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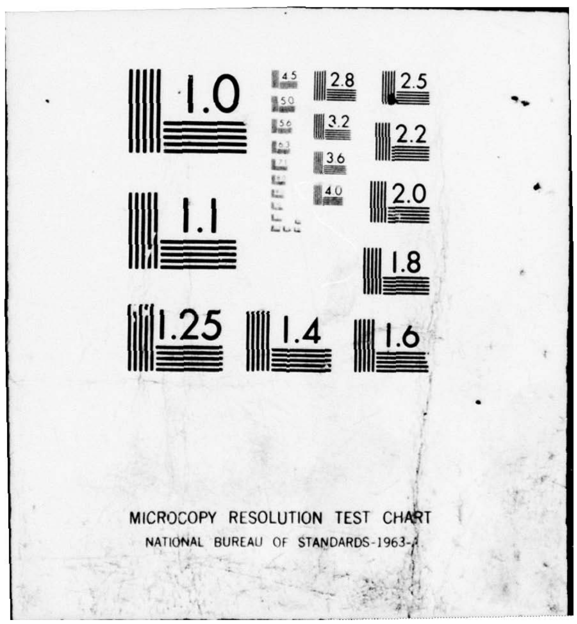
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REPORT NO. CG-D-55-78

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OFFSHORE VESSEL TRAFFIC MANAGEMENT (OVTM) STUDY
Volume I — Executive Summary

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

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FINAL REPORT

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Prepared for

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

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NOTICE

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

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16. Abstract

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 1,000 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 LCDR 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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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

Approximate Conversions from Metric Measures

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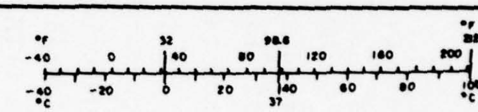

1. INTRODUCTION

The purpose of the Offshore Vessel Traffic Management (OVTM) study is to determine the measures which offer some promise of reducing the occurrence of oil tanker and tank-barge casualties in waters offshore of the United States. The need for improvements in marine safety to prevent oil pollution of the U.S. offshore waters was highlighted by a series of tank vessel casualties in the winter of 1976-77 which included the grounding and total loss of the fully loaded Argo Merchant off the East coast. This rash of tank vessel oil spills together with the continuing growth in oil imports to the United States prompted the President to issue several Presidential Initiatives in March 1977 to the Secretaries of the U.S. Departments of Transportation and Commerce to perform studies and take actions necessary to prevent them.

This study addresses the causes of and alternative measures for prevention of three types of tanker casualties: (a) groundings (including strandings), (b) collisions between vessels, and (c) rammings of offshore oil platforms and aids-to-navigation. The vessels of interest include tankers and tank-barges larger than 1,000 gross tons. The geographical area of interest includes the waters from the U.S. coast out to 200 NM around the contiguous 48 states, Puerto Rico, the Virgin Islands, Hawaii, and Alaska except the area north of the Aleutian Islands. Excluded from the study are all ports, harbors, inland waters, and offshore channels that are less than 1,000 feet wide.

An estimated 121 casualties pertinent to this study occurred during the 6-year study period, July 1971 through September 1977. Seventy-eight cases, which were documented with detailed casualty investigation reports, were analyzed for causal determination and assessment of system alternatives.

2. CONCLUSIONS

The major conclusions of the study are:

o Tank vessel collisions and groundings that occur in U.S. offshore waters account for approximately nine percent of the total of these types of casualties in all U.S. waters. However, this figure does not reflect the propensity for "massive"* oil spills in offshore waters. For example, in 1976, offshore oil spillage reached 40 percent of the total, almost entirely due to the grounding and subsequent breakup of the Argo Merchant.

o The casualty that results in a "massive" oil spill is very rare; only one, the Argo Merchant, occurred in U.S. offshore waters in the six-year study period. Massive spills due to collisions, groundings and rammings (of offshore oil production/transfer facilities) have occurred worldwide at the average rate of three per year. However, the potential for massive oil spills in U.S. offshore waters does exist, and will likely increase with the projected increases in the volume of tanker traffic and in the sizes of tank vessels. Measures being initiated (e.g., dual radars and LORAN-C equipment requirements) will reduce the potential for casualties resulting in massive oil spillage.

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

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

* "Massive" oil spills are defined herein as those exceeding 1,000,000 gallons, and "major" spills are defined as those exceeding 100,000 gallons (see Section 5.1).

o The majority (over 90 percent) of offshore casualties occur within 50 NM of the shore; the greatest distance from shore of any casualty studied is 108 NM. Therefore, there is little justification for any system to provide surveillance coverage out to 200 NM.

o Traffic density is not a factor in the large majority of casualties. It is rare that a collision involves a third independent vessel. In 90 percent of the groundings only the vessel that grounded is involved in the events leading to the incident. The rammings (of oil platforms) have involved only the vessel which rammed the oil platform.

o 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 <u>all</u> available navigation information, (3) inadequate pilot boarding procedures for 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.

o The major causes of collisions are: (1) failure to establish vessel-to-vessel communications and to agree on a plan for passing, (2) poor seamanship, or what may 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) poor execution of an agreed upon or standard passing maneuver.

o The major causes of rammings (of offshore oil platforms) are: (1) failure to maintain proper lookout, (2) poor navigation practice: failure to use all navigation information available on the vessel to determine the vessel's position, and (3) error in judgment or lack of attention by the conning officer in maneuvering the vessel.

