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16. Abstract

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.

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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.

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.)

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 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

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

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 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 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.

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:

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 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 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 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

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.

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.

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 4-8. 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

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

CASUALTY TYPE	GROSS TONNAGE (1000 TONS)										TOTAL
	≤1	1-5	5-10	10-15	15-20	20-30	30-50	50-75	75-100	100-150	
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 4-11. 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

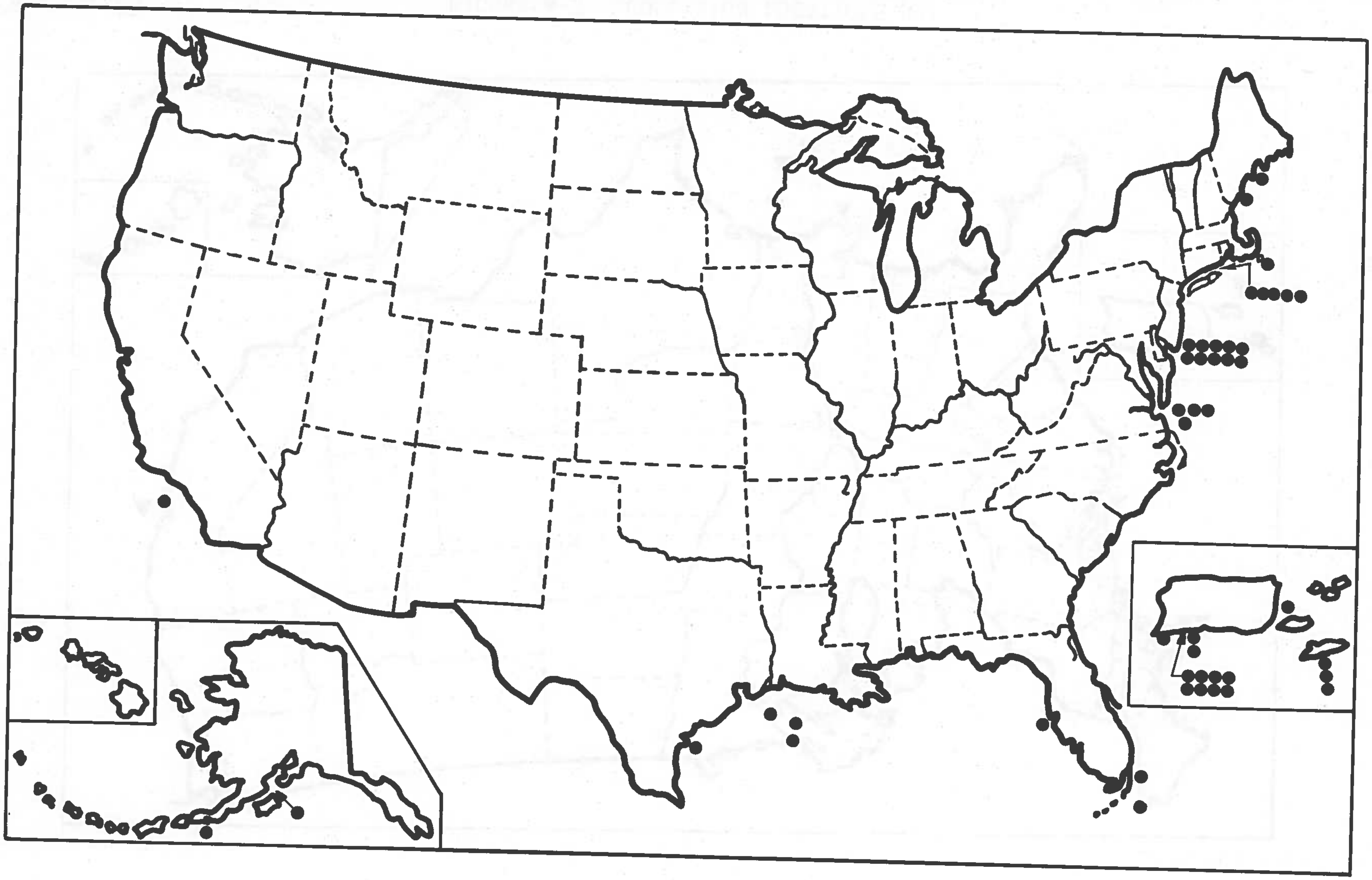

FIGURE 4-2. GROUNDING LOCATIONS MAP

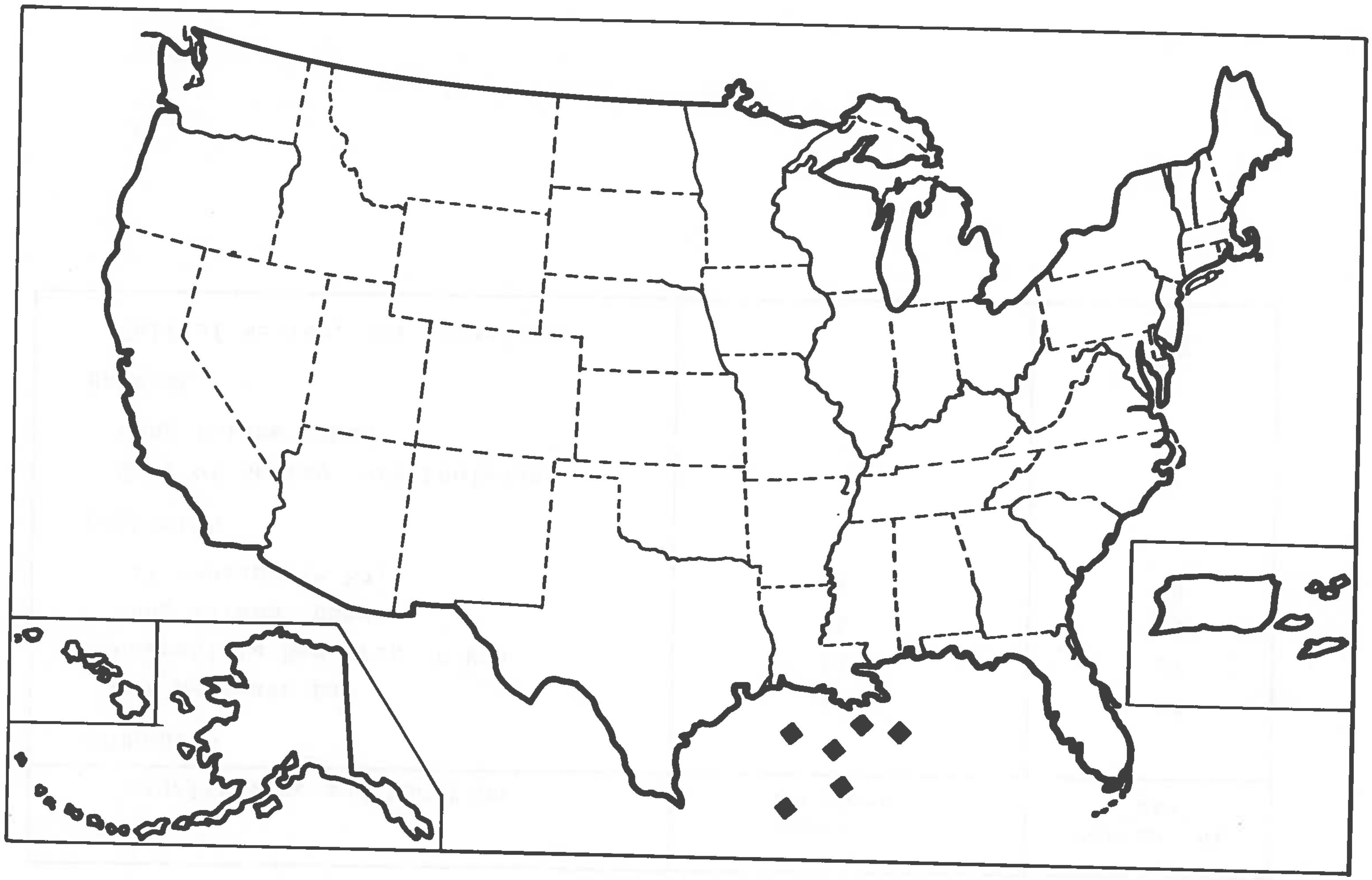

FIGURE 4-4. RAMMING LOCATIONS MAP

TABLE 4-14. CASUALTIES VERSUS DISTANCE OFFSHORE

Casualty Type	Distance Offshore (Nautical Miles)										Total
	≤ 1	1-3	3-5	5-12	12-25	25-50	50-75	75-100	100-150	150-200	
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

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 4-16. 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

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. CASUALTIES BY TIME OF DAY AND VISIBILITY

Nature of Casualty	Time of Day	Visibility (Nautical Miles)					Total
		≤1 (Poor)	1-5 (Fair)	5-10 (Good)	>10 (Unlim.)	Unknown	
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

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.

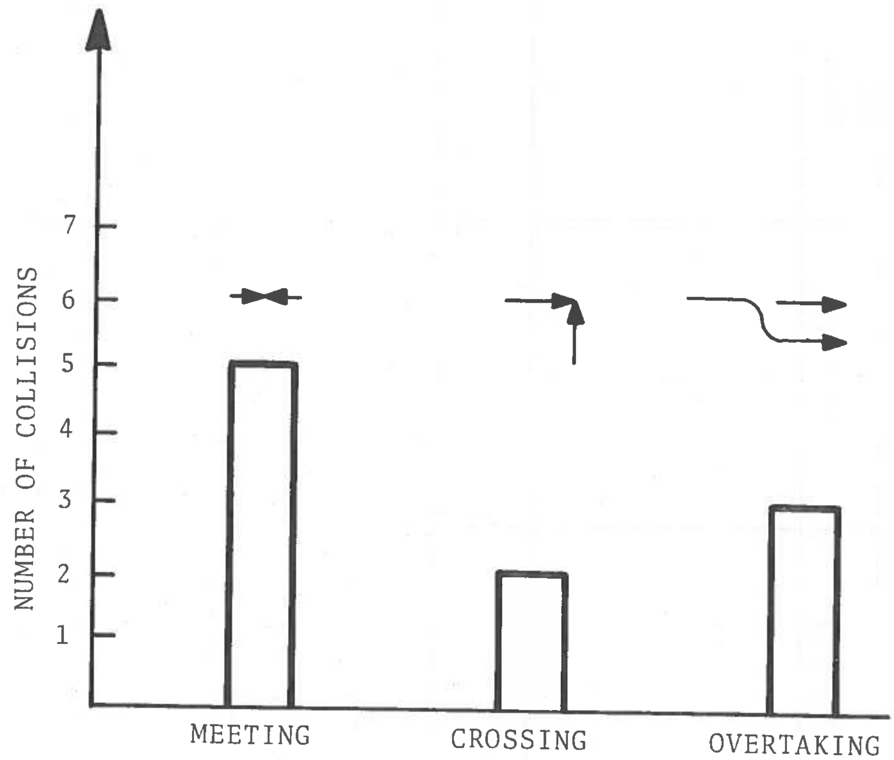

FIGURE 4-9. COLLISIONS BY ENCOUNTER TYPE

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 (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 4-25. 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

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

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 4-31. 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	-

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

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*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 <u>specific</u> actions has not been addressed during this study, except that extended LORAN-C coverage is included as part of the Baseline System.

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 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

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

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.

