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AUG 78 R BLAND, R KALAFUS, R WISLEDER
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OFFSHORE VESSEL TRAFFIC MANAGEMENT (OVTM) STUDY
Volume II — Technical Analyses

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge MA 02142

AUGUST 1978
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Marine Environment and Systems
Washington DC 20590

NOTICE

This technical study examines traffic management alternatives as a means to reduce or eliminate casualties contributing to pollution of the marine environment. Nothing contained in this report should be construed as affecting or changing the Administration's position on offshore claims in general or at the Third United Nations Conference on the Law of the Sea in particular.

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16. Abstract

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The objectives of the study were: (1) to analyze the causes of tanker and other vessel casualties that could potentially result in oil pollution, and (2) to evaluate various alternative vessel traffic management systems and techniques for the prevention of oil-polluting casualties in the U.S. offshore waters. The geographical areas of interest are the waters from the U.S. coast out to 200 NM around the contiguous 48 states, Hawaii, Puerto Rico, the Virgin Islands and Alaska, except the area north of the Aleutian Islands. Three types of casualties are addressed in the study: groundings, collisions, and rammings. Vessels included in the study are tank vessels (tankers and tank-barges) over 1000 gross tons.

The analysis of the causes of tank vessel casualties is performed mainly with the Coast Guard Merchant Vessel Casualty Report (MVCR) data base covering the period from July 1971 to October 1977. Other data sources surveyed include: the Lloyd's Weekly Casualty Reports, the Tanker Casualty Library of Marine Management Systems, Inc., and the Coast Guard Pollution Incident Reporting System. The nature and characteristics of tank vessel casualties that occur in the U.S. offshore waters are described. Systems and techniques considered as alternatives for preventing these casualties are identified, evaluated against each casualty and given an overall rating of casualty prevention effectiveness based on criteria which are defined. The promising systems are selected and conceptual descriptions are presented including the operational features, technical description, cost, staffing and training required, and legal implementation considerations.

The report is organized in three volumes: Volume I -- Executive Summary, Volume II -- Technical Analyses, and Volume III -- Appendixes.

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PREFACE

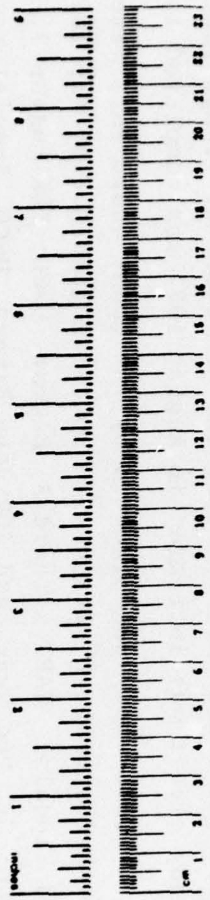
The Offshore Vessel Traffic Management (OVTM) Study was performed in response to Presidential Initiatives issued in March 1977 which were a result of the Argo Merchant oil spill and several other tanker casualties that occurred in the U.S. offshore waters during the winter of 1976-77. These initiatives called for the Secretary, U.S. Department of Transportation, to perform several studies and take other actions to prevent or reduce the effects of oil spills from tank vessel casualties in the U.S. offshore waters. The OVTM Study was referred to in the Presidential Initiatives as "a study of long range vessel surveillance and control systems." The Transportation Systems Center performed this work in support of the U.S. Coast Guard and the Office of the Secretary of Transportation. The study effort was initiated in August 1977 and completed in June 1978.

This study was directed by the Coast Guard Port Safety and Law Enforcement Division with specific guidance by the following individuals: CAPT Richard A. Bauman, USCG; CDR Eugene J. Hickey, USCG; Mr. Don Ryan, and CDR John Bannan, USCG. Special recognition is given to the Coast Guard Project Manager, Don Ryan, for his many helpful contributions to, and close association with, the TSC study team. Other contributors were: CAPT (Ret. USCG) Harold Lynch, CAPT Arthur Knight and CAPT William Mitchell, all of the Boston Marine Society; John Devanney of the Massachusetts Institute of Technology Center for Transportation Studies; and Patricia Concannon and Jeanette Collier of TSC.

METRIC CONVERSION FACTORS

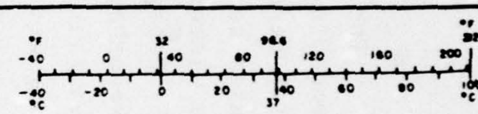
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. CONCLUSIONS AND RECOMMENDATIONS

1.1 INTRODUCTION

This study focuses on tank vessel grounding, collision, and ramming casualties which occur in waters offshore of the U.S. out to 200 NM and are potentially preventable by some type of offshore vessel traffic management (OVTM) system. The term "system" is used in a broad sense to include any combination of rules, procedures, regulations or equipment. Vessels of primary interest to the study include tank ships and tank barges over 1000 gross tons. The major source of data used in the casualty analysis was the U.S. Coast Guard Merchant Vessel Casualty Reports covering the period from July 1971 through September 1977.

The study included two major tasks: a) the determination of the causes of oil polluting casualties in the offshore waters, and b) the assessment of alternative systems for preventing these casualties. An estimated 121 offshore tank vessel casualties occurred during the period of interest (FY72-FY77). Seventy-eight of these cases, which were documented by detailed casualty investigation reports, were analyzed for causal determination and assessment of system alternatives.

1.2 CONCLUSIONS

The conclusions of the study are:

a. The number of tank vessel collisions and groundings that occur in U.S. offshore waters is approximately 9% of the total number of these types of casualties in all U.S. waters. However, this figure does not reflect the propensity for "massive" oil spills (over 1,000,000 gallons) in offshore waters. For example, in 1976, offshore oil spillage reached forty percent of the total, almost entirely due to the grounding and subsequent breakup of the Argo Merchant.

b. Groundings probably constitute the major threat of producing oil spills which may substantially impact the public welfare and environment because these casualties occur close to shore or fishing areas where oil spillage potentially causes the most damage.

c. The casualty that results in a "massive" oil spill is very rare. Only one, the Argo Merchant, occurred in U.S. offshore waters in the six-year period studied. Massive spills due to collisions, groundings and rammings (of offshore oil production/transfer facilities) have occurred worldwide at the average rate of three per year. However, the potential for massive oil spills in U.S. offshore waters does exist and will likely increase along with the projected increases in the volume of tanker traffic and in the sizes of tank vessels. Measures already initiated which will lead to the Baseline system (e.g., dual radars, LORAN-C, etc.) will be helpful in reducing the potential for casualties resulting in massive oil spillage.

d. Costs incurred due to oil spills are highly dependent on the locale and environmental conditions as well as type of oil and spill size, and can run to several million dollars per incident.

e. Many of the factors that contribute to groundings and rammings are unique to the local area, while the factors involved in collisions are generally the same for all areas.

f. The majority (over 90 percent) of offshore casualties occur within 50 NM of the shore; the greatest distance from shore of any casualty in the data base was 108 NM. Therefore, there is little need for any system to provide surveillance coverage to 200 NM.

g. The occurrence of collisions shows strong correlation with weather and reduced visibility, while groundings and rammings do not show such a strong correlation.

h. Rammings of offshore oil platforms rarely result in any oil spill, and very rarely, if ever (none in the data base) cause a spillage of oil from the oil platform itself.

i. Traffic density is not a factor in the large majority of casualties. It is rare that a collision involves a third vessel except in the case of tugs with barges. In 90% of the groundings only the vessel that grounded was involved in the events leading to the incident. The rammings (of oil platforms) involved only the vessel which rammed the oil platform.

j. The major causes of groundings are: 1) lack of attention to and misjudgment of the vessel's location and movement relative to the water depth, 2) lack of vigilance by the crew in using all available navigation information, 3) unsuitable system for pilot boarding of deep draft vessels, 4) lack of knowledge of the presence of submerged objects and shoals, 5) poor navigation/maneuvering practice; and 6) inoperable or malfunctioning navigation equipment.

k. The major causes of collisions are: 1) lack of establishing vessel-to-vessel communications and agreeing on a plan for passing, 2) poor seamanship, or what might be called a "lack of defensive sailing", especially under conditions of poor visibility, 3) lack of timely assessment of the imminent danger of collision, and 4) agreed upon, or standard passing maneuver is performed poorly.

l. Tugs with barges used in the transport of oil present a definite risk of an oil polluting incident occurring. There are many of these vessels carrying large quantities (over 100,000 gallons) of oil or petroleum products with some vessels traveling long distances, from the Gulf of Mexico to the northeastern U.S. ports. These vessels lack navigation equipment and sufficient staffing, certification and training of the crew for such voyages on the open ocean. Some of these newer barges are larger (on the order of 15,000 GT) than the older tankers and have a draft as much as 30 feet; in spite of this, they are exempt from the equipment and certification regulations placed on the tankers.

m. Pilotage transfer operations in some areas are quite inadequate for the needs of tank vessels navigating in bay and port entrances. (Examples are: Delaware Bay and Guayanilla Bay, P.R.)

n. A navigation aid equivalent to LORAN-C should be required equipment on seagoing petroleum carrying tank vessels down to 300 gross tons, because a vessel of this size can potentially cause a major* oil spill if improperly navigated.

o. The results of the study do not at this time indicate a justification for either a satellite surveillance or satellite communications system as a cost-effective alternative for preventing or reducing the risk of oil polluting casualties in the U.S. offshore waters.

1.3 RECOMMENDATIONS

The recommendations resulting from the study are:

a. Implement a rule requiring all seagoing petroleum carrying vessels over 300 gross tons to be equipped with LORAN-C, or an equivalent navigation aid.

b. Install RACONS on selected buoys or towers to positively identify the entrance to harbors, traffic lanes and fairways and other hazardous, frequently traveled offshore areas. Example locations are: Delaware and Chesapeake Bays, and the fairways in the Gulf of Mexico.

c. Perform a study of pilotage practices in Delaware and Guayanilla Bays. Over forty percent of all groundings analyzed in the study occurred in these two bays.

d. Assess the costs and benefits of providing LORAN-C coverage for the Puerto Rico and Virgin Islands area. This aid-to navigation would likely have prevented one grounding and possibly have prevented others.

e. Upgrade the requirements for licensing, license renewal, and training of masters and officers of tank vessels to include periodic tests and demonstration of proficiency (approximately every five years) in the navigation of deep draft vessels, in the use and operation of all navigation aids, and in the knowledge of regulations and Rules of the Road.

*A major oil spill is defined as greater than 100,000 gallons.

f. Implement the "vessel passport" system described in Section 5.2.2 and 7.2. The costs to the user and the Government would be low, assuming existing communications systems are used. This is a "core" system that is expandable as the need develops. In approximately three years a study should be made to assess the need, benefits and costs of upgrading the capability of the "vessel passport" system.

g. Conduct a design and feasibility demonstration study of a low cost transponder system. The projected cost of a proposed VHF/Transponder system, described in Section 5.2.17, appears to be reasonable, but a design study is needed to establish more accurately the hardware costs and feasibility of the system.

h. Change the equipment, licensing and pilotage requirements for ocean-going tugs with barges that carry oil, petroleum products and other hazardous substances to be comparable to those for tank ships. Such vessels should also be required to operate within any offshore vessel traffic management system required of tank ships.

i. Develop uniform pilotage practices and licensing requirements for pilots in all U.S. coastal states and territories.

j. Maintain active involvement in the development of new techniques and systems. The Coast Guard should initiate more feasibility design and demonstration programs of promising systems and techniques in offshore navigation and communications in order to continually upgrade their capability for reducing the potential for oil polluting vessel casualties and to provide valuable technical inputs into national and international maritime safety programs.

k. A study should be made of the applicability of the "recommended" system alternatives proposed in this study to other Coast Guard mission areas.

2. INTRODUCTION

2.1 BACKGROUND

A series of tank vessel casualties in the winter of 1976-77, the most famous of which was the grounding of the Argo Merchant in December 1976, has highlighted the need for improvements in marine safety to prevent oil pollution of the U.S. offshore waters and the associated damage to valuable fishing areas, coastline beaches, and other parts of the environment. It has been suggested by government leaders that a shore-based system providing offshore vessel traffic management services could significantly reduce the risk of tank vessel casualties by assisting vessels in detecting and avoiding hazardous situations.

In recognition of the potential environmental and ecological damage caused by tank vessel casualties, both the United States and the Intergovernmental Maritime Consultative Organization (IMCO) recently considered and continue to consider several proposals for new requirements, including precision ship-board navigation equipments, collision avoidance systems, dual radar systems, vessel routing systems in high traffic areas, more stringent crew qualifications, more stringent ship construction standards, and increased reliability in ship steering and propulsion systems. In February 1978 an International Conference adopted requirements on dual radar systems, improved emergency steering and ship construction. Another conference, concluded in July 1978, adopted provisions for uniform crew qualifications. These actions largely stemmed from the March 1977 Presidential initiatives to reduce maritime oil pollution. These initiatives also called for immediate action on the part of the Secretary of Transportation to perform several in-depth studies and to take regulatory actions as authorized by law to prevent or reduce the occurrence of casualties involving tank vessels and other hazardous cargo carriers.

The problem of oil pollution due to vessel casualties in <u>offshore</u> waters is characterized by the infrequent occurrence, yet definite risk, of a <u>large</u> spill (greater than 100,000 gallons). An example of the rarity of a large spill is that only 6 of 55 offshore groundings analyzed in the period of FY 72-77 resulted in a large spill, and 88 percent of the volume spilled was due to the Argo Merchant incident. However, the potential for these large spills is likely to increase as the tank vessel traffic increases to handle the higher demand for oil imports to the United States.

This study of Offshore Vessel Traffic Management was one of the items called for in the President's March 1977 initiatives to the Department of Transportation, specifically referred to as "a study of long range vessel surveillance and control systems". The Coast Guard was given the responsibility for performing the study and the Transportation Systems Center, in support of the Coast Guard, began work on the study in August 1977. The purpose of this study was to determine the causes of tank vessel casualties and perform an assessment of vessel traffic management alternatives for preventing polluting incidents in waters offshore of the U.S.

This technical study examines traffic management alternatives as a means to reduce or eliminate casualties contributing to pollution of the marine environment. Nothing contained in this report should be construed as affecting or changing the Administration's position on offshore claims in general or at the Third United Nations Conference on the Law of the Sea in particular.

2.2 OBJECTIVES

The major objectives of the study were: a) to analyze the causes of tanker casualties that could potentially result in oil pollution, and b) to define and evaluate various alternative vessel traffic management systems and techniques for prevention of oil polluting casualties in U.S. offshore waters. It was determined early in the study that an essential first step to developing feasible and effective alternative prevention systems was to thoroughly understand the factors contributing to tank vessel pollution incidents. Therefore, an important secondary objective was to investigate all facets of the current total maritime environment, including the rules, regulations, accepted practices, aids to navigation, topography of the heavily traveled port and harbor entrances, pilotage practices, bridge discipline, international rules and requirements, and shipboard and shore based equipment. These elements comprise the operating framework for the present day mariner.

2.3 SCOPE

The scope of the study is defined by the geographical areas of interest, the types of casualties that are potentially preventable by some vessel traffic management system or technique, and the sizes and types of ships which cause oil polluting incidents that result in significant damage to the shore and the environment.

The geographical area of interest consists of the waters from the U.S. coastline out to 200 nautical miles around the contiguous 48 states, Hawaii, Puerto Rico, the Virgin Islands, and Alaska, except the area north of the Aleutian Islands. For the purposes of this report, reference to "offshore waters" includes the high seas and territorial seas adjacent to the U.S. coastline constituting approaches to U.S. ports. Excluded from the study are ports, harbors, and inland waterways. For purposes of this study the boundary separating offshore and inland waters was established as the mouth or narrowest point in the harbor entrance approaching from the sea. Also, offshore channels less than 1000 feet wide were excluded from consideration in the study. The casualties that occurred in Long Island Sound were included in the analysis because the distance between the island and mainland was considered to present navigation problems similar to those in the harbor entrance areas.

Tank vessel casualties resulting in oil spillage are varied in nature. Some involve malfunctions of such things as the engine/propulsion system, ship's structure, steering system, and the electrical power system. Others are caused by cleaning of oil compartments (trapped gases sometimes result in explosions). Some casualties of these types cannot be reduced or prevented by a vessel traffic management system; they were excluded from the study. Casualties which were considered preventable by some vessel traffic management system or technique include groundings, collisions, and rammings. This study concentrates solely on these three types of casualties for determining causes and assessing alternative systems for prevention. The terminology used here (groundings, collisions, rammings and vessel traffic management systems) is defined in Section 2.4.

Vessel sizes of interest in this study include merchant vessels over 1000 gross tons. Military vessels and pleasure craft were not considered because the number of these over 1000 gross tons relative to the merchant vessel fleet is small. However, it is recognized that any operational implementation of the vessel traffic management alternatives considered for preventing collisions and rammings would of necessity require the cooperation of all vessels including these two groups. Since the study addresses the prevention of oil polluting vessel casualties, the analysis of groundings was directed primarily at tank vessel casualties, whereas the collisions analysis included all ships over 1000 gross tons because any ship which navigates improperly can potentially collide with a tanker and cause an oil spill. In the analysis of rammings of offshore oil production and transfer facilities, all vessels over 1000 gross tons were considered while the analysis of rammings of aids to navigation, ice and floating or submerged objects dealt only with tank vessels. The criteria used in the selection of casualties for detailed causative analysis are discussed in Section 4.3. In the case of rammings only those involving offshore oil production and transfer facilities were selected for detailed analysis.

The scope of this study does not include any analysis of other Coast Guard mission areas (e.g., Search and Rescue, Fisheries Patrol, etc.) which may have needs similar to that of oil pollution prevention.

The approach taken from the casualty analysis was to use actual case records of casualty incidents to determine, to the extent possible, the causes of oil pollution casualties. Because of the limited time for performing the study it was necessary to use a data base that already existed, contained the most complete case records and was readily accessible. The U.S. Coast Guard

Merchant Vessel Casualty file covering the period from July 1971 through September 1977 was selected as the primary data base for the study. A description of this data base is presented in Section 4.2.1.

Systems and techniques considered within the scope of the study as potential alternatives for preventing casualties include a full range of approaches from minor changes in operating procedures and regulations to adding new shipboard electronics and shore-based monitoring and control stations.

2.4 DEFINITIONS OF TERMS

Before proceeding with the discussion of the approach and results of the study, some of the more frequently used terms are defined. (Refer to Section 9 for a listing of other terms.) A "vessel" is defined as any ship, barge or boat regardless of size, function or cargo carried. The term "tank vessel" is used most frequently in this report and includes all tank ships, bulk cargo carriers, and barges that transport crude oil or petroleum products. Tank ships, tankers and tank barges are vessels that carry only oil or petroleum products. Hazardous cargo carriers are ships and barges that carry chemicals and other substances hazardous to the environment.

The term "system" is used in a broad sense to mean a group or collective body of things organized in some manner to accomplish a single purpose. Some examples are: a) any combination of operating rules, regulations, procedures, shipboard equipment, marker buoys, signal lights, and government or industry bodies which may be used independently or collectively in any grouping to provide the means for safe passage of vessels among other vessels or natural hazards; b) a set of equipment which performs the function of providing navigation information to the ship's captain, such as the LORAN-C system.

The casualty types (groundings, collisions, and rammings) addressed in the study are defined according to terminology recommended by the Coast Guard. The term "collision" refers to the colliding of two ships where one or both are underway. A "grounding" is defined as any situation in which a ship comes in contact with the ocean bottom, the coast land, a submerged rock, or a reef. A stranding is treated as a grounding. A "ramming" is defined as a ship colliding with a fixed, floating or submerged object. This term is not used in the sense of a ship intentionally ramming another ship as in military combat.

The term "Vessel Traffic Management" refers to the organization of the movement of ships in any given area for the purpose of improving the safety of the vessel and the marine environment. This may be accomplished in a number of ways including operating rules and procedures, navigation aids and communications equipment, and shore-based monitoring and surveillance systems. It should be clearly understood that the vessel traffic management systems and techniques developed in this study were based on the premise that the vessel master always has the responsibility and authority to navigate his ship as he sees fit for the safety of all ships concerned. In this context, the responsibility of a monitoring or surveillance system is to: a) provide additional information (advisories) of hazardous conditions to all ships, and b) detect any ship that is clearly being navigated in an unsafe manner and take appropriate action to assist her to safety to prevent a casualty.

3. STUDY APPROACH

3.1 INTRODUCTION

The philosophy used throughout this study was that a thorough understanding of all facets of the offshore oil spillage problem and the mariner's environment was essential for the development of realistic and effective solutions. Based on this, major attention was given to analyzing actual detailed casualty reports of incidents that occurred in U.S. waters during the past six years. Also, literature and studies on this subject were reviewed, and professionals in the maritime transportation industry were consulted.

The classic approach in a study of this type would be to complete the analysis of the casualties and define the requirements before addressing the potential solutions. However, the limited time available to perform this study made it necessary very early in the program, to initiate the second major task, which was the definition of alternative systems and techniques applicable to the prevention of oil polluting casualties in U.S. offshore waters. This approach is believed valid because development of a general list of reasonable alternative systems was based on a review of pertinent literature and the use of engineering judgement, while the successive steps of evaluating and selecting the promising systems were based on the casualty analysis results.

3.2 DESCRIPTION OF TASKS

This study is divided into two major tasks: Casualty Analysis and Alternatives Analysis. Several smaller tasks are included in these major tasks and are shown in Figure 3-1. The major tasks are discussed below.

3.2.1 Casualty Analysis

This task includes two parts: analysis of casualties and analysis of traffic. The general approach for both was to determine past trends and patterns, and to project future traffic and

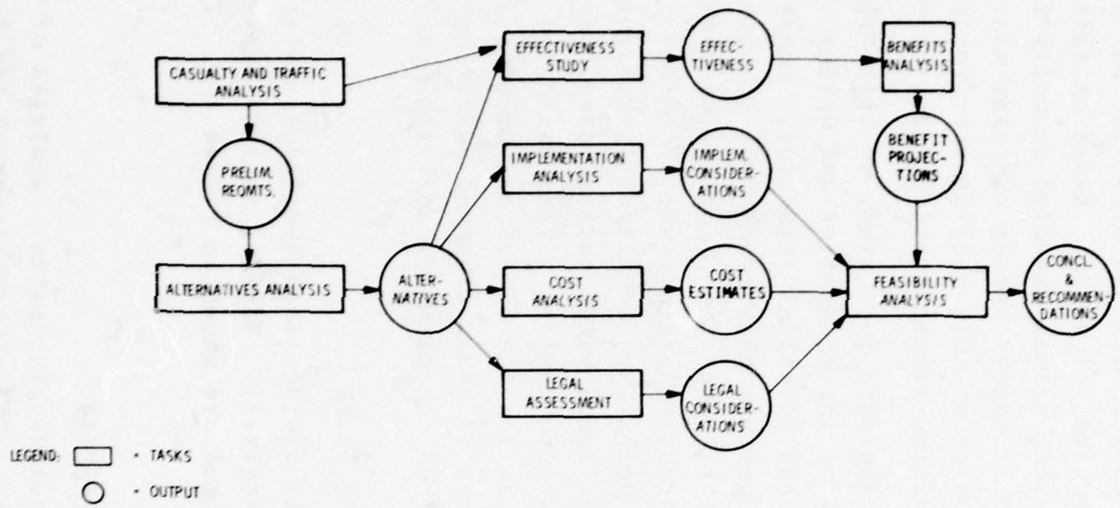

FIGURE 3-1. OVTM STUDY TASKS

casualties using estimates of growth in oil demand and currently expected changes in the future maritime fleet.

The primary objective of the casualty analysis was to obtain sufficient detailed information on past incidents so as to determine the factors that cause or contribute to casualties in the offshore waters. As indicated in Section 2 the types of casualties to be included in the study were limited to only those that some type of vessel traffic management technique or system could potentially prevent, specifically: groundings, collisions, and rammings. The casualty data sources that were examined included: the U.S. Coast Guard Merchant Vessel Casualty Reports (MVCR), the Lloyd's Weekly Casualty Reports, and Marine Management Systems computerized casualty files. The file of Merchant Vessel Casualty Reports covering the period from July 1971 through September 1977 was selected as the primary data base for determining the causative factors because of completeness in the information concerning the casualty situation both from the mariner's and the investigating official's point of view. The cases from this file were treated as representative of the tank vessel casualty problem. Data from the other two sources were used for statistical analysis and examination of other factors.

The output of the causative analysis was used to derive preliminary requirements for a vessel traffic management system. The other significant input to these requirements came from the vessel traffic projections. Estimates of future casualty trends were based on future traffic projections and past traffic and casualty patterns.

The detailed casualty analysis was performed by the Transportation Systems Center staff. Support was provided by the Boston Marine Society and the Massachusetts Institute of Technology - Center for Transportation Studies. The Boston Marine Society provided the services of professional mariners in analyzing the casualty causes and evaluating the effectiveness of system features as preventative measures. The MIT effort was directed toward two areas: the analysis of casualties on a worldwide basis, and the development of estimates of future traffic trends and patterns in U.S. offshore waters. The purpose of the traffic analysis was first, to provide information for projecting future casualty trends, and second, to indicate the capabilities required of alternative vessel traffic management systems in the future. The approach used in projecting traffic trends was to take into account anticipated changes in oil import volume and destination and vessel sizes. This task is discussed further in Section 4.

3.2.2 Alternatives Analysis

The alternatives analysis includes several tasks which are closely related. The approach used was to divide the analysis into four parts:

a. Identify and define: general system types, several applicable systems for each system type, and basic features of each system;

b. Perform detailed analysis including effectiveness of features, technical evaluation of systems, implementation considerations (cost, legal, staffing, and operation and maintenance), and feasibility assessment;

c. Evaluate effectiveness and benefits of the most promising systems; and

d. Select recommended systems or system combinations.

Included in this task was an attempt to thoroughly research the literature and other sources to learn of the systems and techniques that had been examined or implemented in the past and use that information where applicable.

National and international proposals for changes or additions to either rules or equipment were evaluated for applicability to the requirements of offshore vessel traffic management.

The approach used in assessing systems was to first identify all the "features" embodied in each alternative system or technique. (A system or technique may include one or more features.) The effectiveness of each feature in preventing casualties was estimated against each casualty in the primary data base, and, the effectiveness of each system was then derived from the features that make up a particular system. This approach was used because features are significantly less complex than systems, and more readily evaluated and compared. It also makes the effectiveness assessment more consistent for all the casualty cases. The specific features are discussed in Section 5.

3.3 ASSUMPTIONS AND GUIDELINES

The assumptions and guidelines used in the study were established by the Coast Guard. The following is a summary of these assumptions and guidelines.

The study considered only ships over 1000 gross tons. In the analysis of groundings, only those involving tank vessels were considered. Collision incidents involving at least one tank vessel were included. The examination of rammings of offshore oil production/transfer facilities included cases involving all vessels over 1000 gross tons. The analysis of other ramming incidents was limited to those involving only tank vessels. Harbors, bays, and other internal waters were excluded from consideration. Additionally, casualties occurring in restricted channels of less than 1000 feet were excluded, since these typically differ in cause from other offshore casualties. Ship-board equipment, assumed to be on all ships entering U.S. navigable waters and bound for a U.S. port, includes all present navigation and communication gear plus LORAN-C or some comparable long range navigation equipment and dual radars. Although collision avoidance equipment has been proposed as a requirement for ships over 20,000 dead weight tons*, this was not considered an existing requirement for the purpose of this study. Potential sharing of facilities of the Automated Mutual-assistance Vessel Rescue (AMVER) system was to be examined for application in a reporting/monitoring system.

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*One dead weight ton equals approximately one-half gross ton, e.g., 20,000 DWT = 10,000 GT.

Current U.S. regulations applicable to vessel traffic management systems or techniques are enforceable on <u>foreign</u> flag vessels only in the U.S. navigable waters, defined as those within 3 miles offshore. When bound for a U.S. port all foreign vessels are required to notify the appropriate Coast Guard Captain of the Port (COTP) of their planned entry at least 24 hours prior to arrival.*

Any vessel traffic management system involving shore-based surveillance must also include the capability to communicate with vessels. Both "active" and "passive" approaches for vessel traffic management were to be examined. (See Section 9 for definitions of these terms.)

Assessment of each alternative system includes consideration of: benefits, costs (development, investment costs to vessel and to government and operating and maintenance costs), legal requirements, IMCO involvement in acceptance, implementation time, staffing requirements, enforceability, and effectiveness in preventing casualties. The assessment of alternative systems was to be performed for each type of casualty: groundings, collisions, and rammings.

Estimations of casualty trends, assessment of requirements and projections of system capabilities were to be made for five and ten years into the future because any major new system generally takes five to seven years to implement, in addition to R&D time.

In assessing alternative systems employing shore-based monitoring or surveillance techniques, it was assumed that the vessel would communicate the following minimum information: vessel identity, position, course and speed. The refresh rate was to be determined from the casualty analysis.

In considering the potential for oil pollution in offshore waters, bunker fuel carried by vessels was not included.

The level of participation by vessels will be different for voluntary and mandatory systems. For the purpose of this study it was assumed that the system being evaluated would be mandatory.

*Ref. 33CFR 124.10.

4. CASUALTY ANALYSIS

4.1 INTRODUCTION

The study approach described in Section 3 requires access to historical records of merchant vessel casualties. The level of detail and comprehensiveness of the records used has a direct bearing on the validity of the causal analysis and effectiveness evaluation. The records used must cover incidents that occurred in the primary geographical areas of interest of this report, i.e., the coastal waters of the United States, Alaska, Hawaii, Puerto Rico, and the Virgin Islands. These considerations led to selection of the U.S. Coast Guard Merchant Vessel Casualty reports, supplemented by Lloyd's Casualty records and miscellaneous sources of detailed information for specific casualties.

The following sections describe the casualty data base used in the study, the inherent limitations of the various data sources, the methods used to extract the pertinent information, the characteristics of the casualties of interest, the analysis of the causative factors, and the techniques used for making casualty projections. In Section 6, the quantity, effects and cost of oil spillage are discussed in terms of the three types of casualties studied and their characteristics.

4.2 CASUALTY DATA BASES

4.2.1 U.S. Coast Guard Merchant Vessel Casualty Reports (MVCR)

Title 46 of the U.S. Code of Federal Regulations (Chapter 1, part 4) requires the masters of all vessels (U.S. and foreign flag) involved in casualties upon the navigable waters of the United States to file a written report with the Officer in Charge, Marine Inspection, nearest the port of first arrival. Furthermore, vessel masters of U.S. flag vessels are required to file a report for each casualty regardless of the location of the casualty. A report is required whenever the casualty results in any one of the following:

a. Actual physical damage to property in excess of $1,500,

b. Material damage affecting the seaworthiness or efficiency of a vessel,

c. Stranding or grounding,

d. Loss of life, or

e. Injury causing any persons to remain incapacitated for a period in excess of 72 hours.

A Coast Guard officer investigates each marine casualty reported to determine cause, evidence of negligence, and responsibility. If deemed a major casualty, a Marine Board of Investigation may be convened to conduct a more extensive inquiry. (In the process of analyzing incidents to determine causative factors, the report of the investigating officer was generally given the greatest credence. The vessel master's report was generally found most useful in describing the circumstances at the time the casualty occurred.)

Vessel master casualty reports and investigating officer/ Marine Board reports are kept on file at Coast Guard headquarters, Washington, D.C. These reports have been transferred to microfilm beginning with FY 1972 casualties, providing easy access to a multitude of users. Documentation pertaining to two of the casualty incidents selected for evaluation in the study is included as Appendix A, which illustrates the type of information available from these reports.

Selected information from each casualty report is coded and entered into a computerized data base by Coast Guard personnel. (The information content of this data base is described in Appendix B.) Computer tapes containing casualty information for fiscal years 1970 through 1977 were made available to the study team.

Casualties of the following nature are included in the data base: collisions with vessels; rammings of fixed objects, floating or submerged objects, ice, aids to navigation, or offshore rigs; groundings; founderings, capsizings and floodings; explosions and fires; material failure; heavy weather damage; cargo damage; and barge breakaway.

The casualties of greatest importance to the study are those which reflect current tanker traffic trends and tanker equippage, and recent changes in the aids to navigation environment (e.g., LORAN-C). Due to these and other considerations such as the accessibility of microfilmed casualty reports beginning with FY 1972, the relatively time consuming process of obtaining prior year's records from the archives, and the multiplicity of changes to the computer coding in earlier years, only the FY 1972-FY 1977 incidents are included in this study.

Approximately 20,000 incidents are recorded in the computer files for this six-year period. These incidents include all types and sizes of merchant vessels, all nature of casualties, and all locations. (The screening process used to sort the data for casualties of interest to the study is described in Section 4.3.)

The major deficiency of the Coast Guard data base from the point of view of this study results from the fact that foreign flag vessels are not required to file casualty reports if the casualty occurs outside the 3-mile limit of the navigable waters of the United States. As a consequence, estimation of the benefits of an OVTM system covering a distance up to 200 miles offshore on the basis of the number of preventable casualties in the MVCR record becomes tenuous. However, other data sources may be used to estimate the number of foreign flag incidents between 3 and 200 miles offshore that are missing from the MVCR. Sections 4.2.2 and 4.2.3 describe Lloyd's Casualty reports and other casualty data sources, respectively, that were used to supplement information obtained from the Coast Guard's files.

4.2.2 Lloyd's Casualty Reports

Since the Coast Guard Merchant Vessel Casualty Reports data base, by the regulations governing reporting, does not require foreign flag vessels involved in a casualty over 3 miles offshore to file a report, other data sources were consulted. Lloyd's

Weekly Casualty reports published by Lloyd's of London Press, Ltd. has short reports of worldwide marine casualties. The sources of data for Lloyd's include news services, classification societies, and insurance company representatives.

A sample of Lloyd's report is shown in Figure 4-1. These reports usually include the vessel's name and flag, the date of the casualty, the type of casualty, and the present status of the vessel. However, they often include no more than a general description of the location of the incident and usually say little or nothing about the cause. Thus, an analysis of the Lloyd's data could be used to determine certain characteristics of ships that have casualties (e.g., distribution by flag), but could not be used to analyze what caused the casualty. Section 4.6 describes how this data base was used to estimate foreign flag casualties missing from the MVCR.

> CLAUDE CONWAY (Panamanian)
> -- New York, Dec 11 -- Steam tanker Claude Conway grounded Six mile Reef, Long Island Sound, at 1300, Dec 10. Vessel refloated at 2100, Dec 10; en route to Northport.

Figure 4-1. SAMPLE OF LLOYD'S REPORT

4.2.3 Other Casualty Data Sources

The Coast Guard maintains a Pollution Incident Reporting System (PIRS) for the purpose of recording discharges of oil or hazardous substances into inland or coastal waters of the United States. During the study an attempt was made to correlate incidents from the PIRS file for the period 1972-1977 (the years with the most complete data available) with those from the Merchant Vessel Casualty Reports file, with the objective of identifying additional casualties of interest.

The PIRS file was searched for tanker or tank barge groundings and collisions in coastal waters resulting in an actual spill in excess of 50,000 gallons. A total of eight cases was found by this process. The only parameters consistently common to both files are the date and body of water where the incident occurred, and for U.S. flag vessels, the offical number. Furthermore, for the date, the Merchant Vessel Casualty file only records month and year. As a consequence, it was necessary to examine numerous casualty reports to find the one that corresponded to each selected PIRS case. This procedure proved too time consuming to consider its use for other PIRS incidents with lesser volume actual spills or for those PIRS incidents with potential spills.

The single additional incident identified by this process was the Argo Merchant grounding off Nantucket Island in December 1976. One of the reasons for selecting PIRS cases, where large spills actually occurred, was the probability of finding adequate documentation for use in casualty analysis. In the case of the Argo Merchant, an IMCO Marine Safety Committee report was used as the primary casualty data source.

4.3 IDENTIFICATION OF CASUALTIES OF INTEREST

The approach selected for casualty analysis required screening of the Merchant Vessel Casualty report file to identify the incidents pertinent to the study objectives. To create a data base of the casualties of interest, a series of computer data sorts were made.

In line with the assumptions and guidelines described in Section 3.3, data parameters for identifying the casualties of interest are: nature of casualty, type of vessel, gross tonnage, body of water where casualty occurred, and specific location of casualty (refer to Appendix B). Table 4-1 summarizes the descriptors used to program sorts of the computerized data base for these data parameters. The body of water and specific location descriptors are in consonance with the specified areas of interest off the U.S. coast, Alaska, Hawaii, Puerto Rico, and the Virgin Islands. The types of vessels and gross tonnage are in consonance with the selection of casualties with potentially sizeable oil spillage. The nature of casualty descriptors were screened to exclude those

TABLE 4-1. DATA PARAMETER DESCRIPTORS USED FOR COMPUTER SORTS

Nature of Casualty	Type of Vessel	Gross Tonnage	Body of Water	Specific Location
Groundings-With/without damage	Tankships Tank Barges Foreign Flag Tankers	>1000	Inland-Atlantic/Gulf/Pacific (3) Ocean-Atlantic/Gulf/Pacific/Carribbean	All U.S. coastal segments All worldwide grid elements encompassing U.S. waters out to 200 miles
Collisions-Meeting/crossing/overtaking -Anchored -Fog	Tankships (1) Tank Barges (1) Foreign Flag Tankers (1)	>1000 (1)(2)	Same	Same
Rammings-Offshore rigs	All	>1000	Same	Same
-Floating or submerged objects -Ice -Aids to navigation -Fixed objects	Tankships Tank Barges Foreign Flag Tankers	>1000	Same	Same

Notes:

(1) At least one vessel must be of this type and size.
(2) Second vessel must exceed 1000 gross tons in size.
(3) Excludes Western Rivers, Gulf Inland Rivers and Waterways, and Great Lakes.

not controllable by vessel traffic management techniques, viz., collisions while docking/undocking, minor bumps (tug and vessel), explosions and fires, foundering/capsizing/flooding, heavy weather damage, cargo damage, and material failure.

A number of preliminary sorts were made to determine how the total number of applicable incidents was reduced by imposing the study assumptions and guidelines. The first sort yielded the number of incidents involving tankers, tank barges, and foreign flag tankers greater than 1000 gross tons that occurred in the locations of interest to the study, categorized by nature of casualty. Table 4-2 lists the number of incidents in each of these nature-of-casualty categories. The table shows a split between incidents occurring in inland and international waters. These areas are defined by the regions of applicability of the two sets of rules of the road: Inland Rules of the Road and International Rules of the Road.

Of the 20,047 incidents in the total casualty file for the period FY 1972 through FY 1977, approximately 11 percent involved tank vessels greater than 1000 gross tons in U.S. waters. Approximately 15 percent of these tank vessel casualties (325) occurred seaward of the inland rules of the road boundary lines. Eliminating those nature-of-casualty descriptors not controllable by vessel traffic management (VTM) techniques yields a total of 1507 incidents that might be of interest to the study, as shown in Table 4-2. This total is made up of 722 groundings, 260 collisions (eliminating the 135 not controllable by VTM techniques), and 525 rammings.

4.3.1 Groundings

In addition to a "nature of casualty" descriptor, each incident in the computerized data base has a coded "cause" (e.g., adverse weather) and "factor" (e.g., gale force winds). The 722 groundings were subjected to further screening by sorting through the computerized data base to eliminate incidents coded with a cause/factor not controllable/preventable by vessel traffic

TABLE 4-2. TANK VESSEL CASUALTIES IN U.S. WATERS - BY NATURE OF CASUALTY (FY 1972 - FY 1977)

Nature of Casualty	Number of Incidents (2)		
	Inland	International	Total
Groundings			
- With damage	248	13	261
- Without damage	431	30	461
Total	679	43	722
Collisions			
- Meeting/crossing/overtaking	97	22	119
- Anchored	107	12	119
- Docking/undocking (1)	41	1	42
- Fog	18	4	22
- Minor bumps, tug and vessel (1)	74	19	93
Total	337	58	395
Rammings			
- Offshore rigs	0	1	1
- Floating or submerged objects	54	10	64
- Ice	16	2	18
- Aids to navigation	60	5	65
- Fixed objects	371	6	377
Total Rammings	501	24	525
Explosions/Fires (1)	69	14	83
Founderings/Capsizings/Floodings (1)	22	10	32
Heavy Weather Damage (1)	6	42	48
Cargo Damage Only (1)	1	0	1
Materiel Failure			
- Vessel structure (1)	41	18	59
- Machinery/equipment (1)	152	112	264
Other (1)	47	4	51
TOTAL	338	200	538
GRAND TOTAL	1855	325	2180
	-453 (1)	-220 (1)	-673 (1)
	1402	105	1507

Notes:

(1) Not controllable by VTM Tec[illegible]iques.

(2) Tank vessels > 1000 gross ton[illegible].

management techniques. Cause categories excluded were storms/ heavy weather, unusual currents, sheer/suction/bank cushion, restricted maneuvering room, structural failure, unseaworthy/ improper maintenance, and insufficient horsepower/inadequate tug assistance (refer to Appendix B). Table 4-3 summarizes the groundings eliminated by cause using this additional computer sort.

TABLE 4-3. TANK VESSEL GROUNDINGS IN U.S. WATERS - SCREENED FOR CAUSE AND LOCATION

Tankers, Tank Barges, Foreign Flag Tankers >1000 GT

Nature of Casualty	No. of Incidents		
	Inland	International	Total
Groundings			
- With & without damage	679	43	722
- Eliminated for cause	-104	-8	-112
	575	35	610
- Eliminated due to location	-546	-18	-564
	29	17	46

Casualty reports for the 610 remaining grounding incidents, as identified by the computer sorts, were reviewed to ascertain their locations. Approximately 95 percent of the groundings in inland waters occurred in harbors, channels, or restricted waterways less than 1000 feet wide. Groundings in narrow channels are primarily due to problems in maneuvering vessels in restricted waterways. Prevention of casualties of this nature is not considered relevant to the purpose of this study. Approximately 50 percent of the groundings in international waters were found to have occurred either in international waters beyond 200 miles offshore, in foreign waters or in restricted waterways.

The net result of this screening process was the identification of 46 tank vessel grounding incidents in the six year period of FY 1972 - FY 1977 that are considered potentially preventable by some type of offshore vessel traffic management system. As discussed in Section 4.2.3, the grounding of the Argo Merchant was identified from the PIRS data file, making a total of 47 tank vessel groundings.

To expand the data base to be used for deriving casualty characteristics (Section 4.4), analyzing causative factors (Section 4.5), and assessing the effectiveness of system alternatives (Section 5), the casualty file was searched for groundings of non-tankers larger than 5000 gross tons. Non-tanker vessels in this size category were postulated to have navigation equipment and crew characteristics similar to tankers. Casualties were screened in the same manner as described for tank vessel groundings. This computer sort resulted in the identification of 8 additional groundings for a grand total of 55.

4.3.2 Collisions

The 260 collisions identified in Section 4.3 include incidents between tank vessels larger than 1000 gross tons and other vessels regardless of size. In accordance with study assumptions (Section 3.3), at least one of the other vessels involved in a collision with a tank vessel must be larger than 1000 gross tons. Table 4-4 shows that screening out the smaller vessels resulted in identifying 145 collisions.

These remaining 145 collisions were subjected to further screening by eliminating the same cause categories excluded for groundings. As indicated in Table 4-7, this leaves 128 collision incidents.

Casualty reports for these remaining collisions were reviewed to determine their locations. As in the case of groundings, approximately 95 percent of the collisions in inland waters occurred in harbors, channels, or restricted waterways less than 1000 feet wide. Here again, prevention of collisions in locations of this nature are considered outside the scope of this study. Over one-half of the collisions in international waters were found to have occurred in international waters beyond 200 miles offshore, in foreign waters, or in restricted waterways.

TABLE 4-4. TANK VESSEL COLLISIONS IN U.S. WATERS - *SCREENED* FOR COLLIDING VESSEL SIZE, CAUSE, AND LOCATION

FY 1972-FY 1977

(Tankers, Tank Barges, Foreign Flag Tankers) >1000 GT

Nature of Casualty	Number of Incidents		
	Inland	International	Total
Collisions			
- Meeting/crossing/overtaking anchored/fog	222	38	260
- Other vessel <1000 GT	-93	-22	-115
	129	16	145
- Eliminated for cause	-13	-4	-17
	116	12	128
- Eliminated due to location	-111	-7	-118
	5	5	10

The net result of this screening process was the identification of 10 tank vessel collision incidents in the 6-year period FY 1972-FY 1977 that are considered preventable by some type of offshore vessel traffic management system.

Analogous to the discussion of groundings, expansion of the data base was sought by considering collision incidents involving non-tankers larger than 5000 gross tons. Sorting of the casualty file on this basis resulted in the identification of 7 additional collision incidents for a grand total of 17.

4.3.3 Rammings

As shown in Table 4-1, the rammings of interest to the study include casualties involving offshore oil rigs, floating or submerged objects, ice, aids to navigation, and fixed objects. The 525 rammings *identified in Section* 4.3 include all tank vessels larger than 1000 gross tons involved in these types of ramming incidents for the period FY 1972 - FY 1977.

The following sections discuss the findings of the study with respect to the number of applicable rammings of each type.

4.3.3.1 Rammings of Offshore Oil Rigs - In accordance with study assumptions (Section 3.3), rammings of structures, pipelines, and facilities involved with oil production and transfer by all vessels larger than 1000 gross tons are to be considered. Consequently, additional sorts of the computerized data base were made to identify offshore rig rammings by non-tank vessels. From Table 4-5 it is seen that 16 rammings of offshore rigs by non-tank vessels were found. These are in addition to the one tank vessel incident shown in Table 4-2.

