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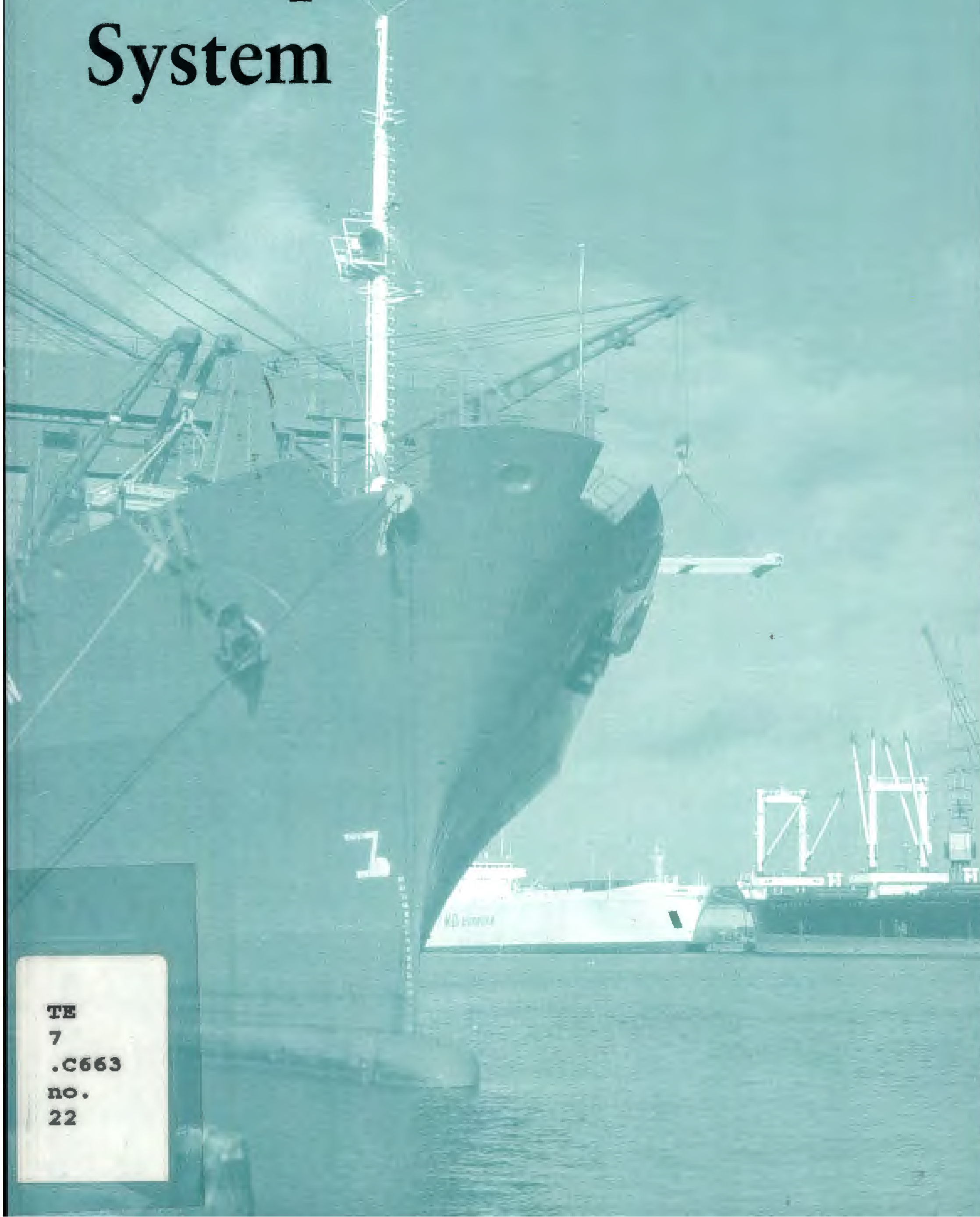
Risk Management in the Marine Transportation System



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Risk Management in the Marine Transportation System

Proceedings of a Conference
Irvine, California
March 29-30, 1999

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Preface and Acknowledgments

The nation's economy depends on safe and efficient maritime transportation that uses major ports and waterways. U.S. ports and waterways are remarkably diverse in terms of the vessel traffic served, the variety of services provided, geography, and environmental conditions. Ports must be able to provide efficient, rapid turnaround capabilities to accommodate not only expanding trade but also the increasing size and speed of oceangoing ships, a growing proportion of which are foreign flag. Many U.S. ports also serve a large volume of coastal and inland vessel traffic with a wide variety of barges, towing vessels, passenger ferries, and recreational boats.

In addition to traffic growth and changes in vessel characteristics, a number of other factors are converging to create potential problems that affect port safety and efficiency. Safety issues include the complex mix of vessel types, hazardous cargo, and the persistence of human error as a cause of maritime accidents. Potential safety problems also stem from the aging of commercial fleets, some substandard foreign-flag vessels and crews, a communications overload, outdated nautical charts, and inadequate environmental data. In addition, many harbors are too shallow to accommodate the deepest-draft ships, and economics sometimes dictates using the largest vessels possible in restricted channels and terminals.

Federal, state, and local agencies are responsible for providing services to waterways users and for coordinating the use of waterways for the maximum public benefit. Safe and responsible management of the uses of waterways can bring significant benefits to specific regions as well as to the nation as a whole. One of the major challenges faced by managers of major port operations in the United States is to keep informed about and to implement, when appropriate, the best available techniques for managing risk and preventing accidents in a situation of increasing volume, complexity, and variety of maritime traffic. Formal analytical risk assessment techniques often are not used to guide port and waterways managers when they make decisions about safety measures. However, systematic approaches can be most appropriate when considering the complexity of safety problems combined with the myriad of public and private entities with safety responsibilities within a given port or harbor region. Formal assessments can provide the most accurate results with regard to risk management by providing a systematic approach for determining levels of risk, opportunities to implement risk reduction measures, and relative benefits of alternative measures.

To the degree that risk evaluation has been used in managing the nation's waterways, there has been a heavy reliance on qualitative inputs of experienced mariners as a major component of the evaluation. However, few if any of the risk evaluations done to date have been replicable or have followed closely the tenets of formal risk assessment methodology as practiced elsewhere. A better understanding is needed of the issues involved in both the methodology of risk assessment and the inherent strengths and weaknesses of using the available data in order to apply risk assessment to marine transportation management and in planning for the future of the marine transportation system.

Many government and industry organizations are currently trying to develop analyses of port safety problems and identify the most effective solutions for managing risks. For example, the U.S. Coast Guard, in cooperation with local port communities, is trying to evaluate risks of accidents in their Ports and Waterways Safety System in order to determine the most appropriate level of vessel traffic management tools that should be proposed for certain ports. Some local harbor safety committees are also evaluating a range of proposals to upgrade safety systems to select those that are most effective.

During 1996 and 1997, the Marine Board investigated risk assessment methodologies under the auspices of a committee that was charged to evaluate the techniques used in a major assessment of tanker safety in Prince William Sound, and a report was published in April 1998 (Committee on Risk Assessment and Management of Marine Systems, 1998). The U.S. Coast Guard then asked the Marine Board to organize and conduct a symposium to present, discuss, and evaluate the application of risk assessment and risk management to the accident prevention problems faced by major U.S. ports and the institutions that are charged with ensuring port safety. A Marine Board steering group was established to plan and implement this effort—the Steering Group on Risk Assessment Methodologies Applied to Accident Prevention in Congested Ports and Waterways. The steering group sought the help of advisors in the areas of risk assessment, risk management, and port management and appointed three cochairs to work with Marine Board staff to organize the symposium, develop its structure and focus, conduct the sessions, and prepare an integrated proceedings of the symposium.

The symposium Risk Management in the Marine Transportation System was held in Irvine, California, on March 29–30, 1999. The goal of the symposium was to promote interactive discussion between risk assessment experts and port safety managers and to link expertise in the theories and methodologies of risk assessment and the use of data to real-world applications for risk assessment in the interest of improving the safety and efficiency of the nation's marine transportation system.

The symposium consisted of an opening plenary session in which formal papers were presented, including three case studies of situations in which risk assessment and risk management were implemented. After the plenary session, participants divided into four discussion groups. The leader of each group and a panel prepared in advance to focus discussion on particular subsets of topics relevant to the symposium theme. After brief presentations by the leader and the panelists, the audience was invited to join in the discussion. Discussion group chairs then prepared summaries of the discussions and presented them in a plenary session on the second day of the symposium. The symposium cochairs summarized the meeting at the end of the second day.

These *Proceedings* contain the cochairs' overview of the discussions and presentations, all the formal papers and presentations, and the discussion group summaries and excerpts from the question and answer sessions after the presentations by discussion group leaders. The symposium program; list of attendees; and biographies of the cochairs, presenters, and discussion group leaders are provided in the Appendixes.

Conference participants represented a diverse set of views from throughout the marine transportation community. Given the broad range of perspectives, the observations and suggestions voiced at the conference were varied and sometimes even at odds. Although some of the "findings" reported here were widely held, they are not to be construed as consensus findings or recommendations of all the participants or of the members of the steering group.

The cochairs and steering group express their gratitude to the staff of the Office of Oil Spill Prevention and Response of the California Department of Fish and Game for their invaluable assistance before, during, and after the symposium.

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the Report Review Committee of the National Research Council (NRC). The purpose of this independent review is to provide candid and critical comments that will help the authors and the NRC make the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the charge. To protect the integrity of the deliberative process, the contents of the review comments and draft manuscript remain confidential. Thanks are due to Jon S. Helmick of the U.S. Merchant Marine Academy, Lester A. Hoel of the University of Virginia, and William A. Wallace of Rensselaer Polytechnic Institute for their review of this report. Although the reviewers provided constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

Reference

Committee on Risk Assessment and Management of Marine Systems. *Review of the Prince William Sound, Alaska, Risk Assessment Study,* National Academy Press, Washington, D.C., 1998.

REMEMBRANCE: The cochairs of the symposium dedicate these proceedings to the late Nancy M. Foster, who served with the National Oceanic and Atmospheric Administration for 23 years and directed its National Ocean Service since 1997. She will be remembered as a strong and energetic supporter of measures to ensure safety and conservation in the marine environment.

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Chairmen's Overview

Peter F. Bontadelli, *PFB and Associates, Sacramento, California*
Jeffrey P. High, *U.S. Coast Guard, Washington, D.C.*
Thomas H. Wakeman III, *Port Authority of New York and New Jersey*

As the 21st century begins, the world is experiencing fundamental and rapid shifts in almost every sector because of the increasing pressures of globalization. Whether driven by trade, technology, or public opinion, leaders in government, business, and the community are examining their past practices and seeking better ways to meet international, national, and local mandates and to provide the services their citizens and customers expect. Economic development, natural environment, educational systems, national and international security, medicine, and many other sectors of today's world are being transformed as the new century unfolds.

The transportation sector is no exception. Rapid changes in the passenger and freight industries have occurred in response to demands for higher and better performance, and these will continue in the foreseeable future. This demand for improvement is particularly apparent in the maritime industry as products move from one part of the world to another. The steady growth of the global economy, the expansion of international trade, and the consolidation under way in the shipping industry have put increasing pressures on the collective performance of the maritime transportation community. Any interruptions or delays to the rapid movement of products or commodities between trading partners impair economic competitiveness and create inefficiencies in the marketplace. Of the multiple critical links in the global transportation and distribution network, the Marine Transportation System (MTS) offers the greatest opportunity for risk assessment and management to minimize the consequences of accidents on the environment and on the economy while striving to deliver a seamless flow of cargo.

Improving Decisions About Risks

The National Research Council (NRC) has been called on for decades to provide guidance for improving decisions about risks to public health, safety, and environmental quality. NRC has conducted many studies and investigations to help decision makers consider how society can understand and manage risk. The problem was of sufficiently broad interest among branches of the federal government that a special study of risk characterization was commissioned in the mid-1990s. A distinguished panel was assembled, called the Committee on Risk Characterization; after investigating a wide array of risk situations, the uses of risk characterizations, and decision types, the committee formulated general recommendations. In its 1996 report, *Understanding Risk: Informed Decisions in a Democratic Society* (National Academy Press), the committee defined the risk assessment process as "a synthesis and summary of information about a potentially hazardous situation that addresses the needs and interest of decision makers and of interested and affected parties." Risk assessment, therefore, must provide decision makers with information that allows them to make informed choices among available options.

Over the years, the NRC's Marine Board has applied risk assessment methodologies to specific studies. Following the 1989 *Exxon Valdez* accident in Prince Williams Sound (PWS), Alaska, the shippers who transport oil from the Port of Valdez by tanker formed a special study team to examine the current level of risk and proposed risk mitigation measures to reduce future incidents. The initiators of the study asked the Marine Board to provide a peer review of the PWS risk assessment. The Committee on Risk Assessment and Management of Marine Systems was charged with reviewing the risk assessment methodology used by the PWS team. The report of the committee was published in 1998 as *Review of the Prince William Sound, Alaska, Risk Assessment Study* (National Academy Press).

During the same period, the United States Coast Guard (USCG) embarked on a more general process to apply risk assessment to many of its activities as part of its overall work-planning program. The agency emphasized risk management in evaluating and prioritizing decision making and began to include risk-based evaluation criteria in its regulatory requirements. In 1996, the Coast Guard dedicated the April–June issue of its publication *Proceedings* to the topic, "Risk Management in the Maritime Industry." Changes in the international regulatory environment prompted interest in risk-based safety requirements for marine transportation. For example, the International Maritime Organization (IMO) adopted the concept of using risk assessment as the basis for future decision making. At the same time, IMO also developed a formal safety assessment and high-speed vessel codes and requirements to comply with the International Safety Management Code. The need to look at the application of risk assessment to maritime activities was still a major requirement.

Developing the Symposium

Recognizing the need to review current knowledge and to formulate the next steps for the application of risk assessment to the maritime field, the Marine Board proposed a symposium on risk assessment and management applied to marine transportation. USCG and the Office of Spill Prevention and Response in the California Department of Fish and Game agreed to provide funding for this activity. The Marine Board convened a steering group, chaired by Martha Grabowski, that included the following members: Peter F. Bontadelli, Lillian C. Borrone, Paul S. Fischbeck, B. John Garrick, H. Thomas Kornegay, Jerome H. Milgram, and Anthony J. Taormina. Liaisons to the steering group from the USCG were Duane Boniface and J. Michael Sollosi. The steering group met in Washington, D.C., on October 2, 1998, to determine the general purpose and program of the symposium. The scope of the symposium was limited to waterways management, to focus more clearly on maritime factors. Three cochairs were selected for the symposium, representing different facets of the maritime community, including regulatory, management, and industry perspectives: Peter F. Bontadelli, Jeffrey P. High, and Thomas H. Wakeman III. The cochairs worked with the steering group in creating the technical program for the symposium. The program's goal was to gather experts on risk assessment methodology and its related data issues together with governmental and industry leaders in the management of maritime risk.

Several themes were considered for the symposium. All previous studies of the application of risk assessment to maritime activities had identified the lack of available data as a major problem. In many cases, this led to overreliance on "expert opinion," which has hindered the applicability of various methodologies to more general uses. Because of this problem (and the likelihood that it would not be resolved in the near term), one of the major goals of the meeting was to focus on the current status of data availability and the need to develop a set of more generally applicable (and replicable) methods and processes.

Participants in the symposium, including invited speakers, represented a broad array of interests and views from the marine transportation community, as well as the field of risk assessment and management. With this wide range of perspectives, the observations and suggestions expressed in the presentations and discussions were varied and sometimes at odds. The following overview presents a selection of the themes and concerns most frequently expressed during the conference. These are not to be construed as consensus findings or as recommendations of the participants or of the steering group.

Symposium Highlights

In the opening plenary session of the two-day symposium, three keynote talks aimed at capturing the perspectives of three different groups of stakeholders in the application and use of risk assessment in the maritime industry. The speakers representing these groups were Thomas Wakeman, Port Authority of New York and New Jersey; Gus Elmer, SeaRiver Maritime, Inc.; and Vice Admiral James C. Card, Vice Commandant, USCG.

Port Operations Perspective

Wakeman outlined the expanding and competing nature of the MTS from a port operations perspective. He also highlighted issues that were discussed at the National MTS Conference held in November 1998 and focused on the ever-increasing need to apply risk management to many aspects of the MTS.

He pointed out that risk assessment traditionally has focused on three categories: financial losses, natural disasters, or accidents; as a result, there has been an emphasis on loss prevention. Wakeman suggested a new emphasis on achieving desired results and improving performance. He also proposed using risk management as a tool for improving overall transportation system performance.

He applied this framework to the implementation of four management principles:

- Strong commitment throughout the organization—beginning with the senior management—to a shared risk management program;
- Open communication and teamwork among government and industry partners to promote successful implementation of these programs (risks do not observe political, governance, or geographical boundaries—nor does the ability to reduce them);
- Risk management that is actively implemented, since prevention is always better than a cure; and
- Acknowledgment within MTS that risk assessment and risk management are iterative—they must be open to appropriate revision and change.

Industry Perspective

Gus Elmer discussed the need for risk assessment and risk management from the perspective of those who are active participants in the marine transportation industry. Elimination of all risks is impossible, yet the requirements and expectations of customers and of the public are more demanding than ever. He noted that to operate competitively and effectively in today's MTS, a company must have a proactive, dedicated commitment to risk assessment and management. From the perspective of industry, an internal commitment is preferable to a system imposed through legislation or regulation.

Risk management was described as the process of weighing alternatives for controlling risks and selecting the most appropriate course of action. Although risk managers may use information from risk assessments when they make decisions, they also may consider information about engineering, economics, law, ethics, and politics. In addition, a risk assessment ideally should provide systematic results to evaluate and to manage technologies. It should answer whether evidence is sufficient to prove specific risks and benefits. Answers to questions about acceptability of risks, or when a risk situation merits regulation, clearly involve values. On the other hand, the information in the assessment of the risk level should be objective.