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

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

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

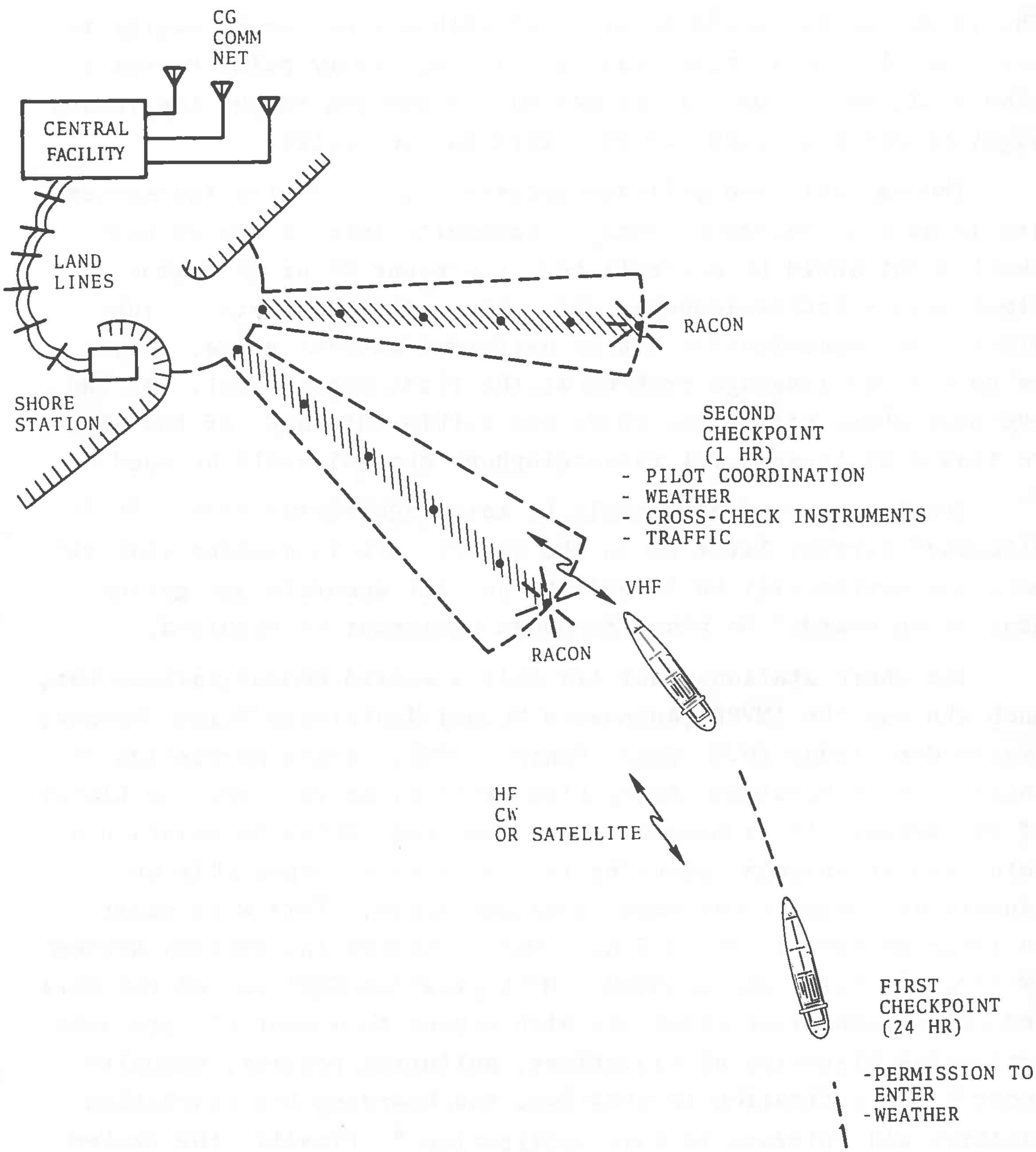

FIGURE 5-1. VESSEL PASSPORT SYSTEM

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.

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

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.

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

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.

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."

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),

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*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.

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

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

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

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.

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.

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.

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.

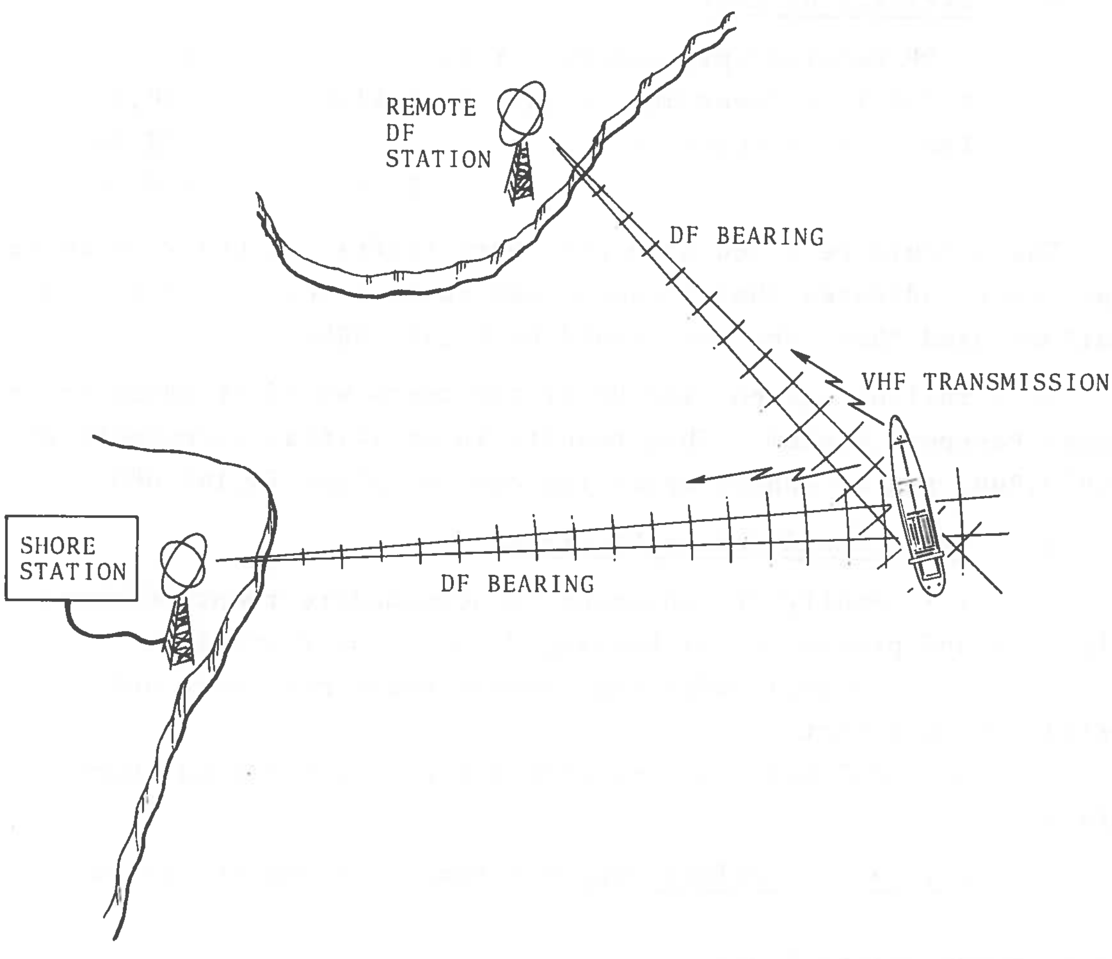

FIGURE 5-3. DF SURVEILLANCE SYSTEM

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

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*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.

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.

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. <u>Training/Workload</u> Implications - Minimal -- transponder need only be turned on.

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%.

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.

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

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

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 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 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.

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*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.

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 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.