o Tugs with barges used in the transport of oil represent an important oil pollution risk. There are many of these vessels carrying large quantities (over 100,000 gallons) of oil or petroleum products, with some traveling long distances; e.g., from the Gulf of Mexico to the northeastern U.S. ports. These vessels often lack adequate navigation equipment and sufficient staffing, certification, and training of the crew for such voyages on the open ocean. Some of the newer barges have capacities as large as 7.5-million gallons and have drafts of 30 feet; despite this, they are exempt from the equipment and certification regulations placed on the tankers.

o Pilot transfer operations in some areas are inadequate for the needs of tank vessels navigating in bay and port entrances; examples are Delaware Bay and Guayanilla Bay, Puerto Rico.

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

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

3. RECOMMENDATIONS

The recommendations resulting from the study are:

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

o Install RACONs on carefully selected buoys or towers to identify positively the entrance to harbors, traffic lanes, and fairways, and other hazardous, frequently traveled offshore areas; example locations are the approaches to Delaware and Chesapeake Bays, and fairway intersections in the Gulf of Mexico.

o Perform a study of pilotage practices in Delaware and Guayanilla Bays. Over 40 percent of all groundings analyzed in the study have occurred in these two bays.

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

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

o Implement the "vessel passport" system described in Section 7. The costs to the user and the Government are low if existing communications systems are used. This is a "core" system, and is expandable as the need for it develops. In approximately three years, a study should be made to assess the needs, benefits, and costs of upgrading the capability of the "vessel passport" system.

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

o 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 with those for tank ships. Such vessels should also be required to operate within any offshore vessel traffic management system required of tank ships.

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

o Maintain active involvement in the development of new techniques and systems. The U.S. Coast Guard should initiate more feasibility, design, and demonstration programs of promising systems and techniques in offshore navigation and communications to (1) upgrade continually their capability for reducing the potential for oil-polluting vessel casualties and (2) provide valuable technical inputs into national and international maritime safety programs.

o Study the applicability of the "recommended" system alternatives proposed herein to other Coast Guard mission areas.

4. STUDY APPROACH

The study approach focuses on analyzing actual casualty reports of tank vessel incidents to determine the causes of groundings, collisions, and rammings, and on using this causal information to develop alternative systems and techniques for their prevention. A flow chart of the study tasks is shown below.

The primary source of data used in the casualty analysis is the U.S. Coast Guard Merchant Vessel Casualty Report (MVCR) data base covering the period from July 1971 through September 1977. This data base includes detailed casualty reports from the vessel master and U.S. Coast Guard investigator. Additional data have been obtained from the Lloyd's Weekly Casualty Reports.

The total number of groundings, collisions and rammings that have occurred in U.S. offshore waters during the 6-year study period is estimated at 121.* From the detailed casualty records in the MVCR data base, the following 63 tank vessel cases are available for detailed analysis: 47 groundings, 10 collisions, and 6 rammings. However, 15 additional casualties involving non-tank vessels over 5,000 gross tons have been used in the analysis of causative factors; i.e., 8 groundings, 7 collisions, and 0 rammings. The total data base for causal analysis is 78 incidents.

Statistical analysis techniques are not suitable for a data sample of this small size; therefore, each case has been examined in detail for causative factors and assessment of alternative systems.

Early in the study, about 30 systems** were identified as holding some potential for reducing casualties. These systems

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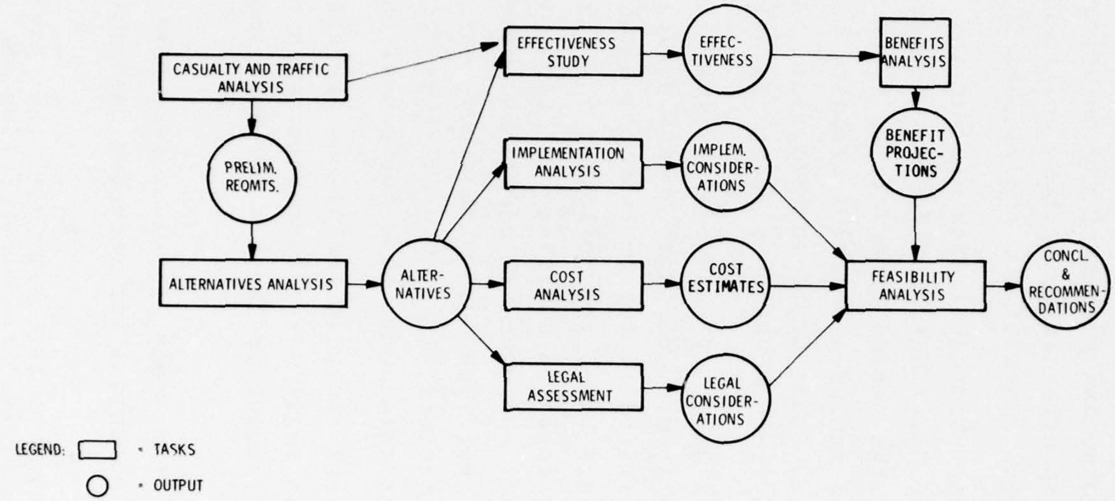
*An exact count of the casualties that have occurred in the U.S. offshore waters out to 200 NM during the study period is impossible since the U.S. Coast Guard casualty file does not usually include foreign-flag casualties outside of 3 NM, and Lloyd's Reports often lack detailed information on casualty location.

