to size the cost and benefit impacts for various alternatives and thereby select a best system for recommendation. Only those components directly related to the surveillance and/or monitoring system were involved in this sizing. In order to operate the recommended system and recoup sufficient benefits from it, there would need to be major changes made to Coast Guard operations. To account for all command and control factors was beyond the constraints of time and funding.

The Coast Guard has started a long-term effort to address Coast Guard command and control as a single system, including a surveillance component. Unlike the mandated study now being reported on, the surveillance portion of this command and control effort is not driven by a requirement for a single, comprehensive system for the entire FCZ. Instead, this long-term effort will use mission requirements to determine surveillance needs. In reviewing the enclosed report it is clear that the recommended system is not single and comprehensive. The long-term command and control effort recognizes this, and its development scheme will be responsive to all Coast Guard programs. Commonalties will give overall direction to these developments and mesh resources when and where possible.

(more)

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-52-80,I		

4. Title and Subtitle	5. Report Date
VESSEL MONITORING SYSTEMS STUDY Volume I - Technical Analysis	Sept. 1980
	6. Performing Organization Code
7. Author(s) R.G. Bland*	8. Performing Organization Report No. DOT-TSC-CG-80-4, I
9. Performing Organization Name and Address U.S. Department of Transportation Research and Special Programs Administration Transportation Systems Center Cambridge MA 02142	10. Work Unit No. (TRAIS) CG018/R0003 11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation United States Coast Guard Office of Marine Environment and Systems Washington DC 20590	13. Type of Report and Period Covered Final Report April 1979-July 1980 14. Sponsoring Agency Code

15. Supplementary Notes
*Significant contributions were made to this study by S. Protopapa (TSC).
Note: This is a two-volume report. Vol. I is the technical analysis. Vol. II contains the appendices.

16. Abstract In the Port and Tanker Safety Act of 1978 the U.S. Congress directed the Department of Transportation to perform a study on the desirability and feasibility of a shore-station system for monitoring vessels (including fishing vessels) offshore within the 200-nm U.S. Fishery Conservation Zone (FCZ). This is the final report which documents the study; it will be delivered to Congress in October 1980. The analysis of Coast Guard requirements for offshore vessel monitoring service indicated that major benefits to the government would accrue in: Port and Environmental Safety, Enforcement of Laws and Treaties, and Search and Rescue. Most other missions would receive secondary benefits. A limited survey of vessel owners and masters indicated that 80 percent of the large commercial vessels would cooperatively report to a CG monitoring system, while 22 percent of the small commercial and domestic fishing vessels and 12 percent of the recreational vessels would participate. Major benefits of a monitoring system to the marine user are: operating cost savings and improved safety at sea. A system concept called the Offshore Traffic Information System (OTIS) was developed. This system utilizes computer correlation techniques to derive vessel tracking information from available vessel movement data augmented with vessel reports and remote sensor data. The goal of OTIS is to collect, process, and provide to both the decision-maker and field personnel all available data bearing on a situation or event. A reliable ship-to-shore communications system is an essential element of the system. Alternative OTIS system implementations were evaluated in terms of cost, effectiveness, benefits, and implementation considerations. A phased implementation of OTIS is recommended, based on these evaluations, with initial effort directed to integrating all current CG programs related to OTIS.

17. Key Words	18. Distribution Statement
Vessel Monitoring, Surveillance, Vessel Traffic Management, Vessel Traffic Services, Coast Guard Missions, Correlation, Communication, Navigation, Tanker, Hazardous Cargo, Law Enforcement	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	320	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

As directed by Section 3 of the Port and Tanker Safety Act of 1978 (Public Law 95-474, 17 October 1978), the Secretary of Transportation will report to Congress his findings concerning the desirability and feasibility of shore-station systems for monitoring vessels including fishing vessels within the U.S. Fishery Conservation Zone (FCZ). Early in 1979, the Office of the Chief of Staff, U.S. Coast Guard, assigned sponsorship of the study to the Office of Marine and Environment Systems, Waterways Management Division. The Transportation Systems Center (TSC) was commissioned to perform the study which is reported herein. This final report will serve principally as the Secretary's Report to Congress in October 1980. In addition, the report will be a major source of information about vessel monitoring requirements and systems for use by the U.S. Coast Guard's recently-approved Command and Control Research Project.

This study largely encompasses two phases of work. In the first phase, it was necessary to define the study by undertaking a preliminary analysis of Coast Guard mission requirements for a vessel monitoring system, by presenting an initial concept design of a vessel monitoring system, and by outlining a program plan for the next phase. The second phase of the study completes and extends the analysis of missions requirements and presents a fully developed conceptual prototype of a vessel monitoring system, the Offshore Traffic Information System (OTIS). The report is documented in two volumes: Volume I presents the technical analysis; Volume II contains the appendices.

This report reflects the involvement of the following agencies and industry groups in the study: Department of Navy, Command and Control Planning Group; the Department of Commerce, National Oceanic and Atmospheric Administration, and the Maritime Administration's Office of Maritime Technology; the Department of the Treasury, U.S. Customs Service; the Department of Justice, Drug Enforcement Administration; the El Paso Intelligence Center (a multiagency center); the U.S. Coast Guard, Atlantic Area, Operational Computer Center; and the American Institute of Aeronautics and Astronautics, Marine Traffic Management Working Group.

This study was completed under the guidance of CAPT Daniel B. Charter, USCG; and CDR Ian Cruickshank, USCG. Special recognition is given to LTJG

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ABBREVIATIONS

AMVER	Automated Mutual-Assistance Vessel Rescue
AOSS	Airborne Oil Surveillance System
BA	Bridge Administration
BATF	Bureau of Alcohol, Tobacco, and Firearms
C^2	Command and Control
CAS	Collision Avoidance Systems
CCIR	International Radio Consultative Committee
CCZ	Coastal Confluence Zone
C.F.R.	Code of Federal Regulations
CG	Coast Guard (also, USCG)
CHRS	Coastal Harbor Radiotelephone Service
CONUS	Continental United States
COTP	Captain of the Port
CR	Contact Report
CVS	Commercial Vessel Safety
CW	Continuous Wavelength
DEA	Drug Enforcement Administration
DF	Direction Finding
DI	Domestic Ice Operations
DOC	Department of Commerce
DOD	Department of Defense
drms	Distance Root Mean Square
ELT	Enforcement of Laws and Treaties
EMIS	Enforcement Management Information System
EPA	Environmental Protection Agency
EPIC	El Paso Intelligence Center
EPIRB	Emergency Position Indicating Radio Beacon
ERMA	Electronic Relative Motion Analyzer
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission; or Fleet Command Center
FCMA	Fishery Conservation and Management Act
FCZ	Fishery Conservation Zone

ABBREVIATIONS (Cont.)

MSO	Marine Safety Office
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration (also DOC-NOAA)
NOSIC	Naval Ocean Surveillance Information Center
OC	Operational Commander
OCC	Operational Computer Center
OEZ	Offshore Economic Zone
OSIS	Ocean Surveillance Information System
OSS	Ocean Surface Surveillance
OTH-R	Over-the-Horizon Radar
OTI	Ocean Traffic Identification
OTIS	Offshore Traffic Information System
OVTM	Offshore Vessel Traffic Management
OVTS	Offshore Vessel Traffic Safety
PES	Port and Environmental Safety
PIRS	Pollution Information Reporting System
P.L.	Public Law
PIO	Polar Ice Operations
PPI	Plan-Position-Indicator
PREC	Pollution Response and Environmental Coordination
PSS	Port Safety and Security
QPSK	Quadraphase-Shift-Key
RA	Radionavigation Aids
RACON	Radar Beacon (transponder type)
R&D C^2	Command and Control Research and Development
RBS	Recreational Boating Safety
RCS	Radar Cross Section
RDF	Radio Direction Finder
RF	Radio Frequency
RPV	Remotely-Piloted Vehicles
RSS	Remote Sensing System
RT	Reserve Training
SAR	Search and Rescue
SAR	Synthetic Aperture Radar
SARSAT	Synthetic Aperture Radar Satellite

EXECUTIVE SUMMARY

1. INTRODUCTION

The Port and Tanker Safety Act (P.L. 95-474) of 17 October 1978 requires the Department of Transportation to "study the desirability and feasibility of possible shore-station systems for monitoring vessels including fishing vessels within the Fishery Conservation Zone.... Each system examined shall be capable of reporting vessel position, identification, course, and speed using either a land, sea, or space monitoring technique.... (The DOT) report shall describe the capabilities, limitations, and cost effectiveness of each monitoring system examined from the standpoint of both the Federal Government and any vessel owners who would be affected by the imposition of each approach. The report shall also include the Secretary's recommendations for a single, comprehensive, cost-effective shore-station system for monitoring vessels within the Fishery Conservation Zone." The Act further authorized the appropriation of a total of $1 million for fiscal years 1979 through 1980 to support the study. These monies were never appropriated. The work of conducting and documenting this study was accomplished by the Coast Guard with resources from existing funds.

Historically, a series of laws and related studies prior to the 1978 Port and Tanker Safety Act have underlying impact on this study of vessel monitoring systems:

The Ports and Waterways Safety Act (1972) authorized the Coast Guard to establish, operate, and maintain the Vessel Traffic Service (VTS) for ports, harbors, and other waterways subject to congested vessel traffic.

The Fishery Conservation and Management Act (1976) established the 200-nm offshore Fishery Conservation Zone (FCZ) and focused on the monitoring of foreign vessels in the zone.

The Clean Water Act (1977) established regulations for cooperative reporting by petroleum- and hazardous-cargo vessels.

The Offshore Vessel Traffic Management Study (1978) reported on the causes of tank vessel casualties and surveyed vessel traffic management alternatives for preventing polluting incidents in offshore U.S. waters.

receive indirect benefits. Other agencies that work cooperatively with the Coast Guard would also receive indirect benefits. The quantifiable benefits are in reduced aircraft flight time and crew costs and in increased services and effectiveness for large-area surveillance and rescue missions due to increased information from the VMS and the increased area covered. Indirect benefits involve costs and resource savings resulting from improved anticipatory planning and response planning for marine incidents, e.g., port preparations for heavy traffic.

3. The benefits that would accrue to the marine user of a VMS are:

   a) improved safety resulting from the Coast Guard's having more accessible radio contact with the vessel when an emergency occurs and having increasing information about vessels which are near the vessel in distress and which can expedite a rescue,

   b) improved operating efficiency for the commercial and fishing vessels resulting in cost savings from advisories about weather, traffic, and port conditions. (Advisory information comes from the CG shore station via coded data or brief verbal statement.)

4. The lowest cost VMS, a cooperative vessel reporting system, is not currently feasible for the whole offshore vessel population because of the following:

   a) Voice communications is the common type available on vessels and the message throughput rate is too low to handle the whole 37,900 vessels on a peak day. (Vessel population includes all vessels over 40 feet long: fishing, recreational, small commercial, and large commercial.)

   b) Conversion to digital communications is a large investment to the vessel owner, and is compounded by a lack of radio equipment commonality and standardization which increases investment costs.

   c) Of the overall vessel population, only 17 percent of the owners/operators, including those that are required to by statute or regulation, indicated a willingness to participate in a cooperative reporting system. (This level of participation is based on a limited survey of commercial, recreational and fishing vessel owners/operators representing large groups of mariners.)

7. The combination OTIS system would potentially be cost beneficial to the government and the user (vessel owners/operators). These costs and benefits are shown in the table below (in 1980 discounted dollars).

	Initial Cost* (1981-86)	Operating Cost* (annual starting from 1987)	Benefits* (annual starting from 1988)
Government	$45.4 M	$20.0 M	$49.8 M
User	$10.6 M	$ 0.8 M	$29.0 M

8. The combination OTIS system could be developed and evaluated in approximately 4 years with another 2 years required for full system deployment. The items of major risk are:

   a) Feasibility of the airlines carrying the LOWCOSS radar sensor pod on an operational basis and at a reasonable cost.

   b) Production cost and performance of the LOWCOSS radar sensor.

   c) Vessel owner/operator willingness to report regularly to a shore station (Note that the voluntary participation level of merchant ships in AMVER is only about 40 percent).

   d) Vessel owner/operator willingness to purchase additional equipment for operational compatibility with shore equipment.

9. The Coast Guard has several ongoing and planned efforts pertinent to offshore vessel monitoring and surveillance. Many of these efforts primarily support specific missions, while some support multiple missions. All of these efforts, which are listed below, are prerequisite to the implementation of OTIS and they will accrue benefits from OTIS. These benefits come from the underlying objective of OTIS: to provide the framework for collecting vessel movement information from many sources and to provide this information to the decision-makers at all levels of command in a readily accessible form for immediate use in determining what and where CG resources should be deployed for situation(s) occurring at a given time. The efforts that are integral with the OTIS concept are:

*Assumes initiation of system development in early 1981 and full system operation beginning in January 1986.

10. Alternative long-range communications techniques should be explored continuously and to the fullest extent in an effort to find an acceptable (i.e., in cost and performance) replacement of HF radio for monitoring the FCZ. An attractive approach was demonstrated in the 1979 Baker experiment of VHF satellite (NASA ATS-3) relay of LORAN-C position reporting and digital communications with low-cost user equipment. VHF vessel equipment is low in cost and less complex than current L-Band satellite marine terminals; therefore, it is concluded that the use of lower frequency band satellite communications should be explored at least as an interim approach to long-distance communications until L-Band costs decrease.

    The currently recognized operational marine satellite communications system is INMARSAT. This is a multinationally-owned system that came into being in 1978 with concordance of the necessary signatories. This system presently uses MARISAT satellites (three located worldwide) leased from COMSAT General Corporation. The satellites offer voice, teletype, facsimile, and high-speed data communications at an attractive cost to large commercial vessels. However, the system protocol design currently does not permit the user to operate in the system with only a low-speed (300 or 1200 baud) data terminal; allowance for low-speed data terminal operation would reduce the users' costs for operation and vessel terminal equipment. It is reported by COMSAT engineers that efforts are underway by the INMARSAT design group to change the system protocol to provide a lower-cost service for the smaller vessel. There is no estimate of when this service would be available, but this would offer an excellent alternative for the long-distance communications needed by OTIS.

11. The major conclusion of this study is that before a decision is made to implement new remote sensors and large-scale communications system modifications for a complete OTIS monitoring system, additional in-depth studies are needed to:

    a) more accurately establish the system costs, both direct and hidden, to the government and the users;

    b) develop clear goals and a well-defined plan with the involvement of other agencies and representatives of the marine community, facilities, headquarters, and outside agencies) in an OTIS to determine:

a. The additional message traffic that would be generated by OTIS.

b. What types and lengths of messages could be expected.

c. The formatting techniques that provide the most time-efficient, reliable service of low cost.

d. Conditioning of telephone circuits required for automated transfer of radio messages to a computer interface.

e. Conditions and causes of traffic loading.

f. Alternatives for efficiently handling communications traffic peaks.

2.a. Perform a study assessing the impact of OTIS on the Coast Guard's long-range HF, and short-range, VHF, radio communications system. Determine the most cost-effective means of handling this communications traffic, e.g., adding to the Coast Guard facility or leasing commercial service. Assess the cost and feasibility of automating the conversion of voice radio messages to digital format for direct input to computer lines.

b. Perform thorough investigations of the alternatives to using HF radio for long-range radio communications over the entire U.S. FCZ with large numbers of users because of the inherent low message throughput rate. This should include the possibility of using satellite transponders at frequencies in the VHF and/or UHF bands as opposed to the current L-Band. This would greatly reduce the user equipment cost. Also, investigations should include the shared use of satellites, such as with the NOAA meteorological satellites.

3. Implement a pilot test program for evaluation of the OTIS concept using existing facilities at a VTS center and covering a local area offshore out to 100 or 200 nm and including a limited vessel group (e.g., large and small commercial vessels carrying oil or hazardous cargo, and foreign fishing vessels). Integrate existing resources such as the AOSS, the FFV, and the AIREYE when it comes on line, as active sensor inputs. The OCC, EPIC, and the Navy-NOSIC data bases

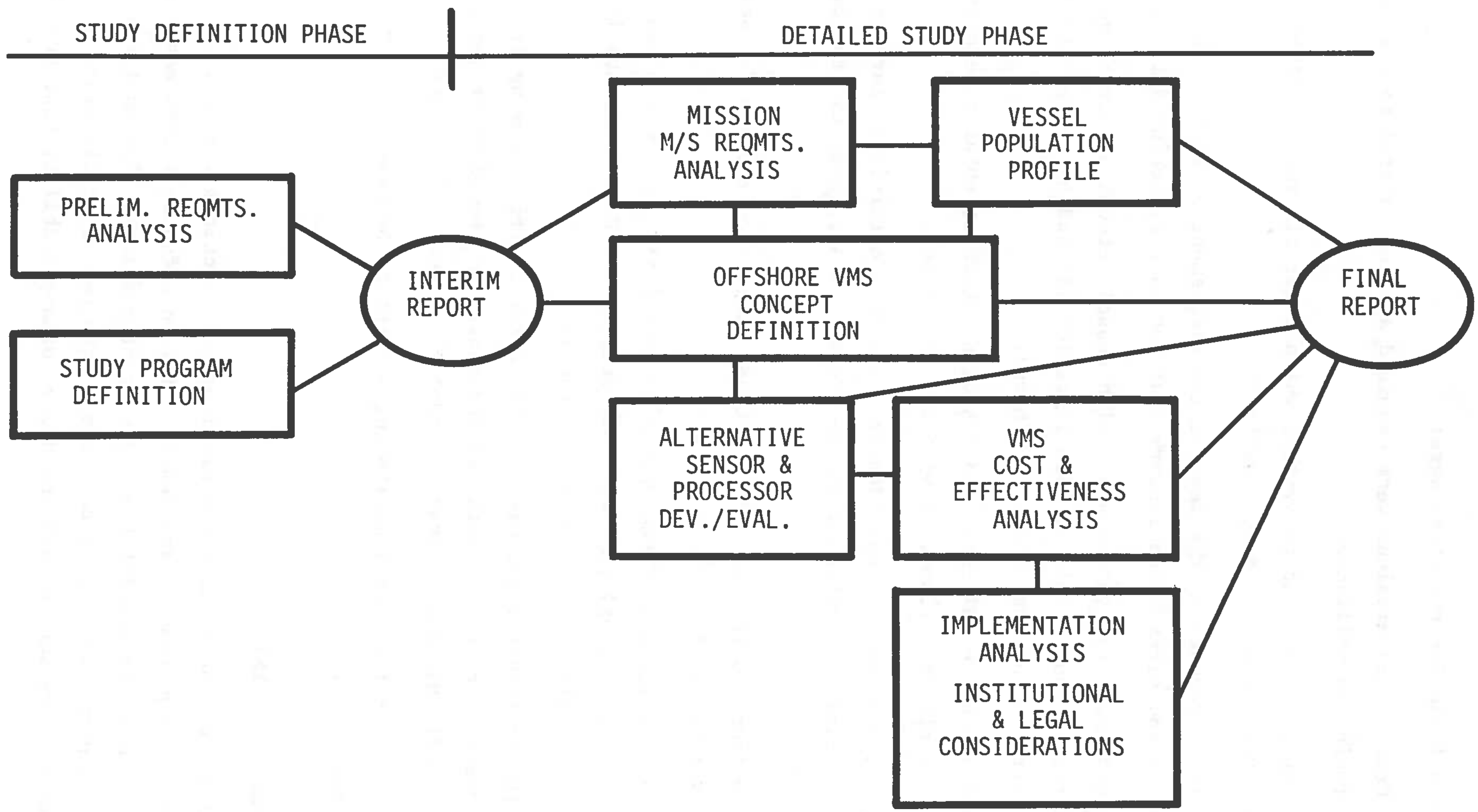

FIGURE ES-1. SCOPE OF VESSEL MONITORING SYSTEMS STUDY would have for each mission. Table ES-1 identifies those missions expected to have "primary" use for a VMS and those missions expected to have "secondary" use for a VMS. All other Coast Guard missions have requirements which are indirectly related to a vessel monitoring system; that is, they would receive some benefits from a VMS.

A major factor influencing mission requirements and, subsequently, the identification of VMS capabilities for meeting those requirements, is the degree of vessel cooperation in complying with U.S. rules and regulations. The specialized functions of the various Coast Guard missions involve interaction with both cooperative and noncooperative sectors of the maritime vessel population. Cooperative vessels can be expected to participate in a VMS either for self-interest or by regulation. Noncooperative vessels can be expected to avoid detection or to be unwilling to participate in a VMS.

Consideration of the cooperation/noncooperation factor helps identify several features of VMS capability needed for multimission application. The system for monitoring the cooperative vessels must include a reliable two-way communications link between the shore and the vessels. Daily vessel reports to the shore giving identity, location, course, and speed, as a minimum, meet common Coast Guard mission requirements. Additional information from the vessel such as destination, estimated time of arrival, local weather/sea conditions, and condition of the vessel can be requested by the Coast Guard shore facility as the need arises. Vessels in the noncooperative group require remote sensing of the vessel's position and course (i.e., surveillance). Identity of vessels in this group cannot be readily established, but identification can be assisted by the remote sensor providing another parameter, such as vessel length or radar cross section.

The correlation screening of cooperative and noncooperative sectors of the maritime population and the synthesis of intelligence data from other Coast Guard missions and government agencies require facilitation by a VMS featuring a central information analysis/dissemination capability. Timeliness of reports is of utmost importance for many missions. Often, data needed by many mission commanders/coordinators exist in other Coast Guard groups or other agencies, but are not available at the needed time and place. One major component of a VMS should be a facility which could assimilate and process all the available data to provide the CG field unit commander with information needed for the missions at hand. These other VMS requirements and considerations were identified by the missions analysis:

1. A position location accuracy requirement for the VMS is set at 2-4 nm 2-drms (the navigation accuracy of the OMEGA system).

2. The vessel-size capability of a VMS suitable for all missions was determined by those vessels which are served by SAR and vessels that are seaworthy for ocean voyages. Detection of 40-foot vessels in heavy seas above sea state 5 is a future goal, but is not technically feasible for now. Currently, the capability of remote sensors in all-weather operational capacity is detection of 100-foot vessels.

3. Seventy-five percent of all offshore vessels are in the 0- to 3-nm area from shore.

4. Fishing and recreational vessels define the system capacity requirements.

5. An offshore VMS is basically an information system, not a command and control system, but a VMS is an integral part of C^2.

6. Major components of an offshore VMS are:
   - Communications
   - Remote Sensor Platform
   - Intelligence
   - Computer Correlation Processing.

7. The cost and complexity of an offshore VMS will be reduced by:
   - a large cooperative vessel group,
   - the availability of information from other agencies, and
   - a powerful correlation processor.

8. The goal of the offshore VMS is to provide information to the appropriate operational commander for effective utilization of resources.

9. An offshore VMS must serve multimission needs for cost-effectiveness.

TABLE ES-2. SUMMARY OF MISSION REQUIREMENTS FOR A VESSEL MONITORING SYSTEM

REQUIREMENTS	MISSIONS	REMARKS
1. Detailed histori-cal vessel data	All	Not all non-cooperative vessels
2. Knowledge of traf-fic environment and two-way commu-nications	All	Non-cooperative vessels excluded
3. Communications of less-than-an-hour intervals	SAR only	Deserves special treatment
4. EPIRB signals	SAR only	Under development with SARSAT
5. Ready-access com-munication contact both ways	ALL	Non-cooperative vessels excluded
6. A minimum of two contact points of communication	All	Non-cooperative vessels excluded
7. Crew involvement in communications	All	Imperative
8. Show of CG presence	Fishery Conservation and Port & Environ-mental Safety (PES)	
9. Intelligence support	All ELT missions	Imperative for terrorist activities
10. Covert, close observation	ELT-Drug and Terrorist, and Intelligence	
11. Surveillance and correlation	All	The following require-ments fall under 11.
11a. Position location accuracy 2-4 nm	All ELT missions and Intelligence	Conservative
11b. Limitation: 3-mile boundary area cut-off	All except SAR and PES	To reduce vessel count noise in a VMS

TABLE ES-3. REQUIRED FEATURES FOR A VESSEL MONITORING SYSTEM

MONITORING CAPABILITIES

RELIABLE TWO-WAY COMMUNICATIONS WITH COOPERATIVE VESSELS

TWO VESSEL REPORTS MINIMUM; INBOUND AND OUTBOUND (APPROX. 200 nm AND 12 nm OFFSHORE)

REPORTS FROM OTHER VESSELS ONCE DAILY

INFORMATION: POSITION LOCATION, IDENTITY, COURSE AND SPEED

VESSEL SIZE: GREATER THAN 40 FT LENGTH

SURVEILLANCE CAPABILITIES

COVERAGE BY REMOTE SENSING: 0 TO 200 nm

POSITION LOCATION ACCURACY: 2 TO 4 nm, 2-drms

SECOND PARAMETER REQ'D., e.g., APPROX. VESSEL LENGTH

SYSTEM OUTPUT CAPABILITIES

OUTPUT: ONCE PER DAY (BASIC REQUIREMENT; ADDITIONAL REPORTS ON REQUEST)

UPDATE RATE: HOURLY WHEN REQUIRED

Further analysis of offshore vessel populations led to the identification of vessel hot spots as a critical factor in the utilization of a vessel monitoring system. A hot spot is an area of unusually high-density traffic within the FCZ; specifically, the study defined a hot spot as a 10-mile square area (100 square miles) in which there are 30 or more vessels at one time. These large concentrations of vessels present a significant problem for a VMS in which remote sensors are used to identify vessel position, maintain discrimination, and track each vessel.

Using Coast Guard vessel sighting data, the area bounded by latitudes 46°00'N and 46° 10'N and by longitudes 124° 10'W and 124° 20'W was found to be a hot spot. This is off the coasts of Oregon and Washington. For the coastal regions of the FCZ, several areas of low and moderate vessel concentrations were identified and tabulated.

A vessel's communication capability determines its ability to participate as a cooperative vessel in a VMS system. Its navigation capability indicates the accuracy of its report of position when it does participate. The type of communications and navigation equipment carried by a vessel is determined by the vessel's size, the type of operations in which it is involved, and the distance the vessel travels from its home port.

There was little available information on communications equipment. By regulation, all large commercial vessels must carry a radiotelephone. A "standard" set of communications equipment for a small commercial vessel includes a single sideband HF radio and a VHF radio. A limited survey indicated that all commercial fishing vessels carry at least a radiotelephone. Finally, almost all recreational vessels over 40 feet long are equipped with a VHF-FM two-way radio, a single sideband HF radio, a commercial broadcast receiver, a weather monitor, and a scanner.

Estimates of navigation equipment for vessels of interest to this study are shown in Table ES-5.

A limited telephone survey of representatives of, or persons knowledgeable about, vessel masters/owners was performed to estimate the number of vessels in each class that might be willing to participate in a vessel monitoring system and be willing to purchase additional communications equipment. The survey sample was selected using a brief screening survey which questioned potential survey participants about the size of their constituency and the length of their constituents' vessels. A population study was performed prior to the implementation of the screening survey. The purpose of the population study was to generate lists of leaders, representatives, spokepersons, and other key members of organizations in each vessel class who could be contacted. These lists were used during the screening process to identify individuals having the largest constituencies. Individuals participating in the limited survey were asked to answer questions in a manner that represented the predominant view of their constituency. Nine interviews were conducted in each of the four vessel groups. Survey results indicate a general consensus within each vessel class. The results of the limited survey suggest that vessel masters/owners of small commercial, fishing, and recreational vessels are not likely to participate cooperatively in the vessel monitoring system. However, the survey results strongly suggest that vessel masters/owners of large commercial vessels will participate cooperatively in the monitoring system. It should be noted that the results of the limited survey should be used with caution because of the small sample size.

Eighty percent of the large commercial vessel masters/owners can be expected to participate in the system. They did not think that it would be necessary to purchase any additional equipment. Also, large commercial vessel operators file a route plan in the AMVER system. This route plan is revised as changes are made to the original plan.

Only 22 percent of the small commercial vessel masters/owners can generally be expected to participate in the system. They believe that they currently have sufficient communications equipment on their vessels.

Fishing vessel masters/owners are opposed to transmitting their position to Coast Guard shore stations in a manner that would reveal preferred fishing grounds to competitors. In general, they cannot afford to purchase additional equipment. The notable exception to this opinion was found among West Coast tuna fishermen, who operate large vessels, usually far offshore and who indicated a willingness to participate in the system. Overall, 23 percent of the domestic fishing vessels were willing to participate. Foreign fishing vessels were not included in this survey; however, these vessels have complied with other monitoring requirements levied under the FCMA of 1976.

The lowest cost technique for acquiring vessel identification data and for tracking vessels is a vessel reporting system in which vessels voluntarily report to a shore station on a periodic basis. This type of system, called the Vessel Passport System, was presented in the Offshore Traffic Management Study report of 1978 as the recommended approach for monitoring tankers in the U.S. FCZ. This can be accomplished by regulation (as with foreign-fishing and hazardous-cargo vessels) or by voluntary cooperation. The limited user survey indicated that less than one-fourth of all vessels over 40 feet in length will be cooperative; therefore, the system would have to be a hybrid of cooperative reporting and surveillance by remote sensing.

The requirements analysis in this study indicated that the primary functions of the VMS would be the collecting, analyzing, and exchanging of information between several Coast Guard groups and government agencies. Thus, it is logical to call the system an Offshore Traffic Information System (OTIS). The central element of OTIS is the information correlation and processing (including intelligence analysis) used for developing the required information. A VMS could potentially provide information to the vessels at sea about harbor traffic conditions and weather en route, and also to the port about vessel arrival time and conditions which would likely save some operating costs and improve the ability to handle emergencies. Access to such information would be given to mariners participating in the VMS. Specifically, the operation of a VMS would allow the Coast Guard shore station to acknowledge receipt of the ship's message; to give the next reporting time; and to indicate any alerts that the mariner needs to be aware of concerning weather, outage of aids-to-navigation, recent notice to mariners, traffic or port conditions. The shore-to-ship message indicates (in brief coded data or by a verbal statement): (1) that there is an alert pertinent to the vessel being called; (2) the type of alert (weather, traffic, SAR, etc.); and (3) the facility or radio station that the vessel should contact for details about the alert.

OTIS is proposed as a framework for organizing and coordinating many current and planned Coast Guard efforts in offshore monitoring and for making the most use of the information from these sources; and then, supplementing that with vessel reports and remote sensor data only to the extent required for the system to perform the monitoring function. (No effort should be expended in implementing any new equipment or resources until full use is made of existing and obtainable information.)

Captain of the Port (COTP), or headquarters officer. The vessel map can be expanded or reduced in size at the request of the user.

An assessment of the advantages and disadvantages of both a centralized and a distributed OTIS configuration indicated that the distributed, or regional, concept is advantageous. In contrast to the single Operational Computer Center (OCC) on Governor's Island NY, which serves all of the Coast Guard districts, it was determined that four VMS centers (one in each region) would be advantageous for the following reasons: 1) The VMS, to be useful and effective, is required to be highly interactive with the CG stations and the lowest level of mission coordination, and to contain detailed data unique to the vessel traffic and the local marine environment of that region; this is not a feasible or realistic amount of data for a centralized, single facility to store; 2) For the volume of use anticipated for a VMS serving all the CG and user needs, the cost of communications between a single facility and remote, coastal areas of the U.S. would exceed the additional costs of existing CG facilities such as the VTS's or district offices. The U.S. FCZ was arbitrarily divided into four regions (East Coast, Gulf Coast and Caribbean, Pacific Coast including Hawaii, and Alaskan Coast), each having an OTIS center. Each center could handle all requests for OTIS information in that region and interface with other agencies, other regions, and Coast Guard Headquarters. A national OTIS center located near CG Headquarters has been included as a valuable optional feature to assist the CG operations group in planning, analysis, and interaction involving missions and functions of major size and national importance.

Technical and interface issues concerning OTIS operation are:

1. The vessel cooperation issue involves the ability and the willingness of vessel operators to participate in a vessel monitoring system. Ability relates to the vessel equipment (communications and navigation) and staff (time to operate reporting equipment). Willingness is determined by benefits accrued to the mariner.

2. Information exchange with other agencies (e.g., Navy, U.S. Customs, Drug Enforcement Agency, the Maritime Administration, and the National Oceanic and Atmospheric Administration) is currently accomplished in varying degrees. This issue involves exploring other sources of information and expanding existing relationships.

and West Coasts, along the Gulf Coast, and from Miami to Puerto Rico provide a ready-made platform with sufficient frequency of flights to support revisit requirements. Their use obviates the necessity for large initial system investment and potentially provides the lowest operating costs of any platforms considered. Two arrangements for carrying the remote sensor on an airliner were considered: internal mounting in a cargo compartment with the sensor antenna installed in a cargo door or fuselage section, or external mounting in an aerodynamically-shaped pod attached to the outside of the aircraft fuselage either fore or aft of the wing. (However, detailed investigations have not been performed to determine the airline or FAA acceptance of either approach.) C-130 aircraft should be used in Alaska and Hawaii because of the absence of commercial airline routes covering the areas of interest. In addition, the vessel populations are low in both these areas so that fewer flights per day would be required to perform the necessary surveillance. The C-130's were selected because of their altitude and time-on-station capability. If the marine patrol airship (MPA) or the remotely-piloted vehicles (RPV) prove to be cost-effective, they could be used to augment or replace commercial aircraft and the C-130's.