TABLE 4-5. TANK VESSEL AND OIL FACILITY RAMMINGS IN U.S. WATERS - SCREENED FOR CAUSE AND SPECIFIC NATURE OF CASUALTY

FY 1972-FY 1977

Nature of Casualty	Number of Incidents		
	Inland	International	Total
Rammings of Offshore Rigs			
- Tank vessels >1000 GT	0	1	1
- Non-tank vessels >1000 GT	+9	+7	+16
	9	8	17
- Eliminated for cause	-2	-2	-4
	7	6	13
- Eliminated for specific nature of casualty	-7	-0	-7
	0	6	6

The 17 rammings of offshore rigs were screened by eliminating the same cause categories excluded for groundings (Section 4.3.1). As shown in Table 4-8, this leaves 13 incidents.

Casualty reports for these remaining incidents were reviewed to determine their applicability to the study. All inland cases were found to involve non-oil production facilities and were therefore eliminated. All international cases were found to be valid for the purposes of this study, leaving six ramming cases for analysis.

The other 524 rammings involving tank vessels are discussed in the following sections.

4.3.3.2 Rammings of Floating or Submerged Objects - Incidents coded with this nature of casualty descriptor were reviewed to determine if the ramming involved a known submerged object such as a shipwreck or oil pipeline. This type of occurrence could be preventable by vessel traffic management techniques. Since in all cases the submerged object was either of unknown identity or location, or both, this entire category was eliminated from further consideration.

4.3.3.3 Rammings of Ice - The 18 casualty reports identified as tanker rammings of ice were reviewed to ascertain if vessel traffic management techniques might be useful in preventing casualties of this nature. It was found that each of the incidents could be characterized as a calculated risk inasmuch as prior knowledge of the presence of the icefield had existed. Therefore, no further consideration was given to this type of casualty.

4.3.3.4 Rammings of Aids to Navigation - Review of the casualty reports regarding rammings of aids to navigation revealed that these incidents occurred while vessels were maneuvering in harbor docking areas or while traversing harbor entrance channels. As observed in the case of inland groundings (Section 4.3.1), casualties incurred by vessels maneuvering in restricted waterways are not relevant to this study. Consequently, no further consideration was given to casualties of this nature.

4.3.3.5 Rammings of Fixed Objects - Casualty reports coded as rammings of fixed objects were found to involve docks, piers, bridges, and locks. As in the case of other incidents occurring in restricted inland waters, these cases were dismissed as irrelevant to the study.

4.3.4 Summary of Casualties of Interest

The various computer sorts and reviews of casualty reports described in the preceding sections produced a data base of casualties of interest to the study (OVTM data base). Table 4-6 summarizes the number of incidents by nature of casualty. Appendix C is an index of the selected cases containing casualty identifiers, vessel/cargo characteristics, location descriptors, and environmental factors.

TABLE 4-6. NUMBER OF INCIDENTS IDENTIFIED FOR CAUSAL ANALYSIS

Nature of Casualty	Number of Incidents		
	Tank Vessel/ Offshore Rig (Basic Data Base)	Non-Tank Vessel	Total (Extended Data Base)
Grounding	47	8	55
Collision	10	7	17
Ramming	6	NA	6
Total	63	15	78

4.4 CASUALTY CHARACTERISTICS

This section describes the characteristics of the tank vessel/ offshore rig casualties identified above. Of the 78 cases in Table 4-9, the 63 cases involving tank vessels (i.e., tankers and tank barges) and/or oil rigs form the "basic" OVTM data base. The remaining 15 cases are the non-tank vessel cases added to increase causal information. The data base including these 15 additional cases is referred to as the "extended OVTM data base.

The following discussions of casualty characteristics will center around the tank vessel and oil rig cases which form the "basic" data base, since these are the cases which had the potential (if the tank vessel was carrying oil) to produce oil pollution. The economic and environmental impact of the "basic" data base casualties is discussed in Section 6.

It is important to keep in mind that this restricted set of casualties of interest to this study, obtained by applying the data sorts described in Section 4.3, represents less than 5 percent of the total number of incidents in the Coast Guard data base (FY 1972 - FY 1977) involving tank vessels greater than 1000 gross tons.

4.4.1 Casualties by Vessel Characteristics

Table 4-7 shows a breakdown of the basic data base casualties by vessel type involved. Note that while tank barges and tankers are involved in about the same number of collisions, tankers account for almost 90 percent of total tank vessel groundings. Also, although all tank barges involved in incidents are under U.S. flag, almost 50 percent of the tanker groundings and tanker collisions involve foreign tankers.

Table 4-8 shows the flag of the vessels involved in data base casualties. This includes all vessels involved in basic data base incidents: tankers, tank barges, tugs, freighters, etc. About two-thirds of the vessels involved are under U.S. flag. One major reason for this is that the Coast Guard MVCR is incomplete with regard to incidents involving foreign flag vessels that occur more than three miles offshore (see Section 4.6). Also contributing to the high proportion of U.S. vessels is the fact that all tugs and tank barges involved in data base casualties are under U.S. flag (foreign flag tank barges in U.S. waters are virtually non-existent).

Of the foreign flag tankers involved in casualties, about one-half are Liberian. A total of seven foreign flags are represented among the tankers.

TABLE 4-7. NUMBER OF INCIDENTS BY VESSEL TYPE INVOLVED

Casualty Type	Total Cases	Casualties Involving Tank Vessels	Casualties Involving Tank Barges			Casualties Involving Tankers		
			All Flag Tank Barges	U.S. Tank Barges	Foreign Tank Barges	All Flag Tankers	U.S. Tankers	Foreign Tankers
GROUNDING	47	47	5	5	0	42	23	19
COLLISION	10	10	6	6	0	7	4	3
RAMMING	6	1	0	0	0	1	0	1
TOTAL	63	58	11	11	0	50	27	23

TABLE 4-8. NUMBER OF VESSELS INVOLVED IN OVTM DATA BASE CASUALTIES BY FLAG

Country	All Vessel Types				Tankers			
	Grounding	Collision	Ramming	Total	Grounding	Collision	Ramming	Total
BAHAMAS	0	0	1	1	0	0	1	1
CANADA	0	0	1	1	0	0	0	0
COLOMBIA	0	1	0	1	0	0	0	0
GREECE	2	1	1	4	2	1	0	3
ITALY	0	2	0	2	0	2	0	2
JAPAN	0	0	1	1	0	0	0	0
LIBERIA	10	0	1	11	10	0	0	10
NORWAY	2	0	0	2	2	0	0	2
PANAMA	4	1	0	5	4	0	0	4
SINGAPORE	1	0	0	1	1	0	0	1
TOTAL FOREIGN	19	5	5	29	19	3	1	23
U.S.A.	33	24	3	60	23	4	0	27
GRAND TOTAL	52	29	8	89	42	7	1	50

Tables 4-9 and 4-10 show the gross tonnage of the vessels involved in OVTM data base incidents. Almost one-half of the tankers involved fall into the 15,000 to 30,000 gross ton range. Tankers of this tonnage normally have a capacity of about 30,000 to 60,000 tons of oil. The largest tanker in the data base is 129,300 gross tons, but only 2 of 50 are over 75,000 tons. For comparison, the Argo Merchant was about 15,000 gross tons. Most of the tank barges were small, only 2 of 13 are greater than 5000 gross tons.

In summary, data base groundings are primarily tanker groundings, but both tankers and tank barges are involved in about the same number of collisions. All tank barges in the data base are under U.S. flag, while the tankers include 7 foreign flags (led by Liberia). Almost all tankers are under 75,000 gross tons, and almost all tank barges are below 5000 gross tons.

4.4.2 Casualty Locations

This section examines the geographic locations and distances offshore of the casualties in the OVTM data base.

The general locations of the data base casualties are shown in Table 4-11. The East Coast, the Gulf Coast, and Puerto Rico are the sites of the vast majority of all incidents; i.e., 44 percent, 25 percent, and 19 percent, respectively. Just over 50 percent of the groundings occurred off the East Coast, while about 25 percent occurred off Puerto Rico. Collisions are almost evenly split between the East and Gulf Coasts. Rammings, as would be expected, were all found to occur in the Gulf, where the oil platforms are primarily located.

TABLE 4-9. NUMBER OF VESSELS INVOLVED IN OVTM DATA BASE INCIDENTS BY GROSS TONNAGE

CASUALTY	GROSS TONNAGE (1000 TONS)										
TYPE	≤1	1-5	5-10	10-15	15-20	20-30	30-50	50-75	75-100	100-150	TOTAL
GROUNDING	5	8	1	6	7	10	8	5	0	2	52
COLLISION	8	9	4	1	3	2	2	0	0	0	29
RAMMING	2	2	2	1	0	0	1	0	0	0	8
TOTAL	15	19	7	8	10	12	11	5	0	2	89

TABLE 4-10. NUMBER OF TANKERS AND TANK BARGES IN OVTM DATA BASE INCIDENTS BY GROSS TONNAGE

TANKERS

	GROSS TONNAGE (1000 TONS)									
CASUALTY TYPE	≤1	1-5	5-10	10-15	15-20	20-30	30-50	50-75	75-100	100-150	TOTAL
GROUNDING	0	3	1	6	8	11	6	5	1	1	42
COLLISION	0	1	0	1	2	2	1	0	0	0	7
RAMMING	0	0	0	0	0	0	1	0	0	0	1
TOTAL	0	4	1	7	10	13	8	5	1	1	50

TANK BARGES

	GROSS TONNAGE (1000 TONS)						
CASUALTY TYPE	≤1	1-3	3-5	5-10	10-15	15-20	TOTAL
GROUNDING	0	4	1	0	0	0	5
COLLISION	0	5	1	1	0	1	8
RAMMING	0	0	0	0	0	0	0
TOTAL	0	9	2	1	0	1	13

TABLE 4-11. GENERAL LOCATION OF CASUALTIES
(SIX-YEAR TOTALS)

Location	Grounding	Collision	Ramming	Total
East Coast	24	4	0	28
West Coast	1	1	0	2
Gulf Coast	5	5	6	16
Off Alaska	2	0	0	2
Off Hawaii	0	0	0	0
Off Puerto Rico	12	0	0	12
Off Virgin Islands	3	0	0	3
Total	47	10	6	63

Table 4-12 shows the breakdown of these casualties by specific location. This is shown graphically in the maps of Figures 4-2 to 4-4. Table 4-13 shows the "hot spots," i.e., locations where large percentages of the data base casualties occurred.

Note that 20 of 47 groundings (43 percent) occurred in only two locations, Guayanilla Bay (Puerto Rico) and Delaware Bay. (Tallaboa Bay which abuts Guayanilla Bay is included in the Guayanilla area.) Over 60 percent of the groundings occurred in only four locations: Delaware Bay, Guayanilla Bay, Long Island Sound, and Chesapeake Bay.

Sixty percent of the collisions occurred in only two locations, in the Gulf of Mexico off Louisiana and in Long Island Sound, however, this breakdown by location is based upon a very small sample (10 tank vessels).

Rammings occurred primarily off the Louisiana coast, with one off Mississippi.

The distances from shore of the data base casualties are shown in Table 4-14 and Figure 4-5. Over 50 percent of all groundings occurred within 3 miles of shore, over 75 percent within 5 miles, and over 95 percent within 25 miles. Fifty percent of the

TABLE 4-12. SPECIFIC LOCATION OF CASUALTIES

Location	Grounding	Collision	Ramming	Total
East Coast				
Gulf of Maine	1	0	0	1
Hussey Sound, Maine	1	0	0	1
Nantucket Shoals	1	0	0	1
Long Island Sound	5	2	0	7
Off New York Harbor	0	1	0	1
Off Delaware Bay	10	0	0	10
Off Chesapeake Bay	4	1	0	5
Off Miami	1	0	0	1
Florida Straits	1	0	0	1
Gulf Coast				
Tampa Bay	1	1	0	2
Off Mississippi	0	0	1	1
Off Louisiana	2	4	5	11
Off Sabine, Texas	1	0	0	1
Off Aransas, Texas	1	0	0	1
West Coast				
Off S.F. Harbor	0	1	0	1
Off L.A. Harbor	1	0	0	1
Alaska				
Cold Bay	1	0	0	1
Cook Inlet	1	0	0	1
Puerto Rico				
Guayanilla/Tallaboa	10	0	0	10
La Parguera	1	0	0	1
Vieques Passage	1	0	0	1
Virgin Islands				
Limetree Bay	3	0	0	3
Total	47	10	6	63

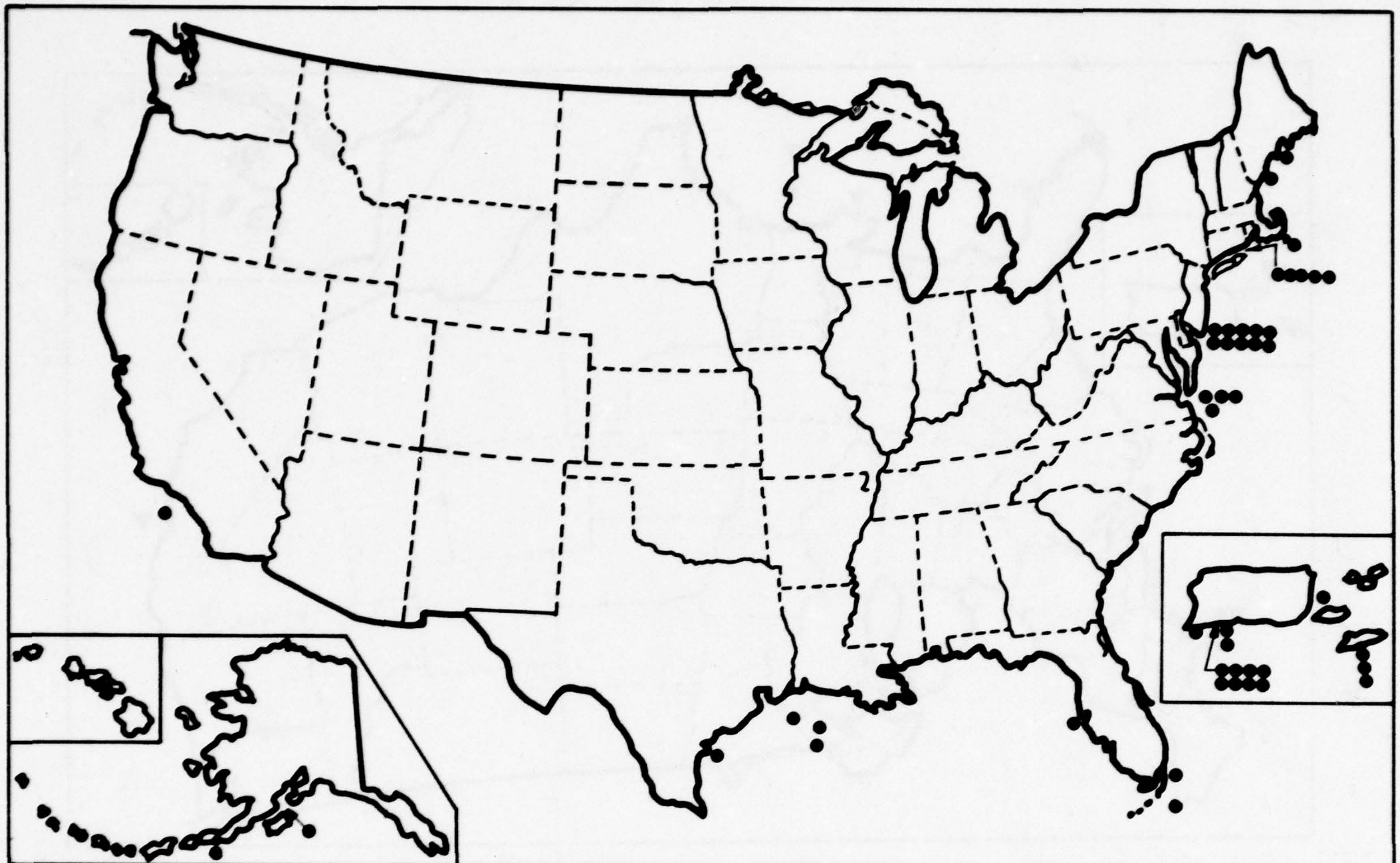

FIGURE 4-2. GROUNDING LOCATIONS MAP

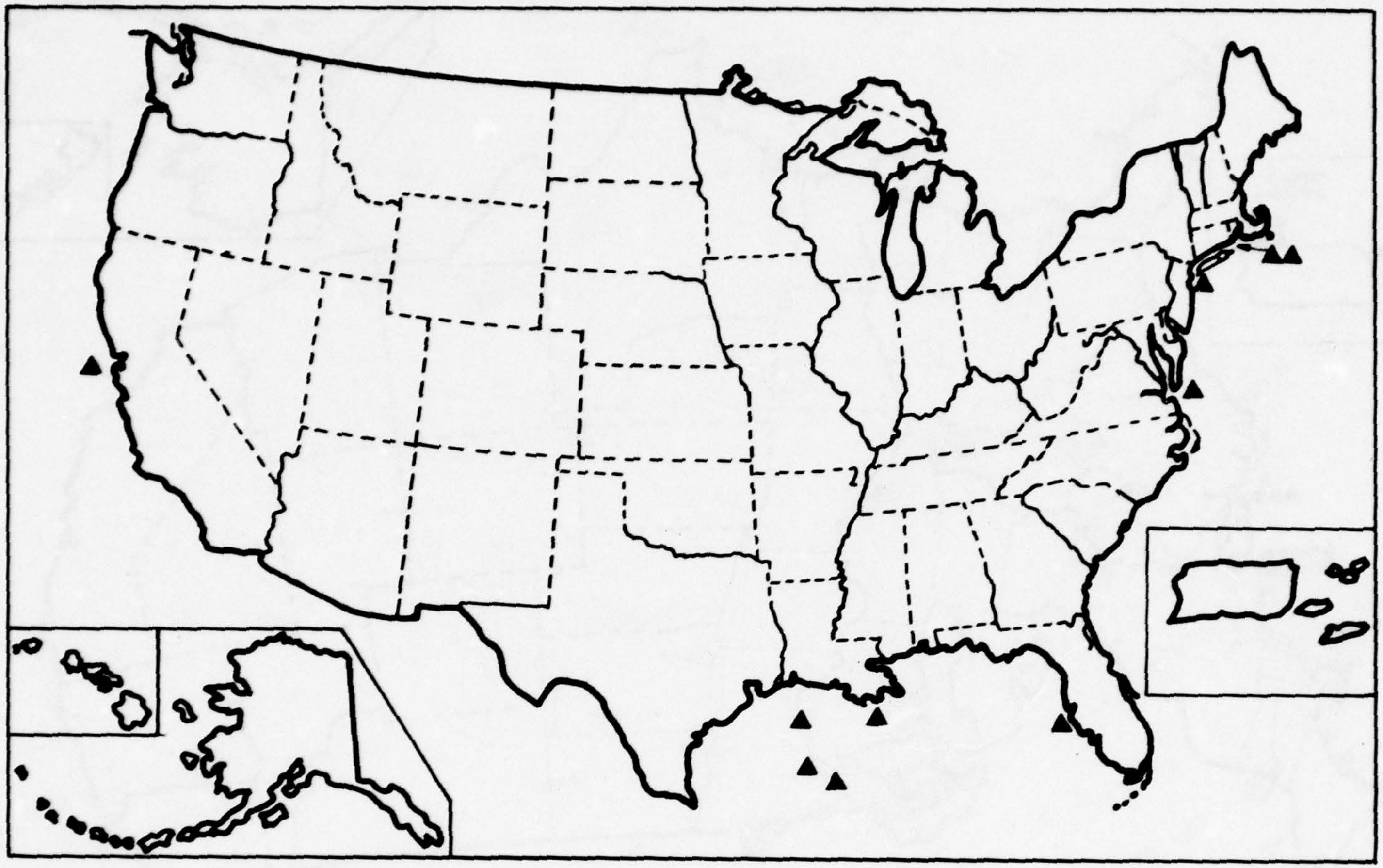

FIGURE 4-3. COLLISION LOCATIONS MAP

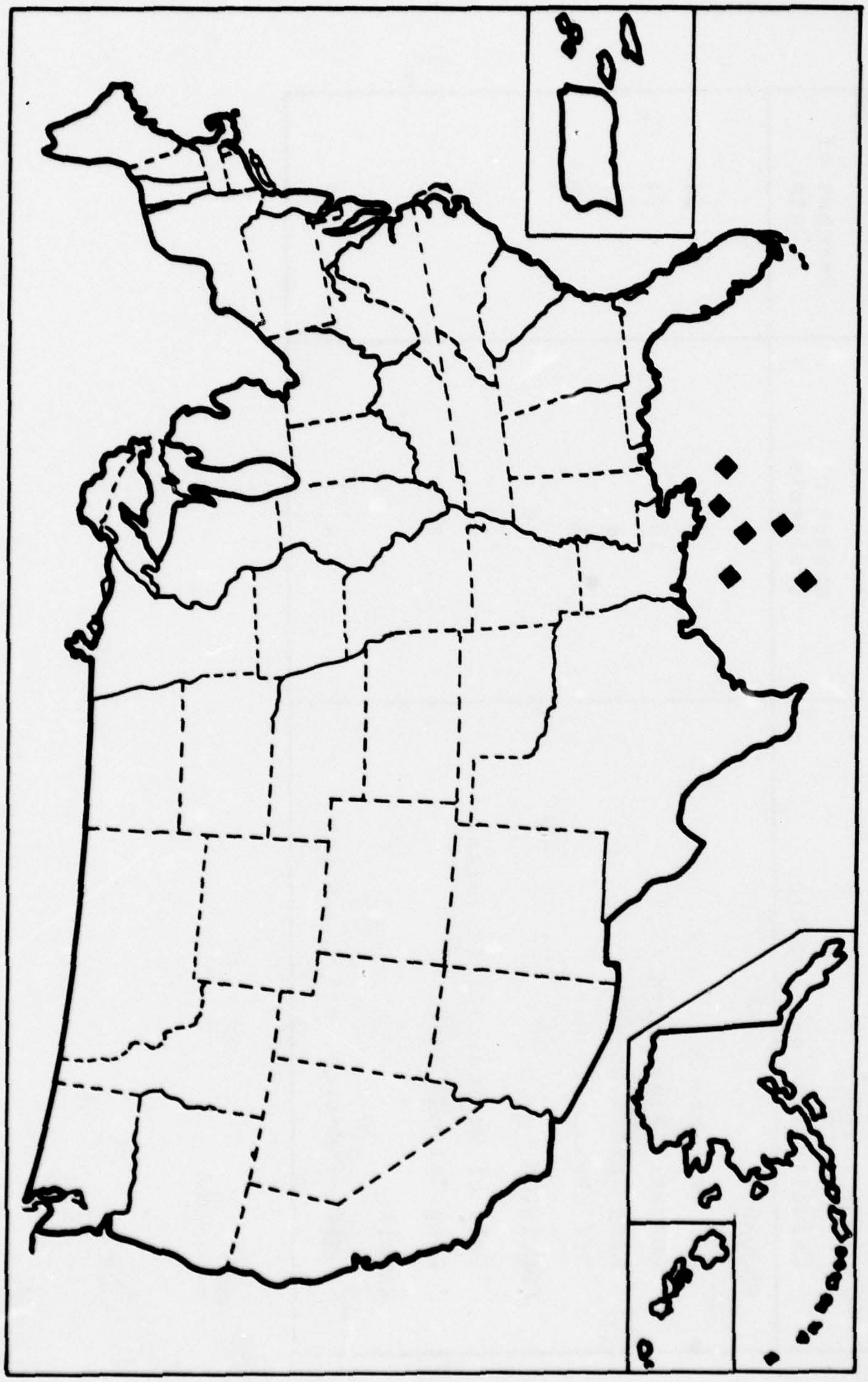

FIGURE 4-4. RAMMING LOCATIONS MAP

TABLE 4-13. FREQUENT LOCATIONS FOR CASUALTIES

Casualty Type and Location	Number of Incidents	Percent of Total
GROUNDING		
Off Delaware Bay	10	21
Guayanilla Bay Area (P.R.)	10	21
Long Island Sound	5	11
Off Chesapeake Bay	4	9
COLLISION		
Gulf of Mexico, off Louisiana	4	40
Long Island Sound	2	20
RAMMING		
Gulf of Mexico, off Louisiana	5	83

TABLE 4-14. CASUALTIES VERSUS DISTANCE OFFSHORE

	Distance Offshore (Nautical Miles)										
Casualty Type	≤1	1-3	3-5	5-12	12-25	25-50	50-75	75-100	100-150	150-200	Total
Grounding	17	9	10	5	4	2	0	0	0	0	47
Collision	2	1	2	1	2	0	0	1	1	0	10
Ramming	0	0	0	0	1	3	1	1	0	0	6
Total	19	10	12	6	7	5	1	2	1	0	63

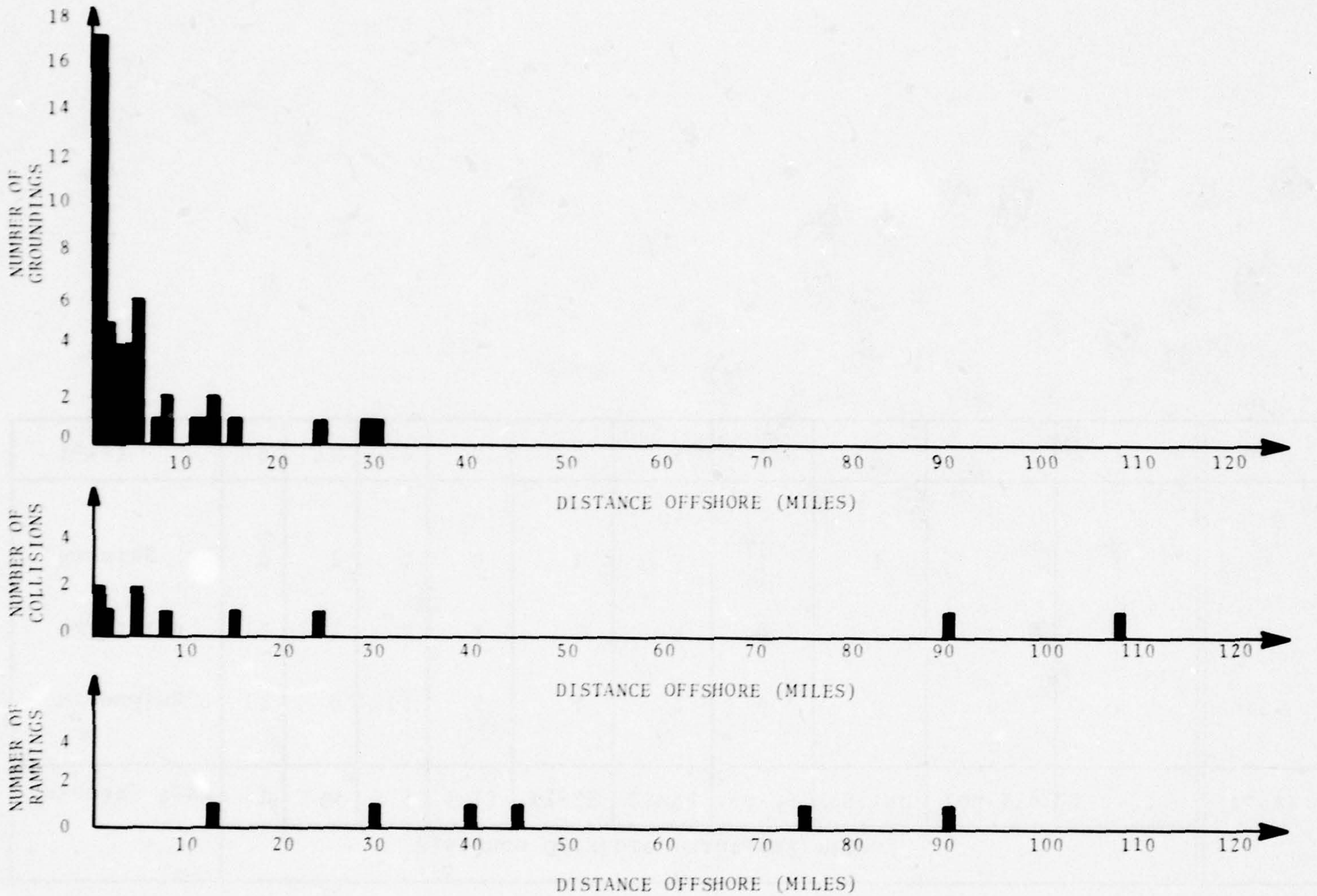

FIGURE 4-5. NUMBER OF CASUALTIES VERSUS DISTANCE OFFSHORE

collisions occurred no more than 5 miles from shore, and 80 percent occurred within 25 miles of shore. All rammings are placed between 12 and 100 miles from shore.

Note that 62 casualties of the 63 in the data base (98 percent) occurred less than 100 miles offshore, and that 59 of the 63 casualties (94 percent) occurred within 50 miles of shore.

Table 4-15 to 4-17 show the distances offshore of the casualties at specific locations.

In summary, data base groundings primarily occur off the East Coast, Gulf Coast and Puerto Rico (especially off Delaware and Guayanilla Bays) and less than 5 miles from shore. Data base collisions primarily occurred off the East and Gulf Coasts and less than 25 miles offshore. Data base rammings occurred in the Gulf of Mexico between 12 and 100 miles from shore. Ninety-four percent of all the casualties occurred within 50 miles of shore.

4.4.3 Conditions for Casualties

This section considers the conditions under which the casualties of interest occurred. Included are the time of day, visibility, time of year, and year. For two incident types, additional conditions will be included: for groundings, the type of ocean bottom; and for collisions, (a) the type of encounter based upon relative bearing, and (b) the amount of time before the collision that the vessels are aware of each other.

An examination of the time of day in which casualties occurred is shown in Figure 4-6. More than one-half of all types of incidents occurred at night, the ratio of night-to-day incidents being 2 to 1 for groundings and rammings and 3 to 2 for collisions.

The visibility when the casualties occurred is shown in Table 4-18. Visibility is more of a factor in collisions (40 percent of the collisions occurred during poor visibility conditions) than it was in groundings (13 percent) or rammings (0 percent).

TABLE 4-15. GROUNDINGS - DISTANCE OFFSHORE VERSUS LOCATION

	Distance Offshore (Nautical Miles)					
Location	0-3	3-12	12-25	25-50	50-100	100-125
East Coast						
Gulf of Maine	0	1	0	0	0	0
Hussey Sound, Maine	1	0	0	0	0	0
Nantucket Shoals	0	0	0	1	0	0
Long Island Sound	4	1	0	0	0	0
Delaware Bay	1	6	3	0	0	0
Chesapeake Bay	1	3	0	0	0	0
Off Miami	1	0	0	0	0	0
Florida Straits	0	1	0	0	0	0
Gulf Coast						
Tampa Bay	0	1	0	0	0	0
Off Louisiana	0	0	1	1	0	0
Off Sabine, Texas	0	1	0	0	0	0
Off Aransas, Texas	1	0	0	0	0	0
West Coast						
Off L.A. Harbor	1	0	0	0	0	0
Alaska						
Cold Bay	1	0	0	0	0	0
Cook Inlet	0	1	0	0	0	0
Puerto Rico						
Guayanilla/Tallaboa	10	0	0	0	0	0
La Parguera	1	0	0	0	0	0
Vieques Passage	1	0	0	0	0	0
Virgin Islands						
Limetree Bay	3	0	0	0	0	0
Total	26	15	4	2	0	0

TABLE 4-16. COLLISIONS - DISTANCE OFFSHORE VERSUS LOCATION

Location	Distance Offshore (Nautical Miles)					
	0-3	3-12	12-25	25-50	50-100	100-125
East Coast						
Long Island Sound	2	0	0	0	0	0
Off New York Harbor	0	0	1	0	0	0
Chesapeake Bay	1	0	0	0	0	0
Cape Lookout, NC	1	0	0	0	0	0
Gulf Coast						
Tampa Bay	0	1	0	0	0	0
Off Louisiana	0	1	1		1	1
West Coast						
Off S.F. Harbor	0	1	0	0	0	0
Total	3	3	2	0	1	1

TABLE 4-17. RAMMINGS - DISTANCE OFFSHORE VERSUS LOCATION

Location	Distance Offshore (Nautical Miles)					
	0-3	3-12	12-25	25-50	50-100	100-125
Gulf Coast						
Off Mississippi	0	0	0	1	0	0
Off Louisiana	0	0	1	2	2	0
Total	0	0	1	3	2	0

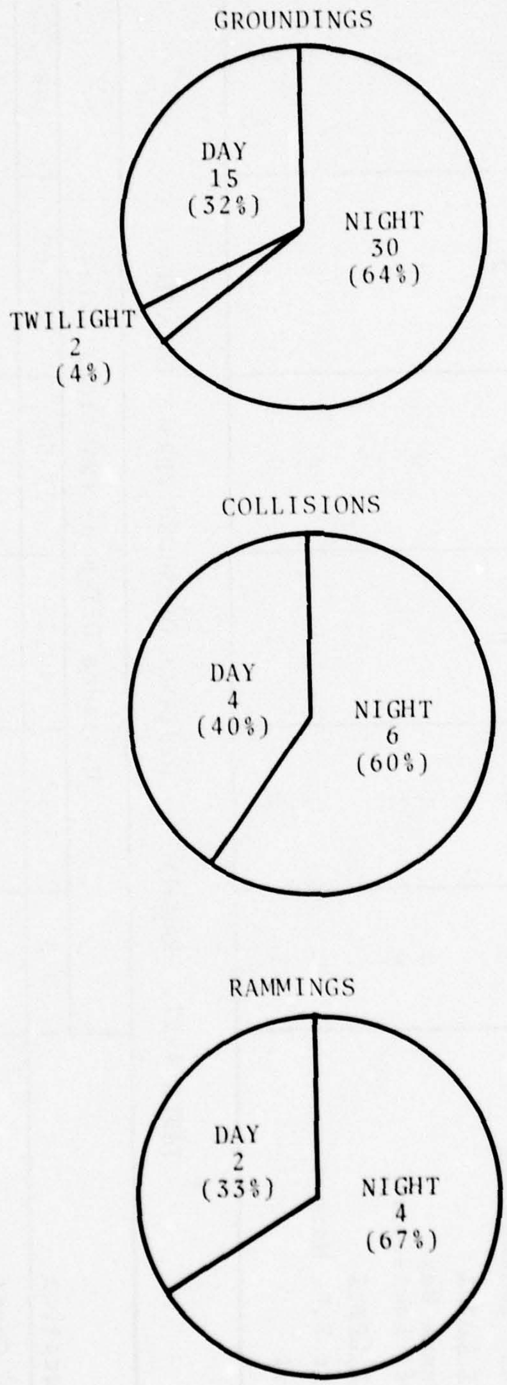

FIGURE 4-6. TIME OF DAY FOR CASUALTIES

TABLE 4-18. CASUALTIES BY VISIBILITY

Nature of Casualty	Visibility (Nautical Miles)					Total
	≤ 1 (Poor)	1-5 (Fair)	5-10 (Good)	>10 (Unlim.)	Unknown	
Grounding	6	8	19	12	2	47
Collision	4	0	2	4	0	10
Ramming	0	1	3	2	0	6
Total	10	9	24	18	2	63

Table 4-19 shows the combined effect of the degree of darkness and the visibility on the OVTM casualties. Note that 69 percent of the groundings, 88 percent of the collisions, and 67 percent of the rammings occurred either at night or in poor visibility, or both.

Figure 4-7 shows the seasonal variation of casualties. Groundings are fairly uniform, peaking in spring. Collisions peak strongly in spring and fall. Rammings tend to occur most often in spring, with 5 out of 6 rammings occurring then. Overall, spring clearly predominates as the season for casualties.

To consider the possibility of long-term trends in casualties, the yearly number of each type of casualty has been determined, and is shown in Table 4-20. During the five calendar years 1972-1976 for which the data base includes complete data, there seems to be no clear long-term trends.

The ocean bottoms for OVTM data base groundings are shown in Figure 4-8. About one-third of the groundings are on mud or sand bottoms. For the leading grounding locations, Table 4-21 shows the ocean bottom distribution. For the Guayanilla Bay area, Long Island Sound and the Cheseapeake Bay area, almost all groundings are on hard and rocky bottoms. Off Delaware Bay, the majority of groundings are on mud and sand bottoms.

For collisions, two items of interest are (a) the type of encounter based upon relative bearing, and (b) the time before the collision that the vessels are aware of each other. Figure 4-9 shows the type of encounter, i.e., meeting, crossing, or overtaking. (None of the "basic" data base collisions involve one vessel having been at anchor, another type of collision encounter.) As can be seen, 50 percent of the collisions involved a meeting situation.

Table 4-22 shows the time before a collision that the vessels are aware of each other. In over 60 percent of the known cases, both are aware of each other for more than 10 minutes before collision and/or are in radio contact.

TABLE 4-19. CASUALTIES BY TIME OF DAY AND VISIBILITY

Nature of Casualty	Time of Day	Visibility (Nautical Miles) <1 (Poor)	1-5 (Fair)	5-10 (Good)	>10 (Unlim.)	Unknown	Total
Grounding	DAY	4	5	2	4	0	15
	TWI	0	0	2	0	0	2
	NGT	2	3	15	8	2	30
Collision	DAY	3	0	1	0	0	4
	TWI	0	0	0	0	0	0
	NGT	1	0	1	4	0	6
Ramming	DAY	0	0	0	2	0	2
	TWI	0	0	0	0	0	0
	NGT	0	1	3	0	0	4
Total	DAY	7	5	3	6	0	21
	NWT	0	0	2	0	0	2
	NGT	3	4	19	12	2	40

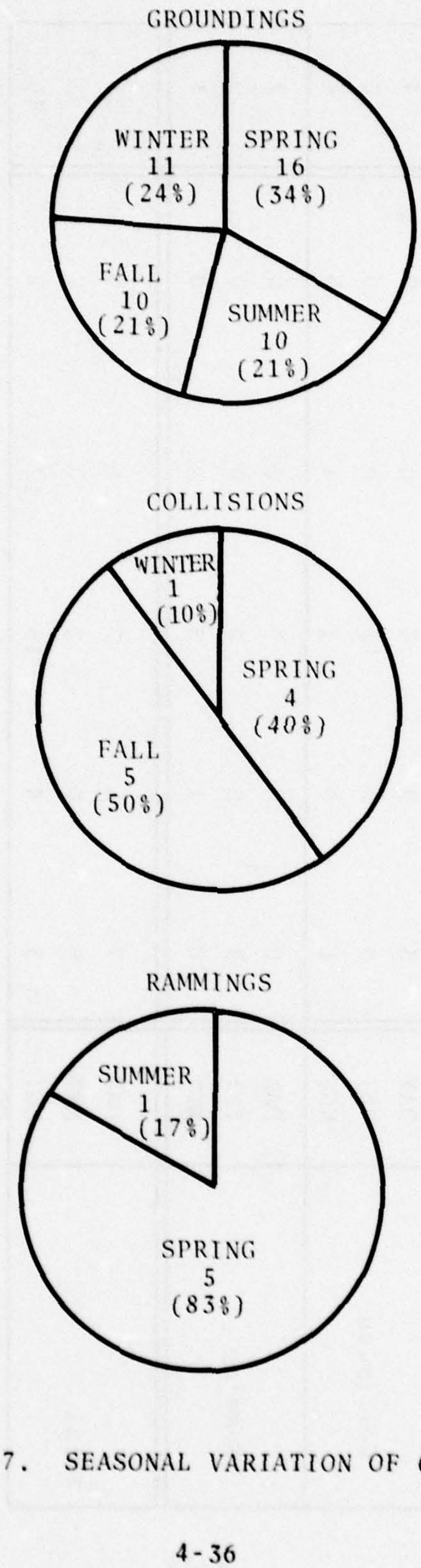

FIGURE 4-7. SEASONAL VARIATION OF CASUALTIES

TABLE 4-20. CASUALTIES BY YEAR

Nature of Casualty	Calendar Year							Total
	71*	72	73	74	75	76	77*	
Grounding	1	9	7	7	7	13	3	47
Collision	2	1	1	1	3	2	0	10
Ramming	0	1	1	2	2	0	0	6
Total	3	11	9	10	12	15	3	63

NOTE:

*Data base does not contain complete data for the years 1971 and 1977.

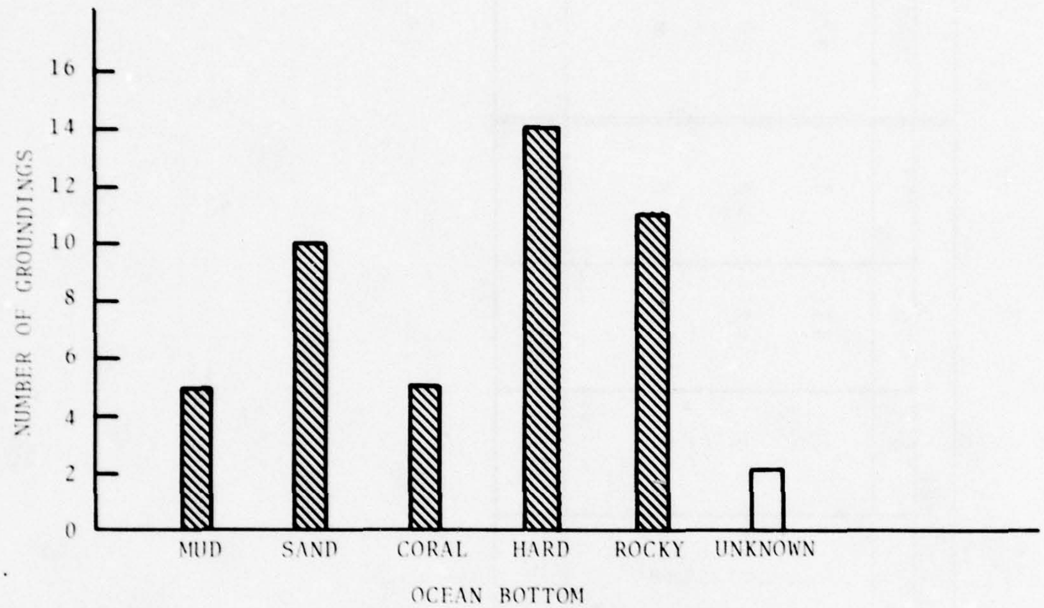

FIGURE 4-8. OCEAN BOTTOM CONDITIONS FOR GROUNDINGS

TABLE 4-21. OCEAN BOTTOMS AT LOCATIONS OF FREQUENT GROUNDINGS

Location	Mud	Sand	Coral	Hard	Rocky	Unknown	Total
Off Delaware Bay	2	4	0	3	0	1	10
Guayanilla Bay	1	0	1	1	6	1	10
Long Island Sound	0	0	0	2	3	0	5
Off Chesapeake Bay	1	0	0	3	0	0	4

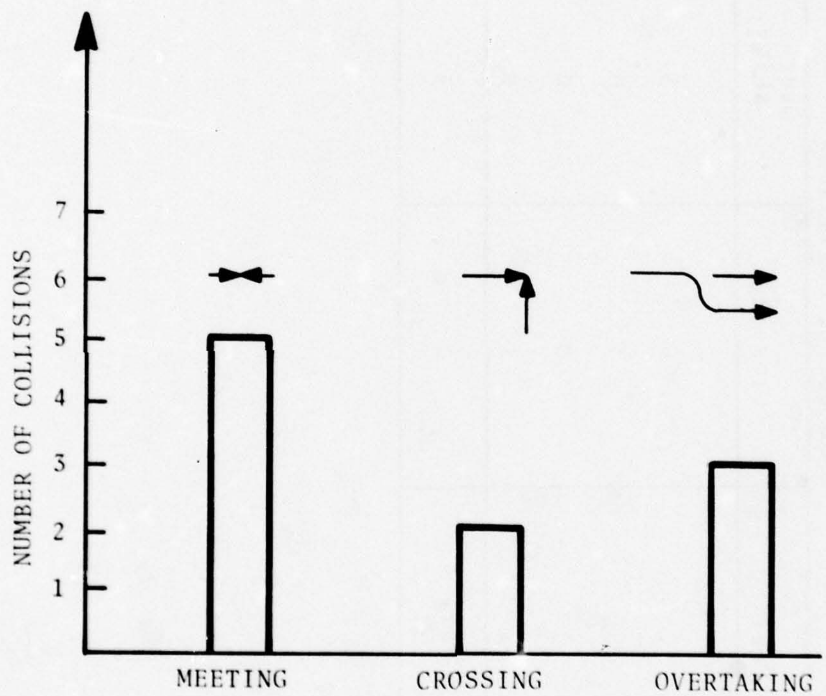

FIGURE 4-9. COLLISIONS BY ENCOUNTER TYPE

TABLE 4-22. AWARENESS OF OTHER VESSEL IN A COLLISION

Aware 10 Minutes Before Collision	Number of Collisions			Total
	Meeting	Crossing	Over-taking	
Both (or in Radio Contact)	2	0	3	5
One	0	1	0	1
Neither	2	0	0	2
Unknown	1	1	0	2
Total	5	2	3	10

In summary, casualties in the data base, especially collisions, occurred mostly at night or in poor visibility conditions, or both. Spring is the primary season for casualties, especially rammings. No clear yearly trend in casualties has been found. Most groundings are in areas with coral, hard, or rocky bottoms. One-half of the collisions involve a meeting situation, and in most collisions, the vessels are aware of each other's presence at least 10 minutes before colliding.

4.5 CAUSAL ANALYSIS

An analysis of the causes of the casualties is discussed. The extended data base of 78 incidents will be used in the discussion of causes since the 15 additional cases have been chosen as involving vessels similar to tankers in such characteristics as size, navigation equipment, crew makeup, etc., thus having many of the same causative factors.

