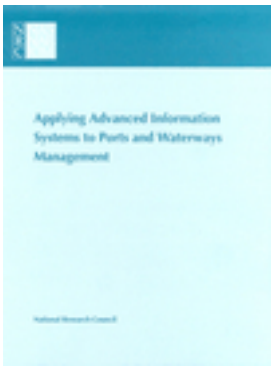

Applying Advanced Information Systems to Ports and Waterways Management

Committee on Maritime Advanced Information Systems, National Research Council

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Committee on Maritime Advanced Information Systems
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Preface

Recent advances in information technology could greatly improve the safety and efficiency of the U.S. maritime industry and the daily operations of ports and waterways. Advanced maritime information systems, singly or in combination, could ameliorate many problems faced by mariners if economic and other barriers to their implementation could be overcome. Improvements are already evident in other nations that have invested heavily in ports, advanced maritime information systems, and supporting infrastructures, leaving the United States at a growing disadvantage.

The Committee on Maritime Advanced Information Systems was established under the auspices of the Marine Board of the National Research Council to identify systems and their infrastructures that could promote safe and effective vessel transits through U.S. ports. In 1996, the committee released an interim report on a variety of issues related to the U.S. Coast Guard's Vessel Traffic Services Program that set the stage for studies of additional safety and waterways management systems, as well as issues related to the efficiency of maritime commerce and the movement of cargo through U.S. ports.

In this final report, the committee has attempted to accomplish the following tasks:

- identify ways that advanced maritime information systems could ameliorate current shortfalls and maintain or improve environmental protection and waterway safety
- describe how those systems could minimize the costs and problems of adapting to changes in transportation and contribute to maintaining the nation's competitive position
- provide a vision of the future showing how advanced information management systems could enhance vessel safety and waterway efficiency

After collecting a substantial amount of background information from the literature and stakeholders,[1] the committee, with sponsor concurrence, decided to focus on information systems that promote navigation safety and improve vessel traffic management. Improvements in the systems offer the greatest benefits for improving U.S. port operations. The committee recognized that information systems that promote transportation efficiency are also important, but many effective systems are already in use or are under development, primarily in the private sector, to meet rigorous commercial demands for efficiency and customer service. The committee assessed these systems only insofar as they contribute to maritime safety. The committee also understands the critical role of information systems and information mapping in the context of intermodal transportation even though limitations of time and resources prevented the committee from focusing on this area.

Eleven of the original 15 committee members carried out this second phase of the study. Members were selected for their scientific, technical, economic, policy, and practical expertise. Committee members include users of maritime information systems, developers of technologies and systems, specialists in information architecture, individuals with expertise in key sectors of the maritime industry, and other stakeholders in port operations. Biographies of committee members are provided in Appendix A. The committee's work was facilitated by liaisons from the sponsoring agencies and the Marine Board.

The committee met eight times during the two-year period of this study. Individual committee members or subgroups visited 10 U.S. ports and several foreign ports where advanced information technology is used to enhance the movement and safety of vessel traffic and cargo handling operations. Since the publication of its interim report, the committee has held three meetings and two meetings of a subgroup, one in Charleston, South Carolina, and one in Seattle, Washington, to investigate existing information systems and identify critical needs for improvements or changes. The information collected by the subgroup and

[1] In this context, a stakeholder is a person or group with a vested interest in a project, proposal, or venture.

other background material are presented in the appendices to the report.

The committee received substantial assistance from a number of federal, state, and local agencies, as well as from private companies. The committee would particularly like to thank the following federal liaisons for providing essential data and advice: Michael Sollosi, U.S. Coast Guard; Frederick Ganjon and Millington Lockwood, National Oceanic and Atmospheric Administration; John Pisani, Maritime Administration; and Michael Onder, U.S. Department of Transportation. In addition, the following experts made valuable presentations to the committee: Gordon Fink, ITS America; John Allen, Sealand Corp.; William Habeck, Tie Logistics, Inc.; Roger Nortillo, Maher Terminals; Brian FitzGibbon, Atlantic Tonnage Center; Timothy Huckbody, Maersk, Inc.; Capt. Richard Softe, Puget Sound Marine Exchange; Mark Walker, Microsoft, Inc.; CDR David McKenzie, U.S. Coast Guard, Puget Sound; Robert Pavia, National Oceanic and Atmospheric Administration, Seattle; Stan Norman, Washington Office of Marine Safety; Joseph Nortz, Washington State Ferries; Douglas Ward, American President Lines; and Janice Granberg, Port of Seattle. These individuals and many others contributed to the completeness and quality of this report.

This report has been reviewed in draft form by individuals chosen for their diverse perspective and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report: Bernhard J. Abrahamsson, consultant; Larry P. Atkinson, Old Dominion University; John P. Basilotto, Texas Transportation Institute; Peter F. Bontadelli, California Department of Fish and Game; Martha Grabowski, LeMoyne College and Rensselaer Polytechnic Institute; Donald G. Iselin, U.S. Navy, retired; Warren G. Leback, consultant; and James G. Wenzel, Marine Development Associates, Inc.

While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms

AIS	automatic identification system
APA	American Pilots Association
COPT	captain of the port
DGPS	differential global positioning system
DWT	deadweight tons
ECDIS	electronic chart display and information system
FCC	Federal Communications Commission
GMDSS	global maritime distress and safety system
GPS	global positioning system
IALA	International Association of Lighthouse Authorities
ICWM	Interagency Committee on Waterways Management
IMO	International Maritime Organization
ISM	International Safety Management
ITOS	international tug of opportunity system
LA/LB	Los Angeles/Long Beach
MARAD	Maritime Administration
NDS	national distress system
NIMA	National Imagery and Mapping Agency
NOAA	National Oceanographic and Atmospheric Administration
PAWSS	ports and waterways safety system
PORTS	physical oceanographic real-time system
RNA	regulated navigation area
TEU	twenty-foot equivalent unit
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
VTC	vessel traffic center
VTIS	vessel traffic information services
VTS	vessel traffic services

Executive Summary

The future safety of maritime transportation in the United States—a major factor in the nation's international trade and economic well-being—will depend heavily on the quality of port and waterways information systems. Many formal studies, as well as informal discussions among port users, have detailed the shortcomings of existing maritime information systems and called for quick remedies. The demands for improvements are becoming increasingly urgent as only scattered, minimally funded system upgrades are made and oceanborne trade continues to grow.

Some of the most urgent needs of mariners are for accurate, real-time information about harbor and waterway conditions (e.g., water depth, weather, currents, and tides); voiceless communications systems that provide navigation and traffic data, as needed, without causing undue distractions; a consistent operating environment nationwide in terms of rules and equipment standards; effective vessel traffic management schemes that can deal with congestion and emergencies; and systems that promote quick responses to cargo spills and other hazards. The requisite technologies are available to meet all of these needs and have already been implemented in some foreign ports.

Many U.S. ports and waterways lack adequate information services, although certain elements of advanced systems are now available in some locations. Barriers to improvements in information systems include the division of responsibilities for waterways management among multiple agencies at all levels of government, a lack of coordination among the federal agencies responsible for waterways management, inadequate budgets for some critical maritime programs, the high costs of some specialized technologies, stakeholder opposition to user fees, limited access to certain key data, the incompatibility of many independently developed systems, and the absence of standards for some attractive technologies.

In this report, the second phase of a three-year study by the Committee on Maritime Advanced Information Systems of the National Research Council, a strategy is presented for overcoming the major barriers and deficiencies and providing a minimum level of maritime safety information nationwide. In this phase of the study, the committee concentrated on maritime information systems that promote safety, which is the area of greatest need. The committee did not examine in detail the relationship between navigation safety and maritime transportation efficiency or evaluate information systems that promote efficiency; the committee believes, however, that these issues deserve further attention.

PUBLIC AND PRIVATE ROLES FOR MARITIME INFORMATION SYSTEMS THAT PROMOTE SAFETY

Federal leadership, backed by input and support from the private sector, will be required to enhance maritime safety information systems. Despite the growing number and diversity of port stakeholders participating in local, regional, and national planning and other activities that affect maritime commerce, the role of the federal government is critical. Stakeholder involvement is now considered essential to the design, implementation, and operation of appropriate information systems, partly because of the unique needs of each port, but mostly because recent federal budget cutbacks have resulted in the delay or cancellation of the deployment, upgrading, and operations of some maritime safety information systems. Nonfederal support is being sought through public-private partnerships for some federally developed systems, such as the National Oceanographic and Atmospheric Administration's (NOAA) Physical Oceanographic Real-Time System (PORTS).[1]

Although growing stakeholder involvement is a positive trend, it is important to remember that the federal government has an acknowledged historical mission to ensure navigation safety. The willingness of local stakeholders to pay

[1] PORTS gathers wind, current, wave, and other data from sensors installed on buoys and transmits the information in real time to central stations and individual users. Full systems are installed in five U.S. ports.

for PORTS, for example, may not be the best measure of whether the national interest in maritime safety is being served. Only the federal government can ensure a consistent operating environment nationwide, enforce U.S. laws, and represent the United States at international standards-setting conventions.

Effective federal leadership will require improved coordination among agencies. In the past, federal allocations for waterways have not been fully coordinated among agencies, and projects have not been subjected to interagency prioritization. This fragmented approach may have exacerbated the gaps in the information infrastructure. For example, many stakeholders have suggested that the recent federal emphasis on vessel traffic services (VTS), which is the responsibility of the U.S. Coast Guard (USCG),[2] has overshadowed the long-standing need for a more basic tool—accurate nautical charts—which is the responsibility of NOAA. The key concern is that the underlying data represented on these charts (paper or electronic) be accurate, timely, and reliable.

NOAA has developed a plan to accelerate surveying and charting but predicts that, at current funding levels, it will take 25 to 30 years to eliminate the existing backlog of outdated hydrographic surveys. Moreover, NOAA can digitize only a small amount of data in a way that meets international standards for the most advanced electronic charts. Other agencies responsible for providing waterways information include the U.S. Army Corps of Engineers, which maintains federal navigation channels, and the National Imagery and Mapping Agency, which publishes *Notices to Mariners* and is responsible for several other maritime information systems.

In 1995, recognizing the need for better communications among agency programs responsible for waterways and their use, the key federal departments and agencies formed the Interagency Committee on Waterways Management. This committee offers a mechanism for coordinating federal funding priorities with regard to nautical charting; electronic charts and other systems for delivering data to users; PORTS and other systems for collecting and disseminating real-time data on weather, currents, and tides; conventional aids to navigation (e.g., buoys, lights, and markers); electronic navigation systems, such as the differential global positioning system[3]; and electronic information-exchange systems. The interagency committee, which is chaired by a USCG division chief and includes representatives of five federal departments and agencies, was formed to "identify, evaluate, develop, and promote the implementation of federal policies and programs to ensure effective management of federal waterways." One of its objectives is to coordinate overlapping functions.

[2] In general, the USCG is responsible for the enforcement of maritime law, port safety and security, providing aids to navigation, and search and rescue operations.

[3] The DGPS enables civilian mariners to fix their vessel positions very accurately by using data broadcast by the USCG to correct signals from a military radio navigation system that uses satellite transmissions.

KEY OPPORTUNITIES FOR MARITIME INFORMATION SYSTEMS TO PROMOTE SAFETY

In the committee's judgment, three types of information systems offer the greatest near-term potential to enhance overall maritime safety: hazardous cargo tracking systems, VTS systems, and automatic identification systems (AIS). A number of steps would have to be taken to maximize the benefits of these technologies, each of which is at a different stage of development.

The committee also believes the full potential of maritime information systems will only be realized if significant national attention is paid to upgrading and maintaining the underlying infrastructure including: reliable and accurate waterways data, common standards for technology, adequate training for personnel, and effective communications networks. This infrastructure is primarily a federal responsibility.

Hazardous Cargo Tracking Systems

Although petroleum and other hazardous commodities are frequently carried by vessels transiting U.S. waters, the USCG does not have an electronic information system for tracking hazardous cargo. Instead, it relies on paper records and the assistance of vessel and shipping terminal personnel. A number of port closings and other shipping delays have been caused by the difficulties in identifying cargoes from spills, fires, or other incidents. The only federal agency that currently operates an electronic cargo-tracking system, the U.S. Customs Service, does so for purposes of enhancing transportation efficiency, not safety, and is not a traditional maritime agency. These systems include electronic manifests from most cargo vessels sailing within, or planning to enter, U.S. waters.

The USCG has explored the possibility of accessing the U.S. Customs Service records on hazardous cargo, but a workable information-exchange system has yet to be arranged. The development of such a system, whether based on this data or some other mechanism, would clearly improve emergency responses to incidents on board vessels and in port terminals.

Vessel Traffic Services

The USCG is in the process of implementing a new program to meet the needs of key U.S. ports and waterways that do not have adequate VTS systems while also satisfying the concerns of local port stakeholders. Formal, objective criteria for selecting ports with the greatest need for VTS, however, have yet to be developed. Moreover, the USCG has not achieved consistency among the eight existing VTS systems it operates or among the various vessel traffic information services (VTIS) operated by a variety of other organizations (e.g., federal, state, and private entities and

combinations thereof). Mariners need—and want—a consistent operating environment internationally, which will require the establishment of uniform guidelines for both VTS and VTIS systems. The need for consistency is heightened by the prevalence of foreign vessels and crews in U.S. waters.

The effectiveness of VTS and VTIS systems would be maximized if they all provided the capabilities judged to be most essential to navigation safety and they included compatible equipment designed to the highest standards. The committee does not believe it is necessary, or even desirable, for all systems to use the exact same technological tools.

Automatic Identification Systems

AIS promises significant safety benefits, simplicity of operation, voiceless communications, and compatibility with a range of traffic management schemes (including VTS).[4] AIS enables mariners and VTS watchstanders to identify and distinguish specific vessels that otherwise appear as identical "blips" on a video display or radar overlay.[5] Another important advantage of AIS is the low cost (relative to many other technologies) of the equipment carried by participating vessels. AIS and similar systems have been used in Prince William Sound, Alaska, as well as in Canada, Sweden, and the United Kingdom. The USCG has recently initiated an AIS demonstration in the New Orleans region of the lower Mississippi River.

For AIS to be effective as a safety measure, all vessels (or at least vessels of certain sizes using specific waterways) would have to carry the same basic information systems and operate them according to uniform standards. Many port stakeholders and the USCG support universal standards and carriage requirements for AIS. The requirements could be generic, but the international character of the shipping industry and the prevalence of foreign-flag vessels in U.S. waters argue for systems that meet international standards.

[4] AIS is one of various technological tools available for, and used in, VTS installations. For example, radar and closed-circuit television, which have traditionally been used by traffic managers for the surveillance of congested waterways, do not require that vessels carry special equipment. Newer technologies, such as AIS, can provide more precise vessel identification and position information but require that vessels carry transponders.

[5] AIS consists of a shipboard transponder operating in the VHF maritime band that can automatically send vessel information (e.g., identification, position, heading, length, beam, type, draft, and hazardous cargo carried) to other ships, as well as to shore. The receiving stations can display the locations of all transponder-equipped vessels on an electronic chart or radar screen.

RECOMMENDATIONS

Recommendation 1. The Interagency Committee on Waterways Management should coordinate the efforts of the U.S. Coast Guard, the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, and the National Imagery and Mapping Agency to develop an integrated, comprehensive plan for maintaining the navigation information infrastructure for all significant U.S. ports and waterways and should solicit consistent, long-term support (public and private) to implement the plan.

Recommendation 2. The U.S. Coast Guard and U.S. Customs Service should develop a system to disseminate electronic information on hazardous cargo automatically from the Customs Service's cargo-tracking database for the purpose of improving emergency responses to spills, fires, and other incidents.

Recommendation 3. The U.S. Coast Guard should continue to move forward, in consultation with local port stakeholders, with its comprehensive national effort to implement vessel traffic services in key U.S. ports and waterways where such systems are needed. Periodic assessments of port safety should be made to keep plans up to date. The U.S. Coast Guard should also provide a uniform national system of traffic management implemented through coordinated federal vessel traffic services and locally adopted vessel traffic information services systems. Specifically, the U.S. Coast Guard should take the following steps while moving forward with the overall program:

- develop, standardize, and implement objective criteria for selecting ports to be served by federally funded vessel traffic services while upgrading existing systems and implementing new systems that are urgently needed
- develop training, certification, watchstanding, and operating standards for vessel traffic services applicable to all services regardless of whether or not they are federally operated
- as the competent authority, ensure that all shore-based vessel traffic management activities, regardless of who operates them, comply with established international standards
- facilitate communication among ports regarding lessons learned about the implementation of these systems

Recommendation 4. The U.S. Coast Guard should work expeditiously toward the implementation of international carriage requirements for electronic navigation and identification/location systems for all major vessels using U.S. ports and should continue to take expeditious actions to provide communications frequencies to ensure that automatic identification systems are internationally compatible.

1

Need for Improved Navigation Information Systems

The United States has a compelling national interest in maintaining the safety and efficiency of its ports and waterways. The nation's global competitiveness and domestic prosperity depend in large measure on the degree to which it can accommodate waterborne trade and ensure safe and efficient marine transportation. Many maritime safety initiatives have been launched in recent years, both in the United States and abroad, including a phased-in requirement for double hulls on oil tankers and targeted, comprehensive inspections of potential high-risk vessels by the U.S. Coast Guard (USCG). In addition, significant changes have been made in the culture of the shipping industry, as evidenced by the recent adoption of the International Safety Management (ISM) Code [1] by the International Maritime Organization (IMO).[2] These efforts are expected to improve maritime safety, and evidence suggests that they already have (NRC, 1994a). In addition, numerous initiatives to enhance trade efficiency have been pursued by the federal government (ITO6 Task Force, 1996) and the shipping industry (Aylward, 1996).

Despite this progress, a number of factors still contribute to persistent safety risks. For example, human error, a cause of 80 percent of maritime accidents (USCG, 1995a), remains a difficult problem to overcome. Concerns have also been expressed about the aging of commercial fleets and recurring anecdotal reports of substandard foreign-flag ships and crews (NRC, 1994a). Most of the deep-ocean commercial traffic in U.S. waters consists of foreign-flag ships.[3] The United States exercises control over equipment and standards on these vessels primarily through the enforcement of international agreements.

Similarly, the efficiency of maritime transportation varies greatly in U.S. ports because of the diversity among ports in terms of governing and funding structures, local shipping patterns, services provided, and geography and environmental conditions. In general, however, the infrastructure of U.S. ports lags behind the most sophisticated ports in Europe and Asia (NRC, 1993, 1996). Although some U.S. shipping terminals have very modern cargo-handling equipment, their approach channels and berths are often too shallow to accommodate the deepest-draft ships (NRC, 1993; Vulovic, 1995). The expansion and maintenance of channels is also a problem; high costs and technical difficulties in handling contaminated sediments often slow the pace of dredging (MARAD, 1994; NRC, 1997).

Heavy traffic and a multiplicity of vessel types in some ports,[4] as well as the hazardous nature of much of the cargo, creates safety concerns. The costs of shipping accidents and public concerns about the potential environmental impact of accidents are also significant. The aging infrastructure of U.S. waterways can compromise safety and efficiency in a number of ways. For example, because some ports cannot accommodate the deepest-draft ships, offshore lightering is commonly used to transfer petroleum from large ships to smaller vessels that can proceed into shallow harbors or waterways. Although the safety record of lightering operations is excellent (NRC, 1998), the number of cargo transfers is increased, which also adds to the costs of petrochemical

[1] The ISM Code lays the foundation for a new operational and cultural framework for ship management, requiring that policies and actions be consistent within an organization and focusing attention on human factors.

[2] A specialized agency of the United Nations, the IMO is the leading international forum for cooperation on issues affecting maritime safety.

[3] In 1992, 24,000 vessels of 1,000 gross tons or more were in operation worldwide. Of these, only 603 were registered in the United States, and approximately one-third of those were government owned (U.S. Bureau of the Census, 1994).

[4] Except for the oil trade, vessel movements in U.S. waters are poorly documented (Research and Special Projects Administration, 1995), so it is not possible to acquire sufficient reliable data to demonstrate recent trends in vessel traffic. However, the following 1994 statistics for New York Harbor reflect the traffic situation at one busy port: 163,664 vessel movements, including 89,075 by ferries; 52,626 by tugs or tows; 6,945 by cargo vessels; 12,545 by tankers; 1,708 by public vessels; and 45 by vessels carrying hazardous materials. Furthermore, almost all cargo vessels carry small amounts of packaged hazardous materials (USCG, 1995b).

products. Lightering also increases the number of trips required to deliver cargo to terminals, and, thus, increases the volume of traffic that must be accommodated safely.

Congestion has increased in some ports because competition for intermodal trade and shifts in trading patterns have led to the concentration of cargo at fewer ports (NRC, 1993). Congestion is also exacerbated by ongoing and projected changes in ship size and other characteristics (discussed later in this chapter). If U.S. ports fail to accommodate these changes, then cargo may be shifted to nearby foreign ports. Unfortunately, U.S. terminal upgrades are often delayed because of declining support from state and local governments and a variety of other reasons (MARAD, 1994). Thus, although it is difficult to determine actual performance levels because of inadequate data, especially data related to safety,[5] continued attention to the safety and efficiency of U.S. ports and waterways is essential to the nation's economic well-being.

For all of these reasons, the need to enhance maritime information systems in the United States is growing. A number of recent studies have detailed the shortcomings of existing systems and planned upgrades (GAO, 1996a, 1996b; INTERTANKO, 1996; National Performance Review, 1996; NRC, 1994a, 1994b, 1996). The national stakeholder discussion group convened by the USCG in 1997 and 1998 to help develop new plans for vessel traffic services (VTS) confirmed the need for immediate attention to maritime information issues (National Dialog on Vessel Traffic Services, 1997; see Appendix B). It was also apparent that recent federal efforts to develop and fund maritime safety information systems have not met mariners' needs.

The demand for better maritime information systems is expected to grow as a result of trade patterns and trends. Forecasts predict continued growth in oceanborne trade, including oil imports to the United States (API, 1996). The condition of the U.S. maritime information infrastructure has implications for the nation's economy, both in terms of providing an attractive environment to shippers and in terms of handling a potential overload of information in a cost-efficient manner. Information systems also have environmental implications because, if properly designed and used, they can help mariners prevent and respond to accident-related spills. Furthermore, information systems can help address concerns raised by the prevalence of foreign-flag vessels in U.S. waters, a pattern that mariners say heightens the need for standardized navigation safety systems.

The remainder of this chapter outlines barriers to expanding maritime advanced information systems, the shortcomings of U.S. ports, and relevant trends in maritime transportation.

BARRIERS TO EXPANDING INFORMATION SYSTEMS

Rapid advances in information technology in recent years could greatly improve business operations in the U.S. maritime industry and in the daily operations of ports and waterways. Advanced maritime information systems, used singly or in combination, could ameliorate many of the problems faced by mariners. Available systems include radio navigation aids that permit individual vessels to determine their positions with a high degree of accuracy, VTS systems that monitor shipping in specific waterways, and automated cargo-tracking systems that serve individual terminals. National systems, such as the massive U.S. Customs Service database, which links dozens of port users with federal agencies, are also in operation.