Of the considered approaches to communicate sensor data from the aircraft to the OTIS ground facility, reading out the data regularly through an existing commercial communications satellite seems to be efficient and of lowest cost.

A review of the computer requirements for OTIS showed that present-day "large mini's" could accommodate the task.

9. COST AND EFFECTIVENESS OF ALTERNATIVE OTIS IMPLEMENTATIONS

The cost and effectiveness analysis of three alternative OTIS implementations was performed. Alternative One assumes 100 percent mariner cooperation; i.e., all mariners will voluntarily report their vessel position and other data periodically to Coast Guard shore stations. The total 10-year (1981-90) cost to develop, implement, and operate an Alternative One OTIS would amount of $25.9 million in 1980 dollars. Development and prototype evaluation costs, covering the period 1981-83, total $1.6 million. The balance of the cost includes implementation investment and five years of operation and maintenance costs.

	Alternative One	Alternative Two	Alternative Three
Cost (1981-86)	$29.41 M	0	$10.06 M
Benefits (1987-90)	$53.26 M	Large, but not measurable	$29.05 M

The benefits to the user are: a) improved safety due to increased accessibility by radio for emergencies and increased information about and contact with vessels which can lend assistance; and b) improved fleet management and operating efficiency resulting in cost savings due to radio advisories about weather, traffic, and port conditions.

The government and user costs and benefits for Alternative Three, the more realistic approach, are summarized below (in 1980 dollars).

	Initial Cost* (1981-86)	Operating Cost* (annual starting from 1987)	Benefits* (annual starting from 1988)
Government	$45.4 M	$20.0 M	$49.8 M
User	$10.6 M	$ 0.8 M	$29.0 M

OTIS operations are greatly facilitated by cooperative vessels because of the ready availability of information on their identification, location, course, and speed, and their identity reduces the computer workload to one of bookkeeping. Establishing and maintaining discrete tracks is much more difficult with noncooperative vessels (OTIS Alternative Two). If vessels are continuously tracked, at a rate of one observation sample every 15 minutes, the system is able to maintain the positions of all noncooperative vessels. However, when two noncooperatives occupy the same senor resolution cell at the same time, separation of vessel tracks is lost and some other technique or information is required. The resolution cell size for LOWCOSS is 1/16 nm. For an update interval of 4 hours, the percentage of noncooperative vessels

*Assumes initiation of system development in early 1981 and full system operation beginning in January 1986.

1. INTRODUCTION

1.1 BACKGROUND

This report documents the Secretary of Transportation's study on the desirability and feasibility of potential shore-station systems for monitoring vessels, including vessels within the U.S. Fishery Conservation Zone (FCZ) as defined in Section 3(8) of the Fishery Conservation and Management Act of 1976[1]. As mandated by the Port and Tanker Safety Act of 1978[2], the Secretary's study must examine each vessel monitoring system (VMS) for its capability to report vessel position, identification, course, and speed by using either a land, sea, or space monitoring technique. The Act further requires that the Secretary report his findings to Congress in October 1980 (Appendix A). Early in 1979, the Office of the Chief of Staff, U.S. Coast Guard, placed responsibility for conducting and documenting the study with the Office of Marine and Environment Systems, Waterways Management Division. Under the sponsorship of this office, Transportation Systems Center (TSC) was commissioned to perform a VMS study, the subject of this report.

In addition to fulfilling the mandate of the Act, the report's treatment of vessel monitoring should provide the Coast Guard with critical information about surveillance requirements and techniques that exposes the multimission, interdisciplinary nature of surveillance as the link toward centralized mission information acquisition, processing, and dissemination. Particularly relevant to the newly-approved Coast Guard Command and Control Research Project (R&D C^2), this study of vessel monitoring systems offers an approach for requirements analysis and a concept for inter-agency data correlation that very closely parallel the follow-on surveillance studies being pursued for the command and control system. The VMS and R&D C^2 studies have been recognized as complementary projects addressing the requirements and techniques of vessel monitoring and surveillance that can promote greater efficiency in Coast Guard operations and provide increased capabilities.

In its attention to vessel monitoring, the Port and Tanker Safety Act has several important precursors. With each one, either the oceanographic area or the sector of the maritime population (or sometimes both) are distinctly defined. In 1972, the Ports and Waterways Safety Act[3] authorized the Coast Guard

VMS study

- analyzes the missions and functions of the Coast Guard's fourteen programs in order to determine the vessel monitoring and surveillance service requirements of, and their applicability to, those missions and functions;

- develops a vessel monitoring population profile for the purpose of assessing how and to what extent the activity of vessel masters/owners will influence VMS requirements (The vessel profile and marine user assessment will refine the Coast Guard missions requirements analysis.);

- presents an operational description of the Offshore Traffic Information Systems (OTIS), a comprehensive concept of a vessel monitoring system;

- presents a technical survey of candidate systems (i.e., alternative techniques) for performing OTIS functions;

- assesses the current costs of Coast Guard missions, preliminary to evaluating the cost and effectiveness of three implementation schemes for OTIS; and

- examines institutional factors to be considered in the development of a phased implementation of OTIS.

1.3 SCOPE

Figure 1-1 charts the scope of the total study. Information developed in the study definition phase and documented in the interim report provided the groundwork for this report. Those tasks blocked under the detailed study phase comprise the scope of this report.

Any attempt to design a single, comprehensive, cost-effective shore-station VMS requires adherence to system performance specifications. The absence of such specifications, however, makes their development a critical and substantial task of this project. Criteria for VMS performance specifications were derived from the analysis of Coast Guard missions and functions (Section 2) and from the development of a maritime population profile (Section 3). Because the Port and Tanker Safety Act comprehensively requires the monitoring of all vessels, with special attention to fishing vessels within the FCZ, an examination of each of the Coast Guard's missions and functions was deemed necessary to determine each mission's requirements for vessel monitoring, to gauge the applicability and value that a VMS would have for each mission, and to provide the best possible correlation to the requirements of the Port and Tanker Safety Act for all-inclusive vessel monitoring. Complementing the Coast Guard mission requirements analysis, the maritime population profile provides additional primary data from which VMS specifications can be determined. The profile describes the population of offshore vessels operating in the FCZ according to vessel use/size classification, domestic or foreign license, and regional concentration. The profile allows for some determination of the extent and consequence of vessel owners'/masters' participation in a vessel monitoring system.

Following the prerequisite analysis for system specification, the definition of a vessel monitoring system, Offshore Traffic Information System (OTIS), is presented (Section 4). This VMS concept definition gives an operational description and a review of technical and interface issues. Section 5 surveys a range of candidate systems that would be capable, available, and acceptable for performing OTIS functions. This section technically evaluates various reporting systems, remote sensing systems, ancillary systems, and a central processor.

The cost-effectiveness assessment (Section 6) examines the cost of current Coast Guard operations involving routine and emergency vessel monitoring, and it projects kick-off and annual operating costs of three OTIS implementation schemes. Cost considerations for current operations include vessels, aircraft, shore units, personnel, and operating and maintenance equipment. Cost considerations for the proposed VMS include R&D, prototype evaluation, acquisition of hardware, software, sensors, and operating and maintenance costs. This evaluation covers cost projections over a ten-year period and discusses the effectiveness of the three implementations.

The implementation analysis (Section 7) considers institutional and operational factors underlying a phased implementation of OTIS. Findings and recommendations (Section 8) identify the proposed VMS concept, OTIS, as an information center for Coast Guard operational field commanders and headquarters staff for the placement of mission resources. Features for the development and implementation of the proposed OTIS concept are summarized; a cost summary

- the identification of vessel size and shape (including registration number and vessel name); and
- for cooperative targets only, knowledge of vessel cargo and the disposition of the cargo.

(7) The parameters of the VMS function exclude

- Coast Guard interaction with a vessel for the purpose of close surveillance, inspection, and apprehension.

(8) The study considers the VMS/Coast Guard requirements in light of anticipated Departmental, political, and legal developments (e.g., the United Nations Conference on the Law of the Sea, the Louisiana Offshore Oil Platform); however, the study assumes the VMS to be time-invariant.

(9) The presentation of OTIS and the analysis/evaluation of alternative systems assume the study to be a feasibility assessment and, therefore, are conceptual models and descriptions (not engineering designs) from which future, in-depth design studies should proceed.

(10) Assumptions underlying the relationship of VMS capability and Coast Guard missions requirements are identified in the introduction to the missions analysis (Section 2.1.4).

1.5 METHODOLOGY

This study of vessel monitoring systems encompassed two phases: a preliminary study definition and a detailed study. The initial phase, the study definition, undertook a preliminary analysis of Coast Guard missions and functions to determine their requirements for a vessel monitoring system, presented preliminary findings, and offered a program plan for the detailed study of vessel monitoring systems. The investigative approaches of the study definition were research in literature and communication with Coast Guard personnel whose expertise, judgment, and opinions were relative to individual assignments in a variety of Coast Guard missions and programs.

These sources of information were used to obtain qualitative descriptions of the various Coast Guard missions and practices, with specific attention given to identifying those missions which would benefit from an offshore monitoring and surveillance system. Concurrently, potential vessel monitoring and

1.6 REFERENCES

1. Fishery Conservation and Management Act (P.L. 94-265), 13 April 1976.

2. Port and Tanker Safety Act (P.L. 95-474), 17 October 1978.

3. Ports and Waterways Safety Act (P.L. 92-340), 10 July 1972.

4. Clean Water Act (P.L. 95-217), 27 December 1977.

5. Offshore Vessel Traffic Management (OVTM) Study, CG-D-55-78. 3 vols. U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, Cambridge MA, August 1978.

2. ANALYSIS OF U.S. COAST GUARD MISSIONS REQUIREMENTS FOR A VESSEL MONITORING SYSTEM

2.1 INTRODUCTION TO THE MISSIONS ANALYSIS

2.1.1 U.S. Coast Guard Organizational and Functional Structure: Operating Programs and Missions

The fourteen operating programs shown here comprise the organizational structure of the U.S. Coast Guard:

Port and Environmental Safety (PES)

Enforcement of Laws and Treaties (ELT)

Search and Rescue (SAR)

Marine Science Activities (MSA)

Ice Operations (IO)

Pollution Response and Environmental Coordination (PREC)

Waterways Management (WM)

Short Range Aids to Navigation (SRA)

Radionavigation Aids (RA)

Commercial Vessel Safety (CVS)

Recreational Boating Safety (RBS)

Military Preparedness (MP)

Bridge Administration (BA)

Reserve Training (RT).

Within each program, the missions fulfill functional objectives related to tasks of response and assignments of opportunity (e.g., safety, rescue, law enforcement, research and regulatory activity, and military operations); the missions are the basic operational units representing Coast Guard responsibilities. Each mission is defined by its specific objectives (referred to herein as "functions") and by its process of response. (In this report, the

TABLE 2-1. VMS APPLICABILITY IN COAST GUARD MISSIONS (CLASSIFICATIONS OF VMS USE)

I. MISSIONS OF PRIMARY VMS USE
 	
Port and Environmental Safety
Enforcement of Laws and Treaties
    Fisheries Conservation and Management
    Control of Drugs and Contraband Smuggling
    Control of Terrorist Activities
    (Enforcement of the Offshore Economic Zone)
Search and Rescue

II. MISSIONS OF SECONDARY VMS USE Marine Science Activities Ice Operations Pollution Response and Environmental Coordination Waterways Management Short-Range Aids to Navigation Long-Range Radionavigation Aids Commercial Vessel Safety Offshore Vessel Traffic Safety Military Operations and Preparedness

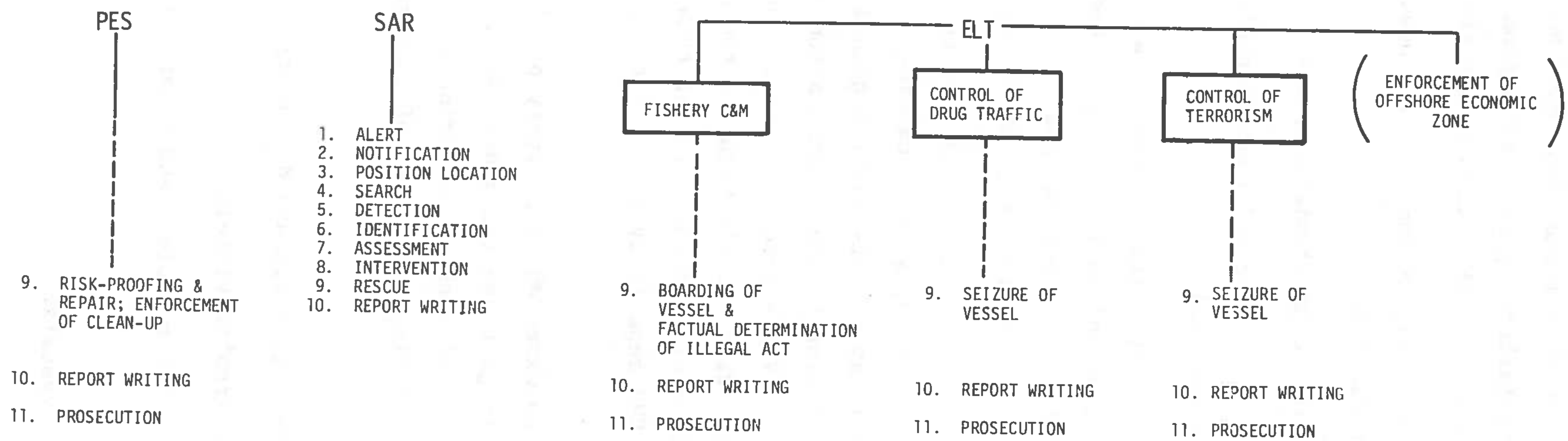

FIGURE 2-1. GENERAL SCHEMA OF MISSION PROCESSES (BASED ON SAR MODEL)

All missions (with the possible exception of Long-Range Radionavigation Aids) involve some monitoring of cooperative vessels. Cooperative vessels require two main features in a VMS:

(1) Immediate access, 2-way (iterative) communication; and

(2) A minimum of two communications contact points for both incoming and outgoing vessels in territorial waters and in waters along the 200 nm OEZ, including vessels of innocent passage and U.S. intra-coastal traffic. (These latter two vessel types report after every 200 miles of offshore travel.)

(Daily reports to the shore giving identity, location, course, and speed, may meet some but not all Coast Guard mission requirements. Additional information from the vessel such as destination, estimated time of arrival, local weather/sea conditions, and condition of the vessel is of value for safe traffic movement and will be requested by the Coast Guard shore facility if the need arises, as in the case of an inbound tanker or LNG vessel entering the FCZ.)

Noncooperative vessels can be expected to actively evade VMS detection, and/or to violate marine laws, or to balk at undertaking participatory monitoring measures. Noncooperative vessels are the subjects of passive monitoring. They require surveillance of their positions and course via remote sensors providing a second parameter, such as vessel length or radar cross-section. Examples of noncooperative vessels:

Certain commercial vessels influenced by business competition
Drug and contraband carriers*
Terrorist vessels
Vessels in innocent passage
Illegal fishing and recreational vessels
Noncooperative recreational and domestic fishing vessels
U.S. and foreign naval vessels in security operations.

Missions of law enforcement and military and intelligence operations require surveillance of noncooperative vessels. For a VMS to encompass surveillance of noncooperative vessels, these two capabilities must be featured.

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*Except the unaware cooperative vessels (e.g., commercial fishing)

Guard field unit commander with information needed for the mission(s) at hand. This potentially offers major advantages in the application of resources (aircraft and cutters) to small-area searches for the specific vessel(s) of interest instead of large-area, routine surveillance flights aimed at checking the general status and actions of whatever vessels may be in the area at the time. (At this time, large-area surveillance with aircraft equipped for gathering documentary evidence of detailed activities on board vessels, as well as identity, position, and course, appears to be a costly and inefficient utilization of resources.)

2.2 ANALYSIS OF MISSIONS WITH PRIMARY REQUIREMENTS FOR A VESSEL MONITORING SYSTEM

2.2.1 Port and Environmental Safety (PES)

2.2.1.1 Mission Description - The U.S. Coast Guard is the principal Federal agency responsible for the safety and security of ports and other shorebased marine facilities, and addresses the pollution of the marine environment caused by the discharge of substances which disturb the marine ecosystem and reduce the recreational value of marine waters. The Captain of the Port (COTP) is responsible for this mission. The zone covered by the COTP, as stipulated in current regulations, generally does not indicate seaward boundary. Each program under the auspices of the COTP has its own seaward boundary, usually defined in the statute. The PES mission covers harbor entrances, harbors and ports, including all shorebased facilities for marine transport, the vessels entering and leaving the port, and environmental protection of marine waters[2].

The tripartite responsibilities for security, safety and environment include:

(1) evaluating vessel cargo for hazard and risk exposure to port facilities and other vessels. (For example, LNG vessels are given special assistance into and out of port.)

(2) inspecting shore facilities, piers, vessels, and marine waters for safety and pollution prevention.

(1) liquid bulk transfer operations in harbors;

(2) offshore lightering operations (mainly in the Gulf area and off the coast of Southern California);

(3) tanker washing, bilge and ballast petroleum dumping;

(4) vessel tanker and tank barge oil leaks that are unknown to the crew or that go unreported to the Coast Guard; and

(5) vessel casualties, especially tanker casualties, involving oil spills.

(Of these pollution sources and incidents, most are conducive to cooperative monitoring and require implementation of steps 1 through 8 only of the Coast Guard mission response process. (See Figure 2-1.) Two incidents, however, are precipitated by noncooperative sources and, therefore, require implementation of the full response process through enforcement of clean-up and prosecution: (1) oil leaks from vessel tanks and tank barges that are unknown to crew or go unreported to the Coast Guard, and (2) illegal dumping of pollutants into marine waters.)

In protecting the environment, the Coast Guard functions in the areas of prevention, enforcement, and surveillance. Surveillance tasks of the environmental protection function include[5]:

(1) Surveillance by aircraft of main harbors, deep-water ports, and their approach channels. Monitoring requirements are based on the quantity of petroleum loaded/shipped and range from one flight per week for 10 million tons of petroleum loaded/shippped to six flights per week for 250 million tons of petroleum loaded/shipped. In FY78, approximately 5,340 hours of aircraft flight time were required for 31 harbors. The estimated requirement for FY83 is 6,675 hours[5,6].

(2) Surveillance by aircraft of the marine waters between ports, including the territorial waters, contiguous zone, and prohibited zone. Monitoring requirements are based on the pollution potential determined by the Coast Guard from analyses of shipping density, location of offshore oil facilities, and the environmental sensitivity of the area. In FY78, approximately 5,230 hours of aircraft flight time fulfilled this task. The estimated requirement for FY83 is undetermined[5,6].

TABLE 2-2. PES SURVEILLANCE TASKS: SUMMARY OF OPERATIONS REQUIREMENTS, PAST AND PROJECTED

TASK #	TARGET AREA	SURVEILLANCE MODE	LEVELS OF ACTIVITY	
			PAST PERFORMANCE FY78	PROJECTED REQUIREMENTS FY83
1	harbors (≈31) deep-water ports approach channels	aircraft	5,340 hr*	6,675 hr*
2	territorial waters contiguous zone prohibited zone	aircraft	5,230 hr*	(undetermined)
3	dumping sites (A: EPA B: general permit)	aircraft	A: 1,260 hr* B: 224 hr*	A: 347 hr* B: 2,240 hr*
4	essential harbors (≈148)	marine vessel	day: 3 patrols/week night: 7 patrols/year	day: 1 patrol/day night: 1 patrol/week
5	remote harbors (≈594)	marine vessel	7 patrols/year	1 patrol/week
6	200 nm offshore zone	aircraft and marine vessel	n/a**	8,150 hr* 5,785 ship days

*Hours indicate aircraft flight time; this time is estimated because aircraft are routinely flown on multi-mission operations with time charged to the priority activity or divided between several activities of a flight.

**Task #6 is a new function to be effected in FY81.

Oil Surveillance System II (AOSS). Expansion of aerial surveillance to include an all-weather capability as well as a day/night capability is provided by the AIREYE sensor, which includes the AOSS sensors plus an aerial surveillance camera and an active-gated television. The AIREYE sensor system will be carried by a new, medium-jet aircraft, HU-25A.

Data bases used in the PES mission are: the Pollution Information Reporting System (PIRS), the Marine Safety Information System (MSIS), and the multisystem Operational Computer Center (OCC). The OCC contains a network of data bases for MSIS, Search and Rescue (SAR), Automated Mutual-assistance Vessel Rescue System (AMVER), and Fishery Enforcement via the Enforcement Management Information System (EMIS).

The extension of PES surveillance to include the 200-nm offshore region (as prescribed under Title II of the Outer Continental Shelf Land Act Amendment of 1978, under the Port and Tanker Safety Act of 1978, and under the Clean Water Act of 1977) will necessitate the expansion of existing requirements and resources of the PES mission. Factors influencing new developments in PES monitoring systems will include the frequency of observation flights (patrols), the systems' capabilities for all-weather and day/night monitoring, and the coordinated use of reporting systems for cooperative vessels and remote sensing systems for noncooperative vessels.

Vessels carrying hazardous cargo or petroleum in areas of dense traffic will require daily observation flights; daily patrols will be especially critical in major harbors and deep-water ports handling more than 50 million tons of petroleum and hazardous material per year. Hazardous-cargo or petroleum-carrying vessels that operate in areas of light traffic will require one observation flight every three days.

The detection and tracking of hazardous materials and petroleum discharges from both legal and illegal dumping require a system with an all-weather capability. Implementation in the 1980's of the Ocean Dumping Surveillance System will facilitate a monitoring level of 100 percent coverage for those dumping operations restricted to EPA chemical and industrial waste sites (Category A) and for those dumping operations under general permit (Category B); this system should lessen demands for PES resources.

FIGURE 2-2. GLOBAL VIEW OF THE U. S. FISHERY CONSERVATION ZONE

establish a comprehensive mechanism for regulating seabed resources, for defining the sovereign rights of coastal states, and for effecting compulsory settlement of international maritime disputes, among many other objectives. (See Appendix D for a summary of UNCLOS objectives and the status of resolutions adopted as of April 1980.) Because this mission is newly conceived and undergoing definition, requirements for its servicing by a VMS can only be generally projected.

2.2.2.2 Mission Requirements for a VMS -

<u>Fisheries Management and Conservation</u> - The FCZ is regulated by plans issued by eight Regional Management Councils and approved by the Secretary of Commerce. The Coast Guard and the National Marine Fisheries Service (NMFS) have joint responsibility for enforcement of the marine conservation laws and regulations. Requirements for the enforcement of the Fishery Conservation and Management Act (FCMA) generally differentiate foreign fishing vessels from domestic fishing vessels and involve elements of both cooperative and noncooperative vessel monitoring for each category.

Foreign nations that wish to fish within the FCZ must first sign a Governing International Fishery Agreement (GIFA) with the U.S. Permits are issued for specific species and for that portion of the optimum sustainable yield which will not be harvested by domestic fishermen. (Appendix B summarizes the monitoring and enforcement processes applied to foreign fishing vessels of nations under GIFA and that enter fishing windows in the FCZ; Appendix C also contains tabulated data of FCMA enforcement measures taken against foreign and domestic fishing vessels.)

As the enforcement data indicate, overall foreign fishing activity within the FCZ has decreased considerably since the passage and enforcement of FCMA. This reduction in foreign fishing activity is an important factor influencing VMS requirements for the Fishery Conservation and Management function of the ELT mission. For example, Table C-1 shows for 1976 a monthly average of 555 foreign fishing vessels operating in the FCZ, while for 1979 the count is reduced to approximately 300. Furthermore, the Coast Guard enforcement effort indicates that the average number of foreign fishing vessel boardings per month has decreased from 146, in 1977, to 63, in 1979, while the by observing a vessel count discrepancy in the area covered by the fishing window. The Fishery Conservation and Management Act of 1976 provides for serving penalties on the U.S. based agent of the foreign vessel, and the Coast Guard presence in the fishing windows is a strong economic incentive for compliance. In fact, in the case of fishing fleets, vessel discipline is maintained by the head of the fleet in the name of his government in order not to jeopardize the GIFA agreement.

Domestic fishing vessels in the 0-nm to 3-nm U.S. coastal zone are under the exclusive jurisdiction of the coastal states and, therefore, are not subject to Federal/Coast Guard regulation and enforcement. Domestic fishing regulations and quotas are designed to limit harvesting so that the optimum sustainable yield is preserved. In contrast with foreign vessels, domestic fishing vessels are more numerous and generally smaller. They usually have less sophisticated equipment on board for fishing operations, as well as for safety and navigation. Commercial fishing vessels constitute 11.9 percent of search and rescue (SAR) assisted vessels[4]. Nearly all of the incidents of convenience (e.g., engine failure, broken steering, and fuel outages) involve domestic fishing vessels that depend on the Coast Guard, instead of calling on other fishing vessels within sight, to provide towing services and fuel. (Appendix C, Tables C-2 and C-4, summarize effort with domestic fishing vessels.)

Possible violations by domestic fishing vessels in the FCZ include exceeding species quotas, fishing in prohibited areas, taking undersize fish, using illegal mesh-size nets, and fishing without a permit. Enforcement of the FCMA for domestic fishing vessels is accomplished by (1) the patrol of fisheries, (2) the boarding and inspection of fishing boats, and (3) inspection of the fish catch when vessels return to the U.S. mainland. It is the first of these enforcement activities -- the fisheries patrols -- to which VMS capabilities apply. The National Marine Fishery Service (NMFS) handles the landside inspection operation, but the Coast Guard and NMFS jointly perform the seaside patrols and inspections. The Coast Guard provides the platforms, watercraft, and aircraft for the fisheries patrols. Usually the patrols and boardings are performed by both NMFS and Coast Guard personnel using a Coast Guard vessel, but the Coast Guard has increasingly been performing fisheries patrols without NMFS personnel on board.

100 to 300 feet in length and is registered as a general-cargo vessel. It may even carry legitimate cargo when it is smuggling. However, much like the smaller vessels, the mothership has a full load of contraband, is manned by a crew involved in smuggling, and operates in areas similar to those of smaller vessels. (Fifty percent of mothership operations can be found along the Florida coast.) The trafficking organization is generally in the source country and the mothership is manned by aliens[10].

Clearly, there is nothing cooperative about the drug vessel population. The vessels employ all kinds of subterfuge and countermeasures with sophisticated electronic equipment to outmaneuver Coast Guard operations. Also, while the mothership has a length range of 100 to 300 feet, the drug vessel population with source-to-destination capability has a length range of 40 to 170 feet. Unless and until the vessel is offloading, interdiction can take place anywhere in offshore waters without regard to the 200-nm FCZ boundary. Therefore, the basic steps of the drug control function require only a rough estimate of position location (pending further analysis, within the detection range of 50 miles provided by side-looking airborne radar, SLAR). Such approximate position location in real time is obtained principally through intelligence information system sources.

The major system of intelligence information supporting the Coast Guard's drug control functions is the El Paso Intelligence Center (EPIC). Established in 1974 and jointly staffed by DEA, INS, U.S. Customs, the Coast Guard, the Federal Aviation Administration (FAA), and the Bureau of Alcohol, Tobacco, and Firearms (BATF), EPIC is the national center for drug enforcement. The Center studies criminal activities of individuals, of national and international crime syndicates, and of foreign countries where drugs are produced and heavily used. EPIC is not a command operation or a communication center. The Center's sole communications purpose is to answer inquiries of agents and field headquarters personnel.

The EPIC vessel program consists of obtaining, processing, and disseminating significant information concerning the smuggling of illicit narcotics via vessels into the U.S. (For example, one contribution to EPIC's drug vessel profile is DEA's model profile of mothership activity which continually provides new data for updated analysis by the Coast Guard, U.S. Customs, and DEA.) EPIC uses cross-correlation and link-analysis techniques which "to cooperate with other government agencies in carrying out international activities... in furthering national policy"[11]--emphasizes the Coast Guard's status as a national agency responsible for advancing U.S. policy and promoting international cooperation of maritime activities.

The subobjectives and specific goals for each of the two major objectives delineate the scope of the SAR missions relative to vessel monitoring requirements[11]:

SUBOBJECTIVE A.1 - Maximize USCG's ability to receive knowledge of distress incidents, effectively process the distress information, and direct appropriate Coast Guard action.

GOAL - Provide 99 percent SAR communications coverage out to a distance of 300 nm offshore, and have the capability to receive 99 percent of the expected calls for assistance.

GOAL - Provide the capability to effectively process and evaluate SAR information to aid in selection of appropriate Coast Guard action.

GOAL - Assign a SAR facility to take selected action within 5 minutes of initial notification of a call for assistance.

SUBOBJECTIVE A.2 - Minimize time to arrive at the scene of a distress incident.

GOAL - After unit notification, dispatch suitable "Bravo Zero" resources within 30 minutes in 98 percent of the distress incidents.

GOAL - After arrival on scene, or in the search area, locate 90 percent of units in distress within 45 minutes.

SUBOBJECTIVE G-2 - Improve international cooperation in Search and Rescue.

GOAL - Maintain an AMVER plot of 75 percent of the worldwide commerical vessels (both U.S. and foreign) which are on offshore or coastal voyages of at least 24 hours duration.

In brief, the subobjectives and goals address six operational areas for comprehensive mission performance and professionalism: distress communications, command and control, readiness posture, area coverage in transit, location of victim/vehicle position, and on-scene effectiveness.

TABLE 2-3. CHARACTERISTICS OF SAR MISSION ACTIVITY (FOR 1977)

I. TOTAL NUMBER OF SAR ASSISTS		83,101		
II. ZONES OF SAR INCIDENTS				
Offshore Assists	95%	77.9% within 3 nm 91.3% within 10 nm		
Land Assists	5%			
III. PROFILE OF SAR SUBJECTS (DISTRIBUTION BY TYPE)				
Marine Vessels	94.0%	recreational	78.2%	
		commercial fishing	11.9%	
		merchant	2.0%	
		touring	.6%	
		other	7.3%	
Persons	4.7%			
Aircraft	.7%			
Land Vehicles & Structures	.6%			
IV. LENGTH OF MARINE VESSELS ASSISTED BY SAR				
Under 100 feet long	95%			
Under 40 feet long	85%			

Source: SAR Statistics, 1978

NOTE: Appendix E contains the series of graphs which detail these statistics.

TABLE 2-4. SUMMARY OF MISSION REQUIREMENTS FOR A VESSEL MONITORING SYSTEM

REQUIREMENTS	MISSIONS	REMARKS
1. Detailed historical vessel data	All	Not all non-cooperative vessels
2. Knowledge of traffic environment and two-way communications	All	Non-cooperative vessels excluded
3. Communications of less-than-an-hour intervals	SAR only	Deserves special treatment
4. EPIRB signals	SAR only	Under development with SARSAT
5. Ready-access communication contact both ways	ALL	Non-cooperative vessels excluded
6. A minimum of two contact points of communication	All	Non-cooperative vessels excluded
7. Crew involvement in communications	All	Imperative
8. Show of CG presence	Fishery Conservation and Port & Environmental Safety (PES)	
9. Intelligence support	All ELT missions	Imperative for terrorist activities
10. Covert, close observation	ELT-Drug and Terrorist, and Intelligence	
11. Surveillance and correlation	All	The following requirements fall under 11.
11a. Position location accuracy 2-4 nm	All ELT missions and Intelligence	Conservative
11b. Limitation: 3-mile boundary area cut-off	All except SAR and PES	To reduce vessel count noise in a VMS

TABLE 2-5. REQUIRED FEATURES FOR A VESSEL MONITORING SYSTEM

MONITORING CAPABILITIES

RELIABLE TWO-WAY COMMUNICATIONS WITH COOPERATIVE VESSELS

TWO VESSEL REPORTS MINIMUM; INBOUND AND OUTBOUND (APPROX. 200 nm AND 12 nm OFFSHORE)

REPORTS FROM OTHER VESSELS ONCE DAILY

INFORMATION: POSITION LOCATION, IDENTITY, COURSE AND SPEED

VESSEL SIZE: GREATER THAN 40 FT LENGTH

SURVEILLANCE CAPABILITIES

COVERAGE BY REMOTE SENSING: 0 TO 200 nm

POSITION LOCATION ACCURACY: 2 TO 4 nm, 2-drms

SECOND PARAMETER REQ'D., e.g., APPROX. VESSEL LENGTH

SYSTEM OUTPUT CAPABILITIES

OUTPUT: ONCE PER DAY (BASIC REQUIREMENT; ADDITIONAL REPORTS ON REQUEST)

UPDATE RATE: HOURLY WHEN REQUIRED

5. Correlation between the two vessel mapping counts and generation of a subset mapping count of noncooperative vessels with at least vessel length size descriptions. This subset is the suspect mapping count.

6. Real-time correlation with intelligence data relating to the incident of interest and generation of a priority ranking for each vessel in the suspect count. This and item 5 include the case when the suspect count is zero which will score as a false alarm for the alert trigger source.

7. Close-range surveillance for all the vessels in the suspect count, depending upon the mission incident of interest. For the enforcement of FCMA regulations, the deployment could lead to vessel boarding. For all the other missions the deployment will involve COVERT OBSERVATION of each vessel on a pairwise continuous basis leading to a further screening of the suspect population. Each vessel of the final screening suspect count is targeted for optimum interdiction operations. Item 7 is an output which constitutes a multimission requirement for a VMS system.