4.5.1 Causes of Groundings

Many different causative factors contribute to groundings. Table 4-23 identifies the primary causes for the 55 groundings included in the extended data base. Of the 29 different causes found, many are similar or have the same causative factors. However, each one of these 29 causes is distinct from all the others. Note that to group the 55 groundings under as many as 29 causes still requires grouping together some cases in which secondary factors are different.

Looking at the case records and at Table 4-23, some prevalent causative factors involved in the groundings are apparent. They are shown in Table 4-24. Note that some groundings involve more than one of the factors listed and some are special cases which do not involve any of the listed factors to a large degree. Of the 55 groundings, 40 involve a navigation error (i.e., poor knowledge of position), including 21 that can be attributed directly to poor navigation practice. Seven cases involve vessels failing to wait for a pilot to board before entering the harbor area, or vessels

TABLE 4-23. CAUSES OF GROUNDINGS

Primary Cause(s) of Grounding	Number Of Groundings
1. Didn't keep informed of position although navigation aids were available.	8
2. Determined erroneous position/course although navigation aids were available.	1
3. Erroneous position. Conning Officer not fully licensed. Didn't use available navigation aids	1
4. Didn't keep informed of position, then turned on wrong buoy. Navigation aids were available.	2
5. Misjudged set, thus didn't know position. On watch over 8 hours. Navigation aids were available.	1
6. Inaccurate position in poor visibility	2
7. Couldn't determine position due to aids to navigation failure. Didn't wait for pilot.	1
8. Didn't keep informed of position. Gyro failed.	1
9. Inaccurate position in poor visibility. Radar failed/unreliable	2
10. Radar failure.	3
11. Radar unreliable due to weather conditions	1
12. Gyro or gyro repeater error.	2
13. Misinterpreted lights seen.	1
14. Water level below normal.	1
15. Read chart soundings in fathoms instead of feet	1
16. Used buoys to navigate. Failed to enter buoy changes on charts.	2
17. Lacked proper charts for area.	1
18. Had less detailed chart than needed.	1
19. Lacked proper charts. Didn't wait for pilot.	1

TABLE 4-23. CAUSES OF GROUNDINGS (Continued)

Primary Cause(s) of Grounding	Number Of Groundings
20. Informed incorrectly by pilot that buoy was off-station. Used it to navigate.	1
21. Didn't wait for pilot in safe area. Navigation aids were available.	4
22. Didn't wait for pilot in safe area. Misjudged set. Navigation aids available.	1
23. Misjudged set or drift in a maneuver.	6
24. Bridge unattended, then wrong maneuver.	1
25. Maneuvered too close to edge of wide passage. Navigation aids were available.	1
26. Made turn too close to edge of wide passage and barge sheered. Navigation aids available.	1
27. Uncharted shoal.	5
28. Inaccurate position in aiding vessel.	1
29. Anchored in unsafe area.	1

TABLE 4-24. SELECTED CAUSATIVE FACTORS FOR GROUNDINGS

Causative Factor	Number of Groundings in which Factor is Involved	Percent of Total Groundings in which Factor is Involved
Navigation Error (e.g., erroneous position) - all causes	40	72
Navigation Error - poor navigation practice	21	38
Navigation Error - inoperable or malfunctioning equipment	9	16
Navigation Error - lack of charts	5	9
Conning Error (i.e., poor maneuvering) - all causes	10	18
Conning Error - misjudged set	6	11
Didn't wait for pilot or didn't wait in safe area	7	13

Note: Some cases involve more than one of these factors, and some cases involve unique factors not listed above.

waiting for a pilot in an unsafe area where the grounding occurred. Ten groundings involve conning errors.

4.5.2 Causes of Collisions

The 17 "extended" data base collisions are analyzed for causes. A brief description of the primary causes of these collisions is shown in Table 4-25. For the 17 collisions, 12 different primary causes are found. Again, some of these causes are similar to others, but all are distinct. Also, it is necessary to ignore secondary features to group the 17 collisions under as few as 12 causes.

Based upon the case records and Table 4-25, some common causative factors can be found for the collisions. They are shown in Table 4-26. Of the 17 collisions, 7 involve lack of agreement as to passing. This is the classic meeting problem (Devanney, 1978), where each vessel knows of the other's presence, but one reads the

TABLE 4-25. CAUSES OF COLLISIONS

Collision Type	Primary Cause(s) of Collision	Number of Collisions
1. Meeting	One passed left, one passed right. No communication.	5
2. Meeting	One passed left, one passed right. Both attempted communication.	1
3. Meeting	Early radar contact. No radio communication.	1
4. Meeting	Agreed on passing, but didn't keep right.	1
5. Crossing	No communication from tug. Tanker thought tug and tow were oil rigs.	1
6. Crossing	Burdened vessel didn't keep clear.	2
7. Overtaking	Communication too late. Didn't know where each other was.	1
8. Overtaking	Failed to maintain proper lookout.	1
9. Overtaking	Unaware of current while coming alongside.	1
10. Overtaking	Rudder jammed, didn't signal. Other ship didn't have lookout.	1
11. Hit Anchored Vessel	Radar failed. Both used fog signals and attempted radio communication.	1
12. Hit Anchored Vessel	No lookout.	1

situation as requiring a standard port-to-port passing and the other reads the situation as requiring a starboard-to-starboard passing. In 3 collisions, passing was either agreed upon or clearly involved standard procedure based upon the rules of the road, but a collision occurred due to poor execution of the passing. In 4 collisions, vessels either lost track of, or did not know the location of the other vessel. It is interesting to note, however, that in almost all cases, both vessels are aware of each other's presence.

TABLE 4-26. SELECTED CAUSATIVE FACTORS FOR COLLISIONS

Causative Factor	Number of Collisions in which Factor is Involved	Percent of Total Collisions in which Factor is Involved
Lack of agreement as to passing.	7	41
Didn't know location of the other vessel.	4	24
Agreed upon or standard passing. Poorly performed.	3	18

Note: Some cases involve unique factors not listed above.

4.5.3 Causes of Rammings

As for the groundings and collisions, the six ramming cases have been analyzed for cause. Brief descriptions of the causes found are shown in Table 4-27. Four different primary causes have been found for the six cases.

Six cases with four different primary causes is a small sample to find common causative factors, but Table 4-28 shows that the failure to maintain a proper lookout is involved in 50 percent of rammings.

TABLE 4-27. CAUSES OF RAMMINGS

Causative Factor Involved	Number of Rammings
Didn't keep informed of position although navigation aids were available.	1
Misjudged set or drift in a maneuver.	2
Failed to maintain proper lookout.	2
Failed to maintain proper lookout when radar was not usable due to weather.	1

TABLE 4-28. CAUSATIVE FACTORS FOR RAMMINGS

Causative Factor Involved	Number of Rammings	Percent of Total
Failure to maintain proper lookout.	3	50
Conning error - Poor maneuvering.	2	33
Navigation error - Poor navigation practice.	1	17

4.5.4 Limitations of the Causal Analysis

The numbers of casualties upon which the characteristics and causal analyses are based are too small to allow any reliable statistical analysis. However, it is possible to use the results of the characteristics study and the causal analysis to define a set of requirements for systems. Systems to prevent casualties could then be proposed, designed, and assessed based upon the degree to which they would prevent groundings, collisions, and rammings which are of the types described in Section 4.4 and which have causes as described in Sections 4.5.1-4.5.3. However, this approach has shortcomings. For example, although the analysis may show that 40 percent of the groundings occur off the East Coast, 37 percent occur under day or twilight conditions, and 38 percent involve poor navigation practice, it cannot be concluded that 40 percent of all groundings include this specific combination of conditions/factors. Nor can it be concluded that 6 percent (the product of the above three percentages) of all groundings include this specific combination. Clearly, the correlation is missing.

It is possible to perform an extensive analysis of the casualty data, and derive the percentages of casualties with certain combinations of characteristics and causal factors. However, even in this approach there are problems. Not only is the number of casualties small, but grouping casualties into causal categories ignores secondary factors that may be important in later analysis.

Based upon the above, each casualty has been considered separately rather than using the overall results of the characteristics and causal analysis. The casualty circumstances are studied, and matched against each possible casualty prevention (operational) feature to determine how effective that particular feature would be in preventing this particular casualty. This method preserves the uniqueness of each casualty and the correlations of its characteristics and its causative factors. The matching is done for all casualties and for all proposed operational features. Then, those operational features that are found to be the most effective in preventing these casualties are combined into total systems, which are evaluated on the basis of total system cost-effectiveness (see Section 5 and Appendix I for a description of the evaluation technique).

4.6 ESTIMATION OF FOREIGN FLAG CASUALTIES MISSING FROM THE OVTM DATA BASE

Due to the limitations of the Coast Guard data base discussed in Section 4.3, a method has been sought for estimating the number of missing foreign flag casualties. To this end, the Coast Guard* contracted with Lloyd's to sort through their casualty reports for the years 1971-1977 for groundings and collisions in United States offshore waters involving tank vessels larger than 1,000 gross tons. A total of 620 reports has been found.

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*Information and Analysis Staff, Office of Merchant Marine Safety.

The OVTM Study team analyzed these 620 reports to find cases which occurred in the areas of interest to this study: United States coast to 200 miles excluding harbors, rivers and channels (and waters of other countries). In some cases the location description in the Lloyd's casualty report is ambiguous, and a best guess is necessary as to whether the location of the case is in or out of the region of interest. A total of 45 groundings and 14 collisions have been found to be in "good" locations, as shown in Table 4-29. Table 4-30 shows a breakdown of these cases by flag(s) and type of tank vessel(s) involved. Note that the flags of the non-tank vessels involved in collisions must be considered, since if any United States flag ship is involved in an accident, it should report the incident under MVCR reporting regulations.

First, looking at tank barge cases, it can be seen from Table 4-30 that all tank barges involved are under United States flag. The OVTM data base also shows that all tank barges involved in those incidents are under United States flag. This agrees with the fact that almost all tank barges in United States waters go from one United States port to another and so, under the Jones Act, must be United States flag. Thus, it may be assumed that there are virtually no tank barge cases of interest that would not fall under the MVCR reporting rules, and thus, except for violations of those rules, the OVTM is not missing any tank barge cases. However, it is clear that <u>tanker</u> cases are missing from the OVTM data base. There is no regulation requiring either foreign tanker groundings or collisions involving only foreign vessels to be reported to the Coast Guard if they occur outside of three miles from United States shores. Such casualties will normally be missing from the MVCR data base and consequently they will be missing from the OVTM data base.

Tables 4-31 and 4-32 show the further analysis of the tanker cases from the Lloyd's sort to estimate the number of tanker cases missing from the OVTM data base. As shown, in the Lloyd's sort of 76 percent of the groundings and 31 percent of the collisions involved foreign ships only. The OVTM data base has only 45 percent foreign flag groundings and no foreign-only collisions. If it is

TABLE 4-29. ANALYSIS OF LLOYD'S SORT

Total in Lloyd's sort	620
Groundings in OVTM locations of interest	45
Collisions in OVTM locations of interest	14
Total in OVTM locations of interest	59

TABLE 4-30. ANALYSIS OF LLOYD'S SORT - CASE TYPES

Incident Type	Flag(s) Involved	Type of Vessel(s) Involved	No. of Cases
Grounding	United States	Tanker	10
		Tank Barge	3
	Foreign	Tanker	32
Collision	United States only	Tanker and non-tank vessel	2
		Tanker and tank barge	1
	Foreign only	Tanker and non-tank vessel	3
		Two tankers	1
	United States and Foreign	United States tanker and foreign non-tank vessel	2
		United States tank barge and foreign non-tank vessel	1
		Foreign tanker and United States non-tank vessel	3
		Foreign tanker and Unites States tank barge	1
		Foreign tanker and United States tanker	0

TABLE 4-31. ESTIMATION OF MISSING TANKER GROUNDING CASES

	U.S. Tanker Groundings	Foreign Tanker Groundings	Total	Percent Foreign
In Lloyd's	10	32	42	76
In OVTM	23	19	42	45
Adjusted OVTM (To Lloyd's percentage)	23	74	97	76
Missing in OVTM	0	55	55	-

TABLE 4-32. ESTIMATION OF MISSING TANKER COLLISION CASES

	Tanker Collision Cases Involving at Least One United States Flag Ship	Tanker Collision Cases Involving Foreign Flag Ships Only	Total	Percent Foreign Only
In Lloyd's	9	4	13	31
In OVTM	7	0	7	0
Adjusted OVTM (To Lloyd's percentage)	7	3	10	30
Missing in OVTM	0	3	3	-

assumed that Lloyd's reports are flag-independent, then for the OVTM data base to be flag-independent it should have about the same percentage of foreign flag-only cases as Lloyd's data. By the MVCR reporting rules, no United States flag cases should be missing from OVTM. Therefore, an estimate of the total number of foreign-only casualties in OVTM can be made by adjusting the OVTM foreign casualties such that the percentages of foreign-only groundings and collisions in OVTM are the same as in Lloyd's data. When this is done, it can be seen in Tables 4-31 and 4-32, that an estimated 55 foreign groundings and 3 foreign-only collisions are missing from the OVTM data base.

Table 4-33 shows the estimated actual number of cases of interest to the OVTM study to be 121, 63 cases in the OVTM data base and 58 cases estimated to be missing. In other words, if the MVCR were complete, the OVTM casualty analysis would have found that approximately 121 casualties of interest actually occurred in United States offshore waters in the (FY 72 - FY 77) time period considered.

TABLE 4-33. ESTIMATED TOTAL OVTM CASUALTIES OF INTEREST

	In OVTM	Estimated Missing Cases	Total
Groundings	47	55	102
Collisions	10	3	13
Rammings	6	0	6
TOTAL	63	58	121

4.7 CASUALTY PROJECTIONS

The casualties discussed in Sections 4.3, 4.4 and 4.5 are a matter of historical record, as documented in the Merchant Vessel Casualty reports maintained by the U.S. Coast Guard. The potential effectiveness of the various system alternatives (to be described in Section 5) is based on an analysis of the casualties of interest derived from this data base and identified earlier in Section 4.3. To estimate the effectiveness of each of the recommended system alternatives (see Section 7) in preventing future incidents, a casualty scenario for the 1980s has been projected.

The objective is to estimate the number of potentially preventable casualties (i.e., groundings, collisions and rammings) involving tank vessels and/or offshore rigs that would occur if no new OVTM techniques are adopted.* The only changes assumed are the number of loaded tank vessels and the number/locale of offshore rigs in United States waters. The time frame chose for projecting casualties is the 10-year period from 1981 through 1990.

Projections of tanker traffic in United States waters for 1982 and 1987 have been obtained from MIT (Devanney, 1978). Table 4-34 shows the number of loaded tankers per year estimated to be in transit in United States coastal areas through 1990. Three percent annual growth in the demand for oil in the United States and the introduction of deep draft terminal facilities in the Gulf (LOOP) in 1980 are assumed. Two separate linear interpolations have been used; i.e., from 1977 to 1982, and from 1982 to 1990.

Projections of the number of offshore rigs that may exist in the 1981-1990 time frame is highly speculative. For example, deployment of rigs in the outer continental shelf lease areas off the eastern seaboard of the United States is very much dependent

*A number of actions taken by the Coast Guard during 1977 will have an impact on the number of casualties occurring in future years. Among the more significant are extension of LORAN-C coverage to the West Coast and Gulf of Alaska, incorporation of Navigation Safety Regulations into Title 33 of Code of Federal Regulations, and institution of the Tanker Boarding Program. Estimation of the individual casualty reduction potential of these specific actions has not been addressed during this study, except that extended LORAN-C coverage is included as part of the Baseline System.

TABLE 4-34. TRAFFIC PROJECTIONS - NUMBER OF LOADED TANKER TRIPS PER YEAR

Location	Flag	Year													
		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
East Coast	Foreign	4844	4985	5126	5267	5407	5548	6036	6524	7011	7499	7987	8475	8963	9450
	U.S.	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Gulf Coast	Foreign	2406	2457	2508	2558	2609	2660	2839	3018	3196	3375	3554	3733	3912	4090
	U.S.	2928	2862	2796	2729	2663	2597	3329	4061	4792	5524	6256	6988	7720	8451
West Coast	Foreign	500	473	447	420	394	367	544	720	897	1073	1250	1427	1603	1780
	U.S.	0	147	294	442	589	736	968	1200	1433	1665	1897	2129	2361	2594
Alaska	U.S. (Crude)	0	147	294	442	589	736	827	919	1010	1102	1193	1284	1376	1467
TOTAL		11678	12071	12465	12858	13251	13644	15543	17442	19339	21238	23137	25036	26935	28832

on the success achieved in the exploratory drilling exercises which are currently underway. For current purposes of casualty projections, no increases in rig deployment have been assumed, yielding what is probably a conservative estimate of ramming incidents. However, since rammings of offshore rigs constitute a relatively small percentage of the total number of casualties, this assumption does not have a significant impact on the system effectiveness estimates.

The following sections describe the methods used to estimate the number of groundings, collisions, and rammings in United States waters based on the foregoing traffic/offshore rig scenario.

4.7.1 Projection of Groundings

The number of groundings is assumed to increase linearly with the number of tankers in transit in United States waters. Since the propensity for groundings varies with coastal region, the number of groundings in each regional area during the base year (1977) is used as the basis for projection. As shown in Table 4-11, the 6-year total (FY 1972 - FY 1977) number of groundings in the OVIM data base is 47. Based on the analysis of Lloyd's casualty reports (Section 4.6), 55 foreign tanker groundings are estimated to be missing from the OVTM data base. These 55 groundings have been assumed to be distributed by region in the same proportion as the actual reported foreign tanker groundings.

United States flag tanker traffic carrying crude oil from Alaska to the West Coast and the Gulf was practically non-existent in 1977. The tanker fleet to be used for this purpose is projected to consist of large, well-equipped United States flag vessels with special traffic routing and high crew standards. Since no historical data exist pertaining to groundings of a fleet of this nature operating in the Alaskan and West Coast regions, it is inferred that the casualty rate in terms of groundings per tanker trip would be half that of the current rate for foreign flag tankers going to the West Coast.

With these assumptions, using the traffic projections of Table 4-34, and the 6-year average as the base year number of groundings, the projections shown in Table 4-35 are obtained for the period 1981-1990.

TABLE 4-35. CASUALTY PROJECTIONS-CURRENT SYSTEM

	Base Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	10-Year Total
Number of Groundings	17.0	19.0	20.0	21.0	23.0	24.0	26.0	28.0	29.0	31.0	32.0	253.0
Number of Collisions	2.2	2.8	2.9	3.8	4.8	5.9	7.1	8.4	9.8	11.4	13.0	69.9
Number of Rammings	1.0	1.0	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.4	16.1

4.7.2 Projection of Collisions

The number of collisions are assumed to increase as the square of the merchant vessel traffic in United States waters. MARAD (MARAD, 1977) forecasts a three percent annual growth rate in both petroleum imports and total imports. Since tanker traffic projections (Devanney, 1978) were also based on a three percent annual growth in demand for oil, it is assumed that the total merchant vessel traffic increases at the same rate as tank vessel traffic.

As shown in Table 4-11, the 6-year total number of collisions in the OVTM data base is ten. Based on the analysis of Lloyd's casualty reports (Section 4.6), three collisions involving only foreign flag ships are estimated to be missing from the OVTM data base.

With these assumptions, the tanker traffic projections of Table 4-34, and using the 6-year average as the base number of collisions, the projections shown in Table 4-35 are obtained. The increased number of collisions with respect to the current average annual rate of 2.2 is due to the projected increase in total traffic from 1977 to 1990 by a factor of 2.5.

4.7.3 Projection of Rammings

The number of rammings of offshore rigs is assumed to increase as the product of the number of the merchant vessels and the number of offshore rigs in United States waters. As discussed in the case of collisions, merchant vessel traffic is assumed to increase at the same rate as tank vessel traffic. The number of rigs is assumed to remain constant. The base annual number of rammings off the Gulf Coast has been obtained by averaging the 6-year total shown in Table 4-11. With these assumptions, and using the Gulf Coast traffic projections of Table 4-34, the projections shown in Table 4-35 are obtained.

4.8 IMPACT OF PROPOSED REGULATIONS

The projections of groundings, collisions, and rammings presented in the preceding section are based on the implicit assumption that the same pattern of causative factors which prevailed during the base years (1972-1977) will continue to occur, with the same percentage of tank vessel trips resulting in a casualty.

Rules have been proposed which would require LORAN-C on board vessels larger than 1,600 gross tons entering United States ports (Federal Register, 1977a), and dual radar on board all vessels larger than 10,000 gross tons (Federal Register, 1978b). The baseline system, to be described in Section 5.2.1, assumes that these regulations will be put into effect, and that vessels will be equipped by 1985.

The effectiveness attributed to the baseline system will reduce the number of casualties projected for the 1981-1990 time period. As shown in Tables 5-6 and 5-7, the effectiveness estimates are 25 percent for groundings, 7 percent for collisions, and 45 percent for rammings, with an availability of 95 percent. The proposed rule requiring LORAN-C equippage (Federal Register, 1977a) estimates 40 percent equippage in 1975. It is assumed that this will increase linearly to 100 percent in 1985.

Based on these assumptions and estimates, the casualty projections for the period 1981-1990 are reduced to the numbers shown in Table 4-36.

TABLE 4-36. CASUALTY PROJECTIONS - BASELINE SYSTEM

	Base Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	10-Year Total
Number of Groundings	17.0	16.0	16.0	17.0	18.0	18.0	20.0	21.0	22.0	24.0	24.0	196.0
Number of Collisions	2.2	2.7	2.7	3.6	4.5	5.5	6.6	7.8	9.1	10.6	12.0	65.1
Number of Rammings	1.0	0.7	0.6	0.7	0.8	0.9	1.0	1.0	1.1	1.3	1.4	9.5

5. SYSTEM ALTERNATIVES

5.1 INTRODUCTION

The data base that was used in the study for assessing system alternatives consists of the 78 casualties identified in Section 4, which include several non-tanker incidents. This data base is too small to attach high statistical certainties to conclusions based on the samples. No doubt there are other human errors, for example, that could cause accidents which are not covered by the human errors committed in the 78 cases. Nevertheless, the assumption is made here that the casualties in the data base are representative of accidents that will continue to occur if no changes are made in procedures or equipment. Furthermore, it is assumed that system alternatives that would have been effective in reducing the accidents in the data base will likewise be effective in reducing future accidents.

The small size of the data base has a definite advantage, on the other hand. It enabled the team to review each case thoroughly, and to treat combinations of systems in a realistic way. That is, if system A could prevent 20% of the accidents, and system B 30%, it doesn't mean that the two systems together could prevent 50% -- the actual number could be any percentage between 30% and 50%, depending on the individual cases. The data base was small enough that this problem could be readily handled.

Early in the study about 30 systems were identified as holding some promise for reducing groundings, collisions and rammings. They were based on suggestions in the literature, suggestions passed on by Coast Guard personnel and shipmasters, suggestions from equipment manufacturers, and on experience with traffic management and control systems in general. The original intent was to assess each casualty against the spectrum of systems to determine which systems appeared most effective in preventing that casualty. However, this approach had the disadvantage that other systems not on the list might prove better; furthermore, the relationship of systems to the causes of the casualties was somewhat obscured. In order to overcome these objections, an intermediate step was performed: a list of "operational features" embodied in the group of systems was defined, and evaluated against the casualties. For example, rather than ask, "would collision avoidance radar system have been effective?" the question was posed, "would a warning signal that automatically sounded when a collision appeared likely have been effective?" This method was found to be more satisfying; it had the further advantage of distinguishing crucial features of different versions of the same equipment.

In each case the assumption was made that the operational feature was "available"; i.e., that any equipment required to provide the operational feature was working, and installed in an appropriate location on the bridge, in the wheelhouse, or in the chartroom. Attempts were made to gauge whether the officer would have used it, based on the general discipline and watchstanding activity of the ship. The number of fixes and course change entries in the ship's log, license/certification of officers, equipment on board, etc. all provided clues. Thus the ease of usage was automatically incorporated into the assessment. Availability is limited by reliability considerations, geographic coverage, and cost. These considerations are system-specific, and so are not incorporated into the operational feature assessments.

Once the operational features were assessed, a set of associated systems was defined. Table 5-1 shows the operational features and the section numbers of the systems which incorporate each feature. The operational features and their evaluations are described in detail in Section I.2 of Appendix I. The systems are listed in Table 5-2. The more promising systems are discussed in Section 5.2, and the less promising systems in Section 5.3. The systems themselves are evaluated considering not only their usefulness as determined from the casualty analysis, but considering costs, geographic coverage, limitations, user acceptance, reliability, stage of development, etc.

TABLE 5-1. OPERATIONAL FEATURES

Operational Features	Section Numbers of Systems Using the Feature
1. More intensive and periodic training	5.2.7
2. Revised Rules of the Road	5.3.1
3. Charting of restricted zones	5.3.2
4. New traffic separation schemes	5.2.8
5. Improved light/buoy system	5.2.2, 5.2.9
6. Improved pilot transfer procedures	5.2.2, 5.2.10
7. Improved equipment standards	5.2.1, 5.2.2, 5.2.11
8. Incentive to repair malfunctioning gear	5.2.2, 5.3.3
9. Mandatory course recorder	5.3.4
10. Improved position accuracy over LORAN-C	5.3.5
11. Ability to obtain a dependable position fix	5.2.1
12. Display of navigation data	5.2.1
13. Display of deviation from intended track	5.2.12
14. Alert indicating excessive deviation from track	5.2.12
15. Maneuvering point alert	5.2.12
16. Improved depth detection	5.3.9
17. Alert indicating shallow depth	5.2.13
18. Forward-looking fathometer	5.3.10
19. Depth mapping with alert	5.2.14
20. RACONs at fairway, traffic lane entrances	5.2.2, 5.2.3, 5.2.6, 5.2.9
21. Ability to obtain dependable, all-weather radar returns	5.2.18
22. Ability to obtain determination of non-moving radar targets	5.2.15, 5.3.11
23. RACONs on oil platforms,	5.2.9
24. Alert that a new vessel has appeared within about 5 miles of own ship	5.2.16, 5.2.17, 5.3.12
25. Warning that a radar target has come within a short range of own ship	5.2.10, 5.3.12
26. Ability to obtain relative position and course projection of radar targets	5.2.15, 5.2.18, 5.3.12
27. Alert if conflict predicted by automatic equipment	5.2.15
28. Ability to obtain immediate radio contact with a selected vessel	5.2.17, 5.2.18
29. Ability to obtain maneuvering intent of other vessels	5.2.17, 5.2.18
30. Incentive to communicate with other vessels to effect passings	5.2.17
31. General advisory of currents, tides, weather, outages	5.2.2, 5.2.3, 5.2.6
32. Voyage plan and checklist submission	5.2.2, 5.2.3, 5.2.6
33. Manual monitoring stations	5.3.13
34. Automatic monitoring stations	5.3.3, 5.2.6

TABLE 5-2. PROMISING SYSTEMS

Promising Systems	Operational Features Used
1. Baseline system	7, 11, 12
2. Passport system	5, 6, 7, 8, 20, 31, 32
3. Auto-Monitoring	5, 6, 7, 8, 20, 31, 32, 34
4. DF-Surveillance	NA
5. Radar Surveillance	NA
6. Satellite Surveillance	5, 6, 7, 8, 20, 31, 32, 34
7. Training	1
8. Traffic Separation	4
9. Aids-to-Navigation	5, 20, 23
10. Pilotage	6
11. Equipment Standards	7
12. Navigation Alert	12, 13, 14, 15
13. Depth Alert	17
14. Scanning Sounder	19
15. Collision Avoidance Aid	26, 27
16. Radar Perimeter Det.	24, 25
17. VHF/Transponder	24, 28, 29, 30
18. Interrogator/Transponder	26, 28, 29

Measures are presently under consideration by the U.S. Coast Guard and Congress which would reduce groundings, collisions, and rammings in the future (U.S. Senate Bill 682, 1978; Federal Register, 1977c). An electronic navigation instrument like LORAN-C will be required equipment on vessels of 1600 gross tons or more, and dual radars will be required on vessels of 10,000 gross tons or more. Since these measures would have prevented some of the casualties in the data base, they are incorporated into a "baseline system." Thus, the effectiveness of each system must be assessed in terms of the extent to which that system's effectiveness exceeds that of the baseline system, while incorporating the features both of the baseline system and the system under consideration. The method by which this is accomplished is discussed in the next section.

5.2 ASSESSMENT OF PROMISING SYSTEMS

The 18 systems that were selected for detailed consideration (see Table 5-2) are described in this section. For each system, the following aspects are discussed:

a. System Description - A technical and operational discussion of the system, including the form of data presentation, communication requirements, and capabilities and limitations.

b. Training/Workload Implications - A discussion of the equipment including the operational complexity, and the time needed to read and interpret data.

c. Estimate of Availability - An estimate of the percentage of time the equipment would be available, considering factors like geographical coverage, equipment reliability, and cost limitations.

d. Present State of Development - A discussion of the state-of-the-art, indicating whether the equipment is off-the-shelf, requiring modification of off-the-shelf equipment or conceptual only; includes development considerations.

e. Estimate of Cost - Estimates of cost to shipowners and government: purchase, installation, maintenance, and development.

f. Coast Guard Actions Required - A list of actions that the Coast Guard must take in order to make the system effective; minimum equipment specifications, requirements on vessel equipment, allocation of frequencies, etc. Many of the alternatives may have liability implications which should be considered by the Coast Guard.

g. Estimate of Effectiveness - The potential effectiveness as obtained from the operational features requires some explanation. Where a system embodies only one operational feature, this effectiveness is the same as the probability of prevention of the operational feature. However, when two or more features are involved, a distinction must be made between "independent" operational features and "dependent" operational features. If two features are dependent* (e.g., "Display of Navigation Data"

*See footnote on p. I-122 for a list of dependent features.

incorporates "Ability to Obtain a Dependable Position Fix"), the maximum of the two point scores is used; i.e., if one feature is assessed at 5 (i.e., 50% probability of prevention) and the other at 6 (i.e., 60% probability), the system is assessed at 6 (i.e., 60% probability). On the other hand, if the features are independent (e.g., "Training" and "Display of Navigation Data"), the probabilities are "ORed"; i.e., the total probability is 50% + 60% - 50% x 60% = 80%, for a system point score of 8. This says that even if one operational feature didn't help, the other might have.

The detailed scoring process is described in Section I.3 of Appendix I for each of the 18 systems, and an example is worked out in Section I.4. A summary of the costs and the measures of effectiveness of each system is given in Section 5.4.

5.2.1 Baseline System

a. System Description - The baseline system is included in order to provide a reference against which other systems can be assessed. It is based on the planned extension of LORAN-C coverage and legislation that is expected to be passed which requires certain equipment on board vessels, particularly tank vessels.

By 1980, the U.S. Coast Guard plans to complete its network of LORAN-C stations which will provide coverage in the Great Lakes, and from Texas to Maine and beyond (Federal Register, 1977b). Coverage already exists on the West Coast and Alaska. At present there are gaps in the Gulf of Mexico and up to South Carolina. It is assumed in this study that, even with unforeseen delays, coastal coverage will be complete by 1985.

The U.S. Coast Guard recently published a notice of rule making (Federal Register, 1977a) entitled "Proposed Navigation Safety Requirements, LORAN-C on Vessels of 1600 Gross Tons or More." The proposed rules would require LORAN-C on board all vessels entering U.S. ports. This was later amended to allow hybrid satellite systems to be used as well (Federal Register, 1977c). The intent of the Coast Guard is to require such equipment in the immediate future. It is assumed that by 1985 such equipment will be on board all vessels of 1600 gross tons or more; it is further assumed that either two LORAN-C time coordinates or latitude/longitude will be prominently displayed on the bridge and near the charts, as the proposed rules require.

These assumptions are cited in the guidelines of the study effort (see Section 3.3).

Rules are also being considered which will require dual radars on board all vessels of 10,000 gross tons or more (Federal Register, 1978). Anticipating that such a rule will be passed, this requirement will also be assumed for the 1985 time frame.

It is pointed out in Appendix I that LORAN-C coverage is not planned for Puerto Rico and the Virgin Islands, where 16 groundings occurred. Thus, the baseline system would have no effect on these casualties. (A recommendation to examine the extension of LORAN-C to Puerto Rico and the Virgin Islands is included in Section 1.3.)

LORAN-C stations along the coast are grouped into "chains," each containing a Master and several secondary stations. Each transmits at 100 kHz, but the transmissions are staggered so that each chain has a recognizable pattern. The chains overlap in coverage, so that it is necessary on most equipments to manually choose the chain and the stations within the chains to be utilized. Some advanced configurations select the secondary stations with the strongest signal; these stations are usually, but not always, the best ones. With some less sophisticated receivers, coarse estimates of the chosen secondary time numbers are required to aid signal acquisition. Once this is done, modern receivers will track the LORAN-C signals and display the time delay numbers. The display consists of two 6 or 7 digit numbers which can be used to provide a position fix on a standard chart.

Hybrid satellite-tracking receiver systems obtain periodic, accurate position estimates when a satellite is in view. During the coverage gaps, which may span up to two hours, another system such as Omega or an inertial system is used. The satellite data are used to calibrate the other system, taking advantage of the fact that the latter's overall errors are partially due to long-term changes; thus, periodic calibrations allow them to be used to a greater accuracy than the systems' ratings.* The display is usually presented in latitude/longitude coordinates. Beyond 1985 global positioning satellites may provide continuous, accurate coverage. However, in the time frame of 1980-1990, satellite navigation will supplement, but not replace, LORAN-C.

Under conditions of low signal levels and high interference, LORAN-C receivers can lock onto the wrong cycle, and introduce errors in multiples of 10 microseconds with no warning. Hybrid satellite systems incur drift errors between satellite scans. LORAN-C is available almost continuously, with high accuracy; its coverage extends only a few hundred miles from the coast, while satellites provide global coverage.

b. Training/Workload Implications - Once the initial operator settings have been entered, signal track is automatic, the display is continuously available, and little effort is required, significantly less than LORAN-A receivers and the older LORAN-C receivers. The initial settings are straightforward. Compared to a radar, it is quite simple to operate and interpret. For these reasons the training and workload implications are minimal.

c. Estimate of Availability - The LORAN-C system has a 99% availability record, according to the "LORAN-C User Handbook" (USCG, 1974), including off-air maintenance. The U.S. Coast Guard predicts that it will be 99.7% in the future. The TRANSIT system has provided continuous service with a fix rate of once every one to two hours, but the system is a military one which can be modified or discontinued at any time. Future satellite positioning systems such as GPS-NAVSTAR are projected to provide 99.7% availability as well, but this remains to be demonstrated.

*It should be pointed out that available evidence indicates that the accuracy and availability of hybrid systems is inferior to LORAN-C.

For the purpose of this study, the system availability is really dominated by the receiver availability. Based on conversations with manufacturers and users, this is estimated to be 95%.

d. Present State of Development - LORAN-C receivers and hybrid satellite receivers can be obtained off-the-shelf. While LORAN-C coverage is not yet available everywhere along the continental coast, it is planned to be by mid-1980 (see Appendix F).

e. Estimate of Costs - Since the baseline system equipment will be required on vessels, the costs from the point of view of this study are zero to both the vessel owners and to the government. That is, the costs relevant to this study are costs incurred over and above the baseline system. However, some cost figures are cited here for navigation receivers as a point of reference.

LORAN-C receivers meeting proposed Coast Guard requirements are available today for $2,000-6,000, plus installation. TRANSIT receiver costs are $15,000-25,000, and Omega receivers, $5,000-15,000.

Extending LORAN-C coverage to Puerto Rico and the Virgin Islands is expected to cost $25M over a 10-year period.

f. Coast Guard Action Required - Only follow-through actions are required: complete the LORAN-C network installation, and promulgate equipment standards and requirements for electronic navigation gear and dual radars.

g. Estimate of Effectiveness - The potential effectiveness* of the baseline system is estimated to be 23% (see Appendix I, Table I-7):

5.2.2 Vessel Passport System

a. System Description - A vessel passport system is the simplest form of an active system, i.e., one involving shore-based

*Potential effectiveness and net effectiveness are defined and discussed in Section 5.4.

personnel. This system is highly oriented toward reducing accidents, especially groundings and rammings, by not allowing ships that are believed to be dangerous and bound for U.S. ports into internal waters, by placing conditions on the entry into (or departure from) ports for ships lacking proper certification, proper charts, or having equipment defects or outages, by issuing helpful advisories on weather, currents, and special conditions, and by coordinating pilot transfer procedures. This system would not continuously monitor ships' positions, and would provide little direct help in avoiding collisions. The mariner with a full contingent of operating instruments would still have to rely on himself, his crew, and his vessel to navigate safely. When on-board equipment experienced difficulties, aid would be rendered (e.g., in the form of escorts) or conditions placed on entry (e.g., enter only during the day with good visibility). This service would first be limited to tankers and vessels carrying hazardous cargo in bulk; it could later be expanded to other vessels. It incorporates many of the features of the Canadian ECAREG system, which is described in Appendix E.

This system shall not be mandatorily applied to any foreign vessel not destined for or departing from a port or place subject to the jurisdiction of the United States -

(1) that is in innocent passage through the territorial sea of the United States, or

(2) that is in transit through the navigable waters of the United States which form a part of an international strait.

Such vessels shall be encouraged to voluntarily participate in the system.

The operation of the system centers around two check points (refer to Figure 5-1): vessels bound for a U.S. port would be required to check into the system at about 24 hours prior to entrance into territorial waters (within a latitude of about 6 hours, earlier or later), and again at another point approximately one hour prior to entry; the location of the second check point

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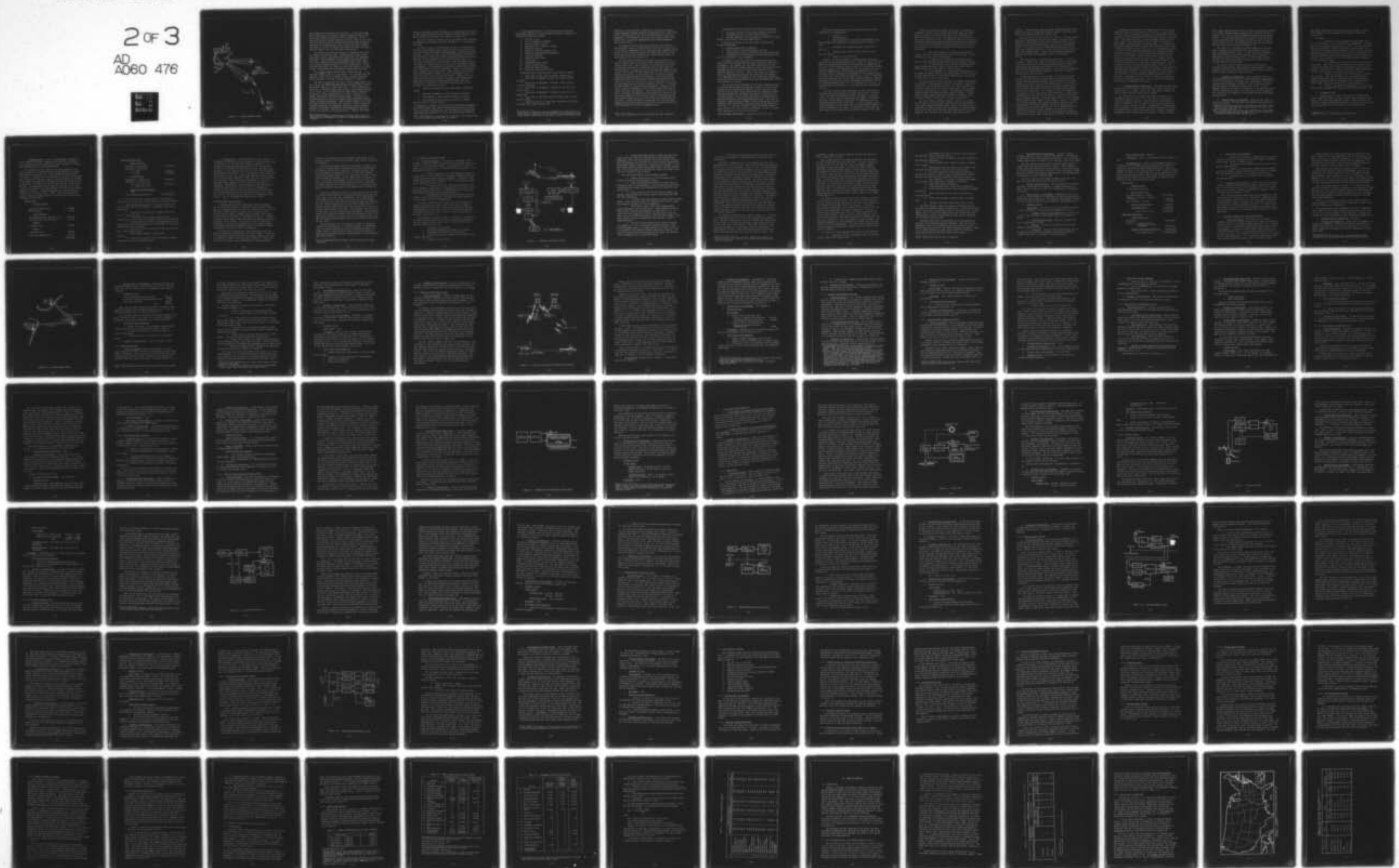

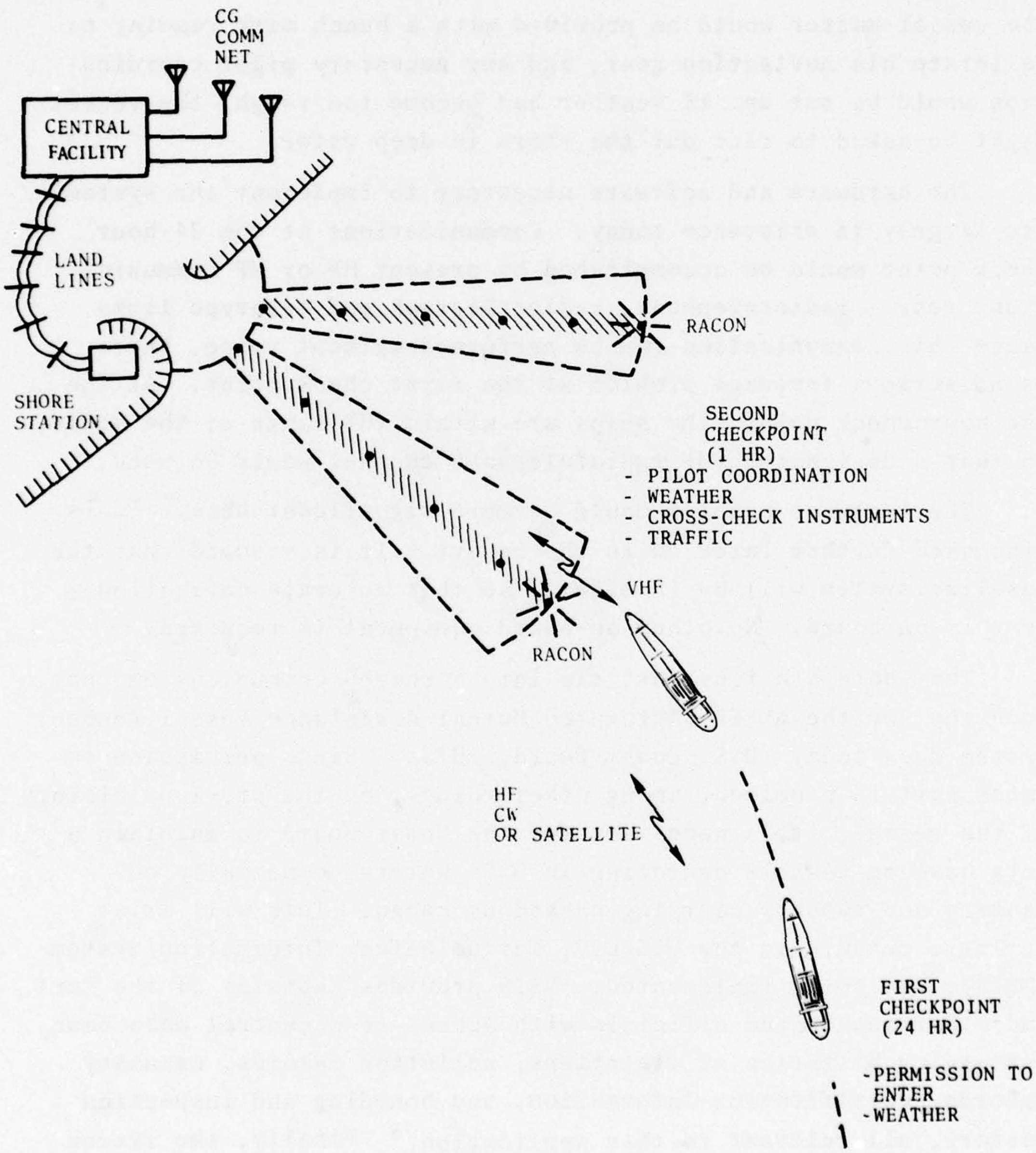

FIGURE 5-1. VESSEL PASSPORT SYSTEM

would depend on the specific port of entry. At the first check point, permission to enter port would be granted or denied, and any special conditions placed on entry at that time. At the second check point, special bulletins could be issued to the vessel. The vessel master would be provided with a bench mark reading to calibrate his navigation gear, and any necessary pilot coordination would be set up; if weather had become too rough, the vessel might be asked to ride out the storm in deep water.

The hardware and software necessary to implement the system are largely in existence today. Communications at the 24-hour check point would be accomplished by present HF or MF communications gear - radiotelephone, radiotelegraph and teletype links. Since this communication can be performed without voice, there is no serious language problem at the first check point. At the one-hour check point, the ships are within VHF range of the shore, so that a designated VHF radiotelephone channel would be used.