Although the technology is available to meet virtually every need, the implementation of these systems across the U.S. has been inconsistent, at best. Barriers to the widespread use of advanced information systems include the division of responsibilities for the management of U.S. waterways among multiple agencies at all levels of government, inadequate budgets for some critical maritime programs, the high costs of some specialized technologies, stakeholder opposition to paying for services that have traditionally been provided at no cost, limited access to certain key data, the incompatibility of many independently developed systems, the absence of standards for some attractive technologies, and the wide range and diversity of available systems. In general, the critical importance of the infrastructure (e.g., accurate real-time data and the training and qualification of system users) necessary to use these technologies effectively has not been appreciated. By contrast, many foreign maritime nations have been investing heavily in their ports, advanced maritime information systems, and supporting infrastructures (INTERTANKO, 1996; NRC, 1996).

Some U.S. maritime information systems are designed, funded, and operated by federal agencies; some are developed in house and used by ship operators, shipping terminals, port authorities, or pilots; and some are marketed by private vendors. Some systems are paid for by users, whereas others are government funded or are supported by a combination of funding sources. Some information stored in these systems is widely shared, but much of it is accessible only to a limited audience. Many systems have been developed and implemented in isolation and are not interconnected, or even compatible with, other databases. Few systems are accessible to all potentially interested users, which has left vast resources untapped and important needs unmet. The effectiveness of many systems is often compromised by an outmoded or inadequate supporting infrastructure.

The lessons that can be learned from the commercial use

[5] Accident data maintained by the USCG, principally through the Marine Investigation Module (part of the Marine Information System for Safety and Law Enforcement), are of limited utility for broad-scale analyses. The value of the data is compromised by several factors, including the integrity of the locally generated accident information and inaccuracies (Research and Special Projects Administration, 1995). Information about near-misses is also inadequate.

of advanced information systems by foreign ports are, in most cases, not directly applicable to the United States because foreign systems are typically configured for the centralized management of both waterway and port operations. In its interim report, the committee investigated the development and implementation of information systems in some major foreign ports and discussed the differences between the management of U.S. and foreign ports. The committee found that in most major ports in Europe and the Far East a central authority is responsible for traffic management and for the collection and dissemination of information regarding operational safety and efficiency. These central authorities provide mariners with standardized, consistent navigational information. In U.S. ports, however, these functions are usually not the responsibility of a centralized management authority but are provided by several federal agencies and a number of state and local authorities. Nevertheless, U.S. ports have the same need for safety and efficiency as foreign ports. The challenge in the United States is to exploit systems that can serve a variety of institutional structures and the common goals of safety and efficiency with no central focus for management and funding.

HISTORICAL PERSPECTIVE ON U.S. PORTS

Ports and waterways are key elements of the U.S. infrastructure that support international and domestic trade, commerce, and recreation. They are also nodes in a global transportation system that must accommodate diverse vessel types and varying shipboard operating skills. Historically, the responsibility for infrastructure has been split among federal, state, and local governments and commercial interests. The division of responsibility developed pragmatically and has generally served the nation well. The federal government, for example, is chiefly responsible for the development and maintenance of, and safe operation in, shipping channels. This responsibility includes ensuring that all vessels that use U.S. waterways adhere to minimum international operating and safety standards. Protection of the environment is also a key federal responsibility; however, environmental protection is also a responsibility of state and local agencies whose efforts must be coordinated with those of the federal government.

Federal responsibilities are spread among several agencies. The Maritime Administration (MARAD) promotes the development and utilization of ports and facilities and provides technical information and advice to other agencies and organizations concerned with ports. The USCG is responsible for enforcing maritime laws, ensuring port safety and security, providing aids to navigation, and providing search and rescue operations; the National Oceanic and Atmospheric Administration (NOAA) is responsible for maintaining accurate nautical charts (and more importantly the underlying data); and the U.S. Army Corps of Engineers (USACE) is responsible for maintaining federal navigation channels. Local and state governments and the private sector are responsible for port management and development, and local measures that promote safety and efficiency vary greatly.

This regime alone makes the effective management of U.S. waterways a unique challenge. With no cohesive vision for coordinating and prioritizing tasks, the maintenance and modernization of the infrastructure has fallen woefully behind those of other nations. The problems are mostly basic, arising from mismatches between the growing needs of commerce and the static dimensions and capabilities of the supporting waterways, shoreside facilities, and intermodal connections. There are also deficiencies in the timeliness and accuracy of available navigation data.

Economic Importance of Ports

Ports and waterways play a critical role in transportation, trade, and employment. For example, the United States leads the world in the value of imports and exports (WTO, 1996), which were valued at almost $1.2 trillion in 1994 (U.S. Bureau of the Census, 1995). Commodity exports rose from 5 percent of the gross domestic product in 1984 to 7.5 percent in 1994 (U.S. Bureau of the Census, 1995). Ports and waterways handle almost all U.S. overseas trade by weight and about half by value (U.S. Bureau of the Census, 1995). In 1997, waterborne transportation of all commodities totaled more than two billion metric tons, about half domestic and half international trade (USACE, 1997). Some 145 ports (including inland ports) handled more than one million metric tons of cargo each in 1996 (DOT, 1998).

Changes and increases in the volume and complexity of vessel traffic in U.S. ports and waterways have highlighted the need for information systems that can provide port and vessel operators with tools to manage the system safely and efficiently. Total U.S. waterborne trade has increased dramatically over the past few decades from more than one billion metric tons in 1965 to more than two billion metric tons in 1996. About one-half of that trade is domestic. The dramatic growth of foreign trade in recent years is expected to continue. Figure 1-1 shows that the waterborne foreign trade of about 875 million metric tons in 1990 grew to 1,050 million metric tons in 1997 and is projected to reach 1,350 million metric tons by 2001 (MARAD, 1998).

This sizable growth has been concentrated in a few major U.S. ports. More than half is concentrated in 20 ports, and more than a quarter (575 million metric tons in 1996) is handled by just five ports. The 50 leading U.S. ports handle almost 90 percent of all waterborne commerce.

Certain segments of waterborne trade, such as the containerized cargo trade, are also substantially concentrated. In 1997, 25 ports handled 98 percent of the foreign container cargo, and the leading 10 ports accounted for 80 percent, with the Los Angeles-Long Beach port complex handling nearly one-third of all container traffic. Container cargo has also increased dramatically, an increase of more than 10 percent from 1996 to 1997.

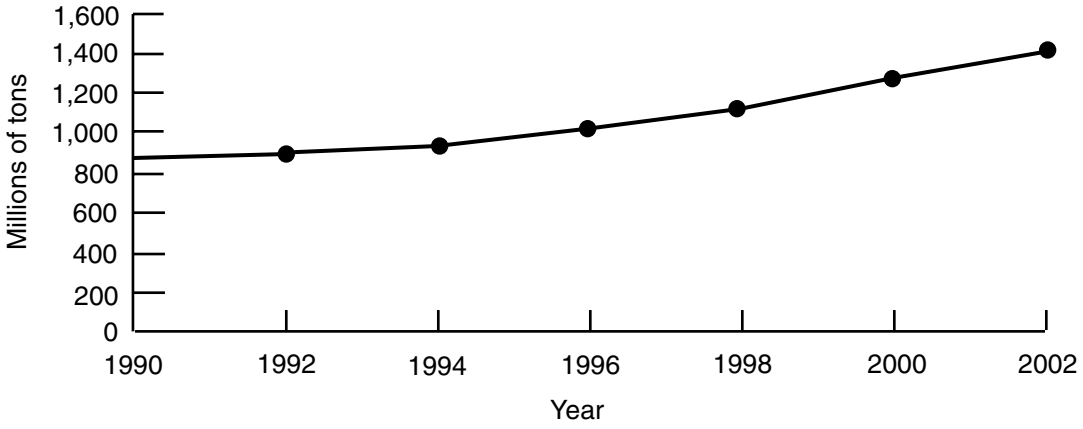

FIGURE 1-1 History and forecast of waterborne foreign trade through U.S. ports. Source: Maritime Administration.

In addition, in certain ports and waterways, other traffic has grown substantially at the same time that the volume of trade and traffic by major commercial vessels has been growing and becoming more concentrated. This includes tug and barge traffic in the major Gulf of Mexico ports; ferryboat traffic in large ports, such as San Francisco, Seattle, and New York; pleasure craft traffic in all ports near major metropolitan areas; and cruise ship traffic in southern ports with access to the Caribbean.

Shipments of oil and petroleum products constitute a major component of U.S. trade. The nation imports more than half the oil it consumes, and imports have been growing steadily (API, 1996). The contiguous 48 states receive about 1.4 million metric tons of crude oil and petroleum products per day by water, primarily from foreign sources and Alaska. Waterborne domestic trade in petroleum products, such as vehicle and aviation fuels, is also significant. The prevalence of these commodities along U.S. coasts poses a risk of accident-related spills—a persistent environmental, economic, and social concern.

Shallow-draft tug and barge traffic constitutes a unique segment of U.S. maritime commerce. According to the American Waterways Operators, barges handle more than 600 million tons of commerce annually. Apart from its role in domestic commerce, barge traffic is also a critical link in international trade. For example, more than half of all U.S. grain exports, as well as 300 million tons of coal, 1 billion barrels of petroleum, and 450 million barrels of liquid chemical products, are transported annually by shallow-draft barges. Barge-tows vary in size from one barge and one towboat carrying 10,000 barrels of liquid chemicals to one towboat and 35 barges carrying more than 50,000 tons of mixed commodities. As a result, barges are often the most prevalent vessels in many harbors and inland waterways.

U.S. seaborne international trade is now carried largely by foreign-flag vessels. In 1997, about 98 percent of U.S. foreign trade by tankers and 85 percent by cargo liners was carried by foreign-flag vessels (DOT, 1998). To accommodate expanding trade in the past few decades, oceangoing ships have grown considerably in size, complexity, and speed. Tankers carrying crude oil imports are commonly 100,000 to 400,000 deadweight tons (DWT).[6] Container ships now carry from 4,000 to 6,000 20-foot-equivalent units (TEU),[7] and even larger vessels are planned. Many other specialized vessels have evolved for specific cargoes or trades, particularly the petrochemical industry. Some of the petroleum and chemical cargoes carried by these vessels (as well as barges and container vessels) can be complex and highly toxic to humans and animals, increasing the public health and environmental risks from accidents.

Shortcomings of U.S. Ports

Changes in vessel characteristics, combined with other recent trends, have created demands that are beyond the capabilities of the infrastructures of many existing U.S. ports and waterways. These trends include changes in the patterns of vessel traffic and cargoes, a growing dependence on foreign sources of oil, changes in the nature and location of the U.S. industrial base, and the advent of just-in-time inventory management, which requires reliable scheduling. Some U.S. ports have been modernized in recent years, but others have not. In general, the emphasis has been on upgrading the land-side infrastructure and the handling and transshipment of cargoes. Less attention has been paid to the supporting waterways.

The lack of improved waterways has created serious problems, especially for the petroleum trade.[8] Many U.S.

[6] Deadweight tons is a measure of a vessel's total carrying capacity, including the weight of the cargo, stores, fresh water, fuel, and crew. The larger crude oil carriers commonly call at deepwater offshore ports or are lightered offshore.

[7] TEU (20-foot equivalent units) is the standard unit of measure for the container-carrying capacity of a vessel (the standard container is 20 feet long).

[8] For a discussion of tanker-related issues, see INTERTANKO (1996).

BOX 1-1
Nautical Charts Provide the Sole Means of "Seeing" Underwater and Dead Ahead

Despite recent technological advances, nautical charts are still the only means for detecting what lies underwater immediately ahead of a vessel. Depth-sounding sonar can detect fish, submarines, and obstacles directly beneath a vessel and can even measure the speed of large tankers. Side-scan sonar can provide accurate information on water depths and measurements from the bottom of a vessel to underwater wrecks and obstructions. But these technologies work only at short ranges in modes where the known inaccuracies are small and acceptable. They cannot be used to "see" an object one to two miles ahead or determine how far it lies below the surface to within two or three feet. Such fine distinctions in the interpretation of sonar returns would be possible if the sonar beam were a very thin, absolutely straight line both from the sonar to the obstruction and, after reflection, from the obstruction to the sonar. Sound waves do travel in straight lines in water with uniform sound speed—but, that requires a very special condition of density, salinity, and temperature that rarely occurs near the ocean surface, where commercial and recreational vessels operate.

Substantial military and industrial resources have been devoted to research on "underwater obstacle finders," and some devices have been placed into service. But these devices do not have the desired look-ahead range and/or the required fine angular resolution (1 part in 4,000). In one tanker development project, for example, the technology to look ahead with the required performance was discussed but never produced, possibly because of high cost estimates of several million dollars per ship (Rafael Gutierrez, Astilleros EspaZoles Technology Center, personal communication, June 10, 1998). Mariners today, as in centuries past, must depend on either paper or electronic nautical charts showing water depths and the positions of reefs, shoals, and wrecks. If the information is inaccurate, then the vessel is at risk.

refineries and petrochemical complexes are located inland and can be reached only by lengthy river passages, dredged channels, or canals. Although the idea of opening new deepwater ports was studied in the late 1960s and early 1970s, only one deepwater terminal for crude oil was developed, the Louisiana Offshore Oil Port. Increasingly large tankers are now being crowded into existing U.S. ports and waterways where they must share the congested waters with a large volume of other commercial traffic and a growing number of recreational boaters. Nevertheless, if mariners had access to timely, accurate, and reliable information, they could safely and efficiently navigate congested ports and accommodate shortfalls that would otherwise impose costs and increase risks to vessels and to the environment. Unfortunately, some of the key shortfalls are related to inadequate information systems.

One fundamental problem is the paucity of authoritative, accurate, up-to-date information about harbors and harbor approaches. Both vessel safety and transportation efficiency depend on the availability of hydrographic[9] data and traffic management information (see Box 1-1). Mariners are forced to operate with incomplete or outdated hydrographic data, conflicting information published by various government agencies, and delays in publishing the most recent information (NRC, 1994a, 1994b). Outdated nautical charts and poor data on environmental conditions (i.e., weather, tides, and currents) create significant risks. In many cases, tidal, current, and water-depth predictions are based on information dating as far back as the turn of the century (NOS, 1995). U.S. coastal waters have never been completely surveyed, and about 60 percent of the nautical charts prepared by NOAA are based on pre-1940 data collected with obsolete technologies (NRC, 1994a).[10] Coupled with the decentralized responsibility and authority for disseminating information at a given port, this situation creates confusion (particularly for masters of foreign-flag vessels) just when, for safety's sake, they most need accurate information on environmental and waterway conditions. NOAA has prepared plans to accelerate surveying and charting in critical regions but predicts that, at current funding levels, the existing backlog of outdated hydrographic surveys will take more than 25 years to eliminate (NOAA, 1996).

Outdated surveys and funding limitations have precluded the use of the most advanced charting systems in U.S. waters. Electronic charts[11] of various types are available but

[9] Hydrography deals with the measurement of the bottom topography of waters and their marginal land areas, with specific reference to the elements that affect safe navigation, and the publication of information in a form suitable for use by navigators.

[10] Mariners often cite new surveys as a critical safety need (NRC, 1996).

[11] An electronic chart is a digitized version of a nautical chart, with graphic representation of water depth, shorelines, topographical features, aids to navigation, and hazards (National Research Council, 1994b, and references therein). An electronic chart is no better than a paper chart unless it is combined with additional information, including, at a minimum, the vessel's position and planned track.

are only as accurate as the underlying hydrographic data, and electronic charts in the format specified by the international community are prerequisites for the use of electronic chart display and information systems (ECDIS),[12] which have been characterized as "the best navigation advance to come along since radar was invented" (Ecker, 1993). The widespread use of ECDIS in U.S. waters will require the development of a hydrographic database that meets established international standards. NOAA is developing a standardized, fully attributed electronic chart for use in ECDIS, but progress has been slow (NRC, 1994b).

Another notable gap in harbor safety information systems concerns the tracking of hazardous cargoes. If a spill or other accident occurs, then emergency response teams need to know what material they are dealing with, or else the cleanup efforts may fail and new hazards may be created.[13] The USCG does not operate any electronic systems that can quickly notify its officers or others about hazardous cargoes. In Puget Sound, for example, notifications are made using paper records (see Appendix C). In general, electronic information about hazardous cargoes is maintained only by U.S. Customs Service and some individual ports, and access to this information is typically very limited. In the busy port of Charleston, South Carolina, the local customs network includes information about hazardous cargoes, but the port police and local firefighters, who would respond to an emergency, cannot access the system directly (see Appendix D). Instead, they must rely on lists of hazardous cargoes printed out and provided by terminal personnel upon the arrival of response teams.

Foreign ports are much more advanced in this respect. When the committee visited Rotterdam, The Netherlands, in 1996, plans were being made to link the elaborate VTS to an electronic notification system for vessels carrying dangerous cargoes (NRC, 1996). The system included the necessary information for mounting an effective response to an incident. Some movement toward this kind of "one source" approach has been made in the United States. For example, emergency response teams in the Delaware River region can obtain hazardous cargo information from a local system that captures electronic manifests for all imported waterborne cargoes transiting the river for dissemination to the U.S. Customs Service and port customers. The system includes a pilot system for tracking sensitive cargo, which provides instant information on petroleum and chemical cargoes to the USCG and other government and spill response agencies.[14]

BOX 1-2
Definition of VTS

The present report uses the IMO definition for VTS, which is a "service implemented by a competent authority designed to improve safety and efficiency of vessel traffic and protect the environment. The service shall have the capability to interact with the traffic and respond to traffic situations developing in the VTS area." Under the IMO definition, the "competent authority" is considered to be the national or local agency responsible for maritime safety.

The term VTIS has not been defined by the international community, but in the United States it is applied to VTS-like systems operated by organizations other than the USCG. These organizations only provide information and do not have the authority to respond to traffic situations.

Vessel traffic management systems also have shortfalls. Although VTS systems operated by the USCG have been established at a number of ports, the justification for them has largely been related to safety, and, consequently, they have not been fully integrated into overall port operations. In addition, VTS systems have not yet been installed in all of the ports that need vessel traffic management (NRC, 1996). In some areas, vessel traffic information services (VTIS) that are not operated by the USCG have been established. Mariners are often unaware of the differences in services and authority conveyed by the two sets of initials (see Box 1-2).

Finally, a variety of communications problems continue to plague mariners. Critical information links, both ship-to-shore and ship-to-ship, are primarily based on voice radio. The oral exchange of important safety and commercial information is subject to error, the risk of which is often exacerbated by language difficulties, including colloquialisms and regional accents.[15] Mariners report frequent interference on bridge-to-bridge communications channels, particularly in geographically complex, heavily traveled areas, such as the lower Mississippi River (Duffy, 1995). Communications are often impeded by unauthorized or inappropriate use

[12] ECDIS receives position data from radionavigation instruments and integrates them with a voyage plan and an "official" hydrographic database to provide a real-time display of the vessel's position with respect to the chart and voyage plan; electronic positioning is required, and a radar overlay is optional (NRC, 1994b).

[13] Petroleum cargoes, for example, have different volatility, density, and toxicity characteristics that affect the material's behavior after a spill or during cleanup operations.

[14] This system was conceived by the Maritime Exchange for the Delaware River and Bay and is now supported by a public-private partnership that provides capital for new technology. The port authority, pilots, and the state all support it.

[15] See comments by the president of the International Maritime Pilots Association (Walsh, 1997) and Cushing (1994), who addresses communications problems in aviation that are also applicable to maritime commerce.

of marine radio frequencies; overloading is common during adverse weather or in heavy traffic, when communications are most needed (NRC, 1994a). A number of solutions, including increased use of data-based systems, such as transponders, have been proposed or initiated. The USCG is beginning a pilot project with a transponder-based automated information system (AIS) as the basis for vessel traffic management in the Lower Mississippi River.

The full benefits of the latest technologies cannot be exploited until the USCG's short-range communications system has been upgraded and modernized. The backbone of the current system is the national distress system (NDS),[16] which provides VHF-FM coverage in coastal areas and navigable waterways used by commercial and recreational vessels. The current system, which consists of about 300 sites with remotely controlled VHF-FM analog transceivers, is outdated, does not provide complete coverage, and does not satisfy current needs. Moreover, NDS does not provide elements needed for the global maritime distress and safety system (GMDSS), which was recently established by the IMO. A cornerstone of the GMDSS is automated listening watches by shore stations on VHF-FM channel 70 for communicating in coastal regions. By February 1999, vessels will be required to have a channel 70 capability, but the United States will not have a listening system in place by that time. GMDSS should be compatible with the operation of AISs.

TRENDS IN MARITIME TRANSPORTATION

The future of maritime transportation is being shaped by substantial projected growth in marine commerce. The aggregate tonnage moving through U.S. ports is projected to triple over the next 30 years (Intelligent Transportation Systems Joint Program Office, 1996), which will certainly change historic vessel traffic and patterns of port use and introduce new vessel-related problems. The growth in trade is being supported by major advances in vessel technology. In addition, U.S. ports are making major new investments in facilities. Public ports reported a record level of investment of $1.5 billion in 1997 and are projected to invest more than $7.7 billion in the next five years (DOT, 1998). In combination, these trends are expected to increase demands on the already overburdened U.S. maritime infrastructure. Unless this infrastructure, including information systems, is improved, patterns of commerce may shift in ways that will be detrimental to the U.S. economy.

The trend toward very large container ships of 6,000 to 8,000 TEU capacity will put serious pressures on many U.S. ports. The issues range from the high costs and delays associated with dredging to the lack of space for additional longshore facilities to the need for improved rail and road corridors to and from ports (DOT, 1998). Adequate space and intermodal connections are becoming more and more important as corollaries to just-in-time inventory management and the general trend toward reducing the resources associated with goods in transit. To accommodate these concerns, goods must be handled promptly on shore, and ships must move in accordance with advertised schedules under all weather conditions and harbor traffic conditions. Information technologies are key to maintaining schedules and managing complex cargo flows.

Other technological advances will also change waterway use. For example, the development of high-speed ferries, coupled with improvements that permit vessels to operate at higher speeds and lower costs, have reduced costs per passenger mile to levels that are competitive with other forms of transportation. Ferries may, therefore, become a preferred alternative to driving on congested highways, especially in areas with growing populations. The Washington State Ferry System, the largest ferry system in the United States, now operates 25 vessels that make a total of approximately 500 trips per day (see Appendix C). The system's managers project a 72 percent increase in demand on major routes in the next 20 years. Passenger services offered by private firms may also increase if water transportation proves to be a viable way of relieving highway congestion. There is a potential downside, however. In some crowded ports, such as New York and San Francisco, high-speed ferry operations have raised safety concerns.[17] Ferry traffic poses safety risks regardless of its speed because it often crosses shipping lanes. The risks from high-speed ferries are even higher. Thus, sound vessel traffic management will be extremely important.