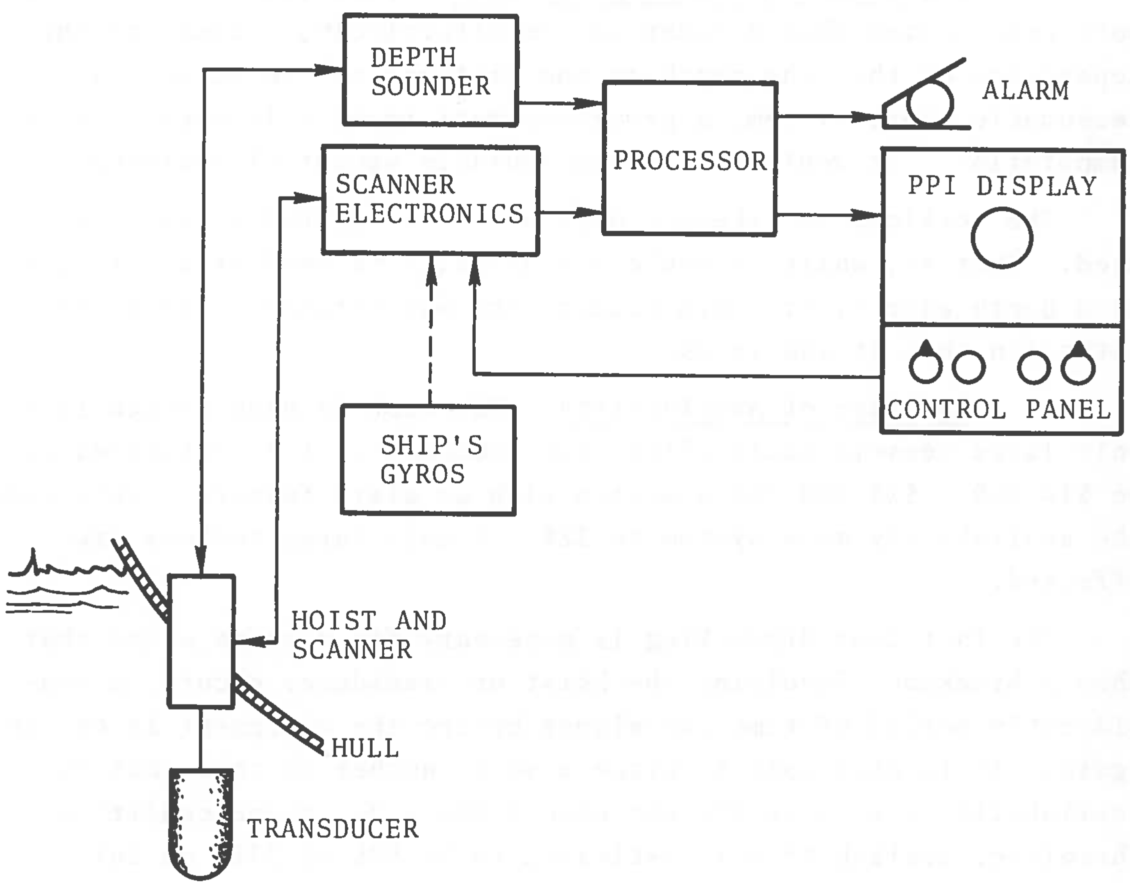


FIGURE 5-7. SCANNING SOUNDER

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

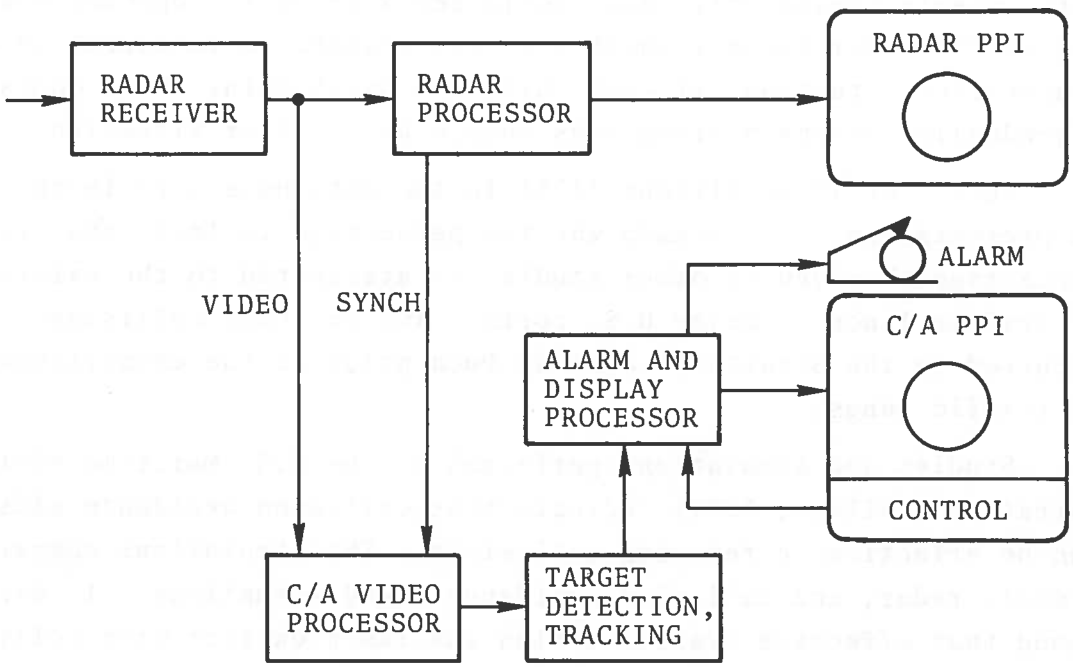


FIGURE 5-8. COLLISION AVOIDANCE AID

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

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 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.

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 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.

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. <u>Training/Workload Implications</u> - 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. <u>Estimate of Availability</u> - 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.

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 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.

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.

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

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

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^{o}-12^{o} 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

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.

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

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.

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.