The language problem could be more significant here. It is discussed further later on in the report. It is assumed that the baseline system will be in effect, so that accurate navigation gear is on board. No other on-board equipment is required.

The shore stations must tie into a shared communications net, much the way the AMVER (Automated Mutual-Assistance Vessel Rescue) system does today (U.S. Coast Guard, 1975). Since permission to enter port is premised, among other things, on the previous history of the vessel, it is necessary for the Coast Guard to maintain a data base on vessels operating in U.S. waters, especially on tankers and vessels carrying hazardous cargo. This will exist in large measure in the U.S.C.G. Marine Safety Information System (MSIS), now being implemented. MSIS provides Captains of the Port and other authorized officials with access to a central data base containing histories of violations, pollution records, casualty records, certification information, and boarding and inspection history, all relevant to this application.* Finally, the system

*MSIS contains casualty records only on foreign flag vessels; it would need to be expanded to include U.S. flag vessel casualties as well.

requires a network of about 40 RACONs to be placed near the location of each second check point, and at other locations along the coast and at fairway intersections (see Appendix G, Table G-3).

Now that the general features of the system have been outlined, the detailed system operation can be described, as it is presently conceived.

At about 24 hours out from arrival at the U.S. internal waters, the radio officer makes radio contact with the system on HF or MF, using existing radiotelephone, radiotelegraph, or teletype channels. Latitude is provided in the 24-hour time requirement to allow the radio officer to perform this function during a normal watch period. The shore is then provided with the vessel's name, draft, call sign, VHF station number, vessel master's name, destination, choice of fairways or traffic lane, and a list of any inoperative navigation equipment, control/propulsion machinery, other primary systems, or missing charts or notices to mariners. Table G-2 of Appendix G shows a format which could be used. Upon receipt of this information, system operators consult the vessel information file to review the past history of vessel and master. Based on the findings, the vessel is either denied entrance, given unconditional permission to proceed, or allowed to proceed under specific conditions.* If the vessel is allowed to proceed, she is also provided with information, such as:

1. Forecast of weather en route, and weather station call number;

2. Relevant information in recent notices to mariners;

3. Buoy changes or other special conditions en route;

4. The location of the second check point, its RACON Morse identifier, and VHF channel.

If permission is denied, the vessel will be contacted and appropriate actions taken, which could include absolute refusal to enter port, diversion to another port, the requirement for boarding and inspection upon entering U.S. waters, or other special attention.

*It is anticipated that approximately 95 percent of the vessels will be given unconditional permission to proceed.

If some equipment defects or missing charts are reported, conditional permission to proceed might be granted. Reasons for conditional permission include:

1. Bad ship record
2. Lack of required instruments
3. Bad vesselmaster record*
4. Defective gyro or magnetic compass
5. Defective radar(s)
6. Defective collision avoidance aid
7. Defective depth-sounding instruments
8. Defective steering
9. Defective power train
10. Leaking oil
11. Loaded deep-draft tanker
12. Lack of proper charts
13. Defective navigation gear
14. Defective communications gear.

Conditions which could be placed on such vessels include:

1. Enter only at high tide, or between certain hours
2. Enter only in daytime, in calm seas, and/or in good visibility
3. Enter only if agreement is obtained to meet pilot at a specified location
4. Enter only if agreement is obtained to wait for, and follow escort
5. Enter only if agreement is obtained to wait for, and employ tugs
6. Enter only if specified repairs are made prior to entry into U.S. water
7. Enter only after U.S. Coast Guard inspection at 3 miles, or beyond traffic lane entrance buoy.

*Currently no records exist on the performance or safety records of vessel masters. Changes would be required in MSIS and MVCR, so that vessel masters names could be accessed, in order to build this file.

Guidelines on the particular conditions to be placed on vessels having equipment problems should be established by U.S. Coast Guard officers and Captains of the Port, with participation by pilots, shipmasters, and shipowners, and using the results of this study. Much of this is presently addressed by Coast Guard Commandant Instruction 16711.4.

The control facility would then inform the local station, which probably would be in the Captain of the Port or VTS facility, of the vessel's impending arrival, the vessel data, expected time of arrival at the second check point, and conditions placed on entry (this step may be coordinated prior to contacting the vessel, if the Captain of the Port requests it).

The discussion presented here assumed the existence of a central facility which receives the vessel transmission from the initial check point. The existence of a central facility raises an important issue which is beyond the scope of this study to resolve, namely: to what extent would the decision-making process reside with a central facility rather than with the officer of the Captains of the Port? As envisioned here, the central facility would grant permission/denial to proceed to those vessels whose condition clearly met the previously established guidelines and determine the port of destination; however, marginal cases would be coordinated with the affected Captain of the Port*. The vessel passport system is costed on these assumptions. However, before such a system is implemented, the U.S. Coast Guard would have to settle the issues of authority. The two extremes are, on the one hand, a completely decentralized system where each Captain of the Port office makes the initial contact and all subsequent contact with vessels headed for ports of call under his jurisdiction; on the other, a highly centralized system where the final decision-making rests with the central facility after consultation with the affected Captain of the Port on marginal cases.

*This still postpones the issue of who has the final authority.

A decentralized system would have the following advantages:

1. No change required in the present authority structure
2. Elimination of the cost of a central facility
3. Maximum flexibility to incorporate consideration of local weather, local traffic, and local tank vessels.

A centralized system, on the other hand, would have the following advantages:

1. Uniform application of standards.
2. Early action by staff dedicated to one task.
3. Elimination of the cost of 24 hour coverage at each port.
4. Elimination of the possibility of "pick and choose" the port of destination by vessel captains.

In addition to the centralized and decentralized options, there are several intermediate divisions of authority that could be workable. For example, one that would combine most of the advantages of the two extremes would be to have the central facility determine the port of call, but leave other decisions to the affected Captain of the Port. These issues need to be addressed before an implementation plan for the system could be defined. It is important for the acceptance of the system that experienced Coast Guard officers be involved in any decision-making that involves costly delays to a vessel.

Once the vessel has proceeded to the second check point area, the conning officer would be required to check in with the local station on the designated VHF channel. At this time the vessel should be within radar range of the RACON; by performing a range/bearing measurement on the RACON, the vessel's position can be accurately fixed. This position would then be compared with the position measured by the on-board navigation gear. This step is important, because possible LORAN-C errors occurring due to cycle-skipping, radar range errors, and gyro errors can be detected at this time.* In the Gulf of Mexico, additional RACONs would be placed farther out, near fairway intersections, to serve a similar cross-checking and position-fixing purposes.

*The instrument data should be required in the ship's log.

The ship-to-shore contact at the second check point would communicate the following data:

1. Vessel ID
2. Vessel position
3. Statement that the cross-check of instruments has been satisfactorily completed, or readings could be relayed to shore
4. Statement that conditions placed on entry have been met
5. Statement that no defects have turned up since the first check
6. Report of any difficulties.

There is a potential problem of communication with vessels whose masters do not speak English well. Usually at least one crew member has enough understanding of the language to communicate by teletype. Several measures could be taken to alleviate the problem. The requirements of the communications at the second check point could be standardized, and printed and distributed to vessels. The data could be teletyped or telegraphed if the language problem was severe; the central facility might act as a relay, if necessary. Canadian experience with users of their ECAREG system has indicated only minor difficulties arising from language differences. While the language problem exists, it is not believed to be serious. As mariners become accustomed to it, such difficulties will probably subside.

The local station would acknowledge the call, and provide a weather/visibility description, a report on currents, a notification of any relevant problems like buoy dislocation or missing lights, a traffic report, and possibly some LORAN-C corrections. The shore station operator would check for compliance with any conditions placed on the vessel entry. If tug assistance, Coast Guard boarding, or pilot contact had not already been arranged, it would be arranged at this time. If conditions of entry were not met, permission to proceed to port could be revoked at this time.

Since pilot transfer procedures were cited so frequently in grounding casualties, this system would require that for loaded tankers a pilot be identified, contacted, and a boarding point selected satisfactory to the shore operator, prior to arrival at the 3-mile territorial limit. The guidelines for the selection of the pilot boarding point would depend on the particular characteristics of the area, and should be negotiated with the local pilots' associations. They should be designed to provide the following assurances:

1. The vessel would not proceed into an area where currents and winds could cause her to drift into a shoal or reef, without the pilot on board and conning.

2. In times of low visibility, the boarding point would be placed further out to provide an extra margin of safety.

3. In rough weather, where the pilot boarding process might endanger the pilot's life, an escort into calmer waters would be provided to the tanker by the pilot boat.

4. If the weather is so rough that the pilot boat is in danger even while underway, the vessel would be either escorted by Coast Guard cutter to a safe pilot boarding area or sent back to deep waters to ride out the storm.

Up to this point in the discussion, only tanker arrivals have been treated. Departing tankers would be required to check in at 24 hours as well (using VHF), and the vessel would be asked to check out as she passed the one-hour check point. There would be no way of enforcing this, of course. The departure requirement would not apply to tankers and tank barges in ballast. Coastal traffic between United States ports would be treated by substituting the departure requirement, using two check points.

The local station would be required to notify the central facility when an arriving tanker checked in at the second check point, when a departing loaded tanker called in 24 hours prior to departure, and when a tanker left port heading for another United States port. The central facility would then enter the arrival/departure into the data base, and notify any affected local stations. Coastal tankers and tank barges operating between United States ports would be required to check in again 24 hours prior to arrival on journeys taking more than one day.

The legal issues are discussed in Section 7.5. Briefly, implementation is presently within the Coast Guard's charter and the authority of the Captains of the Port, with the exception of the locations of the second check points, which are in international waters. This problem can be circumvented by requiring a vessel bound for a United States port to check in about one hour prior to entry into internal waters. That is, time-related requirements are more acceptable than geographic ones in international waters.

Any actions taken in international waters are, in a sense, voluntary. However, the right of the United States to refuse entry can be used judiciously to enforce compliance with existing laws, to encourage good equipment maintenance, to discourage vessel-masters from misrepresenting the status of the vessel and equipment, and to force a conservative judgement in cases where schedules conflict with safe operations.

An important feature of the system is the fact that vessel masters are relieved of the responsibility of choosing between taking risks and meeting schedules; the Coast Guard or its representative would not allow the risk-taking option. Fines would be assessed where port boardings by the Coast Guard revealed discrepancies between the actual condition of the ship and the reports given at the check points. If a shipper covertly encouraged his ship captains to lie about the vessel's condition, it could be used as grounds to refuse entry of the shipper's vessels in the future. When a boarding revealed a violation, the records could be routinely checked against other vessels in the shipper's fleet. If a pattern of violations emerged, that shipper's vessels would be assigned a high priority for future boardings; ultimately detentions or refusals of entry to port could result. It is unlikely that this extreme would ever be needed. However, the existence of its possibility should be quite effective in removing the temptation from the ship owners, thus taking the vessel masters "off the hook."

Geographical variations in the application of such a system depend on the ocean floor profile, the existence or non-existence of traffic lanes, the density of population centers and Coast Guard stations, the distinguishability of the coastal profile (visual and radar), the weather patterns, and the geographic features of the coast. Due to the ocean depth it may not always be possible to place RACONs at the entrances to traffic lanes. For example, the New York-to-Nantucket Shoals traffic lanes continue for 180 miles; a RACON here should be placed closer in. The Gulf of Mexico, with its forests of oil production platforms and a gradually sloping shelf that extends out to as much as 100 miles from shore, has a special set of problems. RACONs should be placed near fairway intersections as a check several hours out. A valuable service presently provided by the Coast Guard in the Gulf of Mexico is the listing of all offshore oil structures, updated annually. Wider distribution of this publication and periodic issuance of the coordinates of new platforms should be considered. These should be available and distributed to all vessels operating in the area. Incoming tankers should be checked individually to assure that all oil platforms are charted and their LORAN-C time delays readily available. Groundings are less likely to be severe in the Gulf, due to the soft sand composition. No oil spills in the data base occurred due to groundings in the Gulf.

b. Training/Workload Implications - The workload implications for the vessel are minimal. The actual time spent in routine communications is 2-3 minutes at most; the cross-checks required are those a prudent mariner should perform anyway.

On shore, the local stations would require availability of personnel around the clock, since 77 percent of the casualties occurred at night or twilight. From the traffic projections discussed in Devanney (1978), it appears that a typical workload is about 2-6 tankers per day per port. In addition to communicating with the tankers, a shore operator would be responsible for obtaining weather reports, and establishing winds, currents, equipment malfunctions, and communicating with pilots. A typical scenario with a light workload would involve an officer designated to periodically review teletype messages announcing the expected arrival of a tanker, or to accept similar telephone messages from the central facility. He would then arrange for an operator to man the local station some time before the expected arrival in order to prepare for the tanker arrival. The operator would stay near the station until the pilot had boarded and assumed the con.

From Table 4-32, the number of loaded tanker port calls per year is expected to be 19,600 in 1985, increasing to 28,400 by 1990, an average of about 24,000. If the local stations spend 1.5 hours with each tanker, about 36,000 hours will be required, equivalent to about 4 watch positions. Divided among 15 local stations, this amounts to about one-quarter of a watch position for each station, on the average.

The central facility would require full-time staffing. Assuming a conservatively high average of twenty minutes of shore attention per vessel, the central facility would require about one watch position to handle 60 vessels per day.

c. Estimate of Availability - Since the marine radio and teletype communications network is highly redundant, communications at the first checkpoint is assumed to be 100 percent.* VHF shore equipment should be highly reliable.** The system might become non-available if the VHF unit on the bridge is out. If this happens, the HF can be used as a backup; i.e., the ship has several ways of contacting the shore. For the purposes of this analysis, the availability is assumed to be 100 percent in those areas where coverage exists.

d. Present State of Development - There are four areas to which this applies: the data base (establishment and maintenance),

*Sunspot activity can cause severe problems over the band. There could be rare situations where contact could not be made until the vessel was closer in.

**It is assumed that towers can be installed that are tall enough and can be placed judiciously enough that 20 miles of range can be reliably achieved at port entrance areas.

the communication and local station facilities, RACONs, and the legal framework. These subjects were covered in the system description.

In summary:

1. The Marine Safety Information System (MSIS) forms the basic data base. It is presently being implemented. It would need to be accessible from a central facility. The data base would have to be expanded to include casualties of United States flag vessels and to include ocean going tugs. Access to files should be keyed by owner's and/or lessee's name as well as vessel name. Consideration should be given to keying records by vessel master name as well. Port arrivals as well as boarding/inspection findings should be entered as data.

2. The communication facilities now exist for the first check point. While VHF facilities presently exist along the coast, a particular channel would need to be designated for each local station. Local offices of Captains of the Port, Marine Inspection Offices, and VTS facilities will suffice for this system.

3. RACONs are now used in the Great Lakes, in Alaska, and in Europe. They are available using existing technology. It should be noted that IMCO is urging the use of fixed-frequency RACONs, which would provide the mariners with a return on every sweep, rather than every few sweeps as present RACONs do.

4. Legally, the authority now largely exists,* and has been further strengthened by the recent IMCO Protocols (IMCO, 1969).

e. Estimate of Cost -

Vessel Costs - The only costs incurred would be those that prudent vessel owners now pay out for proper maintenance and repair. The additional workload is small. Delays caused by conservative, safety-minded shore operators are essential, and as such are not considered to be an extra cost to the vessel owner.

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*COMDTINST 16711.4, 46 USC 391a, and 33CFR 160.37.

Government Costs - Costs to the government include any new transmitting stations, communications facilities, staffing costs, computer facility leasing costs, and the purchase, installation, and maintenance of the RACON network.

The following estimates are based on the assumption of one central facility, 15 local stations, 6 of which would be incorporated into VTSs (see Table G-4). Forty RACONs and ten new buoys are assumed. Staffing costs are based on five officers and enlisted men for each full-time watch station. One watch station is assumed to be adequate to handle the anticipated 24,000 port calls per year in 1985-1990. This amounts to 66 port calls per day at the central facility. An experienced officer would be available at all times to handle the unusual cases and coordinate actions with the affected Captains of the Port. Annual maintenance costs are estimated at 10 percent of the initial costs. Only a few local stations will require a full-time watch position - the others would be part-time, or shared with VTS duties.

Initial Costs

Central Facility	
Land Line Communication	$ 100,000
MSIS Terminal	20,000
Local Stations	
VHF Communications @ $600,000 (x9)	5,400,000
Land Line Link @ $20,000 (x15)	300,000
RACONs	
@ $15,000 (x40)	600,000
Buoys	
@ $16,000 (x10)	160,000
Design and Demonstration	500,000
	$7,080,000

Annual Operating Costs

Central Facility

Maintenance and Leasing	$ 12,000/yr.
Staffing: (1 position)	
3 @ 15,000	45,000/yr.
2 @ 28,000	56,000/yr.
Local Stations	
Maintenance @ 560,000 (x9)	540,000/yr.
Staffing: (1/4 position)	
3 @ 15,000 (x15 x 1/4)	380,000/yr.
2 @ 28,000 (x15 x 1/4)	
RACONs and Buoy Maintenance - small	0
Total Annual Operating Costs	$1,033,000/yr.

It is believed that the estimates here are conservatively high, especially in the area of VHF communications and maintenance.

f. Coast Guard Action Required - These have already been covered in the rest of this section - to summarize, the actions required are:

1. Purchase and installation of RACONs, and the new buoys for some locations.

2. Establishment of a central facility, with communications to ships and local stations, and access to the MSIS.

3. Establishment of procedures and responsibilities at each local station, and designation of a VHF channel for ship/shore communications (can be shared).

4. Publication of the system description and establishment of the effective dates.

5. Hiring and training of central shore operators.

6. At each local station, the establishment of guidelines and criteria for conditional entry.

g. Effectiveness - The effectiveness of this system is estimated by combining the system features of improved pilot transfer procedures (I.2.6), improved equipment standards (I.2.7), incentive to repair malfunctioning gear (I.2.8), the baseline system (I.3.1), RACONs at fairway intersections and traffic lane entrances (I.2.20), general advisories (I.2.31), and voyage plan and checklist submission (I.2.32). In addition to this, each case was reviewed to see if the system might logically provide other services not already identified. There were five cases which met this criterion - they are discussed in Appendix I, Section I.3. While the primary emphasis of the system is on prevention of groundings, improved pilot transfer techniques and advisories on currents proved helpful in some collisions. Rammings were affected by the baseline system, but the check system provided little additional help, for reasons already noted in the system description. The potential effectiveness is estimated to be 54% overall. This is 31% higher than the baseline system.

Vessel Passport System Options

It was pointed out earlier that some collision avoidance service could be provided by a modified Vessel Passport System. The first alternative would be that of a general advisory over the VHF local station channel, advising ships in the area that a loaded tanker or barge is inbound, and to navigate with caution to avoid placing the tanker in a burdened position in a crossing situation, and to contact the tanker before overtaking in order to coordinate such a passing. This message could be repeated every few minutes to increase the probability of the message getting through (the vessel master might be tuned to a different channel, or talking at the time of the first broadcast).

As a practical consideration, ships operating in the area could be requested to monitor the local shore channel. Since they are presently required to monitor the emergency channel 16, there is a potential problem with missed shore broadcasts. While repetition of the message, and an announcement of the approximate position of the tanker will go far towards reducing the risk of collision, there is still the possibility that a vessel could miss the broadcast.

The second alternative would be to broadcast in advance the arrival of a loaded tanker or barge and ask vessels which plan to be operating in the area to check in. The shore operator could then interrogate the reporting vessels to find their intended courses and determine which, if any, could pose a problem. Those involved would be informed, and the tanker would be informed, as well. If the VHF radiotelephone is used for this service, overtaking and coastal cross-traffic would not come into range until the tanker had passed the second check point. To cope with these vessels, broadcasts would need to be repeated every 15 minutes or so.*

The third alternative would be to require all vessels to check in 24 hours before arrival at port and upon departure, giving the vessel name, call sign, port of departure, port of destination, and estimated time of arrival (ETA) at the port of destination. The central facility would then be required to input and keep these records. When a tanker arrived at the second check point, the central facility would provide the local station with a list of the vessels expected to be in the area. Local traffic could check in with the local station, giving similar information. Based on these reports the local shore operator could then interrogate the vessels individually asking for a position fix or any change of plans, and make the necessary precautionary advisories to the affected vessels and the tanker.

The alternatives just discussed are in order of increasing complexity and capability. As a practical matter of implementation, the simplest alternative could be employed initially, and tankers asked to report any near-misses to the local station. Based on the experience gained, stronger measures could be employed when deemed necessary.

*It is assumed that the VHF channel would be shared with other functions.

5.2.3 Automatic Monitoring System

a. System Description - The automatic monitoring system attempts to provide tankers with services over and above those provided by a vessel passport system. It incorporates all the features of the passport system, including the two check points. The additional services are:

1. Traffic information providing tankers with names of vessels likely to be encountered: crossing, overtaking, and where traffic lanes don't exist, meeting encounters. Approximate times of encounter would also be provided. This service might or might not be extended to other vessels.
2. Collision alerts where reported positions and velocities suggest a closest point of approach (CPA) of a mile or less. The shore station would act as a communication relay if any ship/ship communication difficulty were encountered.
3. Grounding alerts where reported positions and velocities of participating vessels indicated a projected course too close to shoals, reefs, or shallow areas.

In order to provide these services, the shore station must acquire all commercial vessels in the area, not just tankers. Frequent updates of position, course and speed must be obtained from each vessel by the shore station. The shore station must then keep track of all vessels, and plot courses and projected positions (see Figure 5-2).

The equipment required on board is a data/voice communications set which interfaces with the electronic navigation instruments, the gyro compass, and the ship's log. The shore station would need the following facilities:

1. 24 hour-per-day staffing
2. Dedicated communication channels (4 estimated)
3. Transmitters and receivers for data/voice
4. Coding/decoding data communication equipment, with computer interfaces
5. Computer-driven displays

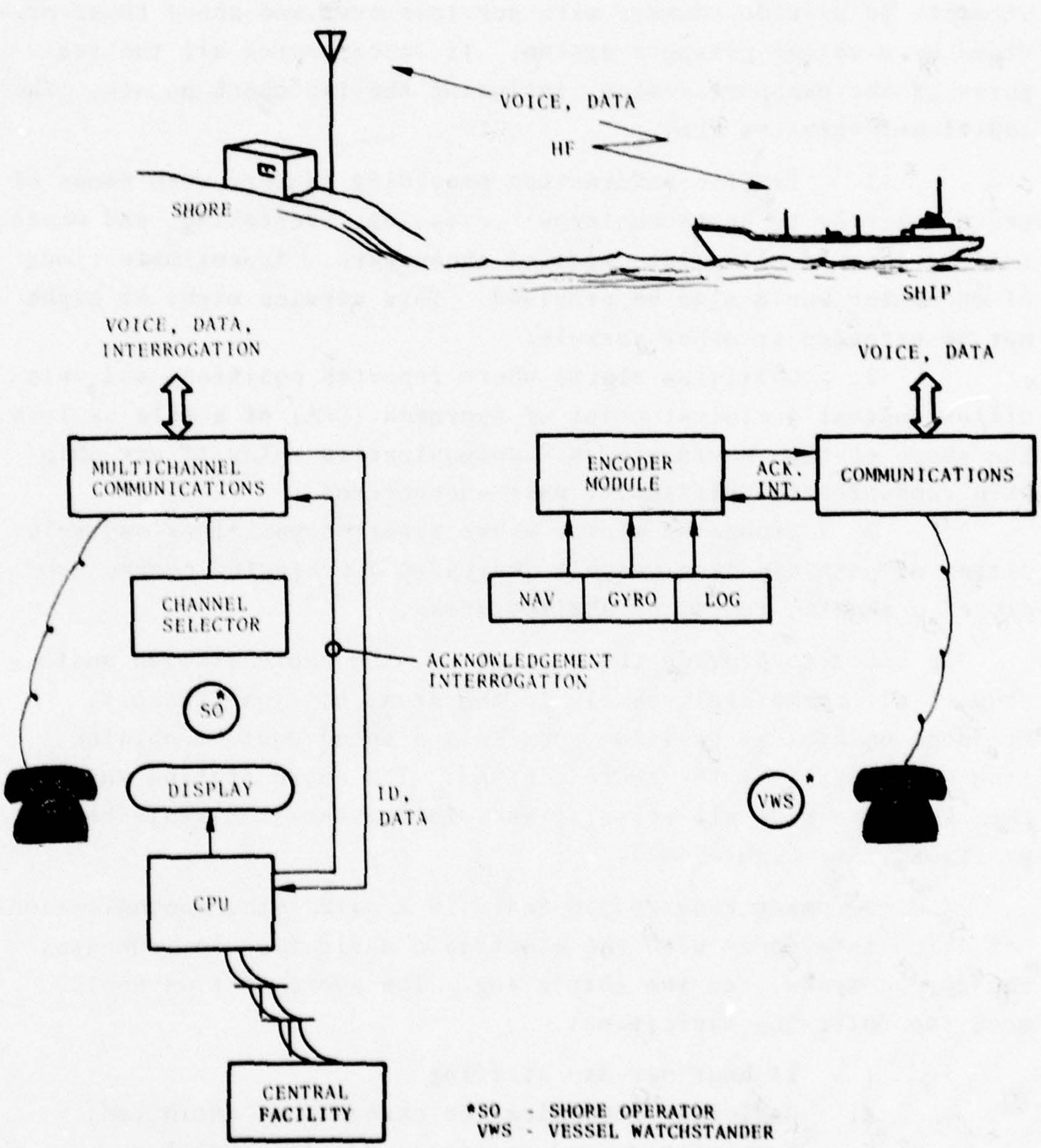

FIGURE 5-2. AUTOMATIC MONITORING SYSTEM

6. A data processing system to create new ship files, update positions, look for projected near-misses and possible groundings, alert the shore operator, drive the displays, control the interrogations, and perform cross-checks between reported data. Voyage plans might or might not be required of all vessels - if so, the computer would also match the planned course with the observed one. This service would be performed for tankers and barges carrying oil or hazardous cargo in bulk.

The system would operate in the following manner:

1. Tankers would check in at the two check points, exactly as with the vessel passport system.

2. Other vessels would be required to carry the communications sets in the wheelhouse. They would be acquired by the system when their unsolicited transmissions were received by the control center.

3. Once acquired by the system, the data update rate would be controlled by the control center by interrogations from the shore transmitter.

4. If voyage plans were required of other vessels besides tankers, newly acquired vessels not having already filed a voyage plan would be contacted for that information.

5. The traffic control center would appropriately adjust the update rate for each vessel. Ships beyond 20 miles in light traffic might be interrogated every half-hour or so. If projected courses appeared to predict passings closer than five miles, the rate could be increased to pick up course changes. Near shore updates could be effected every five minutes or less if deemed desirable.

6. The shore station would contact vessels standing into danger, e.g., if: 1) projected courses indicated a close passing between vessels or a close passing of a shoal or reef, or 2) an imminent close passing between vessels were detected. The shore would give each vessel the name of the other, and instruct them to communicate on a stated VHF channel.

7. The shore station would ask vessels leaving the area to turn off the equipment to reduce unnecessary data files and interference.

The means of communications is an important decision in the implementation of such a system. Some of the problems and considerations are discussed in Appendix G, Section G.2.1. For the purposes of estimating system costs and providing a cohesive design, it will be assumed here that the allocation of a set of frequencies between 1600 KHz and 4000 KHz can be acquired for OVTM usage. Ground-wave propagation at these frequencies provides reliable service out to at least 100 miles, and usually further. One scheme which appears to be reasonable, although certainly not the only one, is to have approximately four adjacent 25 KHz channels; one channel would be used purely for data transmission from ship-to-shore in the one part of the passband, and shore-to-ship interrogations in another. The other three would be voice channels, alternated between local stations along the coast to eliminate the confusion and interference that would result if only one channel were available. The LORAN-A stations and their frequency allocations could be used; the frequency band between 1900 KHz and 2000 KHz appears to be as yet unclaimed.* While each local station would use the same data frequency, interference between them could be eliminated by synchronizing the transmission times such that no two stations with overlapping coverages transmit at the same time. Capacity would still be virtually unlimited.

The equipment configuration is shown in Figure 5-2. The shipboard equipment would be located in the wheelhouse near the VHF unit. The only responsibility the vessel master would have would be to turn the set on when leaving port or when about 200 miles or 24 hours from port of destination. After that, the entire operation would be hands-off, requiring no effort by the mariner. A lamp would be lit once a coded interrogation were received from shore, indicating that the vessel was now "on the system." The

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*Other influential interests are also requesting frequency allocations in this band: broadcasting, amateur radio, and radiolocation interests.

vesselmaster should, of course, check to see that the lamp was on before coming close to shore.

Under normal operation, the ship transmitter would broadcast the data stream about once every half hour. The data stream, consisting of ship's ID (the VHF call sign, for example), LORAN-C coordinates, speed, and course, could use the SELCAL format at 1200 BAUD, which would require about 20 milliseconds to transmit (25 characters at 10 bits per character) (U.S. Maritime Administration, 1973). When the shore received its first transmission from the vessel, the control center would search the records for the ID code. If one were found, and a destination determined, the appropriate local station would be informed and supplied with the essential data. If records were missing, the control center would ask the local station to contact the vessel and determine the voyage specifics first. If difficulty were experienced in getting ship data, the voice link could be used to request manual transmissions (requiring the vessel watchstander to push a button on the communications console).

The shore stations would consist of local stations in contact with the national control center. The control center would maintain any voyage plans and the complete ship files, and would transfer information as needed to the local stations. The control center would establish the voice channel to be used and inform the local station responsible for ships in that area. The local station would interrogate the vessel at a rate controlled by the local station computer. When a vessel passed through one local area of responsibility into another, she would be "handed off" and the vessel watchstander would be requested to change channels (the shipboard equipment could be automated to eliminate the participation of the vessel watchstander). The local shore computer would track all ships and continuously examine courses for possible conflicts or dangers.

To sum up, the shore computer duties would be the following:

1. Receive initial ship information from the national control center, and create a file.

2. Interrogate the vessel to put her "on the system," and check data for position and course.

3. Create new target on display and notify operator by printing ship information.

4. Notify operator when to hand off ship to adjacent local station.

5. Monitor positions and courses of all vessels, and calculate CPAs and TCPAs* of vessels close to each other.

6. Calculate proximity of positions and projected positions of vessels to shoals, reefs and shallow areas (contour map of ocean floor could be stored and corrected for tides).

7. Alert operator if a vessel is standing into danger, or is passing close enough that a reminder is advisable.

8. Drive the display and printer.

9. Accept keyboard data; accept data from decoder.

10. Time interrogations and issue interrogation commands to encoder.

11. Alert shore operator to vessel deviation from intended course.

12. Alert shore operator to inconsistent or missing data.

13. Eliminate ship files when vessel leaves system.

The shore operator would issue general advisories over the dedicated local channel, monitor tankers, etc., at the second check point, issue alerts to particular vessels that appear to be in some danger, act as a ship/ship communications link if necessary, perform emergency services, and perform the other duties identified in the vessel passport system.

Automatic monitoring systems depend on the functioning and accuracy of the onboard navigation equipment. Some errors (e.g., gyrocompass errors) can be detected by self-consistency checks between successive positions and reported heading and speed. Others (e.g., LORAN-C matching on wrong cycle) would not be detected. Surveillance would be required to detect these errors.

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*TCPA: time to the closest point of approach.

b. Training/Workload Implications - The vessel onboard equipment should be simple to operate and maintain. The workload is negligible except when equipment malfunctions - the vessel watch-stander would then be required to be in frequent contact with shore.

The shore operators would have a training program similar in scope to that for the Vessel Traffic Services. The system described here would automatically track vessels, so that there would be little keyboard entry work to be done. The shore operator would spend most of his time watching tanker progress, and issuing alerts and warnings to vessels requiring them.

Each local station would require staffing around the clock. Most stations would require only one watch position.

c. Estimate of Availability - The system would be constantly available, except when the computers or communication gear are down. Based on experience with VTSs, availability is estimated at 99 percent.

d. Present State of Development - Comparable units are now in use for testing purposes in San Francisco and Lake Pontchartrain under Coast Guard sponsorship. The equipment requirements, however, are well within present day state-of-the-art for production units.

e. Estimate of Cost

Vessel Owner - The vessel costs are estimated by considering the components of the postulated communication system:

1. 4-Channel Voice Transmitter/Receiver - Based on the cost of present SSB units, the purchase price is estimated at $1,500.

2. Encoder/Decoder, Modem - Based on a SELCAL unit, this is estimated at $1,500.

3. Antenna - The unit can use the present 2182 KHz emergency channel antenna.

4. Interfaces - Based on similar applications and the assumption that, with each instrument the data are already in decimal form, this is estimated to cost about $1,000.

Total Purchase Price - $4,000.

Installation - Low, if the present 2182 KHz antenna is used.

Government Costs - Costs to the Government include new HF data and voice transmitting and receiving gear, computers, interfaces, and land line data communication links. The costs include the costs of the vessel passport system. Instead of only tankers, all vessels of significant size (e.g., greater than 1600 gross tons) must participate in the system. While tankers can be acquired on the system at the 24 hour check-in, others will be acquired as they come within radio range.

Initial Costs

Central Facility

No additional facilities

Local Stations (15)

HF Communications @ 700,000	$10,500,000
Computer - Terminals - Displays @ 500,000	7,500,000
Data Interfaces @ 50,000	750,000
Vessel Passport System	6,580,000
Development Costs	3,000,000
Total Initial Costs	$28,330,000

Annual Operating Costs

Local Stations (15)

Maintenance	1,875,000/yr.
Staffing: 2 watch positions (average) per station @ $101,000	3,030,000/yr.
Passport System Operating Costs	1,033,000/yr.
Total Annual Costs	$ 5,938,000/yr.

f. Coast Guard Action Required

1. Develop an HF data/voice communications system, consisting of three voice channels and one data channel, preferably using present 2182 KHz or LORAN-A towers.

2. Generate minimum equipment specifications for shipboard HF communications.

3. Conduct a system design, pinpointing requirements and develop modular computer architecture and software to accommodate the variation of traffic at the various local stations.

4. Implement and set a timetable for the automatic monitoring system.

g. Estimate of Effectiveness - On the basis of the casualty analysis, automatic monitoring systems have a potential effectiveness of 81% for collisions, 65% for rammings, and 74% for groundings, or 75% overall, assuming the equipment is working. This is 56% higher than the baseline system.

This estimate should be qualified by the statement that without any form of surveillance, it is difficult to completely cross-check instruments until the vessels pass near a RACON check point or other unique signpost. However, most accidents occur within these bounds, so little effectiveness is lost. It should also be noted that delays will occur when instruments don't check, delays that could be minimized if surveillance were available to resolve ambiguities.

5.2.4 Direction-Finding (DF) Surveillance System

a. System Description - This system is not actually a separate system, but a capability which can be added to the Vessel Passport System or an Automatic Monitoring System. It is inexpensive, and can be accomplished through minor modification of 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 primarily as a backup at the second check point. It is primarily a short-range instrument, not anticipated for usage at sea, or along the coast.

Simply stated, the system involves two DF stations for each port, typically 10-15 miles apart near the water (see Figure 5-3). When a vessel turns on the VHF transmitter on a selected channel, the two DF stations establish a bearing on the transmitter. By plotting the two bearings, a position can be manually charted by the shore operator (this procedure could be automated).

While uncalibrated operation typically gives 2° -5° bearing errors, the long-term drift errors and permanent errors can be calibrated out, so that corrections can be made which allow the measurement to achieve accuracies of about 1°, or better. This amounts to less than a mile at 20 miles range,* good enough so that identification of a nearby buoy would be unique, and good enough to pick up "cycle-mismatch" types of errors encountered in LORAN-C.

The system would operate as follows: if a mariner or shore operator had reason to suspect a problem in the assessment of vessel position, the shore operator would ask the vessel watchstander to key his VHF unit, either on the main channel, or on an alternate. The resulting transmission would be used to establish a fix and resolve any ambiguities.

While it is difficult to attach an effectiveness number to such a capability, it certainly would reduce delays caused by the need to resolve position ambiguities.

DF techniques are being considered as an aid to identifying radar targets in VTSs using a single station bearing. Ship location, by use of cross-bearings as described here, is being considered for Search and Rescue missions (Thompson and Reame, 1978).

b. Training/Workload Implications - Minimal.

c. Estimate of Availability - Better than 95% normally, considered as a component. Some problems could be encountered if channel usage were excessive across the VHF band. As a system which incorporates the passport system the availability is essentially 100%.

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*This assumes the two stations are located favorably enough relative to the coverage area that the GDOP is not excessive.

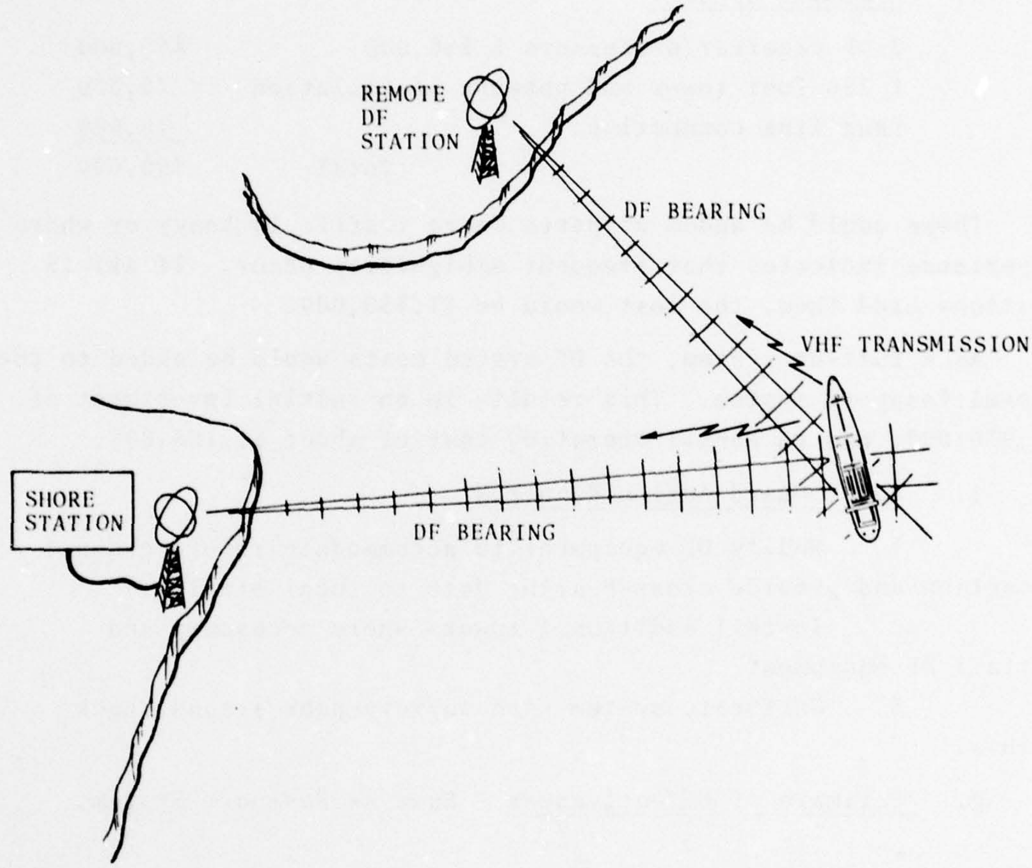

FIGURE 5-3. DF SURVEILLANCE SYSTEM

d. Present State of Development - Now being developed for VTS and SAR* applications. Can be directly applied to OVTM application, but may need modification to accommodate remote channel selection.

e. Estimate of Cost

2 DF receiver/processors @ $30,000	$60,000
1 250-foot tower and antenna installation	20,000
Land line connection	10,000
Total	$90,000

These could be added at ports where traffic is heavy or where experience indicates that frequent ambiguities occur. If all 15 stations used them, the cost would be $1,350,000.

As a full-up system, the DF system costs would be added to the Vessel Passport system. This results in an initial investment of $7,930,000, and an annual operating cost of about $1,168,000.

f. Coast Guard Action Required

1. Modify DF equipment to accommodate remote channel selection and provide cross-bearing data to local station.

2. Install additional towers where necessary and install DF equipment.

3. Calibrate system with surveys near second check points.

g. Estimate of Effectiveness - Same as Passport System.

5.2.5 Radar Surveillance

a. System Description - Radars are presently in use at Coast Guard Vessel Traffic Services in San Francisco, Puget Sound, Valdez, and Houston. They provide the shore operator with a plan-position-indicator (PPI) display of ships, buoys, and terrain features within the range of the radar. The radar antenna is, of

*SAR - Search and Rescue mission of the United States Coast Guard.

of course, located at the center of the sweep.* The range of the radar depends primarily on the height of the antenna, but also on the height of the vessel's masts and her draft. A new picture is painted out typically about once every four seconds.

Much could be said about the subtleties of the use of radar, its capabilities and limitations. For the purpose of this study, a few significant features are adequate to describe the functional usage of radar systems. It is assumed that readers are familiar with basic radar operation.

The main features of interest of the radar as an offshore surveillance technique are:

1. A radar is expensive to install and maintain.
2. It is limited in range to line-of-sight, or about 20-40 miles.
3. It is not subject to "relative-position" errors: when a ship target is shown on the radar display to be 2.5 miles from another radar target (ship, buoy, land), there is little doubt of the range between them.
4. It requires no active onboard equipment (corner reflectors are frequently mounted on small vessels to enhance the radar echo, however).
5. A radar does not provide identification of radar targets - it must be inferred from other information.**
6. Radars can be connected to sophisticated processors which distinguish target echoes and track them. Course projections can be calculated by a computer and superimposed on the radar screen.
7. Shore/ship communication by VHF would be compatible with radars, because their ranges are comparable.

Due to the cost and limited range of the radar, it is not a viable candidate for a surveillance system to provide wide coverage. However, it can be used as an excellent backup to a Vessel Passport System near ports that have special needs that justify

*The sweep center may be placed at points other than the display center on some models.

**However, if compatible transponders become required equipment in the future, they can provide ship identification.

them. Therefore the costs, effectiveness, and availability are assessed on a per-station basis, rather than as a nationwide surveillance system.

b. Training/Workload Implications - None, for the vessel officers. Shore operators would have tasks identical to those of the radar-equipped Vessel Traffic Services. 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.

c. Estimate of Availability - Single station availability is very high, typically 99%. Based on the data base, 80% of the casualties occur within radar range. Thus, the availability of a system of radars is 99% of 80%, or 79%.

d. Present State of Development - 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.

e. Estimate of Cost

Vessel Owner - none.

Government - Based on VTS experience, each new radar installation costs about $1,300,000, 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. For 15 stations, the additional cost would be $19,500,000 initially, and $3,000,000 annual upkeep. This would be over and above the vessel passport system costs.

f. Coast Guard Actions Required

1. Develop operational requirements for the particular port or harbor.

2. Procure the system and monitor its development.

3. Staff the installation.

4. Maintain the facility.

g. Estimate of Effectiveness - On a per station basis, the potential effectiveness of radar surveillance used to back up a passport system is estimated at 78% in the region of its coverage.

5.2.6 Satellite Surveillance System

a. System Description - Satellite systems appear at first to offer a distinct advantage over other systems, since they provide almost global coverage, and high accuracy everywhere. They are discussed in detail in Appendix H and Section G.3.3.3 of Appendix G.

A satellite system designed specifically for this application could be configured in several ways, but a typical one is shown in Figure 5-4. 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 data and time code 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 locations 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.

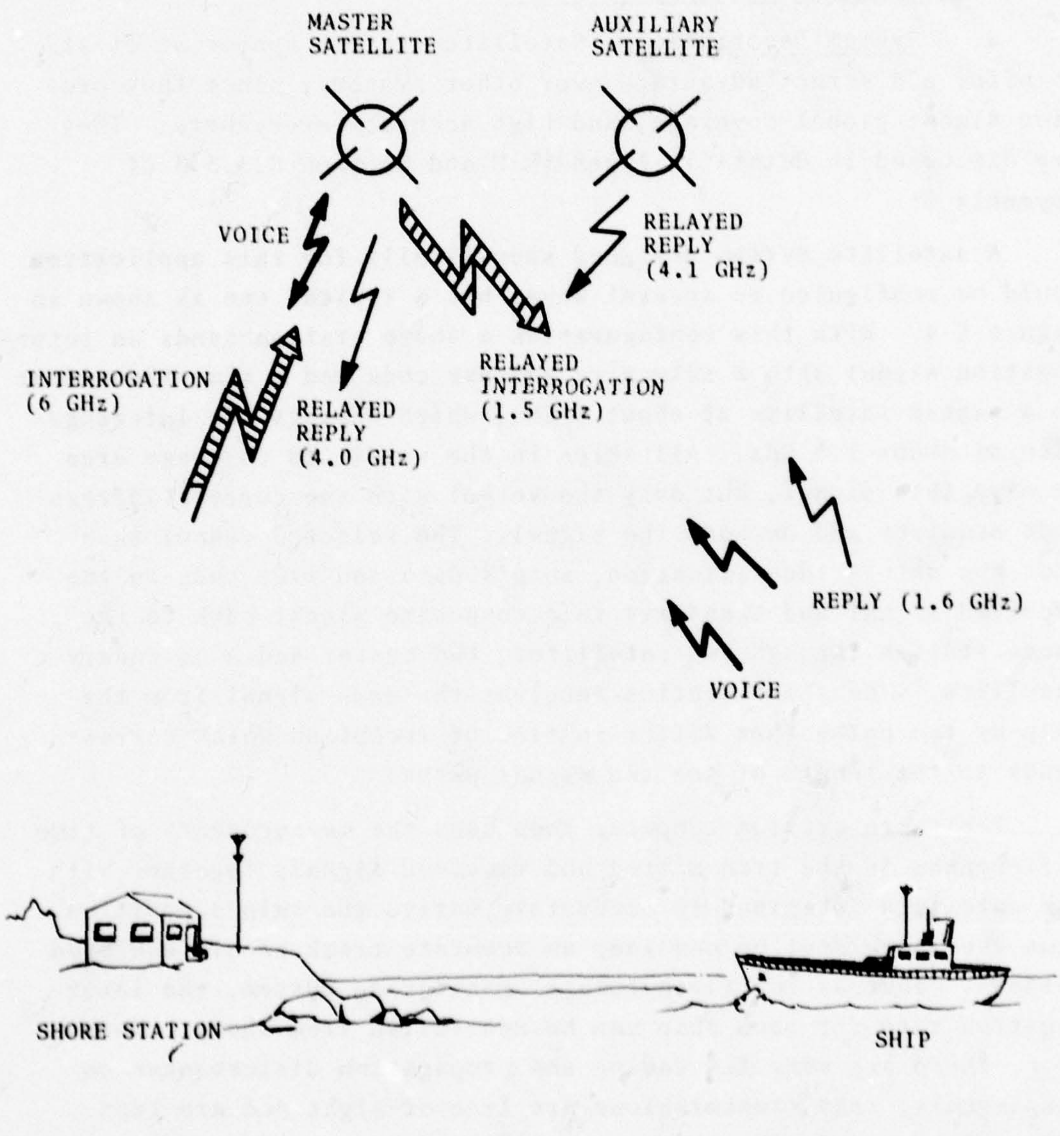

FIGURE 5-4. SATELLITE SURVEILLANCE SYSTEM (AFTER MARISAT)

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

Communications from the shore to the ship via satellite provides the most reliability, quality and range over VHF, HF or MF. 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 as 2.7 to 1. Because of the equipment cost, it is likely that only the larger vessels (over 10,000 gross tons) could afford a satellite communications capability. Therefore, it is assumed all ships between 1600 and 10,000 gross tons would use satellite ranging together with either VHF, HF or MF according to their distance from shore.