These are the baseline VMS requirements for the majority of applicable Coast Guard missions which set the parameters for the design of a basic VMS. Beyond these baseline requirements, each Coast Guard mission, considered individually, has a number of dissimilar requirements; however, these dissimilarities pertain to the detail of each mission rather than to the background base of the mission. In addition, all missions have VMS requirements for supplementary (i.e., indirect) use such as anticipatory planning, in general, and response planning, in particular.

Toward fulfilling the missions' requirements, the VMS must have these basic components:

Communications (2-way reporting with cooperative vessels)

Surveillance (covert observation via remote sensors of noncooperative vessels)

Intelligence

Computer Correlation.

as well as a high level of vessel identification. Such a surveillance system tends to approach the level of sophistication of a spy-in-the-sky-type satellite system. However, even if the Coast Guard were to operate such a surveillance system, the output of the system would be of no use to the indirectly related mission requirements and it would fall far short of satisfying the directly related mission requirements especially those involving the cooperative vessel population including foreign fishing enforcement which would need two-way communications, but a surveillance-only system could not provide this service. In short, such a sophisticated surveillance system by itself would be of some use to a limited number of missions such as those responding to marine drug traffic, terrorism, and intelligence operations.

Therefore, large-area surveillance with aircraft equipped for gathering documentary evidence of detailed activities on board vessels, as well as identity, position, and course appears to be a costly and inefficient use of resources at this time. Instead, the most feasible and desirable VMS would support missions which require deployment strategies to local and regional hot spots. In the aggregate, most Coast Guard missions may, at any given time, require a concentration of resources in one region or another at the expense of coverage to other oceanographic areas. The VMS would ease somewhat the constraint of limited resources by allowing the deployment of equipment and personnel to these hot spots without jeopardizing its missions elsewhere.

2.4 REFERENCES

1. Port and Tanker Safety Act (P.L. 95-474), 17 October 1978, Section 3.
2. USCG Port Safety and Security Operating Program Plan, FY 83-92, Office of Marine Environment and Systems, U.S. Coast Guard, Washington DC, February 1980.
3. Offshore Vessel Traffic Management (OVTM) Study, CG-D-55-78. 3 vols. U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, Cambridge MA, August 1978.
4. SAR Statistics - 1978. COMDTINST M16107.1 Search and Rescue Division, Office of Operations, U.S. Coast Guard, Washington DC, 13 March 1979.

3. VESSEL POPULATION PROFILE

3.1 INTRODUCTION

Relative to the Port and Tanker Safety Act's stipulation that the study of vessel monitoring systems consider not only the interests of the Federal Government but also those of "any vessel owners who would be affected by the imposition" of a VMS[1], this section describes the vessel population operating in the U.S. Fishery Conservation Zone (FCZ). The vessel population of interest here includes these four vessel types:

(1) large commercial vessels - vessels over 500 gross tons of U.S. or foreign registry; for example, merchant/passenger vessels, freighters, bulk carriers, tankers.

(2) small commercial vessels - vessels 40 feet or more in length, weighing less than 500 gross tons; for example, tugs, tows, barges, scows, other unclassified types.

(3) fishing vesples - vessles 40 feet or more in length; classified as (a) domestic (b) commercial sport, and (c) foreign.

(4) recreational vessels - the largest group of vessels; of the 12,750,000 recreational vessels registered in 1976, 99.4 percent were less than 40 feet long with the remaining 0.6 percent (76,500 vessles) 40 feet long or greater[2].

To facilitate this study's analysis of vessel population, the cost of the United States was divided into these four regions:

1. East Coast - This region begins in Northern Maine (at the U.S.-Canadian border) and extends south to Jacksonville, Florida.

2. Gulf Coast and Caribbean - The Gulf Coast region begins just south of Jacksonville, Florida, and extends to the west coast of Florida. It continues west to Mississippi and Louisiana, terminating off the coast of the Texas-Mexican border. The Caribbean region includes Puerto Rico and the U.S. Virgin Islands.

3. Pacific Coast (Including Hawaii) - This region includes the coast of Washington, beginning at the U.S.-Canadian border, extending south

Estimates of vessel populations were made for small commercial, fishing, and recreational vessels registered in the U.S. for 1979 and then projected to 1985 and 1990. Sources of these total population estimates for the respective vessel groups are:

for small commercial vessels, Transportation Lines, on the Atlantic, Gulf, and Pacific Coasts-1977, a vessel listing published by the U.S. Army Corps of Engineers[4].

for fishing vessels, Northeast Fisheries Center Statistics and Market News, published by the National Marine Fisheries Service[5] and Termination of of LORAN-A: An Evaluation of Alternative Policies, prepared by Oregon State University[6].

Estimates for the total population of fishing vessels include domestic fishing and commercial sport fishing vessels and exclude foreign fishing vessels. This third sector of the fishing vessel population is considered, however, in determining the offshore vessel population.

for recreational vessels, Recreational Boating in the Continental United States in 1973 and 1976: The Nationwide Boating Survey, published by the U.S. Coast Guard[2].

The 1976 population of recreational vessels was projected to a 1979 population total by assuming an average annual growth rate of 8 percent, giving an approximate total of 100,000 vessels. Since the drafting of this report, however, additional data have been made available -- Boating Statistics 1979[7] and Boat Documentation Records[8] which indicate that the number of recreational boats in this category may be closer to 48,000, rather than 100,000. Nevertheless, the latter number has been used as the basis for projections and system sizing. If errors exist, they reflect a higher, rather than a lower, system capacity; hence the latter figure is a conservative estimate.

Table 3-1 summarizes the total vessel populations for small commercial domestic fishing, commercial sport fishing, and recreational vessels for 1979, 1985, and 1990. These vessel population estimates are the basis for determining the offshore vessel population of the three vessel groups, which when added to the offshore vessel population estimates of the large commercial vessels, give the total offshore vessel population, the basis for the vessel population profile's consideration of vessel hot spots and vessel communications and navigation capability.

3.2.2 Characteristics of Vessel Fleet Size within the Offshore Vessel Population

Estimated offshore vessel populations are tabulated (Tables G-1 through G-4) for each of the four classes of vessels in the regions of the FCZ and with respect to the two subzones of offshore distances: (1) the area between 0-3 nm from shore, and (2) the area between 3-200 nm from shore. Table 3-2 summarizes the offshore vessel populations for all vessel classes.

3.2.2.1 Large Commercial Vessels - Table G-1 illustrates the offshore vessel population for large commercial vessels in each of the four regions of interest. The population estimates were developed for 1979, 1985, and 1990, and are presented by subzone (0-3 nm and 3-200 nm) and by total for the region. The majority of these vessels are foreign flag vessels since less than five percent of the total foreign trade necessary for the support of the U.S. economy is carried in U.S. flag vessels. More than five thousand foreign flag/ foreign trade vessels and less than five hundred U.S. flag vessels in foreign and domestic trade operate in the proposed monitoring area.

The principal data source utilized to develop the offshore vessel population for large commercial vessels was a microfiche record of U.S. Department of Commerce, Bureau of Census, (Forms AE 350 and AE 750). These forms contain a record of arrivals and departures of large commercial vessels at all U.S. port areas. These data are derived from custom manifest information required to be filed by all vessels engaged in foreign trade and consist of such elements as vessel type, gross tonnage, nationality, cargo, and service.

The offshore vessel population presented in Table G-1 was developed by estimating the number of domestic vessels which primarily travel from port to port parallel to the U.S. coast. These estimates were made separately and then were combined to produce the total estimate.

The methodology used to estimate the foreign and domestic components of the offshore vessel population is identical. A base figure for the population was developed by considering the average number of arrivals and departures per day in each region. An additional factor was then added to the base figure. The additional factor accounts for the number of vessels that could potentially enter the U.S. Fishery Conservation Zone in a 24-hour period from the area beyond the 200-nm zone, vessels waiting to enter the harbors, and vessels traveling through a region parallel to the coast.*

Table G-1 presents estimates of the offshore vessel population projected to the years 1985 and 1990. A nominal growth rate for the number of vessel trips was assumed. The projections were based upon a detailed analysis performed by Temple, Barker, and Sloane, Inc., and are presented in a report entitled, "Merchant Fleet Forecast of Vessels in the U.S.-Foreign Trade," prepared for the U.S. Department of Commerce, Maritime Administration. The study projects increases in the merchant fleet of both U.S. and foreign vessels, by relating increases in the merchant fleet to vessel traffic. Slow growth in large commercial vessel traffic is expected for the following reasons:

1. Dramatic changes are anticipated over the next 11 years. Tanker and container ship traffic is expected to rise substantially during this period. These gains will be offset by a decline in general cargo ship traffic, as the industry develops increasingly specialized vessel types.

2. U.S. oceanborne commerce is expected to rise over the next decade. While this alone would cause traffic gains, fleet capacity is increasing as larger LNGs, supertankers, and other ships are being built domestically and by foreign shipbuilders. As smaller, aging vessels are retired, they are being replaced with fewer, but larger, new vessels.

3. Domestic ports are growing rapidly in the Southwest to accommodate the large vessels. Older established ports are losing traffic and being forced to modernize and build deeper berths to handle the new fleet. The current need for ships to "lighter" their load offshore should diminish.

4. A long-standing gradual decline in the U.S. merchant fleet has led to a decrease in domestic flag ships' activity, perpetuated by strict and insensitive U.S. regulatory policies. Legislative reform is now being directed

*A more complete description of the estimation methodology is contained in a Project Memorandum - Offshore Vessel Population Profile prepared for the Office of Air/Marine Systems of the Transportation Systems Center by Input Output Computer Services, Inc., March 1980.

and Caribbean region, where about 40 percent of the traffic takes place in the 0-3 nm subzone. This is the case for the following reasons:

1. Most of the small commercial vessels can approach the ports as close as one mile from shore and then be towed by the tow boat.

2. Tug/tow boats do not make frequent trips out of their port of operation.

3. Whenever a tug operator makes a long-distance trip, he tries to stay as close to shore as possible.

4. The traffic is evenly distributed over the year. It is higher during the weekdays and lower on the weekend.

The remaining 20 percent of the small commercial vessels are expected to be in the 3-200 nm subzone, except for 60 percent in the Gulf Coast and Caribbean region.

3.2.2.3 Fishing Vessels - This category includes fishing vessels 40 feet or more in length. The fishing vessel population identified is comprised of three different types of vessels:

1. Domestic Fishing Vessels

2. Commercial Sport Fishing Vessels

3. Foreign Fishing Vessels.

Domestic fishing vessels represent the largest component of the fishing vessel population. Domestic fishing vessels fall into two major categories:

1. Registered (undocumented) Vessels. These vessels display a coded number on their bow, a name on their stern, and operate under licenses issued by the state authorities.

2. Documented Vessels. These vessels are permanently identified by official numbers on the main beam, and are licensed to operate by the Federal Government (U.S. Coast Guard).

The vast majority of domestic fishing vessels are documented vessels. Included in the domestic fishing fleet are dredging boats, deep-sea vessels, and several other types. Available data which categorize fishing vessels according to their length indicate that more than one-half (56 percent) of all water. This estimate is intended to be conservative, but necessary because of data limitations.*

The offshore vessel population for foreign fishing vessels was developed from limited U.S. Fishing Conservation Zone enforcement data compiled by the U.S. Coast Guard. The estimate reflects regulations recently imposed by the United States to limit foreign fishermen's catch from U.S. coastal waters.

Generally speaking, large-scale foreign fishing vessel activity currently is in Alaskan waters. Outside Alaska, the foreign fishing vessel population is not expected to increase, and it may actually decrease. The foreign fishing vessel population in the Alaskan region will probably increase slightly during the next eleven years. The estimates contained in Table G-3 are based on the assumption that all foreign fishing vessels in American waters are 40 feet or more in length. The vessels are likely to be at least 100 feet in length.

3.2.2.4 Recreational Vessels - Table G-4 presents the offshore vessel population for recreational vessels for 1979, 1985, and 1990. Because of a lack of detailed information, a simple procedure was used. The U.S. Coast Guard Auxiliary for each of the four regions was contacted. An officer was asked several questions about the characteristics of the recreational vessel population in his/her region. These responses were used in the development of the offshore vessel population presented in Table G-4.

There was surprising consistency in the responses. The maximum percentage of the recreational vessel population that might be on the water in a 24-hour period was 25 percent. Of those vessels, 80 percent would be in the 0-3 nm subzone while the remaining 20 percent would be in the 3-200 nm subzone. The busiest day for recreational vessel use is July 4. One Coast Guard officer stated that recreational vessel use peaks between 2:30 and 4:30 PM on July 4.

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*A range was used in this category because of the limited data available. The average trip rate of 0.63 trips per day seems to understate the true value. The assumption that 100 percent of the fishing vessels could be on the water at any given instant seems a little high, but far more realistic. However, this assumption could not be documented.

TABLE 3-3. HOT SPOTS FOR LARGE COMMERCIAL VESSELS

REGIONS			
EAST COAST	GULF COAST AND CARIBBEAN	PACIFIC COAST	ALASKAN COAST
New York Harbor	Houston, Texas	Long Beach, California	Juneau Harbor
Long Island Sound	New Orleans, Louisiana	Los Angeles, California	Ketchikan Harbor
Elizabeth, New Jersey	San Juan, Puerto Rico	Oakland/San Francisco California	Anchorage Harbor
Wilmington, Delaware	St. Croix, Virgin Islands	Seattle, Washington	
Hampton Roads, Virginia	Virgin and Mona Passages	Portland, Oregon	
Jacksonville, Florida	Gulfport, Mississippi		
Philadelphia, Pennsylvania	Baytown, Texas		

TABLE 3-5. HOT SPOTS FOR FISHING VESSELS

REGIONS			
EAST COAST	GULF COAST AND CARIBBEAN	PACIFIC COAST	ALASKAN COAST
Georges Bank	Florida Coastal Waters	Washington and Oregon coastal waters 0-50 miles from shore	Bering Strait
Gulf of Maine to south New England	Gulf of Mexico	North of Monterey Bay 0-20 miles off coast	Bristol Bay
Mid-Atlantic Region		San Diego Region	Gulf of Alaska
Virginia to North Carolina Region to Jacksonville, Florida			East Bering Sea
			Continental Shelf
			Aleutian Islands

Northeast Coast, recreational boating ceases during the winter months. For much of the East Coast region, therefore, the identified hot spots apply to the late spring, summer, and early fall months. Similarly, recreational boating in Alaska is limited to the warmer summer months.

Large vessel concentrations present a problem for an offshore vessel monitoring system if remote sensors are used to identify vessel position, since maintaining discrimination and track of each vessel can be very difficult. Because of this constraint, initially, a hot spot was defined as an area 10 miles square which contained at least 100 vessels within a 24-hour period.

The primary data source utilized to rigorously identify vessel hot spots was a listing of U.S. Coast Guard vessel sightings. This listing was obtained from the Permit and Data Analysis Branch of the National Marine Fisheries located in Gloucester, Massachusetts[10]. The sightings list indicates the time, location, and vessel type for vessels observed during routine Coast Guard patrols. These listings, however, do not consider vessel length. In this analysis, listings were prepared for one sub-area within each of the four major geographic study regions. These sub-areas are defined as follows:

Northeast Coast Region - This region is bounded on the north by the U.S.-Canadian border, on the south by the 38° north latitude, on the east by the 200-nm FCZ boundary, and on the west by the U.S. coastline. This region includes the waters in the FCZ between Maine and Delaware.

Gulf Region - This region is bounded on the north by 30° 30' north latitude, the U.S.-Mexican border on the west, the FCZ boundary on the south, and the FCZ boundary in the Atlantic Ocean on the east.

North Pacific Coast Region - This region is bounded on the south by 42° north latitude, on the west by the FCZ boundary, on the north by the 48° 20' north latitude, and on the east by the U.S. coastline.

Southwest Alaska Region - This region is bounded on the east by 144° west longitude, on the south by the FCZ boundary, on the west by 170° west longitude, and on the north by 61° north latitude.

Sighting lists which covered the first few months of 1980 and peak days in the summer of 1979 were available to the study team for analysis. This listing for the Northeast Coast region included all vessel classes, while the other

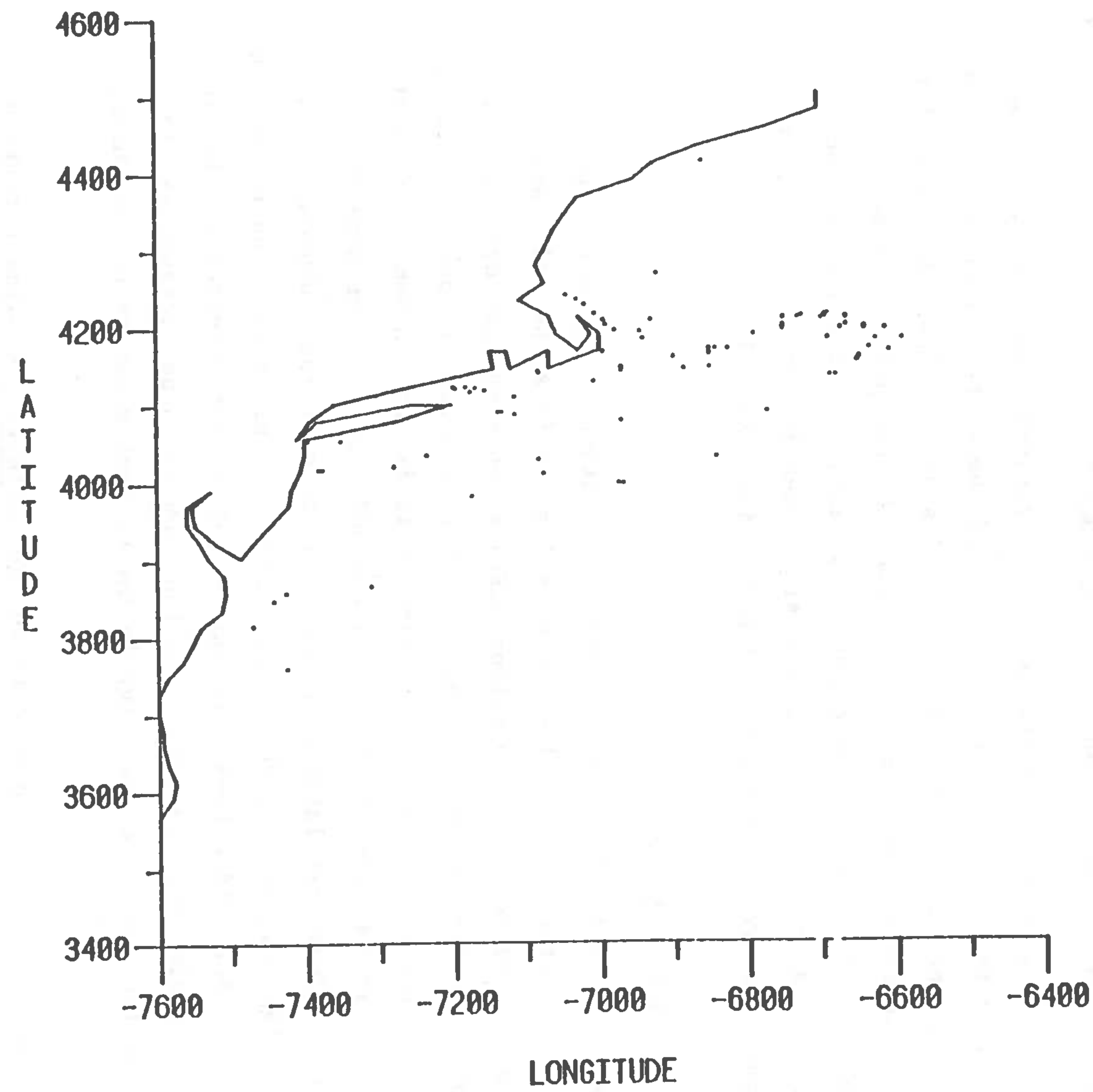

FIGURE 3-1. DISTRIBUTION OF OFFSHORE COMMERCIAL AND FISHING VESSEL TRAFFIC ALONG U.S. NORTHEAST COAST ON A PEAK DAY, 6/7/79 (•=1 vessel)
SOURCE: NATIONAL MARINE FISHERIES SERVICE, NORTHEAST OFFICE

Additionally, the Code of Federal Regulations (CFR) includes information which is directly applicable to large commercial vessels. The Code specifies minimum navigation equipment requirements for large commercial vessels. The following requirements are specified:

CFR, Title 46, Subpart 195-17-Radar

- o All vessels 1600 gross tons and over in ocean or coastwise service are required to carry two radars. (U.S. flag only.) Foreign flag requirements are covered by 33 CFR 164 and SOLAS 174.

CFR, Title 46, Subpart 195.19 - Magnetic Compass & Gyro Compass

- o All vessles in ocean or coastwise service are required to carry magnetic compass.

- o All vessels 1600 gross tons and over in ocean or coastwise service must carry a gyro compass in addition to magnetic compass.

CFR, Title 46, Subpart 195.27 - Sounding Equipment

- o All vessels 500 gross tons and over shall be equipped with deep-sea sounding apparatus.

CFR, Title 46, Subpart 195.15 - Radio Direction Finder

- o All vessels 1600 gross tons or more in ocean service or international voyage are required to carry a Radio Direction Finder (RDF).

LORAN-A will be terminated on 31 December 1980. By 1 June 1980, all vessels 10,000 gross tons or more and, by 1 June 1982, all vessels 1600 gross tons or more will be required to carry LORAN-C or an equivalent navigation system (33 CFR, Part 164). Furthermore, it is expected that an electronic relative motion anlyzer will be required by 1982.

3.4.2 Small Commercial Vessels

A very limited amount of information was found describing the type of communication equipment carried by small commercial vessels. However, based on information obtained from several sources, equipment was identified for small commercial vessels. This equipment includes:

- o Single Sideband HF Radio - used for long-range communication.

TABLE 3-7. TYPES OF NAVIGATION EQUIPMENT CARRIED BY SMALL COMMERCIAL VESSELS* (N = 25)

TYPE OF EQUIPMENT	NO. OF VESSELS	PERCENT
LORAN-A	11	44
LORAN-C	12	48
LORAN-A and LORAN-C	10	40
Satellite	8	32
Depth Finder	25	100
Radar	20	80
Radio Direction Finder	22	88
Omega	5	20

*Excludes barge and scow vessels.

Information contained in "The Termination of LORAN-A"[6] was used to develop a list of navigation equipment carried by domestic fishing vessels. The percentage of domestic fishing vessels 40 feet or more in length carrying each type of navigation equipment. Information contained in "The Termination of LORAN-A"[6] was used to develop a list of navigation equipment carried by domestic fishing vessels. The percentage of domestic fishing vessels over 40 ft or more in length carrying each type of domestic fishing navigation equipment was determined by interviewing Dr. Daniel Panshin, an author of "The Termination of LORAN-A." Table 3-9 illustrates a list of navigation equipment typically carried by domestic fishing vessels over 40 feet in length. A large percentage of the vessels carry a fathometer, radar, and, by 1981, most vessels will carry LORAN-C. The percentages in Table 3-9 were applied to the domestic fishing vessel population to determine the number of vessels carrying each type of navigation equipment. LORAN-A is scheduled to be turned off on 31 December 1980 and, during 1981, the percentage of fishing vessels carrying LORAN-C will increase to between 50 and 70 percent.

Table 3-10 summarizes the number of domestic fishing vessels carrying each type of navigation equipment during 1979, 1985, and 1990 for all four regions studied.

Commercial sport fishing vessels generally carry the same type of navigation aids as domestic fishing vessels. However, the only data that were identified were limited to LORAN systems. Table 3-11 presents the number of commercial sport fishing vessels which carry LORAN-A or LORAN-C.

3.4.4 Recreational Vessels

Data compiled in the national boating survey of 1976[2] were used to develop a list of installed communication equipment typically carried by recreational vessels. This data also indicated the percentage of all recreational vessels which carry each type of unit. The information was used to develop an estimate of the percentage of recreational vessels 40 feet or more in length carrying each type of equipment. These percentage figures were then applied to the population figures for recreational vessels (Table 3-1) to determine the number of recreational vessels carrying each type of installed communication equipment (during 1979, 1985, and 1990).

TABLE 3-10. SUMMARY OF NAVIGATION EQUIPMENT CARRIED BY DOMESTIC FISHING VESSELS

TYPE OF EQUIPMENT	PERCENTAGE OF FISHING CRAFT ≥ 40 FT	TOTAL NUMBER OF VESSELS CARRYING EACH TYPE OF NAVIGATION EQUIPMENT IN YEAR:		
		1979	1985	1990
Radio Direction Finder	10-25%	1,027-2,568	1,203-3,008	1,345-3,364
Fathometer	85-95%	8,730-9,757	10,226-11,428	11,436-12,781
Radar	40-60%	4,108-6,162	4,812-7,218	5,382-8,072
Omega[1]	1%	74	88	99
Satellite Navigation System[1]	1%	74	88	99
LORAN-A	20-30%	2,054-3,081	LORAN-A Off	LORAN-A Off
LORAN-C[3]	30-50%	3,081-5,135	6,015-8,421[2]	6,727-9,418

[1]Omega and Satellite Navigation System are used in San Diego and Puerto Rico by tuna boats.

[2]The percentage range for LORAN-C after 1980 is 50-70%.

[3]Assumes no added coverage of LORAN-C.

Table 3-12 presents a summary of the type of installed communication equipment carried by recreational vessels 40 feet or more in length. The information indicates that almost all recreational vessels over 40 feet are equipped with: a VHF-FM two-way radio, a single sideband radio, a commercial broadcast receiver, a weather monitor, and a scanner. Only a small percentage of recreational vessels are equipped with an emergency position indicating radio beacon (EPIRB) or an emergency locator transmitter.

The types and quantities of navigation equipment carried by recreational vessels, of the class 40 feet and greater, were derived from estimates of LORAN-C equipped vessels in the Puerto Rico and Virgin Island areas[14] and from interviews of recreational boat owners, marinas and navigation equipment manufacturers in the southeastern U.S. and Caribbean region. Table 3-13 presents a summary of the percentage of vessels carrying each type of navigational aid. These percentage figures were then applied to the population figures for 1979, 1985, and 1990 to determine the number of recreational vessels carrying each type of aid, which is also shown in Table 3-13.

The information contained in Table 3-13 indicates that the most common navigational aid for recreational vessels is a radio direction finder. More than one-third (38 percent) of the recreational vessels carry this aid. About 20 percent of the recreational vessels carry some form of LORAN-A (either automatic or manual) and 15 percent of the recreational vessels carry radar. LORAN-A systems will no longer be in operation after 31 December 1980. This fact is considered in the projections for equipment carried in 1985 and 1990.

3.5 ASSESSMENT OF VESSEL MASTERS'/OWNERS' PARTICIPATION IN A VESSEL MONITORING SYSTEM

A limited telephone survey of vessel masters/owners was performed to collect information used to estimate the number of vessels in each class that might be expected to participate cooperatively in a vessel monitoring and surveillance system. While this assessment stressed cooperative participation, it is recognized that there are certain competitive elements related to vessel movements, cargo content, and fishing ground locations which may preclude voluntary cooperation among some commercial vessels. Nine interviews were conducted with vessel masters/owners in each of the large commercial, small commercial, fishing, and recreational vessel groups. A limited survey of

TABLE 3-13. NAVIGATIONAL EQUIPMENT CARRIED BY RECREATIONAL VESSELS

TYPE OF EQUIPMENT	PERCENT VESSELS ≥ 40 FT CARRYING EQUIPMENT 1979	NO. OF VESSELS 1979[2]	NO. OF VESSELS 1985[b]	NO. OF VESSELS 1990[c]
Radio Direction Finder	80%	80,000	94,400	104,000
LORAN-A Automatic	7%	7,000	LORAN-A Off	LORAN-A Off
LORAN-A Manual	13%	13,000	LORAN-A Off	LORAN-A Off
LORAN-C	75%	75,000	88,500	97,500
Omega	2%	2,000	2,360	2,600
Radar	85%	85,000	100,300	110,500
Satellite	15%	15,000	17,700	19,500

[a] Assumes total vessel population of 100,000.

[b] Assumes total vessel population of 118,000.

[c] Assumes total vessel population of 130,000.

were 40 feet in length or greater and 33 percent were 100 feet in length or greater. Seventy-eight percent of the fishing vessels in the sample were 40 feet in length or greater and 18 percent were 100 feet in length or greater. The large majority of the recreational vessels in the sample were less than 40 feet in length. Only 12 percent of the recreational vessels were 40 feet in length or greater. There were no recreational vessels 100 feet or greater in the sample.

Masters/owners of the large commercial vessels who responded to the survey, included managers, assistant managers, and vice presidents of operations, and captains of large commercial vessels. The respondents represented a total of 220 large commercial vessels. Results of two of the surveys were not incorporated into this analysis because it was discovered that they did not represent large commercial vessels. Therefore, the survey results discussed in this section are based on only seven completed surveys. The seven surveys were distributed as follows: East Coast - 2, Gulf and Caribbean - 3, Pacific Coast - 1, Alaska - 1. However, many of the companies contacted have large commercial vessel operations in several regions of the country.

The majority of large commercial vessel masters/owners are willing to report their vessel identification, position, course, and speed to Coast Guard shore stations once per day, twice per day, and to aid in Search and Rescue operations. Eighty percent of the vessels included in the sample are willing to participate once or twice per day; 100 percent are willing to participate to aid in Search and Rescue operations. Only one of the seven respondents (representing 44 vessels) indicated unwillingness to participate in the system once or twice per day.

It was learned that large commercial vessels carry sophisticated navigation and communication equipment and, therefore, the vessel masters/owners surveyed indicated that they were not interested in purchasing any additional equipment.

Respondents to the survey of small commercial vessel masters/owners included owners and managers of tug and tow companies, and captains of small commercial vessels. The respondents represented a total of 88 vessels, of which 36 were between 4 feet and 99 feet in length, and 29 were 100 feet or feet in length or greater) could be expected to report to a Coast Guard shore station once per day, while 14 percent would be willing to report as often as twice per day. Most of the fishing vessel masters/owners (85 percent) are willing to provide information describing their position to the Coast Guard to aid in Search and Rescue operations. Finally, only seven percent of the fishing vessel masters/owners can be expected to purchase additional equipment which would allow information to be transmitted automatically to the Coast Guard.

The primary reason fishing vessel masters/owners are unwilling to participate in the vessel monitoring system is that they do not want to reveal the location of the fish. While an automatic radio device can transmit the information directly to the Coast Guard (without it being received by any other vessels), the fishing vessel masters/owners surveyed are opposed to purchasing any additional equipment. Typical comments from the survey respondents include:

- "If I need help, I will call in. I don't want to give away the location of the fish."
- "Too many regulations now. When there is an emergency, anyone near will help."
- "Too much work - too busy."

One class of fishing vessel masters/owners which can be expected to participate in a vessel monitoring system is tuna fishermen in the Pacific. Tuna boats are usually greater than 100 feet in length and operate in deep waters within the FCZ.

Additional information obtained from the survey indicates that fishing vessels operate about 20 days per month throughout the year. In Alaska, however, the fishing vessels do not operate in the winter months.

Respondents to the survey of recreational vessel masters/owners included commodores, managers, secretary/treasurers, and members of yacht clubs as well as owners of marinas. The yacht clubs and marinas contacted represented 3,120 vessels, of which 375 were 40 feet in length or greater. About 12 percent of the yacht clubs' and marinas' constituents own vessels 40 feet in length or greater. There were no recreational vessels 100 feet in length or

TABLE 3-14. SUMMARY OF SURVEY RESPONSES

Vessel Class	NO. OF VESSELS IN SAMPLE	Vessels $\geq$ 40' in Sample:		Percent of Vessels $\geq$ 40' Willing to Report to Coast Guard			Percent of Vessels $\geq$ 40' Willing to Purchase Additional Communications Equipment
		No.	Percent	1/day	2/day	Upon Request for SAR[1]	
Large Commercial	220	220	100%	80%	80%	100%	0%
Samll Commercial	88	65	74%	22%	20%	78%	0%
Fishing	218	169	78%	23%	14%	85%	7%
Recreational	3,120	375	12%	12.5%	10%	99%	2%

[1]Search and Rescue (SAR) Operations

TABLE 3-15. NUMBER OF VESSELS >40' LONG EXPECTED TO PARTICIPATE IN THE COAST GUARD MONITORING SYSTEM

Vessel Class	Population of Vessels ≥ 40'* 1979	Vessels ≥ 40' Willing to Report to Coast Guard:						Vessels ≥ 40' Willing to Purchase Additional Connumications Equipment	
		1/Day		2/Day		Upon Request for SAR			
		No.	Percent	No.	Percent	No.	Percent	No.	Percent
Large Commercial	NA	NA	80%	NA	80%	NA	100%	0	0%
Small Commercial	2,700	600	22%	540	20%	2,100	78%	0	0%
Fishing (Domestic Only)	10,300	2,370	23%	1,440	14%	8,750	85%	720	7%
Recreation	100,000	12,500	12.5%	10,000	10%	99,000	99%	2,000	2%

*Offshore Vessel Population Profile, Project Memorandum prepared by IOCS, Inc. for TSC March 1980.

6. Panshin, D.A., R.S. Roberts, and R.C. Vars, Termination of LORAN-A: An Evaluation of Alternative Policies, ORESU-T-77-008, Oregon State University, School of Oceanography, Carvallis OR, October 1977.

7. Boating Statistics-1979. COMDTINST M16754.1, U.S. Department of Transportation, U.S. Coast Guard, Office of Boating Safety, Washington DC, 1 May 1980.