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

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

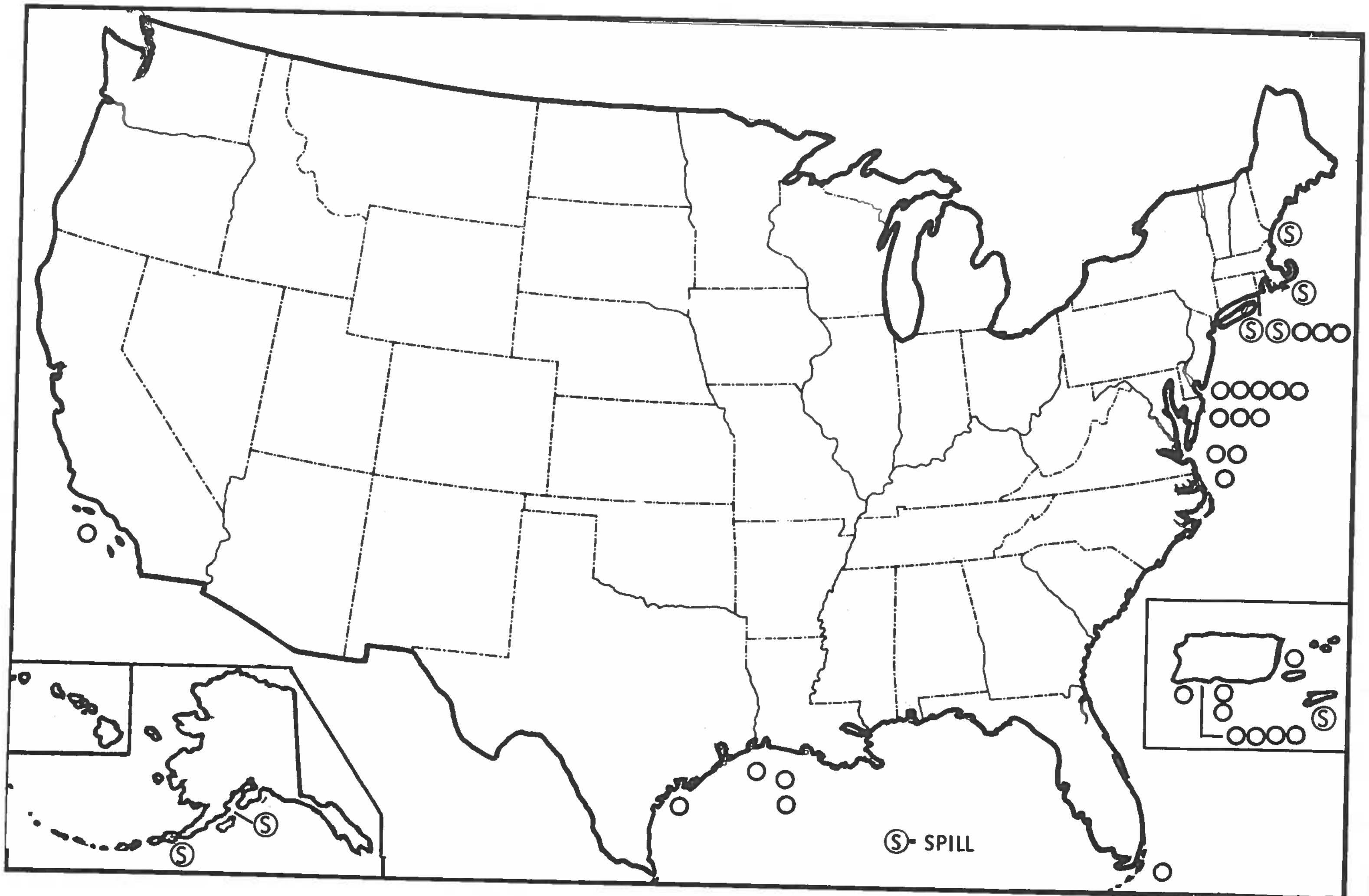


FIGURE 6-1. GROUNDINGS OF TANK VESSELS LOADED WITH OIL (FY 1972 - FY 1977)