According to Elmer, key elements in an industry program include

- Management credibility, so that safety is a core value for the company;
- Unambiguous policies that are believed in and acted on by all employees;
- A company philosophy in which safety has its own learning curve—people learn from past actions and continually make improvements for the future;
- Full information for decision making; and
- A companywide commitment to share information, including approaches and lessons to learn and improve. This commitment must be embraced by the leadership if systems are to improve within a company or within the entire MTS.

A systematic process that ensures objectivity when deciding on risk levels is necessary to guarantee that standards for evidence are objective and scientific. This is critical for obtaining the commitment of all stakeholders to honor and implement the resulting outcomes and recommendations.

Elmer concluded that the preservation of natural resources, the development of a healthy port infrastructure, and the perpetuation of personnel safety and safe operations depended on adherence to the following management principles:

- Promotion of open dialogue and collaboration;
- Blending of the viewpoints of disparate entities;
- Commitment to proven processes;
- The generation of balanced, justifiable solutions; and
- The recognition that the process must embrace continuous improvement.

National Perspective

Vice Admiral James Card opened his presentation by observing that major incidents often create a political reality that can impose value judgments affecting our perceptions when applying risk assessment or risk management. He noted that there is a difference among data, information, and knowledge—there is probably a lot of data, a little less information, and a lot less knowledge. Card outlined the role of MTS to the nation both now and in the future, noting that we are at a critical point. The nation has an aging transportation infrastructure, which affects its competitiveness and increases the risks. The system is under stress, and that stress will increase as more users compete for the waterways—from commercial carriers to ferries to recreational users to people concerned about the overall quality of the environment. These competing users, along with the increased threats of crime, smuggling, and terrorism, as well as the potential needs of national defense, must all be factored in to any efforts to improve the MTS. He noted that unlike other nations, the United States has a port system that includes many local ports of different operating types and sizes and with different systems of management and multiple layers of government. These ports must compete with ports such as a Rotterdam and Hong Kong, which employ centralized systems of port management. To compete successfully, the United States will need a vision for its national MTS.

In an effort to develop this vision, the USCG held regional listening sessions around the country aimed at establishing a dialogue among various federal and local agencies and other stakeholders in the maritime community. The dialogue continued at a national conference on MTS, hosted by the secretary of transportation in November 1998. The conference's objectives included the development of a vision for a more demanding future of MTS and of a framework for national and local coordination; it recommended actions to achieve specific goals in the areas of safety, security, mobility, environment, competitiveness, and infrastructure. Card noted that this vision of a national MTS will succeed only if all stakeholders are involved in its development and implementation.

Following the 1998 conference, a task force was established to coordinate implementation of follow-up activities within federal agencies, including

- Assessing the capability of MTS for the next 20 years;
- Consulting senior public- and private-sector officials as well as users and organizations;
- Participating in public- and private-sector activities to refine and implement the strategies and recommendations and the plans for action;
- Determining the capability for disposing of dredged materials in response to projected increases; and
- Projecting future needs for navigational aids systems.

After completing these activities, the task force will report its findings to Congress (see note, page 6).

One of the recommendations from participants in both the regional listening sessions and the national conference was to implement risk-based decision making. USCG is trying to increase the understanding of the principles of risk assessment and risk management. Card stated that people are the key to success in all areas. There is also a need to apply technologies to improve the MTS, especially when a port with limiting physical constraints faces increasing demands. Leadership is crucial for success in addressing difficult problems. Communication and commitment are fundamental to good leadership.

PRESENTATIONS AND CASE STUDIES

Following the three keynote speeches, which presented the framework for the remainder of the symposium, the primary focus was on specific areas of related interest. These areas were organized into three sections that included

1. Risk assessment methods and data needs;
2. Real-world and agency use of risk assessment and risk management; and
3. Case studies of the application of risk to specific risk assessments or risk management.

Following these presentations, participants gathered in small discussion groups to delve further into specific issues. The presentations appear on pages 17–35, and the summaries of the discussion group sessions on pages 83–101.

Risk Assessment and Data Needs

Karl Weick and Linda Connell introduced the topics of data and methods for risk assessment. Over the past 50 years a wide array of risk assessment approaches has developed, including descriptive and prescriptive models, analytical and behavioral methods, organizational and system models, and statistical and other techniques.

Weick exhorted the attendees to frame their questions carefully before they considered adopting risk assessment methodologies in a particular way. He recommended some fundamental approaches to framing questions effectively with respect to risk assessment methodology, emphasizing that it is important to think "outside the box" to select appropriate methods. This is especially true in looking at broader systems rather than discrete events. Weick specifically discussed one of his recent projects—an analysis of fire-fighting incidents—and concluded that even if we did not use a favorite tool, we can do a lot through intuition, feeling, stories, and experience.

Connell described the Aviation Safety Incident Reporting System, which uses the National Aeronautics and Space Administration as a neutral third party to report accidents and "near miss" incidents. She noted that it took several years for incident reporters to feel comfortable using the system and even longer for system managers to develop a useful database. The database is now at a stage where it will support some truly clinical work on the causes of incidents. Careful listening by project managers and open reporting by users are prerequisites for a viable system. She stated that this might serve as a valuable model for MTS data collection and development.

Real World and Agency Views

The next area of formal presentation was the interaction between real world events and current risk assessment practices and models. Karlene Roberts began by noting that although the marine community is unique, there are common impediments to safety that are closely related to those in other industries. She identified four questions to be addressed:

1. What things really need fixing (and how do I know)?
2. How do I fix them?

3. What are the impediments to fixing them?
4. How much will it cost me to fix them?

Each question had several subquestions framing the concept of risk assessment and management. Roberts noted that the largest impediment to fixing things was not always cost but frequently the culture of the organization itself.

Following this presentation, six representatives of federal agencies offered an overview of agencies' use of risk assessment in their marine and maritime activities (pages 38–52). Todd Bridges of the U.S. Army Corps of Engineers discussed the application of risk to dredging issues through the Dredging Operations Environmental Research Program. Nancy Foster, director of the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA), reviewed several programs relating to risk prevention and restoration of habitat. She observed that these NOAA programs, to be fully effective, must be integrated into those of other agencies and partners.

Alex Landsburg of the Maritime Administration discussed several agency programs and its progress in developing an information safety system for reporting events. Douglas Slitor of the Minerals Management Service (MMS) described how risk management is applied in targeting and analyzing information from the MMS offshore inspection program. Craig Vogt of the U.S. Environmental Protection Agency suggested that environmental concerns be taken into consideration at the beginning of maritime projects and that stakeholders also be involved from the beginning. He emphasized the need to harmonize competing concerns when addressing both a healthy economy and a healthy environment.

Rear Admiral Robert North, who served as chair of the panel, outlined several USCG programs implementing risk management.

Case Studies

The final set of formal presentations consisted of three case studies, found on pages 61–80:

- "The Practical Application of Risk Analysis in the Development of Harbor Safety Plans by California Harbor Safety Committees," by Suzanne Rogalin;
- "The Prince William Sound Risk Assessment: System Risk Analysis Using Simulation and Expert Judgment," by John Harrald; and
- "Oceans Risk and Criteria Analysis," by George Bushell.

Following these presentations, attendees divided into four discussion groups. Group 1, led by John Garrick, addressed risk assessment models and their practical applications. The second group, under the leadership of Paul Fischbeck, focused on the data and information necessary for risk assessment applications. Group 3, led by Anthony Taormina, addressed real world applications. RADM North moderated the Group 4 discussion of agency integration and cooperation. Following these breakout sessions, summary reports of each group's discussion were presented to a plenary session. The summaries are found on pages 83–101.

Summary of Themes

At the conclusion of the meeting, the symposium cochairs summed up the themes emphasized in the sessions. Foremost was the call for a more standardized risk assessment process for the maritime industry—one that would provide a consistent set of methods, standards, and data definitions before a project's start. Also deemed important was the inclusion of environmental considerations at an early stage in a project and the involvement of stakeholders as early as possible in the decision making. Comments indicated that a comprehensive database should be the starting point for doing things differently—and better—in the future. The real-world experience must be included in all of these approaches. For example, many ship crews don't speak English, and, therefore, are going to find it difficult to fill out questionnaires for a database.

The real world also involves competing demands on the marine transportation system and the marine environment from various users, interest groups, and the public. The stakeholders must participate and agree to the process in advance of decision making. It is important to involve stakeholders early and to educate them about the value of the risk assessment process. This will require presenting the processes in terms that nonexperts can understand.

Another often-expressed theme was the need to establish an incident reporting system with the liability protection to provide a data base for conducting reliable risk analyses.

Discussions of institutional responsibilities had acknowledged that a combination of international, national, regional, and local bodies should be involved in decision making and that each entity should adopt risk management as a decision-making tool. Many participants felt that an entity was needed that would be responsible and accountable for gathering all the data and making it available to the various decision makers. USCG was mentioned as the possible agent for this function.

During the closing session, it was observed that risk management was not something out of the ordinary. What many of the participants discovered was that risk assessment and risk management tools were used daily in most companies, agencies, and organizations, whether on a formal or an informal basis. These applications have become the basis for most waterway management decisions made today. Unfortunately, because most of the applications have been informal, they cannot be replicated. A more systematic and formalized approach would provide a body of information and "lessons learned" to build on in the future.

There always are ways to improve the implementation of these useful tools. The array of excellent scientific and trade literature can help. But the keys to any successful risk assessment and management decision are the commitments of all concerned and their recognition of the need for professional expertise in applying risk management strategies. This symposium was a starting point for expanding the understanding and application of these approaches to the U.S. MTS; hopefully, the texts from these proceedings will prove useful in addressing the ongoing issues.

Note

The report of the task force, *An Assessment of the U.S. Marine Transportation System: A Report to Congress,* is available on the Internet at http://www.dot.gov/mts/report.

Papers

Risk Management in Public Agencies: Building a New Context

Application of Risk Management in the Marine Transportation System

The Neglected Context of Risk Assessment: A Mindset for Method Choice

Aviation Safety Incident Reporting: NASA's Aviation Safety Reporting System

The Real World: Blooming Buzzing Confusion

Risk Management in Public Agencies
Building a New Context

Thomas H. Wakeman III, *Port Authority of New York and New Jersey*

Some say the world is getting smaller. That depends on your perspective; from my point of view the world is getting larger and is continuing to grow. The days are gone when public agencies, such as port authorities, could isolate themselves behind a fence line or inside an office. The transportation industry has become the transportation system, and the marine transportation system is rapidly expanding as requirements grow in a globally competitive marketplace.

It has also been said that all politics are local; that may be true but they are also global. The issues we face today in the United States are the same worldwide and include maritime jobs, the health of the tourism and fishing industries, environmental quality, waterway safety, public access, and traffic congestion on highways while we push more cargo and more people through coastal and inland gateways. Although these issues have become focused on the port complex as terminal expansion and throughput pressures grow, the entire national transportation system is being affected by these rapid changes. The scope of each harbor improvement and waterway activity must be examined in the context of regional and national transportation policies and planning to secure the opportunities being offered.

Last year's regional listening sessions and the subsequent national Marine Transportation System Conference began a process to address this evolving milieu. During the listening sessions, the maritime community repeatedly voiced its position that cooperation and communication, between the federal agencies working with one another as well as with local harbor interests, are key to ensuring that the concept of a marine transportation system becomes a reality.

Participants emphasized recognition of multiple values and stakeholder interests. All wanted to see the environment sustained, business competitive, and waterway risks minimized. At the national conference, a new paradigm for the system was established when a multifaceted vision statement was formulated. This vision provides a clear goal for the maritime future. The statement and the conference discussions dealt with systemwide attributes that form the context for today's maritime activities: security, the environment, safety, infrastructure, and competitiveness. Integration of these varied attributes highlights our need to move beyond single-issue planning and actions into a systems approach. The U.S. Coast Guard, Maritime Administration, and other maritime stakeholders have embarked on a process to achieve that objective.

To be successful in ensuring proper examination and evaluation of the maritime system so that it functions as an effective component of the global transportation system, we must address risks. We must develop attitudes, methods, and skills to recognize and to manage *both* the opportunities and the risks being faced. This conference was organized by the National Research Council (NRC) to assist us in that process and I offer my comments to help stir your thoughts as the work of the next 2 days begins.

The NRC has been involved with risk issues for many years. After the *Exxon Valdez* accident, the Prince William Sound Steering Committee asked the NRC to conduct a peer review of their risk assessment study. The NRC's Marine Board established a panel to evaluate the study and published the results last year. The panel reviewed the study's modeling approaches, use of data, treatment of human factors, risk reduction measures, and applicability to other locations. The panel offered several conclusions and recommendations, including the statement that further work to enhance general applicability was needed. Particularly important to the panel was incorporating an overarching study framework, considering human factors in future risk assessments, and analyzing sensitivities and uncertainties. Our task is to build on previous efforts of the Marine Board and provide additional recommendations as warranted. Before this determination can proceed, we should agree on our overall process, educate ourselves about the issues, and explore management approaches.

Typically, the term risk assessment defines application of analysis to one of three broad categories: financial losses, natural disasters, and accidents. In the past, we focused almost exclusively on how to minimize potential losses. Public agencies have been preoccupied with administrative processes and control in risk management programs. In today's competitive context, however, the focus is shifting to systems performance with a desire to enhance the outcomes of our activities. In fact, various federal civil service reforms implemented during the past decade, such as the Reinventing Government Program and the Government Performance and Results Act, which was passed by Congress, have attempted to tilt the balance more toward results. These and similar programs are configured to promote performance as well as to evaluate outcomes.

I propose that we use performance and outcomes as the point of departure for discussions of the three broad risk categories. After all, our performance and the results of our actions dictate the relative success of our organizations. Quite often the industry focus, particularly for frontline managers, is limited to business risks and, to a lesser degree, operational risks. But as competition for market share increases, the maritime industry must move beyond avoiding risk to improving performance. We must now use a systems methodology and look at the issue of risk management. Indeed, successful achievement of this symposium's purpose and objectives may help us reconceptualize risk management as a systems improvement tool.

The concept of risk has two elements: (*a*) the likelihood of something happening, and (*b*) the consequences if it does happen. For most managers, though, the issue is not really the concept of risk but rather what must be done to identify and manage specific risks and, perhaps more problematically, to establish some practical measure to gauge the amount of risk they are willing to take. This piecemeal approach to risk management lacks cohesion and effectiveness in reaching performance-based objectives.

The NRC (1983) has defined risk management as "the process of weighing policy alternatives and selecting the most appropriate . . . action, by integrating the results of risk assessment with engineering data and with social, economic, and political concerns to reach a decision." On the basis of this definition, how should we proceed to influence and achieve our desired outcome of an informed decision? At my homeport, we have identified three essential elements the Port Authority considers critical to a successful risk management program. These elements are not unique to the program; indeed, they are common to many other performance-based programs. Their value is in their implementation and application.

First, there must be a strong commitment to a shared risk management program from senior management, which means the program begins at the top. Managing risk is a necessary part of the way individual industry and agency executives think about their day-to-day organizational tasks. The risk profile can vary, but the broad guidance to managers, regardless of whether they are in the public or the private sector, is to seek to achieve full "value" for time and money invested. This translates to achieving effective performance at least cost.

Guidelines, instructions, and monitoring requirements should aim to return maximum value instead of minimum risk taking. We should stress the desirability of developing a mindset of being conscious of managing risks in relation to every decision without reacting to risk as a barrier to maximizing performance. It is critical for executives to be committed to the risk management process, but it is equally important for that commitment to be in place throughout the organization. Risk management should be an issue that every individual within an agency or firm supports.

Second, industry and government must actively foster open communication. This is key to removing barriers, building synergies, and ensuring the highest probability of success. Success in a risk management program requires a joint effort, with a team approach aimed at maximizing results and minimizing costs. Part of this approach is to recognize that neither industry nor government has the resources today for extensive program reviews or comprehensive risk assessment audits—nor can anyone afford to delay decisions. It is imperative for people to be able to work together as a team to establish preventative measures that allow industry to conduct business efficiently while providing government with adequate safeguards. We need to achieve the right balance between industry responsibility and government oversight.

At the Port Authority, we are working closely with federal and state government counterparts to build greater understanding of individual organizational objectives and needs. There are two examples of this policy at work in the Port Commerce Department. Recently, a U.S. Coast Guard lieutenant completed a 6-month industry training within our department. During his sabbatical, he gained a regional government perspective on waterways management issues as well as a view of a wide variety of other intraagency activities. A U.S. Army Corps of Engineers employee is also working in partnership with our staff. He and others are preparing a comprehensive dredging and port development strategy. Both individuals have been instrumental in providing their agencies with an industry perspective while working directly with Port Authority staff and management. Clearly all three organizations have benefited from the sharing of information and the broadening of understanding.

Risks do not observe political, agency, or geographic boundaries. The ability to look at risk from multiple and different perspectives can generate significant benefits. We must continue efforts to work together to remove barriers and improve processes that yield improved performance. It is through these kinds of partnerships that we can move to a risk management process that is reasonable in its application, well understood, and reinforced throughout government and industry.

The third element is that a risk management program must be proactive in its implementation. Because prevention is better than cure, being well informed and proactive is the key to any risk management approach. Risk management is an iterative process. Continual monitoring and review are necessary for success because not only do risks change over time, but their relative significance may also change. Further, the tools and mechanisms available to manage risks efficiently and effectively also change over time. Constant vigilance is essential for avoiding loss or less than satisfactory use of resources.

Proactive risk management requires exercising judgment about the appropriate weight or balance to be struck in terms of costs and benefits. Balance is relatively simple in principle but it is quite complicated in practice, particularly when there are different perceptions and measurements of accountability. Therefore, it is not surprising that ambiguity has emerged concerning control of process and achievement of required outcomes. A proactive program enhances the definition of tradeoffs and clarifies degrees of accountability. It can foster a transparent process and improve metrics used in determining the appropriate balance to be struck when there is pressure on resources because of constrained budgets or simply the existence of many competing demands.

It is important to remember that, as we progress in developing risk management programs, there will be setbacks. To be successful, we must avoid turning managers into scapegoats when mistakes happen. A correct attitude encourages managers to think proactively about the risk to their activities and to optimize their performance against those risks instead of dealing with problems on an ad hoc basis.