**A system is defined as any combination of rules, procedures, equipment hardware/software, and operating personnel.



OVTM STUDY TASKS

range from simple operating procedures to complex surveillance techniques. From these systems, 34 operational features* are extracted which pinpoint the system elements that are operationally useful in preventing casualties. Each operational feature is evaluated against each casualty in the data base to determine the most useful features. From the results of this assessment, 18 promising systems have been identified, and subjected to a thorough evaluation. They are evaluated not only on their usefulness and effectiveness in preventing casualties, but also on their costs, geographic coverage, operational ease, user acceptance, reliability, state of development, implementability, and Government action required.

Evaluating the 18 systems against the data base casualties does not account for the preventive measures which will soon be in effect, and which will substantially reduce casualties without other systems being implemented. Therefore, a Baseline System has been defined to provide a reference point for the evaluation of the various systems. The effectiveness of other systems is measured by the extent to which casualties will be prevented beyond those prevented by the Baseline System which has an effectiveness of 23 percent. The Baseline System includes all currently required equipment, rules, and procedures plus dual radars on board vessels over 10,000 gross tons, and LORAN-C, or equivalent navigation equipment, on board vessels over 1,600 gross tons.

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*An operational feature is defined as an element of a system. A system may consist of one or more operational features, some of which are included in several systems. Also, some operational features are independent (they stand alone), while others are dependent on other features to perform their functions.

5. FINDINGS

The major findings obtained from the casualty analysis can be divided into three groups: (1) the offshore oil spillage problem in general, (2) the characteristics of casualties, and (3) the factors and causes of casualties.

5.1 OFFSHORE OIL SPILLAGE PROBLEM

o During the 6-year study period a total of 8 oil spills have resulted from the 63 offshore tank vessel casualties for which detailed casualty descriptions and documentation are available. Five spills are "major," exceeding 100,000 gallons, and of them, one is "massive," exceeding 1,000,000 gallons. Therefore, the U.S. average rate of major oil spills has been 0.83 per year, and the occurrence of a massive spill has been 0.17 per year. The oil cargo and oil spillage by casualty and vessel types are given below:

TANK VESSEL CASUALTY DATA BASE

Type of Casualty	No. of Incidents	No. of Loaded Vessels	No. of Spills	Oil Cargo (K Tons)*	Oil Spillage (K Tons)*
Grounding	47	36	7	1763.0	31.2
Collision	10	6	0	81.3	0.0
Ramming	6	1	1	54.0	2.7
Total	63	43	8	1898.3	33.9

*A ton is approximately 290 gallons.

o Traffic and casualty projections (see Section 6) seem to indicate that the potential for larger and more frequent massive oil spills in U.S. offshore waters due to tank vessel casualties will increase.

o Worldwide oil spill statistics indicate that an average of 3 to 4 spills greater than 6-million gallons have occurred per year over the 8-year period of 1969 to 1976.

o The damage caused by an oil spill varies greatly depending on the type of petroleum, the weather and sea conditions, and the location of the casualty relative to beaches and fishing areas. For example, studies performed on the Argo Merchant spill of 7.5-million gallons of crude oil in the middle of the rich Georges Bank fishing area off the Massachusetts coast have found no measurable damage to either the fish/marine population or the nearby shore. The wind and wave motion in this instance has pushed the oil spill farther out to sea where it has dispersed.

o As indicated in the table above, groundings present a greater threat of oil spillage in offshore waters than collisions and rammings. Also, groundings usually cause more pollution and environmental damage because a higher percentage of them occur near shore (see Section 5.2).

5.2 *CHARACTERISTICS OF CASUALTIES*

The casualty analysis has resulted in the identification of a number of important characteristics which help provide a general understanding of groundings, collisions, and rammings offshore.

o Vessel Size: Tankers involved in casualties in U.S. offshore waters are usually under 75,000 gross tons, and tank-barges generally below 5,000 gross tons.

o Vessel Types: The percentage of offshore tank vessel collisions involving tankers is about equal to that involving tank-barges. On the other hand, tankers are involved in 90 percent of the data base groundings.

o Vessel Flag: All tank-barges listed in the casualty file are of U.S. registry, as is expected, since the presence of foreign-flag tank-barges is rare in the area under study. Analysis of tanker casualties in U.S. offshore waters reported in Lloyd's Weekly Casualty Reports reveals a 1:3 ratio between U.S. and foreign-flag vessels. However, a significantly higher proportion (i.e., 1:1) of U.S. tankers appears in the U.S. Coast Guard's casualty files because many foreign-flag casualties beyond 3 NM are not reported since there is no legal requirement to do so.

o Daylight and Visibility: Darkness and low visibility are important factors in the casualties studied, especially collisions. Overall, 88 percent of the collisions, 69 percent of the groundings, and 67 percent of the rammings have occurred either after sunset or in poor visibility.

o Seasonal and Yearly Variations: A study of the seasonal variation of casualties indicates that groundings are uniformly distributed with a small springtime peak, while collisions peak strongly in the spring and fall, and rammings in the spring. Over the six-year study period, there is a small variation in casualties per year and in casualty type per year.