8. Rohrs, R.D., Documented Fishing Vessels, 40 Plus Feet-By Port. U.S. Department of Transportation, U.S. Coast Guard, Office of Merchant Marine Safety, Washington DC, 6 February 1980.

9. Merchant Fleet Forecast of Vessels in U.S.-Foreign Trade, 1980-2000. U.S. Department of Commerce, Maritime Administration, Washington DC, May 1978.

10. Vessel Sighting Data, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries Management Division, Permit and Data Analysis Branch, Gloucester MA, May 1980.

11. CFR Title 33, Part 26 - Vessel Bridge-to-Bridge Radiotelephone Regulations, Section 26.03.

12. Vessel Bridge-to-Bridge Radiotelephone Act (P.L. 92-63), 4 August 1971.

13. Eastern Caribbean LORAN-C User Definition, Project Memorandum, Input Output Computer Services, Waltham MA, 13 December 1979.

14. Benefits and Costs of LORAN-C Expansion into the Eastern Caribbean. (Final Report in preparation), U.S. Department of Transportation, Office of Research and Special Programs, Transportation Systems Center, Cambridge MA, July 1980.

15. Edelstein, P. and G. Hopper, Offshore Vessel Analytical Support: Vessel Masters/Owners Survey, Projected Memorandum, Input Output Computer Services, Waltham MA, July 1980.

4. DEFINITION OF VESSEL MONITORING SYSTEM CONCEPT

4.1 INTRODUCTION

In developing a conceptual design for a Vessel Monitoring System (VMS) the major considerations were:

1. Requirements of the Port and Tanker Safety Act
2. Requirements of the U.S. Coast Guard programs and missions
3. Benefits to marine users.

The following key words and phrases from the Act emphasize the system requirements:

1. "Study the desirability and feasibility of possible shore-station systems for monitoring vessels, including fishing vessels within the FCZ."
2. "Each system examined shall be capable of reporting vessel position, identification, course, and speed."

The wording of the Act which denotes the vessels to be monitored ("monitoring vessels including fishing vessels") is assumed to include all sea-going vessels. The Act calls for the system to be comprehensive. Therefore, the system concept development in this section and the technical alternatives evaluation in Section 5 were based on a requirement to monitor all sea-going vessels in the FCZ. The analysis of vessel sizes in Section 2 resulted in establishing 40-foot length as the lowest size vessel that the system would monitor. In addition, the assessment of Coast Guard need for a shore-station vessel monitoring system covering the FCZ (hereafter called an "offshore VMS") indicated clearly that, to be cost-effective, it must be designed for multimission service. Since we have assumed that the Act included all vessels offshore and a multimission system is the cost-effective approach for the Coast Guard, the system concept development was based on a multimission VMS.

The requirement for the VMS to provide vessel identification is very demanding and can only be met by vessel reporting or close surveillance involving low-flying aircraft or surface craft. The latter technique is currently used by the Coast Guard and is very expensive with regard to the area from 80 percent of the large commercial vessels, 22 percent of the small commercial and domestic fishing vessels, and 12 percent of the recreational vessels combined, this indicates that 17 percent of the total vessel population would be willing to report to a shore station at least once daily. A small part of the remaining vessels could possibly be required by regulation to report cooperatively, e.g., tankers and hazardous material carriers. All others would have to be tracked by remote sensing; therefore, it appears that a hybrid system consisting of both cooperative reporting and remote sensing elements is required.

The requirements analysis presented in Section 2 indicated that the primary functions of the VMS to the Coast Guard would be assembling, analyzing, and exchanging information among the several groups that have vessel movement information and those that need information. On the other hand, the major benefit of a VMS to the mariner would be the availability of vessel location and port condition information to the vessel, the harbormaster, and the Coast Guard; this capability is expected to provide some savings of operating cost and improvement of emergency rescue operations effectiveness. Therefore, it was decided that the vessel monitoring system for the FCZ should be called the Offshore Traffic Information System (OTIS).

The major functions of OTIS, in order of occurrence, are information acquisition, correlation and processing (including intelligence analysis) for the required information, and dissemination of the desired information to the government and to marine users. Information is acquired from the following sources:

1. Periodic (daily) reports from cooperative vessels;
2. Remote sensor data on noncooperative vessels (coincidentally includes information on cooperative vessels);
3. Other agencies (e.g., the U.S. Navy, DEA, U.S. Customs, the Treasury, and the Bureau of Alcohol, Tobacco and Firearms);
4. Captain of the Port (COTP) and marine safety offices, stations, and groups (Data are acquired during the normal course of performing specific missions.);
5. Marine vessel data bases (e.g., Marine Safety Information System [MSIS] and the CG Operational Computer Center [OCC]).

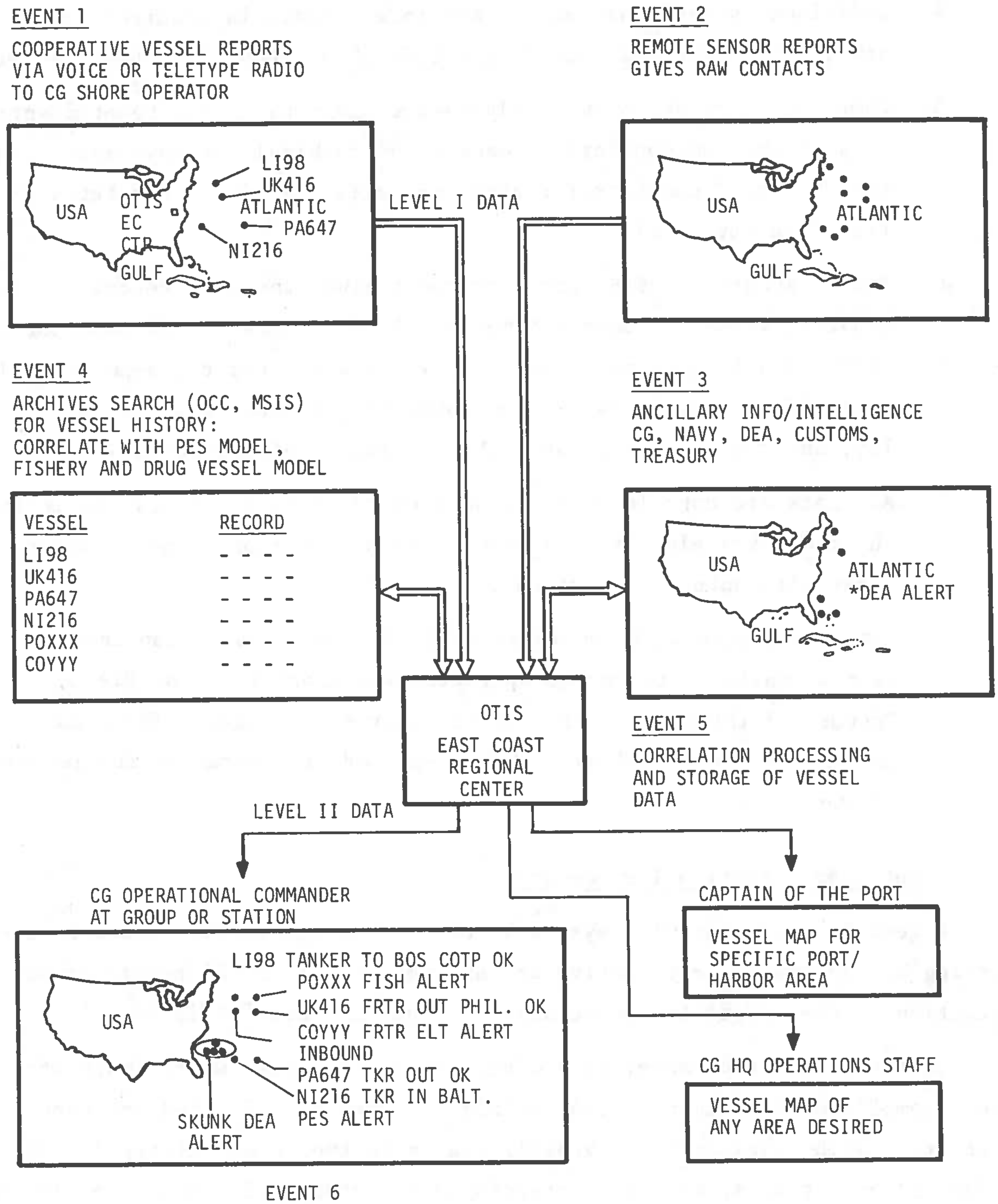

FIGURE 4-1. OVERVIEW OF OTIS INFORMATION FLOW (U.S. EAST COAST)

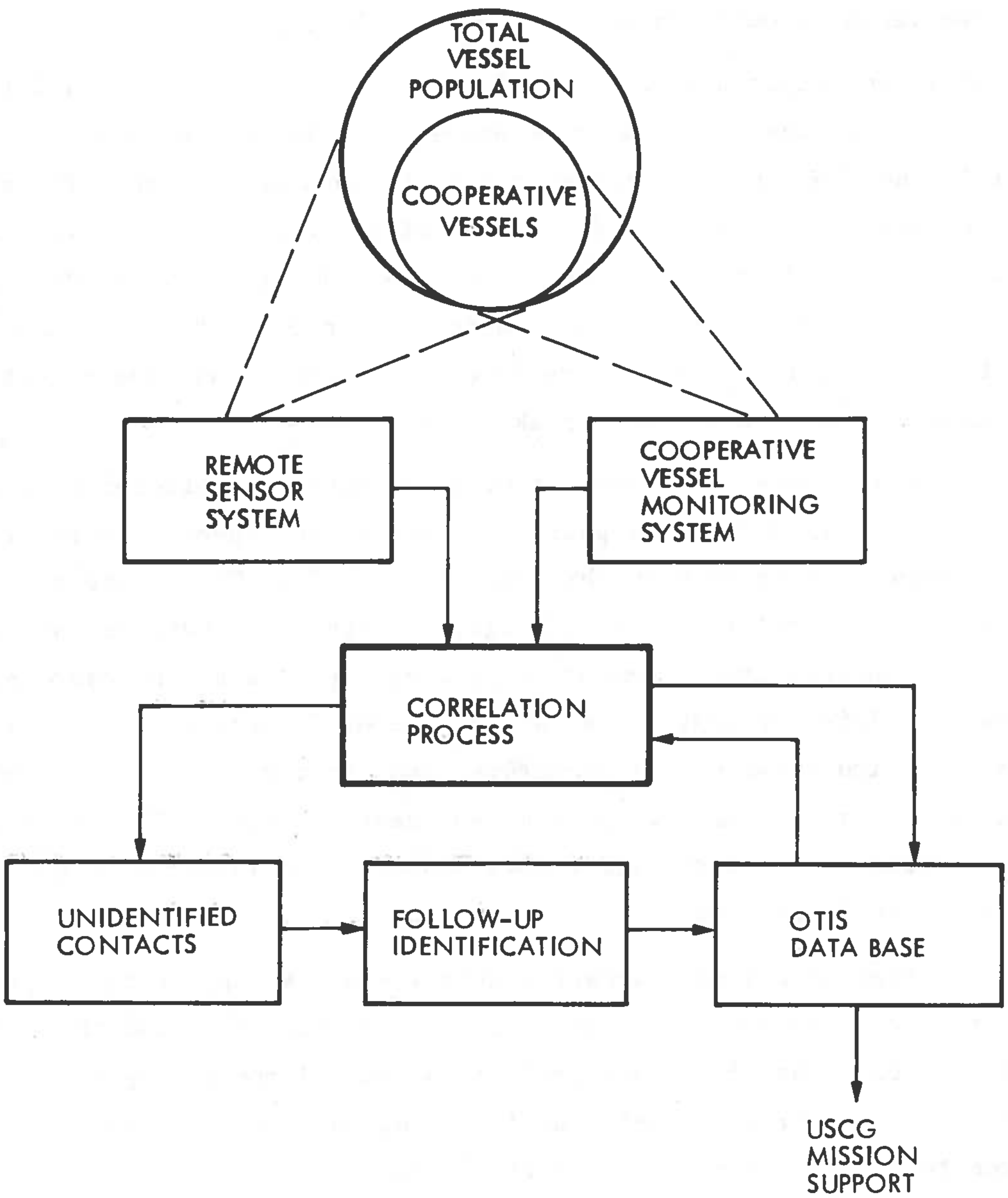

FIGURE 4-2. OTIS OPERATIONAL CONCEPT

4.2.3 OTIS Configuration and Information Flow

An assessment of the advantages and disadvantages of both a centralized and a distributed OTIS configuration indicated that the distributed, or regional, concept would be advantageous. Each region would require only a large mini computer, lessening the number of long-distance communications circuits. In addition, the regional system hardware, software and operating procedures could be tailored to the unique needs of the region served, although this may cause some redundant development work. The distributed, regional configuration chosen is shown in Figure 4-3: Region 1 covers the East Coast of the continental U.S.; Region 2 includes the Gulf Coast and the Caribbean (U.S. Virgin Islands and Puerto Rico); Region 3 includes the Pacific Coast of the contiguous states plus the Hawaiian Islands; and Region 4 covers the Alaskan coast and the Aleutian Islands.

Each region would have an OTIS center, which would handle all requests for OTIS information in that region, perform information correlation and processing, and interface with other agencies, other regions, and Coast Guard Headquarters. A national OTIS center located near CG Headquarters has been included as a valuable optional feature to assist the CG operations group in planning, analysis, and coordination of missions of major size and national importance. Figure 4-4 shows one possible approach for integrating the OTIS centers into the CG organization. Figure 4-5 shows the flow of OTIS information within the Coast Guard. The information from the outside agencies (e.g., Navy) and the archives (e.g., MSIS, OCC) will flow to the regional centers via the OTIS national center, which will act as a communications switching center and as a second drop for the data. This data would be used by CG headquarters for maintaining cognizance of the overall monitoring efforts and to perform analysis of mission requirements and effectiveness for anticipatory planning of resource requirements and operational procedures/techniques. In addition, this communications configuration permits the top-level CG management to be involved in direct monitoring of internationally sensitive data flow.

The underlying philosophy of the OTIS is that providing complete and current information in a timely manner to both the operational commander (OC) in the field who is directing a task or mission and to higher-level commands (including headquarters staff) is the one key to successful accomplishment of

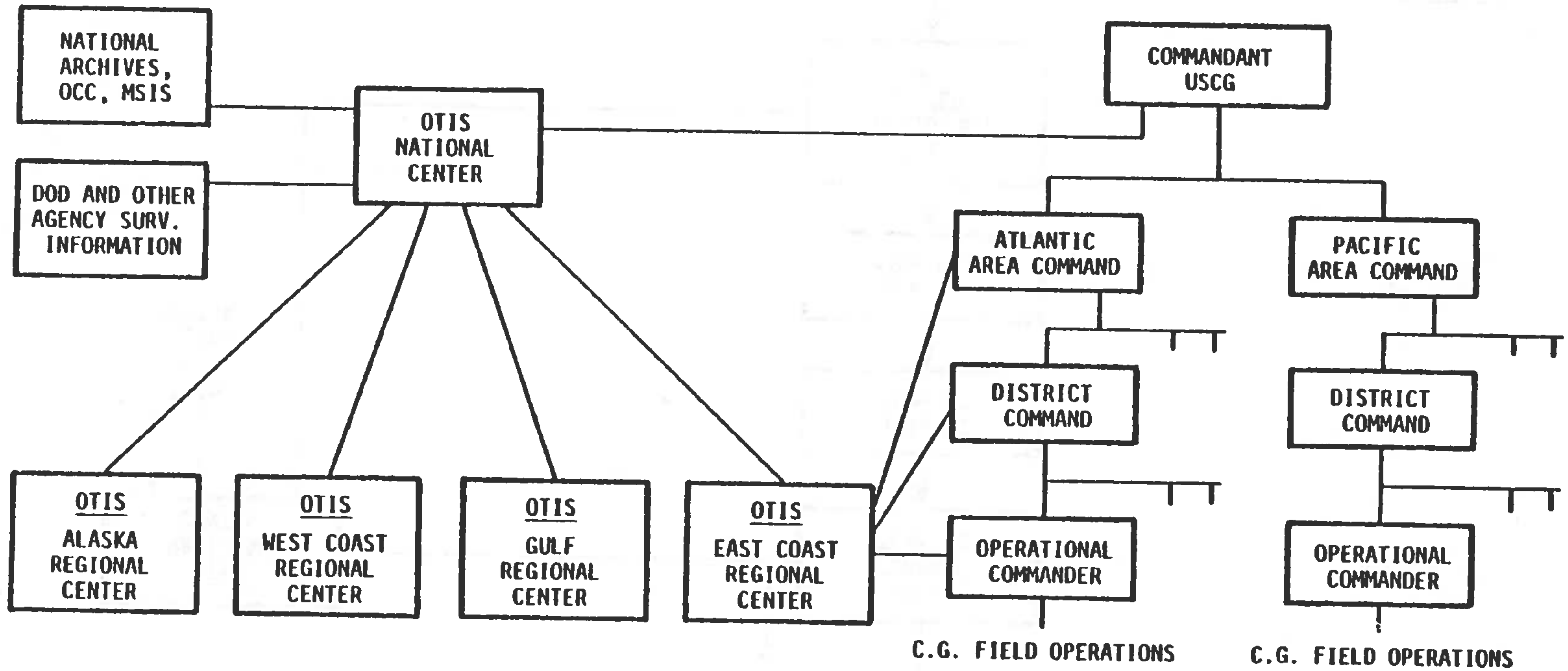

FIGURE 4-4. OTIS ORGANIZATION DIAGRAM

the job. As shown in Figure 4-5, the OTIS regional center assimilates vessel information from the various sources and presents to the operational commander, in facsimile or video display, a comprehensive picture of vessel position, movement, and identity, in the local area of the FCZ for which the OC is responsible. This procedure simultaneously provides vessel information to the local decision-maker and to higher-level management. The OTIS concept makes maximum use of any and all vessel information available from other government agencies and sources as a cost-effective means of accomplishing the large-area monitoring task defined in the Act. This approach is based on the premise that:

a. There is vessel information available (without compromising national security) that is useful for this purpose but that is currently untapped.

b. It is more cost-effective to use computers, communications, and analysis to develop offshore vessel maps than to use Coast Guard-operated, highly complex sensors for the same purpose. Hence, the OTIS operational concept includes the establishment or increase of data transfer from outside agencies to the Coast Guard.

Government agencies presently exchange offshore vessel information. At the El Paso Intelligence Center (EPIC), all raw information received on vessels is available to the Coast Guard on-site personnel as well as to DEA, U.S. Customs, INS, and the Treasury.

A limited flow of vessel information presently occurs between the U.S. Navy and the Coast Guard at the Naval Ocean Surveillance Information Center (NOSIC), which is the hub of the Navy's Ocean Surveillance Information System (OSIS). OSIS is a world-wide, all-source, automated system designed to receive, process, correlate, and disseminate evaluated intelligence on all objects on, under, and over the oceans. There are six OSIS sites: NOSIC, Suitland, Maryland; three Fleet Ocean Surveillance Information Centers (FOSIC's), supporting the Fleet Commanders in Chief at the Fleet Command Centers (FCC's) at Pearl Harbor, Hawaii; Norfolk, Virginia; and London, England; and two Fleet Ocean Surveillance Information Facilities (FOSIF's) located at Kamiseya, Japan, and Rota, Spain which provide local support for the Seventh and Sixth Fleets, respectively.

o Free World	27,847
Fishing Ships	5,116
o USSR	3,824
o Soviet Bloc	1,292

For entry into SEAWATCH,

a. Soviet Bloc-flag vessels and all-flag research ships (including offshore drill rigs) must be in excess of 100 GT or be 100 ft long.

b. Free World-flag vessels must be in excess of 100 GT or be 250 ft long. (In order to satisfy fleet command requirements, there are plans to include all-flag merchant and fishing ships to 100 GT or greater.)

Because of its current and historical all-source data base, it appears that NOSIC could be used as a major contributor to the Coast Guard's national Offshore Traffic Information System. However, definitive USCG information requirements would have to be analyzed and compared with NOSIC capabilities prior to making any final decisions. Other DOD agencies, such as the U.S. Air Force, may also be able to provide ocean surveillance information. Investigation of this source is being pursued.

In addition, the Maritime Administration (DOC-MARAD) has under development the Vessel In-Port Location System (VIPLOC). VIPLOC is being developed to provide accurate and timely information on the in-port location and the interport/intraport movement of vessels operating in domestic and international commerce. As currently conceived, the VIPLOC system will require access to the comprehensive international vessel movement information which is currently resident within OSIS. In this respect, both VIPLOC and OTIS are similar.

It would, however, be unrealistic to expect that all information needed to perform the offshore vessel monitoring function can be obtained from other agencies since they have different data requirements and mission objectives. Information from outside agencies would be supplemented by the cooperative vessel reports and remote sensor data, resulting in reductions in operating costs and response time.

that does not add a significant workload to the crew; this is possible with an unattended terminal that automatically reports or responds to a call. (This will be discussed as a technical alternative in Section 5.)

OTIS operations are greatly facilitated by cooperative vessels because of the ready availability of information on their identification, location, course, and speed, and their identity reduces the computer workload to one of bookkeeping. Establishing and maintaining discrete tracks is much more difficult with noncooperative vessels. If vessels are continuously tracked, at a rate of one observation sample every 15 minutes, the system is able to maintain the positions of all noncooperative vessels until two noncooperatives occupy the same sensor resolution cell at the same time. Then separation of vessel tracks is lost and some other technique or information is required. For an update interval of 4 hours, the percentage of noncooperative vessels tracked drops to 60 percent; and only 25 percent of this population can be tracked when the update interval is 6 hours.

For a population of all cooperative vessels, more than 80 percent of the vessels can be positively tracked with update intervals of only 6 hours (see Appendix I). However, information about course, speed, and vessel identification facilitates the computer's maintaining course tracking of cooperative vessels even with limited positional inputs. In addition, the cooperative system has a built-in failure-saving feature with shore-to-ship communications link because vessel identity is known and radio contact can be used to re-establish position location of a vessel, if necessary for any reason, prior to the next designated reporting time.

A mixture of cooperative and noncooperative vessels which does not exceed a 2 to 1 ratio, of the respective vessels, in an area 3.3 miles square will not diminish the OTIS computer's capability to maintain the track of each vessel. However, if the number of cooperative to noncooperative vessels becomes one out of three (ratio 1:3) then track will be lost if the paths of any two of the three vessels cross. Track will also be lost if the positions from two successive samplings by the remote sensor are such that the OTIS developed track for two vessels occupies the same sensor resolution cell at the same time. (For those vessels that are cooperative, track can quickly be reestablished by the OTIS facility contacting the cooperative vessel for a position update.) There are two methods for reducing the number

5. TECHNICAL EVALUATIONS OF ALTERNATIVE SUBSYSTEMS FOR THE IMPLEMENTATION OF OTIS

5.1 INTRODUCTION

Alternative subsystems and techniques for performing OTIS functions are evaluated in terms of performance, availability, and cost. This technical evaluation addresses cooperative systems, noncooperative systems, platforms for sensors, combinations of systems, correlation processing, and recommended systems.

5.2 COOPERATIVE SYSTEMS

Cooperative systems include both voice and digital radio communications links from ship to shore. Conventional terrestrial communications circuits are used to carry the communications between the shore radio facility and the OTIS regional center. Reliable and readily accessible two-way communications is an essential part of this system. Accurate vessel navigation data are also an important part of the system because this data improves the shore station's ability to track vessels.

Cooperative monitoring systems can be vessel-initiated or shore-initiated. These systems may use verbal or digital communications. The communications timing may be random from the vessel to the shore, or time-ordered (roll-call) by control of the shore station. Not all combinations of these possible communications techniques are attractive for OTIS use because of radio channel availability, efficiency, and reliability of communicating.

The commonly used marine radio communications techniques have been voice, teletype, and telegraphy via high frequency (HF) or medium frequency (MF) channels. These types of channels are also used for low baud rate (100 bauds per second) digital data communications. In the past two decades very high frequency (VHF) channels have become commonly used for communicating over distances up to 20 or 30 miles by either voice, teletype, or digital data of 1200 bauds per second. More recently, in the past five years, large ships have begun using L-band channels via satellite from ship-to-shore for long-distance, high-quality, and high-reliability communications by voice, teletype, or digital data of either 2400 or 4800 bauds per second. The percentage of vessels carrying these different types of communications varies over adjusted to account for variations in traffic density. Centralized timing control by the shore stations connected to OTIS centers and a master clock ensures that all elements are synchronized. This increases system capacity and provides flexibility for handling emergencies involving communications.

b. The system saturates in a "soft" manner. As the number of vessels begins to exceed a threshold value, the update rate can be reduced by a small amount to accommodate the new vessels.

c. The system does not rely on the initiative of the individual vessel watchstanders (VWS) to report positions which could include uncertainties in reliability and timing of reports.

On the other hand, roll-call systems have the following disadvantages:

a. Special methods have to be employed to enter a new vessel into the system: a voluntary call-in or an all-call message from shore asking for new vessels to respond.

b. Valuable shore watchstander (SWS) time is spend establishing contact with each vessel, especially with time consuming HF voice communications which requires the ship's radio officer to be on duty for completion of contact.

Ship-initiated transmission systems have their own peculiar advantages:

a. Vessel watchstanders can integrate the transmission into their work schedules with more ease, rather than drop their immediate task to reply to the shore station call.

b. The transmissions are geared more to significant events: waypoints reached, course changes, etc.

c. Entry into the system is performed in much the same way as updating course data.

Similarly, there are disadvantages as well to ship-initiated systems:

a. If two ship transmissions overlap, the shore will get, at most, one ship's data--thus this type system is more likely to experience interference.

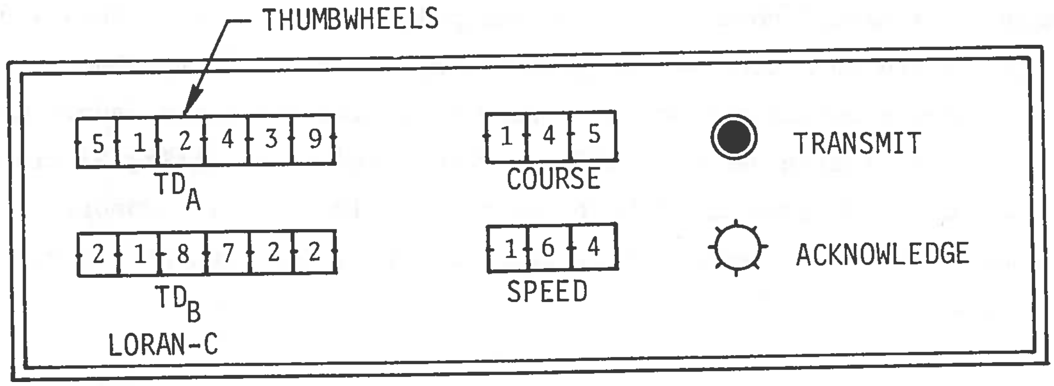

FIGURE 5-1. DATA TRANSMISSION ENCODER MODULE - MANUAL

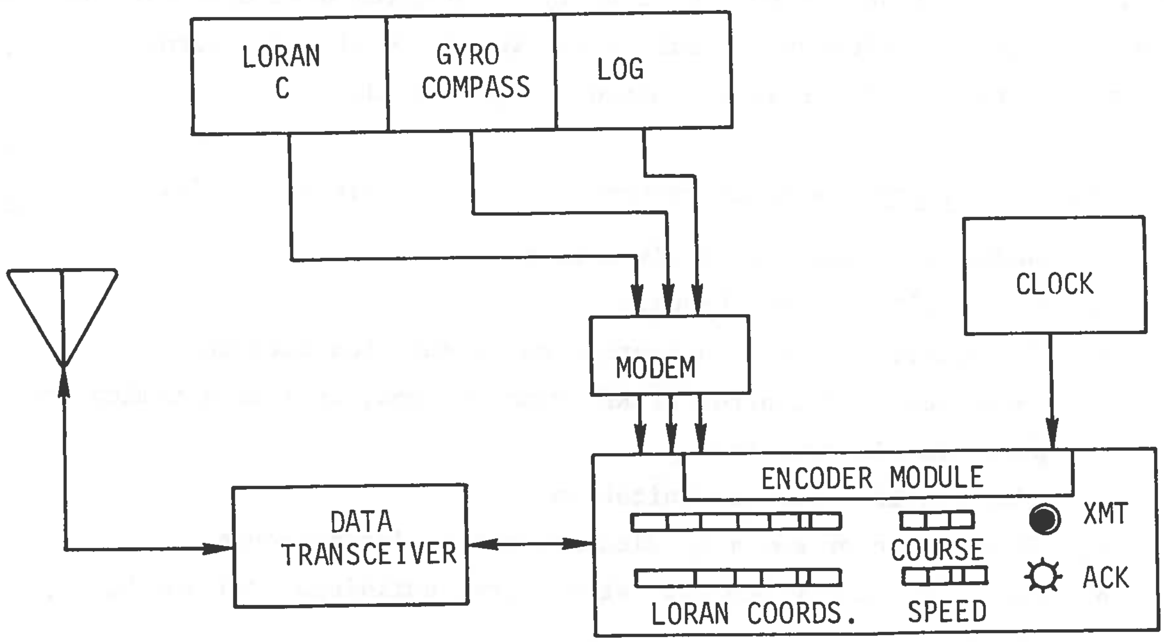

FIGURE 5-2. DATA TRANSMISSION ENCODER MODULE - AUTOMATIC

5.3 ALTERNATIVE SUBSYSTEMS FOR COOPERATIVE SYSTEMS

This section describes and evaluates three cooperative subsystems capable of performing OTIS functions: the Vessel Passport System, an automatic monitoring system, and surveillance systems.

5.3.1 Vessel Passport System

A vessel passport system is the simplest form of an active system; i.e., one involving shorebased personnel. This system is highly oriented toward reducing accidents caused by vessels with substandard equipment, intercepting problems or lack of knowledge about traffic and navigation hazards by restricting the movements of substandard vessels, and providing advisory information. Vessels which are known to have unacceptable histories are treated with caution when they are bound for or departing from U.S. ports.

The operation of the system is centered around two checkpoints (Figure 5-3): Vessels bound for U.S. ports are required to check into the system at about 24 hours or 200 nm prior to entrance into internal waters and again at another point approximately 1 hour or 12 nm prior to entry. At the first checkpoint, permission to enter port is granted or denied, and any special conditions are placed on entry at that time. At the second checkpoint, special bulletins concerning weather, buoy outages, and other vessel traffic are issued; the vessel master is provided a benchmark to calibrate his navigation gear; and any necessary pilot coordination is set up.

In the case of a vessel that departs from and returns to a U.S. port without crossing the 200-nm FCZ boundary, a report is required every 24 hours, as a minimum, and again one hour prior to entering (or departing) internal waters. All other operations are the same as described above.

5.3.1.1 Advantages of the Vessel Passport System - The hardware necessary to implement the Vessel Passport System for large commercial vessels is largely in existence today. Communications at the 24-hour checkpoint is accomplished by present long-distance communications gear, while a designated VHF radiotelephone channel is used at the one-hour checkpoint. No other onboard equipment is required. However, to handle all vessels over 40 feet, the system will likely require additional equipment for both the government and the user, and additional personnel for the Coast Guard.

Access by the U.S. Coast Guard to a data base with information on tankers, tank-barges, and hazardous-cargo vessels operating in U.S. waters is required. This exists for tankers in the U.S. CG Marine Safety Information System (MSIS), which is presently implemented.

The chief advantage of the vessel passport system is that it provides the U.S. Coast Guard with the means to make a judgment, in a timely manner, on the danger that a vessel presents to the U.S. coast and surrounding vessels. Secondly, the system can be implemented immediately for evaluation and development.

Some collision avoidance service can be provided by the vessel passport system's transmitting of advisories (on a broadcast channel) regarding tanker and hazardous-cargo vessel traffic to all vessels in the area.

The Coast Guard is currently taking action to improve the safety of vessels and the environment by: 1) requiring that all inbound vessels carrying hazardous cargo report to the Coast Guard 24 hours prior to arrival; and 2) developing the Operational Computer Center (OCC), which correlates the data bases of the MSIS, Search and Rescue, Fishery Enforcement, and AMVER for ready-access and checking of data on vessels of interest. (Access to the AMVER data base is limited to safety missions.)

5.3.1.2 Disadvantages of the Vessel Passport System - The chief problem in the operation of the Vessel Passport System is the possibility of linguistic communication difficulties at the second checkpoint. The communication requirement at the first checkpoint circumvents this difficulty by allowing teletyped or telegraphed data for a large commercial vessels that almost always carry this type of equipment. As the system is enlarged to include small commercial, fishing and recreational vessels, the system demands will most likely require digital data type communications which will solve the language problem.

5.3.1.3 Cost of Vessel Passport System - The Vessel Passport System implementation in this study includes only communications functions; aids to navigation, added such as RACONS or buoys, are excluded. The costing presented here is based on these assumptions:

a. All vessels over 40 feet in length are cooperative and participate in the system.

b. Vessels use existing communications (HF and satellite as currently equipped, and VHF for close to shore).

c. Vessels use navigation equipment.