I have discussed several elements that I consider essential for a successful risk management program in today's marine transportation system:

- A strong commitment in the organization, beginning with senior management, to a shared risk management program;
- Open communication and teaming among government and industry partners in order to promote successful implementation of these programs; and
- Being proactive in implementation to improve performance and outcomes.

In summary the keys to our success can be found in these simple steps. Risk management can no longer mean public agencies overstressing administrative procedures, regulatory controls, and action avoidance. It should mean being able to systematically assess our circumstances; being prepared to make informed judgments about policy, operations, financial, and political situations; and being willing to act. We need to look at each attribute of the marine transportation system while we are building a new context for assessing value and making judgments.

Regardless of whether you perceive the world of marine transportation as shrinking or growing, I hope you agree that a shared risk management program must be incorporated. To achieve that goal, I believe your active participation is crucial, and I solicit that participation.

REFERENCE

National Research Council. *Risk Assessment in the Federal Government: Managing the Process.* National Academy Press, Washington, D.C., 1983.

Application of Risk Management in the Marine Transportation System

A. Elmer, *SeaRiver Maritime, Inc.*

I am pleased to have the opportunity to participate in this symposium. I attended the Marine Transportation System (MTS) National Conference in Warrenton, Virginia, last November and I consider this a golden opportunity to further develop the foundation that was established there.

I recognize the diverse group of experts representing industry, regulatory agencies, classification societies, port infrastructure, academia, and special interest groups. Like the MTS Conference, the success of this symposium will rely not on our individual expertise but on our collective willingness to participate with an open mind and a discipline to stay focused on the objective: learn from each other.

I am here to discuss the need for risk assessment and risk management from the perspective of those of us who actively participate in the marine transportation industry. It is impossible to completely eliminate operating risk, and the expectations of customers and the general public are more demanding than ever. However, by using risk assessments and by applying sound risk management principles as part of an overall company-wide quality management system, we place ourselves in a *proactive* position by identifying hazards and introducing preventive and/or mitigating steps. This is much preferred to the alternative of being in a reactive state, which can lead to onerous—and sometimes ill-conceived—legislation and regulations and can alienate our customers as well as our fellow citizens.

First, I will cite definitions of risk assessment and risk management. Then, I will show by example how the company I represent integrates risk management and risk assessments in daily work activities, regardless of complexity or size, and strives for continuous improvement. I will close by sharing what I consider to be important factors in conducting a risk assessment from an end user's point of view.

In 1996, the April–June issue of the U.S. Coast Guard publication *Proceedings* was dedicated to the topic "Risk Management in the Maritime Industry." One article included the following definitions of risk assessment and risk management:

- Risk assessment is ". . . the use of information to define the potential safety threats resulting from exposure of individuals or populations to hazardous events, hazardous materials, physical agents, chemicals and situations. While no risk assessment is devoid of value judgements, risk assessment should be an objective engineering/scientific enterprise aimed at approximating the truth about a possible threat to humans or the environment."
- Risk management is ". . . the process of weighing alternatives for controlling risks and selecting the most appropriate course of action. While risk managers may use information from risk assessments when making decisions, they may also consider information about engineering, economics, law, ethics, and politics."

The article went on to say

> Ideally, risk assessment should provide systematic results to evaluate and manage technologies. It should answer whether evidence is sufficient to prove specific risks and benefits. Answers to questions about acceptability of risks,

> or when a risk situation merits regulation, clearly involve values. On the other hand, the information in the assessments of the risk level should be objective. Given answers to questions of acceptable risk, the question of acceptable evidence becomes scientific not political.

I repeat, "Given answers to questions of acceptable risk, the question of acceptable evidence becomes scientific not political."

This is a very interesting and important point that I will come back to after I mention a few words about how the company I represent, SeaRiver, integrates risk assessment and risk management in its daily activities and planning sessions. For those who are not familiar with the company, SeaRiver Maritime, Inc., under different names and forms of organization, has been in the business of transporting crude and petroleum products for over 50 years. It is one of the largest companies that owns and operates U.S. flag tankers. The company owns/operates a fleet of nine oceangoing tankers engaged primarily in West Coast Alaskan North Slope trade and transporting chemicals and refined products from the U.S. Gulf Coast to the East Coast. SeaRiver also owns/operates 10 inland towboats, 6 harbor tugs, and 5 barge units. As such, it represents the only Jones Act liquid bulk carrier operating on all coasts and in the inland waterway system of the United States. SeaRiver serves more than 60 customers. The company also provides a wide range of marine services, including vessel vetting, inland and ocean chartering, offshore lightering management, and marine requirements planning.

SeaRiver is committed to maintaining its leadership presence as a technically proficient, financially stable, high-quality owner/operator of U.S. flag vessels. SeaRiver's reorganization in 1993 was directed at furthering that commitment. SeaRiver's commitment is demonstrated and documented by the quality of its people and equipment; by its dedication to the responsible management of environmental, health, and safety concerns; and by constantly seeking to improve its quality performance.

Consistent with this commitment, SeaRiver's Safety Management System has been audited and certified as complying with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) as well as with International Standards Organization 9002 (ISO 9000 Series of Standards). SeaRiver is also an active participant in industry-sponsored programs, including the American Waterway Operators' Responsible Carrier Program and the Chemical Manufacturers Association's Responsible Care Partnership Program.

The purpose of this overview is not to present a self-serving advertisement to a captive audience in hopes of attracting new business opportunities (although I brought plenty of business cards for those interested). The purpose is to acknowledge that, like many of the entities present today, SeaRiver manages a diverse range of operations, customer needs, and levels of operational risk.

Wednesday, March 24, 1999, marked the 10th anniversary of the grounding of the *Exxon Valdez* in Prince William Sound, Alaska. Before this accident, Exxon Shipping Company, the predecessor of SeaRiver, had a long-standing focus on personnel safety and operations integrity. The *Valdez* spill was clearly inconsistent with that track record. Nevertheless, the severity of the event was such that an intense self-examination was undertaken.

This intense effort continues today as a company-wide approach to risk management and safety that we believe has produced unequaled safety performance by a U.S. flag shipping company. SeaRiver's risk management philosophy begins with the fact that the safety and protection of its people, vessels, cargoes, and the environment is the preeminent core value of the company.

This means that any time safe operations contend with commercial or other interests, all risks must be thoroughly assessed, and if the risks cannot be managed to an acceptable level, the operation is not undertaken. We expect to, and in fact do, incur costs in order to conform to this safety culture and commitment. However, we also believe that there are offsetting benefits that enable us to be very competitive in the marketplace. We truly believe safety is not a net cost but a competitive advantage. For SeaRiver then, safety is the wellspring for all company performance.

For example, we recently evaluated what initially appeared to be a very promising venture barging gasoline upriver for a third party on an inland tow. The commercial opportunities and financial rewards were promising. However, after extensive evaluation by the risk assessment process, we were unable to convince ourselves that we could take the necessary steps to adequately prevent or mitigate the inherent risk in this profitable opportunity. The result—we did not bid on the business.

Safe marine operation is principally a challenge in managing human behavior. Incident investigations continue to confirm that errors made by personnel are by far the greatest single cause of accidents and near misses. Recent industry and government studies confirm that more than 80 percent of all incidents are directly or indirectly attributable to human behavior. There are some, and I fall into this category, who believe that all failure can ultimately be traced to a form of human involvement.

Instilling a safe mindset into management, shore staff, officers, and unlicensed personnel is both an art and an emerging science. There is no silver bullet, no single element, and no unique program that ensures the desired results. Instead, many elements must be consistently followed and credibly addressed to the point where they become second nature, deeply embedded into the company culture. There are certain key elements that SeaRiver has found to be most critical to the creation of this mature safety culture.

1. Management credibility. Safety in all its operations is the preeminent company core value. Management must set the expectations, procure the resources to achieve the expectations, and make financial and commercial decisions that are totally consistent with this focus and that demonstrate management commitment.

2. Clear policies. The company must ensure that its policies are not ambiguous and employees must believe that the policies will be consistently followed and enforced. This means that behavior that leads or could lead to an unsafe workplace, such as alcohol or drug abuse or refusal to follow established safety procedures, is inconsistent with the principal company core value and is not tolerated.

3. Belief and commitment. Our employees must believe in the company and be committed to its objectives—every employee at every level must be actively engaged in safety management. They must feel a personal responsibility to behave safely, look out for the safety of others, and bring constructive ideas for safety improvement to management. If all personnel truly believe in safety then they will adopt it as a personal core value. The extended benefit of this "true belief" is that safety on the job is replicated by safety at home and off the job. If this is not the case, then safety is viewed as a "condition of employment" and not as a desirable personal characteristic and safety results will deteriorate.

Personnel safety is the key to overall safe operations. Recognizing that human factors are a significant contributing element in accidents, the awareness of and attention to detail that are key to having people work safely are also critical to maintaining the integrity of the vessel, the cargo, and the environment. In a mature safety culture, the attitude needed to be successful in these areas must be identical. Failure or poor performance in any of these areas, regardless of the success in others, must be carefully evaluated to determine the nature of the problem. Although corrective action must be clear, swift, and timely, it must not be a knee-jerk reaction. One of management's greatest challenges is to understand this delicate balance.

I mentioned earlier that, in the aftermath of the *Exxon Valdez* grounding, an intense self-examination was undertaken. One area that was reevaluated was in-tank operations. Traditional (industrywide) procedures included tank preparation (tank washing, gas-freeing, and atmospheric testing), monitoring in-tank personnel, notification procedures, and emergency response preparedness. Yet few preventive or mitigating steps were in place to reduce or eliminate the risk of an employee or contractor falling while working along the tank's internal structure.

Historical data suggested that, over the life of a vessel, a significant in-tank-related injury (or fatality) was possible. This finding was clearly inconsistent with our safety culture. We decided to look for a solution outside the marine industry. The answer came from the refinery setting, where fall protection equipment and related procedures are used extensively. In short order, all SeaRiver vessels were retrofitted (in-tank and above deck) with modified ladders and equipped with fixed and/or portable fall protection equipment to ensure the associated risk was prevented or mitigated to an acceptable level. Since its introduction over 8 years ago, fall protection continues to be an integral part of our safety program for in-tank operations and when personnel (employees and contractors) are working aloft.

This example helps illustrate why potential personnel and operating risks must be thoroughly examined by a systematic process to ensure that all aspects of the operation are reviewed. This review can vary in its complexity, ranging from a brief job hazard analysis for routine work activities to formal risk assessments to assess new trade patterns.

In each case, the risk assessment process helps us identify potential risks and, if feasible, prevent hazardous situations. If prevention is not possible, mitigating steps must be introduced to reduce risk to an acceptable level without causing increased exposure elsewhere; if that is not possible, then you must withdraw from the particular activity.

Safety must be an area with its own learning curve. Company management and personnel must be interested in the lessons derived from operating incidents and near misses. Employees need to see relevant changes as a result of the lessons learned. Learning from incidents and near misses then becomes a key input to the company's continuous improvement process.

To achieve success, management must also want to know the complete story. Therefore, the incident investigation component must focus on identifying true causes and consequences. Safety statistics must be compiled with an integrity that eliminates debate about the numbers; deteriorating or improving statistics must serve as a barometer of the underlying soundness of the safety culture and not as the short-term focus of management's attention.

Finally, sharing safety experiences and approaches and lessons learned with industry competitors, customers, contractors, and all industry stakeholders is an essential element in developing an industry safety culture. The elements I have just discussed are essential for the continuing development of SeaRiver's safety culture. And there is one other element that bonds them all together.

Leadership begins with management; the leadership that bonds our safety elements into a mature culture comes from within our company. It comes from the people who, day in and day out, demonstrate the capacity and ability to guide, instruct, direct, conduct, and show others the practice of safe operations. Experienced and knowledgeable crew—the captain, an officer (deck or engine), a seasoned deckhand on an inland tug—are the people who provide the critical leadership that blends these elements into a mature safety culture.

Through procedures, quality people and focused training are key building blocks of operating safety. Documented procedures as found in quality manuals represent the blueprints of safety but only if they are approached systematically and if they accurately reflect how tasks are executed.

The terms systematic and system have become commonplace throughout industry and the quality movement. In fact, this symposium, as well as the National Conference held in Warrenton, focuses our attention on issues in the context of the MTS. But what do we really mean? Do we share a common understanding of what constitutes a sound system?

We at SeaRiver believe that documentation of each defined system must address all five essential elements:

- Definition of scope and objectives,
- Establishment of procedures,
- Identification of responsible and accountable resources,
- Selection of verifications and measurements, and
- Incorporation of a mechanism for continuous improvement.

The continuous improvement element is one that needs constant attention from management because a system's long-term effectiveness and management of change can be realized only if it includes an ongoing feedback process to drive the system to strive for greater effectiveness, continual health, and safety and environmental improvements.

Earlier, I cited the 1996 *Proceedings* article that noted the importance of following a systematic process and maintaining objectivity when deciding on risk levels to ensure that determination of acceptable evidence becomes scientific and not political.

This point is essential to the success of any risk assessment because it has a direct bearing on the value of the resultant recommendations and the level of cooperation demonstrated by all stakeholders during implementation.

As one stakeholder, I am concerned about the collective ability of all stakeholders to abide by the risk assessment protocols and maintain the integrity of the risk assessment process. Preordained conclusions in response to external pressure(s) to take swift action well before the problem is truly understood or accurately defined or the use of incorrect, unreliable, or unsubstantiated data exemplify ways to undermine the risk assessment process and waste precious time and resources. Under such circumstances, a formal, large-scale risk assessment of a major port or waterway runs the risk of being criticized as a good intention that fell short of its mark.

In the spring of 1995, shipping companies that traded in Prince William Sound proposed a risk assessment study to the other principal stakeholders in that area of Alaska. The proposal included involving local residents and special interest groups, government officials at the state and federal levels, and industry representatives. The purpose was to "improve the safety of oil transportation in Prince William Sound." A quantitative basis for understanding the current level of risk and evaluating proposed risk mitigation measures through various modeling techniques was selected.

The result of this risk assessment was an important element in furthering the enhancement to the safe transportation of oil through Prince William Sound. However, the effectiveness of this 2-year effort has been, and continues to be, debated because all participants in one way or another have failed to consistently adhere to the true definitions of risk assessment and risk management and the application of the study's recommendations. If we are not careful, the forthcoming risk assessment of Puget Sound and the Straits of Juan de Fuca may experience similar setbacks.

In review of the key elements of the definitions referenced previously:

- Risk assessment is "an *objective* engineering/scientific enterprise aimed at approximating the truth about a possible threat to humans or the environment."
- Risk management is "the process of weighing alternatives for controlling risks and selecting the most appropriate course of action."

So, in the spirit of continuous improvement, what can we learn from this experience? As with any significant project, to save time, effort, and expense thorough planning must be followed from the start. Stakeholders must take the time to ensure that all participants have a clear understanding and buy in to the scope, objectives, methodology, recommendations, and timing of the overall process and its implementation. Credibility and trust are critical to the process: it is essential for each stakeholder to respect the knowledge, experience, and resources that fellow stakeholders provide.

Quantitative analysis is only as good as the quality of data used, whereas a qualitative process relies heavily on the knowledge and experience as well as the mix and balance of the participants.

The duration of the risk assessment process from initial proposal to final implementation is another important consideration. There is a fine line between conducting a thorough assessment and one that appears to deliberately extend beyond the tolerance of the stakeholders and/or customers.

If the risk assessment is assigned under the auspices of a regulatory body, in this case the U.S. Coast Guard, the process stands a better chance of preserving its objectivity, and results will help identify the best recommendations, strategy, and method(s) of implementation.

The United States is blessed with large ocean area accesses to its ports on the mainland coasts coupled with vast rivers and internal waterway systems that serve the mainstream of commerce. Preservation of these resources, development of a healthy port infrastructure, and perpetuation of personnel safety and safe operations will prosper only through the following:

- Promotion of open dialogue and collaboration;
- Blending of viewpoints of disparate entities;
- Commitment to proven processes;
- Generation of balanced, justifiable solutions; and
- Recognition that the process must embrace continuous improvement.

As we enter the 21st century, we must recognize the importance of our commercial lifeline and agree to do what is necessary to nurture and develop a national marine transportation system that is based on the fundamental principle of safety. Furthermore, the assessment of risk, whether on a global scale or a regional basis, must result from the cooperative effort of all stakeholders, free from the pressures of politics and parochial interests. We recognize that implementation of risk prevention or mitigating measures in most cases will reflect the realities of the political environment and the pressures of specific interests. The real challenge is to ensure that the fundamental findings of risk assessment are not compromised by these external factors.

I ask each of you to join me in accepting this challenge and ensuring that we identify and implement the best strategies needed to improve the safety and integrity of our marine transportation system.

The Neglected Context of Risk Assessment
A Mindset for Method Choice

Karl E. Weick, *University of Michigan*

During World War II, Lancaster bombers deployed by the Royal Air Force were being shot down increasingly often because German air defense aircraft were continuously being improved. When scientists were asked why the casualty rate was so high, they concluded that the Lancasters were vulnerable because they lacked speed and maneuverability. It was recommended that gun turrets be removed to make the aircraft lighter. Military authorities, however, thought that guns were good and more guns were better, so they added guns and gunners, which slowed the aircraft even more, which led to even more casualties. A bomber without gun turrets was inconceivable (Sagan, 1993).

A bomber without gun turrets is like a risk assessment without formal modeling; it is inconceivable to insiders. When I was asked to comment on methods of risk assessment in maritime risk mitigation, the invitation came with the stipulation that it would help if my remarks encouraged people to think "outside the box" on the question of how to do risk assessments. The formal methods of risk assessment that are now common in the maritime industry appeal to the heart of the engineer that lurks in many maritime personnel. But those formal methods are also blunt instruments. They give the misleading impression that risk is well understood, fully mapped, and that, if it weren't for operator error, the maritime system would function reliably.

What formal methods miss is the situated nature of risk taking. Formal methods are less sensitive to local contingencies, subunit norms, informal agreements, idiosyncratic labels and language, tricks of the trade, strong local cultures, emergent changes, unintended consequences, sudden opportunities, resourceful improvisation, and unexpected setbacks. Local variations such as these shape most risk scenarios even though these determinants go undetected. Their presence is not just noise. It is often more patterned and more predictable than people imagine and more tied to personal and organizational factors than people are willing to admit.