o Locations: Groundings have occurred most often in the Gulf of Mexico, off the U.S. east coast, or the coast of Puerto Rico, with the "hot spots" being the entrances to Delaware Bay and Guayanilla Bay, Puerto Rico. Over 75 percent of the groundings have occurred within 5 NM from shore, and over 95 percent within 25 NM from shore. A majority of collisions have occurred in the Gulf of Mexico and off the U.S. east coast. Fifty percent of the collisions have occurred within 5 NM from shore, and 80 percent within 25 NM from shore. All rammings have taken place in the Gulf of Mexico between 12 and 100 NM from shore. (Most U.S. oil platforms are in the Gulf of Mexico.)

o Types of Collision Encounters: Fifty percent of collisions involve an end-on meeting, 30 percent an overtaking, and 20 percent a crossing. In over 60 percent of the cases, vessels are aware of each other more than 10 minutes before the collision. A third vessel is seldom involved in the events preceding a collision.

5.3 FACTORS AND CAUSES OF CASUALTIES

The factors and causes of the 78 casualties subjected to causative analysis are summarized below.

- In general, the causes of the casualties are related to human errors rather than problems caused by faulty equipment.

- In the case of groundings, the most common causative factor is navigational error (i.e., wrong position) which occurs in 72 percent of the casualties. In 38 percent of the cases, poor navigation practice is involved. Other factors are conning errors (i.e., poor judgment in maneuvering) in 18 percent of the cases; and errors in not waiting for a pilot, or waiting in an unsafe area, in 13 percent. Some of these groundings involve more than one of these major factors.

- The major factor in collisions is a lack of agreement in the passing maneuver, which occurs in 41 percent of the casualties. Other factors are one vessel not knowing the location of the other (in 24 percent), and poor performance of standard passing procedures (in 18 percent of the cases).

- The leading causative factor in rammings is failure to maintain proper lookout on the vessel, which has been found in 50 percent of these casualties. Other factors are conning errors (in 33 percent), and navigational errors (in 17 percent).

6. CASUALTY PROJECTIONS

The casualties found in the U.S. Coast Guard and Lloyd's data bases for the six-year study period are a matter of historical record. A casualty scenario for the 1980's is projected to indicate the expected future severity of the problem and to estimate the effectiveness of the alternative solutions (Section 7) in preventing future incidents.

The timeframe chosen for projecting casualties is the 10-year period from 1981 through 1990. As a first step, projections of tanker traffic have been developed from a world petroleum network model used by the Massachusetts Institute of Technology.* Three-percent annual growth in the demand for oil in the United States and introduction of deep draft terminal facilities in the Gulf (LOOP) in 1980 are assumed. Using 1977 as the base year, tanker traffic is projected to increase by a factor of 1.13 by 1981 and 2.47 by 1990. In the next step, a gross prediction of future casualties is made by applying the tanker traffic increases to the casualty rates in effect during the study period. It is assumed that (1) groundings will increase linearly with tanker traffic, (2) collisions will increase as the square of merchant vessel traffic, and (3) rammings will increase as the product of merchant vessel traffic and the number of oil platforms.** This step is based on the implicit assumption that the same pattern of causative factors which have prevailed during the 1972-1977 study period will continue to occur, and with the same percentage of tank vessel trips resulting in a casualty.

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*Devanney, J., "Tanker Spills, Collisions and Groundings," MIT, Cambridge, Massachusetts, Under Contract: DOT-TSC-1481, May 1978. Material on file in the Communication Branch, Transportation Systems Center.

**Due to the highly speculative nature of offshore drilling exercises, no increase in oil platform deployment is assumed.

Adjustments are then made to account for changes and safety improvements which are expected to be in effect during the future period, independent of techniques presently under evaluation. Specifically, it is assumed that: (1) the Baseline System will be 40 percent in effect by 1980 and 100 percent by 1985, and (2) the casualties per trip of tankers engaged in Alaskan oil trade will be one-half that of the base period average, due to the superior condition of these vessels, the existence of Vessel Traffic Services in Valdez, Puget Sound, and San Francisco, and other independent safeguards in effect.

After making these adjustments, the number of tank vessel casualties likely to occur in U.S. offshore waters during the 1981-1990 period is projected as follows: 196 groundings, 65 collisions, and 10 rammings. Of course, the implementation of any independent improvements in marine safety, not foreseen or evaluated in this study, can be expected to reduce these casualty projections to some extent.

7. ALTERNATIVE SOLUTIONS

Of the 30 systems considered early in the study, 18 are effective enough to warrant detailed evaluation. Some of these system concepts have been modified to incorporate desirable operational features. The 18 promising systems are analyzed considering training and workload implications, availability of equipment, state of development, vessel and Government costs, U.S. Coast Guard actions required, and individual estimated effectiveness.

Measures in progress which are expected to be in effect before 1985 include requirements for LORAN-C, or equivalent navigation gear, on all vessels greater than 1,600 gross tons, and dual radars on all vessels greater than 10,000 gross tons. These measures are incorporated into the Baseline System which will be in existence in addition to each of the other systems being considered. The overall measure of effectiveness used in the study, called net effectiveness, accounts for the simultaneous existence of the Baseline and the system under consideration. It incorporates assumptions concerning the availability of the system, and provides a measure of the additional effectiveness of each system beyond that of the Baseline System alone. The costs associated with each system are present value costs, calculated using a 10 percent discount rate. The costs include research and development (R&D), purchase costs of equipment, and annual operation and maintenance (O&M) costs through 1990.