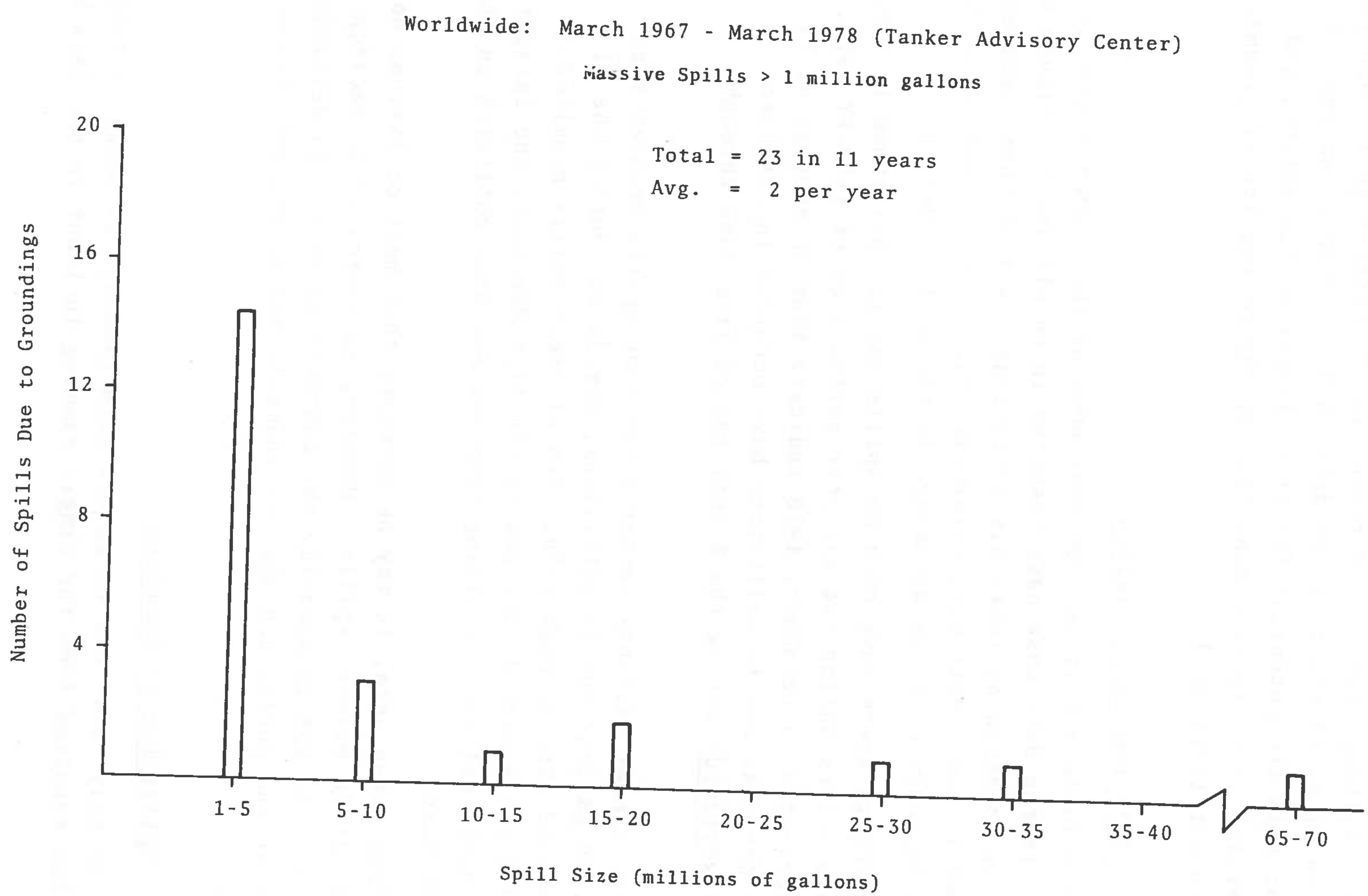


FIGURE 6-2. SPILLS DUE TO GROUNDINGS VERSUS SPILL SIZE

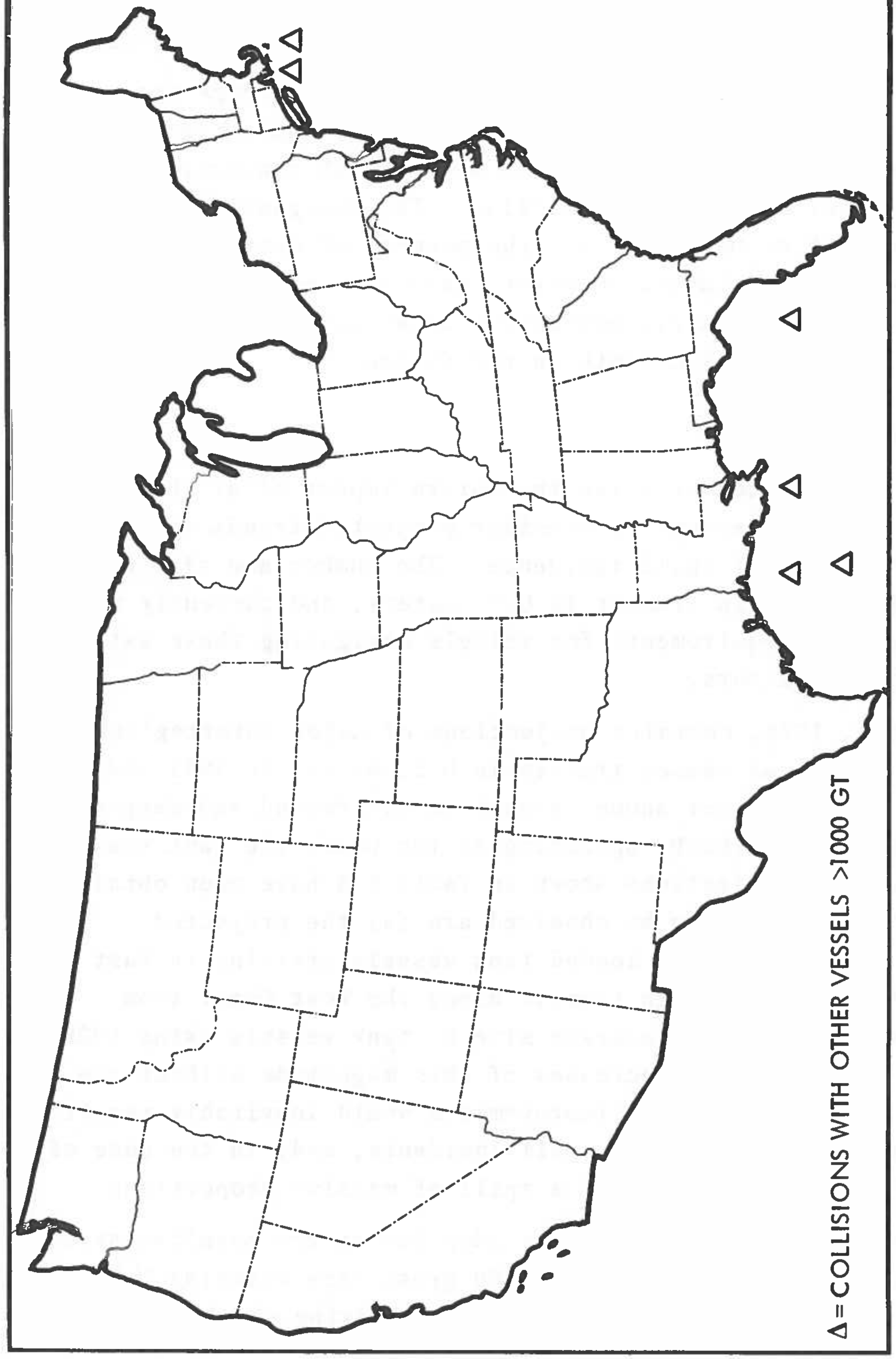


FIGURE 6-3. COLLISIONS OF TANK VESSELS LOADED WITH OIL
(FY 1972 - FY 1977)

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.

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.