To incorporate more of these factors requires a return to some of the basics in inquiry with the question, How has this issue been handled by people currently doing maritime risk assessments? In many cases the answer is, Not very well. Those lapses in procedures of inquiry stand in the way of more effective risk mitigation. If modelers make more of an effort to address problems such as those I will mention, then the adequacy of their database will improve, as will the lessons that practitioners are able to draw from these data. Modeling doesn't need more analytics any more than the Lancasters need more guns. It needs different analytics and nonanalytics. To think outside the box is to take that diagnosis seriously.

Basics of Inquiry

I want to review eight basic features of inquiry that influence what one can conclude from a risk assessment and the uses to which it can be put. These features include (*a*) conception-perception linkages, (*b*) concrete-abstract systems, (*c*) tradeoffs in the accuracy of explanations, (*d*) tools that register complexity, (*e*) the vocabulary of risk, (*f*) traps involved in analyzing accidents in hindsight, (*g*) the choice of comparison, and (*h*) implicit theories of human behavior. These eight features do not exhaust issues involved in choice of methods for risk assessment. But all eight furnish part of the infrastructure of any assessment. Whether one is involved in production or consumption of risk assessments, these eight features provide a standpoint from which one can start to judge the value of what is being proposed.

The context within which these features operate is built in part from practitioners' pleas for objective, scientific, truthful knowledge about risk mitigation that is neither political nor subjective (e.g., Gus Elmer's speech). As will soon become clear, truth can be approximated, but there are no guarantees. Formal inquiry generates data that are more defensible than data that are gathered casually. But the magnitude of the improvements that arise from formal inquiry is often less than is claimed. The combination of a competent researcher and a candid practitioner can increase the size of the improvements. But there are limits to what both can accomplish. These limits are what practitioners get paid to live with and what researchers get paid to document.

Empty Conceptions, Blind Perceptions

Sound risk assessment takes seriously Kant's (Blumer, 1969, p. 168) observation that "Perception without conception is blind, conception without perception is empty." Modelers often work with empty conceptions when they construct variables that have little empirical grounding. But that is no worse than practitioners who work with blind perceptions and are unable to see recurrence, patterns, regularities, and early warning signals because of their preoccupation with details.

Here's an example of blind perceptions in need of concepts. The example comes from a spirited exchange in the magazine *Professional Mariner.* Captain Donald Miley, a retired pilot on both the East and West coasts and a master of a 900-ft (274-m) containership, wondered whether we were looking too closely at accidents. The cause for his concern was a 1994 collision in New York between the *Jean Lykes* and the *Petrobulk Lion* and a glib analysis of the accident made by an inexperienced Coast Guard commander. Miley concluded his critique with the comment "Sometimes I think that Capt. Charles Bamforth, Coast Pilot, American Hawaiian Steamship Company, many years ago, had the right idea. He missed a turn and ran a ship ashore in the Delaware River. His full and complete report to the company was, "I made a mistake and ran the ship aground" (Miley, 1996, p. 16).

In the next issue, William Full, a master of a West Coast VLCC, took issue with Captain Miley's praise of Bamforth's brief report. Full asks of the statement "I made a mistake and ran the ship aground," is that it? Is that the sum and substance of the report? That is NOT enough. The report begs the question "what mistake? Did others on the bridge recognize that a ship-handling error was being made? If so, did they express concern? If not, what training might be provided so that, if the problem were encountered in the future, it would be recognized and action taken?" (Full, 1997, p. 6).

If Bamforth had developed a fuller story, a possible error chain could have been spotted. If that chain had been broken at any point the accident might not have occurred. These chains are not obvious. To notice them requires that blind perceptions be enriched by concepts that alert observers to details that may be important. People need concepts such as fatigue, deference, inattentiveness, complacency, ignorance, production pressure, regression, and culture to understand what to look for if they want to assemble an error chain. Likewise, to avoid empty abstractions, people who talk about fatigue, deference, and inattentiveness need to know what forms they take in everyday life, what they look like, and what contexts encourage and discourage their appearance.

Full (1997, pp. 6–7) concludes his appeal for more complete accident reports this way:

> I have to admit that accident investigations often begin to sound like a refrain with several of the same lessons learned and the same final recommendations, but that is only because many of us have not learned the lessons the investigations offer well enough. Reviewing and understanding the incidents that have befallen others is one way to develop the skill and knowledge to prevent them from happening on our own vessels.

When Full talks about "learning lessons," "understanding the incidents," and "knowledge to prevent incidents that befall others," he is referring to perceptions that are made meaningful through their linkage with concepts.

To do effective risk assessment means to change empirically empty theories into richer theories that are grounded in perceptions of on-site practitioners. But effective risk assessment also means changing blind practice into informed practice by means of more abstract summaries of sequences that happen over and over again. It is in the best interest of practitioners to conceptualize regularities in the incidents they face because concepts free up scarce attention, which then allows people to notice more and catch developing problems at an earlier stage.

Concrete Systems, Abstract Systems

As a slightly different way to pose the issue of blind perceptions and empty conceptions, look at the two lists in Table 1 (these lists and their implications are adapted from Roethlisberger, 1977, p. 438). List A (A-relations) is the world of practitioners. The words in List A are the kind of

TABLE 1 Mindsets Associated with Concrete and Abstract Systems (Roethlisberger, 1977, p. 439)

A-relations	*B-relations*
Concrete	Abstracted
Nonlogical	Logical
Subjective	Objective
Internal	External
Here and now	There and then
Mutually dependent	Simple cause and effect
Exchange	Unilateral
Reflexive	Irreflexive
Intransitive	Transitive
Symmetrical	Asymmetric
Cyclical	Linear
Intrinsic	Extrinsic
Satisfying, rewarding	Optimal
Process	Structural
Emergent	Planned, designed
Diffuse	Specific
Existential	Probabilistic

terminology people use to describe action within concrete, real-world, maritime systems. List B (B-relations) is the world of researchers, modelers, and theorists. The words in List B are the way knowledge makers draw their lines for purposes of theory construction. List B is less about concrete systems and more about abstracted systems, context-free knowledge, and observations made by detached observers. When people try to build conceptions, the language they use and the stance they take, as summarized in List B, are often at variance with the ways practitioners use knowledge for purposes of action, as summarized in List A. That is old news, but the numerous contrasts in Table 1 suggest more places where researchers and practitioners might coordinate their complementary views in the interest of co-investigating risk mitigation.

But that old news is worth revisiting because it lets us talk about what we need to do to improve risk assessment. People who do risk assessments basically try to learn about A-relations by using the language and perspectives embodied in B-relations. That often means that analysts think of organizations by using images that are consistent with B-relations. This is a potential blind spot because these images tend to emphasize detachment, top-down directives, excessive formalism, rigid controls, technical efficiency, procedural rules, and authority structures. All these organizational images imply the need for and the relevance of a formal, quantitative risk assessment. But that conclusion is partly an artifact of an inability on the part of modelers to shed the language of List B and adopt the perspective of List A. Talk of formalism, technical efficiency, and authority structures is consistent with List B, even though it may fail to render accurately the qualities of activity in List A. List A is the world of people on the firing line.

If analysts encode practitioner activity in the language of detached controls and give practitioners diagnoses consistent with this imagery, the diagnoses are of no help. The world being described by List B is not the contingent, subjective, ad hoc world of List A that practitioners encounter. When this discrepancy becomes apparent, well-meaning practitioners often try to help analysts by showing them the conditions of risk they actually encounter. But when practitioners do this, analysts try to improve their methods by making an even greater effort to realize the virtues found in List B. This makes the resulting conceptualization even less relevant to practitioners. Increasingly powerful abstract models have less and less to say about being prepared when a disabled ship enters Long Beach Harbor at night with nonoperational radar.

The solution lies in movement toward grounded abstractions and patterned perceptions. To improve activities of risk mitigation (List A), practitioners need concepts that suggest what they can afford to ignore in order to make better use of their experience. Conceptualizations of risk consistent with List B can help refine self-awareness and understanding and can help in the development of larger institutional structures that embody experience of what works better. But these beneficial effects of work with List B are possible only if investigators stay in touch with the realities of List A.

To stay in touch is not as easy as it sounds. There is a danger that people will try to mix what may be incommensurable when they impose a B vision on an A world. The more productive question for practitioners and researchers to discuss is, For what kinds of problems is each view more useful? Assume that each list is a useful way of representing a system for certain purposes. Sound basic inquiry is built out of thinking that is both about proactive people in the maritime system (B) and useful for proactive people (A) who want to act on and change their environments. People who do that kind of thinking deliberately try to avoid empty conceptions and blind perceptions.

Tradeoffs Among Generality, Accuracy, Simplicity

Sound risk assessment also emerges from the realization that any answer to questions such as What can go wrong?, How likely is it?, and What are the consequences? (Garrick, 1999, unpublished data) can be characterized in at least three dimensions (Weick, 1979, pp. 35–42). Each answer has some degree of generality (answers have degrees of abstractness and may or may not apply to many different kinds of units). Each answer also has some degree of accuracy (answers fit the specific circumstances of a specific unit more or less fully). And, finally, each answer has some degree of simplicity (answers are more or less easy to grasp). If these three criteria are arrayed around a clock face with generality positioned at 12:00, accuracy at 4:00, and simplicity at 8:00, the dilemma in answering questions about risk becomes apparent. A story that satisfies any two criteria is least able to satisfy the third criterion. For example, formal analyses that blend generality with simplicity into a 10:00 explanation are applauded because they are accessible but criticized because of their inaccuracy. If the tradeoff moves in the direction of a general-accurate explanation to meet this criticism, then the recipient cannot understand the explanation because it is too complex and therefore dismisses it. It is inevitable that no one will ever be satisfied with any single assessment. That is a feature of the world and not of researchers who are unable to speak clearly. That can be a problem, but the larger issue and the clearer moral is that risk assessments require a multimethod inquiry that is capable of diverse patterns of tradeoffs. That is what is so important about Robert Bea's research program (1996, 1998) with its innovative blending of qualitative and quantitative methods.

In Bea's discussion of operating safety in offshore structures (Bea, 1998), the explanations fit at 10:00 and 2:00 and 6:00 because earlier (Bea, 1996) he relied on a combination of qualitative surveys, interviews, narratives, and critical incidents; quantitative analyses such as fault trees, probabilistic risk analysis, and other numerical models; and a mixed mode patterned after a safety indexing method. Bea's ability to resist the invisible hand of modeling enabled him to break frame and take fuller account of the less orderly, but no less impactful, context for reliability provided by human and organizational factors.

Principle of Requisite Variety

Sound risk assessment also honors the principle of requisite variety: it takes complex models to register complex events. Complex models cultivated in the interest of capturing complex events are not always tidy. This point is neatly illustrated by Clifford Geertz's edgy question "What is objectivity supposed to prevent: passion, relativity, intuitionism, prejudice?" (Geertz, 1995, p. 18). If those four factors are removed from inquiry, then the result may be truth that is trivial. Risk is not a cool subject. To register with accuracy how risk taking unfolds in everyday life, inquirers need resources such as passion, inconsistency, intuition, and a frame of reference. Those resources do not invalidate the work. Instead, they allow the inquirer to sweep in more potentially important determinants.

Although the principle of requisite variety appears to favor quantitative models, that is not the case. It favors stories. Stories simplify but less than do formal models (Daft and Wiginton, 1979). Stories are attractive because they have enough complexity to register sequence, development, interactions, and simultaneous occurrences, yet they are simple enough to serve as useful guides to action (Klein, 1998, chapt. 11). A big problem with using stories is that investigators are unskilled in collecting them. As a result, they work from "bad" stories that give no leads for risk mitigation, and they conclude that stories are worthless and that models are the only way to go.

Klein (1998, p. 190) and his associates have developed a way to extract stories of nonroutine events, which they refer to as the critical decision method. The procedure consists of four steps:

1. Pass 1: Briefly tell the story.
2. Pass 2: Retell story and get events pinned down to a timeline.
3. Pass 3: Probe the thought processes such as cues involved in initial assessment, meanings those cues hold, and expectations + goals + actions engendered by that assessment.
4. Pass 4: Could a novice get confused? Would a novice see this in the same way, what mistakes would they be likely to make, why would they make those mistakes? Use hypotheticals to evoke dimensions: if a key feature of that situation had been different what difference would it have made in your decision?

The importance of stories as a means for practitioners and researchers to converge on a common set of issues is suggested by Czarniawska and Joerges' (1996) description of how they present their assessments to practitioners.

> We have no intention to tell managers what to do in the face of change or stagnation [or risk mitigation]. We want to tell everybody who wants to listen a complex story of how changes come about and leave the actors to decide which conclusions to draw, fully expecting that managers might come to different conclusions than union stewards upon reading our reports. . . . Organizational actors are perfectly capable of producing simplifications and stylizations—action theories—themselves. . . . We owe them a different type of assistance in tackling the irreducible complexity of organizational life, one we call systematic reflection, as a complement to action-induced simplifications.

There seems to be little question that it takes complicated analyses to understand complicated systems. As Diane Vaughan found in her study of the *Challenger* disaster,

> Invariably, the politics of blame directs our attention to certain individuals and not others when organizations have failures. Invariably, the accepted explanation is some form of "operator error," isolating in the media spotlight someone responsible for the hands-on work: the captain of the ship, a political functionary, a technician, or middle-level managers.
>
> To a great extent, we are unwilling participants because without extraordinary expenditure of time and energy we cannot get beyond appearances. But we are also complicitous, for we bring to your interpretation of public failures a wish to blame, a penchant for psychological explanations, an inability to identify the structural and cultural causes, and a need for a straightforward, simple answer that can be quickly grasped. But the answer is seldom simple (Vaughan, 1996, pp. 392–393).

Although there may be agreement that risk mitigation occurs in complicated systems, there is disagreement about what methods most successfully register that complexity. To think outside the box is to entertain the possibility that words, narratives, and conversations register more complexity than do numerals, formulas, and derivations. Spurious precision in an imprecise world represents a failure to register precursors of risk whose containment is crucial to risk mitigation.

Vocabulary of Risk Assessment

Sound risk assessment affirms the importance of words. A colorful way to make this point is to argue that people who study risk need a "dry word hoard." The phrase comes from the last stanza of a William Meredith (1987) poem called "Partial Accounts" (cited in Weick, 1995, p. 197).

> Language, the dark-haired woman said once,
> is like water-color, it blots easily,
> you've got to know what you're after,
> and get it on quickly.
> Everything gets watered sooner or later with tears,
> she said, your own or other people's.
> The contrasts want to run together and must not be
> allowed to. They're what you see with.
> Keep your word-hoard dry.

It takes a rich vocabulary to catch nuances that are crucial for risk mitigation. It makes a difference whether risk is discussed in the context of ignorance, uncertainty, confusion, ambiguity, the inexplicable, the incomprehensible, or what Rosenthal calls a situation of unness—"unexpected, unscheduled, unprecedented, and almost unmanageable" (Lagadec, 1993, p. xxix). The label risk assessment itself calls forth connotations of stable traits, configurations that cause accidents, typologies, and indexing of some fixed quantity. What it does not imply is attention to process, unfolding, situation awareness, updating, incubation, dynamics, struggles for alertness, heedful interaction, solutions that unravel, and the need to reaccomplish processes (see Pettigrew, 1997, for a discussion of processual analysis and a glimpse of what a cross-section assessment may omit).

Traps of Hindsight

Sound risk assessment is more likely when people work with a deep awareness of the traps of hindsight. When people know how an event came out, they are tempted to look for antecedents that led unequivocally to that outcome. Given a bad outcome, we have a strong tendency to look for inaccurate perceptions, flawed analyses, and incorrect actions that produced that outcome (Starbuck and Milliken, 1988, p. 37). What we are less likely to look for are accurate perceptions that got lost in bad analyses, good analyses that led to incorrect actions, good analyses that were not implemented, and correct actions that had either no effects or unclear effects. If we know that there was a bad outcome then we will look for incorrect perceptions that led to incorrect analyses that led to incorrect actions. We will put perceptions at the beginning of our sequences and argue that perceptual accuracy makes all the difference and that the perceptions that produce accidents were inaccurate. We will conclude, incorrectly, that bad outcomes appeared to be inevitable and have tight causal couplings with antecedents. If those couplings are that tight and that determinant, then quantitative risk assessments are the only way to go because they exploit these tight causal ties. What observers keep missing is that the impression that causal linkages are tight in maritime accidents is an artifact of hindsight instead of a reality of the incidents themselves. What is missing from many accounts is significant information about how the event looked to the participants at the time, in their context, and doing what they were doing. When people switch from hindsight to foresight it is much harder to distinguish accurate perceptions and accurate perceivers in advance from inaccurate ones. This is the lesson that Diane Vaughan has taught us in her analysis of the *Challenger* disaster.

Value of Comparison

Sound risk assessment is grounded in comparison. A simple way to demonstrate the power of comparison is to perform a small experiment suggested by Parmenter (1968). The next time you visit an art museum, before you actually view the exhibit itself, go to the gift shop. Purchase postcard reproductions of several items that are hanging in the gallery. When you get to the original work of art, hold the postcard reproduction alongside the original. What you will discover is that portions of the painting are not well reproduced on the postcard (e.g., the background is not that color at all, the gold sparkles much more in the original, the proportions are more dramatic, and so forth). What the postcard does essentially is alert you to features of the painting you might otherwise have overlooked. The imperfect reproduction serves as a clue to sites where the artist's genius is more evident. Similarly, what any maritime accident means, what is significant in its unfolding, may become clearer when it is compared with another accident and the observer looks for similarities and differences.