If VHF communication is used, the advantage of wide satellite coverage is lost; if HF communication 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; or, if MF communication is used as it is in the automatic monitoring system of Section 5.2.3, the additional costs of an MF communications network must be added to the system costs.

These problems must be considered along with the advantages of surveillance over automatic monitoring. From Table I-7, it can be seen that the potential effectiveness of satellite surveillance is about 79%, as opposed to 75% for automatic monitoring.

b. Training/Workload Implications - Minimal -- transponder need only be turned on.

c. Estimate of Availability - Availability is estimated premised on the assumption that all large vessels greater than 10,000 gross tons would be equipped with full communications (voice and high rate data) and ranging/navigation capabilities, and that all other vessels greater than 1,600 gross tons would be equipped with ranging transponder and low rate data capability, but no satellite voice or high rate data link. Thus, immediate voice communication from shore beyond VHF range would not be available to the smaller vessels. Since 85% of the casualties occurred within VHF range of the shore, availability would be between 85% and 100%. A figure of 90% is therefore assumed for availability.

d. Present State of Development - See Appendix H.

e. Estimate of Cost

Vessel Owner

1. Vessels over 10,000 gross tons:
   - Satellite Communications Terminal - $65,000*
   - Ranging/Navigation Transponder - 12,400
2. Vessels 1,600 to 10,000 gross tons: -
   - Ranging Transponder and Data Communications - 28,600

Government - Assuming the use of planned satellites,** the cost is estimated at $15,706,000 per year.

f. Coast Guard Action Required

1. Require L-band transponders on all vessels.
2. Require satellite communications on large vessels.
3. Design and install a shore-based satellite communications facility to receive and decode ship data, and communicate with vessels.

*Current cost of Marisat communications ship terminal is $62,000.00 plus approximately $3,000 installation costs.

**Reference IMMARSAT Radio Determination Economic Assessment Study, March 1978.

4. Establish data communications links between central facility and local stations.

g. Estimate of Effectiveness - Based on the casualties, the potential effectiveness of the system is estimated to be 79%, or 56% more than the baseline system.

5.2.7 Intensive and Periodic Training

a. System Description - As a "system" training would involve specific courses in the use of navigation instruments, rules of the road, proper navigation and helm procedures, and strict licensing requirements. The specific form of the training is beyond the scope of this study; the critical judgements involved in developing training requirements should be performed by experienced mariners, rather than a technical team. It should be mentioned, however, that simulators offer a chance to experience "dangerous" conditions without the risk of accident. They are expensive to use, but are effective training aids for officers of large tankers.*

b. Training/Workload Implications - This is highly subjective, but a reasonable guess is an additional week of training per year on the average for each bridge officer. This would include training in the use of instruments, relicensing, and in the use of simulators. Many shipping companies already require extensive officer training, and thus would not be affected. The main purpose is to increase training for officers who don't get enough now.

c. Estimate of Availability - Assuming that training affects all United States flag vessels and 50% of the foreign flag vessels, the availability is estimated at 41%, using Table 5-3.**

*A requirement for simulator training would be unrealistic at the present time; there are very few simulators available for such usage -- each one is a multimillion dollar facility.

**The text of a new treaty, the International Convention on Standards of Training, Certification and Watchkeeping of Seafarers, 1978, was agreed upon by an international conference in London in July of this year. The Annex to the Convention contains basic requirements on training, certification, and watchkeeping for masters, officers, and crew of seagoing merchant ships. It will enter into force when 25 nations, with combined merchant fleets constituting 50% of the gross tonnage of the world's merchant shipping, have approved it. This would have the effect of increasing the availability to 90-100%.

d. Present State of Development - Present licensing and training practices.

e. Estimate of Cost

Vessel Owner - Based on one week of training per year for three bridge officers per vessel, and assuming training and salary costs of $3,000, the cost per vessel would be $9,000.

Government - None, unless simulator facilities are constructed.

f. Coast Guard Actions Required

1. Establish strict licensing and training standards (see recommendations of Section 7.4).

g. Estimate of Effectiveness - Training as a "system" was rated by the TSC team as having a potential effectiveness of 35%, or 12% higher than the baseline system.*

5.2.8 Expanded Traffic Separation System

a. System Description - Traffic separation schemes have been in operation for several years at the approaches to New York Harbor, Delaware Bay, Portland (Maine), Boston, Chesapeake Bay, Los Angeles/Long Beach, in the Santa Barbara Channel, San Francisco, and recently in the Straits of Juan de Fuca. These are believed to be quite effective in reducing end-on (meeting) collisions. There were no such cases in the data base in a traffic lane.

However, there are three areas where improvement can be made: in fairways, adjacent to channels and traffic lanes, and in narrow passageways where alternate routes are available.

Fairways are not traffic separation schemes; rather, they are areas where no obstructions such as oil platforms are allowed. They are administered by the U.S. Army Corps of Engineers. They are indicated on the chart, and only serve to demarcate zones free of fixed obstructions. Vessels are free to use them or not, at

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*Other reviewers rated training higher than the TSC team; refer to the discussion in Section I-2.1.

their discretion: they may cross at any angle and navigate along the left boundary line if they choose. Nonetheless, vessel masters generally treat them as lanes, and tend to stay to the right. A system of required procedures pertaining to fairways which would have eliminated the two Gulf of Mexico collisions would consist of the following three rules:

1. Vessels should stay to the right except when overtaking, in order to effect port-to-port passing.

2. Vessels should avoid navigating outside of, and parallel to, fairways within one mile of the fairway boundary, counter to the traffic flow.

3. Vessels should cross at nearly right angles.

The second rule should be extended to channels and traffic lanes. When a shallow-draft vessel is proceeding along a channel boundary in the wrong direction, she is setting up a starboard-to-starboard passing situation, which can be quite confusing and dangerous especially at night. The other vessel may attempt a port-to-port passage, leave the channel, and ground. This is especially true near the entrances and exits to channels. Similarly with traffic lanes, especially like those in Delaware Bay where shallow areas lie nearby, this practice is dangerous.

There are narrow passageways like the one described in Section I.2.4 where safe passage of tankers and tank-barges would be enhanced by avoiding the passage altogether. In view of the importance of environmental protection, such situations should be reviewed, and passage prohibited in one direction or the other.

b. Training/Workload Implications - None.

c. Estimate of Availability - 95%. It is reduced from 100% by the chance that vessel masters would ignore the recommendations.

d. Present State of Development - Not applicable.

e. Estimate of Cost - Zero, except for the salaries of present government employees.

f. Coast Guard Actions Required

1. Work with the U.S. Army Corps of Engineers to set up recommendations for proceeding in fairways.

2. Set up recommendations for limitations on passage parallel to traffic lanes.

3. Work within IMCO to obtain international adoption of the recommendations.

g. Estimate of Effectiveness - The potential effectiveness is estimated to be 27%, or 4% above the baseline system.

5.2.9 Improved Aids-to-Navigation System

a. System Description - A system of improved aids-to-navigation would consist of the following measures being taken by Coast Guard personnel:

1. Buoy Identification Improvements - Means should be explored to improve buoy identification at night by use of varying light signals, to better differentiate between buoys, and to increase the range of visual identification.

2. Buoy Relocations - Buoys marking shoals and reefs should be carefully reviewed to ensure that under conditions where the buoy is at the point on its watch circle closest to the shoal or reef it is marking, the deepest draft vessel that could be in those waters can safely pass with the buoy alongside.

3. Buoy Monitoring - Means should be explored to increase the effectiveness of buoy auditing practices, and to reduce the time between buoy dislocations and their detection and correction.

4. RACONs at Fairway Intersections and Traffic Lane Entrances - RACONs should be strategically placed for position fixing (Section I.2.2.3).

These measures are discussed in Section 7.4.4.

b. Training/Workload Implications - Minimal for the vessel's officers. The RACON symbol appears automatically; a minimal amount of training might be required if new buoy identification techniques are introduced. More likely, this would take the form of a publication.

The Coast Guard workload would be increased somewhat in the following areas:

1. RACON installation
2. RACON maintenance

These are believed to be minimal requirements which can be accommodated with present manpower.

c. Estimate of Availability - This applies primarily to RACONs and lighted buoys. Based on present experience, availability of lighted buoys is estimated to be 95%. RACONs would probably have a similar availability. Experience in the Great Lakes and Alaska suggests a figure of 95%.

d. Present State of Development - RACONs are special-order devices, not presently a shelf item, because of the lack of demand. The RACONs presently in use were purchased as a special order. Any new acquisition will likewise be a special order. However, the technology is presently available, and new solid-state transmitter techniques are expected to improve reliability even further. The MTBF of present RACONs is about 20,000 hours.

The Coast Guard Aids-to-Navigation Division is presently embarking on a full-scale review of buoys - their shapes, colors, locations, markings, etc. This will provide an excellent opportunity to improve buoy identification and placement.

e. Estimate of Cost

Vessel Owners - None, unless IMCO phases out swept-frequency RACONs (IMCO, 1977). If this happens, all shipboard radars will have to be retrofitted, and all new radar equipped with fixed-frequency receiving circuits. The estimated cost is about $600 per radar.

Government - Buoy techniques will be covered in existing programs, and do not represent an additional cost. It is estimated that about 40 RACONs would be required to cover the port entrances, fairways and to provide other checkpoints along the coast (see Section G.3.1). The cost of 40 RACONs is estimated to be about $15,000 apiece, or about $600,000 total.

f. Coast Guard Action Required

1. Review buoy identification techniques, buoy location criteria, and buoy surveying techniques and effect the necessary changes.

2. Specify and procure 40 swept-frequency RACONs plus spares and parts; identify buoys to be equipped and fit them with appropriate brackets.

g. Estimate of Effectiveness - The potential effectiveness of a program of improved buoy techniques plus a system of RACONs, is estimated at 34%, or 11% above the baseline system.

5.2.10 Pilot Transfer Procedure System

a. System Description - The present system of piloting is a mixture of federal, state, and commercial enterprise. Pilots, all commercial, are licensed to operate in a specified zone. The license is issued in a few areas by the federal government, and in the majority by states. Thus there is a jurisdictional issue in any new regulations establishing a different pilot transfer procedure system.

Assuming the jurisdictional obstacles can be overcome by issuing national guidelines, the pilot transfer procedure system would consist of implementing the following requirement:

"Loaded tankers of 10,000 gross tons or more shall not be allowed to procede into (a specified region) without a pilot on board, a pilot escort, or a Coast Guard escort."

The "specified region" would depend on the locations. In Guayanilla Bay, for example, the forbidden zone would probably be within two miles of the southernmost point of land. In Delaware Bay, loaded tankers should not be allowed to approach on the Five Fathom Bank traffic separation lane, but rather the Delaware lane; there they should not be allowed to proceed beyond buoy "DC" without meeting the above conditions. There is presently a strategy, which is "first one to the pilot boarding area gets the pilot." Loaded tankers should be able to arrange for pilot encounter an hour ahead of time, or when within VHF radio range of the pilot station. This would enable them to time their arrival at the encounter point in a dependable fashion, and avoid the first-come-first-served-strategy. Depending on the depth of the water, vessels could wait at anchor (in deep water like New York Harbor approach) or beyond the traffic lanes (in Delaware and Chesapeake Bays, for example), if a significant delay is encountered in pilot boarding.

This system appears as an independent recommendation in Section 7.2. An expanded discussion is presented there.

b. Training/Workload Implications - None.

c. Estimate of Availability - The system would become "unavailable" in the case of scheduling problems, i.e., in cases where the vessel arrived at the agreed-upon encounter point, but due to mixups the pilot boat was not there. The master might choose to go further in, rather than turn around or anchor next to a traffic lane. This requires a subjective judgement, but a reasonable estimate is that this situation would occur less than 10% of the time.

Estimate of Availability: 90%.

d. Present State of Development - Not applicable.

e. Estimate of Costs

To Vessel Owner - The additional cost of hiring a pilot to board further out, less than $1000/trip inbound. It does not appear as critical outbound (based on only one outbound casualty in the data base). Also, the additional delay would cost money, if the pilot encounters were not arranged ahead of time. Pilot transfers would be greatly facilitated with coordination by a shore-based system (see Section 5.2.2).

Cost to Government - None.

f. Coast Guard Actions Required - Issuance of guidelines for pilot transfer procedures for loaded tankers.

g. Estimate of Effectiveness - The potential effectiveness for groundings is estimated at 44%. The overall potential effectiveness is estimated at 38%, or 15% above the baseline system.

5.2.11 Improved Equipment Standards

a. System Description - A system that incorporates improved equipment standards would essentially adopt the practices of a prudent shipowner and try to enforce them on all vessels bound for or departing U.S. port. These practices are:

1. Purchase of equipment meeting a recognized standard.
2. Purchase and maintenance of comprehensive spare parts supply.
3. Preventive maintenance and care of equipment.
4. Requirement of at least one crewman to be capable of making at least simple repairs, and able to install spare parts.
5. Requirement of any necessary repairs to be made at each docking.

The first two can be readily established by occasional inspections. The third and fourth are easily avoided by any shipowner trying to cut costs. The fifth is difficult to enforce, unless a shore-based system exists.

b. Training/Workload Implications - Since a trained radio officer is required on every ship, and most ships also have a qualified electrician, there is no increase in workload, and only a slight increase in training, mainly in the checkout and installation of spare parts.

c. Estimate of Availability - In the context of this system, availability is equivalent to enforceability. In the evaluation of the associated system feature of Section I.2.7, an attempt was made to estimate the likelihood of compliance in arriving at the evaluation. Thus availability is assumed to be 100%.

d. Present State of Development - Backup radars will be required for tankers. This should be extended to tugs towing large barges containing hazardous materials, oil, and fuel. The requirement for navigation gear independent of radar will significantly reduce casualties caused by radar and compass failures, by providing another reliable means of determining positions.

e. Estimate of Costs

Costs to Vessel Owners - It is assumed that the requirements herein are only those above the purchase and installation price, namely for spare parts and maintenance.

Costs to Government - None, except those associated with issuing equipment standards.

f. Coast Guard Actions Required

1. Issue minimum equipment standards on gyrocompass, depth sounder, radar, and navigation gear.

2. Issue a requirement for complete spare parts kit on the same instruments.

g. Estimate of Effectiveness - The potential effectiveness of issuing and enforcing these standards is estimated to be 25%, or 2% above the baseline system.

5.2.12 Processor-Aided Navigation Alert System

a. System Description - With the improvements in performance, cost, and reliability of microprocessors and other digital circuitry, it is now possible to automate and integrate several bridge functions reliably and relatively inexpensively. LORAN-C receivers now automatically perform cycle-matching, and can even choose the strongest stations, and compare the results from different chains; on some units time coordinates can be transformed to latitude/longitude and displayed in that form. Instead of displaying every new measurement, continuous smoothing can be performed to reduce noise errors. Deviation from preselected tracks can be continuously displayed. Continuous cross-checking can take place between independent navigation instruments: Omega vs. LORAN-C, radar vs. LORAN-C, and dead-reckoning vs. LORAN-C, can all be accomplished, and an indication provided if the differences are excessive and suggest a defective instrument. Built-in calibration circuits can automatically test most of the operating circuitry without involving human effort. Set and drift can be calculated and displayed. Traffic lanes and even fathometer readings can be superimposed on radar displays; so can synthetically generated, processed radar target replies from ships, buoys, and coastline.

To complete the automation loop, the deviation-from-intended course can be fed into control circuitry to control the rudder of the ship. Automatic helm controllers have seen some usage for several years, but it is now possible for the processor to calculate control commands designed to reduce rudder wear and increase fuel operating efficiencies, based on the individual ship's shape, weight, and handling characteristics.

In the context of this study, the important system features are safety-related, rather than control or convenience-related. The features of integrated navigation gear of most interest are: (1) the calculation and display of deviation-from-track, (2) an alert for excessive deviation and (3) an alert prior to arrival at waypoints, and to a lesser extent, (4) cross-checking between instruments (see Section I.2.12-15). Shipboard systems that exhibit these features are available off-the-shelf. They are generally bought by the shipowners to reduce travel time and save fuel, rather than as an aid to safety. However, the information provided is valuable: several accidents in the data base could have been avoided had such a system been on board and in use.

In the process of analyzing casualties, several cases were noted where the vessel was awaiting the arrival of a pilot, and drifted onto a shoal or reef. It appeared that the vessel master was unaware of the distance the ship had drifted. It was suggested that a useful capability that could be easily implemented into processor-augmented navigation equipment is a command key that would establish a reference position (the position of the ship at the time the key was pressed), and provide a readout of the distance of the ship from that reference point (see Figure 5-5). This could also be arranged to sound an alert if the ship drifted more than a preselected distance from the reference point. Such a calculated distance would have an accuracy on the order of a few hundred feet or less.

b. Training/Workload Implications - If poorly designed, a system of this kind could be complicated to enter waypoints; however, there are similar units which have fairly simple keyboards with numbers and a few command buttons, and involve no letters other than N-E-S-W. Since LORAN-C charts are corrected for long-term propagation errors, waypoints would be entered in LORAN time coordinates, rather than latitude/longitude coordinates. Otherwise, simple coordinate conversion algorithms would not contain the corrections; this is especially problemmatical near the shore. Once the waypoints are determined on the chart, and the coordinates written down, the actual entry of the data for 10 waypoints into the processor can be accomplished in two minutes.

It should be pointed out that there is a danger: if the navigator makes an error in recording coordinates, from the chart or in keying them into the processor (less likely, since the result is visually displayed), the ship could be accidentally routed into a shoal area. To avoid this situation it would be good practice to have one officer enter the waypoints, and for another officer to take the displayed coordinates and plot the points on the chart to assure the resulting waypoints are correct.

With these constraints, the training and workload implications are minimal - the entire process would not need to be performed more than once a day.

c. Estimate of Availability - Since the additional hardware required for an integrated navigation system (over and above the

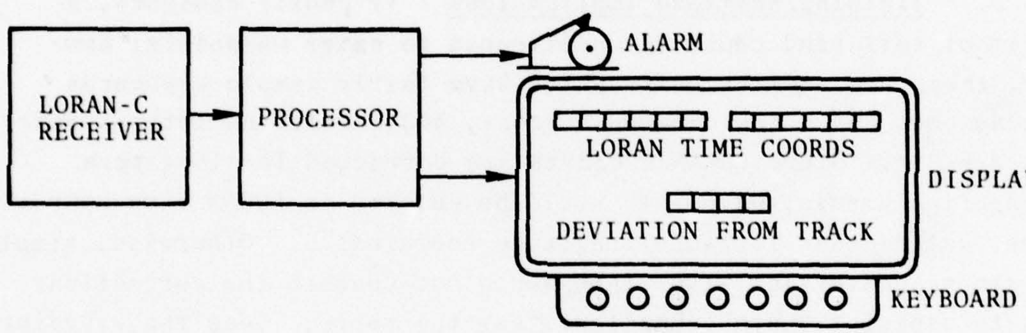

FIGURE 5-5. PROCESSOR AIDED NAVIGATION ALERT SYSTEM

sensors that input it) is digital, and since it will be in a protected environment, the equipment availability will be high, on the order of 99%.

The availability of the system in practice will be limited by reluctance to use the equipment. There are probably a number of vesselmasters who will find it insulting, or too much trouble to use, or who will not want to plot their course in advance in relatively confined waters. The fact that the economic benefit is obtained in open waters, rather than close to shore, will reinforce this attitude. It can be expected that the acceptance and use of the system will increase with time. Any estimate here is greatly subjective.

With the above caveats, the availability is estimated at 70% for 1985, and 80% for 1990.

d. Present State of Development - Equipment exhibiting the three system features of a display of deviation-from-track, an alert for excessive deviation, and a maneuvering point alert, is available off-the-shelf. Some units do not include the latter two features; in all cases the display of deviation-from-track should be more prominently displayed. The distance-from-reference-point feature should be incorporated into the next generation of integrated navigation equipment.

e. Estimate of Cost

Vessel Owners

Purchase Costs: Presently \$15,000 - \$30,000. Eventually \$2,000 - \$4,000 above the cost of a LORAN-C receiver.*

Installation Costs: Small - no antenna or other expensive installation - all on bridge.

Government - None.

*LORAN-C sets with deviation-from-track display while navigating along a "LORAN line" are available today for \$4,000 - \$6,000. This is a very limited version of the capability required for arbitrary tracks.

f. Coast Guard Action Required

1. Establishment of Minimum Equipment Specifications. These specifications should include the requirement for prominent display of deviation from track, an alert for excessive deviation from track, an alert for an approaching waypoint, and a distance-from reference point presentation and alert. They should also include built-in test circuits and calibration, in order to achieve a high reliability.

2. Eventual Requirement of Processor-Aided Navigation Alert Equipment. If this system is selected to be instituted, a rule will need to be drafted requiring this capability on tankers.

g. Estimate of Effectiveness - There were two rammings and 24 groundings where a processor-aided navigation alert system (shown in Figure 5-5) would have provided some protection beyond the baseline system; this assumes the system features of a display of deviation-from-track, an alert for excessive deviation-from-track, and a maneuvering point alert (see Section I.2.13-15). Considering only rammings and groundings (collisions would not usually be affected), the baseline system is expected to reduce casualties by 23%. If a processor-aided navigation alert system had the three features listed above and were available on the bridge of every tanker, casualties could be reduced by 31%, i.e. 8% more than the baseline system.

5.2.13 Depth Alert

a. System Description - Depth sounders are standard equipment on vessels of all sizes. They are highly reliable from the point of view of availability, and are simple to use.

The key element, the transducer, is usually mounted on the hull, and requires piercing of the plate for installation. It must be installed aft of the bow far enough to keep the transducer in undisturbed water. The unit transmits an acoustic pulse periodically downward into the water through the transducer. The pulse is transmitted in a beam a few degrees wide toward the ocean floor.

The reflections of the pulses off the bottom are received by a transducer (usually the same as the transmitter) and converted to electrical signals, which are amplified and displayed. The time difference between transmitted and received pulses provides a measure of the distance from the hull to the ocean floor.

The echoes are displayed in several ways: (1) a rotating light display shows a bright illumination on a circular scale readout; (2) a digital display shows a number representing the depth below the hull; and (3) a chart recorder will show the depth contour of the track recently traversed by the vessel.

It is feasible to attach an alarm feature to a depth sounder, which would sound if the measured depth became less than a preset critical value (refer to Figure 5-6). Equipment is available off the shelf which exhibits this feature. The main difficulty with attaching alarms is that without proper design precautions, false alarms can become a nuisance. With repeated false alarms, the mariner's confidence in the instrument can be reduced to the point where it falls into disuse. False alarms can be caused by a school of fish, a shark, or even a single smaller fish, as well as noise spikes caused by turbulence, engine noise, and electrical disturbances. Alarms set, adjusted or designed to reduce random noise and false echo activation are usually not sensitive enough to provide reliable operation on all types of bottom. Digital type sounders only read the first echo. This is a disadvantage where multiple echoes might be encountered from fish, kelp, trash, etc.. Proper design is necessary to avoid this condition; one of the best methods is to integrate the returns over a number of pulses (e.g., over a 10 second period). This reduces false alarms significantly.

Proper usage of the depth alert system requires the mariner to select the critical depth, based on the charted depths along the intended track, the tides, and the vessel draft. Even if the critical depth is arbitrarily selected to be two or three fathoms below the hull, it could be invaluable. Upon hearing an alarm, the watchstander would watch the display for a brief period or examine the chart recorder to verify that the echoes causing the

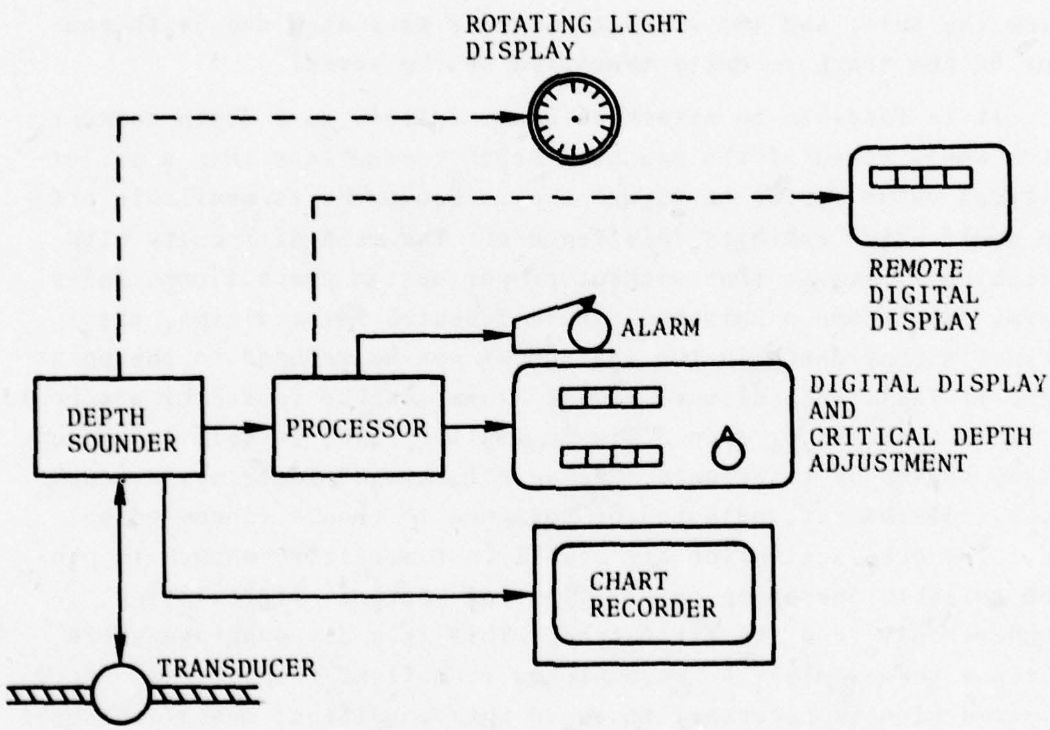

FIGURE 5-6. DEPTH ALERT

alarm were really caused by reflections from the ocean floor. If so, the situation would be reviewed, a position established, and appropriate action would be taken.

b. Training/Workload Implications - The depth alert requires a certain amount of skill to be used properly, but the thinking process of choosing a critical depth is the same as the mariner is trained to do in properly interpreting charts. The extent to which this training is part of a mariner's experience will determine his comfort with using the instrument.

The alert feature acts as a backup, which should actually reduce the workload of a conscientious navigator, because it can reduce the amount of time he would spend examining the depth sounder. This assumes that the false alarm problem is solved, i.e., that false alarms are infrequent.

c. Estimate of Availability - The present cost ($6,000 - $10,000) could be burdensome to smaller tankers, and thus limit the instrument's availability. There were no cases in the data base where tug/barge combinations would have benefited from this feature. However, the cost would be reduced substantially if the demand were there, because the processing is conducive to micro-processor techniques. The cost could be reduced to about $2,000 in the future, which would not be burdensome.

As for equipment reliability, it is quite high, especially if good commercial practices are followed.

Based on these considerations, availability is estimated at 95%.

d. Present State of Development - Equipment is available off the shelf, but more work needs to be done in signal processing of acoustic echoes to achieve low false alarm rates.

e. Estimate of Cost

Vessel Owners

Purchase Costs: $6,000 - $10,000 at present
$1,500 - $2,500 projected.

Installation Costs: None - use present installation.

Government - Development costs, estimated at $1,000,000.

f. Coast Guard Actions Required

1. Establish minimum equipment specifications.

2. Require the use of such systems by approximately 1983.

3. Minimal development is required - generating the market should provide adequate impetus for company-funded development.

g. Estimate of Effectiveness - The potential effectiveness is 32%, or 9% above the baseline system.

5.2.14 Scanning Sounder

a. System Description - The scanning sounder is a device which allows an area on the ocean floor forward and abeam of the vessel to be mapped out (refer to Figure 5-7). Ideally a device such as this would provide depth information out to about 0.5 - 1 mile ahead, and a thousand feet or so to each side. Thus, coupled with an alarm, such a system would incorporate the capabilities of the previous system (depth alert) and additionally would provide an indication of the presence of reefs being skirted by the vessel.

Scanning sonars are available commercially; they are mounted on the forward part of the hull and protrude down into the water. When they are switched off, the hoist system retracts the transducer into the hull. This feature enables a 360 degree scan capability. They are used primarily for locating schools of fish, but they also show the distance from channel banks. Side-scanning sonars can also be used to detect reefs to the side, and to position the vessel within channel banks.

The display typically looks like a radar scope, but requires some interpretation. Depending on the tilt of the transducer, the echoes paint out different pictures. Furthermore, the depth

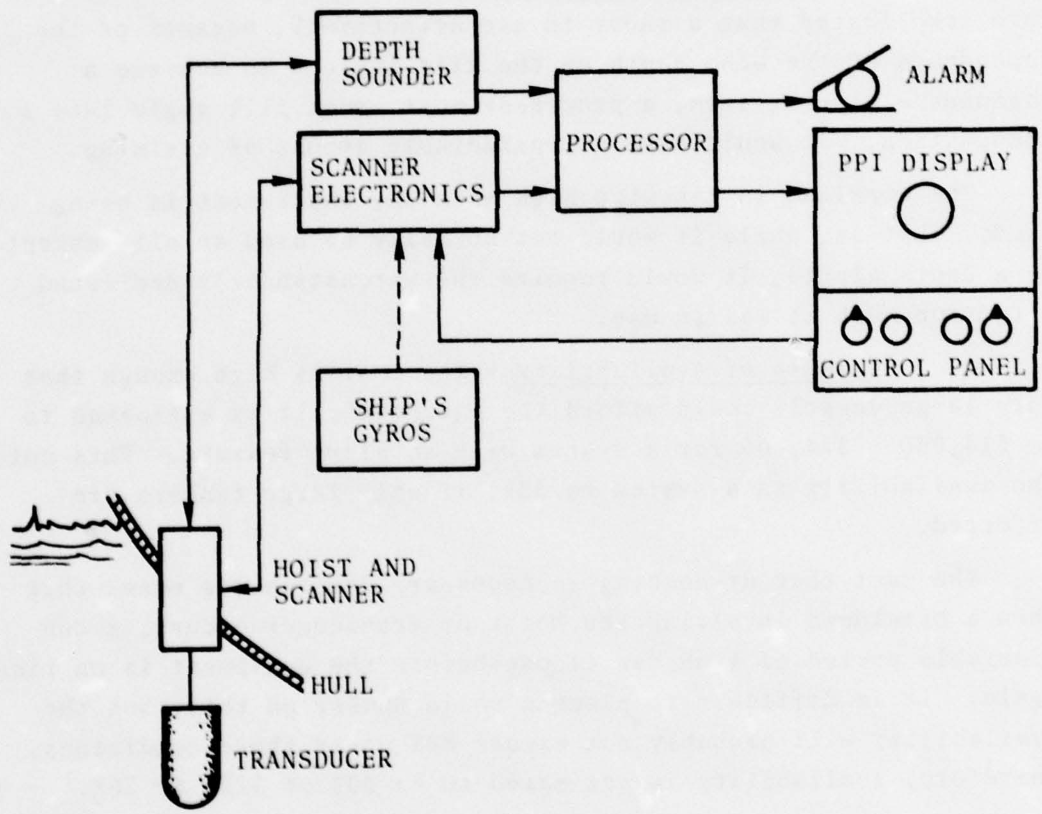

FIGURE 5-7. SCANNING SOUNDER

of the surface causing the echoes varies with range. The tilt of the transducer can be adjusted, which is a valuable feature, but further complicates its usage.

Installation and maintenance of the transducer/hoist combination would be expensive, since they would require dry-docking.

b. Training/Workload Implications - This instrument is even more complicated than a radar to use effectively, because of the dependence of the echo depth on the tilt angle. To achieve a reasonable alert system, a processor must input tilt angle into a computation. It would take a considerable amount of training.

The workload is likewise high when the instrument is being used. That is, while it would not normally be used at all (except as a depth alert), it would require the watchstander's dedicated attention when it was in use.

c. Estimate of Availability - The cost is high enough that only large vessels could afford the equipment; it is estimated to be $14,000 - $24,000 for a system with an alert feature. This cuts the availability as a system to 32%, if only large tankers are affected.

The fact that drydocking is necessary for repairs means that when a breakdown involving the hoist or transducer occurs, a considerable period of time can elapse before the equipment is on line again. It is difficult to place a solid number on this, but the availability will probably not exceed 80% under these conditions. Therefore, availability is estimated to be 80% of 32%, or 26%.

d. Present State of Development - Side-looking sonars and scanning sonars are available off the shelf, although from only a few vendors. To add an alert feature requires the development of a processor to account for range, tilt angle, and azimuth angle.

e. Estimate of Cost

Vessel Owner

Purchase Cost (basic unit):	$12,000 - 20,000
Additional Cost (processor):	2,000 - 4,000
Total	$14,000 - 24,000

Installation Cost: Very high, due to necessity for drydocking.

Maintenance Cost: Very high, due to necessity for drydocking.

Government - Development costs for signal processing techniques. This is estimated to be $1,500,000.

f. Coast Guard Actions Required

1. Establish minimum equipment specifications.
2. Require such equipment on board large tankers (e.g., greater than 10,000 gross tons).

g. Estimate of Effectiveness - In order to properly evaluate this system, it is necessary to eliminate the cases from consideration wherein the operational feature of depth-mapping with alert achieved a score by virtue of its forward-looking capability. In doing this, the depth alert feature was retained. Under these conditions, there were 11 cases identified where the side-scanning capability of a scanning sonar would have helped. Seven involved skirting too close to known reefs, three involved drifting sideways into reefs while awaiting a pilot, and the other involved anchoring in an area of reefs. Adding these to the depth alert cases, the potential effectiveness for groundings is estimated at 49%, and 39% overall; this is 16% higher than the baseline system.

5.2.15 Collision Avoidance Aids

a. System Description - The term "Collision Avoidance Aid" is used to denote what is normally called a "Collision Avoidance System," in order to emphasize the fact that such an instrument does not prevent collisions directly, but rather aids the conning officer in his decision-making in a conflict situation involving one or more other ships.

A collision avoidance aid processes the raw radar signals, identifies certain radar echoes as targets, and tracks their positions; it also projects the future position of each radar target and calculates the CPA (closest point of approach) and TCPA (time to CPA) for each one (refer to Figure 5-8). The projected positions are calculated based on straight-line extensions of the observed course; if the target vessel changes course, the projections will be incorrect, and a period of time will elapse after the maneuver has been completed (10-60 seconds) before the projections are correct again. The CPA (which is displayed digitally on some equipment) provides a measure of the danger of the conflict, e.g., a CPA of less than 0.5 miles is a serious situation for a tanker in open waters. The projected tracks also indicate the type of passing, i.e., whether the other ship will pass astern or across the bow. This information is also helpful in establishing which rules of the road apply to the situation.

The TCPA provides a measure of the time available for decisions, and whether the situation is "in extremis." If several minutes are available timely action can increase the CPA and reduce the danger. The new Rules of the Road (U.S. Coast Guard, 1977) allow timely action to be taken by the privileged vessel before an "in extremis" situation has developed without implying blame on the part of the privileged vessel.* A collision avoidance aid provides a better, quantitative measure of the appropriate time of action through the TCPA calculations.

Early action is desirable, but of itself does not guarantee effective action. This is evidenced by the five meeting, or end-on collisions in the data base. The classic end-on situation is one where one vessel assesses the situation as a no-conflict, starboard-to-starboard passing, and either maintains course, or turns

*Prior to the recent changes, a vessel lost her privileged status if she maneuvered prior to being "in extremis."

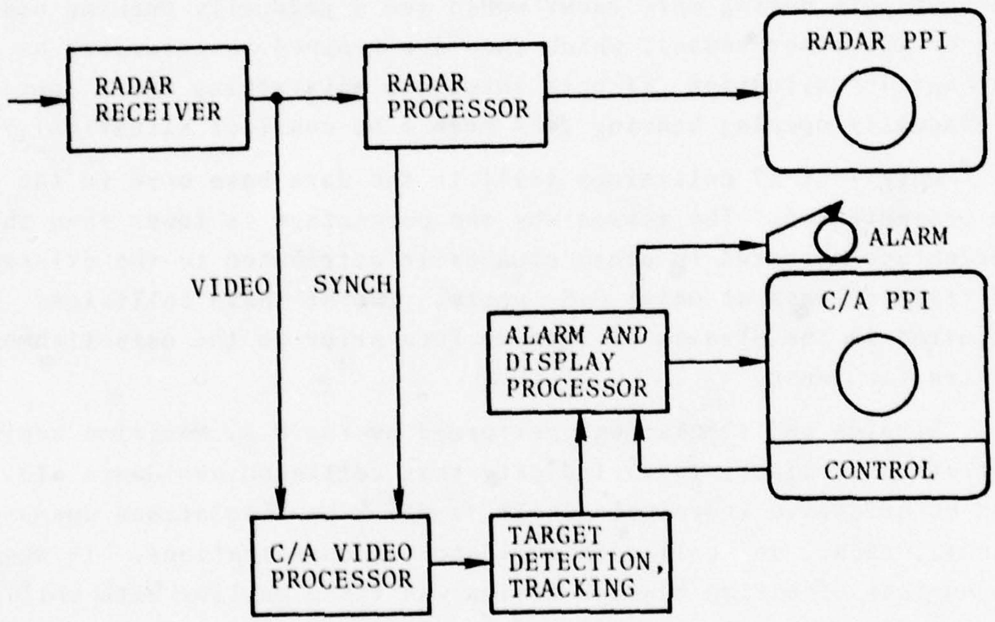

FIGURE 5-8. COLLISION AVOIDANCE AID

to port slightly to further increase the passing distance; the other vessel judges the situation as a conflict, and maneuvers to starboard to effect a port-to-port passing. Thus they turn toward each other's path, each making further adjustments in the same direction as before. Several authors have commented on this (Kemp, 1973; Barratt, 1976; Cockroft, 1976; and Devanney, 1978). A collision avoidance aid helps to make a proper initial assessment based on the initial CPA, and also helps identify the nature of the respective maneuvers as the scenario unfolds. Watchstanders on both vessels having only radar would see a gradually opening bearing on the other vessel, which they are trained to interpret as a nonconflict situation (if both ships are maintaining their courses, a gradually opening bearing does mean a no-conflict situation).

Only 7 of 17 collisions (41%) in the data base were in the end-on presentation. The reason why the percentage is lower than the percentage observed in other studies is attributed to the existence of traffic lanes at major U.S. ports. Two of these collisions occurred in the Straits of Juan de Fuca prior to the establishment of traffic lanes.

Studies and simulations performed by the U.S. Maritime Administration (Pollack, 1977) indicate that collision avoidance aids can be effective in reducing collisions. The simulations compared visual, radar, and collision avoidance-aided situations. It was found that effective evasive action was taken earlier with collision avoidance equipment than with visual sightings of the other vessels involved. With radar, on the other hand, evasive action actually took place later than it did visually. This was attributed to the fact that maneuvering changes the radar picture so radically that it is difficult to assess the new situation; also, any plots are interrupted. Apparently, the tendency with radar is to wait as long as possible before committing oneself to a course of action. The early action with collision avoidance equipment was reflected in larger CPA's, which demonstrated the additional safety margins.

Actually, collision avoidance aid advocates claim that the equipment merely provides an early assessment of a conflict situation; that it buys 3-5 minutes of valuable time; it also reassesses the situation to assure that the early action is effective. Trial maneuvers can be postulated and evaluated. Some equipments project future positions by 1-minute line segments on a true motion display - trial maneuvers can be entered and the resulting radar picture will be shown as it would occur. Other equipments show PADs (Projected Areas of Danger), which are ellipses on the radar screen, to be avoided (the size of the ellipse is determined by selecting the desired minimum CPA); safe maneuvers are found by inspection to be those which avoid the PADs of other ships. Collision avoidance equipment is discussed in more detail in company brochures and in the literature (Merz and Karmarkas, 1976; Luse, 1972; Wylie, 1970; Pollack, 1976).

One feature that would have been crucial in the data base casualties was automatic acquisition. In four rammings and in five collisions, the oil platform or vessels were not detected by at least one vessel until too late. In several collisions, each vessel had noted the existence of the other but didn't maintain radar plots, making it doubtful that the mariners would have bothered to manually acquire targets.

Automatic alarms are likewise crucial. Collision avoidance equipments have true motion display capability, and show fixed targets as stationary.

To sum up the characteristics of a good collision avoidance aid: it should have automatic acquisition of targets, an alarm that sounds if the projected CPA of a target vessel is less than about 0.5 miles (adjustable), and a true motion capability that shows oil platforms, buoys, and anchored vessels as being stationary. These assumptions are used to evaluate a collision avoidance aid as a candidate system in paragraph (g).

b. Training/Workload Implications - With automatic acquisition, the largest workload factor is removed. It is noteworthy that for usage inland and close to the coast, where land echoes predominate, manual acquisition may be necessary to keep them from saturating the system. However, for ocean usage, automatic acquisition is important. Even with this feature, the training will take 1-2 days. Once learned, the controls are fairly obvious, and are geared toward a mariner's thinking processes, so that it probably doesn't require retraining, the way radar usage might. The workload is moderate, but the system's greatest utility would be in limited visibility and at night, conditions where the radar is in frequent use anyway.

c. Estimate of Availability - Collision avoidance aids do not require cooperative equipment the way an interrogator/transponder system would, but suffer from the same cost problem. They are even more expensive than interrogator/transponder systems and thus could not reasonably be required as standard equipment on tugs or small tankers. Assuming that only tankers of 10,000 gross tons or more would be required to have much equipment, the availability will be about 22% for collisions (see Appendix I, Table I-7a). It would not help small tankers and tug-barge combinations avoid each other. It would, however, be effective for rammings, whereas a transponder-type system would not. The availability for rammings would be the fraction of tank vessels on the water that are greater than 10,000 gross tons; this is estimated at 32% from Section 5.4. Reliability is very good - primarily limited by the availability of the radar, taken here to be 80% for each radar, or 96% for a dual radar installation. Availability is thus 96%x22%=21% for collisions, and 32% for rammings.

d. Present State of Development - Available off the shelf. However, some units do not have automatic acquisition.

e. Estimate of Cost

Vessel Owners

Purchase costs: $75,000 - $150,000
Average: $100,000

Installation costs: Low to moderate.

Government - None.

f. Cost Guard Actions Required

1. Establish minimum equipment standards for collision avoidance equipment.

2. Require collision avoidance equipment on all tankers of 10,000 gross tons or more.

The 1978 Tanker Safety and Pollution Prevention Conference deferred action on collision avoidance aids (CAAs). Instead it requested that IMCO "... develop performance standards for collision avoidance aids as a matter of urgency and not later than July 1, 1979." The Conference further requested IMCO to prepare requirements for the carriage of CAAs and to develop a training program for instruction in the use of the aids. In view of the responses to the notice of proposed rulemaking concerning CAAs and action of the Conference, on 24 July 1978 the Coast Guard withdrew the proposal concerning CAAs. The need for U.S. rulemaking will be reevaluated when IMCO has completed its work.

g. Estimate of Effectiveness - If all vessels were equipped with collision avoidance aids, the feature would have helped in 14 of 17 collisions, and 4 of 6 rammings. The potential effectiveness numbers are 63% for collisions and 65% for rammings. The overall potential effectiveness is estimated at 37%, or 14% above the baseline system.