Another trend that requires continuing attention is the apparent increase in the proportion of tug-barge combinations relative to deepwater vessel traffic in many areas. When vessel information and traffic services are established and improved, it is important to ensure the participation of all tug-barge units and other types of vessels. Participation in the Delaware Bay and River VTIS, for example, is voluntary and generally limited to large commercial ships and vessels that use the services of a state pilot (NRC, 1996). From the standpoint of navigation safety, barges and ships will require similar equipment and mariner qualifications to take advantage of advances in technology and participate in

[16] The NDS was built to provide the USCG with a means of monitoring the international VHF-FM distress frequency (channel 16), coordinating search and rescue response operations, and communicating with commercial and recreational vessels. The secondary function of NDS is to provide command, control, and communications for USCG units performing maritime safety, law enforcement, national security, and environmental protection missions.

[17] Safety concerns were described in a paper by a USCG officer (McKernan, 1997) presented at the April 1998 meeting of the Marine Board of the National Research Council. The safety of high-speed vessels has also been a topic of discussion at IMO meetings.

advanced VTS systems. If shoal-draft users do not participate, the effectiveness of waterways management systems may be compromised. One solution to this problem is to require that all vessels using certain waterways carry transponders. Another, which has been instituted in the port of Houston-Galveston, is the establishment of shallow-draft traffic lanes for certain vessels.

Other changes are taking place in vessel crews, operational practices, and navigation technology. The trend is to reduce the size of vessel crews and rely more on automated equipment. Reliable electronic information systems are, therefore, becoming increasingly important. With smaller crews, resources previously available for ancillary shipboard tasks, such as chart maintenance, will no longer be available. Shore-based emergency response teams will be needed to assist with onboard fires and hazardous cargo spills, heightening the need for the USCG and others (e.g., local police and fire departments and spill response teams) to have access to electronic cargo information. At the same time, the administrative workload will increase, partly as a result of new standards for training and qualifying mariners. This workload will be accompanied by a need for up-to-date information on a wide variety of topics to keep pace with the proliferation of cargo- and work-related regulations. To complicate matters, crew size is being reduced at the same time that agreements initiated by the International Labor Organization and governmental regulations are limiting at-sea work hours and establishing crew rest criteria.

Eventually, bridge watchstanders on deep-draft ships may face the same burdens already experienced by crews on tug-barge combinations, where single-person watches have become the rule rather than the exception. The trend toward fewer watchstanders handling increased workloads underscores the importance of the American Pilots Association's (APA) efforts to improve information exchange between masters and pilots. [18] The availability of accurate, up-to-date information about waterways conditions is essential, particularly in ports that do not have suitable anchorages and in areas where passages must be coordinated with tides to ensure adequate under-keel clearance.

A concern related to the prevalence of foreign-flag deep-draft ships in U.S. waters is the increase in vessel personnel who may not be fluent in English. Frequent anecdotal reports have been made of the inability of crew members aboard many foreign-flag ships to communicate with onboard pilots and with VTS and other shore stations. The growing trend toward drawing crews of all grades from developing countries will increase the time required for mariners to exchange information. One partial solution to this problem would be to make essential transit-related information available in written form while the ship is still at sea.

[18] The *Best Practices Summary,* adopted by the APA in 1997, recognizes that the proper exchange of information between masters and pilots is critical to safe navigation.

Information can also help mariners deal with severe and growing problems with channel maintenance. It is becoming increasingly difficult to fund new dredging projects to expand and deepen existing waterways, partly because the permitting process involves lengthy environmental reviews and partly because the costs of dredging, and the disposal of the resulting spoil, have increased almost exponentially (NRC, 1997). One way to minimize dredging requirements is to ensure that accurate, up-to-date bathymetric data are available to mariners, together with real-time information on water depths. Similar data will be required for vessels to exploit the navigational and passage management features of ECDIS, which may be essential for meeting transit schedules consistently in all weather conditions.

SUMMARY

Enhanced maritime information systems should be integral to the modernization of U.S. ports to accommodate shipping trends, including projected growth in international trade and the development of larger and faster vessels. Crucial shortcomings in maritime information include the lack of accurate, real-time information about water depths and underwater obstructions in harbors and approaches; outdated nautical charts; the limited availability of electronic charts; inadequate systems for tracking hazardous cargoes; the incompatible designs of VTS systems; over-reliance on voice communications; and chronic shortfalls in federal budgets for information systems that promote navigation safety.

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2

Federal, State, and Private Roles

Maritime commerce supports both international trade and national security and, therefore, has long been considered essential to the nation's well-being. Historically, the federal government has provided and operated aids to navigation, developed and maintained waterways, and exercised oversight over matters of maritime safety. Today, safety—including protection of the environment—is considered the principal concern of the federal government. Efficiency is most often considered the concern of the commercial sector and, therefore, less deserving of federal funding (NRC, 1996a). However, defining the appropriate role for government can be difficult because of the often blurry line between safety and efficiency.

Policy decisions about federal support for services are not always based on objective analyses of their impact on the nation as a whole, or even on analyses of the beneficiaries of a particular service and, therefore, who should pay for it. The rationale for policy decisions tends to be more subjective. An example is the reduction in funds for charting the nation's waterways at the same time the overall funding for NOAA, the responsible agency, was increased (NRC, 1994a, 1994b)[1] and despite the broad international recognition that up-to-date charting is critical to improving waterway safety. Because of these budget cutbacks, some maritime safety information systems have not been deployed, upgraded, or operated (NRC, 1996a). The obvious negative effects on safety have raised questions about the federal government's fulfillment of its responsibilities in the national interest.

Nevertheless, cutbacks in the federal budget can also be seen as part of the larger goal of transferring some responsibility to the state and local levels or the private sector (NRC, 1996a). Although the merits of this goal were not assessed by the committee, this policy should be scrutinized carefully with regard to its short-term and long-term consequences. Recently, insufficient federal funding has led to efforts by government agencies to secure private support, through public-private partnerships, for some systems developed by the federal government. For example, PORTS (the physical oceanographic real-time system)[2] was developed by NOAA and installed by the government in several major ports for demonstration purposes. But local private interests must now find ways to fund its continued operation and maintenance.

This chapter discusses the best way to achieve an appropriate balance between public and private responsibilities. Topics include the relationship between maritime safety and efficiency, the increased importance of nonfederal stakeholders, the evolution of role sharing, and the need for strong federal leadership.

RELATIONSHIP BETWEEN SAFETY AND EFFICIENCY

At the macrolevel, maritime safety and efficiency are often intertwined, and when the current study began the committee intended to examine opportunities for improving both safety and efficiency. On closer examination, however, differences emerged. The development and implementation of information systems designed to promote efficiency appeared to be progressing satisfactorily because electronic cargo-tracking and other information systems, which are supported by the commercial sector, have been proliferating throughout the industry. At the same time, the federal government has been backing away from funding systems that would clearly improve safety. The committee, therefore,

[1] The budget for nautical charting (taking inflation into account) declined by nearly 50 percent between the mid-1970s and the early 1990s; during the same period, NOAA's fleet of hydrographic survey ships declined from 11 to 5 (NOS, 1998).

[2] PORTS gathers wind, current, wave, and other data from sensors installed on buoys and transmits the information in real time to central stations and individual users. System locations are noted in Chapter 3.

decided to focus its limited time and resources on opportunities for enhancing maritime safety, which emerged as the more serious public problem.

The committee's next challenge was to differentiate safety issues from efficiency issues, or at least to define their relationship, for purposes of this analysis. Is a safer port also a more efficient port? During numerous meetings and site visits, the committee observed that port stakeholders generally support proposals that would enhance safety—but often consider them too expensive, especially if they must be supported by user fees. Port directors and shippers generally want to maximize cargo efficiency for economic reasons and, therefore, prefer that safety regulations not be too onerous, which sometimes conflicts with the USCG's attempts to carry out its mission. Private companies, however, also recognize that ports and companies with reputations for frequent accidents may lose their public stature, as well as business. Thus, there seems to be a useful and creative tension between the USCG's efforts to promote safety and the private sector's efforts to promote efficiency, which could lead to an appropriate balance between them.

There also appears to be a dynamic relationship between safety and efficiency, although it is difficult to define. The committee did not dwell on this issue but believes it deserves further attention. However, at least one area of overlap was noted. The implications for both safety and efficiency of tracking hazardous cargo has not been fully recognized by the federal government. For more than 10 years, the U.S. Customs Service has maintained an automated system that allows carriers to transmit electronic manifest data on all imported cargo while en route to the United States so the Customs Service can determine, prior to arrival, whether to examine the cargo or release it. Almost 75 percent[3] of ships entering U.S. ports now use this system, which is linked to more than 1,500 trade participants, including ocean carriers, data processing centers, port authorities, and inland ports (Aylward, 1996). The USCG, however, does not use this system for tracking hazardous cargo, relying instead on paper records and port-specific notification of emergency response teams (see Appendix C and Appendix D). The committee has heard anecdotal reports of instances in which major ports had to be closed for hours at a time while mysterious hazardous cargoes were being identified. The USCG might be able to use information about hazardous cargoes from the electronic manifests in the U.S. Customs database in near-real time if certain adjustments were made in the system. Although previous discussions of this possibility failed to produce a solution (see Box 2-1), the issue is important enough to warrant further examination in another venue. The confidentiality of the data probably could be maintained, but substantial funding might be required to establish a USCG system that could perform necessary translations and keep track of the data.

BOX 2-1
Tracking Hazardous Materials

Carriers, terminal operators, port authorities, and service centers provide automated manifest data to the U.S. Customs Service for cargo arriving in, or departing from, U.S. ports. In recent years, the USCG and Customs Service have explored the feasibility of using these data for hazardous material notifications but have concluded that the data lacked sufficient detail for this immediate application (Kim Santos, Project Leader for Field Operations, U.S. Customs, personal communication, July 6, 1998). Some of the Customs Service data provide records for hazardous material descriptions and class code entries. However, reporting the quantity, weight, and other details of a cargo is not currently mandatory, so these data have limited value to the USCG.

Another possible mechanism for hazardous material notification is the Ship Notice/Manifest transaction created for the procurement process of the Electronic Commerce Program Office of the U.S. Department of Defense. From these data, a detailed list of the contents of a shipment and descriptions of their physical characteristics can be obtained and sent to one or more selected receivers. Hazardous material code qualifiers allow shippers to use U.S. Department of Transportation or IMO identifiers as cargo descriptors. If the Customs Service were to integrate this transaction set into its new database, the Automated Commercial Environment, then a common mechanism might be established for reporting details on cargo shipments that could satisfy the U.S. Customs Service, the U.S. Department of Defense, and the USCG.

GROWING IMPORTANCE OF NONFEDERAL STAKEHOLDERS

The convergence of public and private roles in maritime transportation is based on common interests, four of which are pertinent to the present study:

- ensuring the safety of lives and cargo, avoiding

[3] This figure was obtained from the U.S. Customs Web site (http://customs.ustreas.gov), August 1998.

environmental damage, reducing the costs of accidents, and promoting law enforcement and national security
- moving vessels and cargo in and out of ports efficiently under all conditions[4]
- ensuring the smooth flow of goods from one mode of transport to another to save time and reduce costs
- fostering economic growth, creating jobs and prosperity in the process

Historically, issues of safe navigation have been the exclusive province of seamen, shipowners, and government. Today, a great many other stakeholders are actively involved. In response to a series of disastrous events, most notably the Exxon Valdez oil spill in Alaska in 1989, the general public is now demanding a voice in ensuring that the movement of potentially polluting cargoes is as safe as possible. The public demand has been manifested in a number of ways, such as the expanded role of state governments in navigational matters. Four state-level organizations dealing with marine safety issues are: (1) the States-B.C. Task Force (which coordinates measures for the prevention of marine pollution and response activities of the four West Coast states [California, Oregon, Washington, and Alaska] and the Canadian province of British Columbia); (2) the Office of Oil Spill Prevention and Response in California; (3) the Spill Prevention Preparedness and Response Division[5] of the Washington State Department of Ecology; and (4) the Alaska Department of Environmental Conservation.

Public port authorities also maintain high profiles, often because their charters extend significantly beyond their responsibilities for piers and wharfs to acting as catalysts for economic development for entire regions. The Port of Seattle, for example, functions in that role for all of King County, a geographic area larger than some Eastern states. Because the port is supported by taxes levied on all county property owners, concerns about port activities and issues affecting the port are much more widespread than one might expect.

Vessel operating companies also have a large stake in navigational issues because they bear the costs of terminal development and operation. For example, a container line that makes a multimillion-dollar investment in a state-of-the-art terminal would rightly demand a voice in decisions about the navigational systems that support vessel movement to and from that terminal. Petroleum carriers have even more reason to participate both to protect their investment and to avoid delays in transits to and from refineries that could affect public health and welfare. Deep-sea operators carrying containers and petroleum recognize that safe passage in and out of harbors is a responsibility shared by vessel crews and shore-supplied services, such as VTS.

Overall, the number and diversity of stakeholders—including both regular users of ports and waterways and the general public, often represented by government agencies—participating in local, regional, and national planning and other activities that affect maritime commerce have grown considerably. Examples include the national dialog on VTS initiated by the USCG and the seven public "listening sessions" held in the spring of 1998 by the USCG and cooperating federal agencies (see Box 2-2). On the one hand, user involvement is now considered an essential element for marshaling support and funding to establish and operate navigation systems, and broad stakeholder participation expands the base of support. On the other hand, stakeholder participation tends to make the process arduous and frustrating because their input can be emotional or self-serving. Arguments and evidence provided by stakeholders must be carefully assessed to avoid giving undue weight to narrow, parochial positions. Stakeholder participation should be related to sources of funding; for example, if tax revenues are used to fund services, then taxpayers (i.e., the general public) have a right to participate in the decision-making process. A recent report on risk management advocates a

BOX 2-2
Listening to Stakeholders

Federal agencies held a total of seven listening sessions in the spring of 1998 at various locations along the U.S. coasts, Great Lakes, and inland waterways to gather input from state and local governments, industry, waterways users, service providers, and other interested parties. These sessions were part of an attempt initiated in late 1997 by the USCG and MARAD, in cooperation with approximately 10 other units of the federal government, to support a safe, environmentally sound, world-class waterways system that would improve U.S. global competitiveness and national security. The results of the regional sessions were presented at a national meeting in November 1998, when critical issues deserving the attention of national policy makers were identified. The initiative is expected to improve coordination and cooperation among all stakeholders. Federal agencies plan to continue this exchange of information at periodic future sessions.

[4] Although all-weather operations is a goal for certain ports that must maintain tight schedules, it may not always be economically feasible.

[5] This division was created in July 1997 when the Washington State Office of Marine Safety was merged into the Department of Ecology.

thoughtful balance between analysis and deliberation in risky enterprises (NRC, 1996b).

Although it is important that all stakeholders participate in the decision-making process, the federal government is the only entity responsible for safeguarding national interests, enforcing maritime law, negotiating and carrying out international agreements, and responding to the wishes of the entire citizenry (as represented by the U.S. Congress). At the same time, the uncertainty of budgets and the necessity of meeting budget priorities have made it difficult for federal agencies to enact and carry out consistent policies.

EVOLUTION OF PUBLIC-PRIVATE ROLE SHARING

The federal government has taken a strong leadership role in the development, funding, and operation of navigation safety systems, whereas the private sector has led the development and operation of cargo management systems. Whenever these two areas intersect or gaps appear, public-private partnerships, a concept supported by both users and outside analyses, have been the solution of choice (GAO, 1996; NRC, 1996a). The weaknesses in the present arrangement, noted earlier, include inadequate budgets for federal agencies to carry out their safety responsibilities and the tendency to develop stand-alone information systems featuring limited collaboration and information sharing (e.g., the general failure by federal agencies to provide existing electronic data on hazardous cargoes to appropriate public safety offices).

Public-private partnerships, a concept that remains in its infancy in the maritime arena, have also experienced some "growing pains," and representatives of private-sector stakeholders have raised a number of concerns about these arrangements. The most frequent complaint is that federal agencies cannot make long-term commitments of resources to partnerships. Another common concern is that private-sector interests may be overridden by federal goals. Some of these concerns could be addressed by clarifying how partnerships should function and establishing formal definitions of public and private roles. Experience with successful partnerships will also raise confidence levels. The classic example of a successful public-private partnership continues to be the VTIS serving the Los Angeles-Long Beach harbor complex, a cooperative effort of the local marine exchange, the state of California, and the USCG. This partnership was described in the committee's interim report (NRC, 1996a).

Finally, problems have also arisen about role sharing among federal agencies. Some members of the user community expressed concerns to the committee about the federal emphasis on VTSs (a responsibility of the USCG), which seemed to obscure the need for a more basic tool—accurate nautical charts (a responsibility of NOAA). These private-sector stakeholders believe that federal money would be better spent on improvements *other than VTSs*. In the National Dialog on Vessel Traffic Services (1997), the need for other types of systems was also emphasized. The frequency with which these concerns have been raised underscores the reality that federal allocations have not been well coordinated among agencies.

In an attempt to address this problem, the Interagency Committee on Waterways Management (ICWM) was established in 1995 to identify, evaluate, develop, and promote the implementation of federal policies and programs to ensure effective waterways management.[6] The ICWM seems to be an appropriate vehicle for dealing with the issues raised in the present report because its vision calls for "federal infrastructure,[7] systems, and services that will fully support the current use and anticipated growth in the use of the waterways with a high degree of efficiency and safety." In addition, the ICWM's objectives include promoting safe, environmentally sound use of waterways and coordinating overlapping management functions. The committee, which meets three times a year, is chaired by the USCG assistant commandant for marine safety and environmental protection. The members include representatives from the U.S. departments of Commerce, Defense, Interior, and Transportation, as well as the Environmental Protection Agency.

NEED FOR STRONG FEDERAL LEADERSHIP

As the roles of various stakeholders are being sorted out, it is important that the federal responsibility, which is broader and more complex than is usually appreciated, be kept in mind. The role of the federal government in maritime safety is broad and well established. Most ocean and inland shipping is international or interstate, and there is a vested national interest in ensuring economic, environmental, and national security. A strong federal role is also essential for mariners if they are to benefit from a common operating environment in national and international waters. All stakeholders recognize the dual need for port-specific systems tailored to local conditions and national standards that would enable the same equipment to be used in any port or waterway (National Dialog on Vessel Traffic Services, 1997).

Areas of government responsibilities are described below:

- **Safe vessels.** The federal government ensures that vessels are built and maintained at acceptable levels of safety by reviewing designs, setting standards, and inspecting vessels. Because most oeangoing vessels in

[6] The origins of the Interagency Committee on Waterways Management date to a 1993 interagency conference on coordinating research and development of federal waterways navigation, at which it was recommended that the idea of a committee be explored as a means of coordinating policy issues and program development.

[7] Infrastructure includes physical infrastructure, navigation support systems and services, and information delivery systems and services.

U.S. waters are foreign-flag vessels, government agencies (the USCG in particular) rely heavily on international rules and standards, which requires close coordination with other governments, international agencies, and classification societies. Information systems are key to ensuring vessel safety through surveillance and enforcement.

- **Safe crews.** Through the licensing and drug testing of mariners, vessel inspections, and accident investigations, the federal government, through the USCG, ensures that crews of U.S. vessels are capable of safe operations. Because of the prevalence of foreign-flag vessels and foreign crews, however, international regulations and coordination are critical to ensuring that crews operate safely. Because of the need for consistent standards, the federal government alone should be responsible for establishing and monitoring personnel levels, standards, and qualifications. The training and qualification of mariners are as important to safe operations as hardware and information systems are to maintaining oversight.
- **Hydrographic and bathymetric information.** On February 10, 1807, the U.S. Congress passed an act authorizing President Thomas Jefferson "to cause a survey to be taken of coasts of the United States, in which shall be designated the islands and shoals and places of anchorage . . ." Since that time, the federal government, currently through NOAA, has gathered coastal data and created, published, and sold nautical charts. Predictions of tidal currents and water depth have also been published, as have compendiums of general information about U.S. waterways. Although authoritative static information is still important, the need for real-time information about navigation variables (e.g., water depth and currents) is growing. Increases in vessel sizes, without commensurate increases in channel dimensions, have raised safety concerns about under-keel clearances since there is a strong commercial interest in loading vessels to the maximum draft possible.
- **Operating rules.** Many operating rules govern the movement of vessels. Although some rules are port specific, based on waterway configurations and other factors, most rules are codified both nationally and internationally. Both mariners and the public should be confident that these rules are being followed and, if not, that prompt remedial action will be taken. Enforcement is a fundamental responsibility of government, principally the USCG, that requires a regulatory framework supported by accurate information about port and waterway conditions and activities.

The proper determination of the federal role in maritime information systems must take into account many factors besides the beneficiaries of individual decisions. The complex issues raised by rapidly evolving technologies have underscored the need for a central arbiter acting in the national interest. For example, a balance must be established between the needs of local ports and the need to provide a consistent maritime operating environment among ports and nations. Deciding how to meet common needs and how to develop, implement, and enforce the technical and operating standards on a global basis is a complicated matter that is becoming even more complicated in light of the growing costs and increasing complexity of advanced technologies.

SUMMARY

Because federal funding for maritime safety technologies and operations has been declining, some federal responsibilities are being shifted to other stakeholders and to public-private partnerships. The reduction in the federal government's support for—and therefore its role in—maritime safety appears to be driven exclusively by budgetary considerations and has been undertaken unilaterally without appropriate input from mariners, industry, or the general public. The current trend toward public-private dialog and partnerships is a positive step toward redressing this problem but could be enhanced by a clear articulation of public and private roles, including a description of the comprehensive federal responsibilities in marine transportation. The federal responsibility for maritime safety systems and services extends beyond the often-subjective issue of who will benefit. Only the federal government can promote the adoption and implementation of national and international standards, coordinate efforts with other nations, enforce national maritime laws and regulations, and balance local interests with the national need for a consistent operating environment from port to port.

Although the effects on maritime safety of the changing public and private roles are not known precisely, the perception is widespread that safety is being compromised and that, because budgeting for all federal maritime agencies is not centrally coordinated, the limited federal dollars allocated for maritime safety are not always spent on the highest-priority needs.

The relationship between maritime safety and efficiency is dynamic and difficult to define. However, there is clearly some overlap with respect to hazardous cargoes. The U.S. Customs Service's extensive electronic system for tracking all cargo in U.S. waters could be tapped to provide real-time information to emergency response teams.

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3

Enhancing Navigation Safety Information Systems

The principal opportunities for improving maritime information systems involve existing or emerging technologies that promote navigation safety. A basic understanding of trends and needs in this area is necessary for clarifying policy and funding issues, this chapter examines information systems that promote overall port and waterways safety, including the safety of navigation and vessel transits through harbors.