The 18 systems and their associated effectiveness and cost estimates are shown below. The Baseline System alone has an effectiveness of 23 percent. The vessel passport system has the highest effectiveness-to-cost ratio of the active* systems. The other active systems achieve higher effectiveness, but at an increase in cost. The passive* systems either call for Government action or require on-board vessel equipment. Voluntary purchases of on-board equipment and additional measures taken by the U.S. Coast Guard, such as tighter licensing standards, can be expected to reduce future casualties beyond any active system implemented.

*"Active" systems require U.S. Coast Guard participation in their day-to-day operations, while "passive" systems do not.

SUMMARY OF PROMISING SYSTEMS

SYSTEM	NET EFFECTIVENESS* (PERCENT)	TOTAL VESSEL COSTS** (MILLION $)	TOTAL GOVERNMENT COSTS** (MILLION $)	TOTAL SYSTEM COSTS** (MILLION $)
1. Baseline	0*	0	0	0
1A. Extended Baseline***	6	0	19.2	19.2
2. Passport System	40	0	9.5	9.5
3. Auto Monitoring	67	18.8	35.2	54.0
4. DF Surveillance	40	0	20.5	20.5
5. Radar Surveillance	57	0	36.2	36.2
6. Satellite Surveillance	65	223.5	84.5	308.0
7. Training	6	37.8	0	37.8
8. Traffic Separation	5	0	0	0
9. Aids-to-Navigation	14	0	0.5	0.5
10. Pilotage	18	0	0	0
11. Equipment Standards	3	0	0	0
12. Navigation Alert	8	15.7	0	15.7
13. Depth Alert	11	6.2	0.5	6.7
14. Scanning Sounder	5	43.0	1.3	44.3
15. Collision Avoidance Aid	5	215.1	0	215.1
16. Radar Perimeter Det.	6	7.7	0	7.7
17. VHF/Transponder	13	28.9	0.9	29.8
18. Interrogator/ Transponder	3	66.5	0	66.5

*Net effectiveness is over and above the Baseline which has an effectiveness of 23 percent.
**Net present value through 1990.
***Extended Baseline consists of extending LORAN-C coverage to Puerto Rico and the Virgin Islands.

7.1 SYSTEM DESCRIPTIONS

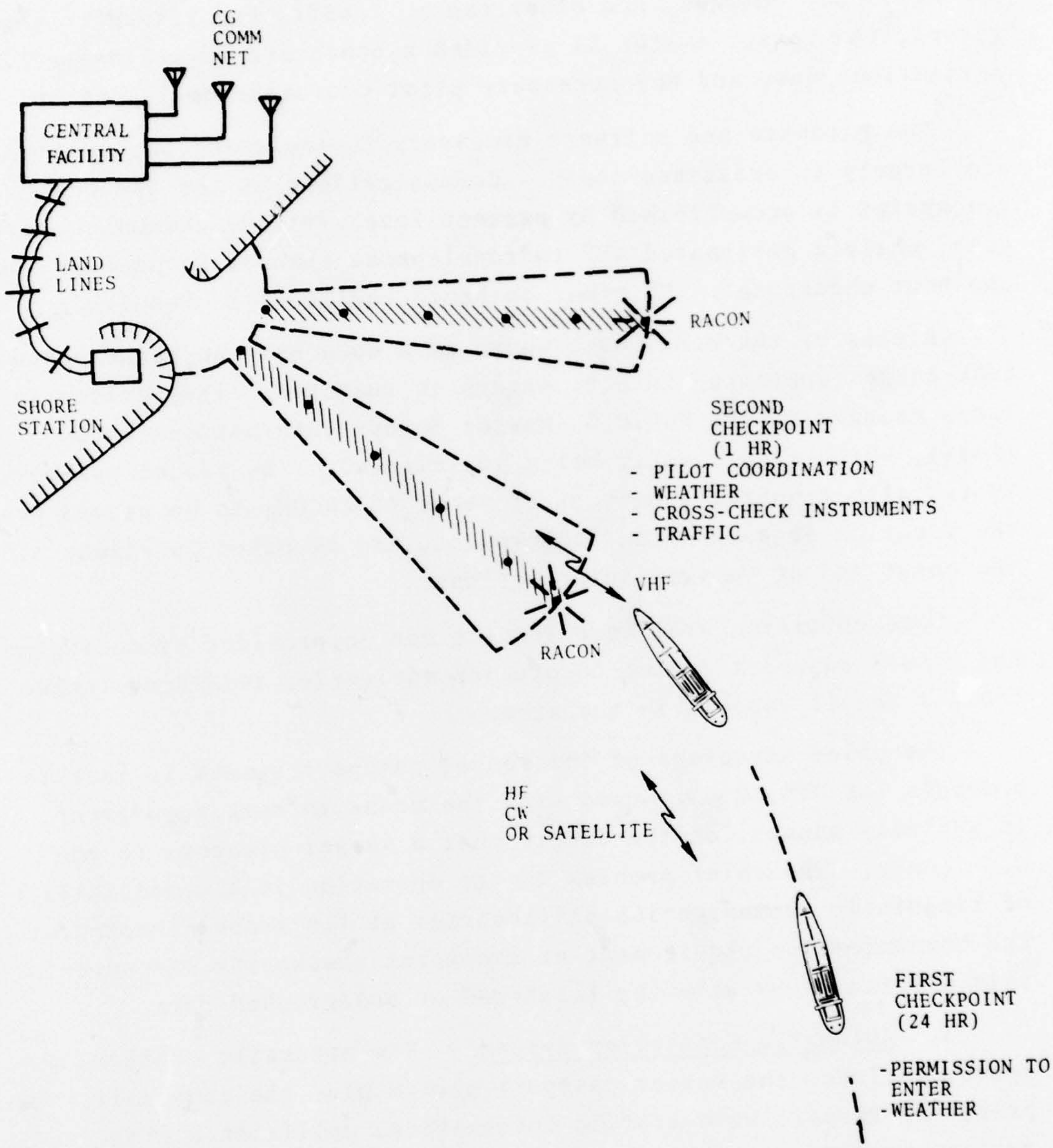
The following paragraphs briefly describe the 18 systems, and their chief capabilities and limitations.