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.

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 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).

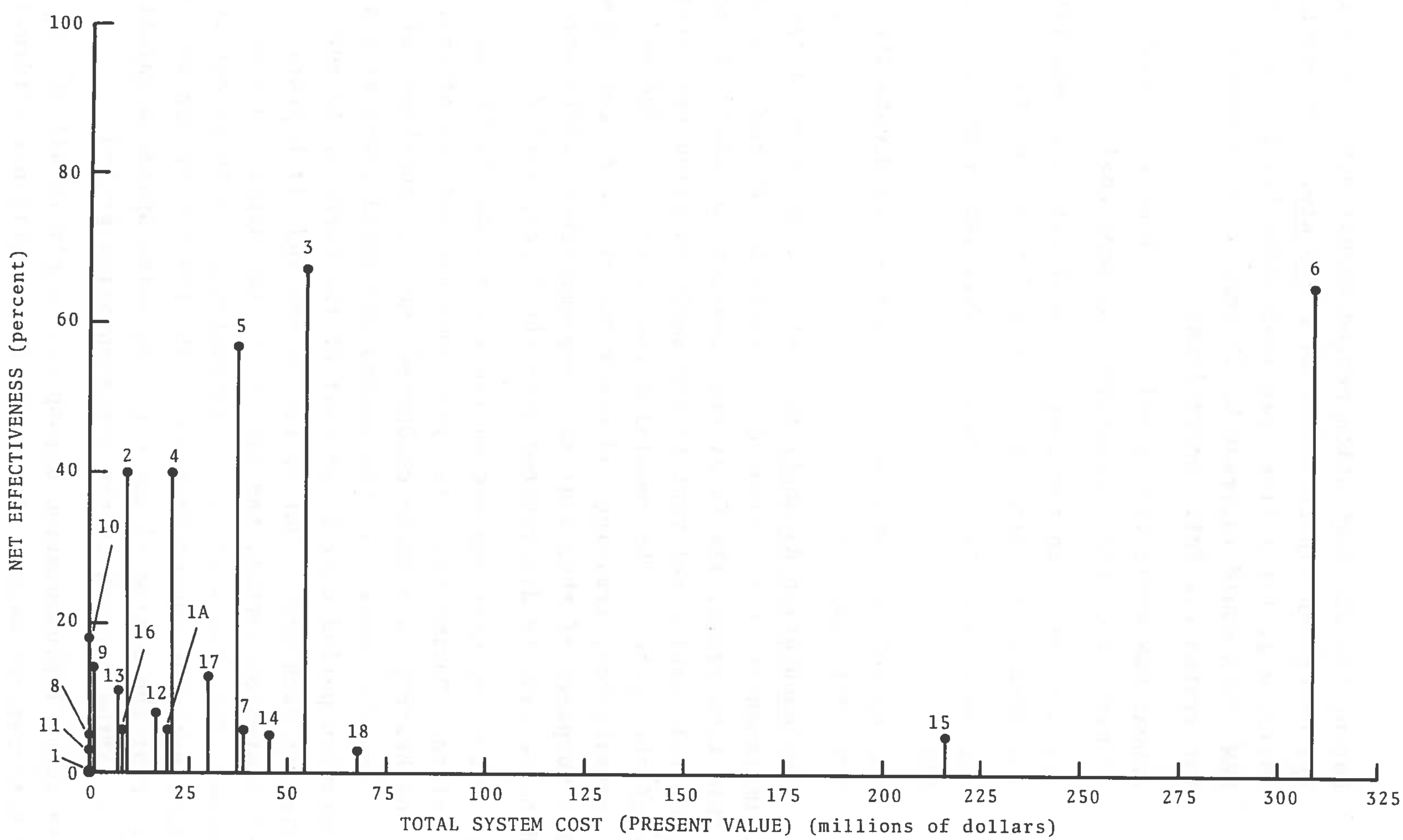


FIGURE 7-1. COST EFFECTIVENESS OF THE PROMISING SYSTEMS

(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.