The only additional equipment will be a coded modem for the fishing vessels which codes the vessel position information that is transmitted in order to protect proprietary fish location data. This unit is estimated to cost approximately $2,000 per vessel. The estimated total U.S. domestic fishing and sport fishing population in 1979 was 12,886 vessels. If 23 percent are equipped with the coded modem, this would represent a total capital investment of $5.93 million; however, if the percentage increases to 25 percent above the 23 percent (total of 48 percent), indicating willingness to participate, then the user's investment is $12.37 million.

The estimated cost to the government of the Vessel Passport System for coverage of all the U.S. FCZ will be $10.69 million, for initial cost, and $6.05 million for annual operating costs. This includes $8.975 million in initial costs for shore radio stations, plus $1.717 million for four regional monitoring centers. Operations and maintenance costs are $2.4 million and $3.6 million, respectively.

It should be noted that this is based on 1979 vessel population estimates and vessel equipment estimates. However, the satellite-equipped world fleet is growing quite rapidly from less than 50 in early 1978 to 265 in early 1980. As this fleet increases, the shore operations cost will decrease from the increased automation of message handling.

time on conflict analysis or on manual (voice, teletype, or telegraph) communications with unequipped vessels.

e. The mariner receives the benefits of being advised of traffic or weather problems, outages of navigation aids, the presence of hazardous-cargo vessels, and, in the case of an emergency, being advised of best action to take and of the estimated arrival of assistance.

f. The capacity of this system is limited primarily by the time spent in communicating with unequipped vessels and with logging new entries into the system.

5.3.2.2 Disadvantages of the Automatic Monitoring System - The disadvantages of an automatic monitoring system are:

a. The shipboard complement of equipment required is considerably more than is usually carried on small commercial, fishing, and recreational vessels; therefore, the user investment may be too great for these groups to afford. The ship must have navigation gear (LORAN-C equivalent), interface equipment, an encoder module, and a data transmitter and receiver (if separate voice and data channels are required). This equipment is also more sophisticated than that which is currently carried, except for the large commercial and tuna fishing vessels.

b. This system depends on the functioning and accuracy of shipboard navigation equipment. However, a back-up feature which can detect some errors through consistency checks of vessel reports is inherent in the computer tracking and prediction capabilities.

c. The OTIS regional computer correlation facility will require more processing and storage capability for assembling, sorting, and processing vessel data in a shorter time than the Vessel Passport System. Also, storage of both automated and manual reports, and data for shore operator trial manuever and conflict assessment service will likely be larger because of the additional capability afforded by more frequent vessel updates. Additionally, more frequent calls will be placed on the MSIS, SAR, and EMIS data files in the OCC; this will place a greater burden on the OCC.

b. Government Costs[1]:

Vessel Passport System		$10.69M
HF Stations - 15 ea @ $700,000		10.5M
Station Computer, Terminals, Displays - 15 @ $500,000		7.5M
Data Interfaces - 15 @ $50,000		.75M
Development Costs (see Item C below)		3.0M
	Subtotal	$32.44M
Annual O&M: Maintenance		1.875M/yr
Staffing		3.03 M/yr
Passport System Operating Costs		6.05 M/yr
	Subtotal	10.955M/yr

c. Government Action Required:

1. Develop an HF data/voice communications system consisting of three voice channels and one data channel, preferably using present LORAN-A towers.
2. Generate minimum equipment specifications for shipboard HF communications sets, and navigation systems.
3. Conduct a system design, specifying requirements and developing modular computer architecture and software to accommodate the variation of traffic at the various local stations.
4. Establish a timetable for implementing the automatic monitoring system.

The L-band satellite* implementation of an automatic monitoring system is presented below. The satellite discussed here serves only communications functions. The satellite system currently available for civil marine use is the MARISAT system managed by the Comsat General Corporation and owned by the MARISAT Joint Venture. There are three satellites covering the world's major

*The marine satellite communications channels currently assigned are in the L-band spectrum, 1535-1645 MHz, for the ship-to-satellite link. INMARSAT is the approved and operating program.

The current cost of MARISAT and HF-SITOR/ARD[2] communications service charge to the user is (current charges for comparison, but may change):

a. The current rate of $3 per minute with a 3-minute minimum is charged by the RCA station WCC in Chatham MA.

b. The current rate charged by RCA Global Communications for MARISAT use if $4 per minute with a 1-minute minimum, within the continental United States.

A major difference in these two communications systems is the throughput rate. MARISAT messages are delivered in a few minutes; whereas, HF SITOR/ARD messages average 2 to 4 hours for delivery, depending on HF atmospheric disturbances[3].

Estimated costs for the L-band satellite communications system are:

a. Vessel Owner Cost:

Complete Ship Terminal		$79,000
Installation (average)		8,000
	Total	$87,000

Total User Investment (for vessels > 100 ft long) = 7573 vessels x $87,000 = $658,851,000 or for only commercial = 730 x $87,000 = $63,510,000

It is assumed that no vessel less than 500 GT will carry a terminal of this cost.

b. Government Cost:

1. Satellite Lease Costs:

Assuming all vessels over 100 ft in length and more than 3 nm from shore, participate in the satellite system, the total number of vessels serviced on a peak traffic day in the U.S. FCZ is based on 1883 vessels (based on Table 3-2 and Section 3.5.1). Of these 1883 vessels, 1150 vessels communicate in experiment described in reference 4, the test vessel was interrogated at 5-minute intervals by a signal sent via the NASA ATS-3 geostationary satellite operating in the VHF frequency band. Data were transmitted at a 100-baud rate and displayed on a screen for the observation of the shore operator. Instructions and requests were communicated on the vessel by the teletype unit. The significance of this experimental system was the feasibility demonstration of a vessel monitoring system using low-cost components both at the shore station, the control center, and the vessel. The major low-cost elements on the vessel were an unstabilized, manually steerable antenna, and a standard VHF (135-149 MHz) transceiver and power amplifier. The estimate for vessel equipment consisting of the VHF transceiver, power amplifier, preamplifier, modem, antenna, and antenna rotor cost is approximately $2000, off-the-shelf[4]. This does not include the LORAN-C receiver or the teletype unit. Installation was simple because of working at low frequencies relative to L-band, i.e., the frequency band of MARISAT and INMARSAT marine satellite systems.

If a simple transponder package in the VHF or UHF band could be "piggy-backed" on another satellite, such as the NOAA meteorological SEASAT or a similar satellite, it would make it possible to provide the wide-area, high-reliability communications afforded by a satellite platform and be within the realm of economic possibility for many mariners who cannot afford $80,000 for an L-band ship terminal

At the 1979 World Radio Conference (WARC-79) the 216-220 MHz frequency band was assigned for maritime mobile use and the 220-225 MHz band for mobile use, which could include marine. No higher frequency bands were considered for marine use although the 900-MHz band has been proposed. It would seem prudent to give serious study and planning attention to the possible use of these lower frequency bands and to place a marine transponder on a planned satellite, if the goal is to provide a high-performance, wide-coverage, low-cost monitoring and communications system that is affordable and attractive to a large portion of the small commercial, fishing, and large recreational vessels.

It is estimated that a simple frequency conversion transponder attached to planned geostationary satellite would cost about $2 million to develop and launch and $200,000 in annual operating costs.

user to operate in the system with only a low-speed (300 or 1200 baud) data terminal; allowance for low-speed data terminal operation would reduce the users' costs for operation and vessel terminal equipment. It is reported by COMSAT engineers that efforts are underway by the INMARSAT design group to change the system protocol to provide a lower-cost service for the smaller vessel. There is no estimate of when this service would be available, but this would offer an excellent alternative for the long-distance communications needed by OTIS.

5.3.3 Surveillance Systems

"Surveillance" has been defined in this study as the remote (shore station, aircraft, etc.) determination of a vessel's location as opposed to "monitoring" which means that the vessel determines her own position and reports this data to a shore station periodically. In this section discussion of surveillance is limited to cooperative vessel detection; noncooperative surveillance systems will be addressed later in this section. In the discussion that follows, the surveillance position measurement is primary, and the ship's reported position is used only for verification by the shore, if at all.

Surveillance systems can use radar, range/range, or multilateration techniques to establish the ship's position. To be useful, the surveillance system range must be matched by communication range. Thus, if a satellite system enabled the shore to know ship position accurately anywhere on the globe, this would be of limited usefulness if immediate radio contact were limited to VHF. Therefore, a satellite surveillance system must have the capability of rapid selective calling via voice circuits to be effective.

The three systems discussed below could offer some real benefits.

5.3.3.1 Direction-Finding (DF) Surveillance System - This system is not a stand-alone system for the whole FCZ, but a component which can be added to the Vessel Passport System or other long-range monitoring systems. It is inexpensive and can be utilized by making minor modifications to existing equipment. It provides a means whereby shore stations can establish the position of a vessel operating within 20 miles of the port entrance. It is expected to be used mainly as a backup for vessel-derived position reports

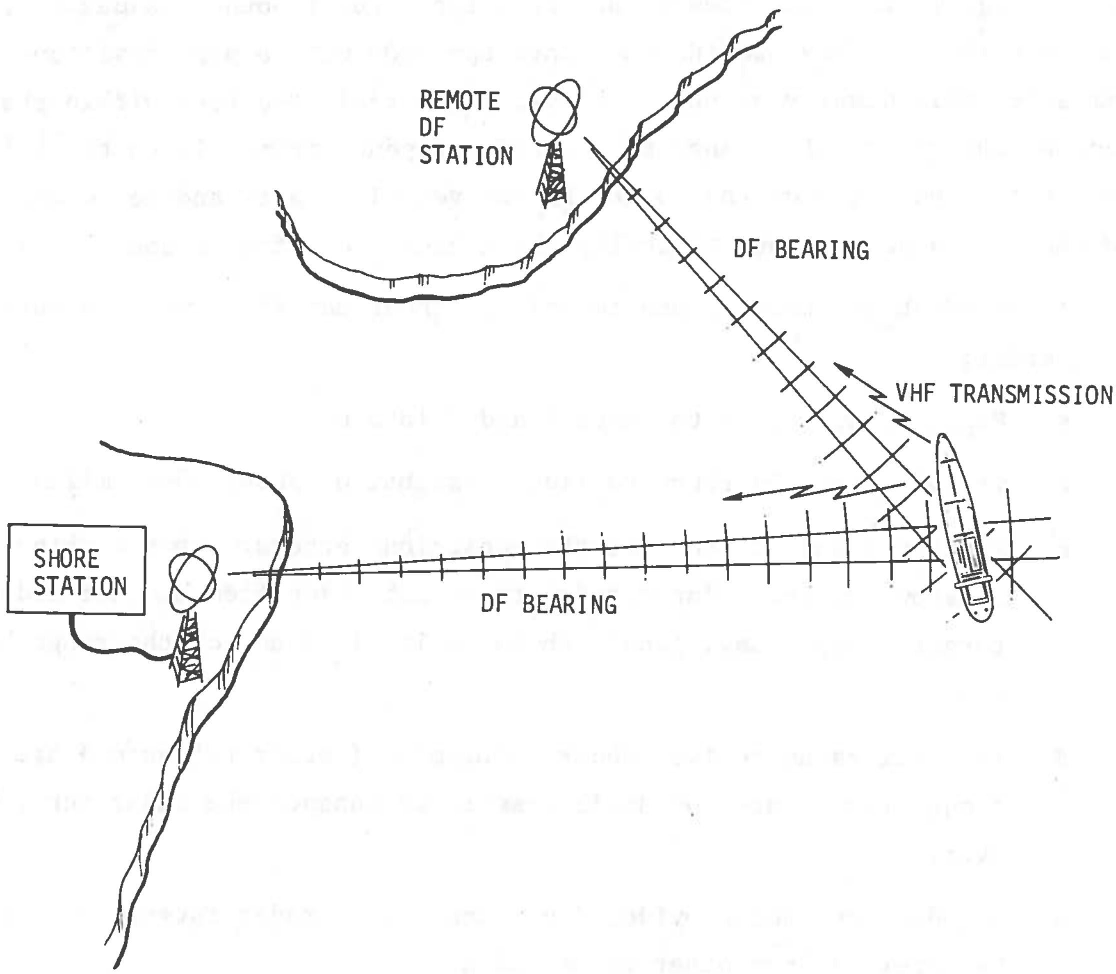

FIGURE 5-4. DF SURVEILLANCE SYSTEM

age. However, it can be used as an excellent addition or backup to a Vessel Passport System near ports with special needs that justify them. Shore operators would have tasks identical to those of radar-equipped VTS's. Target identification is always a difficult problem, more so in this system, because points of reference are obscure in open waters, compared to confined waters. Equipment is available, but not as a shelf item. Every new radar requires some modification of existing designs, especially in the areas of processing and display.

Estimate of Cost

Vessel Owner - none.

Government - Based on VTS experience, each new radar installation costs about $1.3 million including installation. Maintenance is estimated at $100,000 per year. Staffing would require one watch position to staff the display, at an estimated $100,000 per year. These would be over and above the Vessel Passport System costs.

5.3.3.3 Satellite Surveillance System - Satellite systems appear to offer a distinct advantage over other systems, since they provide almost global coverage and high accuracy.

A satellite system designed specifically for this application could be configured in several ways, but a typical one is shown in Figure 5-5. With this configuration a shore station sends an interrogation signal with a selective address code and a time identifier to a master satellite at about 6 GHz, which repeats the interrogation at about 1.5 GHz. All ships in the satellite coverage area receive this signal, but only the vessel with the correct address code acquires and decodes the signal. The selected vessel then adds the ship's identification, ship's time, and other data, as required to the received signal, and transmits this composite signal back to the shore station through two satellites, the master and a secondary satellite. The shore station receives the same signal from the ship by two paths that differ in time of reception which corresponds to the length of the two signal paths.

The shore station computer then uses the measurements of time differences in the transmitted and received signals together with the satellite position location data to accurately derive the ship's position. Thus the shore station can keep an accurate track of all equipped vessels. Just as for the automatic monitoring system, the interrogation rate for each ship can be controlled from shore. Moreover, there are very few fading and propagation disturbances on the signals: the transmissions are line-of-sight and are less affected by multipath - there is no "sky-wave/ground-wave" interference.

However, the fact that the shore station has information about vessel position and course is of little use unless immediate, reliable communication with the desired vessels is possible. Therefore, the ship must not only have an L-band transponder, but some form of long-distance, reliable communications on the bridge.

Communications from the shore to the ship via satellite provides more reliability, quality, and range than either VHF or HF. However, a shipboard terminal capable of voice and data communications is expensive because of the necessity for a high-gain stabilized antenna. In contrast, a ranging terminal on a ship uses a low-gain, low-cost antenna. The cost difference of voice and data communications with ranging/navigation over ranging alone is estimated at 2.7 to 1. Because of the equipment cost, it is likely that only the larger vessels (over 500 gross tons) could afford a satellite communications capability. Therefore, it is assumed all ships between 100 and 500 gross tons would use satellite ranging together with either VHF or HF, according to their distance from shore.

If VHF communications is used, the advantage of wide satellite coverage is lost; if HF communications is used, the system inherits all the reliability and interference problems of that band, as well as the problems posed by the fact that the equipment is normally located in radio rooms distant from the bridge and requires the services of the radio officer who is not on watch full time. These problems must be considered along with the advantages and disadvantages of other systems. The only workload on the vessel crew is to turn on the transponder which functions automatically when interrogated.

Satellite systems of this type are a proven state-of-the-art although each system is "custom" designed to the particular application.

Estimated Cost

Vessel owner costs are estimated:

5.4 NONCOOPERATIVE SYSTEMS

Noncooperative systems for OTIS implementation are defined as remote sensing systems which detect vessels without their knowledge. In this section the alternative sensors and the alternative platforms for conveying the sensors will be presented[7].

5.4.1 Remote Sensor Alternatives

The sensor types discussed are suitable for area surveillance and monitoring. Specific sensors, including radar, infrared, and acoustic will be reviewed.

5.4.1.1 Over-the-Horizon Radar (OTH-R) - Two OTH-R techniques were considered, surface-wave and sky-wave, with a goal of detecting surface vessels greater than 40 feet in length. The surface wave propagates along the curved surface of the earth, while the sky wave reflects off the ionosphere. Both techniques make use of the radial velocity of the vessel with respect to the radar for detection.

The surface-wave technique is capable of meeting the detection requirements, however, there are two problems:

a. Cost is very high, approximately $10M/300 nm of coastline

b. In all likelihood the radars will interfere with each other if a system for continuous coastal coverage is configured. This technique should be considered if there is a single area that would not lend itself to coverage by techniques other than OTH-R.

A few well-placed sky-wave OTH-Rs could provide the coverage needed for coastal surveillance; however, the detection requirement of vessels of 40 feet in length cannot be met. To exceed the detection threshold, vessels of about 300 feet minimum length and a nominal radial velocity of 10 knots are required. (See Appendix L for details of both techniques.)

A sky-wave radar for coastal surveillance would typically be located about 800 to 1600 nm from the coast. Each antenna associated with a sky-wave radar can cover an azimuth of 60° or more (±30° about boresight).

A network of OTH-R stations to cover the U.S. coastlines can be configured in a number of ways. One configuration is shown in Figure 5-6. Two radars could be located in Indiana, one boresighted at 103°T covering the coastline between Maine and Georgia, and the second boresighted at 180°T to cover the Gulf Coast as far as Texas. West coast coverage would be from a station in Colorado, boresighted at 322°T, and Alaska would be covered by a station in the state of Washington, boresighted at 325°T. A fifth radar located on Johnston Island (not shown on the figure) boresighted at 060°T could provide coverage for Hawaii.

The four southern stations could be expected to give reasonable coverage throughout the year. However, the Washington radar, directed north to Alaska, would be looking into the aurora. High-frequency (HF) propagation through the aurora is not very reliable, and coverage of the Alaskan coastline would be poor for a substantial portion of time.

The lack of capability of a sky-wave radar in meeting the objective of high-reliability tracking of small vessels must be emphasized. In one experiment, SRI put a transponder on a small vessel and illuminated it via sky wave using its wide-aperture research facility (WARF). After locating the vessel by observing the signal from the transponder, the transponder was turned off. No skin echo from the vessel was detected.

Therefore, neither technique appears to be suitable to meet the requirement, and it is recommended that neither technique be implemented. However, it should be emphasized that surface-wave radar could be used to monitor any areas of high interest, if indeed such areas exist.

The initial cost of one OTH-R station is approximately $10 million. It is estimated that a minimum of 10 operators would be required per site (two per shift). Two maintenance technicians would be required, plus the usual support personnel. One can easily envisage 15 personnel at each site. Thus, the operating cost is estimated at $1 million per year.

5.4.1.2 Synthetic Aperture Radar (SAR) - Certain forms of radar which employ special signal processing methods can produce photograph-like images of objects and the earth surface. These have come to be known as synthetic aperture radars (SAR) because the receiver antenna is made to appear to be much larger than its physical size. Consequently SAR can use smaller antennas and have much higher resolution and accuracy and can be much more sensitive (i.e., detect smaller targets) than the conventional (beam-type) radar described above. When SAR is used in an aircraft, it is usually

The detection range for smaller vessels will be correspondingly shorter. For a ship with a length of about 123 feet and beam of 25 feet the detection ranges would be about one-third the detection ranges given above. With the smallest ships considered for a VMS (40 feet), the detection ranges will be even shorter. Further reductions in detection range will result when clouds and rain exit along the radar to target path. It is estimated that the reliable detection range for a 40-foot vessel in clear weather (assuming the E-2C) is about 34 nm. In clouds and rain this may drop to about 30 nm. The airborne radar then can provide reliable coverage over a swath of about 60 to 70 nm in width (depending on weather conditions). As the weather worsens and high-sea states develop, the detection range will drop. This is due to the increase in clutter caused by the ocean waves and scintillation of the target due to ship motion.

Side-looking Airborne Radars. The need for high resolution airborne radars with small antennas stimulated the development in the early 60's of the side-looking airborne radar (SLAR). SLAR capitalizes on a range-frequency shift dependence of the signal scattered from stationary objects and observed by a moving receiver. The technique is called synthetic aperture because, by signal processing, the effective size of the radar antenna is many times larger than its physical dimensions. For example, it is possible to obtain an effective aperture of many thousands of feet in width with an antenna a few feet in width.

The search pattern of SLAR differs considerably from that of the conventional airborne radar. In the conventional system the coverage is provided by circularly scanning the antenna beam as the aircraft moves (Figure 5-7). In SLAR, the antenna beam is fixed in direction and as the aircraft moves, it covers a swath on the earth's surface (Figure 5-8). SLAR forms a photograph-like image of the surface in this swath. The physical geometry is such that when the signal is processed the "scene" has the appearance of a vertical incidence photograph.

SLAR has been proven to be very effective for imaging of terrain and ocean waves. The Coast Guard currently uses SLAR in its Airborne Oil Surveillance System, and will use it in the future medium-range search aircraft. Vessels and their wakes stand out prominently in some cases but in others, vessels which are known to be present, do not appear. This is due primarily to target-

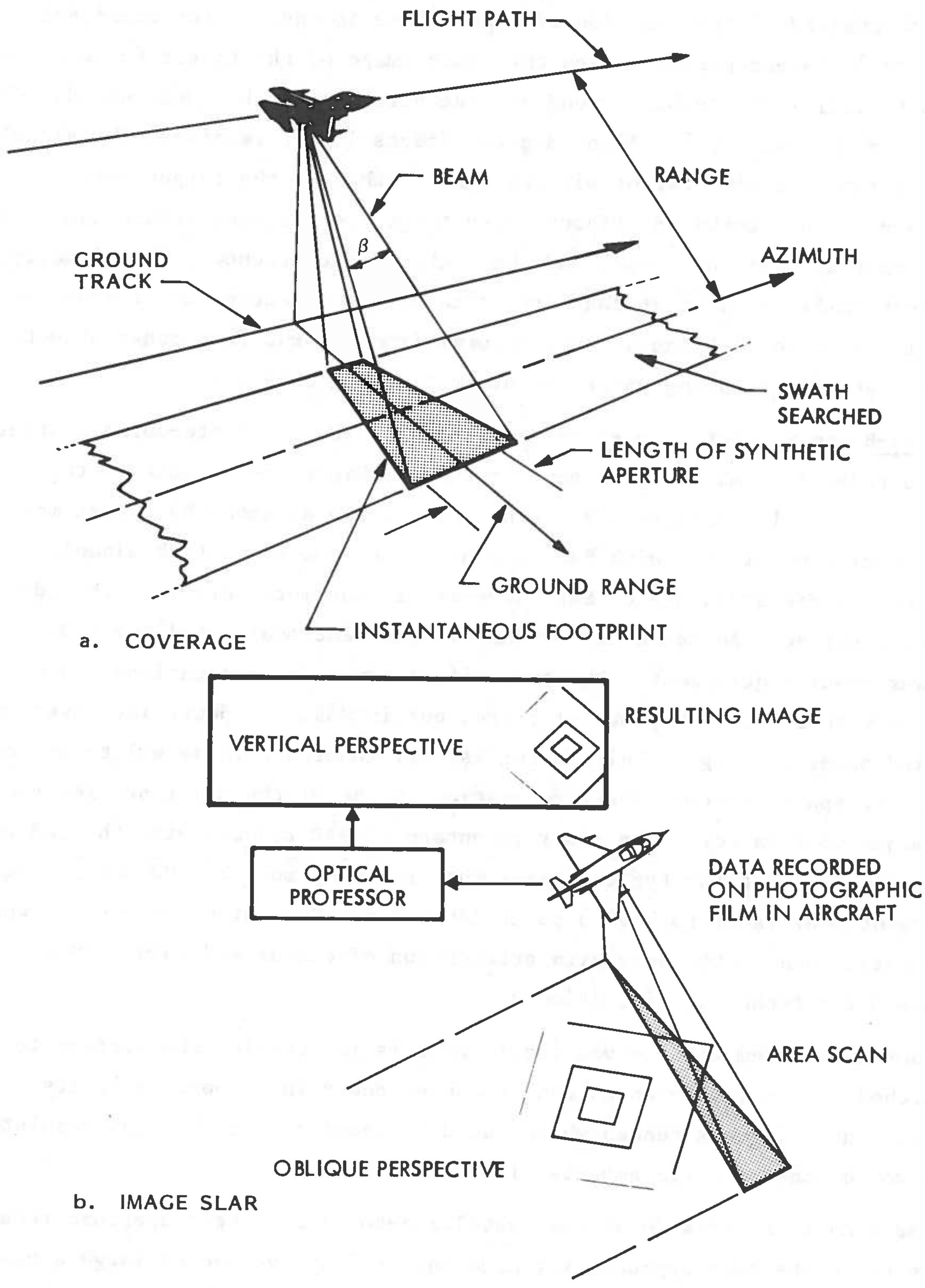

FIGURE 5-8. SLAR SYSTEM

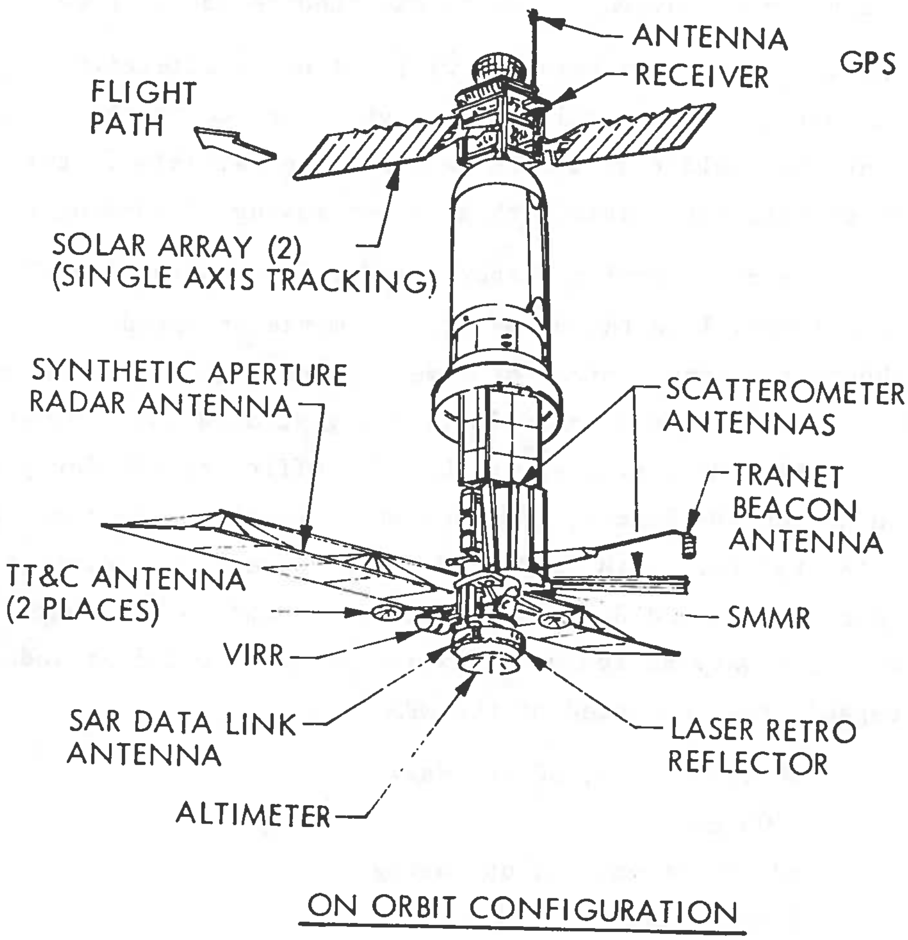

FIGURE 5-9. SEASAT-A: EXAMPLE OF A MODERN SAR RADAR

3) Versatility - broad-area coverage and localized, intense surveillance (e.g., deployment of towed acoustic array on the ocean for small-area monitoring).

4) Effect of Presence - large size works as a deterent to potential law violators.

5.4.1.3 Conventional Radar - Satellite-borne conventional radar could be employed by scanning the ocean surface near the earth horizon as the satellite moves along its orbit (Figure 5-10). Achieving high resolution and accuracy (2 nm) will require a large antenna (approximately 50 feet in diameter). Such antennas have been built and deployed (e.g., the ATS-6 satellite) so they do not pose great technical problems.

Extensive studies on satellite radars for OSS have been conducted by Lockheed Missile and Space Company[7]. Detection of all vessels with radar cross sections of 400 to 800 square feet (depending on sea state) within a 1-million square mile area appears practical. A system consisting of two satellites in low earth orbits and ground stations would cost approximately $200 million.

A limitation of the satellite radar system (SRS) is its inability to provide vessel size and vessel velocity (speed and heading). Obtaining sufficient resolution to provide vessel size would require an unacceptably large antenna.

Furthermore, the system requires land blanking (i.e., rejection of areas where the beam crosses a land mass). Thus, models of all land masses must be incorporated in the signal detection processor. As a safety margin, the system should blank the ocean surface to a distance of approximately 30 miles from land. This restriction could eliminate coverage in some important areas.

5.4.1.4 Long Wave Length Coherent Ocean Surveillance System (LOWCOSS) - This sensor is proposed as a solution to problems discussed above. The sensor is one originally developed under a Naval Research Laboratory contract by Control Data Corporation in 1964. The work has been funded since that time by both the U.S. Navy and U.S. Air Force. Some of this sensor's salient features are:

a. Provides real-time detection, location, course, and speed of vessels out to the radar horizon.

b. Performs these functions automatically without operator intervention.

c. Handles high-density traffic.

d. Performs under all weather conditions including heavy rain or hail.

e. The equipment is all solid-state, low-power, has no moving parts, and requires only a simple antenna.

The nominal characteristics for LOWCOSS radar are shown in Table 5-1. The system would use two frequencies around 500 MHz. (These frequencies ignore the sea clutter.) One would cover an area from directly below the aircraft (8 nm) to about 64 nm out. The other frequency would go from 64 nm to 200 nm. A third radar, a power-managed P-band device with an 11-slot array antenna, would be used to correct for location error and would be introduced into the LOWCOSS results by the SAR technique itself. (A more complete description is presented in Appendix N.)

The sensor "looks out" to the side of the aircraft and thus could be placed on the outside of the fuselage in an area which would not interfere with other antennas, doors, windows, or landing gear. The unit's antennas could be made part of the total integrated package. It could be an entirely self-contained pod, having its own air turbine generator for power, attitude and position location package, and communications. It could then be easily installed mechanically on aircraft which were modified with the proper mounting attachments. For these reasons, commercial aircraft flying the coastal routes of the Atlantic, Gulf, and Pacific Coasts would possibly serve as satisfactory platforms if the airlines would accept this approach, and the aircraft could be certified without difficulty. This approach for carrying the LOWCOSS sensor would obviously require detailed engineering study and demonstration of safety and operational procedures before receiving the acceptance by the airlines and the Federal Aviation Administration. An alternative technique for an aircraft to carry this pod is to design the package to fit in the baggage compartment; this would eliminate any external appearance of the unit. This approach appears attractive because of the lower cost for carrying the sensor as baggage cargo on an airliner than carrying it on a Coast Guard airplane dedicated to this mission.

Such a total system would require no new USCG aircraft or ships. In fact, the data from such a system could better utilize the existing resources. For Hawaii and Alaska LOWCOSS could be carried by USCG C-130's or, if the C-130's are not available, it is suggested that this system would be compatible with a dedicated USCG remotely-piloted vehicle (RPV).

The cost of development of the LOWCOSS sensor and package is estimated at $7.3 million, and cost of unit at $1.2 million plus $40,000 per aircraft for modifications to carry the pod.

5.4.1.5 Passive Infrared Techniques - Feasible means of keeping the offshore regions (to 200 nm) of the mainland U.S., Alaska, and Hawaii under surveillance for locating cooperative and uncooperative shipping by passive infrared techniques were investigated. The effects of frequency of sightings, resolution, and probabilities of missed sightings were also considered in determining the feasibility of various systems.

The large aerial extent of the regions to be kept under surveillance along with the minimal update time of a day for sightings led to the examination of a satellite system of one or two fairly low-altitude satellites (500 km to 1500 km). Passive infrared sensors can yield resolution of about 10 meters with a reasonably-sized optical system, but such sensors suffer loss of target-detection probability since they require a clear line-of-sight through the clouds.

IR Sensor. The objectives of locating ships on the ocean, estimating their heading and speed, and estimating their size can be achieved with an IR sensor which operates in one or several of the spectral bands which are windows in the atmosphere. Two candidate bands are the narrow 4.56 μm to 4.77 μm band and the wider 10 μm to 13 μm band. Figure 5-11 shows the observed radiant intensity (along with extrapolations) of a ship as a function of its projected area for these two spectral bands. Note the difference in the scale for the two bands. (The wider band offers considerably higher target radiant intensity for detection.) These intensities, however, can vary throughout the day. The radiant intensity is at maximum during the day when a ship has been absorbing sunlight and remitting the absorbed energy and at minimum at night when the vessel has been cooling radiatively. The ocean background changes very slowly so the contrast between the vessel and its background goes from a maximum-positive contrast to zero to maximum-negative contrast.

In order to estimate the size of a vessel, the IR detectors must have a "footprint" (i.e., the area on the surface of the earth viewed by a detector) that is not too large compared to that of the vessel. Judicious processing from multiple-detector looks at a ship can allow for good size estimation; even though the footprint is larger than the target, the accuracy of the estimated size decreases as the ratio of footprint to target area increases. Since vessels as small as 15 meters in length are possible targets, cell resolution should be in the range of 40m x 40m to 100m x 100m.

A satellite-borne sensor of 1500 km altitude can achieve this resolution in both spectral bands with an optical system of 0.5m aperture (i.e., 40m at 4.66 μm; 100m at 11.5 μm).