5.2.16 Radar Perimeter Detection Device

a. System Description - This system is an adjunct to a standard shipborne radar. It is designed to be a low-cost, limited capability, collision-avoidance aid. It is based on the concept of guard zones: if a radar target appears within a guard zone, an alarm sounds, alerting the vessel watch officer of the presence of an echo (refer to Figure 5-9). This discussion will assume the existence of an outer and an inner guard zone, independently defined, and each being adjustable within reasonable limits. While azimuth limits can be set in some embodiments of the device, it will be assumed here that the guard zone is a circle with an adjustable outer limit. Typical range limits would be 1-2 miles for the inner zone, and 5-7 miles for the outer; these can be adjusted to the situation: radar clutter, ship speed, the presence of land and buoy echos, and traffic density, all may call

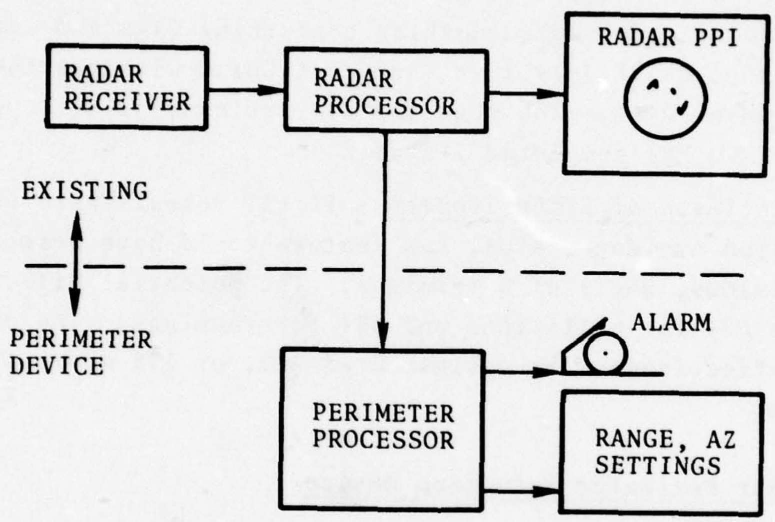

FIGURE 5-9. RADAR PERIMETER DETECTION DEVICE

for adjustments for the situation. With outer and inner settings, the system incorporates the operational features of Sections I.2.24 and I.2.25, both involving alarms if echoes are detected within a given range.

The system would operate in the following manner. The vessel watchstander would set the outer and inner limits to some initial value, e.g., 12 miles and 2 miles. If an alert sounded, indicating another vessel (or oil platform) in the area, he would readjust the outer zone to about 4 miles, after establishing the position of the vessel and the approximate course. If the vessel closed to within 4 miles, the alert would sound again. At this point the vessel watch officer would reassess the situation and might or might not decide to maneuver. In either case the 2 mile warning would sound if the other ship continued to come too close. Another maneuver would be in order, as well as a readjustment of the inner zone limited to one mile. At some point continuous watchstanding would be required to assess the situation.

In practice there are several factors which reduce the effectiveness of the instrument (estimated quantitatively under (c) - Availability):

1. Radar clutter can cause false alarms and obscure targets in rough seas at close range. If the radar gain adjustment is turned down to reduce the clutter, the target can be lost, permanently or intermittently.

2. Frequent attention is required to use it properly. Gain adjustments, and resetting of guard limits must take place frequently to strike a favorable balance between false alarms and missed targets. Failure to reset after an encounter can cause a false sense of security.

3. Frequent false alarms can be irritating. False alarms are caused by clutter from waves, buoys, and land echoes. If the vessel is operating close to land, the device loses utility, because the range limits must be set for values so low that potential conflict situations can be missed.

4. It is of no value when the radar is down.

b. Training/Workload Implications - An officer well-trained in radar will have little difficulty comprehending and using this device. However, it was evident from the casualties and from the frequent lack of certification and licensing of officers that this is frequently not the case. These people will be the first ones to turn the device off when false alarms begin to occur.

The workload is moderate. The actual setting adjustments are not time-consuming or difficult, but the device requires frequent attention.

c. Estimate of Availability - The availability of the radar perimeter detection device is limited by the radar availability, clutter, ease of usage, and the percentage of vessels equipped with the device. The radar availability is estimated at 80%. Clutter can be a problem in rough and moderate seas, which occurred in 25% of the collisions and rammings; since clutter would affect the inner zone more than the outer zone, the availability is estimated to be reduced by somewhat less than 25%, or 17%. The human factors were considered in deriving the potential effectiveness, and so do not appear as a separate factor. It is assumed that all small vessels and large non-tankers will have them, i.e., 78% of the vessels (see Appendix I, Table I-86). The overall availability is thus estimated to be:

$$80\% \times (100\%-17\%) \times 78\% = 52\%$$

d. Present State of Development - These devices are available off the shelf, but they are not standardized.

e. Estimate of Cost

Vessel Owner

Purchase Cost: \$2,000 - \$3,000

Installation Cost: Low - must be mated to the radar.

Government - None.

f. Coast Guard Action Required

1. Establish minimum equipment specifications.
2. Require all vessels to have either this system or a collision avoidance aid.

g. Estimate of Effectiveness - The potential effectiveness is estimated at 45% for collisions and rammings. Overall, the potential effectiveness is estimated to be 32%, or 9% above the baseline.

5.2.17 VHF/Transponder System

a. System Description - This concept was developed at TSC to provide an inexpensive alternative to the transponder system of Section 5.2.18, one which tugs and small tankers could afford. Its chief advantage operationally is that it facilitates bridge-to-bridge contact with a selected radar target.

When a new vessel appears within 5-7 miles of own ship, a bell alerts the bridge officers (refer to Figure 5-10). The bell is activated by a short VHF data transmission sent out every 5-10 minutes from the new vessel, providing her identification code, e.g., the VHF call sign. By this time the vessel's radar return should show up as a target. A small display would contain the ID code. If the watchstander wanted to identify that vessel on the radar, the press of a button beside the display (mounted close to the radar) would result in a RACON-type trail extending from the radar target outward towards the rim of the display, thus identifying the correct radar blip. The conning officer could then selectively call the other ship's master on channel 13 (again by pressing a button) to coordinate the passing, if it appeared there was a problem.

As a valuable option, the equipment could be configured with a set of "turn signals" to indicate when course changes are imminent; the next VHF transmission, which would immediately follow the "turn signal" activation, would contain the maneuver intent.

The radar tag would be caused by an X-band radar transponder having performance parameters similar to a RACON (Henry, 1973). The transponder would be off, except when VHF transmissions occurred, or when a radar tag was requested by the other ship's interrogation. When one of these conditions occurred, the transponder would be enabled for about three seconds, long enough that

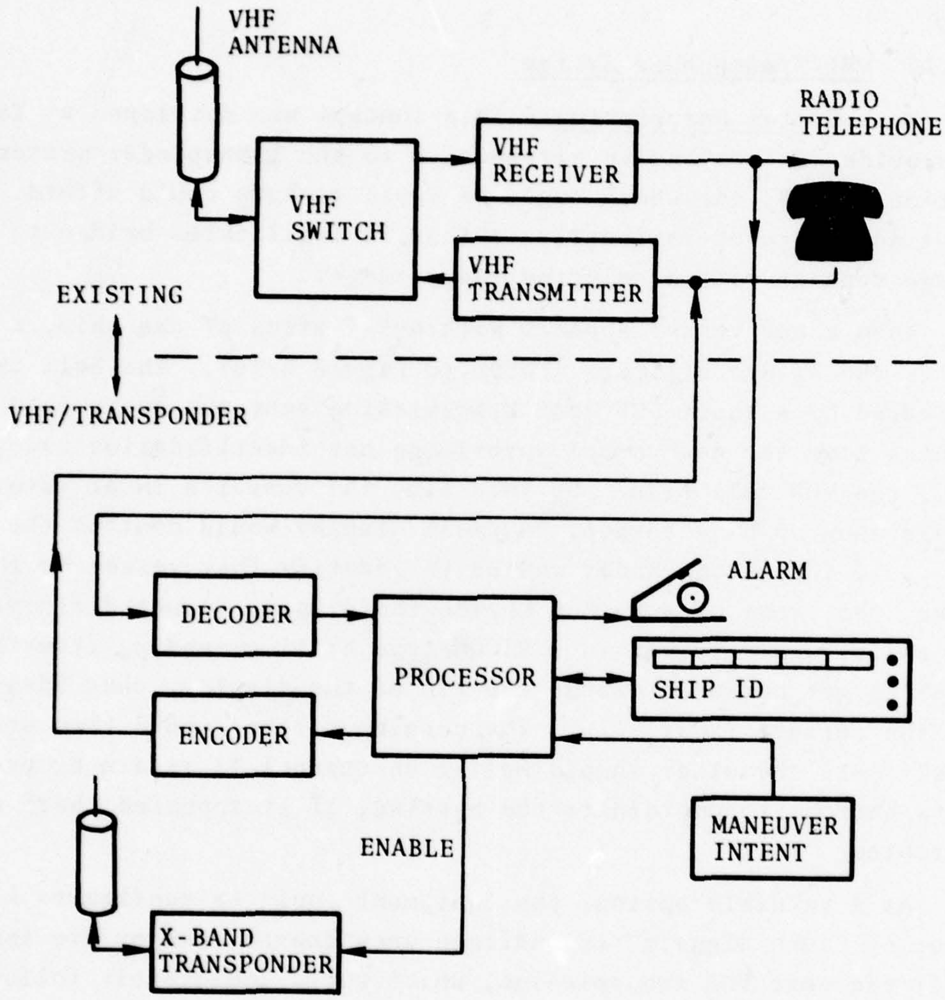

FIGURE 5-10. VHF/TRANSPONDER SYSTEM

the most slowly rotating radar antenna would point at the transponder ship once during a rotation. (This feature keeps down interference.)

There are several possible embodiments of the display:

1. A screen could simultaneously display the ID's of all the vessels heard from in the last 20 minutes (plus maneuver intent, length of time elapsed since first acquired, and time elapsed since last transmission).

2. A simple display could flash one ID at a time with a provision for circulating through the ID's in memory.

3. The simple display above plus a printer could provide a hard copy of the vessel codes.

The system as conceived here does not provide the course and speed of the other vessel, although this could be provided if vesselmasters found it useful - it would appear as a number display (e.g., "WEX5043 MC 15 @ 230" would mean that the ship with VHF call sign WEX5043 plans to Maintain Course at 15 knots on a heading of 230°).

The transponder is simpler than that of the interrogator/transponder system to be described in Section 5.2.18, since there is no data transmitted at X-band, only a fixed, hardwired format. The transponder transmission is swept in frequency so that regardless of the frequency drift of the other ship's radar, a reply is received, looking like a series of bars on the radar face directly beyond the radar blip of the transponder ship. This service is provided to any ship with a radar, without the need for any additional equipment.

The system incorporates the operational features of an alert of a new vessel at 5 miles (Section I.2.24), ability to obtain immediate contact with a selected vessel (Section I.2.28), and ability to obtain maneuvering intent. Once such a system had been successfully tested and used, the admonition to use the radiotelephone could be strengthened. Future training would incorporate this means of establishing contact with other ships.

The system has several advantages. One is that tugs and small tankers could afford the full capability (estimated at $4,000). One of the drawbacks of collision avoidance systems cited in the ORI report (ORI, 1975) was that most of the time the fault in a large/medium ship collision was due to the lack of threat assessment by the smaller, unequipped vessel. The VHF system would make the same information available to the smaller vessel by immediate radiotelephone contact.

The limitations of the system are primarily in the areas of capacity and frequency allocation. The VHF transmissions of ID and maneuver intent are expected to be very short: about 60 bits of data are required, which would take 0.2 seconds at 300 BAUD (low data rate) or 0.05 seconds at 1200 BAUD (high data rate). The capacity of the VHF channel is virtually unlimited (theoretically about 1500 vessels at the low data rate). At X-band, if transponders were enabled about every five minutes for three seconds, interference could become a problem with more than 100 ships nearby, because then the probability of having two transponder replies on the radar screen would be high, and confusion of ID would occur. However, this is still a comfortably large number. The practical capacity is limited, rather, by the number of VHF codes that can be comfortably handled at once by the watchstander; 10 is a reasonable estimate, but this would need to be established by testing.

The other limitation is the problem that exists with any radio communication requirement: the fact that bridge officers of different nationalities with different native languages many times have to speak slowly and carefully choose their words in order to be clearly understood. This problem is magnified when two ships are approaching a hazardous passing situation. Furthermore the respective officers are under pressure and may not wish to reveal this to the world by use of the radio. Perhaps a set of 15-20 standardized statements could be issued with each unit, which would cover most situations and overcome this limitation.

There are several options in the method of sending the coded ID. The coded signals could be superimposed on the VHF channel in use, usually channel 13. If tones in the audible range were used, the coded transmissions would be heard as a short "bleep." If this proved irritating, subaudible (i.e. frequencies below the audible range) could be used, but at a data rate of about 60 BAUD, so that each transmission would be about one second long.

b. Training/Workload Implications - The system is somewhat more complicated to use than a VHF radiotelephone, but is quite simple compared to the interrogator/transponder system, which requires setting range and angle sector limits around a specific target. Here the watchstander presses a button to get a radar tag on a given code that is present on the display.

The workload is minimal: the instrument is only used when needed. The desired information would be typically obtained within half a minute. Signalling intentions (Maintain Course, Port Turn, Starboard Turn, Reverse Engines, Slow Speed, Increase Speed) would require some effort and getting used to, but is simple to do. (If no intentions were signalled, there would be a blank in the other ship's display - this avoids accidentally signalling the wrong intentions.)

c. Estimate of Availability - The availability of the transponder replies on the radar would be limited primarily by the availability of the radar itself. The VHF service, which provides alerts of new vessels, ID codes, and maneuvering intents, would still be available in the event of a radar failure. The overall availability of the VHF service is expected to be comparable to a good VHF set, or about 95%.

The cost is low enough that all vessels and tugs pulling barges of 1600 GT or more could reasonably be required to have this equipment.

Based on the above considerations, the overall availability is estimated to be 90%. This is higher than radar, which is justified because of the important communication services performed by the VHF transmission, even when the radar is down.

d. Present State of Development - Conceptual only. However, transponder requirements are similar to the requirements of RACONs, which are presently available commercially. Digital calling units like SELCAL (U.S. Maritime Administration, 1973) have been demonstrated. Thus the technology required for such a system is available now, and poses little risk. The system parameters should be optimized, however, by field testing of an engineering model.

e. Estimate of Cost

Vessel Owner - Purchase Cost of a VHF/Transponder system is estimated to be between $4,000 - $7,000. The price would be increased by about $600 in radar modifications if IMCO would not allow transponders to use the normal radar band, and limited the frequency to a fixed band such as 9480-9500 MHz. If a dedicated separate channel were required in the VHF band, another $200 - $600 would probably be required. For costing purposes, $5,500 is assumed.

Installation Costs - Installation costs are expected to be low to moderate - bridge installation is primarily involved, but a microwave omni antenna must be installed.

Government Costs - Development Costs, estimated at $1,000,000.

f. Coast Guard Actions Required

1. Establish frequencies and modulation subfrequencies to be used by the equipment. Obtain FCC and IMCO approval and work toward an international standard.
2. Establish minimum equipment standards.
3. Outfit Coast Guard aircraft and cutters with this equipment to aid in Search and Rescue, Enforcement of Laws and Treaties, and Marine Environmental Protection missions.

g. Estimate of Effectiveness - The system incorporates the operational features of a 5-mile alert (Section I.2.24), ability to obtain immediate radio contact (Section I.2.28), and maneuver intent (Section I.2.29). The potential effectiveness is estimated at 56% for collisions, based on the casualties in the data base, or 49% above the baseline system. If maneuvering intent were not included (i.e., no "turn signals" on board), the potential effectiveness would be reduced to about 50%. The operational feature of "incentive to communicate" (Section I.2.30) was postulated to find how often bridge-to-bridge communication would have helped. If this were included, the potential effectiveness would be 69%. Thus, the VHF/transponder system would provide 56% of a possible 69%, considering only collisions. It also means that as the radiotelephone is used more frequently to coordinate passings, the effectiveness of the system would approach the higher number. The overall effectiveness is estimated at 34%, or 11% above the baseline system.

5.2.18 Interrogator/Transponder System

a. System Description - An interrogator/transponder system provides a clutter-free radar-type display of any vessel in the area which are transponder-equipped, complete with identifying codes which can be displayed and used to help establish verbal radiotelephone contact (refer to Figure 5-11). It also allows the vessel watchstander to select a target (by defining a sector segment) and interrogate the vessel to ask her intended maneuvers. It thus incorporates the operational features of dependable all-weather returns (Section I.2.21), ability to obtain immediate contact with a selected vessel (Section I.2.28) and maneuvering intent (Section I.2.29), and can be easily modified to provide alarms if ships appear within a set range (Sections I.2.24 and I.2.25).

The U.S. Maritime Administration has developed such a system, called MRIT (Marine Radar Interrogator-Transponder). It is described in several publications, two of which are referenced here (Mathews, et al, 1976, and Fee, et al, 1976).

The system works similarly to a radar. When the operator wishes to obtain information on a vessel, he selects the all-call mode. The interrogator transmitter then sends a coded pulse stream, slightly in advance of the main radar pulse, into the radar antenna. When the radar antenna main beam is pointing at a transponder-equipped vessel, the transponder receives the pulse stream and replies with its own pulsed data stream, including the

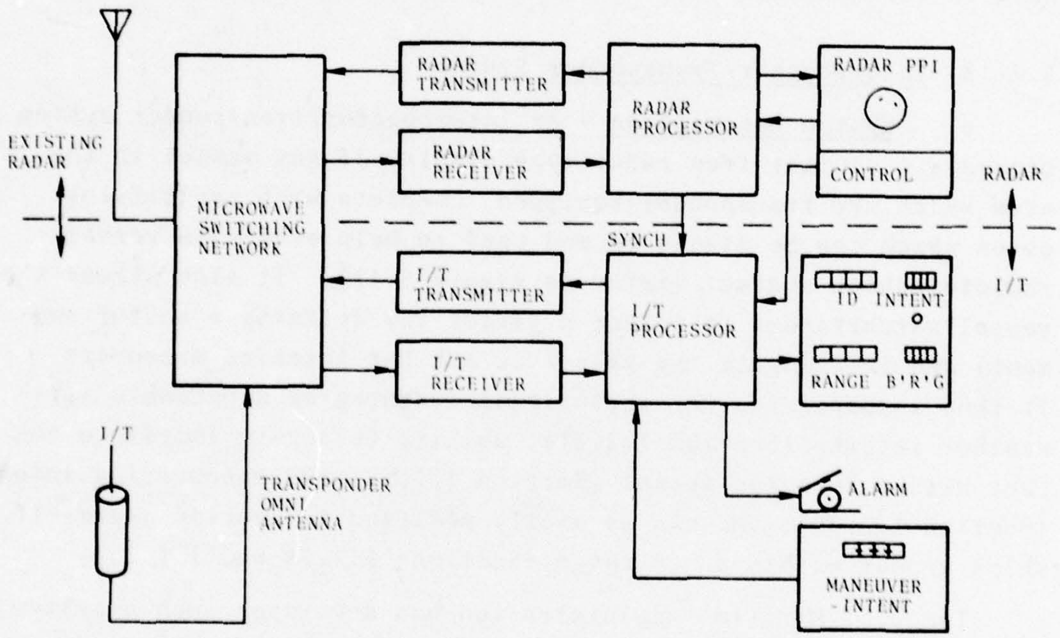

FIGURE 5-11. INTERROGATOR/TRANSPONDER SYSTEM

ship's ID. Other ship data such as course, speed, size of vessel, draft, etc. can also be sent if the interrogator transmits the proper code. Maneuver intent can be learned by interrogating with a third code which alerts the interrogated vessel that a reply is desired. The interrogated vesselmaster replies by pushing an appropriate button which signals his intentions.

The ID code received can be used by the watchstander to attract the attention of his counterpart on a selected vessel, by calling on VHF for a reply from the vessel with that code.

The transponder replies paint a bright echo on the radarscope, superimposed on the normal radar echo.

The MRIT embodiment of this type of system is manual in several respects:

1. Target acquisition is manual.
2. Target track is manual, and ceases when the watchstander stops tracking.
3. Target selection involves setting switches.

These limitations are not inherent in the technique, but in the particular configuration employed. In this case care was taken to severely limit the number of interrogations and replies in order to keep interference between units at a low level. These functions could be automated with no worsening of system interference. In so doing, it would be relatively simple to add alerts indicating that a vessel has come within a preselected distance of own ship. This requires additional digital circuitry to store ship ID's and other data and software to control interrogations.

In its automated configuration, occasional (e.g., once every five minutes) interrogations would detect new vessels. Once acquired they would be tracked by more frequent, discrete address interrogations, (e.g. once per minute). If a vessel came within about five miles, an alert would sound. If a vessel came within about one mile, a warning would sound. At any time the operator could learn the intentions of a specific transponder-equipped vessel by selecting the particular target sector segment on the radar display and pressing an appropriate button.

b. Training/Workload Implications - This instrument would not be as complicated to use as a radar, but does require some interaction and familiarity with the controls. It would be somewhat easier to use than a collision avoidance instrument.

Without the automatic features that are discussed in the system description above, it becomes more complicated to use, and requires considerably more action on the part of the watchstander. He must manually interrogate with sector transmissions in the all-call mode, keep track of codes, and set switches when he wants more data. With the automatic features, new targets are acquired and tracked automatically. There is no need to set switches, nor is there the same opportunity to make mistakes.

c. Estimate of Availability - The equipment availability is roughly that of the radar, especially of the magnetron transmitter, which appears to be the single most failure-prone component. The equipment not common to the radar is largely low power digital and IF circuitry, which has good lifetime characteristics if good commercial manufacturing techniques are used. Radar availability is estimated at 96% for large tankers*, and 80% for other vessels.

The biggest factor in the availability of this system is the fact that transponders (at least) must be on board all vessels if the system is to work effectively. The cost of a complete interrogator-transponder system presently would be $30,000-$50,000, which is prohibitive on most vessels of less than 10,000 gross tons. Certainly tugs and small tankers could not afford them. The alternative is to require all vessels of 10,000 gross tons or more to have complete systems, and require transponders on board all other commercial vessels. Transponders at X-band frequencies will cost $4,000-$8,000, so that tugs and vessels of 1000 gross tons or more probably can afford it, but would be difficult to justify, because it provides protection only from larger, fully-equipped vessels.

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*Large tankers are assumed to have dual radars; the probability of at least one being available is thus 100% - 20% x 20%, or 96%.

The availability assuming a working radar is shown in Table I-8c to be 22%. Coupled with the radar availability, the estimated availability is 18%.

d. Present State of Development - The MRIT is at a prototype stage. If the demand were there, units could be produced within a year. The addition of the automatic features would require a development cycle of design, fabrication, test, and prototype fabrication.

e. Estimate of Cost

Vessel Owners - Purchase cost of an automated unit is estimated to be $30,000-$50,000, but with increased demand, the cost could probably be closer to $15,000-$25,000. An average figure of $20,000 is assumed for costing purposes; the transponder is assumed to cost $5,000. Installation costs would be moderate, because the omni antenna would require mast installation, and radar would be modified.

Government - None.

f. Coast Guard Action Required

1. Require all ships of 10,000 gross tons or more to be equipped with a full interrogator-transponder system.

2. Require all ships of 1,000 gross tons or more, and all tugs pulling or pushing barges of 1,000 gross tons or more to be equipped with transponders.

3. Establish minimum equipment specifications for complete interrogator-transponder systems, and for transponder-only equipment.

g. Estimate of Effectiveness - If all ships were equipped with the full capability, the potential effectiveness would be 64% for collisions and 35% overall, or 12% above the baseline.

5.3 LESS PROMISING SYSTEMS

The following systems were not considered for detailed evaluation. In general, the systems were either not found to be effective, or there were serious feasibility and implementation problems. These systems are:

a. Revised Rules of the Road
b. Charting of Restricted Zones
c. Penalty System for Operating with Malfunctioning Gear
d. Mandatory Course Recorder
e. Navigation System with Accuracy Superior to LORAN-C
f. MF Radiobeacon System
g. Satellite Navigation System
h. Autopilot System
i. Improved Depth Sounder
j. Forward-Looking Sounder
k. True-Motion Radar Display
l. LORAN-C Proximity Indicator
m. Manual Monitoring System

5.3.1 Revised Rules of the Road

On the basis of the data base casualties no revisions in the Rules of the Road were identified as needed for reducing casualties. There were only two casualties in the data base that might have benefited from some revisions, and one of these probably would not have occurred under the 1972 COLREGS (see Section I.2.2). The other involved a grounding by a ship which left the traffic lane to avoid a crossing vessel. While this situation warrants some attention, a system of revised Rules of the Road does not appear needed.

5.3.2 Charting of Restricted Zones

One system that appeared to have merit in reducing groundings was a set of demarcated zones of no entry to vessels, or at least to vessels of a specified draft. However, very few situations were encountered where such prohibited zones would have significantly discouraged a vessel master from proceeding into danger. Further discussion is provided in Section I.2.3. Therefore, charting of restricted zones does not appear to be a promising system.

5.3.3 Penalty System for Operating with Malfunctioning Gear

A system for imposing fines and other penalties to owners of vessels found to have inoperative equipment could be developed. It would involve increased Coast Guard inspections, a series of regulations and penalties, and conditions for approaching (or departing) port with known equipment defects. It would be complicated to administer, primarily because it is difficult to police, and requires voluntary compliance without a tangible benefit to the vessel masters: e.g., a vessel master, required by regulation to delay arrival in port until the following morning because of a radar outage, would have a difficult time justifying such a delay to his employer purely on the basis that by so doing he had reduced the risk of a casualty from "extremely unlikely" to "even more extremely unlikely". This dilemma is resolved, at least partially, by shore-based systems. This is discussed further in Section 7.1.

Due to the problems described above, and the relative ineffectiveness of the operational features in reducing casualties (see Section I.2.8), this system does not appear to be promising.

5.3.4 Mandatory Course Recorder

The operational feature of a mandatory course recorder was not judged very effective in preventing casualties. For post-casualty analysis, on the other hand, it can be useful. Several vessels in the data base had some form of course recorder on board. As a prevention device, it does not appear promising.

5.3.5 Navigation System Having Accuracy Superior to LORAN-C

The guidelines of the study excluded casualties occurring in narrow channels less than 1000 feet wide (see Section 3.3). Narrow channels and inland waterways are the areas where high precision navigation systems are most valuable. For example, the St. Mary's River between Lake Superior and Lake Huron is equipped with a precision mini-chain of LORAN-C transmitters undergoing RDT&E. Acoustic systems employing coded sound transmission (e.g., Cobb, 1972, and Damon, 1972) have been proposed for similar usage.

In the offshore area, however, there does not appear to be a strong need for accuracies better than the quarter-mile accuracy of the LORAN-C system. The probability of prevention of the associated operational feature of improved position accuracy was only 2%. Precision navigation systems may prove to be justified for inland and narrow channel navigation, but it is concluded that for general offshore navigation such systems are not required.

5.3.6 MF Radiobeacon System

The frequency band 285-325 kHz is allocated to the Maritime Radiobeacon Service. This service provides CW signals transmitted from charted points along the shore and on towers and lightships which can be received by a shipboard direction-finding system (DF). Operation of the DF equipment yields a bearing of the station referenced to the ship's heading. By obtaining two or more bearings to charted stations, and knowing the vessel heading, ship position can be calculated. The accuracy of each bearing measurement is 2^{o}-5^{o}, so that positional accuracy at 10 miles from shore is about 1/2-1 mile. This is quite inferior to the baseline system accuracy of 1/4 mile. It can be used as a backup, but the service is primarily intended for smaller vessels which may not have LORAN-C.

Since it offers no advantages in accuracy, coverage, or convenience of usage over the baseline system, it will not be considered further.

5.3.7 Satellite Navigation System

Satellite navigation systems offer the advantages over terrestrial systems of improved accuracy and generally global coverage. Several such systems are described in Appendix H.

In terms of the study, however, the advantages of satellite systems do not appear to offer improvements over and above the baseline system that would have prevented any of the accidents in the data base. The region of concern in the study is from the coast to 200 NM, which will be adequately covered by the LORAN-C network. The promised higher accuracy of a satellite system is not an important factor except near shore, as evidenced by the relatively few cases where LORAN-C accuracy (1/4 mile) was not adequate. Even in those four cases, the probability that perfect accuracy would have prevented the accident was estimated at 37% (see Section I.2.10).

One exception to the conclusions stated above is the coverage that would be obtained in Puerto Rico and the Virgin Islands, where 16 groundings occurred. Assuming performance equivalent to the baseline system, if all the tankers involved had on board satellite navigation receivers (or if LORAN-C coverage were available), nine of these cases would have been affected, and the casualties would have been reduced by 22%. If improved pilot transfer techniques were employed in Guayanilla and Tallaboa Bays in Puerto Rico six of these would have been avoided leaving only three cases which would be affected by having working electronic navigation gear on board.

The attractiveness of global coverage has convinced a few shipowners to install satellite receivers (TRANSIT) on board large tankers and other large vessels. Used to correct long-term errors in the Omega system the hybrid provides adequate navigation service. This possibility is incorporated into the baseline system.

It may well be that by 1990 a satellite system may be operational which provides equivalent world-wide service at a user cost which is competitive with present LORAN-C receivers. If this occurs, and if the effective operating costs to the government are lower than maintaining the ground stations for LORAN-C, it would evolve as a reasonable alternative. However, for the purpose of this study, the question is a narrower one: namely, whether satellite navigation systems offer a sufficient advantage in effectiveness over the baseline system to warrant replacing it. The current answer to this is in the negative.

5.3.8 Autopilot System

The autopilot system is an extension of the previous integrated navigation system, wherein a signal proportional to the deviation from track is fed into a rudder control system. Kalman filtering techniques can be employed which minimize rudder wear and improve fuel economy, accounting for the ship's weight, trim, draft, and handling characteristics. Changes in course can be effected much more gradually than a helmsman could accomplish, saving fuel and maintaining speed.

However, while this system can be effective for economy purposes, there were no casualties in the data base that could be traced to helmsman errors. Therefore, there is no reason to believe that such an automated system would reduce collisions, rammings, or groundings, nor is there any reason to believe that a fully automatic system, which would pilot the ship along a prescribed route (technically feasible), would reduce accidents.

5.3.9 Improved Depth Sounder

Due to the subjective nature of the evaluation of the operational feature of improved depth detection (Section I.2.16) and the resulting low scores, this will not be evaluated as a separate system. Improvements in depth sounders are needed, however, and are incorporated into the acoustic sounder systems of Sections 5.2.13 and 5.2.14.

5.3.10 Forward-Looking Sounder

Sonars with this capability are presently available, but are used primarily for special applications such as submarine detection, charting of wrecks, location of fish, and on research vessels.

The system operates similarly to a depth sounder, but as conceived here, may have some scanning capability. The transducer is mounted forward on the hull, allowing a narrow beam to be transmitted straight ahead. Echoes will be received from any object or from sudden rises in the ocean floor that appear in the beam. The received echoes are timed to provide range, while the direction of the beam provides the angle.

A display would provide range and an estimate of depth; the equipment could be equipped with an alert which would sound if an object were detected within a preselected distance. By having a scan capability, even a manual one, the watchstander could search left and right to determine the extent of the object and help identify the echo as a reef. This procedure could also identify obstacle-free areas that could be safely navigated.

The forward-looking sounder feature was thought to provide useful data in 45 of 50 groundings. Thus a device such as this could be very beneficial for preventing groundings, if it could operate successfully.

However, there are serious technical difficulties that must be addressed before this technique could be seriously considered. The chief problem is that of resolution as a function of range. Present equipment uses a beam typically 6°-12° wide. At a range of one nautical mile, the resolution is about 1,000 feet for a 9° beam. If this device were turned on in water depths less than about 500 feet, the beam would intersect the ocean floor (and/or the water surface, depending on the tilt of the beam). The result would be a cluster of echoes beginning at about a half-mile range which would obscure echoes from any object at one mile. In most of the groundings studied, the depths within a mile of grounding were generally less than 500 feet, and frequently less than

100 feet. In principle, the problem can be overcome using a narrow beam: a 0.6° beam, for example, would theoretically enable the detection of a rise in the ocean floor a mile ahead where the depth changed from 120 feet to 60 feet. This is the kind of performance that was assumed in the evaluation. If the range were reduced to a half-mile (which would be traversed in two minutes at 15 knots, or in six minutes at five knots), it would still require approximately a one-degree beamwidth. To achieve a desired beamwidth, both the operating frequency and the physical size of the transducer must be considered. Typical operating frequencies for sonars are 30 kHz to 160 kHz; the lower frequencies propagate through water with less attenuation than higher frequencies, but require larger apertures. At 30 kHz, a transducer about 10 feet in diameter would be required, clearly an unreasonable requirement. Even at 160 kHz, a two-foot aperture is required, which is still unreasonably large. Whether higher frequencies could be employed has not been assessed.

In conclusion, the serious technical uncertainties rule out this system from consideration as a recommended system.

5.3.11 True-Motion Radar Display

It is pointed out in Section I.2.22 that the ability to distinguish moving targets from stationary or anchored targets was identified as a direct factor in only one collision and in no rammings.

It is concluded that requiring true-motion radars would not, by itself, significantly reduce collisions and rammings. At the same time, there are, of course, no available data on the number of accidents that were prevented for ships already having this radar feature. Since only a small percentage of vessels have them, the conclusion is justified. True motion displays are still desirable, however. They provide an important measure of confidence to the watchstander, reduce worry and effort expended in distinguishing buoys from small boats and oil platforms from ships, and thus have an important indirect effect on accidents.

5.3.12 LORAN-C Proximity Indicator

This system is currently in the conceptual phase. It would use the positions of vessels as measured by LORAN-C to estimate the range and bearing to another ship. Each ship would transmit her ID and LORAN-C coordinates (and possibly course and speed). By receiving the other ship's transmissions, a shipboard processor could compare the LORAN-C coordinates with those of own ship and derive the others' ranges and bearings. The range and bearing could either be displayed digitally or superimposed on a radar-type synthetic display. Such a system would have the advantages of obtaining an identifying code from other ships and not being affected by clutter. It could be configured to sound an alert if another vessel appeared in a particular sector within a given range.

However, such a system would provide no services beyond those provided by transponder at a comparable cost. A reduced version, providing perimeter detection, would be more expensive than the radar perimeter detection device of Section 5.2.16, and perform the same function. It would also entail obtaining a dedicated VHF or HF channel for data transmission purposes. It also suffers from an accuracy problem; while the relative potential accuracy is good (100-300 feet estimated) for two ships having LORAN-C, it would not function well with mixed systems. That is, if a satellite navigation system was on one ship, and LORAN-C on the other, the relative accuracy would be approximately 1,500 feet. This is due to the fact that the better accuracy of 100-300 feet is only achieved by the cancellation of mutual long-term drift terms common to one system. Mixed systems would yield only the geodetic accuracies.

Thus it does not appear that this system is promising at present. However, if an automatic monitoring system of the type employed in Section 5.2.3 is implemented, the frequency allocation problem would be solved, and the scheme would become more attractive. If all ships were required to transmit their positions and courses, the additional cost of equipment would be due only to decoding and processing; the receiver and antenna would be already available.

If an automatic monitoring system is implemented, this system should be reconsidered. With a correction term broadcast from shore every hour or so, the equipment could accommodate mixed navigation systems. However, as a stand-alone system, it is not attractive enough to be considered further.

5.3.13 Manual Monitoring System

What at first appears to be a logical step in complexity and performance is a manual monitoring system, patterned after the present Vessel Traffic Services (VTS) (see Appendix D). Since the Vessel Passport system is primarily aimed at preventing groundings, a VTS-like system would seem to offer the possibility of preventing some collisions and rammings, as well as providing warnings to tankers that navigate too close to shoals or reefs. By obtaining frequent updates on the positions of all vessels in the area, close passings could be detected, and the shore could help enforce vessel-to-vessel communication, which is shown in Section I.2.30 to be quite effective in preventing collisions. Rammings could likewise be prevented by shore detection of a conflict, since the shore station would keep an active, up-to-date list of oil platform locations.

It turns out upon closer examination that the system technique is unwieldy, for the following reasons:

a. System capacity is severely limited: in order to be useful, updates should be obtained every 15 minutes or so, and every time a course is altered. For verbal reporting systems, the channel capacity for a system operating out to 20 miles limits the number of vessels to less than 10 per communication channel, and to less than 7 if the same channel is used to establish initial voyage plan data. This allows little time for cross-checking of reported positions. The shore watchstander's time would be spent primarily keying in new positions and communicating. Even at this low capacity, there would not be enough system slack to allow for misread meters, communication errors, keying errors, reporting errors, etc. (See Appendix G, Section G.2.4.)

b. Requiring updates every 15 minutes would be a burden on the vessel watchstanders, and might cause problems by taking attention away from other tasks, especially when several vessels might be competing for the shore operator's attention.

c. The language problem is particularly severe in view of the large number of foreign tankers.

d. Much of the same function can be accomplished in a simpler way. The Vessel Passport system can be modified to provide a limited collision avoidance service by a general announcement of the arrival of a tanker, and by obtaining the planned courses of vessels who will be operating in the area.

Thus it is concluded that manual monitoring, using verbal reports, is not a viable option. The alternative discussed in item d above is proposed as a series of options to be added to the vessel passport system, and is discussed in Section 5.2.2. On the other hand, automatic monitoring does not involve specific actions on the part of the deck officers, and is not capacity-limited. While costly, it offers some real improvements in service. It is discussed in Section 5.2.3.

5.4 SUMMARY OF SYSTEM COSTS AND EFFECTIVENESS

5.4.1 System Costs

Costs have been cited in Section 5.2 in terms of vessel owner and government costs. In order to compare the total costs of systems, it is assumed that the public will eventually pay the costs, either as consumers or as taxpayers. To provide a reasonable framework, a 10-year life cycle is assumed - i.e., vessel equipment is assumed to last about 10 years before requiring replacement, and government installation costs are assumed to be amortized over a 10 year period.

Vessel equipment purchase costs are simply found by the product of the average equipment price and the number of ships to be outfitted. The number of ships to be outfitted varies with the equipment: all vessels over 1,600 gross tons will have LORAN-C (the number of satellite navigators is negligible), while only those over 10,000 gross tons could reasonably be expected to purchase collision avoidance equipment. The ship populations assumed are shown in Table 5-3. It is assumed that equipment exceeding $10,000 in cost would only be required on the larger vessels.

Vessel maintenance costs are assumed to be 10% of the purchase cost each year, so that over a 10 year period, the maintenance costs equal the purchase costs. Table 5-4 shows the vessel costs for each system.

Government costs are the initial purchase and installation costs, plus 10 years of annual operating and maintenance costs. They are tallied in Table 5-5.

5.4.2 System Effectiveness

Simply stated, the basic measure of a system's effectiveness is the probability that it would prevent an accident. It is desirable to have a single measure of each system's effectiveness, but in the process many important considerations are lost. For example, collision avoidance aids would not often be helpful in avoiding groundings, and depth sounders would not often prevent collisions; thus, one overall effectiveness number does not register this distinction.

TABLE 5-3. VESSEL POPULATIONS USED FOR COST ESTIMATES

Vessel Type	Number
All Vessels > 1,600 GT	6,100[1]
All Vessels > 10,000 GT	2,500[2]
Tank Vessels > 1,600 GT	2,670[3]
Tank Vessels > 10,000 GT	1,600[4]

[1]Federal Register, 1977c.

[2]Approximately 40% of the vessels calling at U.S. ports are assumed to be larger than 10,000 gross tons. This is an estimate based on worldwide fleet projections (U.S. Maritime Administration, 1975).

[3]Approximately 60% of the tank vessels calling at U.S. ports are assumed to be larger than 10,000 gross tons. This is an estimate based on a satellite navigation study (INMARSAT, 1978).

[4]Federal Register, 1977d.

TABLE 5-4. VESSEL OWNER COSTS FOR EACH SYSTEM

System	Purchase Cost per Ship ($000)	Number of Ships	Total Vessel Purchase Costs ($000)
1. Baseline	0	0	0
1A. Extended Baseline[1]	0	0	0
2. Passport System	0	2,670[2]	0
3. Auto-Monitoring	4.0	6,100[3]	24,400
4. DF-Surveillance	0	6,100[3]	0
5. Radar Surveillance	0	6,100[3]	0
6. Satellite Surveillance	{77.5 / 28.6}	{2,500 / 3,600}[4]	296,710
7. Training	9.0	6,100	54,900
8. Traffic Separation	0	0	0
9. Aids-to-Navigation	0	0	0
10. Pilotage	0	0	0
11. Equipment Standards	0	0	0
12. Navigation Alert	3.0	6,100[3]	18,300
13. Depth Alert	2.0	2,670[2]	5,340
14. Scanning Sounder	20.0	1,600[5]	32,000
15. Collision Avoidance Aid	100.0	2,500[6]	250,000
16. Radar Perimeter Det.	2.5	3,600[6]	9,000
17. VHF/Transponder	5.5	6,100[3]	33,550
18. Interrogator/Transponder	{20.0 / 5.0}	{2,500 / 3,600}[4]	68,000

[1]Extended Baseline System consists of extending LORAN-C coverage into Puerto Rico and the Virgin Islands.

[2]Installed on tank vessels only.

[3]Installed on all vessels.

[4]More expensive equipment installed on all large vessels; less expensive equipment installed on smaller vessels.

[5]Installed on large tankers only.

[6]Collision Avoidance Aid installed on all large vessels; Radar Perimeter Detection device installed on smaller vessels.

TABLE 5-5. GOVERNMENT COSTS FOR EACH SYSTEM

System	Initial Shore Costs ($000)	Shore Operating Cost (Average Annual) ($000)	Total Shore Costs (10 Years) ($000)
1. Baseline	0	0	0
1A. Extended Baseline*	15,000	1,000	25,000
2. Passport System	7,080	1,033	17,410
3. Auto-Monitoring	28,330	5,938	87,710
4. DF-Surveillance	7,930	1,168	19,610
5. Radar Sruveillance	26,080	4,033	66,410
6. Satellite Surveillance	89,750	6,731	157,062
7. Training	0	0	0
8. Traffic Separation	0	0	0
9. Aids-to-Navigation	600	0	600
10. Pilotage	0	0	0
11. Equipment Standards	0	0	0
12. Navigation Alert	0	0	0
13. Depth Alert	1,000	0	1,000
14. Scanning Sounder	1,500	0	1,500
15. Collision Avoidance Aid	0	0	0
16. Radar Perimeter Det.	0	0	0
17. VHF/Transponder	1,000	0	1,000
18. Interrogator/ Transponder	0	0	0

*Extended Baseline System consists of extending LORAN-C coverage into Puerto Rico and the Virgin Islands.

With this caution, the definition of a single measure of effectiveness should have the following properties:

a. Each system's effectiveness should be based on the combined effectiveness of the system and the baseline system.

b. Since the study is geared toward improvements over and above the baseline system, the baseline system should register zero effectiveness.

c. The effectiveness measure should incorporate the availability of the system.

d. Obviously, a system that prevented all accidents should have an effectiveness measure of 100%.

An effectiveness measure meeting these requirements, called the Net Effectiveness, is defined by the following formula:

$$NE_S = \frac{A_S \times (PE_S - PE_{BL})}{1 - PE_{BL}}$$

where

NE_S is the Net Effectiveness of the system.

A_S is the Availability of the system.

PE_S is the Potential Effectiveness of the system.

PE_{BL} is the Potential Effectiveness of the Baseline System.

Availability is estimated in paragraph (c) of each system description in Section 5.2. The Potential Effectiveness is the measure of effectiveness used in Table I-6 of Appendix I for the systems combined with the baseline system.

The potential effectiveness, availability, and net effectiveness of each of the systems is shown in Table 5-6.

TABLE 5-6. SUMMARY OF SYSTEM EFFECTIVENESS

	Potential Effectiveness				Availability	Net Effectiveness
	Groundings	Collisions	Rammings	Overall		
1. Baseline	25%	7%	45%	23%	95%	0%
1A. Extended Baseline	33%	7%	45%	29%	95%	6%
2. Passport System	65%	19%	52%	54%	100%	40%
3. Auto-Monitoring	75%	81%	65%	75%	100%	67%
4. DF-Surveillance	65%	19%	52%	54%	100%	40%
5. Radar Surveillance	79%	81%	65%	79%	79%	57%
6. Satellite Surveillance	79%	81%	65%	79%	90%	65%
7. Training	36%	25%	58%	35%	41%	6%
8. Traffic Separation	26%	22%	45%	27%	95%	5%
9. Aids-to-Navigation	40%	7%	52%	34%	95%	14%
10. Pilotage	44%	15%	45%	38%	90%	18%
11. Equipment Standards	29%	7%	45%	25%	100%	3%
12. Navigation Alert	36%	7%	53%	31%	75%	8%
13. Depth Alert	39%	7%	45%	32%	95%	11%
14. Scanning Sounder	48%	7%	45%	39%	26%	5%
15. Collision Avoidance Aid	25%	63%	65%	37%	25%	5%
16. Radar Perimeter Det.	25%	41%	65%	32%	52%	6%
17. VHF/Transponder	25%	56%	45%	34%	90%	13%
18. Interrogator/Transponder	25%	64%	45%	35%	18%	3%

6. BENEFITS ANALYSIS

6.1 INTRODUCTION

Ideally, a rigorous cost/benefits analysis projects the costs and environmental impact of oil spills in offshore waters of the United States to assess the value of future corrective measures. Due to the very small number of spills attributable to groundings, collisions, and rammings in U.S. offshore waters (eight in six years), no quantitative trend analysis can be performed to make such a projection. Also, due to the dependency of spill impact on a complex combination of factors such as size and rate of spill, type of oil/oil product, location with respect to shoreline and fishing grounds, and direction of wind and currents at the time of occurrence, no adequate analytical modeling technique is available for assessing the benefits of spill prevention.