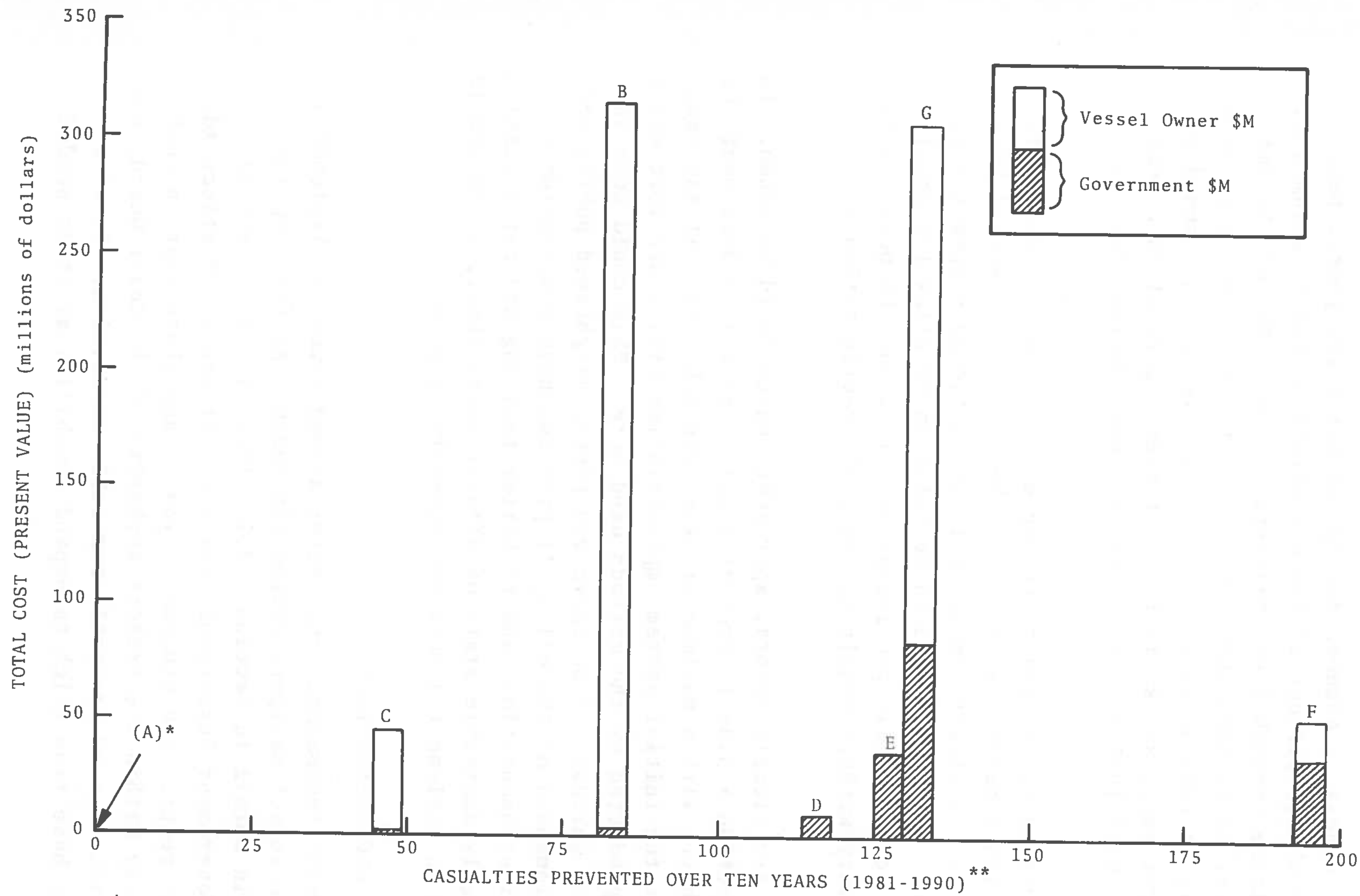
b. High Vessel/Low Government Investment - This extreme would require vessels to be outfitted with several devices; e.g., collision avoidance equipment on all large vessels, navigation alert and VHF/transponder equipments on all vessels, scanning sounders on all large tankers, and depth alerts on all 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

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),



*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

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.

quency (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.