Heading and speed estimation require multiple sightings of the vessel with sightings taken over a sufficiently long time for the slow motion of a ship to be detected. A sensor with a fixed array of detectors that operates in a "sash broom" mode, that is, scanning is accomplished by the motion of the satellite, can meet these requirements. The field-of-view of the sensor need only be wide enough to cover the 200-nm-wide swath, but it should be long enough so that the time between first and last sightings is sufficient for a vessel to move several pixel lengths. The array need not be full. Rather it could consist of two linear arrays, each array several detectors deep to achieve multiple sightings, with an angular separation of the arrays yielding the time difference between sightings. (One array looks ahead, the other behind.) From the sightings in the forward-looking array a good estimate of position of a vessel is obtained but the estimates of speed and heading are poor. The sightings from the rearward-looking array yield again good position estimates but poor heading and speed estimates. However, with the accurately known time between the position measurements, heading and speed are obtained with good accuracy. Implicit in all this are the assumptions of accurate ephemiris for the satellite and accurate line-of-sight determination in the sensor.

Inasmuch as the angular separation of the arrays is rather large, it would be difficult to achieve this separation in a single optical system. For this reason each array has its own optics. This has the further benefit that it allows the arrays to move independently to cover areas on either side of the ground track so as to follow a coast line, for example.

In summary, the IR sensor has the following characteristics:

- Altitude: 1500 nm
- Aperture: 0.5 m
- Number of telescopes: 2
- Spectral bands: 4.56 μm to 4.77 μm, 10 μm to 13 μm
- Si: in extrinsic detectors
- Detector subtense: 23×10^{-6} μrad x 23×10^{-6} μrad at 4.6 μm
  57×10^{-6} μrad x 57×10^{-6} μrad at 11.5 μm
- Detectors per array: 1.1×10^5 in 4.6 μm band
  4.4×10^4 in 11.5 μm band
- Detector size: ~ 100 μm x 100μm
- Array width: 14°
- Angular separation of arrays: 56°
- Passive cooling
- Dwell time: 7×10^{-3} sec = $40m/\sqrt{s}$ = 40m/5700m/sec for 4.6 μm detectors
  17×10^{-3} sec for 11.0m detectors.

If the detectors are sampled at the rate of two samples per dwell time, sampling rates of 7×10^8 samples per second result. Simple thresholding will

5.4.2 Platforms For Noncooperative Sensor Systems

An important element in the design of OTIS is the vehicle, or platform, selected to transport the sensor systems. Several candidate platforms were examined in the course of this study. These included ships, commercial aircraft, Coast Guard aircraft, remotely-piloted vehicles, lighter-than-air craft, and satellite systems. In order to assess each platform's suitability to OTIS applications, five attributes were investigated, i.e., field-of-view, on-station time, search area, contact follow-up, and revisit time. Figure 5-11 synoptically presents each platform's estimated performance for each of the attributes, specifically with respect to the FCZ.

In general, the platform attributes are a function of the operating characteristics of the platform. The size of the field-of-view is primarily related to operating altitude of the platform. On-station time, the ability to see a specific location for a period of time, is a function of platform consumables for all mobile platforms except satellites. With satellites, it is a function of orbital altitude. Search area is related to field-of-view, on-station time, and platform speed. The number of platforms required to cover the FCZ once per day is a function of search area and is also indicated in the matrix. Contact follow-up is the ability of the platform to move close to a vessel for discrimination purposes. Revisit time for most platforms is mission-dependent. For satellites, it is again a function of the orbit.

While it may be questioned whether or not "fixed, landbased" is a meaningful platform type, the fixed sensors possess attributes based strictly on operating position and are therefore included for completeness. The fixed High Frequency Direction Finding (HFDF) can contribute to OTIS information needs across the total FCZ while the other "fixed" systems cannot. Both the HFDF and acoustic sensors require that any target vessel emit a radio transmission in the sensor's frequency band or create acoustical noise in the water.

Use of ships for platforms does not seem practical for large-area search activity, but is very worthwhile if the search area is confined (fishing area). Here, the other ship attributes (e.g., long on-station time and the ability to follow up contacts) make ship use advantageous.

Aircraft can search a larger area than ships, and as a result of altitude, have a much larger field-of-view. The aircraft on-station time is not as long as with a ship platform; however, like a ship, an aircraft can be vectored to a particular vessel to follow up a sensor contact. One further similarity exists between ships and aircraft; during a period of heavy weather in the search area, operations would have to be reduced in may cases.

The Coast Guard C-130 aircraft has characteristics that make it practical for use as an OTIS sensor platform in addition to the roles it now fulfills. It also would lower OTIS costs if existing aircraft could be utilized part-time or concurrently with other missions.

Use of commercial aircraft flying the coastal routes as a platform to carry a surveillance pod presents the possibility of cost savings and fuel savings. Since commercial aircraft would be flying regular routes, there would be little additional fuel used to carry a sensor pod. The pod could be treated as special cargo and handled by the airlines on a contract basis so that a minimal amount of OTIS manpower would be necessary. Two approaches have been proposed for aircraft installation of the pod: a) externally attached to the lower side of the fuselage, and b) internally mounted in the baggage/cargo area with antennas in the cargo door. The latter approach presents less air drag and may be more acceptable overall. With either installation, this concept poses many questions about flight safety, air worthiness, FAA certification, liability, field maintenance and calibration, and rotation of sensor packages to meet equipped aircraft to fly the area needed. However, it the cost saving is as large as indicated by this analysis (over 10:1 advantages using airliner), it would seem worth investigating further, including an engineering design study.

<u>Remotely-Piloted Vehicles</u> (RPV) could also perform the OTIS platform task. RPVs could be launched and recovered from ground stations located along the coastline, remote to civil habitation. Alternative shipboard launch and recovery also could be considered. A "wet" recovery capability for ship retrieval could be provided by inclusion of an emergency parachute. The airborne RPV could be controlled from a shore-based ground control station or control could be passed to a Coast Guard patrol ship. The on-board avionics could be preprogrammed to provide for automatic waypoint guidance of the RPV along a desired search plan. The RPV could have two side-looking radars with a 100-

There are at least three approaches that can be taken to cope with winter night.

- o Pure Fuel Cell Power with Drift Mode - An all fuel cell version (i.e., extra fuel and tanks replacing the solar cells).
- o Microwave or Laser Power Beam-Up - Mobile microwave transmitters (or more covert, though weater-sensitive, lasers) can be used to beam up power (100 kw electricity consumed) to HASPA from the ground. However, this method limits the geographic positioning and short-term repositioning flexibility and decreases the survivability of the overall surveillance network.
- o Nuclear/Rankine Cycle Power - Somewhat better than 115 W/lb specific power (three times that of the Snap 8 Generator) would be needed for competitive size vehicles.

The HASPA vehicle could be deployed in large numbers for survivability enhancing redundancy and broad geographic coverage because of its relatively low initial and operating costs (about $4 million initial cost for the representative vehicle and less than $2 million for its postmission refurbishment).

HASPA can stably carry very large aperture (e.g., 20m by 5m), high-resolution radar arrays internally in a low stress temperature and dynamic pressure environment.

The major drawback in considering powered aerostats as viable platforms for OTIS is their availability. At the present time, their initial operational capability is expected to be realized in 1990 at the earliest. However, the development of a patrolling lighter-than-air (LTA) vehicle called the Marine Patrol Airship, is being studied by the Coast Guard's Office of R&D, and it is believed this platform could be available by the mid-1980's.

Satellites provide the largest field-of-view of all platforms. In many cases the sensor would have to be pointed at a particular target area, because the sensor field-of-view is less than horizon-to-horizon. With respect to search area, the satellite again sees too much and would have to be commanded on and off around the FCZ. On-station time and revisit time are a function of the orbit selected, and this is a function of the vessel population sample period required to maintain vessel track. Low-altitude orbits see the same ground

AN/WLR-8(V)4- Shipboard DF receiver.

AN/SLC-32(V)- Shipboard DF receiver.

OUTBOARD/AN/SSQ-72- Shipboard DF receiver.

COMBAT DF- Shipboard DF receiver.

EA-3B - Tactical electronic support measure aircraft.

SR-71 TECHNICAL OBJECTIVE CAMERA (TEOC) - Airborne camera system.

SR-71 OPTICAL BAR CAMERA (OBC) - Airborne camera system.

SR-71 ELECTROMAGNETIC RECONNAISSANCE (EMR) - Airborne DF receiver system.

PRECISION LOCATION STRIKE SYSTEM (PLSS)- Airborne DF receiver system.

TACTICAL AIR RECONNAISSANCE POD SYSTEM (TARPS)- Airborne DF receiver system.

AN/ALQ-78- Airborne DF receiver.

OV-ID MOHAWK- Airborne tactical intelligence sensor aircraft.

QUICK LOOK II- Airborne DF receiver.

AN/ALR-59 - Airborne DF receiver.

BEARTRAP - Airborne acoustical sensor system.

CLIPPER TROOP - Airborne multisensor collection system.

EP3E - Airborne DF receiver system.

AN/UPD-4(V) - Airborne SLAR system.

RIVET JOINT - Airborne DF receiver system.

SR-71 ADVANCED SYNTHETIC APERTURE RADAR SYSTEM (ASARS) OR (ASARS II) - Airborne SAR system.

SR-71 HIGH RESOLUTION RADAR (HRR) - Airborne radar system.

AIRBORNE RADIO DIRECTION FINDING (ARDF) - Helicopter-borne DF receiver system.

AN/ALQ-151 QUICK FIX - Helicopter-borne DF receiver system.

REMOTELY-PILOTED VEHICLE/TARGET ACQUISITION DESIGNATION AERIAL RECONNAISSANCE SYSTEM (RPV/TADARS) - Airborne imagery system.

FOSIC/FOSIF (OSIS SITES) - Information processing system.

AFLOAT INTELLIGENCE CENTER - Information processing system.

USAREUR INTELLIGENCE INFORMATION SUBSYSTEM (IISS) - Truck-mounted information processing system.

TECHNICAL CONTROL AND ANALYSIS CENTER-DIVISION (TCAC-D) - Truck-mounted information processing system.

ALL SOURCE ANALYSIS CENTER (ASAC) - Tactical deployable information processing system.

TABLE 5-2. SENSOR/PLATFORM SYSTEMS ALTERNATIVES

PLATFORM/SENSOR	ADVANTAGES	DISADVANTAGES
Land		
OTH Radar	- Wide-Area Coverage	- High Cost - $10M each Plus Site Costs. - Vessel Size Limit to 300 ft.
HF DF	- Wide-Area Coverage	- Atmospheric Outage - No Vessel Size Data
Airborne		
RADAR	- Low Cost - Large Search Area	- Cost Approx. $250K each - Limited Range and On-Station Time - Sea Clutter Effects
SLAR	- High Resolution - Large Search Area	- Affected by Target and Aircraft Motion - Cost Approx. $500K each
LOWCOSS*	- Coverage to Horizon - All Weather	- Large Antenna - New Development Sensor - Cost Approx. $7.5M R&D and $1.2M Per Unit
Lighter Than Air		
RADAR	- Continuous Coverage	- Limited RANGE Sensors - Cost Same as Aircraft
SLAR	- Continuous Coverage Platform Has Long On-Station Time	- Limited Resolution on AEROSTAT (Patrolling Platform Resolution Better)
Satellite		
RADAR	- Wide Area Coverage - Area Scan Twice Daily	- Large Size Antenna - High Power Reqd. than SAR - High Cost Platform and System) - $50 M each
SAR	- High Resolution - Large Area Coverage - Lower Power than Conv. Radar	- High Cost Platform and System; Approx. $25 M
IR	- Excellent Resolution (15 meters)	- Complex and Costly; Approx. Cost $40 to $50M
Seaborne		
ACOUSTIC	- Continuous Coverage - Signature Identification - Deployable by Cutters	- Small Area Coverage - Large Number Required - Quiet Carrying Vessel Req'd.

*Long Wavelength Coherent Ocean Surveillance System reported in Section 4 indicated the first approach should be to build a design around the existing communications equipment on the vessels.

The communications requirements for OTIS were determined by examining each input to the system and each output from the system and assessing the data quantity and timing constraints for each. (The accessing of the OTIS data base by any mission user was not included in the determination of communications requirements.)

The assumptions used in this analysis are:

a. All vessels participate in OTIS as cooperative users.

b. Vessel populations for the peak daily estimates shown in Section 3 are used.

c. Vessels within VHF range of the coast will use VHF links; all others will use HF except large commerical vessels equipped with satellite terminals.*

---

*The channel usage by vessel type would be divided as follows:

		1979	1990
Large Commercial Vessels	HF Voice	- 70%	40%
	HF Data	- 25%	10%
	Sat. Data	- 5%	50%
Small Commerical:	HF Voice	- 95%	75%
	HF Data	- 5%	5%
	Sat. Data	- 0	20%
Recreational:	HF/MF Voice	- 20%	20%
	VHF Voice	- 80%	70%
	VHF Data	- 0	10%
Fishing:	HF Voice	- 30%	30%
	HF Data	- 0	0
	VHF Voice	- 70%	70%

i. HF communications channels and transmitting stations used each day for a region are selected from the available frequencies and transmitter-site locations (if there is more than one option) in that area in order to minimize the atmospheric distrubances on HF ship-to-shore communications that day.*

The results of this analysis are presented for coverage of the East Coast Region, which has the maximum requirement:**

HF Voice Comm:	4706 vessel calls per day, requiring 6 RF channels.
HF Data Comm:	113 vessel calls per day, requiring 1 RF channel.
VHF Voice Comm:	8493 vessel calls per day, requiring 11.1 RF channels or, by using space diversity and a 6-station grouping (of different frequencies) repeated every 180 miles along the coastline, 6 dedicated VHF frequencies are need for continuous coastal coverage.
VHF Data Comm:	666 vessel calls per day, requiring 1 RF link which can be satisfied within the previous arrangement for VHF Voice Comm.
Satellite Data Comm:	12 vessel calls per day to OTIS, requiring less than one minute total time per day.

Using the 1990 estimated vessel population, the communications requirements will be as follows for the East Coast:

HF Voice Comm:	6 RF channels
HF Data Comm:	1 RF channel
VHF Voice Comm:	13 RF channels (well within capacity of the 6-station grouping described above)

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*Techniques of path and frequency selectivity, signal design, and error coding are a potential means of improving HF communications operations during atmospheric distrubances and of alleviating the HF outage problem. These advanced HF techniques are currently under study by the FAA in the Oceanic Air Traffic Control Communications project for long-range air-to-ground communications.

**This is based on vessel population estimates for 1979 shown in Section 3.

TABLE 5-3. MESSAGE INPUT TO OTIS REGIONAL COMPUTER (THOUSANDS OF BITS)

MESSAGE TYPE	REGION EAST COAST	GULF COAST & CARIBBEAN	PACIFIC COAST & HAWAIIAN IS.	ALASKAN COAST	TOTAL
1979 Data	4,175	4,010	2,720	570	11,475
Voice	14,650	13,890	9,870	1,620	40,030
Total	18,825	17,900	12,590	2,190	51,045
1990 Data	8,560	8,940	5,260	1,670	24,430
Voice	17,210	16,570	11,830	1,480	47,090
Total	25,770	25,510	17,090	3,150	71,520

Computer system design requirements are presented in Section 5.7. Two examples of the types of data that would be acquired from the sources identified above are:

1. MSIS: Unit Reference No.
   - Current Name/Prior Name
   - Official Regristration No.
   - Call Sign
   - Flag
   - Propulsion
   - Length
   - Gross Tons
   - Net Tons
   - Dead Wt. Tons
   - SOLAS/COI
   - Cargo
   - Violations
   - Boarding Inspections
   - Pollution Incidents

2. EPIC: Source (Each Vessel)
   - S.NO.
   - Date/Time
   - POS/COORD
   - Vessel Name
   - Vessel No.
   - Flag
   - Vessel Type
   - Length
   - Other
   - P/N

5.5.2 <u>Analysis of Communications for Noncooperative System</u>

In this analysis of communications requirements for the remote sensor system, all vessels are considered noncooperative except a small number of foreign fishing vessels and hazardous-cargo vessels that by regulation are the transmission process. Finally, there are more than 20 percent spare bits allocated for growth. Therefore, 150 bits can be considered a realistic, but conservative, number. There may be a few more bits required for additional channel housekeeping tasks, but it would be about 1 percent of the total, and these could easily be included in the allocated spare bits.

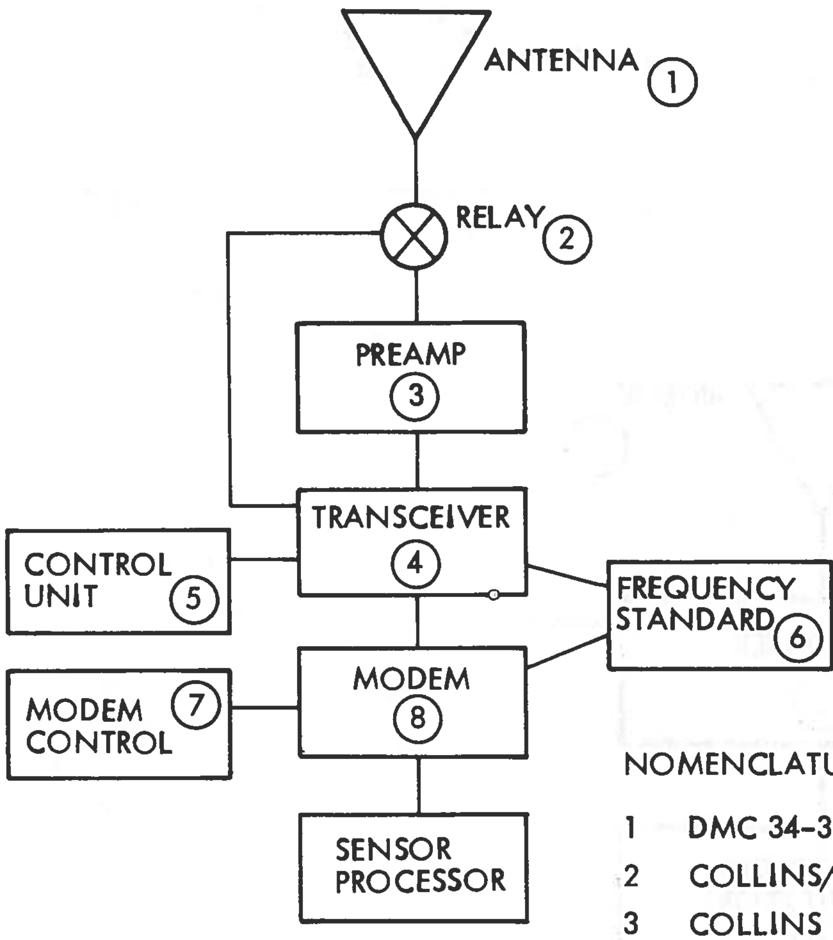
The next step in the determination of OTIS sensor communications requirements was to assess the population of vessels which would be sensed and transmitted to corresponding the OTIS center. The population was derived for each of the four areas by taking the peak population of the 0- to 3-nm and 3- to 200-nm subzones, summing them, and then adding 10 percent of the in-port population. The 10 percent was added because the primary OTIS sensor has a resolution of 1/16 of a mile and two or more vessels within that area will only be detected as a single one. Thus, in port only a small number (i.e., approximately 10 percent) of the vessels will be able to be resolved. This also holds true for the identification transponder return, for more than one code cannot be discriminated within 1/16 of a mile.

Table 5-4 presents an estimate of "peak sensed" population which the communications system will have to transmit.

TABLE 5-4. PEAK SENSED POPULATION

East Coast	Gulf and Caribbean	Pacific Coast	Alaska
21,719	20,678	14,687	2,090

There are existing US Navy systems (e.g., Submarine Satellite Information Exchange System) which transmit digital data directly from remote ships and aircraft to shore facilities. This system is used for illustration of the communications concept. The system incorporates a channelized satellite repeater capable of providing such data services. The normal data rate is 2400 baud. Table 5-5 presents the total time to transmit the "peak sensed" vessel population for each area at this baud rate.



NOMENCLATURE

1 DMC 34-3

2 COLLINS/TRANSCO 11300 RELAY

3 COLLINS AM-6601 PREAMP

4 COLLINS RT-1017/ARC-156
RECEIVER-TRANSMITTER RADIO

5 COLLINS 514E3
RECEIVER-TRANSMITTER CONTROL

6 AUXILIARY
FREQUENCY STANDARD

7 COLLINS 913N-1
MODEM CONTROL

8 COLLINS 9605-1
MODEM
COLLINS 1673-C-101
MODEM MOUNT

FIGURE 5-13. TYPICAL AIRBORNE COMMUNICATIONS INTERCONNECT user acceptance reported in Section 4. It needs vessel information on characteristics, location, identification, course, and speed. The communications requirements for OTIS were determined by examining each input to the system and each output from the system, and assessing the data quantity and timing constraints for each.

The data inputs and outputs were developed for each type of vessel and then multiplied by the number of vessels carried by each center in order to determine the total communications requirements for each center. As a new vessel is sensed and the data enters the computer, external static information can be used to support the process of identification and correlation. This applies primarily to the noncooperative population. As the individual OTIS centers become operational, static data from MSIS will be accessed, as necessary. It is assumed that the East Coast regional center will be colocated with the OCC and will, therefore, not require any communications support to access the MSIS data. The Alaska OTIS population is small enough so that there would be no problem in duplicating all the necessary static data required to facilitate the correlation process.

Potentially large terrestrial communications loads will occur for short periods of time between the OTIS center and MSIS in the Gulf of Mexico and the Caribbean, and in the Pacific areas. Examination of the MSIS data base shows that it does not contain information on the recreational vessels which make up the greatest portion of the OTIS population. One approach would be to maintain selected static data at these OTIS centers and only access MSIS for minor updates.

Information which can be obtained from DEA, Customs, and other non-DOD agencies contains little about vessel traffic. Conversations with DEA indicate that there are no plans to significantly increase their usable data base in the 1985-plus time frame. Thus, there would be no need to increase the existing communications capacity if these sources of information were the only driving forces.

On the other hand, DOD-based information can be obtained from the Ocean Surveillance Information System (OSIS). The interrelationship of this system with OTIS was discussed in Section 4.2.3.

l. Port File

m. Involved Party/Responsible Party File

4. Operational Oceanographic Applications

5. Enforcement of Laws and Treaties (Fishing, COTP, MSO)

6. Unit Readiness Systems

7. Iceberg Drifting Prediction System (ICEPLOT)

The Coast Guard is currently purchasing the services of a Value Added Network (VAN) to serve the communications needs of the Operational Computer Center, to provide data communications between air stations and AR&SC, Elizabeth City NJ, and to permit remote district access to personnel and administrative data bases. Such networks are insensitive to distance. Charges are based on access, time, and traffic volume instead. The VAN concept is illustrated in Figure 5-15.

5.5.4 Summary

The alternative techniques evaluated indicate that an all cooperative random vessel reporting approach, depending on existing communications equipment on the vessels and the masters/operators to voluntarily report to a shore station once or twice per day, is the lowest cost to the user. However, this technique has many short comings including the overlap and jamming of radio signals at peak traffic periods, the throughput rate of the HF radio channels, the reliability of the reports being done on time or at all due to workload on the vessel, and the ability of the shore station operators to handle the large amount of voice traffic and enter the data efficiently and accurately into OTIS.

It was concluded the best approach for monitoring the large daily peak vessel population (37,900) of vessels over 40 feet in length is to have a polled system with the shore station interrogations of vessels which automatically reply with a digital data message. This approach would also require a satellite relay to handle the total vessel population because of throughput limitations with HF links. The impact of this on the small vessel owner is quite severe in that the following new equipment is needed: satellite transceiver terminal, data encoder/decoder, interface with ship's navigation equipment and data input/output terminal, all totalling approximately $90,000 at current prices. It is anticipated new designs and technology advances plus demonstration of user benefits will likely foster the desire of the users for digital communications. Further, the willingness of vessel owners to cooperatively report their position as shown in Section 4 led to the conclusion that OTIS would have to be a hybrid of cooperative vessel reporting (approximately 17 percent of total vessels) and remote sensing of noncooperative vessels. It was assumed 80 percent of those cooperative vessels would be willing to use digital communications and the fishing vessels would want a coded message to protect their fishing grounds. The cooperative part of the system is a sufficiently small population to operate with ship-initiated reports. The digital data transmitted signal makes for direct message conversion (without a person in the link) to the computer interface at the shore station.

Level I message processing occurs at the shore station which includes digital data transfer plus manual conversion of analog voice to digital form and computer input. Level I data also come from the remote sensors to the OTIS computer. Level II data is the data input at the regional centers from other sources:

1. CG sighting data from own ships and aircraft;
2. Ancillary CG data from VTS, COTP, MSO, MSIS; and
3. Outside data from: DOD-Navy, DEA, Customs, INS, A.T.&F.A., and US Air Force.

At the regional centers all data are integrated and handled by the correlation processor.

The remote sensor and platform chosen for OTIS is the LOWCOSS sensor and an airborne platform, either Coast Guard or commercial aircraft. The latter has many problems yet to be resolved before feasibility is established but is worth consideration.

The LOWCOSS concept includes an inexpensive vessel transponder for cooperative vessel identification to increase the accuracy and reliability of the sensor data. The cost of the LOWCOSS sensor and platform for the whole vessel population is estimated as follows:

- Provide the capability to display geographically, the current location, course, and speed of each vessel; provide track history on each vessel, and identity of those vessels that can be identified.
- Provide the capability for operation intervention to resolve ambiguities where position update data does not match vessels in the current monitoring inventory.

The autocorrelation function of OTIS is a dynamic information retrieval system in which all system products are derived from data files. To better understand the correlation function, a brief description of the major data files is described. Figure 5-16 gives the correlation and update data flow. Another major function of OTIS is the display capabilities as indicated in the file structures.

Input Stack File (INSF). Data entering the system are initially stored on the INSF. The automatic input processor (AIP) retrieves data from the stack for processing. This file is a temporary holding file for input messages that back up due to automatic input-processing time.

Message Log File (LOGF). This file contains a record of messages received and action taken. These data include the source, input mode, time of input, report data-time group, message and report serial number, alert status (i.e., special-interest vessel), quality, and report disposition. This file is available for operator review.

Technical Information Data Base File (TIB). The information contained in this data base is a reference library of technical information associated with each vessel, such as vessel ID and characteristics, in the station area. This data will be accessed from MSIS.

OTIS Track File (TRK). The track file is a product developed during the data-processing operation of the system. Each track file record contains all available data pertaining to one discrete vessel (such as: vessel ID, time of last update, location, course, and speed).

Ambiguity File (AMB). The AMB file contains input track data records that do not automatically update the track file.

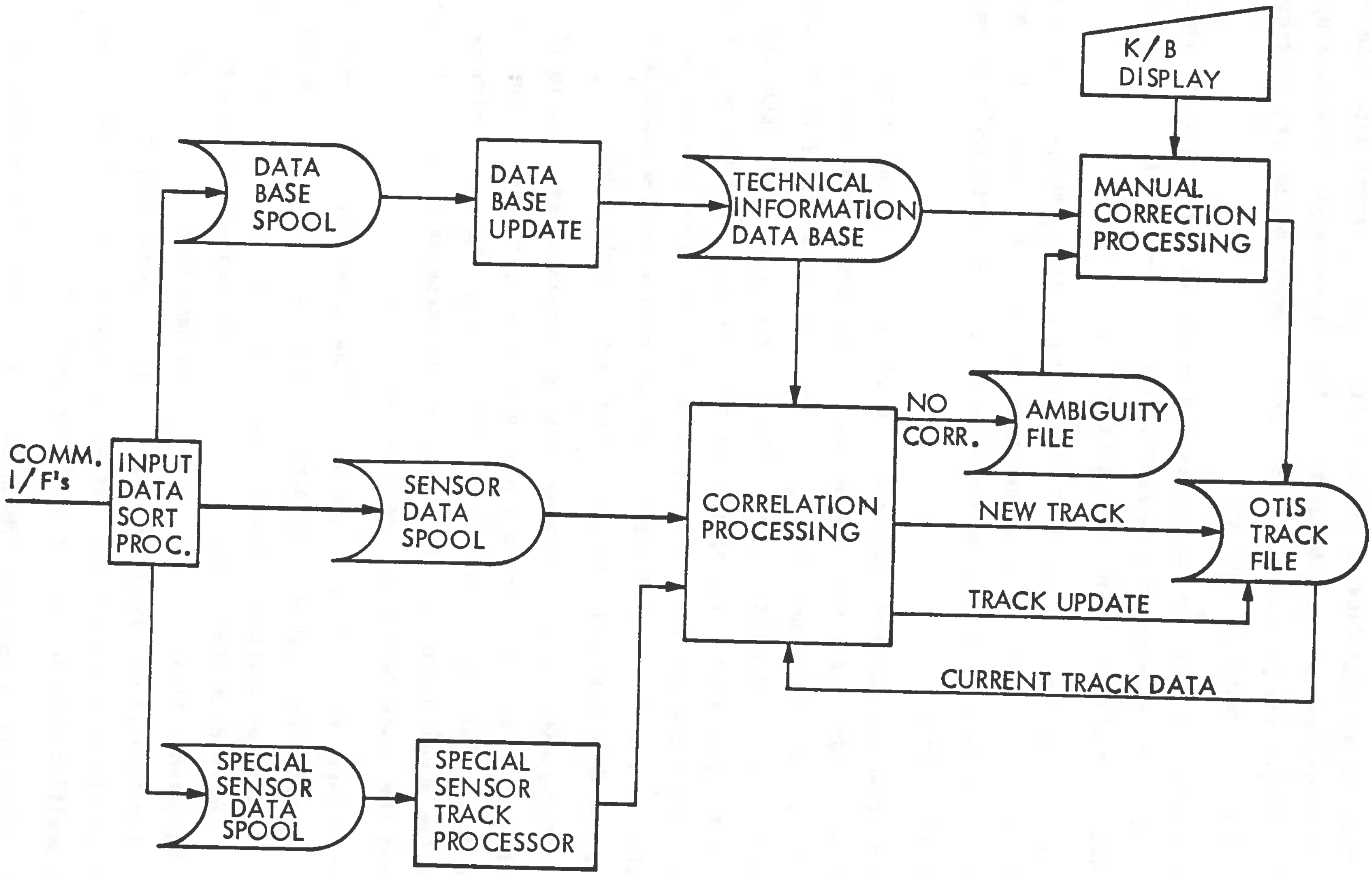


FIGURE 5-16. CORRELATION/UPDATE DATA FLOW

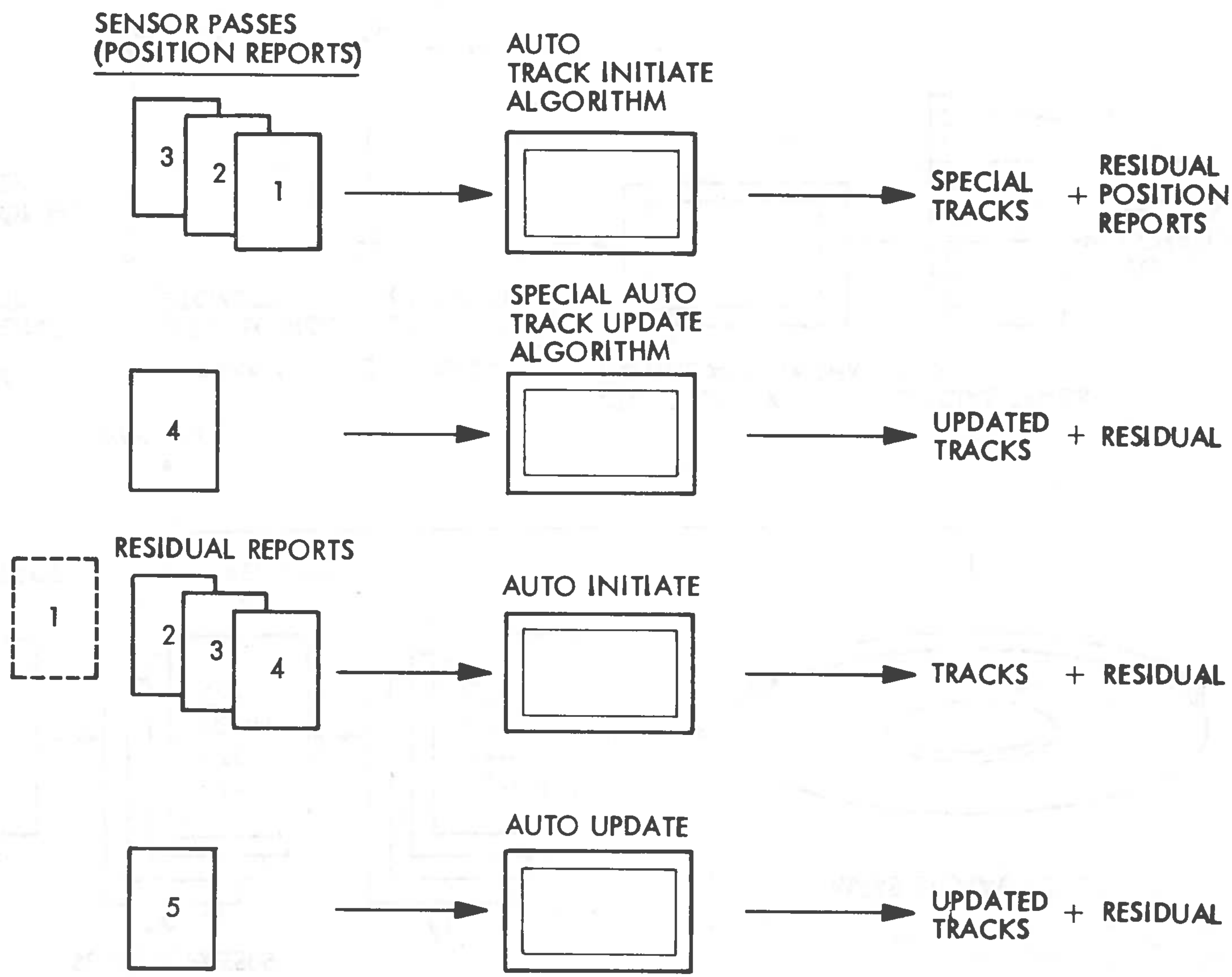
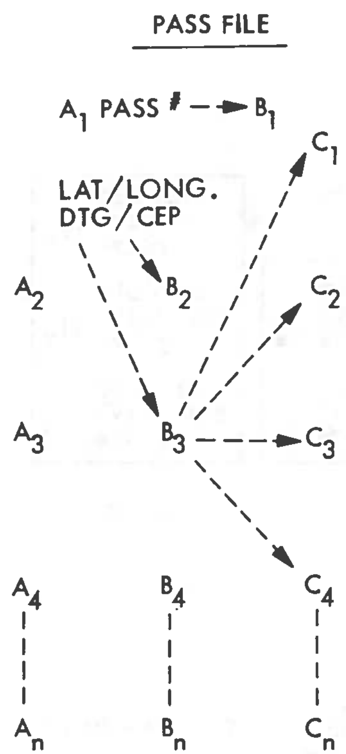


FIGURE 5-17. OTIS SPECIAL SENSOR AUTOMATIC TRACK PROCESSING



STEP 1

CALCULATE COURSE AND SPEED BETWEEN A_1 AND EACH B ELEMENT UNTIL A SPEED OF < 20 KT IS FOUND (SAY THAT THE SELECTED B ELEMENT IS B_3), THEN

STEP 2

- CALCULATE COURSE AND SPEED BETWEEN B_3 AND ALL C ELEMENTS.
- CALCULATE COURSE AND SPEED Δ'S BETWEEN A_1, B_3 AND B_3 $C_1 - C_n$ ELEMENTS.
- ASSIGN "GOODNESS OF FIT" NUMBER TO EACH $B_3 - C$ ELEMENT THAT MEETS CRITERIA OF < 2 KTS AND < 4° (REFERENCED TO A_1 B_3).