For these reasons, the recommended system alternatives described in Section 7 are assessed on a cost-effectiveness basis, with effectiveness measured in terms of the number of groundings, collisions and rammings prevented based on the casualty projections of Section 4.7.

The following sections characterize the spills that have occurred in offshore waters, describe the trends in some of the variables that affect spill incidence, and provide some insight into spill cost considerations.

6.2 SPILL CHARACTERISTICS IN OFFSHORE WATERS OF THE U.S.

The seriousness of offshore spills depends on factors such as size and rate of the spill, type of oil/oil product, location with respect to shoreline and fishing grounds, direction of wind and currents, and the effectiveness/availability of oil spill cleanup equipment. Spill sizes are difficult to classify with respect to severity since any discharge that poses a substantial threat to the public health or welfare, or results in critical public concern is considered a major discharge. However, offshore spills greater than 100,000 gallons are considered of sufficient magnitude to warrant alerting of the National Response Team. "Heavy" oils such as crude and No. 6 are of much greater concern than the lighter oil products such as gasoline, jet fuel, naphtha, etc., which are highly volatile. Oil spill cleanup equipment currently available tends to be less effective in offshore waters, particularly with wave heights in excess of two feet.

Section 4.3.4 summarizes the number of casualties identified as being of interest to the study. Of the 78 incidents depicted in Table 4-6, only casualties involving loaded tank vessels and off-shore rigs are pertinent to characterization of oil spills.

The index of selected cases presented in Appendix C contains data pertaining to tank vessel cargo and the amount spilled as a result of the casualty. Table 6-1 summarizes the number of spill incidents due to groundings, collisions, and rammings which have occurred in U.S. offshore waters during the period FY 1972-1977. As discussed in Section 4.2.3, pollution incidents in U.S. waters are recorded in a Pollution Incident Reporting System (PIRS) maintained by the U.S. Coast Guard and based on reports from its district offices. The National Response Center (NRC), located at U.S.C.G. Headquarters, also maintains records of pollution incidents which are reported by official and unofficial observers. PIRS data for the period 1973-1977, are used to identify actual spills greater than 50,000 gallons which are pertinent to this study. It is highly probable that these files contain all spill incidents during this period that have posed a substantial threat to the environment, or were of great public concern. Five of the eight oil spills indicated in Table 6-1 are larger than 100,000 gallons. These spills occurred during the period 1973-1977. The other three spills, all smaller than 100,000 gallons, occurred in 1972.

Spills of heavy oil have a great potential for causing environment damage and posing a threat to the public welfare. Three

TABLE 6-1. SPILLS IN OFFSHORE WATERS OF THE U.S. (FY 1972 - FY 1977)

NUMBER OF INCIDENTS

NATURE OF CASUALTY	TANK VESSEL/ OFFSHORE RIG CASUALTIES	TANK VESSEL CARGO				SPILLS	
		Light Oil/Oil Products	Heavy Oil/Oil Products	Other	None	Light Oil/Oil Products	Heavy Oil/Oil Products
Grounding	47	16	20	3	8	3	4
Collision	10	4	2	3	1	0	0
Ramming	6	0	1	3*	2*	0	1**

* non-tank vessels

** spill from tanker - no spills from offshore rigs of the five heavy oil spills are greater than 100,000 gallons. The spill causing the greatest concern was the Argo Merchant, with over 7,500,000 gallons discharged into the waters between Nantucket Island/Cape Cod and the Georges Bank fishing grounds. The other two heavy oil spills were of much lesser concern; one of approximately 800,000 gallons (Globtik Sun) occurred 90 miles off the Louisiana coast, the other of approximately 370,000 gallons (Michael Lemos) occurred off Limetree Bay, St. Croix, VI.

6.2.1 Spills Due to Groundings

Referring to Table 6-1, it is seen that approximately one out of five groundings of tank vessels loaded with oil resulted in a spill. All of these spills have occurred when the tank vessel struck a hard or rocky sea bottom. Referring to Figure 6-1, two spills have occurred off the New England coast, two in Long Island Sound, two off the coast of Alaska, and one off St. Croix VI. None of the groundings off Delaware Bay, off Chesapeake Bay, in Guayanilla/Tallaboa Bays (Puerto Rico), or in the Gulf of Mexico have resulted in oil spills.

It is also seen from Table 6-1 that an average of approximately 1 spill per year due to groundings has occurred in U.S. offshore waters during the 6-year period from FY 1972-FY1977. Data presented in Devanney, 1978 indicates that an average of 10 spills per year due to groundings occurred in offshore waters worldwide during the 8-year period from 1969 through 1976.

The size of spills due to groundings in U.S. offshore waters during a 6-year period is shown in Table 6-2. Figure 6-2 gives the spill size distribution for massive spills greater than 1,000,000 gallons that occurred due to groundings, worldwide, over an 11-year period. Six of these spills, most total losses, have exceeded the 7,500,000 gallons discharged by the Argo Merchant. The largest worldwide spill to date is the recent Amoco Cadiz grounding, with 60,000,000 gallons discharged off the coast of France. The largest tankers currently entering U.S. waters have the potential to discharge a similar amount of oil. The average maximum potential discharge from tankers in U.S. waters is approximately 12,000,000

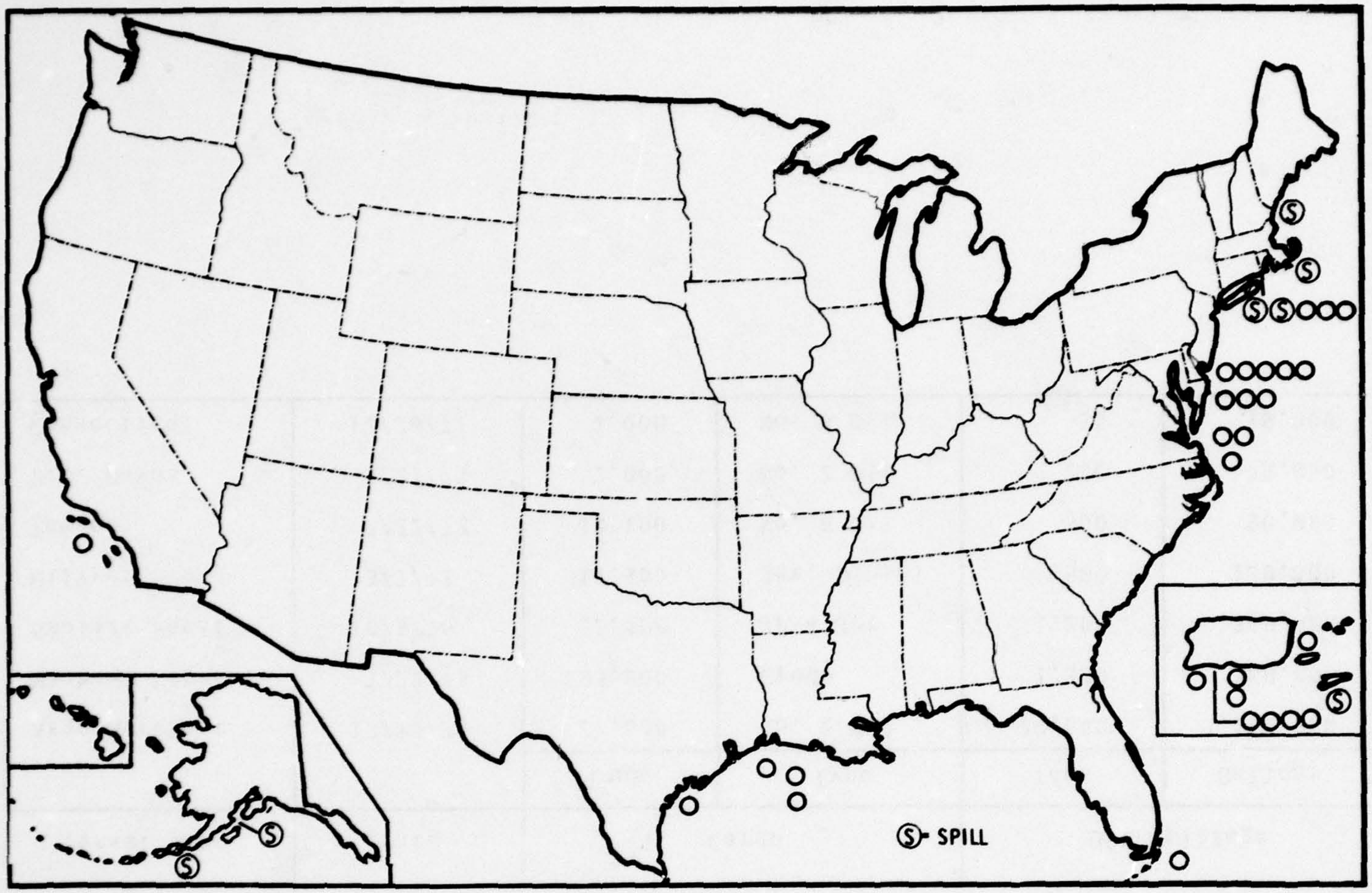

FIGURE 6-1. GROUNDINGS OF TANK VESSELS LOADED WITH OIL
(FY 1972 - FY 1977)

TABLE 6-2. SIZE OF SPILLS DUE TO GROUNDINGS IN U.S. OFFSHORE WATERS (FY 1972 - FY 1977)

Vessel Name	Date	Cargo		Oil Spillage	
		Tons	Type	Tons	Gallons
Argo Merchant	12/15/76	27,600	No. 6 Oil	27,600	7,600,000
Michael Lemos	1/22/75	193,900	Crude	1,200	360,000
Sealift Pacific	10/5/76	22,400	JP-4 Jet	1,200	360,000
Hillyer Brown	3/7/73	18,500	Jet, Diesel	600	180,000
Tamano	7/22/72	82,100	No. 6 Oil	300	90,000
F.L. Hayes	3/21/72	2,000	No. 2 Oil	250	75,000
Connecticut	12/26/72	4,000	No. 6 Oil	50	15,000

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OFFSHORE VESSEL TRAFFIC MANAGEMENT (OVTM) STUDY. VOLUME II. TEC--ETC(U)
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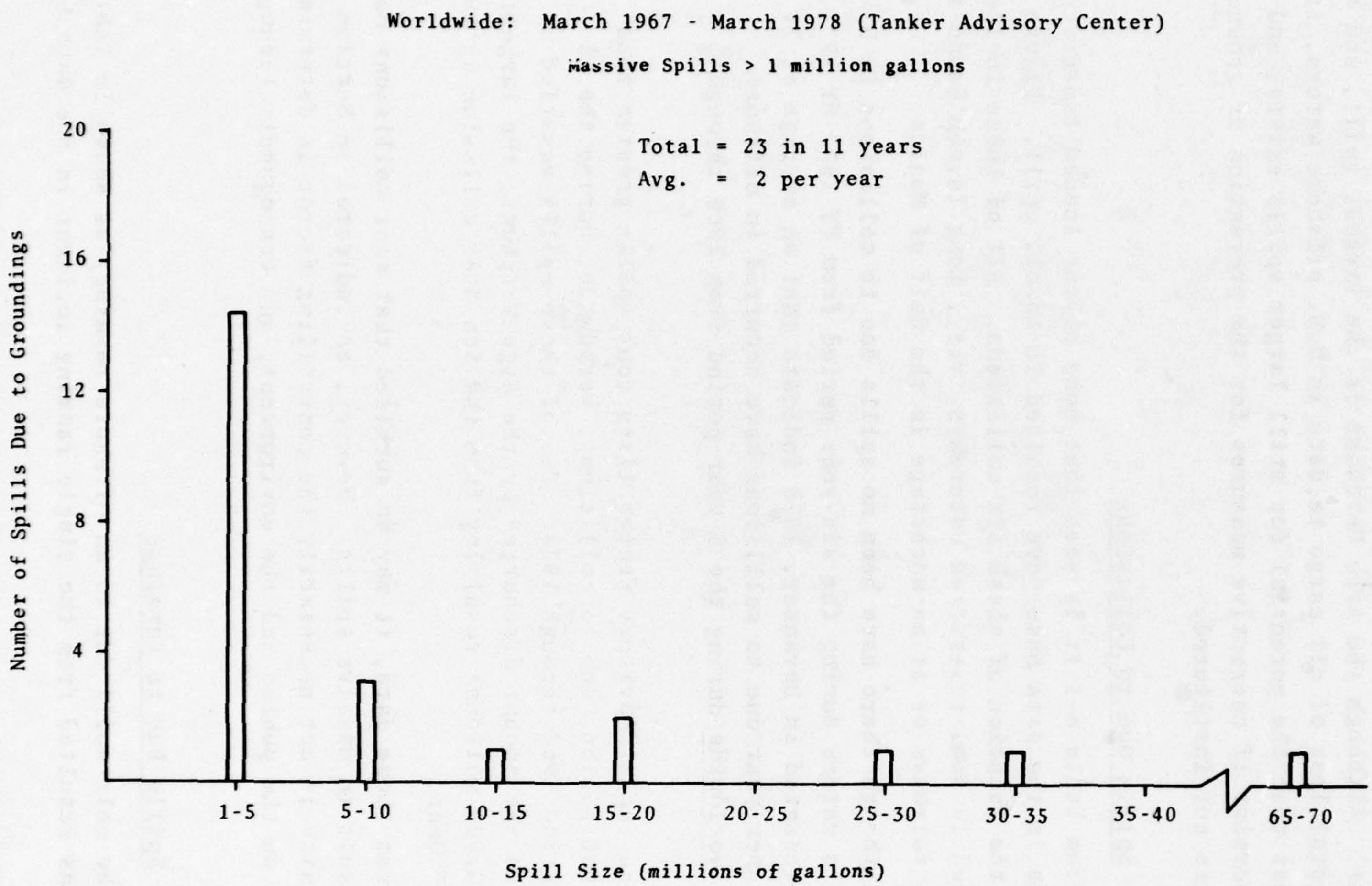


FIGURE 6-2. SPILLS DUE TO GROUNDINGS VERSUS SPILL SIZE

gallons. Although the Argo Merchant is the largest spill, and the only total loss of oil cargo to date in U.S. offshore waters, it is clear that the potential for still larger spills exists, and will persist if corrective measures for the prevention of groundings are not instituted.

6.2.2 Spills Due to Collisions

From Table 6-1 it is seen that none of the loaded tanker collisions in the data base have resulted in an oil spill. Figure 6-3 shows the location of these six collisions. All of these incidents occurred in semi-restricted waterways, viz., Long Island Sound and within fairways or at an anchorage in the Gulf of Mexico.

Although there have been no spills due to collisions in U.S. offshore waters during the six-year period from FY 1972-FY 1977, data presented in Devanney, 1978 indicate that an average of 11 spills per year due to collisions have occurred in offshore waters worldwide during the 8-year period from 1969 through 1976.

The Tanker Advisory Center lists four spills greater than 1,000,000 gallons due to collisions, worldwide, during the 11 year period 1967 through 1978. Two of these spills equalled or exceeded the amount discharged by the Argo Merchant, the largest (30,000,000 gallons) resulting from the Sea Star collision in the Gulf of Oman.

From these data, it may be surmised that most collisions do not result in massive spills. However, as indicated in Section 6.4, spill size is not necessarily the controlling factor in determining impact on the public and the environment, and consequent cleanup costs.

6.2.3 Spills Due to Rammings

The only spill due to an offshore ramming, as shown in Table 6-1, has resulted from the single ramming incident in the data base

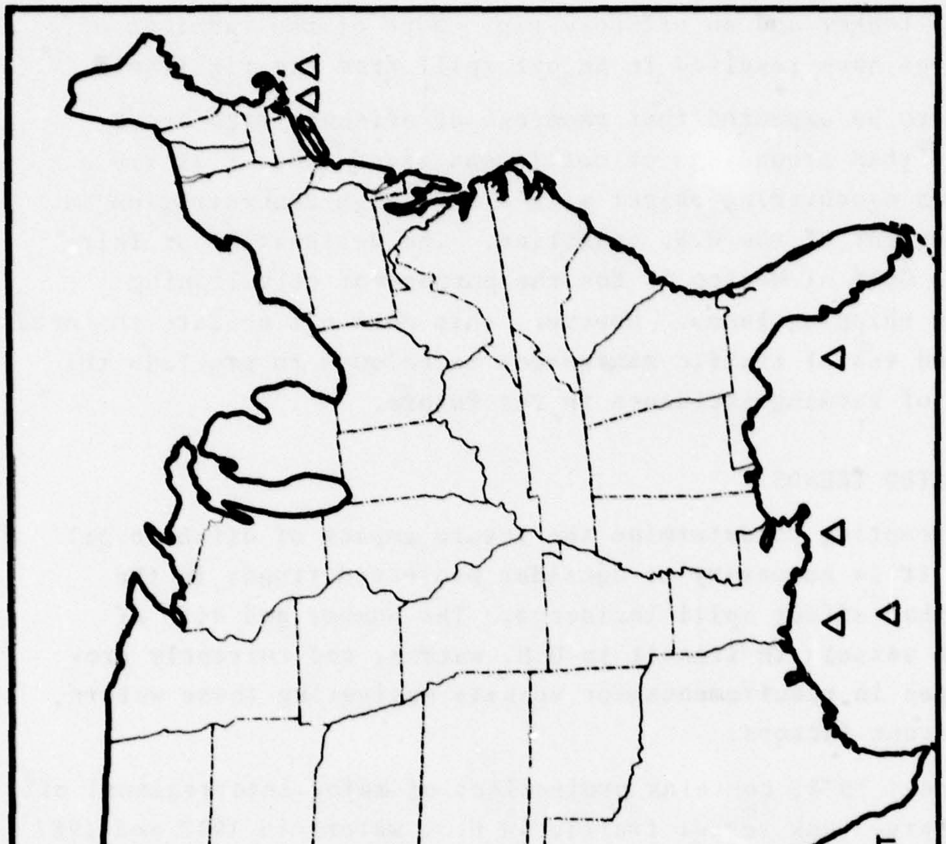


FIGURE 6-3. COLLISIONS OF TANK VESSELS LOADED WITH OIL
(FY 1972 - FY 1977)

involving a tanker and an offshore rig. None of the rammings of offshore rigs have resulted in an oil spill from the rig itself.

It is to be expected that rammings of offshore rigs are a rarer event than groundings or collisions since these rigs are a visible, non-maneuvering object with a very high concentration in only one segment of the U.S. coastline. The designation of fairways in the Gulf of Mexico is for the purpose of establishing hazard-free shipping lanes. However, this does not obviate the need for improved vessel traffic management techniques to preclude the occurrence of ramming incidents in the future.

6.3 PROJECTED TRENDS

In attempting to determine the future impact of offshore oil pollution, it is necessary to consider projected trends in the variables that affect spill incidence. The number and size of loaded tank vessels in transit in U.S. waters, and currently proposed changes in requirements for vessels navigating these waters, are significant factors.

Devanney, 1978, contains projections of major interregional oil flows and large tank vessel traffic in U.S. waters in 1982 and 1987. Assuming a three percent annual growth in oil demand and deep draft terminal facilities (LOOP) operating in the Gulf, the tank vessel traffic and size projections shown in Table 6-3 have been obtained. The significant points to be observed are (a) the projected increases in the number of loaded tank vessels arriving in East Coast and Gulf ports and in transit along the West Coast from Alaska, and (b) the large average size of tank vessels using LOOP facilities in the Gulf. Increases of this magnitude without compensating traffic management improvements would inevitably result in an increased number of oil spill incidents, and, in the case of LOOP traffic, the potential for a spill of massive proportions.

As discussed in Section 5, the adoption of the baseline system requiring all vessels larger than 1600 gross tons entering U.S. ports to be equipped with improved position-fixing capability

TABLE 6-3. PROJECTED TRENDS IN TANK VESSEL TRAFFIC AND SIZE IN U.S. WATERS

(Ratio: 1987 to 1977)

	Foreign Oil to East Coast	Landed in Gulf Ports	LOOP	Alaskan Oil Passing West Coast
Number of Loaded Tank Vessels	1.6	2.0	NA	9.0
Average Size of Tank Vessels	1.0	1.0	6.0	0.7

(LORAN-C or equivalent)would be 25 percent effective in reducing the probability of a grounding and 45 percent effective in reducing the probability of a ramming. This would reduce the potential impact of increased tank vessel traffic and size.

6.4 SPILL COST CONSIDERATIONS

When an oil spill occurs in U.S. waters, various Governmental agencies and private organizations commit resources to aid in clean-up operations in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (part 1510, Chapter V of Title 40, Code of Federal Regulations). In addition to these clean-up costs and the value of the unrecovered oil, damage claims may be instituted based on the cost of restoration or replacement of property or wildlife destroyed by the polluting substance.

Table 6-4 is a summary of total costs, actual and estimated, associated with the Argo Merchant spill of December 15, 1976 (Comptroller General, 6/77). Since the oil drifted away from coastal areas due to prevailing winds and currents, there were virtually no actual clean-up operations.

TABLE 6-4. SUMMARY OF ARGO MERCHANT OIL SPILL COSTS

	Amount
Cost incurred by:	
Coast Guard	$1,755,273
Military service	130,262
Other Federal agencies	635,248
State agencies	63,018
Universities	160,551
Scientific organizations	28,893
Private organizations	19,382
Total	2,792,627
Estimated value of waterfowl killed by the oil spill	5,535
New Total	$2,798,162
Estimated value of oil spilled	2,362,500
Grand Total	$5,160,662

The estimated costs incurred by the various Governmental agencies and private organizations totalling 2.8 million dollars were for:

a. Potential salvage and clean-up operations — $1.80 million

b. Surveillance and monitoring of the spill — $0.03 million

c. Waterfowl rehabilitation, clean-up and counting — $0.06 million

d. Scientific research and analysis — $0.78 million

and

e. Airlift of personnel and equipment — $0.13 million

No monetary value has been determined for the effects or potential effects of this spill on various species of fish and other forms of sealife. However, a coalition of Cape Cod fishermen has sued the owners of the vessel for more than $60 million for shoreline, fisheries, and personal damages.

In another spill incident cited in Comptroller General, 6/77, a majority of costs were for shoreline clean-up and the estimated value of the birds killed by the oil. In this case, 27 miles of shoreline were contaminated and approximately 30,000 waterfowl killed (vs. 500 in the Argo Merchant incident). Although the amount of oil spilled was 3 percent of the amount attributed to the Argo Merchant, the total cost, excluding the value of the oil, was approximately 45 percent of the Argo Merchant cost. It is therefore apparent that the cost per gallon of oil spilled will have a wide fluctuation, being highly dependent on the locale and environmental circumstances at the time of the spill.

The Pollution Incident Reporting System (PIRS), referred to in Sections 4.2.3 and 6.2, records the total cost of clean-up expended by all parties, Federal,state, and private, although these cost data may often be incomplete. For the period 1973 through mid-1977, 111 spills greater than 10,000 gallons have cost information entered into the PIRS data base. Seventy-four percent of the spills in this sample have clean-up costs recorded as less than 100,000 dollars; 18 percent are between 100,000 and 500,000 dollars; 3.5 percent are between 500,000 and 1 million dollars; and 4.5 percent greater than 1 million dollars.

Cost data for 65 of the largest spills that have occurred worldwide in the last 10 years, based on various sources of information available to the public, show an average clean-up cost of 1 million dollars per spill, with 6 spills exceeding 3 million dollars.

Note that clean-up, fisheries, and waterfowl costs are only part of the potential costs of an unfortunately located major spill. Others include damage to shore industries (e.g., tourism), disruption of local economies (possibly permanently), inconvenience and disruption of local citizens, permanent environment damage, etc. Some of these factors are being seen in connection with the Amoco Cadiz spill in France. For many of these costs of a spill, it is very difficult to estimate a dollar amount.

From the above, it is seen that the preponderence of spills incur clean-up costs of less than 100,000 dollars; however, a much greater expenditure of funds, often in excess of 1 million dollars, has been incurred in individual spill incidents.

7. RECOMMENDED SYSTEM ALTERNATIVES

7.1 INTRODUCTION

In the previous sections eighteen systems have been evaluated using the casualties in the data base. The casualties in the data base are believed to be representative; i.e., it is assumed that future accidents will occur for similar reasons. The data base is too small to conduct a statistical analysis with tight confidence limits; therefore, judgments must be made on the basis of a few accidents, aided by comparable studies in other geographic areas, for different periods of time, and under other conditions. In addition to the limits posed by the size of the data base there are a number of less tangible factors which have not yet been fully taken into account: user acceptability, tradition, implementability, and state of development of the equipment. While some of these have been mentioned, the effectiveness estimates of Section 5 have not taken them into account. The recommendations presented below attempt to take these factors into account.

7.1.1 System Implications

The Baseline System assumes that by 1985, all vessels of 1600 gross tons or more will have a LORAN-C navigation instrument with direct readout of coordinates, or a navigation system of comparable accuracy. However, the planned coverage of LORAN-C does not include Puerto Rico and the Virgin Islands, where 16 of the 55 groundings occurred, so that in these locations an on-board LORAN-C set is useless. The potential effectiveness of the baseline system would be 25% higher if LORAN-C coverage were extended into that area. The resulting extended Baseline System would have a potential effectiveness of 24%, 6% higher than the Baseline System. Vessels with satellite navigation (assumed to be a negligible fraction of the fleet) could, of course, operate there with limited capability.

The vessel passport system is the simplest form of an active system. The user acceptance should be high, because it requires no additional on-board equipment, and makes minimal demands on the mariner's time, except when unusual situations occur. Its main strengths are in deterrence and improved ship discipline: tankers will be reluctant to depart a foreign port in substandard conditions, knowing that to do so would risk delays or fines. The checkpoints force all tankers to perform duties the well-trained, prudent officer would routinely perform. It provides a means of enforcing equipment standards and appropriate pilot transfer procedures, and of alerting ships to unusual conditions.

Automatic monitoring systems are potentially very effective, but require a significant increase in costs to the government for both installation and operation.

Surveillance systems are also expensive, but are slightly more dependable than automatic monitoring, since they rely less on shipboard equipment. Both surveillance and monitoring systems incorporate the desirable features of the passport system.

Opinions on the effectiveness of training are highly subjective, so that it is difficult to quantify its usefulness or make specific recommendations. Poor bridge discipline played some part in most of the casualties, but the question of how helpful training would have been is subject to widely different estimates. Members of the Boston Marine Society scored training higher than the TSC team, but also indicated the difficulty and expense of developing and enforcing training requirements on foreign flag vessel officers, tug operators, and small vessel operators.

Traffic separation schemes are in use at several major ports now and appear to be quite effective. There were no end-on collisions and only one crossing collision in any traffic lanes. There does not appear to be any reason, based on the data base, to recommend the establishment of lanes at other ports. Specific recommendations are given in Section 7.4 for improving their effectiveness.

Aids-to-Navigation equipment and procedures are constantly undergoing review by the Coast Guard, both at local and headquarters levels. There is a natural resistance to adding more buoys to a national system of buoys that boasts a density far above the global average. Such recommendations were avoided, and don't appear in the evaluation, even though additional buoys could have been helpful in some cases. However, buoy identification, the expanded use of RACONS, and buoy maintainance and reporting procedures are areas that could be improved.

Recommendations for changing pilot transfer procedures are complicated by the jurisdictional split. While some pilots have federal licenses, most are state-licensed. (License requirements are generally more stringent for state pilots.) Also, pilots are commercially employed, and have unions which would be involved with any changes. Thus the effectiveness of unilateral action by the Coast Guard is difficult to assess. There are two "hot spots," namely Guayanilla/Tallaboa Bays in Puerto Rico and Delaware Bay, where most of the groundings caused by improper pilot transfer procedures occurred. The passport system alleviates these problems by involving the Coast Guard in a coordinating role.

Improved equipment standards, including preventive maintenance and higher reliability requirements, are difficult to enforce. Merely issuing a set of guidelines and minimum equipment specifications does not ensure their adherence. The enforcement problem is best handled by some coordinated Coast Guard efforts in inspection and boarding, features incorporated into the active systems.

The navigation alert system is hardly used at all today, even though there are equipments available commercially. The concept of deviation from track is not as familiar to most mariners as deviation from course. However, this is expected to change in the near future independently of Coast Guard actions. The reason is that once a mariner has a LORAN-C receiver, the additional hardware needed to implement a navigation alert system is small. This is just one manifestation of the revolutionary changes taking place in instrumentation, occasioned primarily by the advent of microprocessors. These highly complex devices have become available at such low prices and high reliabilities that tasks such as coordinate conversion (e.g., converting LORAN time delay numbers to latitude/longitude) and deviation-from-track are quite simply implemented. It can reasonably be anticipated that as mariners become accustomed to the direct readout capability of modern LORAN-C sets, gain confidence in the instruments, and begin to incorporate the continuous readout into their navigation procedures (e.g., by following a track defined by a LORAN-C chart line), the advantages of the use of deviation-from-track will become apparent, and usage will increase. Minimum equipment standards requiring deviation and maneuvering-point alerts would increase the safety potential of the device.

The comments above on the impact of microprocessors on instrumentation apply as well to depth alert and scanning sounder systems. As "smart" instruments become available at reasonable costs, it can be anticipated that they will become widely used, especially when their benefits become apparent.

Collision avoidance equipment is available off the shelf and does not require cooperative equipment on other vessels. Units are being installed routinely on new VLCCs, and many other tankers and large vessels are being retrofitted with them. While the effectiveness of collision avoidance aids was not judged to be high, they instill considerable confidence in the mariner because of the manner in which they interpret and display the situation, and thus provide benefits difficult to quantify.

Radar perimeter detection devices are not as effective as other techniques, but do provide some collision and ramming protection at a low cost. While false alarms may reduce their effectivenss within 5 miles of shore, they could be quite useful for smaller vessels. They would be especially useful in the Gulf of Mexico for maneuvering among oil platforms. Minimum equipment specifications by the Coast Guard would be helpful.

The VHF/transponder system is only a conceptual design at present. It requires an X-band transponder, but provides collision avoidance service to the smaller vessels, which the interrogator/transponder system does not. Its overall effectiveness for collision prevention is reduced only by radar outages. Since it has not been demonstrated, it must undergo a development cycle before its feasibility and unit costs can be established. There is the risk, as with any new item, that the practical implementation would reveal limitations now unapparent; this risk is believed to be small. Obtaining a frequency allocation at VHF is probably a more serious problem.

While interrogator/transponder systems have a high potential effectiveness, the high unit cost for large vessels and the requirement for smaller vessels to be equipped with transponders that provide little service to the user make the overall effectiveness low. If X-band transponders become standard equipment for other Coast Guard missions (e.g., Search and Rescue, Enforcement of Laws and Treaties), they might be configured to be compatible with this system. This system would then become attractive in the future.

In summary:

a. The shore-based, active systems provide enforcement of rules and provide a redundancy of function which reduces the chance that human errors will result in a casualty (Vessel Passport, Automatic Monitoring, and Surveillance).

b. Some systems only achieve a reasonable effectiveness in practice when enforcement measures, or other shore-based actions, are taken (Aids-to-Navigation, Pilot Transfer, and Equipment Standards).

c. Some of the existing systems and procedures should be continually reviewed and improved by the Coast Guard (Training, Traffic Separation, Aids-to-Navigation, and Pilot Transfer).

d. Some systems will probably be installed on ships in the future as their usefulness becomes apparent. They can become required equipment as experience demonstrates their usefulness (Navigation Alert, Scanning Sounder, Radar Perimeter Detection, and Collision Avoidance).

e. Some systems require development and backing by the Coast Guard (Depth Alert and VHF/Transponder).

7.1.2 Cost Analysis

Total 10 year system costs have been used in Section 5 without regard to the schedule of expenditures by the government and vessel owners. In order to properly compare the costs of the various systems, and to take into account factors such as state of development, implementation schedule, and rate of user equippage, a present value analysis in which the flows of expenditures for the various system alternatives are discounted back to the present, was performed. The net effectiveness of each system versus the net present value of systems cost through 1990 is shown in Figure 7-1. The assumptions and methodology used in deriving these cost figures are described below.

a. Costing Assumptions - The ten year system costs taken from Tables 5-4 and 5-5, were used as the basis for this analysis. Costs were distributed between government and vessel depending upon the system alternative analyzed and consisted of operations and maintenance, implementation or equipment, and research and development. Costs were determined on an annual basis based on constant 1978 dollars and accumulated through 1990. Present value costs were determined using a 10 percent discount rate. No inflation rate was used.

In addition to the above, the following assumptions were used in the analysis:

- Government R&D costs were uniformly distributed throughout the R&D period for the individual equipment or system to be used.
- Industry R&D costs associated with the development of equipment to be installed on board the vessels were assumed to be reflected in the equipment prices.

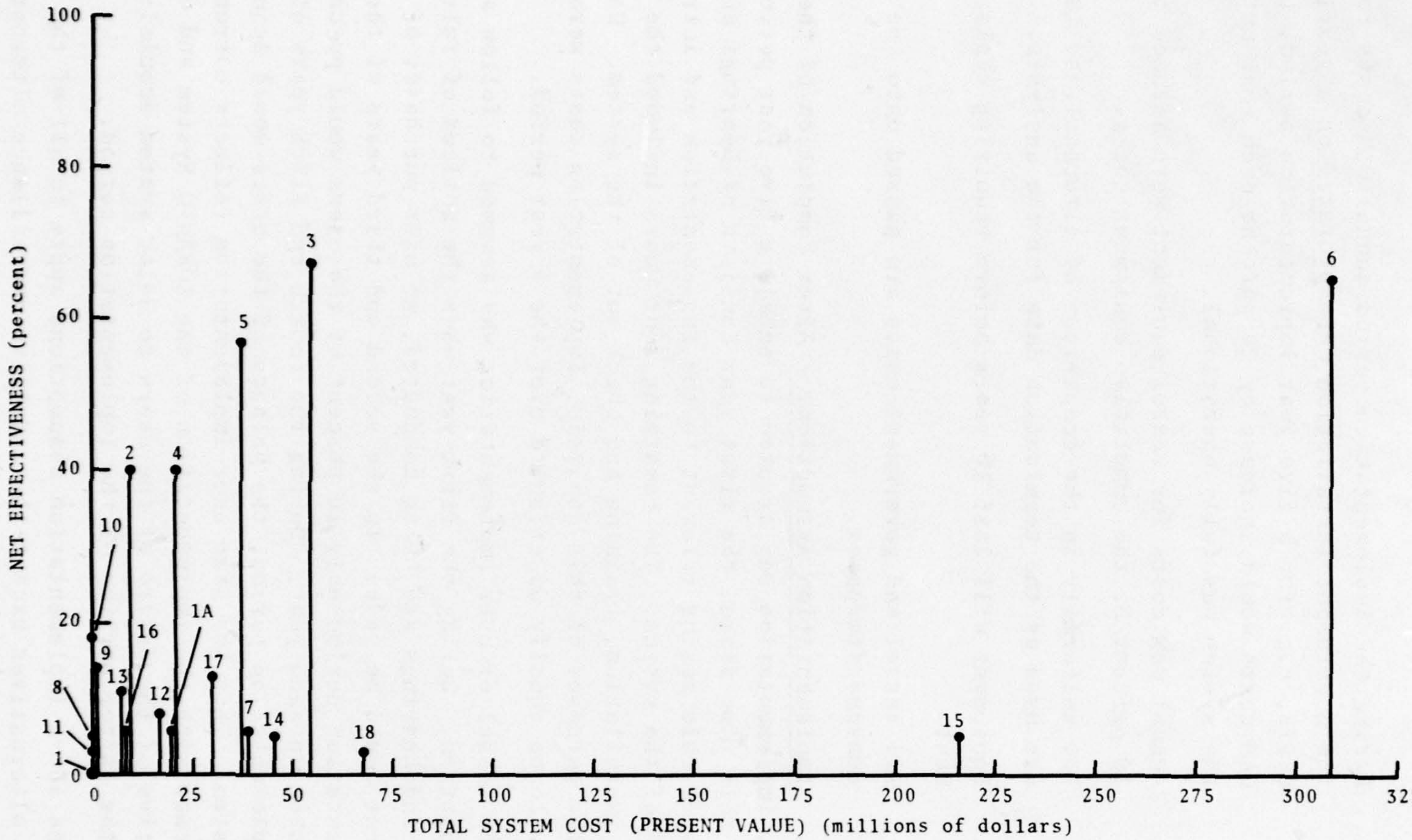


FIGURE 7-1. COST EFFECTIVENESS OF THE PROMISING SYSTEMS

- During the implementation period annual O&M costs for the Government installation were <u>prorated</u> on a yearly basis, e.g. for a five year implementation period, the O&M costs would increase by 20 percent each year until the system was fully operational.
- Annual O&M costs for vessel equipment were assumed to be 10 percent of the cumulative equipment costs.
- For uniformity in the comparison of alternatives, 1990 was used as the termination date for the analysis.
- Equipment will last 10 years before requiring replacement.
- All vessel and government costs are passed onto the consumer/taxpayer.

b. <u>Implementation Assumptions</u> - After completion of the R&D period, implementation was assumed to entail a five year period. Within this time frame, the first year consists of hearings and notices of rule making relevant to the implementation and introduction of the system. The remaining four years included the actual installation, training and check out of the system. However, for purposes of this analysis, implementation costs were assumed to be equally distributed over the 5 year period.

The vessel or user implementation was assumed to follow a two phase pattern. During the first year when the notices of rule making and hearings are being conducted, no user purchases of equipment would be made. In the second and third years of the implementation period only 10 percent of the users would purchase the system in each year. During the fourth and fifth years of the implementation period, the balance of the users would acquire the system. This two step user implementation reflects current experience with the implementation of the LORAN-C System and is indicative of the desire of the users to delay system acquisition until the latter portion of the implementation period.

The above implementation assumptions apply to all of the system alternatives except the satellite surveillance alternative

(System 6). Because of the international implications and the extended period of time required for treaties and rule making agreements, the implementation period for this alternative was assumed to be six years. The first two years of this six year period consist of the policy and rule making period, the remaining four years would include installation, training and system acceptance. Government implementation costs were assumed to be spread uniformily throughout the entire six years. Vessel implementation costs were assumed to begin during years three and four, with 10 percent of the vessels equipping each year. The remaining vessels (40 percent each year) would implement in years five and six.

7.1.3 Possible Strategies

There are several possible strategies that can be employed to determine the "best" system or combination of systems, based on different balances between investment in vessel equipment and investment in government facilities. Seven such possibilities are:

a. No Further Action - This is the Baseline System described in Section 5. By implementing the planned requirement of LORAN-C or equivalent instrumentation on all vessels greater than 1600 gross tons, and requiring a backup radar on vessels greater than 10,000 gross tons, it can be anticipated that casualties will be reduced by about 23%. The net effectiveness is defined to be zero for the Baseline System in order to provide a point of reference.

b. High Vessel/Low Government Investment - This extreme would require vessels to be outfitted with several devices; e.g., collision avoidance equipment on all large vessels, navigation alert and VHF/transponder equipments on all vessels, scanning sounders on all large tankers, and depth alerts on all tank vessels. The government's participation would be to issue minimum equipment specifications, and possibly to supply development funds for equipment not yet available. This is not considered a viable option, because of the financial burden, especially to smaller vessels. It also would have severe political implications, because it would affect U.S. flag vessels first, and might cause international repercussions when its enforcement was extended to foreign flag vessels.

c. <u>Moderate Vessel/Low Government Investment</u> - A less expensive, but less effective strategy would be to require an anti-collision aid (such as the VHF/transponder and a navigation alert system on all vessels.

d. <u>No Vessel/Moderate Government Investment</u> - This strategy is represented by the vessel passport system. It requires no further on-board equipment, and requires moderate government expenditures.

e. <u>No Vessel/High Government Investment</u> - This strategy requires surveillance without ship-board transponders in addition to the vessel passport system. It would require extensive radar installations. There would still be a problem with identifying ships. The geographic coverage would be limited to about 25 miles from port and harbor entrances, so that significant gaps in coverage would occur. This strategy is actually less effective than the automatic monitoring system because of the reduced coverage.

f. <u>Low Vessel/High Government Investment</u> - This strategy describes the automatic monitoring concept. It would require vessels to have special radio data encoding and decoding equipment, possibly at 1900-2000 kHz. Likewise, the U.S. Coast Guard would share some old LORAN-A and 2182 kHz emergency antennas and require new data encoding and decoding equipment. Also, computer techniques would be required to collect the information from the various receivers and perform the required monitoring functions.

g. <u>High Vessel/High Government Investment</u> - This could take a variety of forms, the most reliable of which could be a satellite surveillance system. It would require a ship board transponder (probably at L-band, about 1600 MHz) which could be interrogated via satellite, a set of satellites, and a shore station to establish the position of each interrogated vessel. The advantage of this system over the automatic monitoring system is that the positional measurements would not depend on ship-board measurements.

The complexity of the data processing for position establishment, and the costs of operating such a system are quite high.

The cost/effectiveness estimates of the strategies discussed above are shown in Table 7-1 and Figure 7-2. The costs presented in Table 7-1 are net present value, and are derived using the assumptions and methodology described in Section 7.1.2. The vessel distribution used to obtain the costs is the same as that of Section 5.4; the vessel population numbers are taken from Table 5-3.

Strategies B and C in Table 7-1 are subdivided to show the contribution of each item of equipment to the cost and effectiveness of the strategy. The net effectiveness of strategy C was found by adding the two net effectiveness numbers; this is reasonable because of the fact that the navigation alert is primarily aimed at preventing groundings and rammings, while the VHF/transponder system is aimed at preventing collisions. The High Vessel/Low Government strategy can not be so simply treated. The anti-collision systems (collision avoidance, radar perimeter detection device and VHF/transponder) overlap in function and provide a combined net effectiveness of between 13% (the largest) and 24% (the total) of the three. A median figure of 19% is assumed for the combined effectiveness. The other three equipment items in this strategy (navigation alert, scanning sounder, depth alert) are different in function, since they are aimed at groundings, rather than collisions. They overlap each other in function and provide a combined net effectiveness of between 11% (the largest) and 24% (the total). Again a median figure is assumed, in this case 18%. Adding 19% and 18% gives 37% for an estimate of combined net effectiveness.

In Figure 7-2, the vessel owner and government costs (present value) of each strategy, taken from Table 7-1, are plotted against the casualties prevented by that strategy. Consistent with the implementation assumptions made in Section 7.1.2, the casualties prevented take into account partial system effectiveness during the five year implementation period. For strategies requiring additional equipment on board the vessels (Strategies B, C, F, and G),

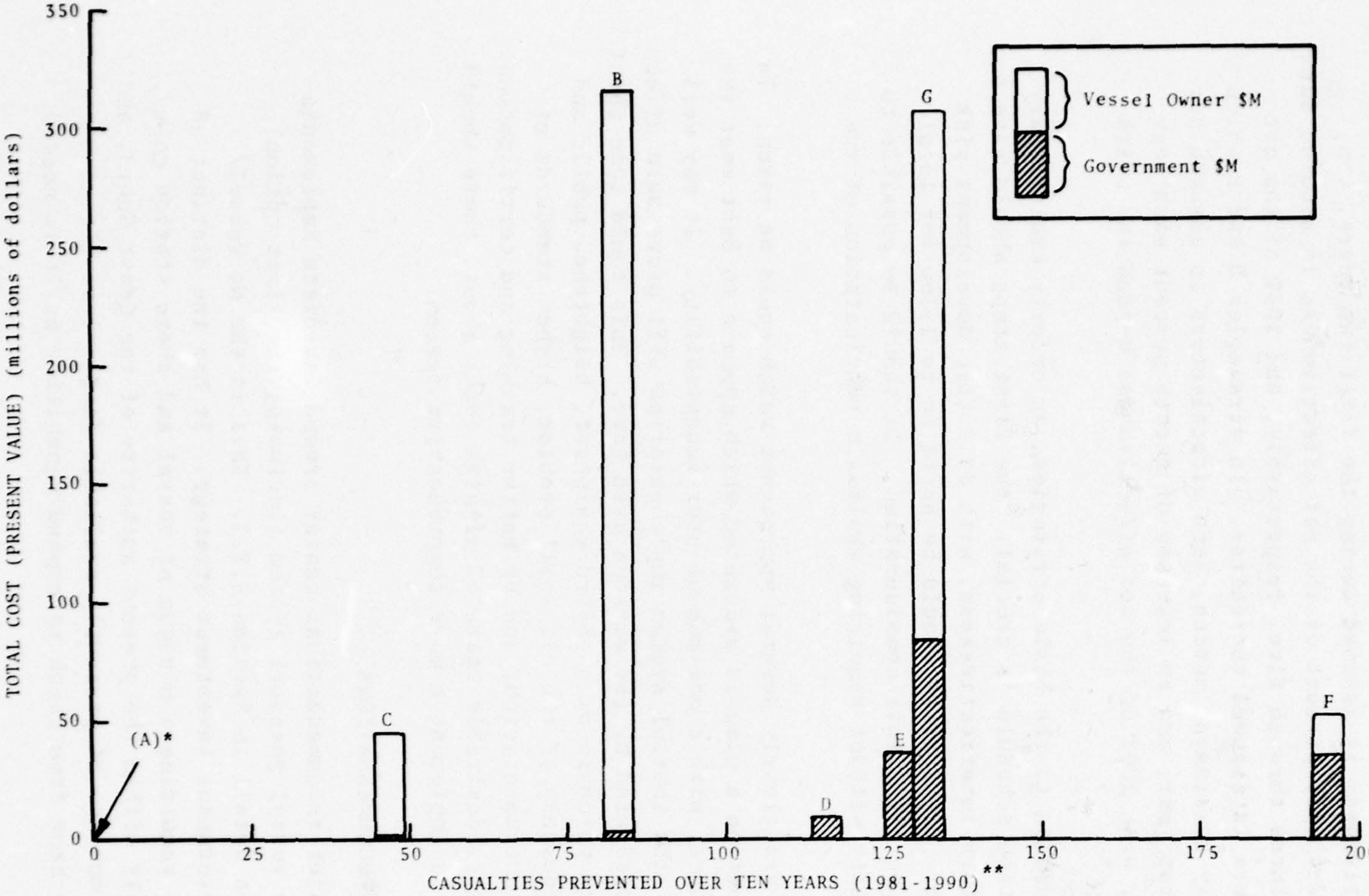
TABLE 7-1. COST AND EFFECTIVENESS OF SEVEN POSSIBLE STRATEGIES

Strategy	Number of Vessels	Vessel Cost* (Million $)	Government Cost* (Million $)	Total Cost* (Million $)	Net Effectiveness (percent)	Casualties Prevented Through 1990
A. Baseline System	6100	0	0	0	0 (23)**	0 (68)**
B. High Vessel/Low Gov't.						
- Navigation Alert	6100	15.7	0	15.7	8	
- Collision Avoidance	2500	215.1	0	215.1	5	
- VHF/Transponder	6100	28.9	0.9	29.8	13	
- Radar Perimeter Device	3600	7.7	0	7.7	6	
- Scanning Sounder	2500	43.0	1.3	44.3	5	
- Depth Alert	3600	6.2	0.4	6.6	11	
Total		316.6 (622.0)	2.6 (3.0)	319.2 (625.0)	37***	83
C. Moderate Vessel/Low Gov't.						
- Navigation Alert	6100	15.7	0	15.7	8	
- VHF/Transponder	6100	28.9	0.9	29.8	13	
Total		44.6 (87.6)	0.9 (1.0)	45.5 (88.6)	21	47
D. No Vessel/Moderate Gov't. (Vessel Passport System)	2670	0	9.5 (16.4)	9.5 (16.4)	40	116
E. No Vessel/High Gov't. (Radar Surveillance)	6100	0	36.2 (62.9)	36.2 (62.9)	57	128
F. Low Vessel/High Gov't. (Automatic Montoring)	6100	18.8 (39.8)	35.2 (69.9)	54.0 (109.7)	67	195
G. High Vessel/High Gov't. (Satellite System)	6100	223.5 (471.8)	84.5 (157.1)	308.0 (628.9)	65	131

*Net present value through 1990. Cumulative cash outlays shown in parenthesis.