1. Baseline System -- The Baseline System is the reference against which other systems are assessed. This system includes all current equipment, rules, and procedures plus LORAN-C, or an equivalent navigation system, on all vessels over 1,600 gross tons, and dual radar systems on all vessels over 10,000 gross tons. It is assumed that the Baseline System will be fully implemented by 1985. However, it does not include LORAN-C coverage of Puerto Rico and the Virgin Islands area because there are no present plans for this addition. The Baseline System is assumed to be operating simultaneously with all other systems discussed below.

1A. Extended Baseline System -- The Extended Baseline System includes the expansion of LORAN-C coverage to the Puerto Rico and Virgin Islands area plus all of the Baseline System.

2. Vessel Passport System -- A vessel passport system is the simplest form of an active system; i.e., one involving shore-based personnel. This system is highly oriented toward reducing accidents, especially groundings and rammings, by restricting the movements of substandard vessels: i.e., by not allowing vessels bound for U.S. ports and with unacceptable histories into territorial waters; by placing conditions on the entry into (or departure from) ports for vessels lacking proper certification, proper charts, or having equipment defects or outages; by issuing helpful advisories on weather, currents, and special conditions; and by coordinating pilot transfer procedures.

The operation of the system centers around two checkpoints (refer to figure below): vessels bound for U.S. ports are required to check into the system at about 24 hours prior to entrance into internal waters (within a tolerance of about 6 hours, earlier or later), and again at another point approximately 1 hour prior to entry. At the first checkpoint, permission to enter port is granted



VESSEL PASSPORT SYSTEM

or denied,* and any special conditions are placed on entry at that time. At the second checkpoint, special bulletins concerning weather, buoy outages, and other tanker traffic are issued to the vessel, the vessel master is provided a benchmark to calibrate his navigation gear, and any necessary pilot coordination is set up.

The hardware and software necessary to implement the system are largely in existence today. Communications at the 24-hour checkpoint is accomplished by present long distance communications gear, while a designated VHF radiotelephone channel is used at the one-hour checkpoint. No other on-board equipment is required.

Access by the U.S. Coast Guard to a data base on tankers and tank-barges operating in U.S. waters is required. This exists in large measure in the U.S.C.G. Marine Safety Information System (MSIS), which is presently being implemented. The vessel passport system also requires a network of about 40 RACONs to be placed near the location of each second checkpoint, and at other locations along the coast and at fairway intersections.

Some collision avoidance service can be provided by modifying the vessel passport system to provide advisories regarding tanker traffic to all vessels in the area.

The chief advantage of the vessel passport system is that it provides the U.S. Coast Guard with the means to make a judgment, in a timely manner, on the danger that a vessel presents to the U.S. coast. The chief problem in its operation is the possibility of linguistic communication difficulties at the second checkpoint. The communication requirement at the first checkpoint circumvents this difficulty by allowing teletyped or telegraphed data.

3. Automatic Monitoring System -- The automatic monitoring system includes the vessel passport system plus the capability of providing vessels with traffic information, collision alerts, and

*It is anticipated that 80 to 90 percent of the arriving tank vessels will be granted unconditional entry, and that this will approach 95 percent as vessel owners and officers become familiar with the system. The total time spent by a vessel's crew in meeting the requirements of the system on a routine voyage is expected to be less than 15 minutes -- a very minimal burden.

grounding alerts. A data/voice communications set, which interfaces with the electronic navigation instruments, gyro compass, and ship's log, is required on board all commercial vessels. The communications set provides the shore station with automatic updates of position, course, and speed. No action is required of the vessel master other than turning on the equipment. The shore station keeps track of all vessels, and plots courses and projected positions using data/voice communications equipment, computers, and computer driven displays.

4. Direction Finding (DF) Surveillance System -- Rather than being a separate system, DF surveillance is a capability which can be added to the passport or automatic monitoring systems. It utilizes two DF stations at each port to determine the position of vessels operating within 20 NM of the port. When the VHF transmitter on board a vessel is turned on, two bearings are established by the DF stations which the shore operator can plot to determine position. (This procedure can be automated.)

This system has the advantage of providing an inexpensive way of checking a vessel's position from shore. It is somewhat limited in range and accuracy.