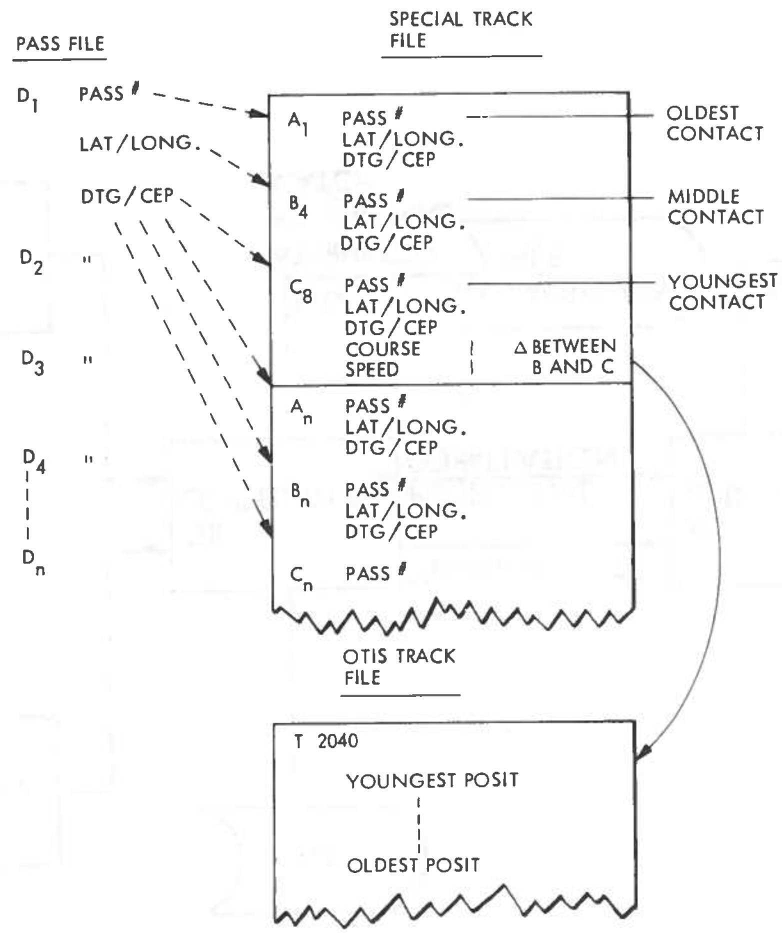
STEP 3

- SELECT AND STORE IN SPECIAL TRACK FILE A, B, AND C ELEMENTS WITH HIGHEST "GOODNESS OF FIT" VALUE.
- REMOVE ALL A, B, AND C ELEMENTS USED TO FORM TRACKS FROM PASS FILE.

STEP 4

- REPEAT STEPS 1-3 UNTIL ALL A ELEMENTS HAVE BEEN PROCESSED.
- CHANGE VALUE IN STEP 1 TO < 12 KTS AND Δ'S IN STEP 2 TO < 3 KTS AND < 12°
- REPEAT STEPS 1-3 UNTIL ALL A ELEMENTS HAVE BEEN PROCESSED.
- ALL ELEMENTS NOT USED BECOME RESIDUALS.

FIGURE 5-19. SPECIAL TRACK INITIATE ALGORITHM



STEP 1

- CALCULATE COURSE AND SPEED BETWEEN D_1 AND "YOUNGEST CONTACT" OF EACH TRACK IN SPECIAL TRACK FILE
- FLAG ALL SPECIAL TRACKS WITH SPEED < 30 KTS
- GO TO STEP 2
- IF NONE IS FOUND D_1 BECOMES A RESIDUAL

STEP 2

- CALCULATE COURSE AND SPEED Δ'S BETWEEN STEP 1 VALUES AND VALUES IN EACH SPECIAL TRACK IN THE SPECIAL TRACK FILE
- FOR ALL Δ'S OF < 3 KTS AND < 5°, ASSIGN A "GOODNESS OF FIT" VALUE

STEP 3

- SELECT SPECIAL TRACK WITH HIGHEST "GOODNESS OF FIT" VALUE AND REPLACE LAT/LONG., DTG & CEP VALUES IN ITS "YOUNGEST CONTACT" WITH D_1 VALUES
- REPLACE COURSE AND SPEED DATA IN SIMILAR FASHION
- REMOVE D_1 FROM ARRAY AND STORE FOR CORRELATION PROC.

STEP 4

- REPEAT STEPS 1-3 UNTIL ALL D ELEMENTS HAVE BEEN PROCESSED
- CHANGE Δ PARAMETER VALUE OF COURSE IN STEP 2 TO <12° AND REPEAT STEPS 1-3 FOR ALL D RESIDUALS
- WHEN COMPLETE, GO TO AUTO TRACK INITIATE ALGORITHM USING DATA FROM 3 MOST RECENT PASSES

FIGURE 5-21. AUTO TRACK UPDATE ALGORITHM

- o special sensor track data
- o position update information from remote sensors.

The data from the special-sensor processor was discussed previously. Both data inputs are processed in the same manner as described below.

As data is input to the TIB correlation process via sensor data spool stack file, or special sensor file, correlation candidates are first identified for additional evaluation to identify a match between the unique attributes or specific identification data.

Additional candidates are identified for processing during the second step, if a track can be dead-reckoned to within 150 nm of the incoming track reported position at the incoming track report date-time group. The correlation candidates are there reviewed in detail to provide ranking in both attribute and positional criteria.

The attribute correlation review is conducted utilizing either of two modes. The subtractive mode is utilized if there is a match of any unique attributes between the incoming position report and the correlation candidate. If the subtractive mode criteria are not met, the additive mode is used.

Although the system sizing for OTIS was based on an extrapolation of the AN/USQ-81(V), it was determined that a number of present-day, off-the-shelf computers and peripherals can satisfy OTIS computational requirements. For purposes of comparing computer system cost, the East Coast Regional Center is used as a model because it fulfills the greatest number of requirements. Figure 5-23 illustrates the basic configuration and components of the East Coast computer. The prices of "large minicomputers" and associated peripherals from five computer manufacturers are shown, for comparison, in Table 5-6. The assumptions for these costs are also presented.

Included in the list of candidate computer systems satisfying the OTIS requirements is the Prime 750 equipment presently installed in the Coast Guard OCC at Governors Island, New York. It was logical to consider duplicating subsets or supersets of the OCC equipment since there could be a cost savings on spares, maintenance training, and general familiarity with the equipment. The physical and data interfaces between the OTIS and the OCC potentially would also be simpler with the same equipment. The proposed OCC graphic displays would

TABLE 5-6. ALTERNATIVE COMPUTER SYSTEMS COSTS* (IN 1980 DOLLARS) FOR EAST COAST REGIONAL CENTER

VENDOR / ITEM	DEC VAX/11780	PERKIN/ ELMER INTER. 32-400	PRIME 750	DATA GEN. MV/8000	IBM 4341
CPU	176,800	164,900	187,000	165,850	271,350
DISKS	114,400	84,000	108,000	86,400	121,000
TAPE	12,000	13,000	13,000	13,000	10,960
TERMS (4)	180,000	180,000	180,000	180,000	180,000
COMM 1/F	12,000	12,000	12,000	12,000	12,000
TOTAL	495,200	453,900	500,000	457,250	595,310

*NOTE: Assumption for Comparison of Computer Systems

A. Support of East Coast Center

B. One additional spindle of disk storage to assure reliability

C. All disks identical in each system

D. Main memory: 2 MB. CPU { 32-bit word size; Floating point hardware; Virtual addressing }

E. Terminal cost: $45K ea CG spec. terminals

F. Software includes operating system only

AOU Filter. The area of uncertainty (AOU) filter is provided to prevent update of a track position by an incoming report which will provide a position update less accurate than the previous positional uncertainty. New data, other than position and time, contained in the incoming report will be used to update the track.

The filter interacts only with reports containing axes/angle of accuracy of position information (A to C). The default values used for accuracy of position are:

A = 9 x 9

B = 34 x 34

C = 75 x 75

D = no value

The AOU contained in the track file is expanded at the rate of .67 miles/minute and compared with the AOU contained in the incoming report. If the incoming report AOU is less than the expanded track AOU, the track is updated. If the incoming AOU is greater than the expanded track AOU, the position is not updated and the proper notation is made in the report log.

The manual correlation processing involves the site operator to resolve ambiguities associated with non-correlated reporting data. The operator is concerned only with selected non-cooperative vessels since the software will be able to automatically associate all cooperative vessels with the corresponding data in the track file and provide similar association for a significant number of the non-cooperative population.

5.7 COMPUTER SYSTEM REQUIREMENTS

Assessment of information processing capability required in each OTIS regional center and in the national center considered the projected vessel traffic, message traffic, length of messages, expected information flow from additional sources (remote sensors, CG ancillary reports, and outside agency data bases) and the estimated information user requests. For this conceptual design it was determined that a reasonable approach for sizing the computer for OTIS would be to extrapolate specifications from an existing operational stations, the various vessel traffic service systems, and the offices such as the Captain of the Port and the Marine Safety Office. These components are currently functioning well and in most instances performing specialized tasks unique to their roles. The new systems and techniques initiated with OTIS provide information on vessels in parts of the U.S. Fishery Conservation Zone requiring extensive coverage - both in the time spent and in the area covered - that existing resources cannot undertake without jeopardizing, or compromising, the performance of their first responsibilities.

In summary, the new components for OTIS are to supplement current CG systems in monitoring more efficiently an increased area of coverage. The underlying objective of OTIS is for the system to be a center for collecting vessel movement information and for providing this information to those in need of it in a form for immediate use in responding to the range of situations occurring at any given time. In this regard, the concept for OTIS is to provide a framework in which both current and new information sources are organized and focused to the Coast Guard functions, providing information to the decision-makers so that they can determine where CG resources should be deployed. OTIS is a valuable tool to the Command and Control Manager. It provides significant data that only a centralized data collection and correlation processor can provide. This is the reason why the military has a facility such as the OSIS which features a powerful correlation processor.

It is clear from examination of the alternatives that the monitoring of all vessels greater than 40 feet requires a rapid acquisition, time-ordered communications system such as a shorebased polling system that interrogates vessels within 20-nm of shore by VHF digital links and those beyond 20-nm by a satellite link. The waiting times of HF channels are too long to handle the traffic of all vessels over 40 feet. However, if the vessels to be monitored are eliminated at 100 feet, then an HF-polled system will work. A random access system in which vessels initiate reports at prescribed waypoints will function with HF and VHF links if the population of vessels in the system excludes all vessels less than 100 feet and all recreational vessels completely.

This latter vessel population group would be a reasonable size group for prototype evaluation of an all-cooperative monitoring system with voice radio reporting. It would be best to limit the geographical area to one coastal region in order to evaluate operational problems and to develop procedures.

5.9 REFERENCES

1. Offshore Vessel Traffic Management (OVTM) Study, CG-D-55-78. 3 vols. U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, Cambridge MA, August 1978.

2. Gutman, G.A. "Should My Ships Use Sitor or MARISAT?" Symposium Papers, Vol. 1, Radio Technical Commission for Marine Services, April 1980.

3. LaRosa, R. M. "Maritime Satellite Requirements and Utilization," Symposium Papers, Vol. 2, Radio Technical Commission for Marine Services, April 1977.

4. Baker, J. L. "Satellite-Aided Vessel Monitoring and Traffic Advisory System," Symposium Papers, Vol. 1, Radio Technical Commission for Marine Services, April 1980.

5. Thompson, P. M. and J. C. Reame, "Identification of Vessels on a Radar PPI by VHF Direction Findings," Symposium Papers, Vol. 2, Radio Technical Commission for Marine Services, April 1978.

6. INMARSAT Radio Determination Economic Assessment: Engineering and Economic Assessment, Vol. 2. U.S. Department of Commerce, U.S. Maritime Administration, March 1978.

7. Offshore Traffic Information System (OTIS) Study, DTS-57-80-C-00066, Lockheed Missiles and Space Company, Inc., Sunnyvale CA, July 1980.

6. COST-EFFECTIVENESS ANALYSIS

6.1 INTRODUCTION

The cost-effectiveness analysis presented here assesses the benefits of the Offshore Traffic Information System (OTIS) to Coast Guard programs[1] and to marine users. The analysis is based on the Coast Guard program structure that was in effect prior to 1 May 1980 (Table 6-1). Use of the former organizational structure for the costing analysis is necessitated by the absence of substantial historical data, and detailed program descriptions and operating plans for the new programs. Therefore, where the missions analysis (Section 2.2.1) refers to 14 programs (12 of which have VMS applicability), this section names and refers to 13 programs (11 of which are VMS-related). Table 6-1 illustrates the recent reorganization of Coast Guard programs and clarifies this section's use of the old order. In this section, the principal discrepancy with Section 2 revolves around the cost assessment of the Marine Environmental Protection (MEP) mission as one of the three primary-use missions for a VMS. (In May 1980, the Marine Environmental Protection mission merged with the Port Safety and Security (PSS) mission, giving rise to these three new missions -- Port and Environmental Safety (PES), Pollution Response and Environmental Coordination (PREC), and Waterways Management (WM). [Cf. Section 2.1.1.] Of these three new missions, the PES mission is -- for the VMS study -- the one which most closely corresponds to the MEP mission.)

With regard to the maritime population, the user cost benefits are discussed for three of the four classes of vessels — large commercial, small commercial, and fishing vessels. Attention to user costs is salient for these groups because portions of their vessel population are subject to regulation. Consideration here of recreational vessels, however, has been suspended because (1) only 12 percent of these vessels could be expected to participate in a VMS; (2) only 2 percent would be willing to purchase the necessary communications equipment; and (3) as a whole, the recreational vessel group is unregulated.

The cost analysis first reviews the operating costs of the Coast Guard programs (i.e., the program structure prior to 1 May 1980) as well as the current costs for users to operate vessels under typical circumstances. Then,

b. estimating the costs that would be incurred by the Coast Guard if OTIS was implemented (i.e., cost estimates for all three alternative implementations are developed);

c. determining the direct and indirect benefits to the Coast Guard resulting from the implementation of OTIS; and

d. estimating the cost savings to Coast Guard programs and marine users (i.e., under typical operating situations and conditions) which can be achieved with OTIS implementation.

The cost-effectiveness analysis involves four steps:

1. The first step develops cost estimates for each of the 13 Coast Guard programs. Additionally, cost estimates are developed for the two principal modes (cutters and aircraft) utilized by the Coast Guard in their monitoring and surveillance programs. Included in the latter estimates are: personnel compensation costs, operating and maintenance costs, electronics program costs, craft program costs, shore unit program costs, operating costs for cutter and aircraft, and total costs. In addition, the operating hours per year for cutters and aircraft are estimated. All cost estimates are developed for each of the 12 Coast Guard districts.

2. The second step estimates the costs that the Coast Guard would incur from the implementation of OTIS. Cost estimates for three OTIS implementation alternatives are developed for four regions: the East Coast, the Gulf Coast and Caribbean, the Pacific Coast (including the Hawaiian Islands), and the Alaskan Coast. The costs for each region have been determined by estimating the cost and the quantity of hardware required as well as the operating and maintenance costs.

3. The third step identifies which of the 13 Coast Guard programs would be affected by the implementation of OTIS and develops estimates of the potential savings to those programs that would receive significant benefits. This involves an examination of each program to assess whether or not it will be affected. Additionally, the direct and indirect benefits to the Coast Guard are determined. This is accomplished by examining the elements involved in each program and assessing the impact that OTIS will have on each. An

TABLE 6-2. U.S. COAST GUARD PROGRAMS

SAR	- Search and Rescue
SRA	- Short Range Aids to Navigation
RA	- Radionavigation Aids
BA*	- Bridge Administration
DI	- Domestic Ice Operations
CVS	- Commercial Vessel Safety
RBS*	- Recreational Boating Safety
PSS**	- Port Safety and Security
MEP**	- Marine Environmental Protection
ELT	- Enforcement of Laws and Treaties
MSA	- Marine Science Activities (includes Polar Ice Operations)
RT*	- Reserve Training
MP	- Military Preparedness

*These programs do not involve monitoring and surveillance.

**These two programs have recently been redefined, changing from two to the following three programs: Port and Environmental Safety, Pollution Response and Environmental Coordination, and Waterways Management. However, the analyses of costing and effectiveness presented are based on the two previous programs because of availability of data and detailed program plans.

Approximately $279 million, or 28.3 percent of the total amount, was allocated to the Search and Rescue (SAR) program; this represents the largest amount of funds allocated to any program. The SAR program also employed the largest number of people of the seven programs considered -- 12,262, or 28.3 percent.

The funds allocated to Aids to Navigation (AN) amounted to $253 million, or 25.6 percent of the total amount. The AN program employed 11,104 individuals, or 25.6 percent of the total personnel employed by all seven programs.

The Enforcement of Laws and Treaties (ELT) program ranked third among seven programs in terms of funds allocated to it, 18.8 percent, and personnel employed, 16.8 percent.

The Marine Safety (MS) program ranked fourth in terms of funds and personnel allocated to it, 13.4 percent for both.

The Marine Environmental Protection (MEP) program ranked fifth in terms of funds and personnel allocated to it, 7.0 percent for both.

The Marine Science (including Polar Ice Operations) and the Military Readiness programs ranked sixth and seventh, respectively, in terms of funds and personnel allocated to them.

Of the total funds ($986 million) allocated to all seven programs, $445 million represents costs associated with the deployment of cutters, aircraft, and other services in support of the missions. The balance of the funds are related indirectly to the mission, in such areas as travel and transportation of persons, personnel benefits, and others. Because of data limitations pertaining to the latter cost components and the degree of complexity in analyzing them, this analysis was limited in scope to assessing the costs which were directly charged for the operation of cutters, aircraft, and other services in support of the missions. It should be pointed out, however, that future research should be directed towards the assessment of the other cost elements.

6.2.2 Cost by Program

To estimate the range of probable savings that each Coast Guard program could attain with OTIS implementation, it is necessary to determine the costs

TABLE 6-4. OPERATING COST OF CUTTERS AND AIRCRAFT BY PROGRAM

PROGRAM	FUNDS ALLOCATED FOR CUTTERS IN THOUSANDS OF DOLLARS	FUNDS ALLOCATED FOR AIRCRAFT IN THOUSANDS OF DOLLARS	TOTAL
Search and Rescue (SAR)	$ 11,089	$ 54,118	$ 65,207
Short Range Aids to Navigation (SRA)	34,490	8,200	42,690
Radionavigation Aids (RA)	1,364	4,289	5,653
Bridge Administration (BA)	4	-	4
Domestic Ice Operations (DI)	9,571	1,981	11,552
Commercial Vessel Safety (CVS)	35	484	519
Recreational Boating Safety (RBS)	622	328	950
Port Safety and Security (PSS)	1,750	716	2,466
Marine Environmental Protection (MEP)	1,257	20,437	21,694
Enforcement of Laws and Treaties (ELT)	73,205	27,257	100,462
Marine Science Activities (MSA)	5,169	2,550	7,719
Polar Ice Operations (PO)	15,767	2,610	18,377
Military Preparedness (MP)	12,812	295	13,107
TOTAL	$167,135	$123,265	$290,400

TABLE 6-6. TOTAL FUNDING BY PROGRAM

PROGRAM	FUNDS ALLOCATED IN THOUSANDS OF DOLLARS*
Search and Rescue (SAR)	$128,437
Short Range Aids to Navigation (SRA)	55,556
Radio-Navigation Aids (RA)	7,222
Bridge Administration (BA)	215
Domestic Ice Operations (DI)	12,101
Commercial Vessel Safety (CVS)	17,978
Recreational Boating Safety (RBS)	8,795
Port Safety and Security (PSS)	19,411
Marine Environmental Protection (MEP)	40,522
Enforcement of Laws and Treaties (ELT)	114,583
Marine Science Activities (MSA)	8,111
Polar Ice Operations (PO)	18,847
Military Preparedness (MP)	13,358
TOTAL	$445,136

*These estimates were derived from Tables 6-4 and 6-5.

For each implementation, costs are estimated for:

a. research and development, and prototype evaluation;

b. acquisition, construction, integration, and operation and maintenance for oceanographic regions (the East Coast, Gulf and Caribbean, Pacific Coast, and Alaskan Coast); and

c. acquisition, construction, integration, and operation and maintenance for a national facility.

6.4.1 Assumptions of the Cost Analysis for Coast Guard Implementation of OTIS Alternatives

OTIS Alternative One assumes 100 percent mariner cooperation. This implies that mariners will voluntarily report their vessel identification, position, course, and speed directly to Coast Guard shore stations. OTIS Alternative Two assumes zero percent cooperation from mariners. Vessel position, course, and speed must be determined using remote sensing devices. OTIS Alternative Three assumes that 17 percent of the vessels will be cooperative and 83 percent will be noncooperative. The system resources for each type of vessel have been increased a small percentage to 20 percent for cooperative and 85 percent for noncooperative to assure full accommodation of all vessels in each group.

The cost estimates for OTIS Alternative One, Two, and Three were derived from the following assumptions:

1. Alternative One

   a. All costs are in 1980 dollars, no inflation added.*

   b. The research and development phase occurs in 1981.

   c. The prototype evaluation phase occurs in 1982.

   d. The operating costs associated with the prototype evaluation phase represent a 6-month operation period occurring in 1983.

   e. All equipment for the complete system is bought in 1984.

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*Present value costs were computed using a 10 percent discount rate per year as defined in OMB Circular A-95, 27 March 1972.

quantity of hardware required for the radio shore station, the national OTIS facility, and the operational commander facilities. Operating and maintenance costs, personnel costs, and personnel training costs were then added to the hardware estimates in each category, as appropriate, to derive the total cost of each facility. Two billets per radio shore station are included in personnel costs with the assumption that part of the added operations are handled by the system being automated. These cost estimates do not include additional VHF and HF radio transceiving equipment consisting of audio modulator/demodulator, transmitter up-converter and power amplifier, receiver RF amplifier and down-converter, and antenna with coupler (Figure 6-1). It is estimated that this additional equipment, if required over and above the current radio station equipment, will cost approximately $4 million for investment and $1.2 million annually for operation and maintenance for each of the VHF and HF networks.

Based on the estimates presented in Tables R-2 through R-5, it will cost $5.3 million, $4.2 million, $4.7 million, and $8.5 million to implement OTIS Alternative One in the East Coast, Gulf and Caribbean, Pacific Coast, and Alaskan Coast, respectively. Additionally, a national facility is required for OTIS Alternative One. The costs associated with the national facility (Table R-6) amount to $1.6 million. The total cost of implementing Alternative One would amount to $25.9 million in 1980 dollars. Included in this estimate are operating and maintenance costs from 1986 through 1990.

6.4.3 Cost Estimates for Coast Guard Implementation of OTIS Alternative Two

Costs for OTIS Alternative Two were developed in the same manner as those for Alternative One. Since Alternative Two is based on use of airborne sensors to gather data on vessel position, course, and speed, the system costs are much greater than those for Alternative One. Table S-1 shows that costs associated with the development and prototype evaluation phases amount to $21.5 million.

Tables S-2 through S-5 present the costs associated with buying the equipment and operating the system from 1987 through 1990. It will cost $10.9 million, $14.9 million, $33.6 million, and $47.4 million to implement Alternative Two in the East Coast, Gulf and Caribbean, Pacific Coast, and Alaskan Coast, respectively. Table S-6 shows the cost of the national OTIS facility, which amounts to $1.3 million. Thus, it will cost $129.6 million to implement Alternative Two.

6.4.4 Cost Estimates for Coast Guard Implementation of OTIS Alternative Three

This system is a combination of Alternative One and Alternative Two. In developing the cost estimates it was assumed that the system will utilize 20 percent of the OTIS Alternative One equipment and 85 percent of the OTIS Alternative Two equipment. Table T-1 shows that the costs associated with the development and prototype evaluation phases amount to $22.4 million. Tables T-2 through T-5 present the costs associated with buying the equipment and operating the system from 1987 through 1990. It will cost $10.0 million, $13.3 million, $39.3 million, and $39.9 million to implement Alternative Three in the East Coast, Gulf and Caribbean, Pacific Coast, and Alaskan Coast, respectively. Table S-6 estimates the cost of the national facility for Alternative Three to be $1.3 million. Thus, it will cost $126.2 million to implement Alternative Three.

Table 6-7 summarizes the total implementation costs for Alternative One, Alternative Two, and Alternative Three of OTIS.

6.5 USER COSTS AND BENEFITS

6.5.1 Costs and Benefits for Users of OTIS Alternative One

The costs to the user for the purchase of equipment to operate upon implementation of OTIS Alternative One are presented. The items of new equipment and the associated users are:

a. HF and VHF data modems* - large commercial, small commercial, and fishing vessels

b. message encoder** - fishing vessels

Developed from the vessel population given in Section 3 are the estimated number of users of each type of equipment, the subregion of the ocean in which the vessels tend to operate, and a subjective estimate of the percentage of

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*Based on the digital selective calling (SELCALL) system specified in CCIR recommendation 493-I for marine radio communcations.

**message scrambling technique applied to position data.

types of vessels that would choose to use each particular type of equipment. The same estimation process was performed in the development of the communications sizing in Section 5.5. The results of this analysis are:

a. HF Data Modems-	2910 Vessels at $3K each, total initial cost = $8.73 million
b. VHF Data Modems-	6660 Vessels at $3K each, total cost = $19.98 million
c. Message Encoder	8210 Vessels at $1.5K each, total cost = $12.315 million
d. Annual Operation and Maintenance-	17,780 Equipments at $200 each per year, total cost = $3.556 million.

Therefore, the total investment is estimated at $41.025 million. Assuming that the system becomes fully operational in 1986 and the vessels are given two years (1984-1986) to become equipped with one-half of the vessels purchasing equipment each year, the total cost in 1980 dollars is $29.41 million with annual <u>operating costs</u> of $1.82 million in 1987.

Using the average daily operating costs identified in Section 6.3, the benefits are calculated for the three classes of vessels:

a. If each large commercial vessel equipped with the OTIS equipment listed previously were to save one day of dead (lost) time per year in getting into port (by participating and receiving reports of weather, navigation aids, or port condition advisories), the monetary savings would equal $58.2 million, which, discounted to 1980 dollars from 1986, is $29.86 million.

b. If one-half the small commercial vessels in 1986 save one day of dead time per year from their participation in OTIS, the savings would be $17.08 million in 1980 dollars.

c. If, in one year, one-fourth of the fishing vessels listed above save $6000 worth of fish because of their participation in OTIS, the savings equal $12.32 million, or, in 1980 dollars, $6.32 million.

be applied to the costs and benefits presented in Section 6.5.1. The resulting user costs are:

a. HF Data Modems	1055 vessels at $3K each, total initial cost = $3.165 million
b. VHF Data Modems	1777 vessels at $3K each, total initial cost = $5.316 million
c. Message Encoder/Decoder	1054 vessels at $1.5K each, total initial cost = $1.581 million
d. Annual Operation and Maintenance	3881 equipments at $200 each per year, total = $0.776 million

Total costs are $10.062 million, or $6.656 million in 1980 dollars. The benefits that accrue for the three examples in Section 6.5.1 are: large commercial - $23.9 million, small commercial - $3.76 million, and fishing vessels - $1.39 million (in 1980 dollars).

The costs and benefits to the user for the three alternatives are shown in Table 6-8.

6.6 EFFECTIVENESS ANALYSIS

In order to determine the benefits potentially achievable by OTIS, an analysis of the three primary-use programs was conducted. The programs specifically assessed for cost-effective OTIS implementation were the Marine

TABLE 6-8. SUMMARY OF USER COSTS* AND BENEFITS

	ALTERNATIVE ONE	ALTERNATIVE TWO	ALTERNATIVE THREE
COST	$29.41M	0	$10.06M
BENEFITS	$53.26M	Large, but not measurable	$29.05M

*All cost and benefit estimates are in 1980 dollars.

TABLE 6-9. ELEMENTS OF THE MARINE AND ENVIRONMENTAL PROTECTION PROGRAM

ELEMENT	IMPACT OF OTIS
1. Monitor liquid bulk transfer operations of oil or hazardous substances.	No Impact
2. Board tank vessels to ensure compliance with oil and hazardous substance discharge prevention regulations.	No Impact
3. Conduct surface patrols of essential harbor areas.	5-10% Reduction in Boat Hours[1]
4. Conduct patrols of remote harbor areas.	25% Reduction in Boat Hours[1]
5. Spotcheck liquid bulk waterfront facilities.	No Impact
6. Inspect liquid bulk waterfront facilities.	No Impact
7. Survey liquid bulk waterfront facilities.	No Impact
8. Send monitor to scene of oil discharge to ensure adequate removal, ..., send monitor to scene of all hazardous substance discharges.	2-5% Reduction in Aircraft Hours[2]
9. Remove polluting discharges when responsible party fails.	No Impact
10. Conduct aerial surveillance flights in port areas handling over 10 million tons of petroleum per year.	25% Reduction in Aircraft Hours[2]
11. Conduct coastal surveillance flights over territorial waters, contiguous zone and the prohibited zone.	80% Reduction in Aircraft Hours[2]
12. Send Coast Guard representative to scene of all reported polluting discharges; follow through with investigations in support of enforcement actions taken.	No Impact
13. Conduct Surveillance of Ocean Dumping Operations	No Impact

[1] There is a reduction of 10 man-hours for each boat hour that is eliminated due to OTIS.

[2] There is a reduction of three man-hours for each hour of aircraft time that is eliminated due to OTIS.

to operate the vehicles (boats and aircraft) as well as operating and maintenance costs. The total estimated savings that could result in the MEP program from OTIS is between $10.8 and $12.1 million per year.

6.6.2 Enforcement of Laws and Treaties

Included in the ELT program are four subprograms, all of which involve monitoring and surveillance of vessels at various capacities. There are:

- Enforcement of Fisheries Management and Conservation
- Drug and Contraband Smuggling Enforcement
- Terrorist Activities
- Enforcement of the Offshore Economic Zone*

In 1979, a total of $165.9 million was allocated to the ELT program and was distributed as follows:

- Cutters operation	$73.2 million
- Aircraft operation	$27.3 million
- Shore Units operation	$14.1 million

The balance represents indirect costs such as transportation of personnel, retirement pay, and others. In 1979, approximately 17,831 aircraft flight hours, charged to the ELT program, were distributed to Fisheries Management and Conservation (37.7 percent) and to the Control of Drug and Contraband Smuggling (59.2 percent). The balance was allocated to the other two subprograms. Cutters accounted for approximately 160,470 operating hours, of which 52,470 were devoted to Fisheries Management and Conservation and the balance to all other subprograms.

Apparently the majority of resources are devoted to the fisheries management and the drug control subprograms; implementation of OTIS would principally affect these two. The above-mentioned information, with the cost

*This is anticipated to be a requirement by the mid-1980's but is not included in this analysis.