Implicit Theories of Behavior

Sound risk assessment is grounded in an implicit theory of human behavior as well as an implicit theory of what constitutes reliable evidence. Methodologists make assumptions about people. Sometimes these are explicit and sometimes they are not. In my own work, I assume that respectful interaction is fundamental to everything else (see Weick and Roberts, 1993). We all profit from our own experience and from the experience of others, which is all well and good until those experiences appear to conflict. Then we have the problem of what weights to put on our vantage point and on that of the others. Because the world is fallibly and indirectly known, and because our frames of reference are limited, we cannot afford to ignore completely what others think is happening. Therefore, if we want to pool our observations with theirs for maximum adaptiveness we have to live by three imperatives (Campbell, 1990):

1. The imperative of trust: It is our duty to respect the reports of others and to be willing to base our beliefs and actions on them.
2. The imperative of honesty: It is our duty to report honestly so that others may use our observations in coming to valid beliefs.
3. The imperative of self-respect: It is our duty to respect our own perceptions and beliefs and to seek to integrate them with the reports of others without deprecating them or ourselves.

Wherever tragedy occurs, it is likely that there has been a breakdown in one or more of these three imperatives. The wildland fire disaster at Mann Gulch is a breakdown in the imperative of trust. Crew members failed to believe that foreman Wagner Dodge's escape fire would save them, they refused to use it, and they perished. The wildland fire disaster at South Canyon is a breakdown in the imperative of honesty and self-respect. Crew members fighting this fire had serious doubts about who was in charge, where the escape zones were, and why they were digging line downhill, but they expressed none of these and 14 people perished. It is interesting that procedures for handoffs and briefings that have been adopted in the aftermath of these tragedies tend to incorporate all three imperatives. For example, a growing number of crew chiefs use the following protocol when they brief people on their assignments: here's what I think we face, here's what I think we should do, here's why, here's what we should keep our eye on, NOW TALK TO ME!

In this protocol, there is trust (the crew chief invites observations from others and listens to them), honesty (the crew chief gives a candid appraisal of how he or she sees things), and self-respect (there is an effort to resolve the differences among observations without either dismissing one's own observations or deprecating the observations of others). When people practice respectful interaction, they are in a better position to update their understanding of what is taking place and to mitigate risk.

The point is not that respectful interaction is necessarily the assumption methodologists should adopt. Instead, the point is that methodologists need to be explicit about what assumptions they make about people and organizations that guide their choices of what to assess. This explicitness enables practitioners and researchers alike to affirm those assumptions or to replace them and to judge the consequences of this replacement. What is mischievous in risk assessment are assumptions about people that are invisible and therefore not discussed and not examined.

Conclusion

Risk taking in the maritime system unfolds in an unknowable, unpredictable world of fallible people, unreliable technology, and lousy weather. Given that context, mariners rely on one another to make sense of what they face and what they should do about it. This core scenario tends to be missed by formal analytic models of risk assessment. To make these models more valid, inquirers need to be more mindful of the following:

- Dual dangers of empty conceptions and blind perceptions;
- Different mindsets associated with abstract and concrete systems;
- Tradeoffs among generality, accuracy, and simplicity;
- Need for complex analyses to register complex events;
- Importance of word choice in descriptions of risk taking;
- Traps when accidents are viewed in hindsight;
- Value of comparison for diagnosis; and
- Theories of human behavior that lie behind the risk assessment.

As a final prod toward thinking outside the box in risk assessment, I want to invoke a disturbing puzzle that has emerged in fatalities that have occurred in wildland firefighting. When a wildland fire explodes and threatens to overrun a crew of firefighters, the crews' ability to outrun the fire improves if they drop their packs and tools so they can run faster, cover more ground, and escape to a safety zone. Given this relatively clear way to mitigate the risk of being burned, why is it then that, since 1990, 23 firefighters in four separate incidents refused to drop their tools when ordered to do so, were overrun by fire, and died with their tools beside them? Six died at the Dude fire, 14 died at South Canyon, 2 died at the California fire, and 1 died at the Buchanan fire. All died within sight of safety zones they could have reached had they been lighter and moved faster.

At the South Canyon disaster outside Glenwood Springs, Colorado, 14 firefighters were killed on July 6, 1994, when they failed to outrun a fire that exploded through a flammable stand of Gambel Oak just below them. When the bodies were being recovered, a site and thermal analysis was written for each body recovered. Part of the analysis for firefighter 10 reads "was still wearing his back pack. . . . Victim has chain saw handle still in hand with chain saw immediately above right hand. Saw blade is parallel to firefighter 9's left leg." The body of firefighter 10 was about 250 ft (76 m) below the safety of the ridge above, a distance that could have been covered had this person exerted the same amount of energy but dropped his pack and saw 5 minutes earlier.

There appear to be parallels in other settings. As researchers we need to be mindful of which tools slow our progress and need to be dropped so that we become faster, lighter, more agile analysts. We need not fear that if we drop our favorite analytical tools we are necessarily left empty-handed because we still have our intuitions, feelings, stories, experience, ability to listen, shared humanity, capability for fascination, and vocabulary to trigger both lines of questioning and ideas about what the answers might mean. To face mariners without our usual tools is not always a bad thing. When we do so, our identity as "scientists" may momentarily take a hit. If it does, we will probably survive.

References

Bea, R. G. Quantitative and Qualitative Risk Analysis. The Safety of Offshore Platforms. Presented at 28th Annual Offshore Technology Conference, Houston, Tex., 1996.

Bea, R. G. Human and Organization Factors: Engineering Operating Safety into Offshore Structures. *Reliability Engineering and System Safety,* Vol. 61, 1998, pp. 1009–1126.

Blumer, H. *Symbolic Interactionism: Perspective and Method.* University of California, Berkeley, 1969.

Campbell, D. T. Asch's Moral Epistemology for Socially Shared Knowledge. In *The Legacy of Solomon Asch* (I. Rock, ed.), Erlbaum, Hillsdale, N.J., 1990, pp. 39–52.

Czarniawska, B., and B. Joerges. Travels of Ideas. In *Translating Organizational Change* (B. Czarniawska and G. Sevon, eds.), Walter de Gruyter, New York, 1996, pp. 13–48.

Daft, R. L., and J. C. Wiginton. Language and Organization. *Academy of Management Review,* Vol. 4, 1979, pp. 179–191.

Full, W. S. Reports Useful for Accident Avoidance. *Professional Mariner,* Vol. 23, February/March, 1997, pp. 5–7.

Geertz, C. *After the Fact.* Harvard University, Cambridge, Mass., 1995.

Klein, G. *Sources of Power.* MIT Press, Cambridge, Mass., 1998.

Lagadec, P. *Preventing Chaos in a Crisis.* McGraw-Hill, New York, 1993.

Miley, D. F. Are We Looking Too Closely at Accidents? *Professional Mariner,* Vol. 21, October/November, 1996, pp. 15–16.

Parmenter, R. *The Awakened Eye.* Wesleyan, Middleton, Conn., 1968.

Pettigrew, A. M. What Is Processual Analysis? *Scandinavian Journal of Management,* Vol. 13, No. 4, 1997, pp. 337–348.

Roethlisberger, F. J. *The Elusive Phenomena.* Harvard Business School, Boston, 1977.

Sagan, S. D. *The Limits of Safety: Organizations, Accidents and Nuclear Weapons.* Princeton University Press, Princeton, N.J., 1993.

Starbuck, W. H., and F. J. Milliken. Executives' Perceptual Filters: What They Notice and How They Make Sense. In *The Executive Effect: Concepts and Methods for Studying Top Managers* (D. C. Hambrick, ed.), JAI, Greenwich, Conn., 1988, pp. 35–65.

Vaughan, D. *The Challenger Launch Decision.* University of Chicago, Chicago, 1996.

Weick, K. E. *The Social Psychology of Organizing,* 2nd ed. Addison-Wesley, Reading, Mass., 1979.

Weick, K. E. *Sensemaking in Organizations.* Sage, Thousand Oaks, Calif., 1995.

Weick, K. E., and K. H. Roberts. Collective Mind in Organizations: Heedful Interrelating on Flight Decks. *Administrative Science Quarterly,* Vol. 38, 1993, pp. 357–381.

Aviation Safety Incident Reporting

NASA's Aviation Safety Reporting System

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Safety is a top priority for all participants in aviation operations. Historically, significant safety issues have been identified with a variety of sources, and attempts have been made to actively address problems that occur within the aviation environment. To the credit of all participants, the aviation accident rate in the United States is one of the lowest in the world. But a new era has been initiated in aviation safety through several national safety efforts, notably the White House Commission on Aviation Safety and Security (1997).

Pertinent and timely safety information is necessary to make the constructive changes that are required to reach these safety goals. Some of this safety information is obtained from accident investigations, such as those done by the National Transportation Safety Board (NTSB). However, because of the crew member fatalities that commonly occur in tragic accidents, crucial information that is needed to assist accident prevention efforts may never be known.

Aviation incident reporting can provide this information. The information gap often involved in accident investigation—specifically, the events leading up to the accident, factors that increased risk, how problems were detected, and attempts made to successfully resolve the problems—can be provided by individuals who are involved in incidents that did not end in accidents. Incident reporting is a rich source of safety information as well as descriptions of human factor variables involved in the timeline of the event.

The Aviation Safety Reporting System (ASRS) was created in 1976 by the FAA and the National Aeronautics and Space Administration (NASA) to receive, process, and analyze voluntarily submitted aviation safety reports. The ASRS operates under two mandated purposes:

1. Identify deficiencies and discrepancies in the National Aviation System,
2. Provide data for planning and improvements to the National Aviation System by enhancing the basis for human factors research and making recommendations for future aviation procedures, operations, facilities, and equipment.

The aviation industry has learned valuable lessons from incidents that have occurred in the dynamic environment in which aircraft and their crew members fly. These lessons provide compelling motivation and encouragement for participants in the national aviation system to submit incident reports to the ASRS. Evaluation of specific incident descriptions can be used to more accurately determine major safety issues, identify potential problem areas, and create solutions before accidents occur.

Guidelines for Incident Reporting

The ASRS is governed by the Federal Air Regulations (FAR 91.25) and an Advisory Circular (AC No. 00-46D) as well as by an advisory subcommittee composed of representatives from the aviation industry. This government/industry collaboration was created to establish a forum for constructive discussion concerning aviation safety incidents. Although the FAA is the major benefactor of the ASRS, NASA, a nonregulatory government research organization known for its aviation human factors programs, was chosen as the institution that would protect these often sensitive data. NASA is therefore regarded as the honest broker of ASRS incident data. Throughout the 23 years of ASRS operations and more than 470,000 report submissions, there has never been a breach of any reporter's confidentiality. This is a record of great pride to the ASRS. A significant event may attract the interest of FAA enforcement action, news media, legal interests, and industry operators, but there is no compromise on the confidentiality principles that have been established within ASRS functions.

As with any system that maintains a delicate balance among numerous parties, the ASRS has guidelines under which it performs the mandates of the program. A special form was created to gather consistent information on all incidents reported to the ASRS. The top of the form, called the ID strip, is returned to reporters as proof of receipt after a report is processed. Currently, there are four ASRS reporting forms. The original reporting form (NASA ARC 277B) is generally used by pilots. There are specific reporting forms for air traffic controllers (NASA ARC 277A), cabin crew members (NASA ARC 277C), and maintenance/ground crew personnel (NASA ARC 277D).

In addition to confidentiality, another important aspect of ASRS program provisions is immunity. The FAA has endorsed incident reporting as a valuable accident prevention tool by providing limited immunity from disciplinary action to any reporter who files a NASA/ASRS report in the event of a real or suspected regulatory violation. The main guidelines addressing immunity provisions are explained in detail in the Advisory Circular (AC No. 00-46D). Copies of AC No. 00-46D may be obtained from NASA/ASRS, the FAA, or the ASRS Home Page at http://olias.arc.nasa.gov/ASRS.

Briefly, the requirements for filing are as follows:

- The violation was inadvertent and not deliberate.
- The violation did not involve a criminal offense, accident, or action under 49 U.S.C. Section 44709, which discloses a lack of qualification or competency, wholly excluded from this policy.
- The person has not been found in any prior FAA enforcement action to have committed a violation of the 49 U.S.C. Subtitle VII or any regulation promulgated there for a period of 5 years before the date of the occurrence.
- The person proves that, within 10 days after the violation, he or she completed and delivered or mailed a written report of the incident or occurrence to NASA under ASRS. Proof of timely submission is provided to the reporter by the returned ID strip from the top of the NASA form. A date/time stamp appears in the upper right corner, which indicates receipt at NASA/ASRS.

The advice often given to reporters involved in incidents is "When in doubt, fill it out." Often a reporter is involved in an event where final determination of whether it is an incident or an accident cannot be made by the FAA or the NTSB before the 10-day time limit for filing the ASRS report has elapsed. However, if the reporter is aware that the event is determined to be an accident by NTSB criteria, a criminal offense as determined by the Department of Justice, or a deliberate act, there is no immunity advantage in submitting a report to NASA/ASRS. These types of events are ineligible for consideration within the provisions of the program.

One of the primary reasons ASRS exists is to identify and constructively address safety issues in a timely way. The immunity provisions, although a strong motivation for submission, are not the sole reason for reporting to ASRS. Even if an event or incident is not a violation or does not qualify for the program's immunity provisions, it still may contain information of safety value to aviation personnel, operators, regulators, and researchers. The ASRS is receptive to reporting on any unsafe conditions that are observed or directly experienced. The program encompasses a wide range of safety issues.

ASRS Incident Report Database

More than 470,000 incident reports from a variety of aviation personnel and operations have been submitted voluntarily to ASRS since the program's beginning in 1976. More than 2,600 of these reports are processed through the system every month. ASRS maintains an active database of 80,000 of these reports. This database is used to detect current problems and to provide relevant information for aviation safety efforts involving human factors research, evaluation of current policy, and improvements to aviation procedures.

ASRS staff and human factors researchers are particularly concerned about the quality of human performance in the aviation system. Areas of special interest include problems involving human interface with various elements of the aviation system, including highly automated equipment, barriers to effective human performance, communication problems, and decision-making errors. The ASRS reporting form is designed to capture information about these areas of interest as well as a broad spectrum of incident particulars.

When an incident occurs, the reporter submits an ASRS reporting form, which provides a detailed summary of the conditions and situation variables involved in the incident. The form requests information about the type of operation, type of aircraft, qualifications of the reporter, weather, type of airspace, and many other event-specific details. The most vivid portion of the reported event, however, is provided in the narrative section, in which the reporter recounts the actual events before, during, and after the incident. This combined information is the single, largest advantage of incident reporting to the ongoing efforts of accident prevention. The reporters involved in the event are able to relate the conditions surrounding the incident, and they are also able to relate how they detected and resolved the problem. Incident analyses can and do provide information that is useful for targeting potential areas for safety improvements.

Because of the richness of the data provided to the ASRS, much effort and attention to quality are put into the analysis of each incident report. Each incident report is reviewed and analyzed by a team of experienced aviation safety analysts. This team is composed of retired pilots, air traffic controllers, mechanics, flight attendants, and other experts in specific subject areas. The analyst team has varied experience in all types of operations and environments, such as commercial Part 121 and Part 135, corporate, general aviation, and air traffic controller operations at all levels. ASRS analysts evaluate each incident report, make selections for full-format (database) processing, initiate telephone callbacks to selective reporters for needed clarifications, and process each report into a selection of categories describing the incident event characteristics.

Figure 1 presents the reports received from a variety of different aviation environments. As indicated, several categories of aviation personnel (air traffic controllers, cabin crew, maintenance/ground personnel) report in lower numbers than those in the pilot (air carrier and general aviation) reporter categories.

There are several reasons for differential reporting. Air traffic controllers historically have reported in lower numbers because they are subject to different disciplinary measures than are pilots, and they have less incentive to take advantage of the immunity provisions offered by the FAA for ASRS report submission. The ASRS program did not introduce customized reporting forms for the maintenance and cabin crew communities until 1997. The numbers of reports received from these members of the aviation community have increased since then.

Database Reporter Distributions and Incident Types

The ASRS database contains more than 80,000 records with reporters' narratives of incidents that took place and their assessment of the factors that contributed to unwanted events. The database has the capability to sort information on many variables, including the annual numbers of reports in each of the major reporter cate-

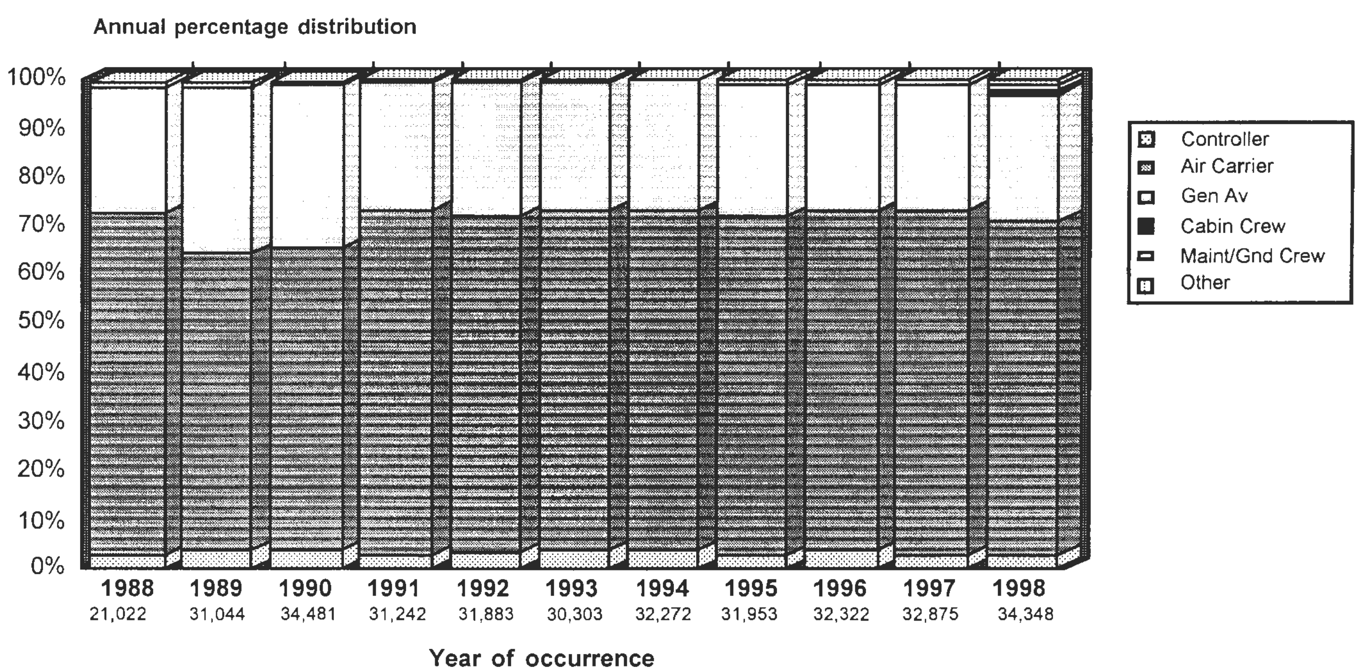

FIGURE 1 Annual ASRS report receipts, 1988–98. (Data for 1999 are incomplete and are not included.)

gories. Table 1 shows this breakdown for a 10-year period, 1988–98, as well as comparisons of each reporter category with the annual total database incidents.