5. Radar Surveillance -- Radar provides the shore operator with a plan-position-indicator (PPI) display of vessels, buoys, and terrain features within the range of the radar, with a refresh rate of about once every four seconds. It requires no equipment on board the vessel, but does not provide identification of targets.* Due to its cost and limited range (20-40 NM), it is not a viable candidate to provide wide surveillance coverage, and is considered only as a backup to a vessel passport system near ports that have special needs justifying its use.

6. Satellite Surveillance -- Satellite systems offer high accuracy and nearly global coverage. In a typical system, a shore station sends an interrogation signal, selectively addressed and including a time identifier, to a master satellite, which

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

retransmits it to the selected vessel. Equipment on board the vessel recognizes and decodes the signal, adds vessel identification, vessel data, and time code, and retransmits the signal back to the shore station through the master plus one additional satellite. The shore station computer then uses the measurements of time differences in the transmitted and received signals over the two different paths, together with the known satellite locations, to determine the vessel's position.

Position information at the shore station is of little use without reliable communication with the vessel. To take full advantage of the wide coverage of the system, equivalent communications coverage is required, such as via satellite using the same receiver terminals. Satellite systems hold promise of high effectiveness, but at a cost that may be prohibitively high.

7. Intensive and Periodic Training -- As a "system," training involves 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, and the critical judgments involved in developing training requirements must be performed by experienced mariners. Simulators offer a chance to experience "dangerous" conditions without the risk of accident, and can be an effective training aid. The major problem with training recommendations is that they require international agreement to be effective. Recent developments have been encouraging however.

8. Expanded Traffic Separation Schemes -- Traffic separation schemes are currently in use at several major ports, and are effective in collision prevention.* While the casualty analysis does not indicate the need to establish more of them, there are three areas where improvements can be made: in fairways, adjacent to channels and traffic lanes, and in narrow passageways where alternate routes are available. While such improvements are not costly, they are hampered by the need for coordination with the U.S. Army Corps

*In the six-year study period, there have been no end-on collisions and only one crossing collision in traffic lanes.

of Engineers and adoption by IMCO.

9. Improved Aids-To-Navigation -- The present system of aids-to-navigation, maintained by the U.S. Coast Guard, is probably the most comprehensive of its kind in the world. Specific areas for improvement have been identified in the study, notably in buoy identification, buoy location and monitoring, and the need for more RACONs. Such improvements will benefit the prudent mariner, but without measures to ensure their use, cannot by themselves guarantee a reduction in casualties.

10. Pilot Transfer Procedure System -- The present procedures by which a pilot is contacted and a time and location arranged for pilot boarding has serious shortcomings in a few areas. The system of rules and procedures needs to be strengthened, at least for tank vessels, to limit their entry to specified safety zones until a pilot has boarded. The main problem is that each port has unique ocean bottom topographies, and unique traditions, making it difficult to formulate National standards. In addition, most such pilotage requirements are established under state, rather than Federal, authority.

11. Improved Equipment Standards -- A system that incorporates improved equipment standards essentially adopts the practices of a prudent vessel owner, and tries to enforce them on all vessels bound for or departing from a U.S. port. These practices include: purchase of equipment meeting a recognized standard, maintaining a comprehensive spare-parts supply, preventive maintenance, and one member of the crew capable of making at least simple repairs. The first two measures can be readily established by occasional inspections. The third and fourth are easily avoided by any vessel owner trying to cut costs.

12. Processor-Aided Navigation Alert System -- With 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. For example, deviation from preselected tracks can be

continuously displayed, cross-checking can take place between independent navigational instruments (e.g., Omega and LORAN-C) and an indication provided if the differences are excessive, set and drift can be calculated and displayed, and traffic lanes and even depth sounder readings can be superimposed on radar displays. Alarms can be designed to sound if the vessel is off course.

Capabilities like these will be available at reasonable costs within the next few years. The chief concern is that capabilities will become widely used before the subtleties of use have been adequately assessed, and appropriate equipment standards determined.

13. Depth Alert -- Depth sounders are standard equipment on vessels of all sizes, are highly reliable from the point of view of availability, and they are simple to use. It is feasible to attach an alarm feature to a depth sounder, which will sound if the measured depth becomes less than a preset critical value. Without proper interpretation however, false alarms can become a nuisance. False alarms can be caused by a school of fish or even a single fish as well as by engine noise and electrical disturbances. Proper signal processing techniques must be developed and proven before this system can be used with confidence. If such techniques are developed, depth alert devices will probably be available at a low cost.

14. Scanning Sounder -- The scanning sounder is a device which allows an area on the ocean floor forward and abeam of the vessel to be mapped out. Ideally, a device such as this provides depth information out to about 0.5 - 1 NM ahead, and 1,000 or so feet to each side. It can be coupled with an alarm to incorporate the capabilities of the depth alert. This display is typically similar to a radar scope, but is somewhat more complicated in its interpretation. At present, such sounders are limited in use primarily to research and military applications, although some are used to locate fish. Scanning sounders meeting the above requirements can be very effective in avoiding shoals and thus reducing groundings, but they are limited in usefulness by their high cost, complexity of interpretation and use, and need for development in the area of signal processing.

15. Collision Avoidance Aid -- Collision avoidance aids are presently available commercially. They process radar data, identify targets, track vessels and other targets, project future vessel courses on a display, and provide a warning in case of a predicted collision. Automatic acquisition of targets is crucial to their effectiveness in offshore waters; however, not all collision avoidance aids have this capability. They are quite effective, but are slow to adjust to frequent maneuvers of other vessels. Their expense limits them to use on large vessels. This reduces their availability, and thus reduces their net effectiveness as a general countermeasure to collisions.