Safety systems for general navigation are the basic tools used by mariners to fix vessel position, obtain information about the physical environment and operating conditions, and communicate with other vessels and shore-based personnel. These "foundation" systems also include databases used for safety-related policy making and decision making. Foundation systems include the global positioning system (GPS) and differential GPS (DGPS),[1] other navigational aids, hydrographic data, nautical charts, port-specific and general information about waterways, and data on tides and currents. Shore-based components and systems are generally designed, funded, and operated by federal agencies for the benefit of all mariners. However, onboard equipment must be purchased and operated by the users. Thus, national or international standards and requirements may be necessary to ensure that systems function effectively. The effective application of technology also requires that users have a minimum level of training.

The next section is a brief discussion of the role of technology in waterways management, which relies heavily on people and rules. The remainder of the chapter describes four key technology suites that could be improved or more widely deployed: NOAA's plans for updated hydrographic surveys and nautical charts; the current status of PORTS; prospects for AIS[2]; and a new perspective on VTS systems.

WATERWAYS MANAGEMENT

Technology alone cannot guarantee maritime safety. People, working according to rules governing safe vessel transits, are necessary to any effective waterways management system. Information is useless unless it gets to the right people at the right time. Vessel safety is influenced by a great many individuals: the master and crew, who are ultimately responsible for handling the vessel and who know its capabilities and limitations; system operators, who provide navigation information to vessels; marine pilots, who need accurate and timely information on local harbors or waterways; VTS personnel, who must make decisions based on the conditions and other traffic in the area; local service providers, such as tug masters and shipping agents; and mariners on other vessels in the area. In many foreign harbors, the activities of all of these individuals are coordinated by a central authority. In the United States, this is seldom the case, although marine exchanges or agents sometimes coordinate the flow of some information among the key players.

Recognizing the need for vessel masters and pilots to have continuous access to accurate, real-time information, both the USCG (National Dialog on Vessel Traffic Services, 1997) and INTERTANKO (1996) have recommended that waterways management systems be defined for each U.S. harbor based on continuous input from local harbor safety committees, whose members would include pilots and other frequent users of local waters. The safety committees would make recommendations to the USCG regarding system

[1] The GPS, a military radionavigation system that uses transmissions from satellites, provides accurate and continuous worldwide position fixes in three dimensions. For civilian users, the GPS provides horizontal accuracy to within 100 meters 95 percent of the time. Differential corrections to GPS range measurements are provided by the DGPS, which is currently accurate to within 10 to 15 meters.

[2] Although AIS has only recently become a popular initiative in certain areas in the United States, it has a long history of promotion, development, and testing in the international maritime sector.

elements, such as navigation regulations, anchorage procedures, traffic separation schemes, and improvements in the types and locations of navigation aids. Information needs and flows would be defined according to local needs, but the delivery methods and equipment would adhere to international standards.

A regime of appropriate rules, widely followed (and enforced as necessary), would make the operating environment orderly and predictable and is, therefore, a significant safety measure. Considerable documentation supports this thesis, including studies that credit a passive system of rules with significantly reducing traffic accidents in the Port of London (NRC, 1996). Strong anecdotal evidence shows that similar results have been achieved by harbor safety committees in California (Marsh and Richards, 1996). Self-policing can be highly effective, but it requires oversight coupled with the authority and capability to enforce rules. For example, a dramatic improvement was observed in self-policing in Los Angeles-Long Beach once the captain of the port had access to a surveillance system—a VTIS operated by the marine exchange with oversight by the local harbor safety committee (NRC, 1996).

NAUTICAL CHARTING

Some progress has been made in updating hydrographic surveys and nautical charts of U.S. waters. Since 1994, approximately 5,000 square nautical miles designated as "critical needs areas" have been surveyed using modern methods (i.e., multibeam depth-sounding equipment that can cover the entire seafloor and DGPS for determining location); another 38,000 square miles judged to be critical need areas remain to be surveyed (NOAA, 1997a, 1997b). About 60 percent of the critical backlog is in Alaska (NOS, 1998).

In response to a congressional mandate, NOAA recently finalized a plan for reducing the backlog of requests for hydrographic surveys (NOS, 1998). The plan specifies outsourcing of at least 50 percent of its hydrographic services to private contractors. In the next 5 to 10 years, NOAA plans to contract out most of the data acquisition in the Gulf of Mexico and the Pacific coast of the mainland (NOS, 1998). The agency will also operate its own three survey ships, provide quality control, maintain nautical databases, ensure nationwide coverage, provide leadership in setting and meeting international standards, and work with the private sector and other federal agencies to develop new survey technologies. Even so, NOAA estimates that, at fiscal year 1998 annual funding levels, it will take 25 to 30 years to eliminate the existing survey backlog (NOAA, 1997b).

NOAA recognizes that maintaining a level of capability and expertise entails more than facilitating contracting efforts. The government must also retain expertise and competency in order to meet its international and other responsibilities. The public nature of these responsibilities cannot be readily transferred to, and are not appropriate for, the private sector (NOS, 1998).

In a complementary effort, the NOAA Office of Coast Survey has developed a plan for accelerating nautical chart updates for the busiest commercial ports and trade routes, as determined by the tonnage of goods that moves through them (NOAA, 1997a). Other high-priority areas include some coastal and cruise ship routes that have never been adequately surveyed. If resources continue to be severely limited, charts of lower priority areas will be published less frequently than in the past. The agency's FY 1998 budget will support the production of 360 new chart editions, 30 percent of the charts for U.S. waters (NOAA, 1997a). But many of these "updated" charts will not include new survey information because none is available.

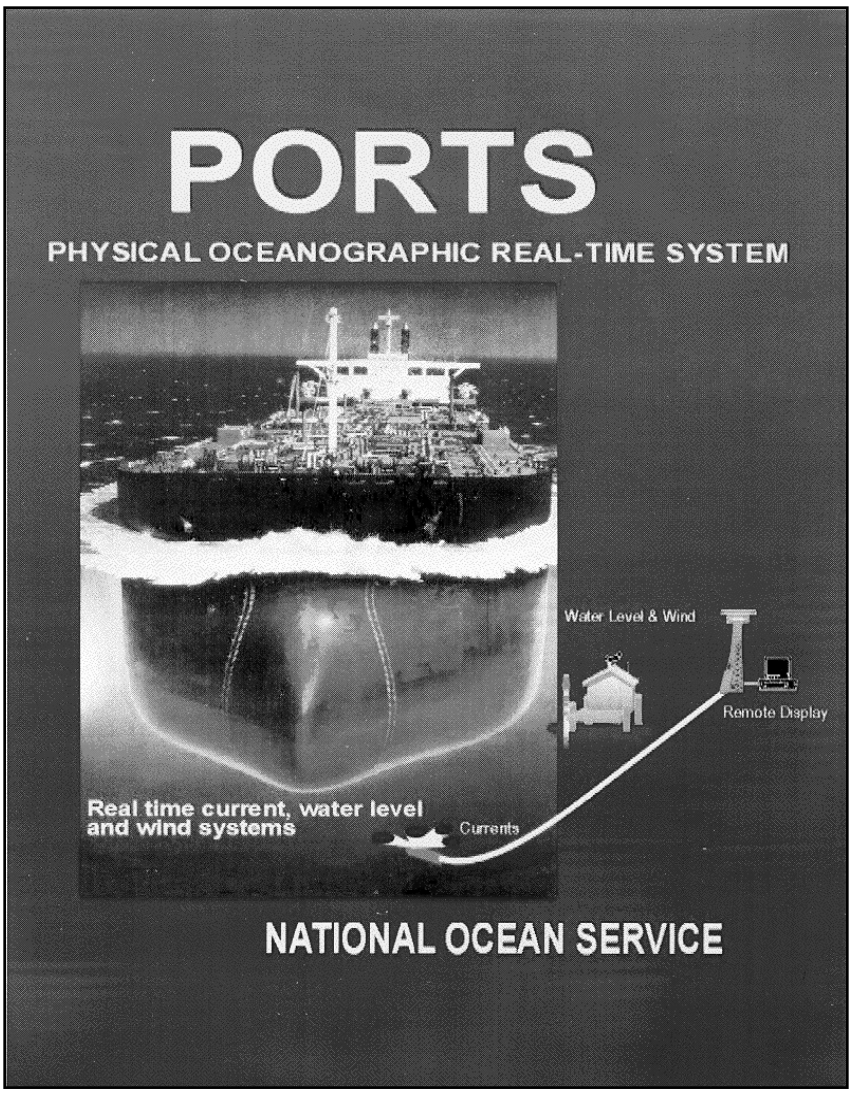
NOAA is moving toward the production of IMO-compliant, fully digitized vector charts as rapidly as budgets allow (Lockwood, 1998). The agency plans to release 190 electronic navigation charts by the end of 1999 and will increase the number of electronic navigation charts as resources permit. NOAA will also continue to maintain raster charts and the Raster Chart Notice to Mariners Update Service.[3]

PORTS AND "PORTS LITE"

Because PORTS has proven to be effective, users, at least in some areas, have agreed to help pay for its operation. PORTS is a sensor-based system, developed by NOAA, that gives vessels access to real-time data on currents, tides, winds, waves, temperatures, and salinity. The system helps mariners avoid collisions and groundings, assists in planning safe passage, and enables mariners to ascertain the drafts their vessels must maintain when transiting ports and waterways. Nautical charts show only minimum charted channel depths, but mariners need real-time water depths corrected to allow for changes caused by severe weather or abnormal tides.

PORTS is operational in Tampa Bay, New York Harbor, San Francisco Bay, and Galveston Bay. Six candidate areas have been identified for future systems (see Figure 3-1). Smaller systems, known as "PORTS Lite," are operational in Nikisiki and Anchorage, Alaska; Seattle and Tacoma, Washington; Baltimore, Maryland, and Hampton Roads, Virginia. All PORTS systems are operated and maintained with local funding; NOAA provides only the initial prototypes and overall quality control. Although this funding approach has enabled ports with active local initiatives to enjoy the benefits of this safety-enhancing system, it does not ensure safety benefits for all vessels that may need PORTS.

[3] NOAA plans to continue to rely heavily on raster charts, which were initially created by passing paper charts through a scanner. The features in these raster charts cannot be deleted or manipulated individually. In contrast vector data consist of individual position and attribute information for each feature on the chart.



- **PORTS**

  Existing
  - Houston/Galveston
  - New York/New Jersey
  - San Francisco
  - Tampa

  Potential
  - Corpus Christi
  - Jacksonville
  - Los Angeles/Long Beach
  - Philadelphia
  - Providence
  - Valdez

- **PORTS Lite**

  Existing
  - Anchorage
  - Baltimore
  - Hampton Roads
  - Nikisiki
  - Seattle
  - Tacoma

  Potential
  - Boston
  - Fall River
  - New Haven

FIGURE 3-1 Status of PORTS implementation (October 1998). Source: NOAA.

BOX 3-1
How AIS Works

Maritime AIS is similar to the technology used (in conjunction with radar) by air traffic controllers to keep track of aircraft. The basic maritime AIS technology is a shipboard transponder that operates in the VHF maritime band and is capable of sending a variety of vessel information (e.g., identification, position, heading, length, beam, type, draft, and cargo) to other ships and to shore. The receiving stations can display the locations and identity of all transponder-equipped vessels on an electronic chart. Because the data transfer is automatic, there is no need for extensive voice-radio communications—a major benefit because it frees mariners for other duties and reduces what some perceive as the intrusiveness of VTS systems.

A complete AIS system consists of a VHF transmitter, a frequency-agile VHF receiver, an accurate positioning system, and a display of ship vector and other information on an electronic chart. (A single vessel that has a complete system on board can both transmit its own signals and receive and display information from other vessels.) Position information is usually derived from DGPS. Operational requirements are for 2,000 reports per minute with updates every two seconds.

A functional example of a ship-shore tracking system is the international tug of opportunity system (ITOS), which is designed to prevent drift groundings of disabled vessels in the Puget Sound area. The local marine exchange maintains a database of the location and capabilities of local tugboats outfitted with transponders. The tug nearest to a vessel in need can be located within seconds of entering the vessel's location into the ITOS system. The system is entirely funded by industry (SMART Forum, 1997), but visual readouts of the identification, location, course, and speed of each tug are displayed at USCG offices.

AUTOMATIC IDENTIFICATION SYSTEMS

Support is growing among U.S. port and waterways users for AIS (see Appendix B, for example), an emerging technology that could have significant safety benefits, is simple to operate, and is compatible with a range of traffic management schemes. One advantage of AIS is that it enables mariners and VTS watchstanders to identify and distinguish specific vessels that otherwise appear as anonymous identical "blips" on a video display or radar screen (see Box 3-1). Another advantage is the low cost of the equipment (relative to many other technologies) carried by participating vessels. Developmental AIS or AIS-like systems have been used in a number of operational systems, including in Prince William Sound, Alaska, and ports in Canada, Sweden, and the United Kingdom. The USCG began an AIS demonstration with 50 vessels in the Lower Mississippi River in 1998.

The effectiveness of AIS as a safety measure depends largely on the proportion of vessels that participate and the ability of AIS to function in the ship-to-ship mode. Existing systems are limited to a few specific vessels or a local coverage area or only a ship-to-shore mode. However, many stakeholders support the universal use of AIS (National Dialog on Vessel Traffic Services, 1997). International efforts to upgrade and promote the application of this technology are under way, and the USCG now supports the completion of universal shipborne AIS standards and the establishment of carriage requirements for vessels nationally and internationally as early as July 2002.

AIS can be used as a stand-alone system to provide vessel-location and identification data to mariners on the many waterways that do not have shoreside traffic management systems. AIS can also be combined with radar or VTS systems, depending on local needs and choices.[4] Universal requirements for the carriage of AIS transponders cannot be implemented until an agreement has been reached on standards and requirements.[5] In general, this emerging technology appears to meet the vessel traffic management needs in many situations and will probably be adopted more widely

[4] The various technological tools available for, and used in, VTS installations are discussed in the committee's interim report (NRC, 1996). For example, radar and closed-circuit television have traditionally been used by traffic managers for surveillance of congested waterways and do not require that vessels carry special equipment. Newer technologies, such as AIS, would provide more precise vessel identification and position information but would require that vessels carry transponders.

[5] A performance standard describing the operational requirements for shipboard AIS transponders was adopted by the IMO Maritime Safety Committee in May 1998. (The final standard is expected to be available soon on the IMO Web site, http://www.imo.org). The standard is based on a recommendation made in 1996 by the International Association of Lighthouse Authorities (IALA), which has been the primary organization sponsoring and coordinating the development of AIS. In 1997, at the request of the United States and other countries, IALA hosted a working group of AIS manufacturers and administrators to decide on a standard technology for AIS transponders that meets the IMO performance standard. The working group's recommendation was submitted to the International Telecommunications Union, which is now defining the telecommunications protocol for AIS.

in the next several years. However, some technical problems, such as the allocation of standard worldwide radio frequencies for AIS operation, must still be resolved.

The United States will not be able to dedicate either wideband or narrowband VHF channels to AIS anytime soon, although it should be able to designate an available channel locally for AIS purposes. The National Telecommunications and Information Administration has been asked to develop a nationwide AIS frequency plan based on the results of a forthcoming decision by the Federal Communications Commission (FCC).[6]

NEW PERSPECTIVE ON VESSEL TRAFFIC SERVICES SYSTEMS

The most contentious debates about public and private roles in navigation information systems have centered around the funding and operation of VTS systems. The USCG has established and operates eight VTS systems. The information generated by these systems, and their traffic management, also benefit commercial interests at the affected ports (NRC, 1996). However, the commercial benefits have probably not been maximized because much of the data cannot be accessed easily by all potential users. Because both private interests and the public benefit from VTS systems, questions have been raised about who should design and operate these systems and whether the costs should be borne by the federal government alone or should be shared by system users.

Proposals for user fees have sparked controversies about overall system costs and capabilities. If users are asked to pay, then they want maximum utility from the VTS information at the lowest possible cost. The USCG's plans to install VTS systems in as many as 17 ports were canceled in late 1996 when Congress eliminated funding for the procurement program, which was criticized by some as overly expensive and not suitable for all local port communities (U.S. House of Representatives, 1996).

Various means of reconciling these conflicting concerns have been suggested. One solution is public-private partnerships, exemplified by the Los Angeles-Long Beach (LA/LB) VTIS, where users cover the costs of operation, and the USCG uses the system to carry out its responsibilities. To ensure that authority is properly exercised, USCG personnel are assigned as watchstanders. The cost of their services is currently borne by users, but the USCG is seeking federal funds to pay for its watchstanders. The LA/LB VTIS is the model for partnerships being developed in the San Francisco Bay region (involving federal, state, and private entities) and the Port of San Diego (involving the U.S. Navy and the port). Box 3-2 describes the partnership evolving in San Francisco.

The overall approach to vessel traffic management is still evolving. The Port and Waterway Safety System (PAWSS) project, which is being developed by the USCG with input from the national dialog group, is currently building a VTS system in New Orleans and other locations (see Figure 3-2), and locations for new VTS systems will be selected using a process based on risk analyses. The PAWSS approach envisions traffic management as a five-stage hierarchy, with traditional aids to navigation providing the most basic safety baseline. At the next level, which provides additional security and controls, is vessel-to-vessel AIS. The third level is enhanced AIS, which includes additional shore-based sources of information. The fourth level is VTIS. The top level is full VTS (24-hour-a-day shore-based surveillance and advisory activity under the direct authority of the USCG).

In the meantime, the private sector has often stepped in where no formal VTS systems exist. A few VTS-like systems are operated by pilots, some of whom carry laptop computers that combine electronic charts with satellite positioning systems. Although these private systems are narrower in scope than USCG-operated VTS systems, the laptop devices offer several important benefits, including independence of shipboard equipment, training focused on a single device, and growing confidence with ongoing use of the same equipment (NRC, 1996). (These benefits may be outweighed by the tendency to exclude the master and bridge management team from the navigational process, which could encourage reliance on separate systems.) Growing confidence in and increasing use of DGPS systems might allow more vessels to be moved under a wider range of conditions, but only if system limitations are known and users have been adequately trained.

The previous report of this committee (NRC, 1996), called for the definition of a "generic, baseline system" in response to the USCG's original plans to use a single systems integration contractor for all new VTS systems. Those plans were canceled, however, and the USCG and the maritime community have adopted a cooperative approach to defining specific user needs and the most effective roles of key stakeholders.

It has now become apparent to stakeholders—and to this committee—that the process of identifying ports and waterways that require VTS systems, and determining their capabilities, will be more complex than was originally recognized. The basis for the original plans, the cost-benefit analysis in the *Port Needs Study* (Maio et al., 1991), focused only on preventing and avoiding oil spills, whereas the current selection and design criteria have many more dimensions. Most stakeholders now believe that a comprehensive approach to maritime safety should extend far beyond VTS systems.

[6] The 1997 World Radio Conference designated two worldwide channels for AIS, channels 87B and 88B. In the United States, channel 87B is used for "public correspondence" coast stations, and channel 88B is a federal land mobile frequency designated for use by all government agencies. The conference decided to remove public correspondence designations from both channels 87B and 88B. In August 1997, the USCG petitioned the FCC for two duplex channels from the VHF maritime band for the AIS transponder. The FCC incorporated the USCG petition as a comment in PR Docket 92-257.

BOX 3-2
Information Systems and Partners in San Francisco Bay

The San Francisco Bay region features a VTS system, PORTS, laptop navigation and identification units carried by pilots, a cooperative marine information service, NOAA's prototype electronic charts, and a variety of ongoing waterways management experiments. The benefits of these systems are being maximized through the cooperative efforts of many entities, including five federal agencies,* the state Office of Oil Spill Prevention and Response and the Department of Boating and Waterways, and private sector organizations, such as the San Francisco Marine Exchange, marine pilots, and tug and ferry operators. One of the notable aspects of this partnership is that federally funded research and development projects were expanded to fill the urgent needs of other levels of government and the private sector.

The goal of the evolving partnership is to provide mariners with timely, accurate information about hydrographic and meteorological conditions in San Francisco Bay, together with near real-time information about vessel traffic and harbor construction and dredging projects. This comprehensive information will be distributed through AIS and the Internet.

The Marine Exchange will serve as the information "hub." To facilitate the flow of information, it could be co-located with the VTS Vessel Traffic Center (VTC), which would have to be modified to accommodate both operations. VTC equipment would have to be adapted to display information generated by AIS on vessel movements. Transponders have been installed in tugs and ferries operating in the bay, and pilots will carry portable AIS units when on board deep-draft ships. The use of AIS in the total system could allow the USCG to reduce its staffing, which would free personnel for transfer to other duties. The Marine Exchange currently provides a Web site with PORTS data and other, more general information. The Bay Area VTC image will be added to the Web site and updated frequently using data available from AIS and the VTS.

The two California state agencies will fund the operation, as well as maintenance of the PORTS system, for two years and will contribute funds to the AIS program. Responsible parties plan to seek legislative authorization to implement user fees to support long-term operations of the overall information system, including PORTS.

A project known as SmartBridge sponsored the development of an integrated VTS and intelligent pilot carryaboard system that was installed at the VTS for evaluation during 1997–1998.

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* In addition to the USCG and NOAA, the U.S. Geological Survey is using PORTS data in hydrodynamic models; a MARAD grant was used to test the portable pilot units; and USACE is working with NOAA on experiments to detect variations in ship drafts in real time using DGPS (Marsh and Richards, 1996).

Elements of VTS

Based on new information and perspectives since the interim report, the committee has identified five factors that should be considered in decisions regarding the establishment of VTS systems: (1) the conditions requiring vessel traffic management and the role of VTS in ameliorating them; (2) funding mechanisms for VTS installations and operations; (3) the operating government agency or private entity; (4) the extent of the services; and (5) the selection of technologies.

Other factors, which have been identified elsewhere, should also be taken into account (National Dialog on Vessel Traffic Services, 1997). First, many waterways do not require a VTS to achieve an appropriate level of safety. VTS is only one of many factors involved in maritime safety, and other systems may be more critical to safety in a particular waterway. Representatives of a wide range of port communities have noted that assigning proper priorities is critical.

Second, VTS is not a synonym for "high technology," although it does require technological tools to perform its intended functions. VTS is a systematic regime for managing a waterway. In the committee's judgment, overemphasis of VTS technology could overshadow the consideration of other management tools.

Third, VTS is not a new concept. It is a proven, internationally accepted tool that enhances vessel safety, promotes the efficient movement of vessel traffic, and helps protect the environment. Until the 1990s, the United States had held back from the conceptual development and application of VTS. A positive consequence of this delay is that the United States can now benefit from VTS developments by European nations and others.