Further inspection of Table 1 shows that the proportion of reports in most categories has remained remarkably constant over the years, even though the annual number of database reports has nearly doubled. Air carrier pilot reports represent about 60 percent of database records, and general aviation pilot reports represent another 20 percent of the records. The most striking exception to this general pattern of stability is found in the air traffic controller category. Air traffic controller reports dropped dramatically in 1991, after a national controllers' strike and never regained their pre-1991 levels. In 1998, the numbers of reports submitted by maintenance personnel and cabin crew jumped dramatically because ASRS introduced a customized form for them the preceding year.

Types of Database Unsafe Events (Anomalies)

A collection of several incidents that share common characteristics can also illustrate safety issues. To further explore the group of incidents submitted by different reporter groups, we analyzed the "Anomaly" category. This category is evaluated by ASRS analysts during report processing. After analyzing an incident report, the analyst classifies the major types of unsafe events ("anomalies") that occurred in the incident. Most incidents involve more than one anomaly (i.e., anomalies are not mutually exclusive). The top six anomaly categories in the ASRS database are presented in Figure 2.

The anomaly categories presented in order of frequency in Figure 2 show that more than one-third of all anomaly citations involved a nonadherence violation—nonadherence to an air traffic controller clearance, to a FAR, or to a published procedure. These incidents exemplify how even professional, well-trained pilots, controllers, and others can find themselves in a nonadherence situation to a regulation or procedure. They can be very instructive about the compatibility of a FAR or published procedure with the human's ability to comply in a unique situation. The last three categories deal with severe aircraft equipment problems, airborne loss of separation incidents, and navigation deviations.

It is important to note that all the anomaly categories may interrelate with each other and therefore are not mutually exclusive. For example, one incident may involve an "Aircraft Equipment Problem/Critical," which contributed to "Nonadherence/Clearance" and "Conflict/Airborne Less Severe." This type of flexible classification system allows each incident to be evaluated in some depth. Analysis of the actual report narratives contributes to an understanding of these types of incidents.

ASRS Products and Services

From its large database of information, the ASRS has a commitment to distribute pertinent safety information to the aviation community. This feedback is accomplished in various formats. There are a wide variety of products and services produced from the incident data submitted to the ASRS. One of these products that has become a very familiar ASRS publication is the safety bulletin *Callback*.

This publication, produced monthly since 1979, provides a quick review of many timely issues that have been submitted through incident reporting. A more recent publication, *Directline*, is now being produced for the aviation management and training audience. This publication also deals with recent topics of interest being presented to the ASRS. These articles are longer analyses usually involving presentation of several incident reports on the same subject, with interpretive commentary by ASRS analysts and research consultants.

TABLE 1 Reporter Groups in the ASRS Database, 1988–98

Reporter	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Air Carrier Operators	2580	3482	4158	4054	3929	3983	4073	5981	4934	4867	5032
Air Traffic Controllers	480	1055	1037	693	655	749	722	394	744	633	647
Cabin Crew Personnel	9	6	5	7	3	9	4	10	23	61	388
General Aviation Operators	1077	2055	2415	2035	1770	1861	1720	2356	1980	1970	1912
Ground Crew Personnel	11	18	35	38	63	86	84	90	120	220	288
Other Personnel	207	221	277	301	260	291	247	364	305	343	225
Total Database Incidents	4301	6748	7832	7040	6598	6860	6766	9129	8043	8024	8402

NOTE: Incidents may be reported by more than one person or reporter group (e.g., a pilot and air traffic controller may report the same incident); thus reporter categories are not mutually exclusive. Column totals represent number of discrete incidents.

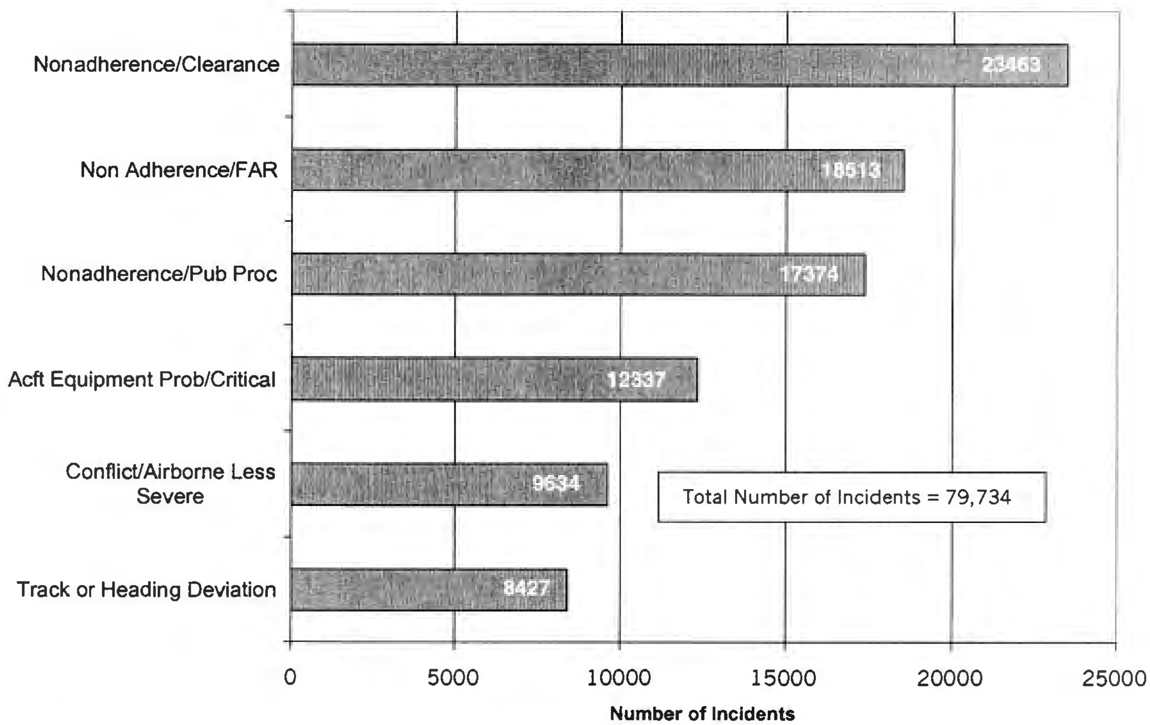

FIGURE 2 Selected ASRS database incident anomalies (January 1988–January 1999).

In response to its obligation to "identify deficiencies and discrepancies in the National Aviation System," ASRS has several options available to alert the aviation community. When ASRS receives a report describing a hazardous situation (e.g., a defective navigation aid, mischarting, a confusing procedure, or any other circumstance that might compromise safety), a series of alerting functions are in place to relay this safety information. This information is prepared in a deidentified form and sent to individuals who are in a position of authority so they can investigate the allegation and take needed corrective actions. ASRS has no direct operational authority of its own. It acts through and with the cooperation of others (ASRS Program Summary, 1998).

The alerting function involves three mechanisms: (*a*) Alert Bulletins (a well-documented safety problem involving a serious safety concern), (*b*) For Your Information Notices (information on a safety issue or a safety problem of lesser severity), and (*c*) FAA Telecons/Safety Communications. Depending on the severity of the incident, one or all of these mechanisms may be used. Severity is determined by a team of ASRS expert analysts. As with any product of the ASRS, these alerting messages are deidentified and remain confidential. Another ASRS service provided to the aviation community is database search requests. Information in the ASRS database is available to all interested parties. Individuals and organizations who need specific ASRS data will be provided with relevant reports retrieved during a search of the database. The current ASRS database includes reports submitted from 1988 to 1999. The search request reports can be provided in printed form or in Macintosh or IBM disk format. There is also a CD-ROM commercial product available on the market that has a copy of the ASRS database with annual updates available.

New Reporting Communities and ASRS

Reporting of maintenance and cabin crew incidents is being strongly encouraged so that this information will be available in greater quantities for the ASRS database. The current database has about 695 incidents submitted by maintenance personnel and 672 cabin crew reports.

The next challenges for the ASRS are to promote distribution of the newer reporting forms, educate potential users, analyze the data received, and disseminate the resulting safety information to the industry. Through this tailored system of reporting, many current efforts in aircraft safety and human factors will be enhanced. This information is crucial to support ongoing airline, industry, and government activities and research. Summaries, research projects, and data searches of these reports will be instructive for education, training, and accident prevention efforts.

The bottom line of "reduced accidents" is saving lives. All efforts toward gathering information on a national level for use by all interested organizations, unions, airlines, and others are imperative for improving safety. NASA/ASRS is looking forward to broadened participation by members of the aviation community in the program and is available to assist with any aviation safety efforts.

REFERENCES

Aviation Safety Reporting System: Program Summary. ASRS Reference, Dec. 1, 1998.

Chute, R. D., and E. L. Wiener. Cockpit/Cabin Communication: A Tale of Two Cultures. In *Proc., Eleventh Annual International Aircraft Cabin Safety Symposium and Technical Conference,* Southern California Safety Institute, Torrance, Calif., 1994, pp. 46–59.

White House Commission on Aviation Safety and Security. Final Report to President Clinton, Feb. 12, 1997.

The Real World: Blooming Buzzing Confusion

Karlene H. Roberts, *University of California, Berkeley*

My purpose here is to discuss some of the issues we come face to face with when we try to deal with risk and tools relevant to risk in the real world. Imagine for a minute the manager or operator beleaguered from every side with the requirement to engage in "risk-based" management. What's wrong with this?

- First, if you're like me, you don't know what risk-based management means.
- Second, you may have some gnawing notion that some things need fixing.
- Third, there are a lot of would-be "Mr. Fix-Its" (and fewer Ms. Fix-Its) who probably want to help you fix things.

What do you do? Today I want to try to answer that question. Although I'm somewhat familiar with the commercial marine industry, I'm going to try to answer the question by drawing on experiences faced by both the marine industry and other industries. I don't buy the notion that the commercial marine industry is so different from anything else that lessons learned there can't at least be tried out in ports, on offshore platforms, and on the waterways. My assertion is at least partially based on research Bob Bea, his students, my students, and I have done showing that safety impediments in your industry are closely related to similar impediments in other industries.

Four questions gnaw at us in trying to operate nearly failure-free organizations:

- What things really need fixing (and how do I know)?
- How do I fix them?
- What are the impediments to fixing them?
- How much will it cost me to fix them?

Let me address the last question first because it is the easiest. What will it cost me to fix them? Plenty. Whatever the problem, the cost of fixing it will be more than you or your company wants to pay. The company may believe the worst-case scenario will never happen here and refuse to fix the problem, or it may rely on cost models of fixing the problem that greatly underpredict actual cost, which happened to Ford Motor Company in the case of the Pinto. Here's what Carolyn Libuser says about the problem (Roberts and Libuser, 1993):

> Traditional risk analysis utilizes mathematical modeling and expected values to aid in making decisions about risk or about pricing risk. While this is a valuable methodology, we argue that in some cases it is not the appropriate way to assess risk and other methods need to be utilized. This is illustrated with two examples.
>
> In the case of pricing life insurance conventional risk analysis is highly appropriate. Insurance companies use actuarial tables to assess the probability of an insured person's death at any particular age. Companies also know the probability that a policy will lapse (a large number lapse within five years). Insurance companies make money by establishing price so the expected value of the policy (the probability of death during the expected time period of the policy times its face value) is, on average, less than the accrued value of the premiums paid on the policy.
>
> On the other hand, the January 17, 1994, Northridge, California, earthquake points out how other types of in-

surance are risky bets for companies (the industry's losses from the quake are currently estimated at about 10 billion dollars according to various insurers such as Allstate, Farmers, and State Farm). Earthquake insurance is a tremendous loser for insurance companies because they are unable to predict accurately the probability of a quake or the amount of damage it inflicts. Thus, the expected value of policies cannot be determined. As a result insurance companies charged a premium based on best estimate of a quake and in 1994 those estimates were very wrong. Consequently, insurance companies absorbed huge losses at the time of the Northridge earthquake and most companies withdrew from writing homeowners policies in California.

This example can be applied to the case of the *Exxon Valdez*. Even if the expected value of that oil spill had been calculated correctly (which it wasn't) before the spill, once the spill occurred the only relevant cost was that of the spill and the cleanup that followed. The moral of this story is that it almost always costs more to fix something after the damage is done than it costs to fix it before the accident. How industries deal with this is a big problem. They usually fail to deal with it at all. Or they deal with it through legislation that is insufficient at best. It needs to be dealt with through shared cultural values about things like environmental protection or even more simply the impact of catastrophic organizational outcomes on the organization's reputation.

What things really need fixing? This really breaks down into three subquestions: (*a*) How do I find out what's wrong? (*b*) Where do I get my notions about how to think about what's wrong? and (*c*) How do I assess the match between what I think is wrong and what is really wrong?

First, how do I find out what's wrong? Generally, as an industry you know what's wrong because you have data on things such as accident rates. So, for example, you know that bulker accidents happen more frequently than tanker accidents and over time probably result in greater loss. And sometimes it's easy to find out what is wrong—CNN or Mike Wallace from "Sixty Minutes" pays you a visit and exposes what's wrong. Alternatively, a regulator may have exposed what's wrong. These things can more or less identify the big things—things that can overwhelm even the best-defended system. But it's better for the organization to figure out what's wrong before CNN or anyone else gets there.

Many of the things that creep up on us year after year until they finally result in the "big one" are cumulative and opaque. Jim Reason has produced an enormously popular model for thinking about these things, the Swiss cheese model. This model identifies more than simply human errors or the usual operator name-and-blame syndrome that is still prevalent in many industries. The important thing about Reason's contribution is that he identifies "fire walls" increasingly distant from the perpetrator of the error that contribute to some catastrophic outcome and asks us to look at what can go wrong at these successive fire walls—just as Karl Weick asked you to do. One would do well to lay over the static fire wall model some of the more dynamic ways of thinking about identifying processes that lead to error that Karl alerted us to earlier.

Consistent with Karl's approach but from more of an engineering perspective is the approach used in medicine and discussed in the February 1, 1999, *New Yorker* article "When Doctors Make Mistakes." On page 51, the article cites Jeff Cooper's efforts to uncover the nature of mishaps in anesthesiology. Jeff relied heavily on "critical incidents methodology," which had been used since the 1950s to analyze mishaps in aviation and is at the foundation of the Aviation Safety Reporting System (ASRS). Although critical incidents methodology has been used in the marine industry, it is not a tool most of you would think to pull off the shelf in your own diagnostic efforts. But those of us who have had surgeries are pleased it was used in medicine because it was part of the foundation for reducing errors in anesthesia.

Where do I get my notions about how to think about what's wrong? You need to find a way to think about what contributes to the things you don't want to happen, like the bulk carrier that hit the River Walk in New Orleans in 1996, the fire on the cruise ship *Ecstasy* in summer 1998, or the Tosco refinery fire in the San Francisco area that killed four people in February of this year. This is the same refinery where one person was killed in 1997 and where there have been four fatalities in 16 years.

Karl's reminder to us that we want methods that produce explanations that are at once general, accurate, and simple is a good place to begin, particularly as he tells us that we can at best get only two out of three. He also reminds us that there are different kinds of knowledge. And he shows us that the way we organize our thinking determines our actions. We need to develop or borrow some sort of model that offers us a starting place for organizing our thinking.

I want to offer a first. I think the focus on risk in this industry is misplaced. It is a loaded word that conjures up visions of wrongdoing, hapless behaviors, and other negative things. If we move to its opposite—in this context, improving reliable, safe operations—we go a long way toward reducing the defensiveness and self protections that get in the way of any real problem solving. Let's take a different tack to thinking about the outcomes we all want to realize—reliable, error-free operations—and search for mechanisms to improve reliability. A reliability model focuses on a different set of issues than does a risk model. The National Patient Safety Foundation (NPSF) of the American Medical Association takes this broader tack in its view of patient safety. Here's part of what NPSF thinks safety is:

> Safety emerges from the interaction of components of the system. It is more than the absence of adverse outcomes and it is more than the avoidance of identifiable "preventable" errors or occurrences. Safety does not reside in a person, device, or department. Improving safety depends on learning how safety emerges from the interactions of the components.

We need to focus on realizing the good as opposed to thwarting the bad or at least focus on the two simultaneously. Reason's Swiss cheese model does both and was my way of introducing you to another organizing principle, one that can show us where to look for causes of error. It tells us to look at the operator as embedded in his or her organization, and we can carry this further to talk about the organization as embedded in its systems of regulation and competition.

I'm sure if one looked closely at the air tragedy on April 3, 1996, that killed Commerce Secretary Ron Brown and 34 other people on a flight from Croatia to Dubrovnik one would find more than simply operator error. In a press release on the accident the Air Force stated that the field command approved the mission despite orders to the contrary from headquarters. Other questions I've not seen addressed raise other issues that direct our attention to the larger fabric within which the accident happened. Why did the aircraft fly to Dubrovnik in such bad weather? What was the urgency? Who determined the urgency? Why didn't the pilots turn back? Didn't the Dubrovnik airport perceive that a landing could be very risky? If not, why not?

In the real world do managers and other decision makers really use models to guide their behavior about what to look for? Yes. Here are two examples. In 1968, after United Airlines lost an aircraft in Portland, it began to look for some answers to reducing flight error and improving safety performance. United adopted findings from the then current social psychological literature on team performance in developing its version of crew resource management training. The concepts and models borrowed from social psychology did not suggest the necessity of looking beyond the skin of the cockpit but it did allow the airline industry to begin somewhere. Today those models and concepts are sufficiently developed that they are borrowed to inform bridge team training in the maritime industry and they're widely used in other industries as well.