3. The cutter's role in detection and identification can provide the basis for scheduling aircraft patrols[7].

Table 6-11 shows the anticipated patrol aircraft hours and ship days to fulfill the enforcement standards in 1978. In 1979, because the number of fishing vessels in the U.S. waters was reduced from 324 to 286 per month, the number of patrol hours per aircraft was reduced from 9,345 (1978) to 6,719 hours. Similar data do not exist for cutters. Approximately 80 to 90 percent of all foreign vessels are greater than 40 feet in length. The balance represents principally small Canadian vessels fishing in the Atlantic (Maine) and Alsaka, and a few small Mexican vessels fishing in the Gulf and the Southern Pacific. It would be safe to assume that all large foreign vessels will register in the OTIS data base. U.S. authorities could either deny permits to noncooperative countries or reject applications to review permits of noncooperative vessels.

If OTIS is implemented, Coast Guard and National Marine Fisheries Center personnel would have at their disposal data to determine the fix of foreign vessels within 0.25 nm accuracy. This accuracy is assumed because most foreign fishing vessels are likely to be equipped with LORAN-C and/or satellite equipment. This equipment is used to relocate fishing areas and to navigate safely and effectively since these vessels sail to U.S. waters from overseas (U.S.S.R., Japan, Spain, and other countries).

Assuming that 80 percent of all aircraft flight hours are devoted to patrolling the foreign vessels, a number of aircraft flight hours could be saved because the Coast Guard would no longer have to monitor the position of the foreign fishing vessels by utilizing aircraft. However, a small number of flight hours would still be necessary to make the presence of U.S. enforcement units visually apparent. It can be expected that 20 percent of the current flight time may suffice to serve this purpose. Thus, approximately 1,075 aircraft hours would be needed for this function (6,722 flight hours devoted to fishery management x 0.80 number of flight hours devoted to the patrol of foreign fishing vessels x 0.20 expected flight hours to make apparent the presence of enforcement units). Potentially, approximately 4,302 flight hours per year could be saved if OTIS were implemented.

This analysis is valid for all vessels greater than 100 feet in length because they may be sensored effectively by OTIS. However, the probability of sensoring vessels 40 to 100 feet is assumed to be 0.50. Vessels 40 to 100 feet comprise 10 to 15 percent of the total foreign fishing population and operate principally off the coasts of Maine, California, and Washington. Since these vessels represent a small portion of the total population, it is assumed that they could be monitored and surveyed from the aircraft conducting routine flights without requiring additional aircraft hours.

Cutter patrols serve the purpose of collecting information on the operations of foreign fishing vessels by "boarding" them to check the amount of catch, species caught, mesh size of nets, and other relevant data. Though this function would become more effective by utilizing OTIS information, for obvious reasons it is not desirable to decrease the number of foreign vessel boardings. The number of hours required to carry out the other two functions (to provide the basis for scheduling aircraft patrol and to provide a physical presence in the fisheries) could be reduced.

In 1979, approximately 52,470 cutter hours were devoted to enforcement of fisheries laws, but it is now known how many hours were distributed to each of the three functions. Cutters and aircraft are deployed on a multimission basis and it is difficult to separate the time spent on each specific mission. For illustration purposes it can be assumed that boarding operations absorb 50 percent of all hours, collecting data to schedule aircraft patrols absorbs 25 percent, and providing for physical presence utilizes 25 percent. Since OTIS will provide all information required to schedule aircraft patrols, the cutter hours allocated for this purpose could be eliminated completely. The function of the physical presence would no longer be necessary because it could be provided by the boarding of foreign vessels. Thus, in theory, approximately 50 percent reduction of cutter operating hours could be achieved. The total savings for aircraft and cutters resulting from OTIS implementation would amount to $17,856,549. This figure was obtained as follows:

Aircraft	4,302 flight hours saved x $1,437 average cost per flight hour = $6,181,974 per year

units would be noncooperative vessels. Assuming that the majority of the non-drug smuggling vessels greater than 40 feet are cooperative units, any drug smuggling vessel would create a discrepancy in the number of vessels which are supposed to operate in a given region.

In that case, the Coast Guard could contact the "suspicious" vessel to identify its name, type, cargo, destination, and other relevant data. These data could be correlated with EPIC records to determine whether further action (e.g., boarding the vessel to inspect it) is necessary. Although this operation would become more effective with OTIS, it is not clear what the reductions of aircraft flight and cutter operating hours would be. The state-of-the-art sensors to be utilized can monitor all vessels greater than 100 feet. Since the majority of vessels involved in drug smuggling (80 percent) are 40 to 100 feet in length, a continuous patrol effort would still be required. It can be expected that the current level of the total patrol effort could be reduced 15 to 25 percent. This reduction in patrol effort represents approximately $7,570,000 to $12,615,000 savings per year.

6.6.3 Search and Rescue

The approach selected to analyze the impact of OTIS on this program consisted to two steps:

1. The first step was to estimate what percent of SAR missions would be affected by OTIS. Figure E-2 shows that approximately 94.2 percent of all units assisted are vessels; the balance are aircraft, land vehicles, structures, and individuals. Since OTIS would primarily benefit vessels, the percent of SAR missions to be affected by OTIS can be assumed to comprise approximately 94.2 percent of all missions. Approximately 78.2 percent of all vessels assisted are recreational vessels, 11.9 percent are commercial fishing, 2.0 percent are merchant, 0.6 percent are tug/tow, 0.2 percent are naval, 0.1 percent are oceanographic vessels, and 7.0 percent are various other types of vessels. The majority of recreational vessels assisted, 64 percent, were less than 40 feet in length. By definition, the OTIS monitoring and surveillance capability is constrained by the length of the vessel.

additional vessel monitoring data. Table 6-12 shows various search statistics. Approximately 47 percent, or 35,432 distress cases, involved some searching effort to locate distressed vehicles. Of those, 30,324 were successful operations; in 5,108 cases the search effort failed to locate the units. Furthermore, in 11,255 additional cases the search failed to locate persons and property. Assuming that all 29 percent of the vessels affected by OTIS (i.e., those greater than 40 feet in length) are cooperative vessels, these vessels would represent 8,794 cases (30,324 x 29%). On the average, the Coast Guard meets its locating standard (45 minutes or less) 71 percent of the time[6]. Assuming that, because of OTIS, this time is reduced to 20 or 30 minutes, each cooperative vessel would require 10 to 20 minutes less time to be located by the Coast Guard. Thus, the product of the multiplication (8,794 cases x 71% = 6,244 cases) represents the number of cases located within 15 to 25 minutes or less, 71 percent of the time. The total time saved by OTIS would be 1/3 hours x 6,234 cases = 2,078 hours or 1/6 hours x 6,234 cases = 1,039 hours. Applying an average cost of $941 per operating hour (average operating cost for cutters and aircraft), it can be determined that potential savings from these cases are $978,000 to $1,955,000. The remaining 29 percent, or 2,560 cases, usually require more search time. Assuming that the time required to search for these cases is reduced by 30 to 40 minutes per case, potential cost savings would represent $1,204,000 to $1,606,000.

Furthermore, it can be expected that a percentage of the 16,333 cases representing the "searched but failed to locate the distressed vessel" group would have been carried out successfully. It is assumed that approximately 29 percent, or 4,736 cases, would correspond to cooperative vessels greater that 40 feet in length. Because of their complicated nature (poor weather conditions, distance from shore, and other factors) these cases involve more search time than less complicated cases. Assuming that first, these vessels are located, and second, the time required to search and locate these distressed vessels, persons, and property is reduced by 40 to 50 minutes per case, potential cost savings would range from $2,971,000 to $3,714,000.

The total potential savings to Coast Guard SAR effort could range between $5,153,000 to $7,275,000 per year.

6.7 SUMMARY OF EFFECTIVENESS ANALYSIS

Three Coast Guard programs (MEP, ELT, and SAR) involving the monitoring and surveillance of vessels were examined and analyzed to determine how they will be affected by OTIS implementation. In addition, an attempt was made to estimate potential savings achievable from OTIS implementation. The latter estimates are not exact figures but they indicate the magnitude of potential savings. Based on the analysis, it can be concluded that savings associated with the Enforcement of Laws and Treaties would amount to $30.5 million; Marine Environmental Protection, $12.1 million; and Search and Rescue $7.2 million. Thus, total savings for these three programs would amount to $49.8 million per year.

A combination system (i.e., OTIS Alternative Three) of 20 percent cooperative reporting and 85 percent remote sensing was identified as the most acceptable, desirable, and feasible of the VMS options for the greatest sector of the marine user population. (The five percent overlap in coverage is intentional.) The costs and benefits of OTIS Alternative Three indicate that this combination cooperative/noncooperative system would be cost-effective for both the Government and the user (i.e., the vessel owner/master). In 1980 discounted dollars, these cost benefits are:

	Initial Cost (1981-86)	Operating Cost (annual starting from 1987)	Benefits (annual starting from 1988)
Government	$45.4 M	$20.0 M	$49.8 M
User	$10.6 M	$ 0.8 M	$29.0 M

This discussion has pointed out the impact that OTIS will potentially have on the cost of current Coast Guard programs. The analysis was based on limited data with additional constraints stemming from the multimission character of Coast Guard operations and from the numerous and highly variable factors influencing the mariners' daily operations. Thus, the purpose of the analysis was to indicate the approximate magnitude of savings to the Coast Guard and to the mariners, rather than calculating the savings in a precise manner. Precise estimation of reductions in CG aircraft flight time,

4. Aviation Operating Cost for Fiscal Year 1979, U.S. Coast Guard, Washington DC, 1980.

5. Operating Cost of Shore Units for Fiscal Year 1979, U.S. Coast Guard, Washington DC, 1980.

6. SAR Statistics - 1978, COMDTINST M16107.1, Search and Rescue Division, Office of Operations, U.S. Coast Guard, Washington DC, 13 March 1979.

7. USCG Search and Rescue Operating Program Plan FY82-91, Office of Operations, U.S. Coast Guard, Washington DC, January 1979.

8. Patrol and Boarding Standards for Fishery Enforcement, U.S. Coast Guard, Washington DC, 1978.

7. IMPLEMENTATION CONSIDERATIONS

The range of feasible and desirable VMS application schemes considered here includes the three implementation alternatives for OTIS and other OTIS related alternatives involving Coast Guard activities.

7.1 IMPLEMENTATION OF THREE OTIS ALTERNATIVES

For each of the three alternative OTIS applications, there are three phases of implementation: development, prototype evaluation, and full-system implementation for coverage of all of the U.S. Fishery Conservation Zone (FCZ).

7.1.1 Implementation of Alternative One

Implementation of OTIS Alternative One is based on the assumption that all vessels are participating cooperatively. In the development phase for the cooperative system, the following items require design and development to fit this particular application:

1. Interface unit to perform temporary data storage, format organization and timing for input to HF and VHF data link transmitting equipment.
2. Level I Processor to perform digital signal clean-up and buffering between HF and VHF receivers and the regional computer. The receivers and computer are connected by land line communications equipment. (It may be feasible to combine the Level I Processor in the same housing with the Interface Unit.)
3. Computer specification and software package.
4. Voice-to-digital converter to interface with the audio input and output of VHF and HF voice transceiver equipment to perform: (a) conversion of radio-received voice reports from vessels to digital data format for direct input into the OTIS regional computer, and (b) conversion of computer digital data output into voice for input to the VHF and HF transmissions to the vessels.*

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*This concept is based on an FAA development of a computerized voice response system for flight service station upgrading.

Costs for the three phases (in nondiscounted dollars) are: Development - $435,000; Evaluation - $1.504 million; and Complete System - $12.052 million, plus $12.884 million operating costs per year for the government and user equipment. Total cost will be $41.025 million, plus $3.556 million per year operating cost.

7.1.2 Implementation of Alternative Two

In this implementation, for the sizing of remote sensor capabilities, all vessels are considered noncooperative. However, certain vessels are considered cooperative by regulation: foreign fishing and hazardous-cargo-carrying vessels. It is assumed that this latter group will carry a government-provided transponder of simple design for identifying and locating these vessels as part of law enforcement activities. Other vessels will be encouraged to carry this equipment to lessen the workload on the remote sensor data processor. The implementation of this system follows the same phases as those of Alternative One.

This alternative of OTIS uses the LOWCOSS radar sensor with either Commercial Aircraft or USCG C-130 aircraft as platforms for the detection of the vessels in the FCZ. A dedicated SATCOM channel is used for communications from the aircraft LOWCOSS sensors and cooperative transponders to the OTIS data processing and correlation facility. The primary OTIS developments are in the aircraft/pod system, LOWCOSS sensor system, and the computer software for the OTIS regional centers. The aircraft-pod developments include the pod design, the aircraft structural modifications for pod attachment, and mechanical and electrical safety features for meeting FAA certification requirements. The ground handling equipment must be developed for transfer of the pod from aircraft to aircraft or to a maintenance area.

The cooperative vessel transponder development for this alternative includes the design, tooling, and manufacturing production preparations. The communication equipment used by the OTIS is all off-the-shelf MIL-STD or commercial equivalent and requires no development.

The implementation schedule is based on a "go-ahead" decision for CY81. The time required for the three phases is:

C-130's were selected because of their altitude and time-on-station capability. RPV's were eliminated in favor of existing platforms in the final consideration because of the $60 million to $80 million in development costs and high procurement costs. If however, additional C-130 platforms are required, only because of OTIS requirements, then RPV's should again be considered. The sensor development cost of $5 million is a Control Data Corporation (CDC) estimate derived from taking a system that they designed, built, and demonstrated some years ago for the U.S. Navy and from tailoring the device for the OTIS application.

In the prototype evaluation phase for OTIS, several of the LOWCOSS systems would be tested in an operational mode over a specific area for a 6-month time period. This evaluation phase would allow OTIS to be debugged in an operational mode and, more significantly, it would determine the size of the vessel population in one, or part of one, of the OTIS areas. It may be that, as a result of the evaluation system, the size of the correlation requirements can be reduced along with the associated costs.

The prototype evaluation system cost estimate is based on the procurement and operation of six sensor pod systems for a 6-month period. For estimating purposes, the East Coast was used as the model region of application. In the procurement phase the greatest cost is in the sensor system which includes six systems, each costing $1.2 million. This figure is from a CDC estimate of $1 million for the LOWCOSS plus 20 percent for the command package, the pod attitude pointing reference system, and costs for the pod itself. Eight commercial and four USCG aircraft would be modified for attaching the pod at the cost of $480,000 ($40,000 each).

The cooperative vessel transponder procurement costs are based on 1770 units at $200.00 each. This number is based upon large commercial vessels, small commercial vessels, and the foreign fishing fleet, all estimated to be operating along the East Coast. In this phase it is suggested that the monitoring system's costs be borne by the program. However, in the operational phase later, these costs might be shared by the subject vessel. The communications costs are based on use of an AN/WSC-3 transceiver and a standard FLTSATCOM antenna.

It should be noted that the C-130 costs are quite high in relation to the

2. User's willingness to buy additional equipment (e.g., data modems and message encoders);

3. Development of a voice-to-digital converter workable with radio quality voice, especially HF ratio;

4. The operational feasibility of a reporting system handling approximately 9,500 users (estimated, in Section 3, for the 3- to 200-nm subzone) using HF radio which has message throughput delays of several minutes to several hours;

5. Obtaining sufficient numbers of frequency allocations for the HF and VHF radio channels required. There are likely to be significant hidden costs in getting and implementing new frequency allocations (e.g., the development of new equipment standards and the replacement cost of current equipment made obsolete);

6. Reliability of system operation with a vessel-initiated reporting scheme. It appears from initial analysis that some form of shore-based polling technique with automatic or semi-automatic vessel reply is the only way to achieve reliable and time-efficient reporting. (Semi-automatic operation is an approach in which the vessel watch-stander manually receives the shore call for a report and replies by simply pushing a designated reply switch which automatically and simultaneously connects the ship's navigation gear to a data encoder, connects the encoder to the ship's transmitter, and energizes the transmitter sending the message to the shore.)

The OTIS Alternative Two has these major risks associated with implementation:

1. The feasibility and airline acceptability of the LOWCOSS pod being carried by a commercial airliner presents many issues of uncertainty to be resolved: e.g., effect on airworthiness, flight certification by the government, interference with navigation instruments or communications radios, acceptance by the flying public, field handling and calibration, and scheduling arrangements that synchronize the place and time of equipped aircraft and pods for the surveillance schedule.

2. The alternative platforms are either costly to operate (e.g., C-130 aircraft) or still in the development phase and require a huge outlay

3. The El Paso Intelligence Center which has Coast Guard personnel on site as part of its joint operation with other departments and agencies contains data and intelligence which OTIS would tap for law enforcement missions support.

4. The Navy Ocean Surveillance Information Center has information and a small Coast Guard staff that is resident and could service the input requirements of OTIS. However, in the course of this study it was discovered that this Navy resource is planning to expand to include a wider variety of vessels and sizes; this will aid the CG missions significantly. To take full advantage of this resource may require that several more Coast Guard personnel be resident at the Navy facility.

5. There are long-standing, close-working relationships between the CG and the U.S. Customs, DEA, Department of Treasury, and DOC-NOAA and DOC-MARAD that provide information of useful input to OTIS.

6. The airborne oil surveillance system (AOSS) and the future AIREYE acquire information of great value to OTIS. The AIREYE will be an excellent tool for rapid deployment and close examination of a localized incident; however, its 3- to 4-hour on-station time indicates useful information about the problem area that is needed to make the best decision about where and when to deploy this aircraft. On the other hand, its high speed makes it an excellent tactical monitor platform for quick response to distant areas, even from one coast to another.

7. The AMVER and EMIS data bases maintain information files on current vessel activities which would be of significant value to OTIS for safety and law enforcement missions, respectively.

8. A regulation for 24-hour notice to U.S. ports of the arrival of vessels with hazardous cargo will provide reports needed by OTIS.

The monitoring and surveillance information that OTIS will provide is the type of vessel movement data needed as an input to the comprehensive Command and Control System (R&D C^2) that the CG Office of Research and Development is designing. As a dynamic, interactive information network, OTIS should be

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

The major issue addressed in this study was desirability and feasibility of shore-station systems for monitoring vessels in the U.S. Fishery Conservation Zone (FCZ). This assessment of shore-station monitoring of vessels was approached from the standpoint of both the Coast Guard's needs and desires, and the marine users' needs and desires.

The Coast Guard represents the major government user and supplier of vessel monitoring services in the U.S. FCZ. The significant conclusions and major recommendations from this study are presented below.

8.2 CONCLUSIONS

1. For any vessel monitoring system (VMS) of the size required to cover the whole U.S. FCZ to be cost-effective, it must be multimission in in nature, serving the needs of all Coast Guard missions that have any involvement in the FCZ as well as the needs of the mariners.

2. A few Coast Guard missions would receive direct benefits (e.g., reductions in flight time and/or operating costs and increases in services and effectiveness) from an offshore VMS; while other missions would receive indirect, or secondary, benefits (e.g., anticipatory planning information to the COTP, assistance in detection of some oil spills, and assistance in detecting outages of naviagation aids).

   The Coast Guard missions that would receive direct benefits are: Port and Environmental Safety, Enforcement of Laws and Treaties, and Search and Rescue. All other missions receive secondary benefits of varying number and degree. However, the importance of these benefits on the basis of individual incidents may be quite large; for example, the situation of providing information to the COTP that enables early warning and preparation for expeditious and safe handling of a hazardous-cargo vessel with navigation equipment difficulties.

3. The benefits that would accrue to mariners participating in a VMS relate to the improved access to information. Specifically, the operation of a VMS would allow the Coast Guard shore station to

5. The vessel monitoring system defined by the Coast Guard and mariner requirements analysis is primarily an information system which collects information from ships at sea, from historical files, from Coast Guard sighting reports, and from other agency reports. The information is then assimilated, correlated, and processed for immediate output to the user on location and in the form required by the Coast Guard operational mission commander and the situation at hand. This same information is also available to the headquarters staff.

Correlation processing of data from many sources with computer analysis techniques is the heart of the system. The correlation processing technique uses partial and incomplete information about vessel identity and movement to develop a more complete description of a situation than is otherwise possible. The system concept is named the Offshore Traffic Information System (OTIS).

Cooperative vessel reports are the most economical means of collecting the desired information on vessels in the offshore waters. Noncooperative vessel detection and tracking by remote sensors provide less data (no identification), and this data is more expensive to acquire. Vessel data in other Coast Guard files and other agency data bases are a major asset to OTIS in that these sources include a variety of unique information available at very little cost. Cooperative vessel reports made once or twice a day from ships at sea together with reports at 12 nm and 200 nm from port are sufficient for general monitoring. Vessel identification permits more frequent communications from shore to ship if a situation requires it, (e.g., a SAR incident may require hourly contact).

OTIS is proposed as a framework for organizing and coordinating many current and planned Coast Guard efforts in offshore monitoring and for making the most use of the information from these sources; and then, supplementing that with vessel reports and remote sensor data only to the extent required for the system to perform the monitoring function. No effort should be expended in implementing any new equipment or resources until full use is made of existing and obtainable information.

over-the-horizon radar offers large area coverage sufficient for the FCZ with only five installations but the lower vessel discrimination limit is 300 feet length and 10 knots radial velocity so this was down-rated as a primary choice.

Department of Defense systems examined revealed that they generally are spot area coverage systems and are focused on other waters than the U.S. FCZ. However, the Navy's expanding Ocean Surveillance Information System potentially offers a significant amount of useful information to the Coast Guard.

A combination system made up of 20 percent cooperative reporting and 85 percent remote sensing was determined to be acceptable (i.e., in cost and performance) to the user. (Five percent overlap in coverage is intentional.) The cooperative reporting initially would be by voice radio (vessel-initiated) at prescribed times or distances from shore. Later, a polled system controlled from shore with a digital SELCAL format such as CCIR specification 493-I would be implemented in order to include more users.

7. The costs and benefits to the government and user (i.e., the vessel owners/operators) of the combination cooperative and remote sensing implementation of OTIS (Alternative Three) indicated that this system would be potentially cost-effective to both groups. The costs and benefits, in 1980 discounted dollars, are shown below:

	Initial Cost (1981-86)	Operating Cost (annual, starting from 1987)	Benefits (annual, starting from 1988)
Government	$45.4M	$20.0M	$49.8M
User	$10.6M	$ 0.8M	$29.0M

8. The combination OTIS (Alternative Three) could be developed and evaluated in approximately 4 years and deployed as a full system covering the whole FCZ in 2 years after evaluation. The major items of risk are:

   a) Feasibility of the airlines carrying the LOWCOSS radar sensor pod on an operational basis and at a reasonable cost.

   b) Production cost and performance of the LOWCOSS radar sensor.

MRS jet aircraft provide valuable information on vessel activities and environmental hazards with the latest area coverage SLAR.

e) Surveillance information (which OTIS can provide) is an integral part of the newly-initiated Coast Guard command and control system development program.

f) The new requirement for vessels bound for U.S. ports and carrying hazardous cargo mandates a notice of arrival to be filed 24 hours prior to arrival.

g) Additional current capabilities include the Coast Guard communications system (long-range radio and terrestrial), the aircraft, cutters, and Coast Guard Stations. Other operations supportive of offshore vessel monitoring are the vessel traffic service (VTS) systems, the Captain of the Port, and the Marine Safety Office.

h) OTIS relies on the support gained from the continuation of long-standing working relationships with other agencies involved in ocean monitoring: U.S. Customs, DEA, INS, the Treasury, Navy, DOC-NOAA, and DOC-MARAD.

10. Alternative long-range communications techniques should be explored continuously and to the fullest extent in an effort to find an acceptable (i.e., in cost and performance) replacement of HF radio for monitoring the FCZ. An attractive approach was demonstrated in the 1979 Baker experiment of VHF satellite (NASA ATS-3) relay of LORAN-C position reporting and digital communications with low-cost user equipment. VHF vessel equipment is low in cost and less complex than current L-Band satellite marine terminals; therefore, it is concluded that the use of lower frequency band satellite communications should be explored at least as an interim approach to long-distance communications until L-Band costs decrease.

The currently recognized operational marine satellite communications system is INMARSAT. This is a multinationally-owned system that came into being in 1978 with concordance of the necessary signatories. This system presently uses MARISAT satellites (three located worldwide) leased from COMSAT General Corporation. The satellites offer study authorized $1 million and two years to perform the work; however, no funds were appropriated and the CG provided limited funds for the work. The results of the study indicate that a VMS of the OTIS type would potentially be cost-beneficial to both the government and the mariner. However, additional studies and evaluations are needed in specific areas to more clearly establish the system technical details and to assess the impact of an OTIS on the current systems and costs for the present operations of both the Coast Guard and the marine community. Those studies and evaluations recommended as follow-on to this study are listed here and discussed below: 1) assessment of the impact of additional terrestrial communications traffic which OTIS would generate between CG facilities, 2) assessment of the impact of OTIS on the CG long-range and short-range radio system including investigation of other alternatives for long-range radio communications, 3) evaluation of the OTIS concept with a small test program, 4) detailed engineering design and costing studies of alternative remote sensors and platforms, and 5) in-depth studies of costs and benefits (both direct and hidden) to the government and the marine user of a complete OTIS implementation.

1. Perform a detailed study of the information traffic flow between the several terminals (radio stations, regional center, group and station facilities, headquarters, and outside agencies) in an OTIS to determine:

    a. The additional message traffic that would be generated by OTIS.

    b. What types and lengths of messages could be expected.

    c. The formatting techniques that provide the most time-efficient, reliable service of low cost.

    d. Conditioning of telephone circuits required for automated transfer of radio messages to a computer interface.

    e. Conditions and causes of traffic loading.

    f. Alternatives for efficiently handling communications traffic peaks.

2.a. Perform a study assessing the impact of OTIS on the Coast Guard's long-range HF, and short-range, VHF, radio communications system. Determine the most cost-effective means of handling this communications traffic, e.g., adding to the Coast Guard facility or leasing for final tradeoff evaluations. The suggested options are: LOWCOSS radar, satellite SAR, and over-the-horizon radar.

5. In-depth studies of costs and benefits to the government and the user are recommended before a decision for new remote sensors or major communications system additions as part of OTIS is made. Secondary benefits of OTIS to other Coast Guard programs should be assessed as well as the OTIS related costs. Similarly, the secondary, or indirect, benefits and costs to the user need to be addressed in detail.

9. BIBLIOGRAPHY

Analysis of the Potential Application of Space Telecommunications Systems to U.S. Coast Guard Missions, FIS-75-0018, Westinghouse Electric Corporation, Baltimore MD, October 1975.

Application of High Altitude Surveillance Aircraft to Future CG Mission Objectives, CG-D-14-77, Lockheed Aircraft Corporation, Burbank CA, July 1976.

Coastal Zone Monitoring Study, Technical Memorandum 120-78, NAS5-25099, Operations Research, Inc., for Goddard Space Flight Center, NASA, October 1978.

Coast Guard Action Needed to Promote Safer Marine Transportation, the Comptroller General, General Accounting Office, 21 May 1979.

Development of a Prototype Airborne Oil Surveillance System, Aerojet Electrosystems Company, Azusa CA, May 1975.

Drug Enforcement, Drug Enforcement Administration, EPIC Annual Progress and Activity Report, September 1978.

Eastern Caribbean LORAN-C User Definition, Project Memorandum, Input Output Computer Services, Inc., Waltham MA, April 1980.

History and Development of the El Paso Intelligence Center: A Report Specially Prepared for the Visit of the Select Committee on Narcotics Abuse and Control, Drug Enforcement Administration, El Paso Intelligence Center, El Paso TX, 26 March 1977.

INMARSAT Radio Determination Economic Assessment: Engineering and Economic Assessment, Vol. 2. U.S. Department of Commerce, U.S. Maritime Administration, March 1978.

Identification, Clarification and Quantification of Surveillance Activities Within the USCG Operating Programs, 2 vols., CG83-230-8B (PAH), MAR, Inc., Rockville MD, September 1978.

Marine Safety Manual, Vol. VI, Ports and Waterways Activities, CG-495, Office of Merchant Marine Safety, U.S. Coast Guard, Washington DC, October 1979.

Nature and Magnitude of CG Operational Law Enforcement Requirements through the Year 2000, DOT-CG-74236-A, Charles W. Williams, Inc., Alexandria VA, February 1979.

Offshore Traffic Information System (OTIS) Study, DTS-57-80-C-00066, Lockheed Missiles and Space Company, Inc., Sunnyvale CA, July 1980.

10. GLOSSARY OF TERMS

AMVER - (Automated Mututal-assistance Vessel Rescue System) - an international program operated by the U.S. Coast Guard designed to assist the safety of merchant vessels on the high seas. Merchant vessels of all nations are encouraged to participate in this voluntary program by sending sail plans and periodic position reports to cooperating radio stations for forwarding to the AMVER Center on Governor's Island, New York. The AMVER Center can then provide a computer-predicted listing of ships in the vicinity of an emergency at sea. Vessel locations are disclosed only for reasons related to maritime safety.

Captain of the Port (COTP) - the officer who is responsible for the CG Port and Environmental Safety mission and who has the overall responsibility for the security and safe operation of the port he is assigned to.

Coastal and Confluence Zone (CCZ) - the region from the coastline or harbor entrance to 50 nm offshore or the edge of the continental shelf (100 fathom curve), whichever is greater.

Collision - the colliding of two vessels when one or both are underway.

Command & Control (R&D C^2) - Coast Guard management and direction of resources for several missions in order to achieve optimal effectiveness; applies to a system the CG Office of R&D recently undertook to develop, update, and improve C^2 operational capabilities.

Commercial Sport Fishing Vessels - vessels engaged in fishing activities for sport fishermen; those chartered by individuals for daily fishing are available on a regularly scheduled basis; others are chartered by groups for longer periods of time.

Contiguous Zone - waters between 3 and 12 mi from U.S. shores.

Cooperative Vessels - vessels that can be expected to actively participate in the monitoring system; use two-way communication with Coast Guard stations to report position location, course, speed, size, type, registration, cargo, and cargo disposition.

of crew/master, seizing of vessel, military action, etc.; this step and all subsequent ones are beyond the scope of a VMS.

Monitoring - the act of observing vessels via land, sea, or space techniques, to determine vessel position, identification, course, and speed. This may be performed either overtly or covertly:

Active Monitoring - involves cooperative reporting between vessels and Coast Guard shore stations.

Passive Monitoring - distinguished as "surveillance," is the covert observation and tracking of a noncooperative vessel, one that evades monitoring; involves no participation of subject vessel, and Coast Guard station; accomplished by remote sensing devices and intelligence data.

Navigation Aids: Long Range Radionavigation - marine navigation aids which are designed for use of radio determination techniques by which a vessel may fix her position; usually employed by a visual when outside visual range of land, buoy, or other navigation objects. Examples: LORAN-C, OMEGA, Marine Radio Beacons.

Navigation Aids: Short Range - marine navigation aids which are designed for visual or audible detection and identification by the mariner for fixing vessel position and bearing. Examples: buoys, lights, whistles, landmarks.

Noncooperative Vessels - vessels that can be expected to actively evade detection; to violate marine laws; or to balk at voluntary reporting of identity, position, course, and speed to the Coast Guard.

Offshore Traffic Information System (OTIS) - the concept design of a system for monitoring vessels within the 200-nm offshore Fishery Conservation Zone.

Offshore Vessel Population - a measure of the maximum number of vessels in each vessel class operating within the U.S. Fishery Conservation Zone during a 24-hr period.

Position Accuracy - a measure of the error between the point desired and the point achieved, or between the position indicated by measurement and the true position. Accurate determination of position is dependent upon the capability of the navigation system to provide precise information, the user's ability to interpret this information, correct geodetic coordinates, and proper cartography

System - a term used in this report in a broad sense to mean all or part of a group of rules, regulations, laws, treaties, national and industry organizations, and equipment which work together to serve a common purpose.

Tank Vessels - includes all tankers, tank ships, bulk cargo carriers and barges used to transport crude oil or petroleum products. As used in this report, tankers, tank ships, and tank barges carry only oil or petroleum products.

U.S. Fishery Conservation Zone (FCZ) - 2.2 million sq mi of ocean along an 8,700-mile perimeter and an 11,650-mile coastal baseline; established by the Fishery Conservation and Management Act of 1976. Defined as area from U.S. coastline out to 200 nm seaward.

USMER - Mandatory reporting system for U.S. vessels over 1,000 GT engaged in foreign commerce. System is operated by DOC-MARAD.

Vessel - any ship, barge, or boat of any size and carrying any cargo.

Vessel Monitoring System (VMS) - a system of land, sea, or space resources to observe vessel position, course, speed, and identification.

Vessel Population - the number of vessels operating inside of and outside of the U.S. Fishery Conservation Zone, including all vessels that are docked at harbors; the base population from which the offshore vessel population is determined.

Vessel Traffic Service - an integrated system including the techniques, equipments, and personnel to coordinate vessel movements and provide advisory information to vessels in or approaching a port or inland waterway for the purpose of improving the safety of all vessels and their crews.

Waters

Navigable Waters of the United States - means territorial seas of the United States, internal waters of the United States subject to tidal influence, and certain internal waters not subject to tidal influence.

Territorial Seas - (a) with respect to the United States, "territorial seas" means the waters within the belt, 3 nm wide, that is adjacent to its coast and seaward of the territorial sea baseline; (b) with respect to any foreign country, "territorial seas" means the waters within the belt that is adjacent to its coast and whose breadth and baseline are recognized by the United States.