Redefining the Federal Role in VTS

The new perspective on VTS requires that the federal role be redefined, based in part on evolving international standards. The IMO is in the late stages of incorporating VTS capabilities, requirements, and operations into a regime of internationally accepted standards. To date, the IMO has

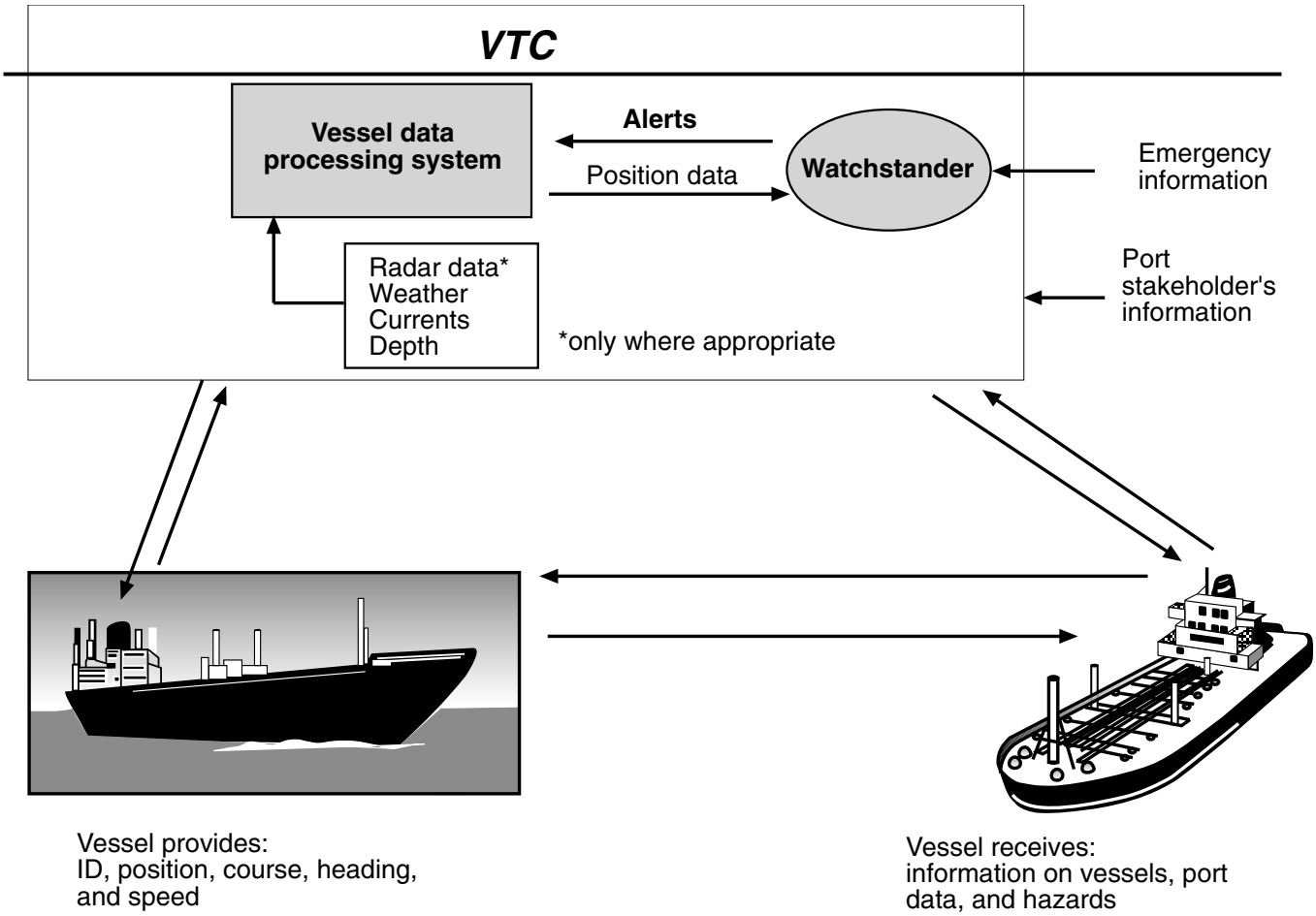

FIGURE 3-2 PWASS project concept—VTS system based on automatic identification system (AIS).

established *Guidelines for Vessel Traffic Services*[7] and *Guidelines for the Recruitment, Qualifications and Training of Vessel Traffic Service Operators*.[8] It has also defined VTS as "a service implemented by a competent authority, designed to improve safety and efficiency of vessel traffic and to protect the environment. The service has the capability to interact with the traffic and respond to traffic situations developing in the VTS area."[9]

In the committee's judgment, based on interactions with stakeholders, a significant percentage of the U.S. maritime community has no personal experience with VTS because they do not exist in many U.S. ports. Consequently, many U.S. mariners do not fully understand the role of a VTS and two elements of the IMO definition are sometimes misinterpreted. Competent authority has been defined as "the authority made responsible, in whole or in part, by the Government for the safety, including environmental safety, and efficiency of vessel traffic and the protection of the environment."[10] The phrase "interact with traffic and respond to traffic situations" is interpreted by the IMO to mean the ability of a VTS to recognize, analyze, and intervene in a situation that might otherwise lead to an accident, and, through its intervention, prevent incidents from developing into accidents.

Comprehensive guidelines for establishing and operating VTS are included in a manual published by the International Association of Lighthouse Authorities (IALA) (1993). The IALA membership consists of government agencies from many countries responsible for aids to navigation, including VTS. The manual, therefore, represents an international consensus, which, in the absence of binding international conventions, has become a de facto standard. The IMO is expected to seek greater standardization for VTS and related activities, and operator qualifications will undoubtedly be

[7] IMO Resolution A.857(20), adopted November 27, 1997.

[8] IMO Resolution A.857(20), adopted November 27, 1997.

[9] As adopted by the Subcommittee on Safety of Navigation, 39th Session of the IMO, London, November 27, 1997.

[10] Annex 20 to MSC67/22, Guidelines for Vessel Traffic Services.

added to the International Convention on Standards for Training, Certification and Watchstanding, 1978. Other aspects of VTS requirements will be brought within the framework of the International Convention on the Safety of Life at Sea.

Federal Government as Competent Authority

The committee considers the federal role in VTS as having two dimensions. The first is to serve as competent authority and fulfill the associated duties and responsibilities. The second is to provide vessel traffic management—and funding—in areas where the national interest would be served by VTS.

Although arguments can be made for individual states assuming the role of competent authority for VTS systems that operate wholly within their waters, maritime safety is best served in a consistent operating environment among ports and among nations. Consistency can be maintained only if standards, operator qualifications, and procedures are uniform, nationally and internationally. Most VTS areas of responsibility extend beyond state waters to ensure that vessels are entered into the system before they reach congested port approaches. For these reasons, the role of "competent authority" should be reserved for the federal government and should be carried out exclusively by the USCG, the nation's primary maritime safety organization.

The role of the competent authority is primarily to establish standards for VTS operations, including the training and certification of operators and monitoring to ensure that standards are met. This role should be extended to the development of a process for formally authorizing nonfederal VTIS systems to ensure that they have adequate support infrastructures.

Establishing VTS to Serve the National Interest

From a national perspective, the committee identified four possible reasons for establishing a VTS to serve the national interest. First, the USCG may determine that a VTS is necessary in a port for the fulfillment of its responsibilities for maritime safety as articulated in the Ports and Waterways Safety Act (P.L. 95-474). This determination would be likely, for example, for a port or waterway where a maritime accident might result in a "spill of national significance." [11]

Second, a formal traffic management capability may be required for reasons of national security, including conducting naval operations and logistics support for major military deployments, or to fulfill USCG mission requirements. A port that is home to a large number of Navy ships operating on a cycle that causes peaks of congestion might develop problems related to safety or affect the movement of commercial vessels.

Third, a formal traffic management capability may be required for national economic reasons. The committee identified two representative situations. Ports that are critical to the transport of heating fuel could, in the winter, be considered essential to the public welfare. Ports that serve as hubs for container shipments could be critical to the economy.

Fourth, traffic management requirements of an international waterway could necessitate the participation of more than one nation. An example is the Strait of Juan de Fuca, where traffic is co-managed by the United States and Canada.

If a port or waterway meets one or more of these criteria, a VTS system could be justified, and installation and operation of the system could be considered the responsibility of the federal government.[12] The USCG has begun a process (see Figure 3-3) of evaluating risks at individual ports to determine their safety needs. A five-tier hierarchy of safety enhancements has also been developed, with a full VTS system as the top tier (see Figure 3-4). The process is a combination of a risk assessment, a cost-benefit analysis, and consultations with stakeholders, including selected agencies of the departments of Transportation, Commerce, and Defense. Planners would also do well to involve port authorities, vessel operators, pilot organizations, and other port-related entities that would be affected by changes in the traffic management regime.

As part of the process, the USCG could conduct analyses to identify the ports that warrant federal vessel traffic management based on national economic importance. The USCG could use NOAA's identification of priority areas for surveys and charting as a basis for some analyses. The U.S. Department of Defense could also be asked to identify areas where defense considerations require traffic management capabilities. To obtain the greatest benefit from limited funds, the analyses should be appropriate to the situation. Where simple, inexpensive systems can be implemented, only simple analyses are necessary to justify them.

To ensure that the process is consistent and fair, a standard set of questions could be used to determine the requirements for VTS. For example, the following questions were developed by the National Dialog on Vessel Traffic Services (1997):

- What existing local navigational management systems are in place and how effective are they?
- What are the existing or likely future conditions in the

[11] Commandant Instruction 16465.1, Spills of National Significance Response Management System, summarizes the factors for determining if a spill has national significance. The factors include the extent of the potentially affected area; the probable impact on public health and welfare and the economy; the period of time over which the pollutant would be discharged or that would be required for cleanup; the level of public concern; and the level of political and public interest.

[12] Whether the systems were funded from general revenues or user fees would, according to the current approach, depend on their safety functions as compared to improvements in efficiency.

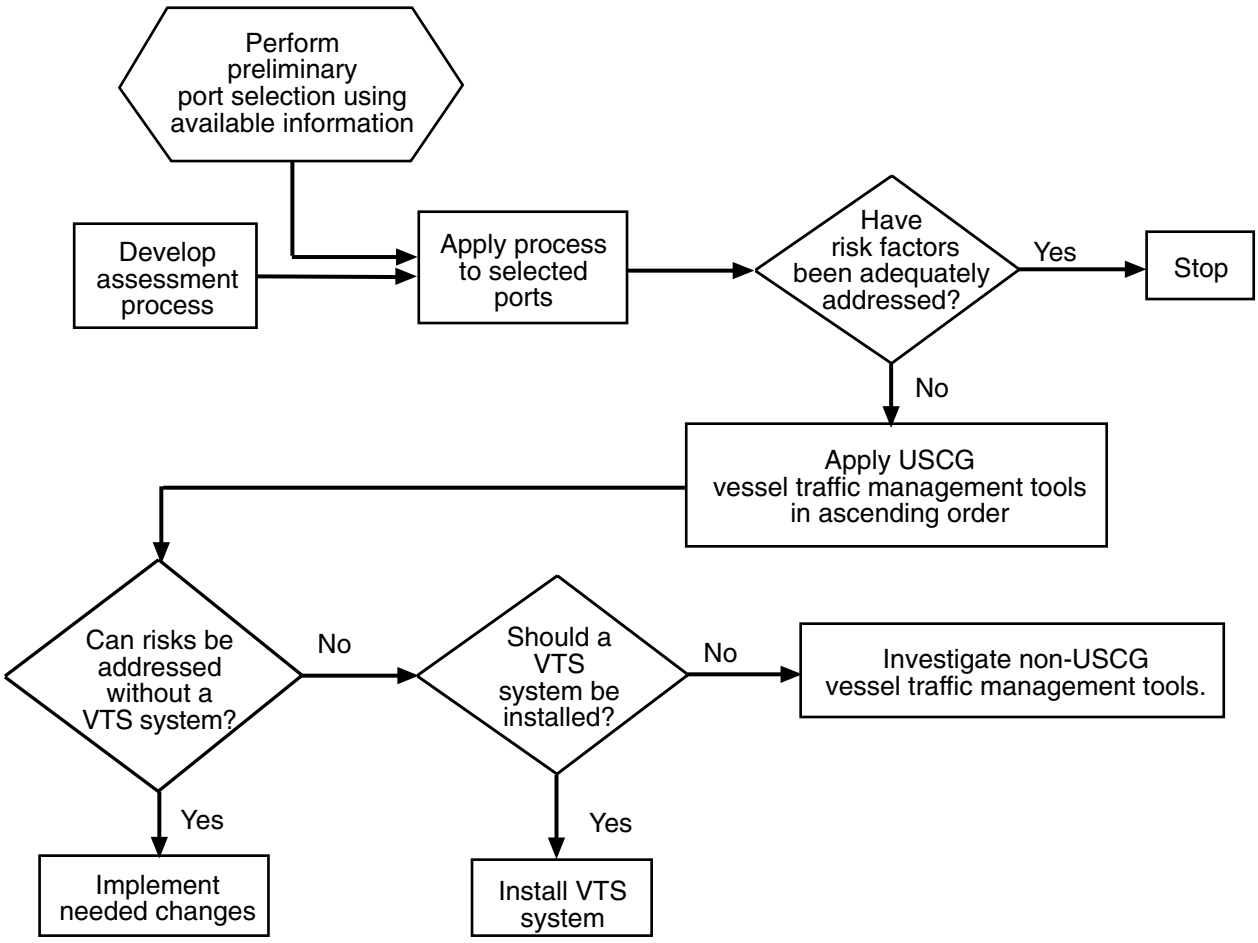

FIGURE 3-3 U.S. Coast Guard risk-based port selection process.

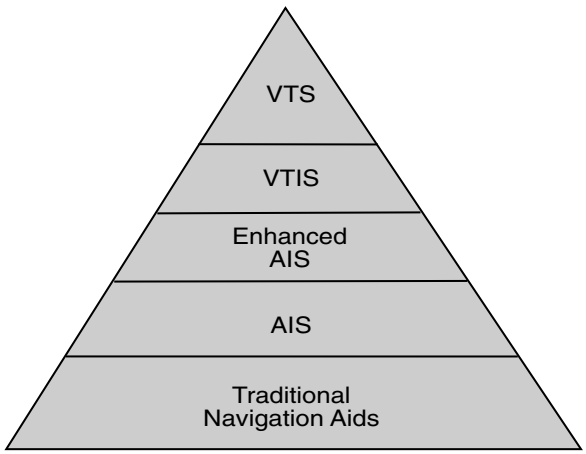

FIGURE 3-4 Vessel traffic management hierarchy.

port with respect to traffic density, traffic patterns, and complexity of traffic or vessel movements?

- What are the sizes, types, and numbers of vessels operating in the port area?
- What is the history (including the causes) of accidents, casualties, pollution incidents, and other vessel safety problems within the port area?
- What are the physical limitations of the port?
- What types and amounts of hazardous or environmentally sensitive cargoes are transported within the port?
- What are the prevailing conditions and extremes of weather and oceanography in the port?
- What are the environmental, safety, and economic consequences of having or not having a VTS within a given port?

The dialog group did not consider USCG missions, such as national security and law enforcement, which should also be included.

Nonfederal VTIS

In some areas, a federal VTS may not be warranted but regional or local interests would support a traffic management scheme. The legislature of the state of California, for example, has identified waterways for which environmental protection is a matter of significant state interest.[13] Some of these waterways were not even evaluated in the *Port Needs Study* and hence were not identified as being of national significance.

When considering the establishment of a VTIS, the issues to be considered include: whether or not a system is really necessary; who would pay for its installation; who would operate it; and who would be liable if the VTS contributed to an accident. The need for the system can be determined by state or local governments (such as port authorities) or the user community; the USCG, the competent authority, should participate in the process. The USCG would determine if national interests, including support for its own missions, would be served by federal involvement in the establishment or operation of the system, and, if so, to what extent.

Defining a Baseline System

In its interim report, the committee recommended that the Coast Guard select ports with the greatest safety needs for VTS and define a minimum generic baseline system that would meet national safety needs as well as Coast Guard mission requirements. The committee's description of a "generic, baseline system" can now be modified in terms of its updated perspective on VTS. The tools needed to provide VTS capabilities will vary from place to place depending on waterway shape and dimensions, vessel traffic patterns, and other considerations. The capabilities, however, will be generally the same for all waterways. It can be argued that national safety needs are subsumed within the statutory responsibilities of each captain of the port (COTP) for ensuring vessel safety, waterways management, and environmental protection. It follows, then, that the national VTS baseline for federal systems can be defined in terms of the capabilities required by COTPs to discharge their statutory responsibilities. In some cases, a VTS may be justified based on the USCG's mission and not directly related to commercial vessel safety (e.g., law enforcement or national security). The catalog of capabilities can be used to select the technological tools appropriate for each port on a case-by-case basis, giving due consideration to relevant policy issues and costs.

A port-by-port definition of system requirements would help minimize costs and maximize the benefits of investments in VTS by tailoring each system to meet the needs of a specific port. Some tools, of course, will be useful for all ports regardless of the complexity of the system or the volume of traffic. Certain communications technologies, for example, will be useful in all areas.

As an example of how the necessary tools can be derived from general capabilities, consider the issue of enforcing compliance within a regulated navigation area (RNA). Obviously, the necessary tools will depend on the requirements imposed in the RNA. For example, in Hampton Roads, Virginia, rules have been established for vessel movement and anchorage (33 CFR 165.501). In Tampa Bay, the requirements deal only with communications (33 CFR 165.753). The Hampton Roads RNA may require surveillance, whereas the Tampa Bay RNA may require only monitoring and recording of VHF-FM Channel 13 transmissions.

All federal VTS systems must support the full range of USCG mission areas, including search and rescue operations, law enforcement, and maritime defense. If cost-effective enhancements can support these missions without compromising the USCG's primary focus on safety and environmental protection, then the additional capabilities should be provided. It is also appropriate for a traffic service to address the needs of the commercial port community for traffic management and information exchange. The commercial aspects of VTS will undoubtedly vary by port, however, and can best be determined through partnerships between the port community and the USCG. The user community should also be involved in the development of port-specific operating rules and procedures. The California harbor safety committees provide useful models for this process.[14]

The technical components of a baseline system would be determined on a port-by-port basis. For example, the benefits of AIS may warrant the incorporation of this technology into all future and existing federal VTS systems. The services provided by a VTIS should be tailored to support the needs of the sponsor(s), subject to the approval and oversight of the USCG (the competent authority). Like federal systems, VTIS systems might be improved by the incorporation of AIS.

Technology Selection

The selection of VTS technology is an important exercise because it will substantially influence the effectiveness and cost of the system. The committee identified several considerations that may be helpful in the selection process. First, system capabilities should be defined before the technology

[13] See the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act of 1990.

[14] The requirements for these committees, including membership and responsibilities, are spelled out in the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act of 1990, Section 8670.23. A key provision requires the development of harbor safety plans that address the safe movement of all vessel traffic in ports covered by the plans.

is selected to prevent the system design from being driven by equipment vendors or the acquisition process rather than actual needs. Second, the components should not increase the workload of vessel crews unnecessarily. From this standpoint, the best technology is one that limits verbal radio exchanges to critical matters, minimizes the need to exchange fixed data, and enables mariners to extract the right data at the right time. Third, onboard equipment should meet both international carriage requirements and domestic standards, so the operating environment is consistent, training requirements can be standardized, and costs to vessel operators can be controlled. It is assumed that the equipment will meet appropriate standards of performance and interfacing.

Another key issue is the cost of the infrastructure required for mariners to benefit from a new technology. For example, the combination of DGPS and ECDIS promises to enhance both maritime safety and efficiency; however, several major infrastructure issues (e.g., upgrading nautical charts to the same level of accuracy as the positioning system) must be addressed before these benefits can be fully realized.

Intelligent Transportation Systems

New technologies for the enhancement of rail and highway traffic efficiency and safety have been the subject of research carried out by the Intelligent Transportation Systems Office of the U.S. Department of Transportation. Some of the research areas have included electronic tracking tags, identifiers, position locators, and other automated systems that could perform the labor-intensive operations in traffic management. A recent review of these systems as applied to intermodal freight transportation listed applications ranging from smart cards and bar codes to cargo tracking using DGPS and transponder identifiers (Alyward, 1996). The USCG should monitor this research to take advantage of the latest innovations in transportation technology to help solve waterways management problems.

SUMMARY

Waterways management depends fundamentally on well trained personnel following rules for safe vessel transits. However, technology can also contribute substantially to navigation safety. A number of opportunities exist for enhancing the effectiveness and application of technologies in the United States. The greater availability and use of electronic charts, PORTS, and AIS could enhance safety in many U.S. ports and waterways, if reliable funding can be arranged and carriage requirements can be established for transponders.

Determining where VTS systems should be installed and the specifics of their design is a complex process. The committee's vision calls for uniform VTS standards and capabilities across the nation, but the technological tools for each system would be selected on a port-by-port basis. The federal government is responsible for maritime safety, ensuring a consistent operating environment and compatible technologies, and enforcing regulations. Therefore, the federal government should be the competent authority for VTS systems and should provide vessel traffic management in areas where this would serve the national interest. The process for identifying ports that require new or enhanced VTS systems and for selecting the technologies to be used in each system should be updated and formally adopted. This process should take into account all of the USCG's missions.

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4

Vision of the Future and How to Achieve It

In the long recorded history of navigation, many important advances have been made in mariners' ability to travel the seas with safety, speed, and reliability. From the beginning, improvements in information and in the knowledge of how best to use it have been at least as important to mariners' survival in perilous seas and crowded harbors as improved vessel design, construction, and materials or the many other advances in seafaring.

The earliest charts of land masses, currents, wind patterns, and a few hand soundings, for example, apprised succeeding generations of seafarers of the conditions and hazards their predecessors had encountered. With advancing knowledge of the positions and movements of heavenly bodies, expert sailors using astrolabes (the predecessors of sextants) could approximate their position. A rudimentary compass was used to keep the vessel on course even when the heavens were obscured. A critical breakthrough was the invention of the Harrison chronometer, which for the first time provided accurate and reliable time so that longitude could be determined to within a few miles. For near-shore piloting, increasingly sophisticated visual and audible navigation aids were developed over a period of several centuries.

More recent breakthroughs, mostly resulting from military research and development, have included the gyrocompass, radio aids to navigation (from radio direction finders to Loran and Decca), and satellite navigation. All of them have improved a navigator's ability to determine the vessel's location and physical challenges, including shoals, reefs, tides, water depths, currents, and weather conditions. Radar, a World War II breakthrough, in combination with the VHF radio, has improved the sailor's ability to identify the challenges posed by other vessels. Despite all of these advances, however, if visibility was poor or traffic very heavy, none of these systems assured mariners that they had accurate and complete information or the technical capability of solving their navigation and traffic problems.[1]

[1] Reliance on imperfect technology can even introduce new hazards, like "radar-assisted collisions," for example. (NRC, 1994).