In 1995, after losing three F-14D Tomcats from the same squadron the U.S. Navy wondered how to assess performance safety in its air community. They borrowed a model that was originally developed in the banking industry. Some of you have seen this simple model developed by Carolyn Libuser in her Ph.D. dissertation (Exhibit 1).

It goes a step beyond something like the original crew resource management approach of the commercial airlines by introducing notions that the behavior of the organization at large is as important as the behavior of the team. This is more in keeping with what Jim Reason and Karl Weick would have us look at. The model addresses the following processes, and in a minute I'll tell you something more about its Navy application.

Where do you get your models or schemes for thinking about error reduction and high performance behavior? You might get them from inside your industry, or you might unabashedly and unashamedly borrow them from other industries or directly from the fields in which they were developed. You use engineering models every day in the design and operation of what you do. It's possible that other kinds of models can be equally helpful. After all, crew resource management is based on social psychological concepts, and Carolyn's management model is based on research on organizations. Now that I have a scheme for organizing my thinking about how things should work, how do I find out if they work that way?

How do I assess the match between what I think is wrong and what is really wrong? Many times managers and other well-meaning people believe they have an adequate description of what is wrong (for example, no process auditing here, inattention to appropriate rewards there, and so forth) and they move to fix it, often at considerable cost. But that may not be what's wrong here or, more likely, a little more of one thing you think is wrong really is wrong, and a little less of another is wrong.

Part of the problem with the crew resource management approach is that it has been applied to settings where no one knows if it is useful. In many of these situations it would be tough to test its utility and so managers are left to go on blind faith that it improves things. In the real world new programs of any sort are rarely tested for utility. This is true for virtually all the quality programs instituted in the United States.

But you can run various kinds of tests of your notions about what will work, some more rigorous than others. All require someone to get their hands dirty and go into the organization and find out what's happening. Is something you're doing making a difference? You can't assess its value through probabilistic risk assessment. You want to assess "that something" against performance data, but often this is where the problem is. There are no performance data. I'm going to give you two examples of what can be done.

Greg Bigley at the University of Cincinnati has a problem of no performance data. He deals with community emergency service teams and is particularly interested in how incident command systems function. That's the sit-

EXHIBIT 1 Libuser's Risk Mitigation Model

Process Auditing

Establish a system for ongoing checks designed to identify expected and unexpected safety problems. Safety drills and equipment testing are important aspects of this audit. Follow up on problems identified in prior audits.

Appropriate Reward Systems

Reward systems must reward desired behaviors. Organizational reward systems have powerful influences on the behavior of individuals.

High-Quality Systems

The quality of the system must compare favorably with the quality of a referent system that is generally regarded as the standard for quality.

Risk Perception

Risk perception has two elements:

1. Knowledge that risk exists at all, and
2. If risk exists, the extent to which it is acknowledged appropriately and minimized.

Command and Control

Command and control have five subfactors:

1. Command by negation—this includes migration of decision making to the person with the most experience, not necessarily the highest-level person;
2. Redundancy—in people or hardware; backup systems exist;
3. Formal rules and procedures—a hierarchy exists but it is not a bureaucracy in the negative sense;
4. Training; and
5. Senior managers who have the "big picture"—the senior managers don't micromanage.

uation where a big community emergency happens and teams of experts from different geographic areas who probably have never worked together come together to solve the problem. Greg has a model that includes the notion that the way these people are successful depends on a number of things, two of which are the development of instantaneous or swift trust and the way people form a joint representation in their heads of the problem they are trying to solve.

Greg can measure these things. His problem is that emergency task forces don't keep performance data. The best he can do is describe what he thinks happens and ask operators if what he says makes sense to them. Remember, it's the operators, not the managers, who know what's going on where the rubber meets the road. From his analyses Greg can then help managers try to decide what changes they think might be useful. He can even try to develop some performance measures against which they can later assess the old versus the new ways of doing business. Sometimes those outcome measures should not include the usual about how many mishaps were prevented, how the accident rate was lowered, and so forth. Maybe a good outcome measure would be "worker contentedness" because a contented, trained work force is not as apt to walk off the job and leave the manager in a less safe situation.

As I mentioned previously the Navy has a simple management model and, based on its evaluation of the banking research at the foundation of the model, thought that the processes operating in high-performing banks might be equally important in high-performance air squadrons. The Navy decided there were two ways to assess whether encouraging operation of the processes in the model would be helpful to them. An initial step was to ask squadrons to assess their performance on these processes and have them discuss the value of each process to them in maintaining high safety performance.

From Carolyn's model they developed a questionnaire and gave it to 1,245 aviators in randomly selected squadrons. A team analyzed the data and told squadron commanding officers how well their squadrons were doing at process auditing, making sure the correct rewards were in place, ensuring high standards of quality, and so forth. The squadron commanders thought this way of conceptualizing what goes on in their squadrons and using this conceptualization as a discussion springboard with squadron members was helpful in alerting them to attend to the "right" safety characteristics.

The conundrum comes about when you think about the fact that the Navy (or your organization) doesn't often experience the awful things it tries to avoid. So it is difficult to match questionnaire responses to catastrophic outcomes. The appropriate step is to think about what might be precursors to the really awful things. Often you can measure them and match some of the organizational processes, in this case the five emanating from the model, to the outcomes. That is what the Navy is in the process of doing for all its aircraft squadrons. Clearly, the organization will discover that some processes are more important than others and that still others are simply irrelevant to the goal of aviation improving safety performance. But the organization will have in place, and in data banks, a way to assess the safety health of aircraft squadrons.

You may think such an approach won't work or that it is impossible to do in the marine industry. Not so. Bob Bea and his students developed a similar approach to assessing management processes in the marine industry. The approach has been tested in a marine terminal, on an oil drilling platform, in U.S. Navy diving operations, and in U.S. Coast Guard bridge operations.

We've discussed how you come to know what really needs fixing—through believing what CNN identifies as bad problems or, better yet, by engaging in some activity that can get at the source of the genotypic processes that underlie the phenotypic outcropping of bad practices. It is entirely possible to consistently treat the symptom (five people killed over a 2-year period in the same refinery) without ever getting to the underlying processes, which means the symptom will return. You get at these underlying processes by developing or applying some model of them and then adjust that model for your specific situation. Then you try to test whether the model is related to or possibly predicts the behavior you want in your situation.

How do I fix things? This is the difficult part because it usually involves changing the norms of an entire organization or set of organizations. For people with the kinds of backgrounds most people in the maritime industry have (engineering backgrounds) fixing some things is easy. You take a wrench and fix it. But if you believe what is often said, that "80 percent of the problems are people problems," tweaking an engineering solution one more time will not help. Surely you can work toward making some engineering improvements, such as replacing old equipment and making sure the equipment itself is safe.

But the rest is the difficult part. Many of you don't believe what every industry is learning—that the real problems reside in things such as the organization's structure, culture, training, and reward systems. Implementing a good process auditing system in an organization that doesn't have one will probably require changing its structure. Being sensitive to keeping the right quality standards in place rests on good training. These are things organizations don't want to put money into. But ignoring these things results in huge costs when the "big one" happens and even when some of the little ones happen. Tosco paid fines after the 1997 accident, and the company found itself living in a county that, because of its behavior, instituted stronger safety regulations; is disliked by the environmentalists; is threatened with shutdown; and today has one of the poorest reputations of any organization in its industry in the San Francisco Bay Area. Surely, these things are borne as cost to the organization.

What are the impediments to fixing things? I'm tempted to say I think the largest impediment is cost, but I don't think that's true. The largest impediment to organizations doing what they should be doing is the culture of the organization itself. It is in part created by the larger economic milieu in which the organizations live. In the Tosco case, the company tried to respond to falling oil prices with employee layoffs. Layoffs often contribute to lowered safety standards. Until companies take the long-term view by including a fix-it line in their accounting systems instead of the short-term view of "not on my watch," calamities will continue to occur. It is also in part contributed to by what I call "John Wayne management." That is, a sense of invulnerability on the part of top management, the feeling that if we just keep moving down this road things will turn around.

Cost alone is decisively a factor. Until organizations recognize that the cost of not fixing is higher than the cost of fixing, fixing won't get done. The cost of fixing Tosco now is much higher than it was in January 1999. And one wonders what the decision makers at Chernobyl in 1986 think today about preaccident versus postaccident fix-it costs.

Another impediment to change is that often we don't know what to change. The regulators don't know what to change, the organizations don't know what to change, and the industry doesn't know what to change. The commercial nuclear power industry attempted to address this problem when it formed INPO and its international counterpart. INPO is the industry's clearinghouse for training and other activities relevant to nuclear power plant safety. The FAA attempts to do this through the ASRS, offering airlines and everyone else an opportunity to learn by studying near misses. Today there is a growing amount of research coming from a number of different fields about what to change. And today I've offered you a primer about how to figure out what to change in your setting.

To find out more about some of the things that go wrong and some things various industries have learned about change, see the short reading list in the Bibliography.

References

Bogner, M. S. (ed.) *Human Error in Medicine.* Lawrence Erlbaum, Hillsdale, N.J., 1994.

Flin, R. *Sitting in the Hot Seat: Leaders and Teams for Critical Incident Management.* Wiley, New York, 1996.

Gawande, A. When Doctors Make Mistakes. *New Yorker Magazine,* Feb. 1, 1999, p. 40.

Grabowski, M., and K. H. Roberts. Risk Mitigation in Large Scale Systems. *California Management Review,* Vol. 39, 1997, pp. 152–162.

Moran, K. Danger Aboard. *Houston Chronicle,* Aug. 20, 1996, pp. 1A, 6A.

Morris, J. Pressure to Set Sail. *Houston Chronicle,* Aug. 18, 1996.

Morris, J., and K. Moran. Lost at Sea. *Houston Chronicle,* Aug. 18, 1996, pp. 1A, 24A, 25A.

Moss, T. H., and D. L. Sills. *The Three Mile Island Accident: Lessons and Implications.* New York Academy of Sciences, 1981.

Pauchant, T. C., and I. I. Mitroff. *Transforming the Crisis Prone Organization.* Jossey Bass, San Francisco, 1992.

Perrow, C. *Normal Accidents: Living with High-Risk Technologies.* Basic Books, New York, 1984.

Pfeiffer, J. The Secret of Life at the Limits: COGs Become Big Wheels. *Smithsonian Magazine,* July 1989, pp. 38–48.

Phillips, D. F. "New Look" Reflects Changing Style in Patient Safety Enhancement. *Journal of the American Medical Association,* Vol. 281, No. 3, Jan. 20, 1999, pp. 217–219.

Read, P. P. *Ablaze: The Story of the Heroes and Victims at Chernobyl.* Random House, New York, 1993.

Reason, J. *Managing the Risks of Organizational Accidents.* Ashgate, London, 1997.

Rees, J. V. *Hostages of Each Other: The Transformation of Nuclear Safety Since Three Mile Island.* University of Chicago Press, Chicago, 1994.

Roberts, K. H. Managing Hazardous Organizations. *California Management Review,* Vol. 32, Summer, 1990, pp. 101–113.

Roberts, K. H. (ed.). *New Challenges to Understanding Organizations.* Macmillan, New York, 1993.

Roberts, K. H., and C. Libuser. From Bhopal to Banking: Organizational Design Can Mitigate Risk. *Organizational Dynamics,* Vol. 21, 1993, pp. 15–26.

Sagan, S. *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons.* Princeton University Press, Princeton, N.J., 1993.

Short, J. F., and L. Clarke (eds.). *Organizations, Uncertainties, and Risk.* Westview, Boulder, Colo., 1992.

Shrivastava, P. *Bhopal: Anatomy of a Crisis.* Ballinger, Cambridge, Mass., 1987.

Vaughan, D. *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA.* University of Chicago Press, Chicago, 1996.

Weick, K. E. Organizational Culture as a Source of High Reliability. *California Management Review,* Vol. 29, 1987, pp. 116–136.

Presentations

Marine Transportation System (MTS) Task Force Presentations

Keynote Presentation

MTS TASK FORCE PRESENTATION

Implementation of Risk Assessment

Robert C. North, *Rear Admiral, U.S. Coast Guard*
Chair, MTS Task Force

It is a pleasure to be here to lead this federal panel. We are going to present an overview of implementation of risk assessment in the federal government, by a series of regulatory agencies, including the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, the Maritime Administration, the Minerals Management Service, and the U.S. Environmental Protection Agency.

Although people readily accept the concept of risk management in the marine transportation system as a good idea, and although it has been used in a lot of ways for a lot of years, there does not appear to be a common understanding of what it means. I will attempt to give you some thoughts from the perspective of the U.S. Coast Guard and we will try to solidify some of the thoughts from this morning, looking at what's been done in various agencies.

Our hope is to achieve the following three goals: (*a*) a shared understanding of what risk-based decision making is and how it can be applied to the marine transportation system at the local, regional, and national levels; (*b*) a knowledge of where each of the agencies stands with respect to its own development of risk-based decision making; and (*c*) sharing the work that has already been done and coordinating our efforts to develop a systematic approach to risk-based decision making among the multitudes of stakeholders involved in the marine transportation system ports, waterways, and intermodal connections.

The Coast Guard is responsible for diverse aspects of marine transportation safety, from inspecting a vessel's machinery to marking the waterway with aids to navigation. We certify the competency of ships' crews and establish routing measures. We approve vessel designs and operate vessel traffic services. As you all well know, the Coast Guard exerts enormous influence over the activity of the marine transportation system.

In managing these diverse programs, the Coast Guard is seeing ways to best allocate resources across waterways and across programs to achieve the best possible level of marine safety at the best value to the taxpayer and the least cost to the transportation industry. To do this, we have to compare the relative value of more inspections with more aids to navigation, better trained ships' crews, more efficient routing measures, improved vessel designs, and better traffic services. We see risk assessment as a valuable tool to help us do this.

The concept of risk is straightforward: it is the probability (likelihood) of an accident or incident taking place (e.g., collision, fire) combined with the magnitude of the consequences (e.g., fatalities, hazardous material spills). Risks also may encompass programmatic, political, legal, and economic aspects as well as technical and environmental ones.

Risk analysis consists of three parts: risk assessment to evaluate the problems and challenges facing the organization; risk management to identify and appraise the potential solutions; and risk communication to review the process of using risk analysis to help carry out critical management responsibilities.

The fundamental reason why we are using risk analysis in decision making is that it allows a proactive, coherent allocation of resources—budget, personnel, equipment—according to the severity of the risk involved. This happens because risk analysis is a systematic process that compels decision makers to consider a broad range of safety challenges and potential solutions (for example, current and future trends, regulatory and nonregulatory interventions, prevention and response) when addressing an issue, so that both the efficiency of resource allocation and the overall safety performance of the system are improved.

One example of how the Coast Guard intends to use risk-based decision making is in our Vessel Traffic Service (VTS) program. We're refocusing this program on user needs, partnerships, and automated delivery of information, thus redefining the process by which we determine which ports need a VTS.

We intend to use a systematic risk assessment process that we call a ports and waterways safety assessment (PAWSA) to evaluate navigation safety conditions in ports and waterways and to determine whether additional or alternative vessel traffic risk mitigation measures are necessary. It's based on criteria provided by local waterway users and provides a structure for identifying risk drivers and then evaluating potential mitigation measures through expert input from local waterway users.

These safety assessments will consider various safety-enhancing alternatives based on their applicability to the risk conditions the port users identify and their projected cost and effectiveness. The PAWSA process is designed first to identify the risk drivers in a port or waterway that cause accidents leading to injury, loss, and environmental damage and then to identify the effectiveness of various safety interventions relative to the identified risk.

We have selected a methodology for identifying the dominant risk-inducing factors, evaluating the probability of each risk factor occurring, and determining the consequences if it does occur. Using an analytical hierarchical process model developed by the George Washington University Institute for Crisis, Disaster, and Risk Management, we will solicit expert opinion on port conditions. The model ranks port risk factors by asking a series of questions. Next, we evaluate the existing risk reduction regime and any additional interventions in terms of their cost and effectiveness.

Beginning with a list of U.S. ports that move more than one million tons of cargo each year, we will rank them based strictly on data such as vessel transits, passenger traffic, movement of hazardous material, and weather conditions. From this internal evaluation, we will develop a short list of ports that should be examined in greater detail with the analytical hierarchical process risk assessment model. Our goal is to identify areas for improvement and make sound, defensible budget decisions to implement those improvements.

We intend to strengthen the use of risk-based decision making in other areas. We plan to develop and use risk-based tools and methods for five broad areas of decision making: business plan development; regulatory development; compliance and enforcement of regulations, laws, and treaties; resource allocation; and operational decision making.

A common theme we have heard today is the idea of sharing lessons learned and sharing the kinds of things we can do to do the risk-based decision making well. So, please give some thought as you listen to the agency representatives describe what their agencies have been doing.

MTS TASK FORCE PRESENTATION

Application of Risk Assessment

Todd Bridges, *U.S. Army Corps of Engineers*

In this symposium we have focused on risk and human safety. I've been asked to briefly describe how the U.S. Army Corps of Engineers addresses concerns about the environmental risks of dredging and disposal of dredged material. The Corps has had the responsibility for maintaining navigation channels in this country for about 200 years. Currently, maintaining navigation channels nationwide requires the Corps, or those whom we permit, to dredge about 400 million yd^3 (305.8 million m^3) of sediment every year. That's enough dredged material to bury Washington, D.C., under 6 ft (1.8 m) of sediment, what some consider a potential beneficial use.

The challenge faced by the Corps and the U.S. Environmental Protection Agency, with whom we jointly manage the dredging program, is how to manage 400 million yd^3 of sediment in an environmentally responsible manner. Because of the physical and chemical properties of sediment, pollutants introduced into aquatic systems will accumulate in sediment. We are required by federal statute and regulation to assess the potential risk the dredged material may pose to human health or the environment when we make decisions about where to place that material.