16. Radar Perimeter Detection Device -- The radar perimeter detection device is an adjunct to a standard on-board radar, and is designed to be a low-cost, limited capability, collision avoidance aid. It is based on the concept of guard zones, or circles with own vessel at the center. If a radar target appears within a guard zone, an alarm sounds, alerting the vessel watchstander to the presence of an echo. A particularly useful design incorporates outer and inner guard zones, each independently defined and adjustable by the operator. It does not track targets or project courses, but merely alerts the bridge of a nearby target. It is quite inexpensive, but requires the watchstander to interpret and assess the situation manually. It is also susceptible to saturation and false alarms by clutter and land echoes.

17. VHF/Transponder System -- The VHF/transponder system is an anti-collision concept developed at TSC to provide an inexpensive alternative to the interrogator/transponder system described below. It consists of a simple VHF code transmitter/receiver and an associated radar transponder. It provides the vessel watchstander with an alert and identification information when another equipped vessel approaches within a few miles. The watchstander can ascertain the corresponding radar target by manually interrogating the identified vessel. The system facilitates bridge-to-bridge communications by providing vessel identification, and can be configured

to provide the intended maneuver of the vessel as well. Thus, its chief advantage is in providing these services inexpensively, making it widely available. The chief difficulty is that it requires FCC and IMCO approval to transmit even the simple codes at VHF.

18. Interrogator/Transponder System -- An interrogator/transponder system provides a clutter-free radar-type display of all vessels in the area which are transponder-equipped, complete with identifying codes which can be displayed and used to help establish verbal radiotelephone contact. It also allows the vessel watchstander to select a target, and interrogate the vessel to ask its intended maneuvers. The U.S. Maritime Administration has developed such a system, called MRIT (Marine Radar Interrogator-Transponder).

The system works similarly to a radar. When the operator wishes to obtain information on a vessel, the all-call mode (CQ) is selected. The interrogator transmitter on board own vessel then sends a coded pulse stream which causes any transponder-equipped vessel in the area to reply with its own pulsed data stream, including vessel identification. The replies also paint a bright echo on the radarscope, superimposed on the normal radar echo. Other vessel data such as course, speed, size of vessel, draft, etc., can also be obtained if the interrogator transmits the proper code.

The chief advantages of the system are the clutter-free feature, the target identification, and the bridge-to-bridge communication capability, all of which are useful in avoiding collisions. Unfortunately, its higher cost precludes its installation on smaller vessels, so that it only provides protection against the larger vessels which can afford to install similar equipment.

7.2 SYSTEM STRATEGIES

Describing the systems individually and citing their costs and effectiveness estimates do not highlight the tradeoff in costs between vessel owners and the Government; nor do they consider the effect of requiring several on-board instruments or various combinations of systems. To accomplish these objectives and provide a clearer picture of the relative merits of Government versus vessel owner expenditures, seven strategies are postulated. The parenthetical numbers refer to the systems described above.

A. No Further Action -- This is the Baseline System (1).

B. High Vessel/Low Government Investment -- This strategy requires Navigation Alerts (12) and VHF/Transponders (17) on all vessels over 1,600 gross tons, Radar Perimeter Detection (16) and Depth Alerts (13) on all tank vessels, and Collision Avoidance Aids (15) and Scanning Depth Sounders (14) on all tankers greater than 10,000 gross tons.

C. Moderate Vessel/Low Government Investment -- This strategy requires Navigation Alerts (12) and VHF/Transponders (17) on all vessels greater then 1,600 gross tons.

D. No Vessel/Moderate Government Investment -- This strategy consists of the implementation of the Vessel Passport system (2).

E. No Vessel/High Government Investment -- This strategy consists of the implementation of Radar Surveillance (5) (without on-board transponders), in addition to the Vessel Passport system (2).

F. Low Vessel/High Government Investment -- This strategy consists of the implementation of Automatic Monitoring (3).

G. High Vessel/High Government Investment -- This strategy consists of the implementation of Satellite Surveillance (6).

The figure below shows the costs (present value) and total casualties prevented for the seven stategies through 1990, and takes into account the time required for implementation. It is apparent from this figure that even with large expenditures in vessel equipment, the total effectiveness of low Government cost strategies (B and C) is less than that of the vessel passport system (D). The figure also shows that for other strategies,

*Sixty-eight casualties are prevented with only the Baseline System. All projections of casualties prevented by other strategies are in <u>addition</u> to those prevented by the Baseline.

**A total of 271 casualties is projected over the 10-year period (see Section 6).

TOTAL COST (PRESENT VALUE) OF EACH STRATEGY VERSUS CASUALTIES PREVENTED increased effectiveness beyond that of the vessel passport system is achieved at progressively higher costs.

The vessel passport system emerges as the clear choice of the various system designs considered. The automatic monitoring system (F), which includes the vessel passport system, achieves a significant increase in effectiveness, but with a reduced effectiveness-to-cost ratio. It can be phased into the vessel passport system at a later date if experience justifies this action. Adoption of either of these systems can be expected to reduce substantially collisions, rammings, and groundings in the offshore waters of the United States. This reduction can be further enhanced by the several independent programs of action recommended in Section 3.

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