Most of these problems can now be solved, at least conceptually. Furthermore, a common vision of the future is emerging within the maritime community, both in the United States and abroad, in which computers, satellites, and electronics will be deployed wisely and widely to provide a new level of navigational safety. This chapter describes the vision and the elements the United States must have in place to realize it.

THE VISION

Environmental Conditions

In the future, existing and emerging technologies will provide mariners with timely warnings of obstacles in surrounding waters and accurate predictions of inclement weather. Highly accurate information will be available in various formats—electronic displays, by radio, or on the Internet. Mariners will also be able to fix their positions quickly, easily, and accurately. Basic hydrographic information, regularly updated, will be available for geographic regions of interest to all types of users. The technical means are already available to acquire all types of data, but adequate resources are lacking for updating obsolete data. The information will include geographic positions of land masses, shoals, and important features to the accuracy standard of 5 to 10 meters now set by DGPS.

Real-time hydrographic and meteorological data are essential for large, fast vessels entering dredged channels with minimum under-keel clearance. The technical means for obtaining these data have been proven effective by the success of the PORTS and other systems. Once the issue of chronic underfunding has been addressed, either through increased budgets or through partnerships, these vital information systems will realize their full potential.

Data will be available to users in many formats, ranging from updated paper charts to the most advanced electronic charts, which will be written to international specifications and will enable many users to take advantage of full ECDIS

capability. Tides, currents, and *Coast Pilot*-type information will be published in hard copy and on the Internet and updated through electronic transmissions in varying degrees of detail (e.g., more detailed for big commercial ships and less detailed for recreational boats). However, because shipboard systems are not likely to match the speed of land-line data connections (now 28,800 bits per second) in the near future, some files, especially long or graphics-laden documents, may take too long to download from the Internet to benefit mariners.

Precision electronic navigation technology, such as DGPS, has already proven to be extremely accurate. In the future, fixing positions in all weather will not only be possible (as it is today) but will also be reliable. Prudent mariners, however, will continue to fix their positions by multiple, independent means when their vessels are close to hazards or in constricted waterways, especially when visibility is poor.[2] In other words, the mariner of the future will not rely solely on any one technology but will continue to exercise his or her critical judgment and will have the necessary training and qualifications to do so.

Other Vessels

In the future, mariners will be able to detect the presence and determine the position of other vessels quickly and accurately, regardless of weather or location. They will also have the tools to make sound decisions about taking evasive action, if necessary. All vessels will be equipped with AIS, which will be linked to shore-based VTS systems in busy harbors.

AIS, in combination with precision navigation systems, will become a critical tool for detecting other ships and selecting anticollision strategies, especially in low visibility. This technology suite will enable mariners on the bridges of two or more vessels to identify each other and exchange information silently and immediately on their courses and speed. "Silent, bridge-to-bridge VTS" will be tested in a prototype installation in the AIS pilot project on the Lower Mississippi River. Similar systems in Alaska, Canada, and Europe have demonstrated their usefulness in close-quarters situations and in avoiding collisions.

This "VTS of the future" will have many advantages over radar (which cannot "see" around corners, such as islands) and will enable mariners to interact over dedicated frequencies that are not blocked by competing or extraneous transmissions. Silent, screen-to-screen interactions will enable mariners to communicate when and how they choose, eliminating the distraction of constantly monitoring VHF channels from several vessels and sometimes from shore.

The success of the "VTS of the future" will depend on all vessels (or at least all vessels above a certain size) carrying internationally compatible transponders and other equipment and all operators being trained in their use. The equipment will be internationally interchangeable and not dependent on unique or proprietary technology. Future VTS systems will be easy to use and affordable. Fortunately, the proliferation of electronic equipment and the tendency for prices to decline over time suggests that this vision of the future can be achieved.

Traditional systems, such as radar, automatic radar plotting aid,[3] and VHF radio, will continue to be used for redundancy and to ensure reliability. Furthermore, in most heavily trafficked harbors, an information link to a shore-based VTS system will provide both information and active traffic management by the appropriate authority, when necessary.

REALIZING THE VISION

Realizing the vision described above will not be easy. A firm foundation will first have be laid so that the most effective systems can be widely deployed in the United States. The committee identified eight elements of this firm foundation.

Coordinated National Policy on the Maritime Information Infrastructure

At least four federal agencies are currently responsible for various types of information and data critical to the navigation of vessels. USACE is responsible for channel maintenance and inland waterway operation, including locks on federal systems; NOAA is responsible for hydrographic surveys, charts, bathymetric data, *Coast Pilot* information, and weather information; the USCG is responsible for aids to navigation, *Notices to Mariners*, navigational broadcasts, *List of Lights*, and VTS; and the National Imagery and Mapping Agency is responsible for rebroadcasting some information from *Notices to Mariners*, keeping track of mobile drilling rigs and acts of violence directed against shipping, the Navigation Information Network, and sailing directions.

The effective use of the data depends on the capability of these agencies to coordinate their activities, set common priorities for collecting and disseminating data, and cooperate in the delivery of services to users. Too often mariners must evaluate a variety of services and sources to determine which one is most accurate and reliable in a given situation. A coordinated policy on the development and support of the maritime information infrastructure would eliminate, or at least lessen, this uncertainty. Coordinated planning could provide mariners with the most accurate data on a timely basis in a user-oriented format.

[2] DGPS has some limitations when used in constricted waterways (USCG, 1997).

[3] Automatic radar plotting aid is a computer that quickly and automatically plots radar targets based on information about the target vessel's course and speed. It is used to assess passing or overtaking situations and can help prevent collisions.

Mechanisms for Identifying and Responding to Stakeholder Needs

Identifying all stakeholders in port and waterways operations, let alone cataloging and satisfying their needs, can be difficult. Nevertheless, stakeholders' needs must be met in a way that enhances safety for all users, not just the most vocal ones or a select group. If improving efficiency is the goal, then competing interests should be balanced to raise the overall threshold, not just the efficiency of one sector at the expense of others. In some ports, organized stakeholder groups, such as harbor safety committees, are already in place and can provide a mechanism for making decisions. In others, federal agencies should encourage the formation of stakeholder organizations and decision-making procedures.

Technical, Operational, and Performance Standards

Standards for data exchange, component interfaces, and user interfaces with critical navigation systems are all essential for creating a uniform operating environment among all ports and waterways. Other standards may also be necessary for mariners to act confidently on the basis of safety information, other types of data, instructions, or guidance. Centralized, consistent, reliable sources of navigational information will provide a solid foundation for realizing the future vision. Responsible parties should move forward expeditiously with the development, especially in the international arena, of technical standards and carriage requirements for essential navigational technology, including ECDIS and AIS. The federal government has sole authority to act on behalf of the nation in setting international standards.

Appropriate and Predictable Funding

Although adequate and predictable funding are not always available at the federal level, the future vision can only be realized if support is somewhat predictable. The minimum level of support could plausibly be ensured through a combination of public and private funds through partnerships to fund and operate systems.

Development and Maintenance of the Maritime Information Infrastructure

Federal agencies must develop and maintain the basic infrastructure necessary for navigational safety. The infrastructure must include the following essential elements:

- Up-to-date charts of all waterways essential to U.S. commerce must be available in both hard copy and electronic form, with chart data identical to those of GPS and as accurate as those of DGPS. Electronic formats must meet the international standards for use with ECDIS.
- Real-time data on tides, currents, wave heights, and weather conditions for all waterways essential to U.S. interests must be electronically accessible (with backup hard copy) to vessels far enough offshore to plan a safe passage.
- Up-to-date, port-specific navigational data (e.g., information now available in *Coast Pilots*, light lists, and *Notices to Mariners*) must be made available to mariners electronically (with backup hard copy) sufficiently far offshore to enable the planning of safe passage.
- Vessels must be equipped with a mechanism for electronic vessel-to-vessel and vessel-to-shore exchanges of information essential to emergency responses and navigational safety.
- Maintenance of conventional aids to navigation must be continued.
- An electronic system, accessible by the USCG and emergency response teams, must be in place for keeping track of hazardous cargoes carried by vessels in U.S. waters or stored at U.S. marine terminals.

Appendix E describes the necessary data and formats from the point of approach to the departure from a port. This description could be used to guide all agencies or organizations that coordinate and deliver information services.

Silent, Automated Systems for Information Exchange

Information should be delivered in ways that do not interfere with or distract shipboard personnel, particularly bridge watchstanders, from the performance of their duties. Thus, the reliance on voice communications should be drastically reduced, and the availability of real-time data, on an as-needed basis, should be greatly expanded. Two necessary advances will be an Internet service that enables mariners to access and print out information directly, as needed, thus eliminating the need to maintain an onboard library of preprinted and corrected hard copies, and AIS for the exchange of selected data on vessel movements and other information.

Strict Compliance with Rules for Waterway Operations

Mechanisms should be established to ensure that all mariners and vessels transiting U.S. waterways comply with established rules and regulations so that everyone can enjoy the benefits of safe, consistent, and orderly operations. Enforcement methods may vary among ports and regions, but the federal responsibility for this function is well established. In addition to traditional USCG enforcement, economic

incentives might be used to reward, and thereby encourage, the use of advanced safety systems and practices. Another enforcement technique would be to create peer pressure for compliance through forums, such as harbor safety committees. If nonpunitive measures do not result in consistent compliance, punitive action should be taken.

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Conclusions and Recommendations

Advanced information systems are needed to ensure the rapid, accurate exchange of vital information related to navigation safety. To provide a safe operating environment in U.S. ports and waterways and support the nation's economic and national security in the future, a variety of navigation information technologies, strategies, and practices will have to be improved and integrated. Rather than focusing on specific changes that should be made in individual information systems, the committee defined the general steps the government should take to make U.S. ports and waterways as safe as possible.

Information systems that promote navigation safety are already being used by a number of federal agencies to carry out their missions. These systems also contribute to the national goals of protecting the environmental and human health. The federal government has a responsibility to take the lead in the development and implementation of these systems to promote navigation safety. At the same time, the government should take into account stakeholder needs and should attempt to secure private sources of cofunding, wherever it is appropriate or essential to operations. Cooperation among federal agencies and partnerships of public and private stakeholders are emerging mechanisms for improving navigation safety.

PROVIDING AN INFORMATION INFRASTRUCTURE

The navigation information infrastructure includes nautical charts (based on timely, accurate underlying data); systems for delivering chart data to users; systems for collecting and disseminating real-time data on weather conditions, currents, and tides; conventional aids to navigation (e.g., buoys, lights, and markers); electronic navigation systems (e.g., DGPS); and electronic information exchange systems. Some of the nation's most vital water transportation links do not have an adequate navigation information infrastructure or accessible, accurate, real-time data.

Most federal agencies with responsibilities in these areas have already defined infrastructure needs, but no integrated implementation plan or arrangement for ensuring consistent support has been developed. Furthermore, many of the federal responsibilities are shared with other public or private entities; areas of responsibility often vary from port to port.

Conclusion 1. The federal government should strengthen its commitment to providing the basic infrastructure necessary for navigation safety and environmental protection. The best way to promote the consistent implementation of critical infrastructure elements is to develop a national plan, with local input and periodic reassessments of the needs of particular ports and waterways. The development of a national plan will require strong leadership from both the government and port stakeholders to justify the necessary public and private investments.

Recommendation 1. The Interagency Committee on Waterways Management should coordinate the efforts of the U.S. Coast Guard, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, and National Imagery and Mapping Agency to develop an integrated, comprehensive plan for developing and maintaining the navigation information infrastructure for all significant U.S. ports and waterways and should secure consistent, long-term support (public and private) to implement the plan.

TRACKING HAZARDOUS CARGO

The USCG does not operate any electronic systems for tracking hazardous cargo and does not currently have regular access to the U.S. Customs Service comprehensive information systems, which contain electronic manifests from most cargo vessels sailing within, or planning to enter, U.S. waters. Furthermore, port information systems (which are often linked to the U.S. Customs Service database) rarely provide emergency response teams with direct access to this

data. A number of port closings and other shipping delays have been caused by difficulties encountered by public safety personnel trying to identify unknown cargo after spills, fires, and other incidents. Time is of the essence in an emergency, and real-time access to electronic data on hazardous cargoes would be much quicker than the current practice of relying on paper records and hoping that marine terminal and vessel personnel who can identify cargoes are available.

Conclusion 2. The safety of U.S. ports and waterways would be enhanced if the USCG and local emergency response personnel had access to electronic manifest data for commercial cargo vessels.

Recommendation 2. The U.S. Coast Guard and the U.S. Customs Service should develop a system to disseminate automatically electronic information on hazardous cargo from the existing cargo-tracking database to emergency response organizations and personnel.

IMPROVING VESSEL TRAFFIC MANAGEMENT

The USCG is implementing a program to meet the needs of key U.S. ports and waterways that do not have adequate VTS systems while also satisfying the concerns of local port stakeholders. The committee's interim report recommended that the Coast Guard involve local stakeholders and promote public/private partnerships in its efforts to implement VTS systems in ports with identified safety needs, and the Coast Guard has incorporated these recommendations into its current program. However, the committee still has some concerns about maintaining national standards of operation and accommodating local needs and circumstances. Mariners need consistent rules of operation and compatible equipment worldwide. The committee is concerned about the inconsistencies among VTS systems and the VTIS systems operated by a variety of organizations (e.g., federal, state, and private entities and combinations thereof). Mariners need—and want—a consistent operating environment, which can only be provided if uniform guidelines are devised for VTS and VTIS systems. Furthermore, the effectiveness of these systems will be maximized if they all use compatible equipment designed to the highest standards and if they provide the most essential capabilities for navigation safety.

Conclusion 3. Minimum system design and operational standards compatible with established international standards would enable VTS and VTIS systems to maintain a baseline level of safety nationwide.

Recommendation 3. The U.S. Coast Guard should continue to move forward, in consultation with local port stakeholders, with a comprehensive national effort to implement vessel traffic services systems in key U.S. ports and waterways where such systems are needed. Periodic assessments of safety needs should be made to keep up to date. The U.S. Coast Guard should also provide a uniform national system of traffic management implemented through coordinated federal vessel traffic services systems and local vessel traffic information services systems. The U.S. Coast Guard should take the following steps while moving forward with the overall program:

- develop, standardize, and implement objective criteria for selecting ports to be served by federally funded vessel traffic services systems; upgrade existing systems; implement new systems that are urgently needed
- develop training, certification, watchstanding, and operating standards applicable to all vessel traffic services regardless of who operates them
- as the competent authority, ensure that all shore-based vessel traffic management activities, regardless of who operates them, comply with established international standards
- facilitate communication among ports on lessons learned about the implementation of these systems

UNIVERSAL CARRIAGE REQUIREMENTS

Consistent traffic management depends on all vessels, or at least all vessels of certain sizes using specific waterways, carrying the same basic information systems and operating them according to uniform standards. A VTS system that incorporates AIS will not be very effective if, for example, only 50 percent of the cargo ships in local waterways carry transponders. The requirements for AIS can be generic, but the international character of the shipping industry and the prevalence of foreign-flag vessels in U.S. waters argue for the carriage of systems that meet international standards. The presence of significant numbers of large ferries, tugs, and other vessels operating in certain waterways argues for carriage requirements that cover that traffic as well.

Conclusion 4. To achieve the committee's vision of the future, all major vessels must be required to carry certain advanced navigation information systems so they can participate in traffic management schemes and navigate safely in and out of all U.S. ports.

Recommendation 4. The U.S. Coast Guard should work toward the implementation of international carriage requirements for electronic navigation and identification/location systems on board all major vessels using U.S. ports and should continue to take steps to provide necessary communications frequencies to ensure the international compatibility of automatic identification systems.

APPENDICES

APPENDIX A

Biographies of Committee Members

H. Thomas Kornegay, *chair,* is executive director of the Port of Houston Authority, which he joined in 1972. He previously served as the port's planning and administrative engineer, chief engineer, director of engineering, managing director, and acting executive director. Mr. Kornegay is a member of the American Society of Civil Engineers, the Permanent International Association of Navigation Congresses, and Chi Epsilon, an honorary fraternity for civil engineers. He has a B.S. degree in architectural engineering from the University of Texas and an M.S. degree in architectural engineering from Oklahoma State University.

William A. Wallace, *vice chair*, is professor of decision sciences and engineering systems at Rensselaer Polytechnic Institute. As a researcher and a consultant in management science and information systems, Dr. Wallace has more than 20 years of experience in developing decision-support systems for industry and government. He has held academic positions at Carnegie-Mellon University and the State University of New York at Albany and served as chairman of the Statistical, Management, and Information Sciences Department at Rensselaer. Dr. Wallace also has been a research scientist and visiting professor at a number of institutions abroad, including the Swiss Federal Institute of Technology and the National Center for Industrial Science and Technology Management Development in China. He has authored or co-authored six books and more than 100 articles and papers. He has a B.S. in chemical engineering from the Illinois Institute of Technology and an M.S. and Ph.D. in management science from Rensselaer.

Anne D. Aylward is a senior consultant to the Volpe National Transportation Systems Center, which advises the U.S. Department of Transportation on port and freight issues. She is past maritime director of the Massachusetts Port Authority and served as executive director of the National Commission on Intermodal Transportation. She has provided local and national leadership on port and intermodal freight issues while serving as chair of the American Association of Port Authorities and a board member of the North Atlantic Port Conference, North Atlantic Ports Association, Boston Shipping Association, and Boston Harbor Association. Ms. Aylward has also served on the National Research Council's Marine Board and is currently a member of the Transportation Research Board's Committee on Intermodal Transportation. She has an A.B. degree from Radcliffe College and an M.S. degree in city planning from the Massachusetts Institute of Technology.

William O. Gray is president of Gray Maritime Company, a marine consulting firm. He works closely with INTERTANKO, which represents 70 percent of the world tanker fleet, to promote safe waterway transits in the United States. Previously with the Skaarup Group, Mr. Gray initially operated the Skaarup fleet and then managed special tanker projects, working with organizations such as the National Academy of Sciences and INTERTANKO. Mr. Gray also spent more than 22 years with Exxon Corporation working primarily in the development of very large tankers. He managed Exxon's Arctic Tanker Project, a successful transit of the Northwest Passage by the *T/V Manhattan*. Mr. Gray also spent four years with Bethlehem Steel working on the preliminary design of merchant ships, especially tankers. He previously served as vice chair of the Marine Board Committee on Tank Vessel Design. He has a B.S.E. degree in naval architecture, with honors, from the University of Michigan, and an M.E. degree in mechanical engineering from Yale University.

Jerrol Larrieu is director of management information systems for the Port of New Orleans, where he supervised the installation of the nation's most sophisticated automated port information system. Previously, he was a consultant to the port on its automation project, coordinating design teams for major portions of the community cargo release system. Prior to that, Mr. Larrieu was manager of computer services for the Ingram Corporation for nearly 10 years, providing corporate consulting services. He has 28 years of experience in

advanced information systems, including service with General Electric Company and the Chrysler Corporation. He is currently chair of the American Association of Port Authorities Information Technology Committee and is a member of the Executive Board of the U.S. Customs Automation Advisory Committee. He has a B.S. degree in mathematics from Xavier University of Louisiana.

Robert G. Moore is president of Coastwatch, Incorporated, a maritime management and consulting firm involved in the design of vessel traffic service (VTS) systems. The firm has developed VTS design requirements for 23 U.S. ports. Previously, he was a career officer in the U.S. Coast Guard. As chief of military readiness, he was responsible for service-wide security, contingency and defense planning, and training. Capt. Moore also has broad international experience. He was the U.S. State Department advisor to the government of Somalia and served in London as deputy commander, U.S. Coast Guard Activities Europe. Capt. Moore's extensive experience with VTS systems includes visits to major VTS systems in Europe and service as the U.S. observer to the international committee that developed the traffic separation schemes for Dover Straits and the North Sea. He also played a leading role in the 1991 *Port Needs Study,* a study for the U.S. Coast Guard that identified U.S. ports that require VTS systems. Capt. Moore has a B.S. degree in engineering from the U.S. Coast Guard Academy.

J.S. Niederhauser is an active marine pilot and past president of Puget Sound Pilots. He is the pilot representative to the Port of Tacoma project for the computer simulation of large container ship navigation in the Blair Waterway. He holds an unrestricted pilot license for Puget Sound waters from the U.S. Coast Guard and the state of Washington and is a member of Masters, Mates, and Pilots and the American Pilots Association. Previously, Capt. Niederhauser spent 19 years with Foss Maritime Company, where he gained sea experience on ocean, coastal, river, and harbor towing vessels. As a tug captain, he qualified for pilotage in British Columbia waters and pilotage while towing loaded petroleum barges on the Columbia River and southeast Alaska inland waters. A charter member and past commodore of the Pacific Northwest Fleet of the Classic Yacht Association, Capt. Niederhauser also has considerable experience in recreational boating on Puget Sound and British Columbia waters. He was educated at Western Washington State University in Bellingham.

F.D.R. Posthumus is director of fleet projects for Sea-Land Services, Incorporated. He has a wealth of experience in virtually all aspects of vessel operations and fleet management and has managed foreign-flag charter vessels as well as U.S.-flag vessels. Capt. Posthumus was also manager of Marine Operations Europe, Booking and Equipment Control Europe, and vessel operations in several areas of the world. Prior to joining Sea-Land in 1970, Capt. Posthumus sailed extensively with the Dutch Merchant Marine. He has a master's license from the Hogere Zeevaartschool and a license as chief engineer of unlimited powered diesel ships. He is a graduate of the Dutch Army Transportation Corps Officers Academy.

Steve Valerius is executive vice president of Hollywood Marine, Incorporated, one of the largest tank barge companies in the United States. He is active in numerous marine industry organizations, serving on the boards of directors of the American Waterways Operators, Texas Waterway Operators Association, and Louisiana Association of Waterway Operators. He is an advisory director of LaPorte State Bank and a member of the Texas General Land Office Oil Spill Commission. Mr. Valerius is also chairman of the Executive Committee of the Galveston Bay Foundation. He is a graduate of the University of Texas at Austin and has a J.D. degree from the South Texas College of Law in Houston.

Cameron Williams is vice president for academic affairs at the Massachusetts Maritime Academy. He is also a professor in the Joint Diploma Programme in Shipping and Port Management, Graduate College of Marine Studies, University of Delaware and Singapore Port Institute. Previously, he taught marine transportation, economics, and marketing at the U.S. Merchant Marine Academy. He holds U.S. Coast Guard licenses as master of steam and motor vessels up to 1,600 tons (oceans), second mate of vessels of any tonnage (oceans), and radar observer. He is also a captain in the U.S. Naval Reserve, specializing in naval control of shipping and convoy operations. He is a member of the Academic Advisory Committee and Intermodal Association of North America and a past member of the Chief of Naval Operations Advisory Board for Naval Control and Protection of Shipping. Dr. Williams has a B.S. degree in marine transportation from the U.S. Merchant Marine Academy, an M.A. degree in business management (marketing) from Central Michigan University, and a Ph.D. degree in business administration (marketing) from the University of North Carolina at Chapel Hill.