**Effectiveness of Baseline over system in use during FY 1972-1977.

***See text for explanation.



*Sixty-eight casualties are prevented with only the Baseline system. All projections of casualties prevented by other strategies are in addition to those prevented by the Baseline.

**A total of 271 casualties is projected over the 10 year period (see Section 4.8).

FIGURE 7-2. TOTAL COST (PRESENT VALUE) OF EACH STRATEGY VERSUS CASUALTIES PREVENTED zero effectiveness is assumed during the first two years, ten, twenty, and thirty percent of the net effectiveness is assumed during years three through five, respectively, and 100% of the net effectiveness is assumed thereafter. In strategies D and E which require only government action, zero effectiveness is assumed during the first year, and an increase of twenty percent each year thereafter, with 100% of the net effectiveness beyond the sixth year.

In addition to the basic strategies, an orderly evolutionary implementation schedule is crucial: the first steps should have a maximum return in effectiveness, with as little development risk as possible. Flexibility should be built in to allow for local factors to be given full consideration. It should be possible to add capability without requiring wholesale reorientation of the system.

There are clearly several approaches which could be taken. In the next section a plan is presented which appears to best meet the criteria above, with a maximum of user acceptability. It may well happen that the initial system implementation will prove more effective than predicted by the methods used here. This could come about by voluntary purchase of on-board equipment, heightened public and crew consciousness of the oil spill problem, higher standards of shipboard instrumentation, and by better training and certification. If this highly desirable state of affairs comes about, there should be no need to implement a more comprehensive system.

7.2 MAJOR RECOMMENDATIONS

The major recommendations center around immediate implementation of the vessel passport system (including the first option) described in detail in Section 5.2.2. This is the No Vessel/Moderate Government Investment strategy. It has the distinct advantages of requiring a minimum of vessel and shore station costs, being largely within the present authority of the Coast Guard, and making maximum use of presently available facilities. It also serves as a base from which to expand capability as it is needed.

The system would be initially applied to loaded tankers, tank-barges, and ships carrying hazardous cargo bound for a United States port. They would be required to check in about 24 hours before arriving in internal waters, and again at about one hour out, and perform an instrument cross-check with a RACON reference. Once the pilot has assumed the con, the vessel would be off the system. It is expected that 90-95% of the port calls would be routine - the entire communications exchange would take 5-10 minutes of the bridge officer's time.

Several services would be provided, services which other vessels might like to have as well. At the outer check-in call, ships would be given weather forecasts, traffic information, and notice of any unusual outages or conditions. At the inner check-in, they would be given information on currents, tides, wind, and weather, LORAN-C corrections, notice of buoy changes or other unusual conditions, and traffic conditions. The local shore station would also ensure that a pilot had been contacted, and an appropriate meeting place agreed upon. These and other considerations are discussed in detail in Section 5.2.2. These services could be extended to other large vessels such as bulk cargo carriers and container ships on a voluntary basis.

In a small percentage of the cases, lack of charts, malfunctioning gear, or a bad history of violations would result in restrictions being placed on the vessel's entry. Tankers leaving U.S. refineries, or otherwise leaving a U.S. port, partially or fully loaded, would also be required to check in 24 hours ahead.

Some collision protection would be provided by a broadcast on VHF by the local shore operator, warning vessels that a tanker was approaching or departing and giving expected times (option one, Section 5.2.2). The presence of the RACONS would also reduce collision risk by helping to ensure that any vessel, not just tankers, can get a radar fix on a known point. The general information provided to the large vessels can be picked up by other vessels as well, who can benefit by it.

The vessel passport system has flexibility in its application. While major ports will have local watchstanders, not all ports need them. Ports with low casualty histories and infrequent port calls by tankers may not; for tankers destined for those ports no second check-in would be necessary. Permission would be granted at the initial check in to proceed into port. Where Vessel Traffic Services (VTS) are located, one of the VTS watchstanders could incorporate the local offshore function into his duties. Guidelines governing pilot boarding stations and procedures, the treatment of deep-draft vessels, and the treatment of equipment defects can be oriented to local conditions; pilots, ship masters, Captains of the port, and shipping companies should be consulted in establishing realistic guidelines.

RACONS are important in cross-checking onboard navigation instruments and providing an unambiguous reference point. They are presently used in Alaska; two are in the Straits of Juan de Fuca, two in the Gulf of Mexico, and one in Portland, Maine. A list of recommended locations for other RACONS is given in Table G-3, Appendix G. Their usage is crucial to the success of the system: 80% of the casualties took place at night or in visibilities of less than two miles. These are the conditions under which radar is routinely used for navigation, and where RACONS would be most helpful.

The vessel passport system can be implemented in stages:

a. Establish a central facility: provide data terminal access to the Marine Safety Information System (MSIS); tie into the Coast Guard communications network precisely like the AMVER system does.

b. Purchase and install RACONS at the appropriate locations.

c. Establish local stations at major ports: provide access to and from the central control facility; where VTS's don't exist, establish a VHF channel (e.g., channel 12) as the shore/ship frequency (this does not need to be exclusively dedicated), and provide shore-based communication gear; establish local guidelines for pilot transfer, and for restrictions to be imposed in case of equipment defects.

d. The effectiveness of using the vessel passport system to reduce casualties is estimated to be about 40%. It is similarly expected to reduce the number of major oil spills by 40%. If the frequency of massive spills (e.g., greater than 1,000,000 gallons, or about 4000 tons) is assumed to be once every 10 years, this system is expected to reduce the frequency to once every 17 years.

However, there is good reason to believe the effectiveness will be higher, because it will discourage "rogue" ships from setting out for U.S. ports in the first place. The Argo Merchant was kept out of Canadian waters by edict of their ECAREG system, which is also a check-in system (See Appendix E). It's likely that the captain of the Amoco Cadiz would have radioed the Coast Guard of her plight, if she had lost power near the U.S. coast. In certain circumstances, the Captain of the Port may direct the use of tugs to prevent imminent threat of danger to the U.S. shoreline. However, on the High Seas the constraints imposed by the Intervention Convention (IMCO, 1969) will have to be met. While the investigation of the Amoco Cadiz disaster is not complete, the accounts available suggest that several hours elapsed between the time the tanker lost power and the time the tug assistance was rendered. This kind of delay might have been avoided, and timely assistance administered using a vessel passport system.

Once the vessel passport system is set up in its initial configuration, a limited form of surveillance can be added in some locations. The Direction-Finding (DF) technique can be used, upon request from a vessel, to provide a position fix from shore by monitoring the vessel's VHF transmission. Bearing information from two stations on shore can provide fixes with an accuracy of about 0.5 mile if properly sited and calibrated. This would be a useful additional instrument where RACONS can't be placed 15-20 miles from shore; it also could be helpful where smaller vessels are likely to stray into traffic lanes.

After the system has been in operation for two years or so, it should be evaluated to assess the effects on casualties - their frequency and location. If the results are satisfactory near the major ports, but not near the minor ones, the system could be expanded in its local station coverage. Guidelines for each local area should be reviewed and modified. A suggested implementation schedule is shown in Figures 7-3 and 7-4.

7.3 HIGH EFFECTIVENESS OPTION

If the U.S. Coast Guard decides to attempt to achieve the higher effectiveness of the more sophisticated strategies (e, f, and g), the automatic monitoring system (e.g., Low Vessel/High Government Investment) is the recommended approach of three strategies. Satellite systems place a heavy financial burden on smaller vessels. Radar systems don't provide vessel identity.

It is conventional wisdom that radar surveillance or its equivalent is necessary to establish ships' positions accurately. The argument is premised on the usually unstated assumptions that: (1) shipboard equipment is not reliable in determining position, and (2) disaster is highly likely if a ship either fails to report information because of an equipment outage or communication problem, or reports erroneous information (e.g., LORAN-C cycle slips). Neither assumption is, in fact, correct. Shipboard equipment is quite reliable, and the accuracy is quite adequate. If a loss of navigation data from a particular vessel occurred, the oil spill risk of that vessel would be reduced to the risk of the vessel passport system, which is still quite safe. Cycle slips are the most likely source of error in LORAN-C: they occur abruptly and for limited periods of time. If a cycle slip occurred, the shore computer would immediately detect the change, which would be seen as a 10 microsecond jump of one of the reported time coordinates; thus the system can accommodate these errors. Radar would be justified only where traffic density is so heavy that traffic flow (i.e., control arrival times and spacings) is being managed from shore. For these reasons and for reasons of cost, the automatic monitoring system is the recommended approach.

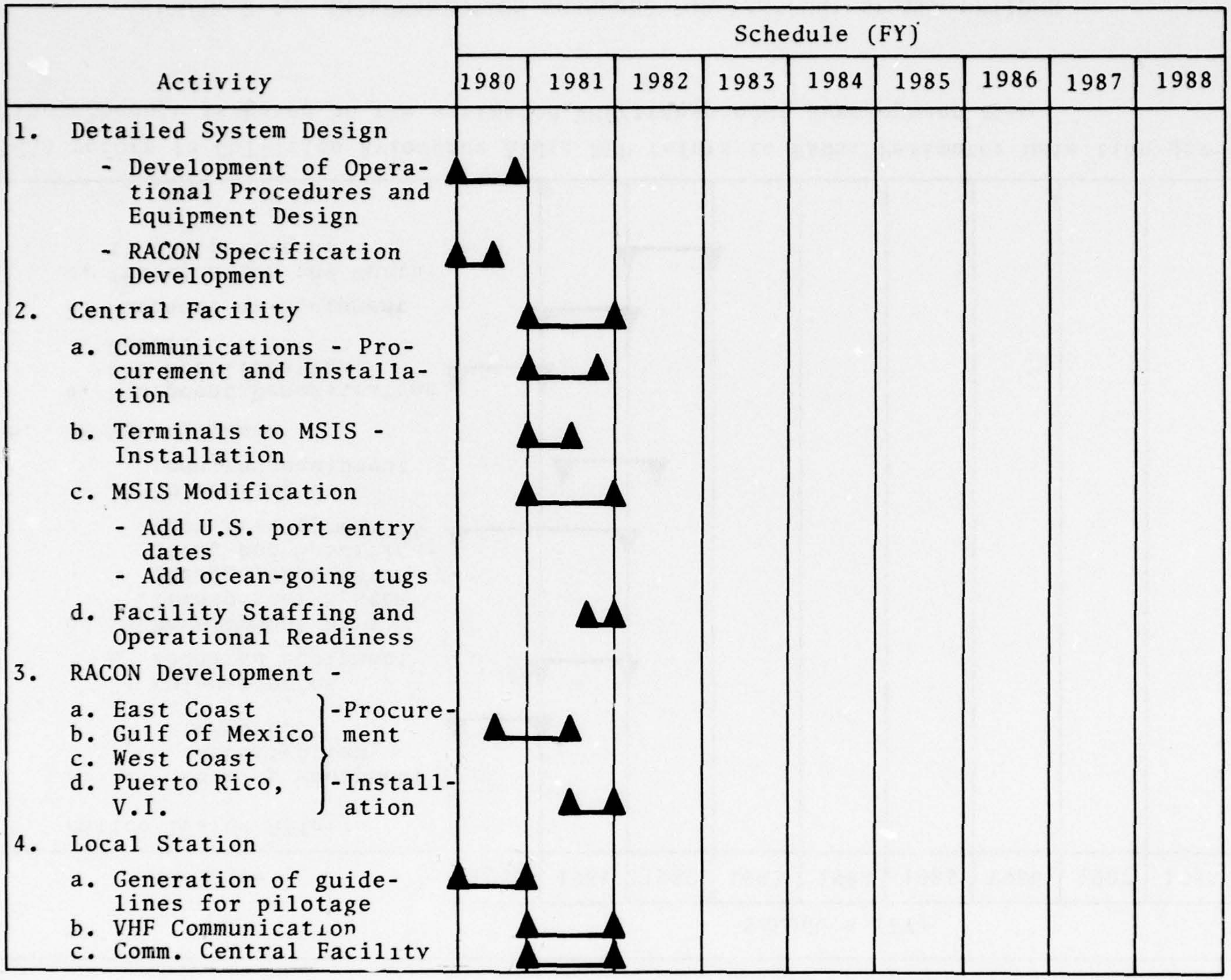
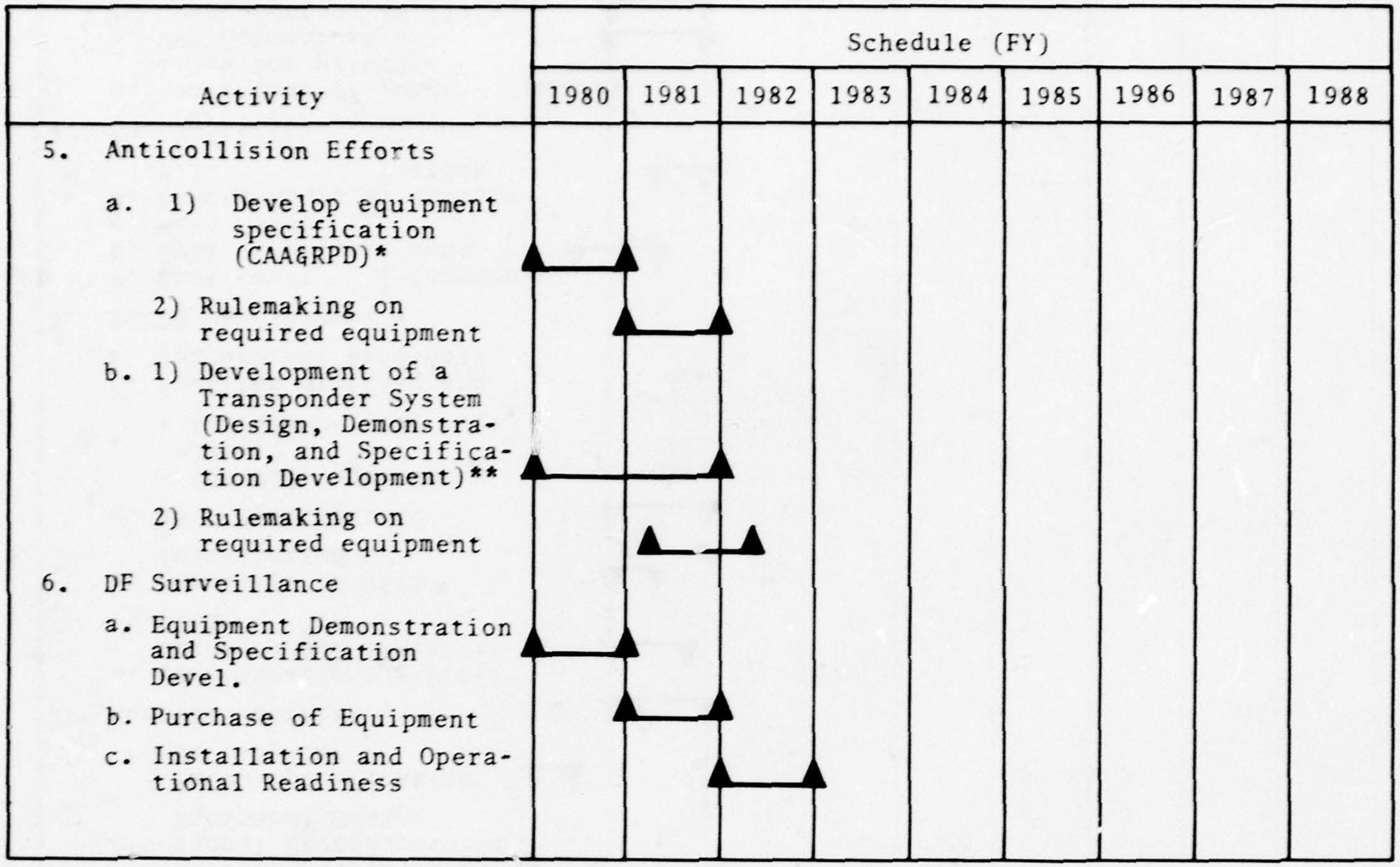


FIGURE 7-3. IMPLEMENTATION SCHEDULE FOR PASSPORT SYSTEM



*CAA refers to Collision Aviodance Aids; RPD refers to Radar Perimeter Detection devices.

**The schedule is based on the estimated VHF/transponder development time.

FIGURE 7-4. IMPLEMENTATION SCHEDULE FOR PASSPORT SYSTEM OPTIONS

Each participating vessel would be required to have a communications unit on the bridge, consisting of HF-SSB communications, encoder/decoder module, and interfaces to the LORAN-C (or satellite) navigation instrument, the master gyro, and the ship's log.*

In the conceptual design (Section 5.2.3 and Appendix G), four channels are used: one for data transmission and reception, and three for voice communication. At the initial check-in the vessel master would be asked to turn this equipment on, and told which voice channel to tune to. Since the range of the 2000 kHz communications system varies from 100-200 miles or more, it would encompass the offshore regions where all of the data base casualties occurred, but it would not usually be sufficient to reach an incoming tanker (and certainly not a fast container ship) at the 24 hour check-in. The ship would transmit her data stream about every half hour until she came within range of the shore system. After that the shore system would control ship transmissions by interrogations. (Note that the workload on the watchstanders is minimal.) In most cases these communication channels would be used instead of VHF. Thus the VHF channels would be freed up as the new stations are installed.

Again, a limited surveillance service can be instituted for service on request, using shore-based direction finding on VHF transmissions. There appears to be no need for such service beyond line-of-sight ranges (15-30 miles), so that DF-ing on the VHF transmissions is adequate. This is valuable for locating vessels either unequipped with the monitoring gear or experiencing outages.

The implementation of this system should begin with the implementation of the vessel passport system. At the same time, development should begin on the detailed design and fabrication of the communications and data transmission and reception equipment. The design of the computer equipment is more straightforward; and it

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*The measured speed from the ship's log is notoriously inaccurate, and would not be relied on for predicting future ships' positions.

can use the same architecture as is employed in VTS; one significant difference here is the requirement for real-time interfacing with the data transmission and reception equipment. Maximum use should be made of present 2182 kHz emergency communications antennas and decommissioned LORAN-A antenna facilities.

To provide adequate collision avoidance service and adequate oil pollution prevention in general, a large population of vessels should be required to have the equipment: vessels of 1600 gross tons or more and ocean-going tugs which pull barges should all be covered under the rule making which accompanies the system.

A suggested implementation schedule is shown in Figure 7-5.

7.4 OTHER RECOMMENDED ACTIONS

7.4.1 Introduction

Training, Traffic Separation, Aids-to-Navigation, and Pilotage are areas within the aegis of the Coast Guard that should, and do, undergo constant review. In the course of reviewing the 78 casualties, a number of issues became apparent where present practices can be improved. They are discussed below, and in Subsections 1, 4, 5, 6, 20, and 23 of Sections 5.2 and Appendix I.2 and Subsections 2, 5, 6 and 7 of Section 5.3.

These actions should be taken even if the major recommendations are not followed.

7.4.2 Training and Licensing

a. Licensing examinations and requirements should include demonstrated proficiency with radars, depth sounders, LORAN-C, and other navigation aids.

b. Relicensing should require at least a course in, and preferably demonstrated proficiency with, the above instruments and procedures.

c. All tug pilots operating with ocean-going barges carrying oil, fuel or hazardous cargo should have stringent training requirements comparable to those that apply to officers of small tankers.

Activity	Schedule (FY)								
	1980	1981	1982	1983	1984	1985	1986	1987	1988
1 thru 4 (Same as Passport System, Figure 7-3)									
5. Development of Monitoring System (Includes Retransmitted LORAN-C)									
a. System and Equipment Design (Shore Station and Ship)									
b. Fabrication of Demonstration Equipment									
c. Field Tests									
d. Develop Equipment Specification									
e. Purchase and Installation of Shore Equipment									

FIGURE 7-5. AUTOMATIC MONITORING SYSTEM IMPLEMENTATION SCHEDULE

d. The requirements for obtaining a pilot's license should be standardized in all U.S. states and territories.

e. The U.S. Coast Guard should continue to lobby in IMCO for strict and uniform global standards of training and licensing for officers of all ocean going tank vessels.

7.4.3 Traffic Separation

Traffic separation schemes are known to be effective in reducing collisions, especially in meeting or end-on situations. There are further actions which can be taken, which would increase their effectiveness, and provide some of their benefits in fairways. Fairways are not traffic separation schemes (See Section 5.2.5), but can provide some of the same protection. Procedures involving Gulf fairways will require coordination with the U.S. Army Corps of Engineers.

The following rules are recommended:

a. In fairways and traffic separation schemes, vessels outside of them but within one mile should avoid courses parallel to the boundaries but counter to prevailing traffic flow (this avoids dilemmas posed by starboard-to-starboard passings).

b. In fairways in the Gulf of Mexico, vessels should stay to the right except when overtaking (this also helps avoid starboard-to-starboard passing).

c. Vessels should cross fairways at nearly right angles (this avoids confusion of intended ship course).

To the extent that these go beyond COLREGS and IMCO resolutions, further IMCO action would be appropriate.

In addition, it is recommended that in confined areas like bays and Long Island Sound, a study should be made of narrow passageways to see if one-way traffic can be instituted without causing undue delays to vessels navigating in the opposite direction.

7.4.4 Aids-to-Navigation

The U.S. Coast Guard system of aids-to-navigation is one of the most comprehensive in the world. In spite of this, there are a few areas where improvements can be made (see Section 5.3.6). They were identified in the analysis of the casualties.

a. Buoy identification. There are several places where buoys within two miles of each other have the same light signals and general visual appearance from a distance. Means should be explored to remove these ambiguities.

b. Buoy locations. Especially in areas where deep draft vessels operate, buoy placements should be reviewed to ensure that in the worst possible position of a buoy in its watch circle, the deepest draft vessel can safely skirt a reef or shoal while passing close abeam of the buoy.

c. The use of RACONs should be expanded. This theme was noted repeatedly in conversations with vesselmasters. RACONs provide a uniqueness of identification that can be established at 8-20 miles range. They should be located at entrances to traffic separation lanes, on lightships, near fairway intersections, and on selected oil platforms bordering fairways.

d. Oil platforms. The Coast Guard should explore means with oil companies to get latitude and longitude displayed on oil platforms, preferably on all four sides. This would establish their positions on the charts and provide invaluable fixes for smaller vessels not equipped with an electronic navigation instrument, and would provide cross-reference points for those which are so equipped.*

7.4.5 Pilot Transfer

Fully one third of all tanker groundings occurred in preparation for pilot boarding. None resulted in oil spills, probably due to the low impact energies involved at slow speeds and the soft

*This suggestion was profferred by Captain Arthur M. Knight of the Boston Marine Society.

bottom in some of the areas where they occurred, plus good luck (major spills do occur at slow speeds). While casualties of this type are less likely to cause spills, the situation is still serious. The following recommendations are offered:

a. Deep-draft tank vessels approaching Delaware and Chesapeake Bays should be met by pilots before they enter the precautionary areas. Procedures should be reviewed with the local pilots' association to develop guidelines which accomplish this without endangering the pilots.

b. The pilot boarding point in Guayanilla and Tallaboa Bays in Puerto Rico should be moved out beyond the sea buoy to provide greater margins of safety.

c. Pilot standards and training requirements should be strengthened in general (see recommendation d, Section 7.4.2), and should apply in Puerto Rico and the Virgin Islands.

d. Coordination in some form by the Coast Guard should be pursued. This is provided in the recommended Vessel Passport System (see Section 7.2).

7.4.6 Anti-Collision Aids

The Coast Guard should pursue a modest program to reduce the probability of collisions. While collisions have been rare in U.S. offshore waters, there are still improvements that can be made:

a. The U.S. Coast Guard should lobby at IMCO for a bridge-to-bridge frequency to be monitored by vessels at all times for encounter coordination.

b. Minimum equipment standards for sophisticated collision avoidance aids should be issued, and should require automatic target acquisition for use in offshore coastal waters. Such equipment should eventually be required on large tankers bound for U.S. ports.

c. Minimum equipment standards should be issued for radar perimeter detection devices for use by smaller vessels. This should eventually be required on all tank vessels bound for U.S. ports which are not equipped with the more sophisticated collision avoidance aids.

d. Transponder system concepts should be developed and tested. If successful, such systems should eventually become required equipment on all commercial vessels (e.g., those greater than 1,000 gross tons).

7.5 LEGAL CONSIDERATIONS

This section reviews United States jurisdiction under international law to carry out the "vessel passport" system described in this chapter, and the authority of the U.S. Department of Transportation, the department in which the Coast Guard is located, to implement this system. Because it is well established that a sovereign state has exclusive jurisdiction to regulate vessels of its registry or flying its flag wherever they may be on the high seas,[1] this analysis will focus primarily on United States jurisdiction over foreign flag vessels.

The vessel passport system described in Section 7.2 would establish vessel reporting and equipment requirements and port entry conditions applicable to tank vessels en route to U.S. ports. Jurisdiction to establish such requirements and conditions lies within the broad authority of a port state to set conditions for the entry of vessels into its ports.[2] The United States has previously asserted this type of jurisdiction in promulgating vessel conduct and equipment-related requirements applicable to vessels entering its ports in order to promote vessel safety and avoidance of ocean pollution. For example, U.S. Coast Guard regulations governing the design, equipment, and operations of tank vessels of

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[1] Myres McDougal and William Burke, The Public Order of the Oceans, Ch. 8, esp. pp. 1011-12 (1962) (hereafter referred to as McDougal and Burke); see, articles 5 and 6, 1958 Geneva Convention on the High Seas, T.I.A.S. No. 5200, [1962] 13 U.S.T. 2312 (entered in force for the United States Sept. 30, 1962).

[2] McDougal and Burke, supra note 1, at 107-108 and references cited therein at notes 48-53.

150 gross tons or more are applicable to U.S.-registered tank vessels and to foreign tank vessels which "enter the navigable waters of the United States to engage in commercial service."[3] Vessels which call at U.S. ports must give at least 24 hours advance notice of their port arrival to the cognizant Captain of the Port.[4] The Coast Guard has recently proposed that vessels of 1600 gross tons or more calling at U.S. ports be equipped with and required to use LORAN-C or equivalent electronic position fixing devices meeting certain performance specifications.[5]

The scope of U.S. port state authority under customary international law was discussed in detail in connection with Senate action on S. 682, the proposed "Tanker and Vessel Safety Act of 1977." This bill would amend the Ports and Waterways Safety Act of 1972, 33 U.S.C.§§1221-1227 (1972 Supp.), to improve Federal regulation of navigation and vessel safety in order to better protect the marine environment. In Senate committee hearings on this measure, the U.S. Department of State endorsed reliance upon port state jurisdiction as a basis for the regulation of foreign vessels. Ambassador Elliot Richardson stated:

> "It is of great importance to distinguish here between assertions of jurisdiction over vessels that are not visiting our ports, and the application of our unquestioned authority to establish conditions for use of American ports which can and will provide considerable protection even before vessels arrive in our ports and after they leave.
>
> "The former implies similar control over American ships by coastal countries they may never visit or even wish to visit, control that can inevitably be abused. The latter simply leaves up to each country the question of how

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[3] 33 C.F.R. part 157 and § 157.01(a), promulgated pursuant to 46 U.S.C. § 391a ("Tank Vessel Act").

[4] 33 C.F.R. part 124, promulgated pursuant to 50 U.S.C. § 191. Depending on vessel speed, application of this requirement could require that notice be given when a vessel is several hundred miles offshore.

[5] 42 F.R. 59012 (Nov. 14, 1977).

> to exercise its existing right to decide when it wishes to permit ships to visit its ports.
>
> "Our concern in this regard is sufficiently weighty that we have decided against any reference to specific zones along our coast, even if the effect is limited to vessels entering or leaving our ports."[6]

The bill which the Senate Commerce, Science and Transportation Committee reported adopted this approach:

> Several bills introduced during this session of Congress (including S. 682) called for the unilateral establishment of a 200-mile pollution control zone. The zone would have extended U.S. jurisdiction over vessel safety and pollution control out beyond its current 12 mile limitation (the so-called contiguous zone). The jurisdiction would have included the right to set design and construction standards for all passing ships, to limit discharges from any ships, and to control ship movements and operations.
>
> However, representatives of the Administration argued strongly against unilateral extension of such jurisdiction as being contrary to U.S. policy and possibly damaging to U.S. interests. It was also pointed out that perhaps 80 to 90 percent of all traffic passing within 200 nautical miles enters U.S. ports. The remainder are enroute to points in Mexico or Canada. Therefore, an approach using regulatory authority based on the Nation's nearly plenary jurisdiction over any vessel entering a U.S. port was adopted by the Committee.[7]

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[6] Statement of Ambassador Elliot Richardson, Special Representative of the President for the Law of the Sea Conference, in hearings, "Recent Tanker Accidents: Legislation for Improved Tanker Safety," Senate Committee on Commerce, Science, and Transportation, 95th Cong., 1st sess., p. 851 (Serial 95-4, part 2, Mar. 18, 1977). See also, State Department comments on a staff working paper version of S. 682 contained in a letter from Douglas J. Bennet, Jr., Assistant Secretary of State for Congressional Relations, to Senator Warren G. Magnuson, Chairman, Senate Committee on Commerce, Science and Transportation, April 1, 1977 (reprinted in hearings, supra, at 924).

[7] S. Rep. No. 95-176, 95th Cong., 1st Sess., at 11 (1977).

The specific elements of the vessel passport system--that is, advance notice prior to vessel arrival in U.S. waters en route to a U.S. port, maintenance of safety records on all vessels entering U.S. ports, navigation-related vessel equipment requirements applicable to vessels bound for U.S. ports, vessel master's assurance of proper equipment operation, and imposition of specific conditions on port entry as necessary--appear to constitute conditions on vessel entry as comprehended in the above-quoted discussion of S. 682. Although call-in requirements at 24 hours and one hour prior to entry into internal waters can be distinguished from advance notice of arrival at the port itself, this distinction does not seem significant. It would seem to matter little to a vessel bound for port whether advance notice of its arrival must be given 24 hours prior to its port entry or 24 hours prior to entry into internal waters--the notice to be given is the same in either case. (An arriving vessel may prefer in some situations to relate its advance notice to enter into internal waters because that bound is more precisely defined than the bounds of a particular port.) The use of time-related notice requirements and the internal waters boundary as the measuring bound also eliminates the need to establish new fixed-distance offshore demarcation lines at which vessels must comply with notice requirements. The precise distance from the U.S. coastline at which a vessel must report under the vessel passport system would vary with its speed and trajectory.[8] Requiring notification of vessel arrival at the entrance to a port-bound traffic lane would likewise avoid the need for new fixed-distance offshore zones.

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[8]The requirement that arriving vessels give advance notice of arrival as a condition of port entry a specific number of hours rather than a prescribed distance out from shore meets the State Department concern that no new offshore pollution control zones be established because of the possible precedential effect of such actions. See Bennet letter, supra note 6, reprinted in hearings, supra note 6, at 924-925.

Statutory authority beyond that contained in existing legislation (principally the Ports and Waterways Safety Act of 1972, 33 U.S.C. §§ 1221-1227) is needed to authorize full implementation of the vessel passport system. For example, the Secretary of Transportation now lacks explicit authority to establish vessel traffic services outside the territorial waters of the United States.[9] Although both foreign and U.S.-registered vessels must now give at least 24 hours advance notice prior to arrival at U.S. ports,[10] the authority for this requirement is derived from the Magnuson Act, which by its terms is applicable in time of national emergency.[11] In recognition of the need for additional statutory authority, the Senate has passed and the House is now considering S. 682, "The Tanker and Vessel Safety Act of 1977."[12] Section 3 of S. 682, as passed by the Senate, would direct the Secretary of Transportation to establish "advisory vessel traffic services in appropriate areas of the high seas."[13] Although deemed "advisory," no vessel carrying oil or hazardous materials in bulk would be permitted to operate in navigable waters of the United States[14] or to transfer cargo in U.S. ports if it failed to comply with such a vessel traffic

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[9] See 33 U.S.C. § 1221; Senate Commerce, Science and Transportation Committee Report No. 95-176 on S. 682, supra note 7, at 21.

[10] 33 C.F.R. § 124.10.

[11] 50 U.S.C. § 191; see Senate Commerce, Science and Transportation Committee Report No. 95-197 on S. 682, supra note 7, at 21.

[12] S. 682 passed the Senate May 26, 1977 (legislative day May 18, 1977). In the House, the bill has been referred jointly to the committees on Merchant Marine and Fisheries and on International Relations.

[13] S. 682, § 3, to amend § 101 (c) of the Ports and Waterways Safety Act of 1972, 33 U.S.C. § 1221.

[14] "Navigable waters of the United States" is defined to include the territorial seas of the United States. 33 C.F.R. § 2.05-25.

service.[15] The proposed legislation would further authorize the Secretary to exclude from U.S. ports or navigable waters any vessel with a history of accidents, pollution incidents, or serious repair problems if there were reason to believe the vessel unsafe or a threat to the marine environment.[16] Under the bill the Secretary could also order a vessel to anchor or operate as he directs if he reasonably believed the vessel did not comply with applicable law or regulation, if weather or sea conditions or the condition of the vessel justified such action in the interest of safety, or if the vessel did not satisfy conditions for port entry.[17] And, the bill would require establishment of a data bank containing vessel ownership, accident, repair and inspection data, and other information on vessels carrying oil or hazardous cargo which enter or

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[15] Several provisions of S. 682, as passed by the Senate, including the one just described in the text, could by their terms be interpreted to apply to vessels not bound for U.S. ports which traversed the U.S. territorial seas in innocent passage. Implementation of these provisions may violate foreign vessels' right of innocent passage through the territorial sea. In view of the vessel passport system's focus on U.S. port-bound vessels, however, implementation of the system would not involve exercise of jurisdiction over foreign vessels engaged in innocent passage.

[16] S. 682, § 3, to amend § 106 of the Ports and Waterways Safety Act of 1972, 33 U.S.C. § 1226. See note 15, supra.

[17] Id. at § 3, to amend § 101(b) of the Ports and Waterways Safety Act of 1972, 33 U.S.C. § 1221. Section 4 of S.682 would amend the Tank Vessel Act, 46 U.S.C. § 391a, to grant the Secretary of Transportation general authority to set standards for the design, construction, repair, operation, manning and maintenance of vessels which operate in U.S. navigable waters or transfer cargo in U.S. ports and to which the section otherwise applies. Specifically, this section would mandate certain minimum equipment for oil tankers of more than 20,000 deadweight tons, including a dual radar system, collision avoidance system, long-range navigation aid, adequate communications equipment, fathometer, gyrocompass and up-to-date charts.

transfer cargo within the jurisdiction of the United States.[18] Passage of this (or similar) legislation would thus provide sufficient authority to permit full implementation of the vessel passport system.

[18] Id. at § 3 to amend § 107 of the Ports and Waterways Safety Act of 1972, 33 U.S.C. § 1227. The U.S. Coast Guard has recently proposed establishment of a "Marine Safety Information System" applicable to tank vessels over 20,000 deadweight tons carrying oil in bulk within U.S. navigable waters. As proposed, the regulation would require each vessel subject to it to report to the Captain of the Port 24 hours prior to port entry stating its beneficial owners, past registered vessel names, and country of registry. 43 F.R. 15586 (Apr. 13, 1978).

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9. GLOSSARY OF TERMS

Active Systems - those in which a shore station monitors vessel movement on a real time basis with frequent interaction and communications with the vessel.

Adjusted Potential Effectiveness - the potential effectiveness of a system, adjusted downward to reflect the fact that some unpreventable accidents did not appear in the data base.

Aid to Navigation - a device or system external to a vessel intended to help operators determine their position or warn them of danger.

AMVER (Automated Mutual-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 Governors 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.

Availability - the percentage of time that a system service is expected to be available, accounting for equipment malfunctions, lack of coverage, and lack of onboard equipment.

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 where one or both are underway.

COLREGS 1972 - The International Regulations for Preventing Collisions at Sea, 1972, an international convention developed under the auspices of IMCO. These navigation rules came into force July 15, 1977, and superseded existing U.S. statutory navigation provisions (33 U.S.C. 1051 et seq.). COLREGS '72 are set forth in U.S. Coast Guard Publication CG-169, "Navigation Rules," (May 1, 1977). See 42 Federal Register 35782 (July 11, 1977).

Conning Officer - the person on the bridge of a ship, at any given time, who is responsible for commanding the ship's crew and course at that time.

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

CPA (Closest Point of Approach) - the passing distance between two vessels, predicted by projection of their present courses.

Dead Reckoning - calculation of position by advancing a previous, known position in accordance with the vessel's course and speed.

Deep Water Route - a route in a designated area within definite limits which has been accurately surveyed for clearance of sea bottom and submerged obstacles to a minimum indicated depth of water for passage of deep draft vessels.

Direction Finder - a radio receiver used on a vessel to determine the bearing of the ship in relation to a land-based radio transmitter at a known location. A vessel may determine its position by finding its bearing to two land based transmitters.

DRMS - the distance root mean squared is a measure of error. It assumes that the statistical distribution of errors is normal (gaussian). On this basis, an error expressed as (drms) refers to the probability that a circle (or a circle equivalent to an ellipse) of radius shown will contain 63.2 percent of all data points. 2-drms is a 2 times drms, and refers to the circle containing 95 percent of the probable readings.

External Referenced - applies to a position established with reference to one or more external points whose locations are known or can be calculated accurately.

Fairway - (Shipping Safety Fairway) - a designated area of the sea within which the erection of structures is controlled or prohibited. These are established by the U.S. Army Corps of Engineers, and pertain only to the erection of structures. In practice, as in the Gulf of Mexico, their establishment creates a "fairway" for ocean traffic.

Fix - a relatively accurate measure of vessel position at a given time, determined without reference to any former position, and obtained by establishing the location of a vessel with respect to one or more external points.

Grounding - any situation in which a vessel comes in contact with the ocean bottom. A stranding is included as a grounding.

Hazardous Cargo Carriers - ships and barges that carry chemicals and other substances hazardous to the environment.

Homing - navigating toward a point by keeping constant some navigational coordinate, usually a bearing.

IMCO - (Intergovernmental Maritime Consultative Organization) - A specialized agency of the United Nations established in 1958 to promote international cooperation on technical matters affecting maritime shipping, safety of life at sea, efficient navigation, and the exchange of maritime information among nations.

Inshore Traffic Zone - a designated area between the landward boundary of a Traffic Separation Scheme and the adjacent coast intended for coastal traffic.

Internal Waters - see "waters"

Location Identification - the location of a point on the earth's surface expressed in terms of the coordinates of some grid.

Major Oil Spill - spill greater than 100,000 gallons when in the offshore, ref. Federal Register Vol. 40, No. 28, Feb. 10, 1975.

MTBF - Mean time between failures

Monitoring - See "Surveillance/Monitoring"

Nautical Miles (NM) - 1852 U.S. standard meters (meters defined by Department of Commerce as standard).

NAVAID - a device or system on-board a vessel which operators use to determine their position or determine their proximity to dangerous objects.

Navigable Waters - see "waters"

Navigation System - a system capable of being used to navigate. It includes the transmission receiving equipment, its operators, the rules and procedures governing their actions and, to some extent, the environment which affects the whole vessel.

Net Effectiveness - The measure of system effectiveness over and above the baseline system, incorporating any lack of availability.

Offshore Vessel Traffic Management (OVTM) - organizing and coordinating the movement of vessels in the offshore waters for the purpose of improving the safety of the vessel and her crew.

Passive Systems - regulations, rules, procedures, equipment requirements, and vessel routing schemes which do not require a dedicated shore station's real-time interaction with vessels.

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 (when required). There are many ways of expressing position accuracy. In general, the error is statistical in character and can only be expressed in terms of a distance that will not be exceeded in some percentage of cases.

a. System Accuracy - is the expected accuracy of the system expressed in drms units, not including errors which may be introduced by the user, or geodetic or cartographic errors.

b. Predictable Accuracy - is the accuracy of predicting position with respect to precise space and surface coordinates.

c. Relative Accuracy - is the accuracy with which users can measure their position relative to that of another user of the same navigation system at the same time.

d. Repeatable Accuracy - is the accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.

Potential Effectiveness - a measure of the effectiveness of a system to prevent casualties, assuming that all ships are fully equipped, that the system service is everywhere and always available, and that the baseline system is in effect.

Probability of Prevention - a measure of the effectiveness of a system to prevent casualties, assuming that all ships are fully equipped, and that the system service is everywhere and always available.

RACON - transponder type Radar Beacon which responds to interrogations from a radar and replies with a unique identity code that appears on the screen of the interrogating radar.

Radiodetermination - the determination of position, or the obtaining of information relating to position, by means of the propagation properties of radio waves.

Radiolocation - radiodetermination used for purposes other than navigation.

Radionavigation - radiodetermination used for the purposes of navigation, including obstruction warning.

Ramming - the accidental collision of a vessel with a fixed object.

Routing (or Routeing) - a complex of measures concerning routes aimed at reducing the risk of casualties. It includes traffic separation schemes, two-way routes, tracks, areas to be avoided, inshore traffic zones and deep water routes.

Sealane - a broad and vague term referring to routes normally traveled by ships. Although in common use, it is not geographically specific.

Surveillance/Monitoring - the practice of a shore facility tracking and observing the movement of vessels in order to provide information and guidance to assist in preventing collisions, groundings and rammings, and otherwise facilitate the safe movement of a vessel or group of vessels.

a. Surveillance - the shore facility determines the vessel's position and estimates its course and speed.

b. Monitoring - the ship determines its position and relays this to the shore facility where estimates of course and speed are made. The relay may be made automatically (Automatic Monitoring) or involve the crew of the ship (Manual Monitoring).

Study Region - the geographical area of interest in this study; i.e., the United States waters from the coastline out to 200 NM, excluding ports, harbors and channels less than 1000 feet wide.

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

Tank Vessel - 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.

Territorial Sea - see "waters."

TCPA (Time to the CPA) - the time interval from the present time until the time that two vessels will pass each other, based on the projection of their present courses.

Time Differences - the difference in the time of reception of synchronized signals emanating from different sources.

Track (or Track Line) - the recommended route to be followed when proceeding between predetermined positions.

Traffic Lane - an area within definite limits inside which one-way traffic is established.

Traffic Separation Scheme (TSS) - a scheme which separates vessel traffic proceeding in opposite or nearly opposite directions by the use of a separation zone or line, traffic lanes, natural obstacles, or other means. All TSS's are submitted to IMCO for approval to comply with international agreements.

Two-way Route - a route in an area within definite limits inside which two-way traffic is established. The "fairways" in the Gulf of Mexico are effectively two-way routes. (See the definition of Fairway.)

U.S. Waters - see "waters"

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

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 crew.

Waters

a. 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.
   Ref. 33 C.F.R. § 2.05-25(a).

b. Territorial Seas - (a) with respect to the United States, territorial seas means the waters within the belt, 3 nautical miles 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.

Ref. 33 C.F.R. § 2.05-5

c. <u>Territorial Sea Baseline</u> - the delimitation of the shoreward extent of the territorial seas of the United States drawn in accordance with principles, as recognized by the United States, of the Convention on the Territorial Sea and the Contiguous Zone, 15 U.S.T. 1606.

Ref. 33 C.F.R. § 2.05-10

d. <u>Inland Waters</u> - generally equivalent to Internal Waters.

Ref. 33 C.F.R. § 2.05-20(b).

e. <u>Internal Waters</u> - with respect to the United States, the waters shoreward of the territorial sea baseline.

Ref. 33 C.F.R. § 2.05-20

<u>Weight of Oil</u> - the estimated average weight of oil transported by tank vessels, as used in this report, is 7.5 pounds per gallon.

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