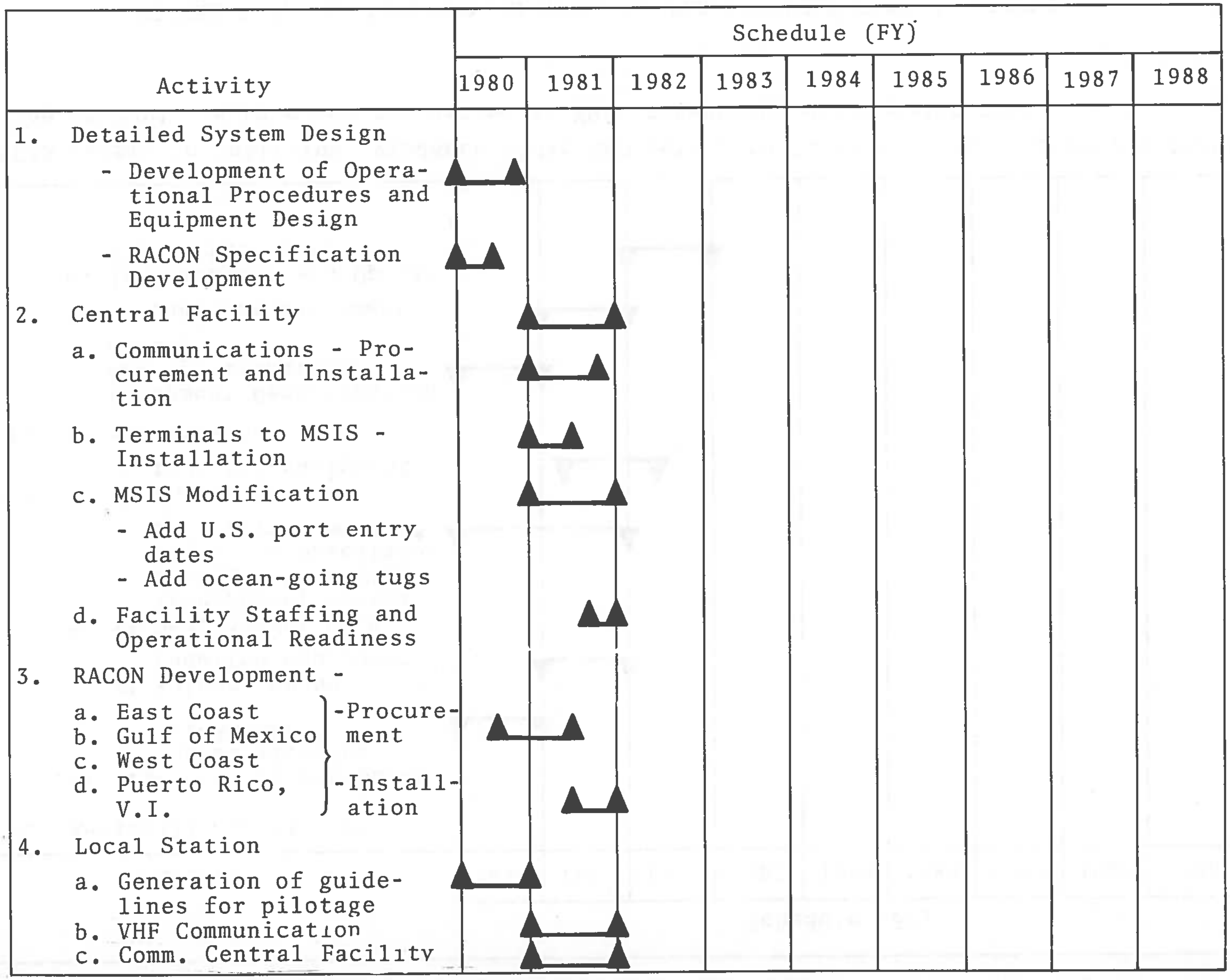


FIGURE 7-3. IMPLEMENTATION SCHEDULE FOR PASSPORT SYSTEM

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.

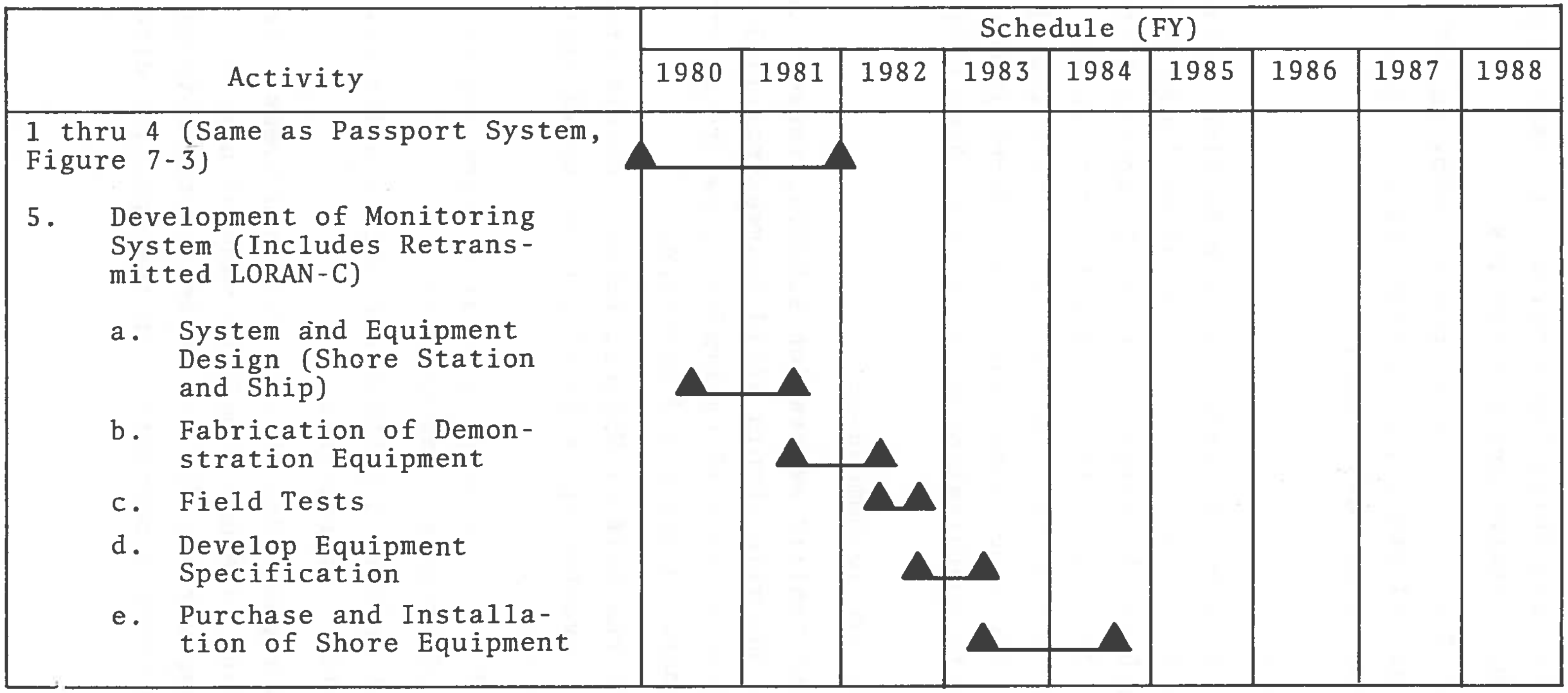

FIGURE 7-5. AUTOMATIC MONITORING SYSTEM IMPLEMENTATION SCHEDULE

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.

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.

> 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).

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.

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.

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.

b. <u>Predictable Accuracy</u> - is the accuracy of predicting position with respect to precise space and surface coordinates.

c. <u>Relative Accuracy</u> - 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. <u>Repeatable Accuracy</u> - 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.

<u>Potential Effectiveness</u> - 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.

<u>Probability of Prevention</u> - 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.

<u>RACON</u> - 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.

<u>Radiodetermination</u> - the determination of position, or the obtaining of information relating to position, by means of the propagation properties of radio waves.

<u>Radiolocation</u> - radiodetermination used for purposes other than navigation.

<u>Radionavigation</u> - radiodetermination used for the purposes of navigation, including obstruction warning.

<u>Ramming</u> - the accidental collision of a vessel with a fixed object.

<u>Routing (or Routeing)</u> - 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.

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