Russell Woodill is executive vice president and national positions chairman for the Council of American Master Mariners, which represents more than 1,500 shipmasters and pilots. He is also master of the Sea-Land *Performance*, which trades internationally and is one of the largest container ships in the world. He has been active in the U.S. Merchant Marine for nearly 30 years, rising through the ranks of junior officers to his current position of licensed shipmaster, unlimited tonnage, any ocean. Captain Woodill has expertise in marine navigation, ship management, ship construction, cargo requirements, and vessel operations. He has a B.S. degree from the Massachusetts Maritime Academy.

APPENDIX B

Excerpt from The National Dialog on Vessel Traffic Services *April 1997*

PREAMBLE

In January 1997, the U.S. Coast Guard (USCG) convened a national dialog with maritime and port community stakeholders[1] to identify the needs of waterway users with respect to Vessel Traffic Service (VTS) systems or other means of ensuring the safety of navigation in U.S. ports and waterways.[2] The stakeholders, representing all major sectors of the U.S. and foreign-flag maritime industry, port authorities, pilots, the environmental community, and the USCG, were asked to provide guidance on the following issues:

- the information needs of a mariner to ensure a safe passage;
- the process that should be used to identify candidate ports for the installation of VTS systems; and
- the basic elements of a VTS, where such a system is determined to be necessary.

A list of all participants in the stakeholder dialogue is attached. Under the auspices of the Marine Board of the National Research Council (NRC), the group held four meetings between January and March 1997. This document is **not** an official report of the NRC, which has neither endorsed nor taken any other official position on its contents.

The national dialog was intended to provide the foundation for the development of an approach to VTS that would meet the shared government, industry, and public objective of ensuring the safety of vessel traffic in U.S. ports and waterways, in a technologically sound and cost-effective way. It is important for the United States to move forward in developing and implementing such an approach so as to remain at the forefront of maritime safety.

Underlying Premises

The responses of dialog participants to the specific questions posed to them were based on the following underlying premises:

- The primary goal of a VTS system is to ensure the safety of vessel traffic in U.S. ports and waterways and to protect the marine environment by ensuring that the mariner has the information necessary to prevent or avoid collisions, allisions, and groundings. By promoting safe navigation, a VTS also fosters the goal of efficient navigation. A VTS should have the capability to interact with traffic and respond to traffic situations in its area.
- Existing aids to navigation; charts, radar, VHF radios, publications, and other navigation tools; pilotage systems; navigation regulations, including the International and Inland Navigation Rules; current licensing and training requirements for mariners; existing navigation management systems; and existing USCG regulatory authority and enforcement practices make a significant contribution to the safety of navigation in U.S. ports and waterways today. These existing tools serve to ensure a high level of safety and environmental protection, and therefore, VTS systems are not needed in all ports.
- In some ports, additional tools may be necessary to ensure an acceptable level of safety and environmental protection. These tools may include a VTS system. The specific needs of individual ports to ensure safe

[1] These stakeholders included: the Natural Resources Defense Council, U.S. Chamber of Shipping, American Association of Port Authorities, Passenger Vessel Association, Council of American Master Mariners, American Pilots Association, American Waterways Operators, INTERTANKO, and U.S. Coast Guard.

[2] This summary uses the International Maritime Organization (IMO) definition of VTS as "a service implemented by a competent authority designed to improve safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area." In its proposed Guidelines for VTS, the IMO defines "competent authority" as "the authority made responsible, in whole or in part, by the government for the safety, including environmental safety, and efficiency of vessel traffic and protection of the environment."

navigation may vary given port and waterway traffic characteristics. However, certain common elements of a VTS (where such systems are deemed necessary) may be applied.

- The decision to establish a VTS in a given port should be made cooperatively by the USCG and the port user/stakeholder community. It is not the intention of dialog participants to invalidate existing navigation safety systems established by states, pilot associations, or other entities but rather to provide guidelines for the implementation of future VTS systems.
- Every mariner has the responsibility to operate vessels in a safe manner. In addition, the USCG has the statutory obligation to ensure the safety and environmental protection of U.S. ports and waterways. The USCG is the federal agency with primary responsibility for ensuring port safety and as such should play the leading role by ensuring that the mariner's navigation information needs for safe passage are being met.
- Waterways users are seeking enhanced navigation capabilities that would be compatible with new VTS systems but that would also have utility beyond a VTS-covered area. Safe navigation and environmental protection outside of port boundaries—in coastal waters, rivers and other inland waterways, as well as on the high seas—are equally important.
- Dialog participants strongly endorse the widespread use of Automatic Identification Systems (AIS) employing Differential Global Positioning System (DGPS) and onboard transponder technologies. These technologies provide a foundation for effective navigation safety, both within and outside areas where VTS systems are determined to be necessary. They also provide for improved vessel-to-vessel information exchange in ports and waterways in which no VTS system is established. Dialog participants believe that national use of AIS technology on the greatest number of vessels is essential both as a foundation of a VTS system, where such a system is necessary, and as the basis for improving navigation safety. Dialog participants strongly urge the USCG to take the lead both domestically and internationally in developing equipment and procedural standards that will promote universal use of AIS technology. Although port conditions and user/stakeholder needs may favor the establishment of VTS systems in selected ports, dialog participants believe that widespread use of AIS can serve as an effective navigation safety system.

Basic Information Needs of a Mariner to Ensure a Safe Passage

Dialog participants identified the following as the basic information needs of a mariner to ensure a safe passage:

1. up-to-date knowledge and/or information regarding the route to be transited;
2. timely, relevant, and accurate information about other vessels within the area that might affect safety or the decision making of the mariner (this information should include vessel identity, type, size, position, course, and speed);
3. timely information about emergency and environmental conditions that might affect safety or the decision making of the mariner;
4. reliable bridge-to-bridge communications; and
5. transmission of relevant information to the mariner in a manner that does not distract from the task at hand, particularly in narrow, confined channels where there is heavy traffic.

Existing navigation aids and tools, pilotage systems, navigation management systems, and regulations may be sufficient to provide this information effectively to a mariner given the characteristics of a particular port.

Factors to be Considered in Determining Whether a VTS is Necessary

As noted above, dialog participants agreed that existing navigation aids and tools, pilotage systems, navigation management systems, and regulations may be adequate to meet a mariner's information needs for safe operations in a given port. Dialog participants agreed that the process of determining whether a VTS is necessary in a particular port should include the USCG and port users/stakeholders. Questions to be considered in making this determination include, but are not necessarily limited to, the following:

1. What existing local navigation management systems are in place and how effective are they?
2. What are the existing or likely future conditions in the port with respect to traffic density, traffic patterns, and complexity of traffic or vessel movements?
3. What are the sizes, types, and numbers of vessels operating in the port area?
4. What is the history (including the causes) of accidents, casualties, pollution incidents, and other vessel safety problems within the port area?
5. What are the physical limitations of the port?
6. What types and amounts of hazardous or environmentally sensitive cargoes are transported within the port?
7. What are the prevailing conditions and extremes of weather and oceanography in the port?
8. What are the environmental, safety, and economic consequences of having or not having a VTS within the port?

Dialog participants agreed that the USCG should use these questions to conduct an initial screening and identify ports which might be candidates for a VTS. Port users/ stakeholders should be engaged to consider these questions in more detail and to determine whether a VTS is in fact necessary in a given port.

Basic Elements of a VTS

Where the USCG and local stakeholders determine that a VTS is necessary, dialog participants identified several basic elements that such systems should include. Within the framework provided by these elements, local variations may be needed to meet the particular needs of a given port community. However, vessel-based equipment required for participation in a VTS should be consistent from one port to another and should have utility outside port boundaries.

Where the need for a VTS system has been identified, it should include the following elements:

1. A **VTS should be based upon AIS technology** as a means to provide timely, relevant, and accurate navigation information to the mariner. Widespread use of vessel transponders that use DGPS for positioning is essential to a VTS system for three reasons:
   a) AIS technologies will improve safe navigation both inside and outside of a VTS area;
   b) Information collection and transmission by the VTS will be less intrusive and distracting to the mariner than will a voice-based control system; and,
   c) DGPS-based transponder systems are gaining worldwide acceptance as an effective and cost-effective means of vessel-to-vessel and vessel-to-shore information exchange.
2. **Local conditions may require the use of other surveillance and communications technologies**.
3. With emphasis on minimizing distractions, the common goal of dialog participants, including the USCG, is to fully employ AIS technology to **minimize voice communications in a VTS area.** Dialog participants believe that use of AIS technology should largely obviate the need for USCG-to-vessel voice communication except in navigation emergency situations. The VTS system should be as transparent to the mariner and to the USCG as possible.
4. **AIS technology should be applied in a cost-effective manner** using commercially available technology in an open architecture. Successful implementation of an AIS-based VTS system will depend on adherence to the following guidelines:
   a) The federal government should **develop and distribute accurate electronic navigation information**, including
      - up-to-date navigation charts in electronic format;
      - DGPS broadcasts; and,
      - timely updates of information, including USCG Notices to Mariners, in electronic format where appropriate.

   The USCG should **develop standards for reliable, electronic vessel-to-vessel and vessel-to-shore information exchange** that minimize voice communication and that can provide essential information to the mariner both within and outside designated ports or VTS areas.
      - Standards should be performance-based, allowing the use of technology and equipment that is commercially available on a competitive basis.
      - Information system requirements should be compatible nationwide and, preferably, internationally.

   b) **Timely and appropriate emergency and environmental information** should be provided in a compatible format.
5. To be effective, **a VTS system should be implemented by a competent authority**. The USCG's involvement, at a minimum, means the promulgation and enforcement of minimum technical standards, promulgation and enforcement of on-board equipment requirements, and responsibility for securing, if necessary, adequate spectrum capacity for operation of the system. USCG involvement in a VTS system should not preclude VTS partnership options and cooperative arrangements with other entities such as state governments, port authorities, or pilot associations.
6. **The competent authority's fulfillment of statutory obligations and enforcement of mandatory participation may require some level of shoreside oversight.** The level of oversight needed will vary from port to port; however, this oversight component should take full advantage of AIS technology as the primary means for monitoring waterway activities and vessel movements in the port to avoid potentially burdensome and costly systems. In general, dialog participants believe that use of AIS technology will greatly reduce the number of shoreside personnel and other resources needed for effective involvement in a VTS. The USCG's use of VTS to accomplish related missions and responsibilities should not interfere with the primary goal of promoting safe navigation.
7. VTS systems should be **compatible with international guidelines** for VTS.

Participation (including the carriage of AIS-compatible equipment and technology) **should be mandatory** for vessels identified in 33 CFR Part 161 (all vessels greater than 20

meters, vessels greater than 8 meters while engaged in towing, and vessels certified to carry 50 or more passengers).[3]

ATTACHMENT C-1

ADDITIONAL COMMENTS OF THE NATURAL RESOURCES DEFENSE COUNCIL

April 24, 1997

The Natural Resources Defense Council (NRDC) has the following additional comments to make regarding the National Dialogue on Vessel Traffic Services Summary Guidance document, dated April, 1997. NRDC represented by Sarah Chasis participated in the national dialogue, convened by the U.S. Coast Guard, to discuss Vessel Traffic Service (VTS) systems to enhance safety for our nation's waterways.

On page 3 of the draft Guidance document, we have problems with the wording of the last sentence of the first full paragraph ("Although...). We favor substituting the following sentence: "The stakeholders believe that AIS has utility both as the foundation of a VTS system (where such a system has been determined to be necessary) and as the basis for improved vessel-to-vessel information exchange in ports and waterways in which no VTS system is established." We believe this better reflects the value of Advanced Information Systems—either as a basis for a VTS system or for improved navigational safety in the absence of a VTS system. We do not believe that AIS is a substitute for VTS systems.

On page 4, we have problems with the suggestion in each of the paragraphs that the Coast Guard *and port users determine* whether a VTS is necessary in a particular port. The Coast Guard has the legal duty to protect safety and the environment in the nation's waterways and, therefore, *it* must be the one to determine whether a VTS is necessary. This determination should be made in consultation with "local stakeholders" (who, we believe, should include environmentalists and other interested in protecting the marine environment), but ultimately it is the Coast Guard who must decide.

Finally, in the discussion on the last page regarding what constitutes a VTS, it should be made clear that a VTS system provides for *control* over vessel movements by the competent authority, that it *requires* shoreside oversight of vessel traffic and that, while AIS technology may be an integral part of VTS, it is *not always necessarily* the *primary* means of monitoring vessel movements.

We appreciate this opportunity to provide these additional comments.

[3] According to 33 CFR Part 161, vessels greater than 40 meters must participate but vessels greater than 20 meters must monitor the system. To monitor an AIS system, a vessel requires the related equipment. Therefore, participation is in effect required of vessels greater than 20 meters

APPENDIX C

Maritime Advanced Information Systems Puget Sound Region

REGIONAL CHARACTERISTICS

The Puget Sound region includes two major container and general cargo ports, Seattle and Tacoma. These two ports combined rank second in volume of container traffic among U.S. ports on the West Coast. Besides containers, Seattle and Tacoma also handle a variety of other cargoes, such as lumber, automobiles, fruit, and grain. The smaller ports in Cherry Point, Ferndale, Bellingham, Anacortes, Port Angeles, Port Townsend, Everett, and Olympia handle petroleum and forest products.

The northern seaward entrance to Puget Sound is through the Strait of Juan de Fuca, which is the U.S.-Canadian border. The strait is also the entrance to the Canadian port of Vancouver to the north. Seattle is approximately 125 miles down the strait from the ocean, and Tacoma is approximately 150 miles from the ocean.

Major oil terminals receiving tanker shipments from Alaska and elsewhere are located in the northern section of Puget Sound, which is also home to a large deep-sea and local fishing fleet, several major U.S. Navy installations, and a substantial coastal freighter fleet. In addition, many passenger and car ferries operate throughout the region because of the numerous large bodies of water separating population centers.

Because of its natural beauty, Puget Sound is highly regarded as a recreational boating center, and pleasure boat traffic is substantial. The local population is very concerned with protecting the environment of the sound and numerous other adjacent waterways. Dating back at least to 1935,[1] the state of Washington has imposed special requirements for shipping in state waters to protect the environment and natural resources.

The Puget Sound waterways are subject to a variety of weather and oceanographic conditions, including storms, strong currents, and low visibility due to rain and seasonal fog. Although the main channels are deep and wide, navigation in some waterways in ports is restricted by vessel size and draft. Because of the diversity in vessel types and sizes in the area, mariners must exercise extreme care in monitoring other vessel traffic. The substantial numbers of ferry operations, often crossing at right angles to the shipping lanes, present special traffic management problems.

The ports of Seattle and Tacoma are mainly "landlord ports," owning and leasing property for terminal operations. The major container terminals are operated by large steamship lines (e.g., Sea-Land, American President Lines, Hanjin, NYK, Maersk) and certain independent terminal operators, such as Stevedoring Services of America. The Port Authority's role is to serve as a catalyst for economic growth and job creation through port development and the expansion of private industry. The port has substantial investments in land and certain capital improvements but is not responsible for day-to-day operations of terminals or other facilities.

SUMMARY OF MARITIME INFORMATION SYSTEMS

A committee work group held a one-day meeting in the Port of Seattle. Representatives of government and industry organizations that provide or use certain key port or terminal information systems were invited. Participants included the U.S. Coast Guard, National Oceanic and Atmospheric Administration, Washington State Office of Marine Safety, Puget Sound ferry operators, terminal operators, and the marine exchange. The major systems they use are described below.

U.S. Coast Guard

The vessel traffic service (VTS) system in Puget Sound is one of the most comprehensive systems operated by the U.S.

[1] In the state Pilotage Act of 1935, "the legislature finds and declares that it is the policy of the state of Washington to prevent loss of human lives, loss of property and vessels, and to protect the marine environment through the sound application of compulsory pilotage . . ."

Coast Guard (USCG). It covers an extensive geographic region that includes a number of harbors and cooperates with the Canadian Coast Guard in monitoring vessel traffic along the international border. The Vessel Traffic Center (VTC) in Seattle receives signals from 12 strategically located radar sites throughout the Puget Sound area. These radars cover approximately 2,900 square miles, including the Strait of Juan de Fuca, Rosario Strait, Admiralty Inlet, and Puget Sound south to Commencement Bay at Tacoma. In addition, several critical waterways are covered by closed-circuit television.

This system has been in continuous operation since 1972, and participation has been mandatory for certain vessels since 1974. (All powered vessels more than 40 meters in length, tugs more than 8 meters in length, and vessels carrying 50 or more passengers are required to participate.) The three major components of the VTS are the surveillance network, a traffic separation scheme (as adopted by the International Maritime Organization), and a vessel movement reporting system. The reporting system uses a VHF-FM communications network with 10 low-elevation, low-power sites and 3 high-elevation, high-power sites continuously maintained by the VTC in Seattle. The VTS operators process all information received from vessels and disseminate all navigational safety information to mariners who ask for or require it.

The VTS data management, processing, and display systems were recently upgraded and, according to most users and the local maritime community, they now provide excellent traffic monitoring and oversight, as well as safety in the region. The system has broad support even though the available analyses of benefits are subjective and rely on anecdotal evidence. One drawback is the lack of compatibility between the current software and other Windows-based systems and databases; improvements are planned in that regard.

Plans for future enhancements include the addition of an automatic identification system (AIS), which will enable the VTC to receive continuous identification and tracking information from each vessel equipped with a transponder and will eliminate the need for voice communications for identification. The local USCG office and the state ferry system are participating in demonstrations and tests of using transponders on ferries. Experience to date indicates that AIS offers benefits both in terms of safety and improved ferry operations, and discussions are under way to move ahead with adopting a specific system.

Although the Puget Sound VTS system is achieving its mission of safe traffic management and aiding navigation, it operates as a self-contained system, with virtually no electronic connection to other maritime information systems in the regional port complex. For example, every two hours VTC operators fax a report on vessels in the system to the local marine exchange, which maintains a database on ship arrivals and departures. It is theoretically (and probably technically) possible to link the VTS data directly with the marine exchange database, but this option has not been explored because the USCG is concerned about unauthorized access to its data.

The USCG does not even integrate its own information systems. There is no electronic data link between the VTC and the local USCG Marine Safety Office (MSO); instead, the data are exchanged by fax. The MSO operates the marine safety information system, which was developed in the 1970s and is difficult to integrate with other databases. These information systems do not provide adequate support for the ship inspectors, who must sort through numerous paper documents to check a vessel's accident history. Similarly, the USCG maintains paper records of hazardous materials notifications for all vessels entering the port.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) performs its traditional maritime information services, including hydrographic surveys and nautical charting, weather forecasting, and operation of tidal gauges. Weather information, forecasts, and tidal gauge data have recently been available to all users over the Internet. Updated survey information is made available to local pilots, and electronic charts are already available for the region.

Because local mariners do not seem willing to support an extensive physical oceanographic real-time system (PORTS) in the region, NOAA operates a modest system, which includes user-accessible tidal gauges at three locations. The ports of Seattle and Tacoma have been encouraged to contribute to system maintenance.

NOAA also is engaged in a variety of local research and investigations to promote safe marine transportation and prevent environmental damage. NOAA's other responsibilities include tracking the movement of oil spills and evaluating their effects on sensitive areas. Because the relevant data systems have to be coordinated with the rest of the maritime community, NOAA works closely with local stakeholders and supports the collection of data on marine casualties.

Washington State Department of Ecology

The Washington State Department of Ecology is responsible for enforcing certain state regulations governing vessel transits within state waters and certain required safety features. The office has developed a system to evaluate the potential environmental threat posed by a vessel, based on factors such as age, flag state, and casualty history. Information from the USCG, Lloyd's, and other sources is entered into the system. The agency screens vessels entering the sound and selects certain ones to board and inspect based on the risk factors determined by the model. In addition, a near-miss reporting system is being developed as another accident-prevention tool.

Representatives of this office assert that a central database for the entire region, accessible to everyone, would help reduce vessel accidents and protect the marine environment. To achieve this vision, greater cooperation would be required among federal and local agencies and the industry, and existing databases would have to be linked (requiring improvements in interfaces and systems compatibility). Data from the American Waterways Operators and the Washington State Pilotage Commission could also be included.

Washington State Ferry System

The high volume of ferry traffic on numerous waterways in the Puget Sound region poses unique challenges for vessel management. The state ferry system operates 25 vessels that engage in a total of 450 to 550 trips per day, depending on the season. Many of these transits take place in busy port regions, and routes typically cross the major shipping lanes. Safety is a primary concern to the operators.

All ferries participate in the VTS system, which provides important safety information. Recent tests of transponders aboard ferries suggest that this technology enhances the VTS system's capabilities and may also improve operational efficiency and customer service. The ferry operators are now considering whether to make transponders a permanent part of their operations and evaluating the various purposes for which they might be used. For example, it might be possible to track each vessel's position and estimated time of arrival at a terminal continuously and accurately. This information could be used to manage automobile traffic at terminals and provide customers with up-to-date information about traffic delays and other particulars. Thus, it may be possible to justify the cost of a complete transponder tracking system based on both business and safety concerns. Currently AIS is only installed on selected ferries.

Container Terminal Operations

Several major container terminals are located in the ports of Seattle and Tacoma. Each has an information system that provides data on cargo entering and leaving the terminal and manages the cargo data needed by ocean and land carriers, shippers, agents, and government agencies. Most systems are automated and are electronically connected with the U.S. Customs Service system. The terminal information systems are usually internal to an organization and contain proprietary data. Independent terminal operators handle cargo from many ocean carriers and must accommodate the systems used by each one. Several large terminals are operated by ocean carriers themselves and, therefore, can readily integrate ship-to-terminal information flow.

The terminal operated by American President Lines is experimenting with a satellite-tracking and container-tagging system that is capable of providing location information within four feet for each container, in a terminal (or any other location with an electronic relay station nearby). The system appears to offer substantial benefits in terms of improving the management of cargo movements within terminals. Whether this system can be used efficiently to track containers on vessels and land carriers depends on the value of the information compared to the cost and difficulty of obtaining it.

Puget Sound Marine Exchange

The Puget Sound Marine Exchange is active in this port region. It maintains data on commercial vessels, their movements, and their projected and actual port arrival and departure times. These data are supplied to a variety of users in the marine industry. The marine exchange is thus an information broker of increasing importance. It is one of four marine exchanges on the West Coast that recently formed a cooperative organization known as the Maritime Information System of North America. The partners are currently sharing data on vessel movements and locations through the Internet in an effort to improve both the accuracy and timeliness of information. They also plan to discuss the concept with marine exchanges in other areas of the United States interested in inproving data exchange. The marine exchange database is not linked electronically to the VTS system. Nor is it linked to the data system operated by local pilots.

Another project developed by the Puget Sound Marine Exchange on behalf of vessel owners and operators is the international tug of opportunity system (ITOS). This project is an industry response to a proposal for a dedicated standby tug stationed at the entrance to the Strait of Juan de Fuca to assist tankers and other vessels during emergencies. The ITOS was proposed by stakeholders as a less costly and more effective alternative to the dedicated, standby tug.

Under ITOS, the marine exchange maintains a database on the location and capabilities of all tugs in the region at all times, manages an emergency response plan, and notifies the right persons to dispatch a capable tug to the scene in case of an incident. The program requires both an automated data system and an accurate vessel tracking system. A transponder-based tracking system has been proposed for the tugs. An AIS (different from the ferry system) is currently installed on tugs and other craft and is being evaluated.

The marine exchange is developing information systems that serve the local and regional maritime community as a nonprofit organization offering fee-based services. It is the only industry organization that integrates information flow for customers who pay for the service. The marine exchange is investigating whether the collection and dissemination of real-time data on water depth would be supported by industry.

Puget Sound Pilots

The Puget Sound Pilotage District is managed by the Washington State Board of Pilotage Commission under state regulations. Pilots must pass a rigorous examination and

demonstrate both a high level of knowledge and the appropriate and accurate use of that knowledge. They use many sources of navigational information, including *Coast Pilots*, Light Lists, applicable excerpts from the *Code of Federal Regulations*, NOAA charts, U.S. Army Corps of Engineers surveys, berth surveys from port and terminal operators, and maritime reference manuals and textbooks.

On-duty pilots are assigned to vessels by dispatchers using a special computer system. This system is accessible to dispatchers at the Seattle office during working hours and at their homes by modem after hours and on weekends. The system is also accessible to pilots and boatmen standing by at the Port Angeles pilot station, and by pilots from their homes when standing by for outbound assignments. The system provides the following primary functions:

- transmits orders to dispatchers and provides a list of pending and assigned vessel movements
- calculates billing amounts from pilotage tariffs and prepares invoices
- maintains a vessel database that dispatchers can verify and update based on the vessel itself, a printed Lloyd's List, and other sources
- maintains a database of predicted tides and currents and calculates tide levels at scheduled departure and arrival times
- stores and maintains assignment information (e.g., berth spotting criteria, number of tugs assigned, name of tug company) relayed from the vessel master or agent
- provides dispatchers with information needed to assign rested pilots
- uses historical data to forecast the end of assignment time and total pilot requirements so that off-duty pilots can be called, if necessary, to accommodate heavy vessel traffic
- creates reports required by the state of pilot assignments, rest periods, and analysis of assignments and billing used to substantiate manning levels and tariff adjustments

The pilot dispatch computer system also incorporates warnings, which are activated if a dispatcher enters data that exceeds set limits, such as a vessel draft. The system also provides a warning if a vessel is bound for a berth that is already occupied. This design allows the dispatcher to coordinate vessel arrival and departure times with each vessel's agent and thus minimize delays. Certain warnings may be reviewed by the pilot association president, who advises on the most appropriate transit times and other aspects of vessel movement.

In addition to using the computer system, dispatchers also verify scheduling of vessel movements by telephone with the marine exchange, tug companies, and others to minimize conflicts and delays. Also, the arrival times of vessels under way are obtained from the VTS system or directly from the vessel by VHF radio or a pilot's cellular telephone.

APPENDIX D

Maritime Information Systems Port of Charleston, South Carolina

PORT CHARACTERISTICS

The Port of Charleston, South Carolina, is the second largest (after New York/New Jersey) container port on the U.S. East Coast. The port serves a brisk trade in container, bulk, and chemical products at both private and public terminals along the banks of two of the three rivers that converge at the port. A growing volume of vessel traffic poses challenges with regard to physical space, traffic management, and information systems that will have to be solved for the port to grow, remain competitive, and operate safely. In this way, Charleston is representative of many U.S. ports.

As a river port, Charleston is affected by seasonal flow levels of the Ashley, Cooper, and Wando rivers, as well as twice-daily variations in ocean tides. The interaction of flowing, freshwater rivers with ocean tidal fluctuations generates unpredictable currents. Silting from the rivers creates a constant need to maintain berth and channel depths. In addition, differences in water temperatures contribute to seasonal fog.

Most of the private berths and all three public terminals are located very close to dense population centers. The Columbus Street terminal is approximately one mile from the Charleston city center. The city's status as a major tourist attraction has generated a great deal of concern about the presence of oil, chemicals, and hazardous commodities and the potential threats these materials represent to nearby residents, tourists, and the environment.

Protection of the environment is a serious matter to the citizens of Charleston. The tourist industry is based in large measure on the scenic beauty of the city, the harbor, and rivers. Wildlife is abundant and varied. A substantial boating industry and thriving commercial fishing industry use the port, rivers, and the surrounding coastal areas. Aquaculture is being developed nearby, and seafood is a staple of Carolina low-country diets.

MARITIME INFORMATION SYSTEMS

In June 1996, a work group of the Committee on Maritime Advanced Information Systems interviewed representatives of 16 organizations[1] with interests in port activities to determine the capabilities and deficiencies of the information systems. Based on the information collected, the work group made the following general observations:

- No single resource or authority is responsible for coordinating or promoting the use of advanced information technology in the Port of Charleston.
- A wide range of relevant and important information is available, but it is not being fully exploited to optimize the safety and efficiency of maritime transportation.
- Stakeholders are generally satisfied with the quality and amount of information they receive or have access to, but they believe that current levels will not be adequate in the future as the port expands. They say additional relevant, real-time information would be useful now, but only if it is selective and easy to obtain. All stakeholders acknowledge that advanced navigation and information systems would enhance the safety and efficiency of what is generally considered a safe and well run port.
- With the exception of the port's Orion system for processing U.S. Customs Service data, very little information is exchanged among stakeholders by computer or

[1] Charleston Port Authority; Sea-Land Service, Inc.; Carolina Shipping Co.; Charleston Marine Exchange; Charleston Harbor Pilots; Charleston harbormaster; U.S. Coast Guard; National Oceanic and Atmospheric Administration; National Weather Service; U.S. Army Corps of Engineers; U.S. Customs Service; U.S. Naturalization and Immigration Service; Carolina Port Police; Mount Pleasant Fire Department; Coastal Carolina Council; and the South Carolina Department of Natural Resources.

the Internet. Most information exchanges take place by fax, with telephone calls and mailed newsletters as alternatives.
- With the exception of the Orion system, most stakeholders use hardware and software that meets their own information needs. Very little, if any, consideration has been given to developing information systems that are accessible by other local port stakeholders or are network compatible.
- No single organization is capable of developing an overarching port information infrastructure without substantial financial and technical assistance from other sources.

INFORMATION SYSTEMS BY ORGANIZATION

U.S. Coast Guard

In Charleston, the U.S. Coast Guard (USCG) fulfills its traditional roles and is an active participant in most port advisory committees. Charleston does not have a vessel traffic services (VTS) system and is not a candidate for a VTS system in the eyes of either the USCG or the local port community. Except in emergencies, vessel traffic management is left to the pilots and waterways users.

The USCG does provide some real-time information services within the port. When notified that a navigational aid is extinguished, missing, or improperly located, the USCG notifies waterways users through the local navigational warning broadcasts on radio channel 22A. If they miss the broadcast, then waterways users can obtain the information by calling the local USCG office, accessing the NAVINFONET, or reading the next *Notice to Mariners*. (The USCG reports the problem to the Miami office for inclusion in the notices, which are updated weekly and mailed to subscribers.) The Charleston USCG office is creating a Web site and intends to include some of this information. Most port stakeholders say that timely reporting of this information is a low priority.

The USCG appears on all the National Weather Service (NWS) severe weather warning checklists and can rebroadcast information as a navigational warning as well as take the appropriate actions regarding waterways safety.

U.S. Customs Service

The U.S. Customs Service, working with the port authority, has been a leader in using advanced technology to promote efficiency. This agency has long collected cargo manifests electronically and provided pre-arrival and departure clearances of cargo, either through its own automated systems or through the Charleston Port Authority's Orion System (described below). The U.S. Customs Service appears to be moving steadily toward a paperless system that takes full advantage of available technology.

National Weather Service

The Charleston office of the NWS serves the local maritime community in a number of ways. It provides the forecast information for the National Oceanic and Atmospheric Administration (NOAA) weather radio broadcasts, including a specific Charleston harbor forecast. Weather forecasts can also be obtained by telephone recordings, which are updated several times a day. The Charleston station is manned around the clock and accepts calls requesting information.

The office maintains four severe weather warning call lists: (1) a special marine warning checklist, (2) a winter storm/high winds watch/warning checklist, (3) a tornado/severe thunderstorm/flash flood watch/warning checklist, and (4) a coastal flood watch/warning checklist . The USCG, harbor pilots, and South Carolina Ports Authority appear on every checklist and are contacted by the NWS whenever severe weather is forecasted. Conditions favorable for harbor and coastal fog are also relayed to the checklist participants.

The NWS provides their weather radar picture to several approved and contracted vendors, which market the image and information to the maritime community. Updated radar information can be viewed on a computer monitor in near real time. The pilots were the only stakeholders interviewed who used this service.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers generates considerable waterways information. The Corps is involved in several proposed dredging projects, and the hydrographic information generated is made available to the Charleston maritime community by mail.

CHARLESTON PORT AUTHORITY

The Charleston Port Authority uses its Orion System for U.S. Customs Service pre-arrival and departure clearances, as well as for inventory control. Initially, stakeholder participation in Orion was mandatory in the port. However, the system has since been eclipsed by the U.S. Customs Service's systems, and larger commercial stakeholders can now bypass Orion and go directly to these more sophisticated systems for clearance. Smaller commercial stakeholders who cannot afford a direct Customs interface still use Orion. The port authority intends to upgrade this prototype system and perhaps expand its functions to promote efficiency and keep the system viable.

Information concerning traffic congestion, berth space, navigational warnings, draft restrictions, and severe weather is gathered and exchanged by telephone and fax on an as-needed basis. The port authority does appear on the NWS severe weather warning lists. The port authority, harbormaster, and pilots coordinate their information by telephone

and fax. The port authority is considering expanding Orion to capture and distribute some of this information to its customers.

An advantage of Orion is the capability for local control of the cargo information database. Information passing through Orion is captured, stored, and used for analysis of port activities. Real-time cargo-related information, including a running inventory of hazardous commodities, is also available. Unfortunately, hazardous-cargo information is not readily accessible and is not currently transferable to those responsible for responding to an emergency. For example, in the event of a terminal fire, a list of the hazardous materials currently located in the terminal would have to be printed out by personnel capable of operating the system who would then meet the arriving Mount Pleasant firefighters. It is not clear how well this approach would work in the middle of the night, for example, when no cargo operations were under way.

Charleston Harbormaster

The Charleston harbormaster, an employee of the South Carolina Ports Authority, coordinates the docking and undocking of vessels calling on Charleston harbor. The harbormaster relies heavily on telephone and fax messages. Although not specifically listed on the NWS severe weather warning call lists, the harbormaster can call the NWS or pilots to ask about weather conditions or can obtain faxed information from the port authority.

The harbormaster is in a unique position. In the event of an emergency, this individual is expected to provide information that may, or may not, be obtainable. For example, if a container of hazardous material falls over the side of a vessel docked at a public terminal, then the harbormaster, in conjunction with the port police and USCG, is responsible for the recovery of the container and cargo. Yet there is almost no real-time information available concerning tidal stage or the direction and strength of currents. If spills of hazardous materials are within the harbor or river system they pose a serious threat to the port. The need for improved, real-time hydrographic information was expressed by the harbormaster and others (including pilots, the port authority, and the port police).

Charleston Harbor Pilots

The information hub in Charleston is the pilots association. Most stakeholders say they obtain waterways and harbor information by telephoning the pilots' office. The pilots are normally the first to report missing or damaged navigational aids. They are also the most well informed sources of information on vessel arrivals, departures, and the immediate status of the harbor. In the absence of a VTS system in Charleston, the pilots have assumed the role of traffic manager, and they play a major part in coordinating the use of local waterways.

To handle the growing volume of traffic, the pilots have computerized their operations and maintain a database of customers and their vessels. They can fax vessel arrival and departure information to port stakeholders. They can receive weather information by fax from the NWS and are on the severe weather warning call list. In addition, the pilots subscribe to a third-party weather service that provides video images of local weather that can be viewed on personal computers and are updated hourly.

To improve the coordination of vessel arrivals with working pilots, they have extended the operational range of their VHF station out to 250 miles. In addition, they can access real-time information from a NOAA-operated water-level gauge that is linked by a telephone line to the pilots' office. The water-level information is available to anyone who calls. No information on currents is available from this station or anywhere else in the port harbor area.

The pilots find themselves playing a public relations role of dispensing waterways information to a wide range of information seekers. The demand for information has been growing along with the port. Therefore, it is no surprise that the pilots support the formation of a local marine exchange that could act as an information broker.

Charleston Maritime Association/Marine Exchange

The Maritime Association of Charleston is attempting to establish a marine exchange. The concept is still in its early stages, and the services that would be provided have not been fully defined. Supporters of the marine exchange envision an organization that will take the lead in collecting and distributing port-related information and coordinate the various port advisory committees, of which the association is one. Clearly, the attempt to create a marine exchange is directly related to the recognized need among port stakeholders for the expansion, centralization, and management of information.

Port advisory committees address common problems in the area. Existing panels include the Port Advisory Committee, Liquid Spillage Control Committee, and Maritime Association (within which the Intermodal, Navigation, and Operations Committee and Hazardous Materials Response Committee operate). Various subcommittees, such as the Vessel Agents Subcommittee, have been established as well. Communication among the various committees, their members, and the larger maritime community takes place during meetings and by telephone, fax, newsletters, and published reports. Computers are used very little.

Sea-Land Service, Inc.

Sea-Land's Wando Terminal is the East Coast test bed of the company's terminal automated system (TAS). When fully functional, TAS will provide the company with complete gate, yard, and inventory control over containers entering

and leaving the terminal. At the time of the work group's visit, only the shore gate portion of the system was operable.

The shore gate consists of 13 unmanned gates. An arriving truck drives into a vacant gate and telephones a checker located in a nearby building. The checker records the trucker's verbal information while using several scanning cameras to enter the container and chassis number into the TAS computer. The information is then fed into the company's mainframe computer, where it can be used as needed for business purposes.

Once through the main gate and checked into the TAS, the truck driver proceeds to another gate, where the chassis and container are checked for damage and serviceability. An employee with a hand-held, short-range, radio-equipped computer/transmitter relays the inspection information to the TAS, and the equipment is routed into the yard or a service area. (The hand-held computer/transmitter was unsuccessful in trials.)

The number and location of a container in the yard is recorded on paper by individuals driving through the yard. The transfer and loading of containers through the sea gate is also recorded by hand, on paper.

The TAS is an in-house system that serves only the container information needs of Sea-Land. Used in conjunction with the mainframe computer, TAS does allow Sea-Land to determine the terminal status of hazardous cargo (although not the exact location of individual containers) and to participate in the port authority's Orion system.

Information concerning port traffic congestion, navigational warnings, tides and currents, and severe weather is acquired as needed by telephone, fax, and sometimes local weather and warning broadcasts. Pilots are informed of vessel arrival times by telephone or fax. Sea-Land does not receive the local NWS radar image and is not listed on the severe weather warning list.

Carolina Shipping Company

Carolina Shipping Company uses the Orion system for U.S. Customs Service activities and, as an agent, operates its own in-house data system. Company officials are satisfied with the way they gather information, even when not electronic. For example, to determine the arrival of a vessel they simply telephone the pilot's office. This works well for them.

Representatives of the company expressed little interest in the idea of forming a local marine exchange that would provide information (at a price). They acknowledged that real-time information on navigational restrictions, water depth affecting vessel loading drafts, and severe weather would be of some indirect value to them and would promote a safer port. However, they are most interested in information that would contribute to their business mission and cost effectiveness.

South Carolina Ports Police

Local police and fire departments oversee the police and fire protection of private terminals. Accordingly, the ports police need port and cargo-specific information. They are among the first responders in the event of a casualty in the water adjacent to the public terminals or an emergency in public terminal areas. In the event of a fire, the police are in charge until the firefighters arrive.

Nevertheless, the police have no access to real-time port or cargo information, such as the information provided by Orion. Instead, they rely on terminal tenants to supply relevant cargo information. Access to this information is not always available, and terminal personnel do not always know what is in the individual containers. Terminal personnel often require assistance to identify hazardous materials and dangerous products, and they have no in-house means of determining the appropriate first responder for a hazardous commodity fire. The police also expressed a need for easier access to the information on crews and hazardous materials for vessels berthed at a terminal.

Mount Pleasant Fire Department

The Mount Pleasant Fire Department is responsible for fighting fires at the Wando terminal, which is used by several container companies. The department also responds to fires on board vessels alongside the terminal. Like the police, the fire department generally has to respond to emergencies without knowing exactly what commodities are involved or what hazardous commodities are on board. The department does not have direct access to cargo information systems, such as Sea-Land's TAS or the Port Authority's Orion.

Upon arriving at a vessel fire, firefighters rely entirely on a printed list of hazardous cargo and the capability of the vessel's personnel to locate those commodities. Crew lists, cargo plans, ventilation systems, and safety/fire plans also have to be provided by the vessel crew. Firefighters could obtain information from the terminal operator, but it would have to be delivered by hand. Delayed delivery of a list of hazardous cargo clearly impedes firefighting. Municipal firefighters are not necessarily familiar with all of the hazardous commodities carried in the international shipping trade, and it could take some time for them to determine an appropriate response. To compound the apparent safety risks, fire departments are not on the NWS severe weather warning call lists, and none directly receives real-time harbor information.

South Carolina Department of Natural Resources

The South Carolina Department of Natural Resources does not generate real-time information related to the movement of cargo in Charleston, but its impact on the port is

considerable. Its mission includes balancing the demands of trade with the maintenance of a healthy environment for other marine activities in the harbor and along the coast. The department reviews plans for the expansion of existing terminals, the location of new terminals, proposed bridges, and vessel anchorage areas. The discharge of vessel ballast water into local waters is another concern of this department that has a direct effect on vessel cargo operations.

To make good decisions, the department needs real-time data on tides and currents as well as improved hydrographic data on bottom types, accurate location of the shoreline, and shallow water depths. Thus, the use of advanced information systems would enhance its decision making regarding the environmental parameters within which the port must operate. Port efficiency depends on how well trade activities can meet the challenges of environmental concerns.

APPENDIX E

Arrival-to-Departure Information Exchange

Working Outline of Efficient Vessel Waterways Navigation Using Advanced Technology in Systems for U.S. Ports

1. Introduction

The following summary of the information exchange between ship and shore upon the arrival in or departure from a U.S. port indicates the scope of information required and the means by which data are currently obtained by ships in trans-oceanic transit.

2. Pre-arrival Harbor Transit Preparations

Situation: Ship at sea, open ocean, 24 hours prior to arrival at a major U.S. port. Systems used and information exchanged are shown below.

Ocean Navigation Information and Supporting Systems
- Inmarsat A, B, C, or M (communications system)
- MF/HF/VHF (NBDP - radio telex)
- GMDSS (global maritime distress and safety system)
- GPS (global positioning system)
- LORAN C (long range radio navigation system)
- ECDIS (electronic chart display and information system)

Information Exchanged
- automated notice to mariners
- automated local notice to mariners
- automated chart corrections in electronic chart and ECDIS support
- local port weather and visibility conditions and predictions
- available port real-time hydrographic information/history
- available port real-time water height, current, and density information/history
- transmit vessel ETA for pilots, U.S. Coast Guard, vessel traffic services, U.S. Customs Service, and others
- transmit crew lists for immigration pre-arrival clearance
- transmit vessel entry documents and certificates for pre-arrival Customs clearance
- transmit entry documents for agriculture pre-arrival clearance

3. Vessel Arrival and Harbor Transit to Berth

Situation: Ship in harbor approaches and harbor, transiting to its assigned berth. Systems used and information exchanged are shown below.

Harbor Navigation Information and Supporting Systems
- U.S. Coast Guard aids to navigation (buoys, fixed aids, racons and ranges)

- Inmarsat A, B, C or M (communications system)
- GMDSS (communications system - VHF-DSC, etc.)
- VHF Radio Network (communications system - VHF-DSC, etc.)
- cellular telephone network (communications system - VHF-DSC, etc.)
- transponder system network (communications/navigation system)
- vessel traffic services (information and management system)
- GPS/DGPS (differential global positioning system - navigation)
- ECDIS (electronic chart display and information system)
- PORTS (physical oceanographic real-time systems)

Information Exchanged
- arrival at pilot station
- real-time vessel position (aids to navigation and electronic charts)
- real-time channel water depth and density information (PORTS)
- real-time channel current information (PORTS)
- real-time port weather and visibility information (PORTS, NAVTEX, VTS, and VHF)
- real-time navigational information/vessels in system (ECDIS, VTS, and transponder)
- real-time VTS system waterways management (VTS)
- vessel emergency information (via transponder/hazardous commodities list, etc.)
- route prediction and time of arrival at berth (ECDIS, VTS, and transponder)

4. Vessel at Berth

Situation: Ship at berth, preparing for departure. Systems used and information exchanged are shown below.

Operations Navigation Information and Supporting Systems
- GMDSS (communications system)
- VHF radio network (communications system)
- cellular telephone network (communications system)
- transponder system network (communications/navigation system)
- PORTS (physical oceanographic real-time system)
- vessel traffic services (navigation information and management system)

Information Exchanged
- navigational warnings (Navtex, VHF radio, and VTS)
- weather warnings and predictions (Navtex, VHF radio, and VTS)
- real-time water height and density with 24 hour predictions (PORTS)
- real-time current conditions with 24-hour predictions (PORTS)
- real-time weather conditions with 24-hour predictions (PORTS)
- waterways traffic status (VTS)
- real-time emergency response status (transponder messages/real-time cargo ops)

5. Vessel Departure and Port Transit to Sea

Situation: Ship in harbor and harbor approaches, transiting from assigned berth to departure to sea. Systems used and information exchanged are shown below.

Harbor Navigation Information and Supporting Systems
- U.S. Coast Guard aids to navigation (navigation system)
- Inmarsat A, B, C or M (communications system)
- GMDSS (communications system -VHF-DSC, etc.)
- VHF Radio network (communications system)
- cellphone network (communications system)
- transponder system network (communications/navigation system)
- vessel traffic services (navigation information and management system)

- GPS/GPS (differential global positioning system, navigation)
- ECDIS (electronic chart display and information system)
- PORTS (physical oceanographic real-time systems)

Information Exchanged

- real-time vessel position (aids to navigation and electronic charts)
- real-time channel water depth and density information (PORTS)
- real-time channel current information (PORTS)
- real-time port weather and visibility information (PORTS, NAVTEX, VTS, and VHF)
- real-time navigational information/vessels in system (ECDIS, VTS, and transponder)
- real-time VTS waterways management (VTS)
- vessel emergency information (via transponder/hazardous commodities list, etc.)
- route prediction and time of departure at pilot station (ECDIS, VTS, and transponder)