Environmental risk is defined as the probability of undesirable effects resulting from exposure to known or expected stressors. In our case, the expected stressor is the chemical mixture in harbor sediments.

There are a number of benefits to using environmental risk assessment in decision making. Risk assessment provides a framework for synthesis and integration of large data sets; the data sets used as the basis for dredged material management decisions have become very large. We're looking at risk assessment as a way to effectively manage the environmental data we collect to support decision making.

In its environmental application, risk assessment acknowledges the ever-present existence of uncertainty in decision making and promotes the application of methods for describing the impact of uncertainty on decision making. The decision-making processes should be transparent—that is, the assumptions made during analysis of potential risks should be readily visible to those who evaluate the decisions. Risk assessment also provides measures for doing comparative analysis, which is particularly important considering that in many cases managers are asked to decide among a range of disposal options for the dredged material. The risk associated with each of those alternatives will not be equal. So being able compare the alternatives is a very powerful tool.

The two federal statutes that govern dredging and placement of dredged material, the Marine Protection Research and Sanctuaries Act and the Clean Water Act, contain language that suggests the need for using risk-based approaches. Words such as "unacceptable," "possibility," and "potential" suggest that using risk-based techniques is consistent with federal regulations governing the disposal of dredged sediment.

The approach we currently use to evaluate dredged material is consistent with risk assessment, but we are looking for ways to improve this testing framework. We use a tiered approach for reaching our decisions (see Figure 1). We progress through the tiers only as far as necessary to gain sufficient information to reach a decision about how the material should be managed. By moving

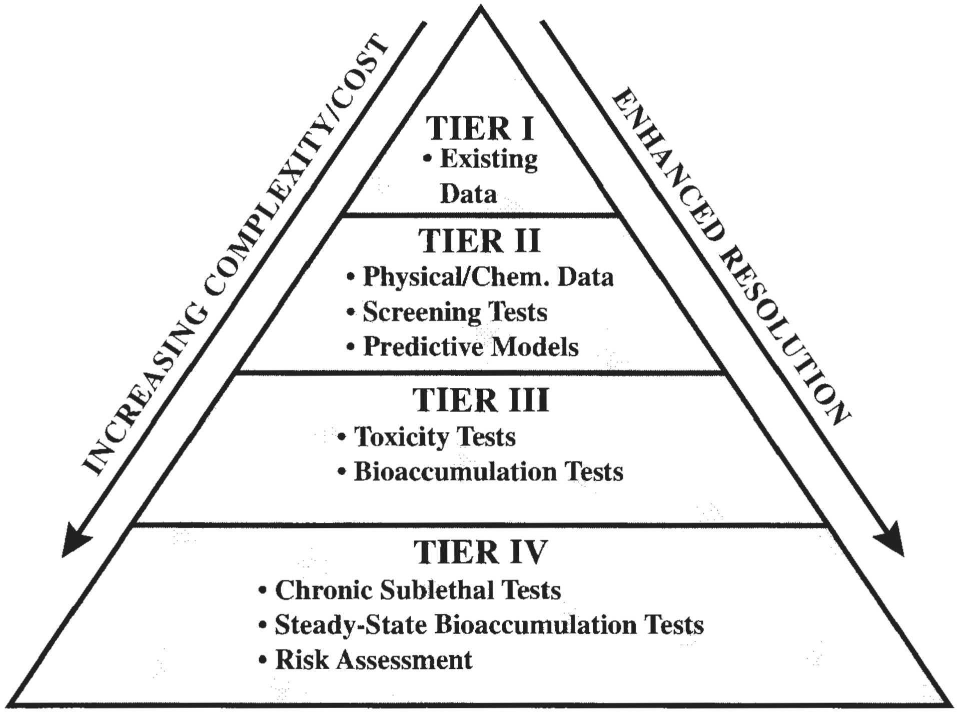

FIGURE 1 The tiered approach for reaching decisions.

to the next tier you are trying to resolve specific deficiencies in your data set. But as you move through the tiers your data set becomes more complex and you also have incurred greater costs associated with collecting the additional information. So there is a balance that should be sought. Don't move to the next tier unless you need to in order to reach a decision.

Our current approach contains the essential elements for conducting risk assessment. We assess exposure—that is, the likelihood that some organism, whether it is a human or a fish, is likely to come in contact with the contaminants in the material. We also evaluate the effects that may occur once an organism is exposed to those materials, whether that effect is cancer in humans or an effect on an ecological receptor.

Environmental risk assessment includes three major phases: problem formulation, analysis of effects of exposure, and characterization of risk. The problem formulation stage generally involves developing a conceptual model that describes the parameters and the pathways associated with a particular scenario. An analysis phase follows, which basically consists of collecting numbers and crunching those numbers to describe potential routes of exposure and the nature of any adverse effects. Finally, there is a characterization phase, which allows us to bring this information together for the purpose of decision making.

The Corps of Engineers currently has a research program called the Dredging Operations Environmental Research (DOER) Program. It's an 8-year, $32 million research program that has a risk focus area as one of its components.

The purpose and scope of this focus area is to provide guidance on doing risk assessment and managing environmental risks in the dredging program. The risk guidance we develop in this program will supplement, not replace, the existing guidance we have. What is referred to as a full-scale environmental risk assessment in most cases would remain a tier 4 exercise. The most effective application of risk assessment will be for those projects in which conditions or parameters are somewhat atypical.

Risk assessment can also be effectively used as a research tool for resolving the complex issues involved in assessing and predicting the environmental impacts of dredging. We are currently using risk assessment as a way to prioritize how to use our research funds in helping to resolve and clarify the dominant uncertainties.

Up to this time our evaluations have focused on small temporal and spatial scales (Figure 2). Societal and regulatory concern is focused in the upper right-hand portion of Figure 2, where the temporal scales are longer and the spatial scales are larger. Projecting effects from short-term, local scales up to long-term, regional scales is a complex process that will require using models and other risk-based techniques.

We tend to focus much of our technical attention at very small scales. For example, we focus a lot of our attention on the bioavailability of the contaminant or the amount of contaminant absorbed to sediment particles that is actually "available" to cause effects in an organism. However, most of our concerns about impacts are at much larger scales.

The processes that operate at large scales, which is where the regulations focus our concern, are quite a bit different than the processes that lend themselves to convenient study in a laboratory setting, which is our primary source of data. Risk-based approaches are required to make these jumps in scale.

We produced a summary of a workshop we conducted last year on risk assessment and dredge material management that was attended by a broad cross section of people from academia and the federal and private sectors. Improving dredge material management decisions with uncertainty analysis describes the major sources of uncertainty in our current evaluation framework. This document will be used to focus our research efforts to reduce the uncertainty associated with our management decisions. This year we are working on two guidance documents for conducting human and ecological risk assessments in aquatic and upland environments.

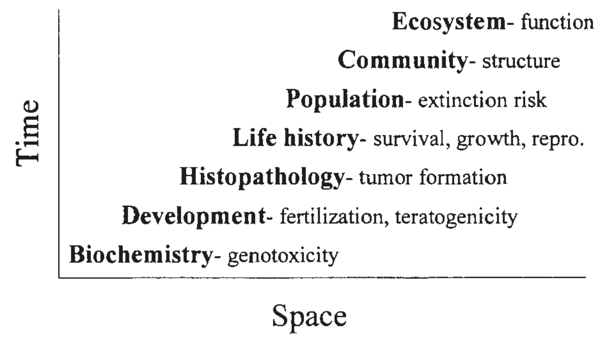

FIGURE 2 Scales of relevance for extrapolating effects.

In conclusion, we expect to derive a lot of benefit from the application of risk assessment and expect that risk concepts will form the basis for future regulatory revisions within our program.

MTS Task Force Presentation

Risk Prevention and Response

Nancy Foster,* *National Ocean Service, National Oceanic and Atmospheric Administration*

In the Department of Commerce and the National Oceanic and Atmospheric Administration (NOAA), the National Ocean Services (NOS) is the focal point for coastal stewardship. We cover a range of issues and responsibilities ranging from navigation services to coastal zone management; to marine protected area management; to research, response, and restoration.

Because of the very nature of our business, the word "partnership" is not the fad that it sometimes appears to be today. We have always had strong partnerships with state and local government, the academic community, the private sector, and nongovernmental organizations.

One thing that already should be apparent at this meeting is that risk assessment and risk management have an array of meanings. I particularly like the descriptor that says risk assessment is characterized by uncertainty. Because we very often have limited data, we are required to be continually making assumptions. Sometimes they are good assumptions; sometimes they are not. It all depends on the quality and the quantity of the data on which they are based.

Because we have responsibilities for safe navigation and for coastal resource management, the risks that concerned us fall into two categories: (*a*) the risk to ships, crew, and property; and (*b*) the risks to coastal resources and coastal communities. Our key objective in NOS is to bring the two categories together, because we believe they are inseparable. We integrate our approach to risk management through a continuum of prevention, preparedness, response, and restoration. I will touch just briefly on those categories.

The focus of our risk management strategy is prevention. We produce lots of products and services, some of which I will mention today. For example, we have been doing nautical charts since the days of Thomas Jefferson, and today we've seen the traditional paper charts that we're all used to give way to electronic charts—charts that use digital data are much more accurate than paper charts and are able to detect hazards as well as the time it is going to take a mariner to bump into that hazard in a meaningful timeframe for the mariner. We also have a system called Electronic Chart Display and Information System (ECDIS) that brings this information to the bridge of a ship. It can display the location of the ship, update the information every few seconds, bring in radar images, and bring in all kinds of real-time data—tides, currents, water levels, and any meteorological information that might be needed. The real-time data are also being developed for major ports around the country through our Physical Oceanographic Real Time System (PORTS). This system can be accessed through the Internet or by telephone. It was designed primarily to benefit commercial mariners, but we are finding more and more that it is being used by recreational boaters and commercial fishermen.

We also designate areas to be avoided on our nautical charts, particularly marine areas with special resources, like those in our National Marine Sanctuary program, and we use the mandatory ship reporting system. For example, the International Maritime Organization recently ap-

* Deceased, June 27, 2000.

proved a U.S. proposal to designate two areas off the Atlantic coast as mandatory reporting areas. These areas are the caving grounds and the feeding grounds for the world's most endangered whale, the northern white whale.

When and where preventive efforts fail, we move into the response and restoration activities. No matter how hard you try and no matter how sophisticated your prevention methods are, accidents will happen in this business because people are involved.

We have developed a variety of tools to assist in risk assessment. For example, we do environmental sensitivity indices where we plot the distribution of critical resources and their habitats as well as their sensitivity to various chemicals and various types of oil. These indices are available on paper. They are also available on CD-ROM and we are hooking them into our next edition of the Coast Pilot, so it will all be tied together. We also have developed what we call a trajectory analysis planner, which is a computer-based tool that analyzes the probability of the movement of various chemicals and various oils within a particular area. This provides a planning tool that can be used to prepare for an event, whatever it is and whenever it occurs.

We also prepare manuals and teaching materials. We do training courses to get the information out to local communities so that they can be better prepared. We also serve as a primary scientific advisor to the Coast Guard during spills of oil and hazardous material.

An example of one of the tools we're using is the International Tug of Opportunity System. This is a system that was used in Canadian and U.S. industry to protect the resources in the Olympic Coast National Marine Sanctuary and in the Straight of Juan de Fuca. This system is a call-in system so we can monitor the availability of tugs: we can determine where they are, what they are doing, and what their capability is to respond to ships in distress from either loss of power or loss of steering. We conducted a ship drift analysis and developed a model simulating what would happen and how long it would take a ship to run aground in a particular area; this is useful to the Coast Guard because it tells them how much time they have to respond to a situation.

Restoration is also a big part of our program. We are the federal trustees for living marine resources and their habitats. We exercise those responsibilities through something called a damage assessment and restoration program, which assesses damages and restores resources that have been injured as a result of oil spills or other hazardous material spills. We do Superfund work and we practice damage assessment and restoration for resources within national marine sanctuaries when they are injured.

Since we have been in business, we have generated close to $280 million for restoration activities. What we attempt to do is to restore the resource to a baseline condition, the way it was before the accident, and then compensate the public for the interim loss of those resources, pending restoration. For example, when a ship went aground on an ancient spur and groove system in the Florida Keys National Marine Sanctuary, we worked with the state and the responsible party to do some emergency restoration; we came in and reattached corals and cleaned up rubble (if you leave the rubble there as the currents come in and the storms go through, it just scours the area again). Then we did some longer-term restoration; we moved in large boulders and put down flexible concrete mats to allow the corals to recolonize. When we had to calculate compensation to the public, we wondered if there was anything we could do to prevent this type of accident in the future while the reef was restoring. We came up with the idea of installing a warning system so other ships could avoid having the same kind of accident. The responsible party paid for this and the Coast Guard has agreed to manage it. It is now in place.

In this case, the responsible party was very responsible—they worked with us from the beginning and they paid for everything. The case never went to court as many cases do.

We like to view the programs in NOAA and NOS as part of a picture puzzle. Usually, we use a slide to discuss the pieces of NOS programs—hydrographic surveys, real-time data, nautical charts, hazardous materials response—but you can just as easily take those puzzle pieces and put in the Maritime Organization, the Coast Guard, the Corps of Engineers, and the Port Authorities. The message is that if any of those pieces is missing, then the mariner and the coastal resource manager are likely to have a problem.

MTS TASK FORCE PRESENTATION

Making Maritime Transportation Safe and Effective

Alexander Landsburg, *Maritime Administration*

The purpose of the Maritime Administration (MARAD) is to foster a safe and environmentally sound U.S. maritime transportation system that provides national security and economic growth. MARAD is the only agency that focuses primarily on the commercial marine transportation system and on having it ready for a variety of critical national purposes.

One of MARAD's goals is to ensure intermodal sealift capability to provide national security. We have been working in the shipbuilding area to provide a strong base for security. Tied into this is improving system performance through technology and innovation, thereby reducing the cost of the system. Finally, we want to increase U.S. participation in foreign trade. The more efficient our system is, the better we can compete. Within the United States there are many domestic cargo movements; waterborne transportation is by far the cheapest method.

Why is MARAD interested in risk assessment? It comes down to the desire for productive capability and competitiveness, which depend on effectiveness, efficiency, and error-free processes. That has been a theme in all the discussions today—doing things up front to avoid errors and make things safer.

Japanese shipbuilding, for instance, has a very low accident rate. It is not because the Japanese are focused on having very safe operations. It comes from trying to do things efficiently, starting up front, planning carefully, and doing things well. The Japanese data may be underreported, but, according to statistics, the danger of working in a shipyard in Japan is about the same as that of working in an office in the United States! There is a lot to be said for preplanning and for looking at things carefully. The human-related aspects are the key, and I think the earlier presentations have echoed that today.

Theoretically, risk assessment provides a good basis for providing an objective comparison of alternatives. Everyone in the engineering field uses this type of approach for everything they do. In a broader view, however, the ideal is to have a risk assessment system that says precisely what the level of safety is; then society can decide where to go from there, up or down.

MARAD is very much involved with educating and training mariners. We work with the six state maritime academies to try to provide a basis for training; we also work with the U.S. Merchant Marine Academy, a MARAD activity at Kings Point, New York. MARAD is involved with many issues related to education. The real questions are, what do you need to teach, how do you test to make sure people know what they need to know, and what kind of things do you do to accomplish that.

One of the projects we have initiated is a cooperative program with the academies to look at the various changes that are happening in the industry. We have a joint project with the U.S. Coast Guard to look at the examination process for mariners. This is a longer-term research and development effort, but it is facilitated within the industry to engage collective thinking processes and determine what needs to be done. The first thing that needs to be done is to look at where the risks are: start by going to accident databases to see where the risks exist and then try to determine what type of knowledge, skills, and abilities are required. Of course, this is done during a dynamically changing situation.

Again, from the MARAD point of view, competitiveness is the driver. Internationally, a complete set of regulations and rules have been developed through the International Maritime Organization. The U.S. Coast Guard has fought for many years to bring the international standards up to or past those that are applied in the United States. The standards now are very high in most areas and we are at the stage of trying to rationalize our systems with what has happened internationally so that we are equally competitive.

I have outlined the basis of where MARAD comes from with regard to risk assessment. We want to have a level, competitive playing field but recognize that we need to look at everything if we are going to determine what that is and how to reach it.

The challenge, and this has been mentioned before, is lack of data, particularly lack of good human factors data. That is a continuing problem that we need to work on. We also need validated tools—tools that are going to stand up and processes that we can look to and point out to other people and say, here is what we really need and here is why. This is a far better process than waiting for a catastrophic accident to occur and then having to fix a problem when public pressure demands quick action, which often does not result in an ideal balanced, long-term solution. We need good tools that tell us what is the level of safety, allowing rational decisions on where to go from there.

Linda Connell's description of the Aviation Safety Reporting System leads to one of the cooperative projects we have with the U.S. Coast Guard. MARAD and the U.S. Coast Guard are working together to facilitate development of an international maritime information safety system with industry leadership. We stay away from the word "incident" in describing the system, as we want to ensure that any information that is of concern is reported. Things to be gathered are things that are not already required to be reported. Another key point of this initiative is that over time the cultural attitudes of individuals will change—their view of how they fit into the system including reporting their own errors and introspectively looking at how things can be changed and taking responsibility for the total system.

It is important to recognize that, for every accident, there are really about 100 incidents that could have been that serious accident. For each incident there are another 100 situations that could have become an incident. So, if you think about it, we actually have very little data for learning how to prevent accidents.

The fundamental basis for the system is the need to acquire precursor data. Along with meeting that need, particularly in the early term, is the opportunity to gather some lessons-learned knowledge that can be spread around that will make a real difference immediately. The bottom line is to identify problems and address them before an actual occurrence takes place.

I talked a little bit about the human factors taxonomy. We need to think more about standards. The aviation industry held a full symposium on human factors taxonomy recently. Also, under the Transportation Research Board this past January, we held a small intermodal workshop and spent a day focusing on the different taxonomies that are being used. We concluded that on a top level or two of categorization there is one particular approach that could be used by all modes. Standardization here would open up the opportunity to share data modally.

The key ingredient of a voluntary system is the deidentification and confidentiality process. When the data are acquired, they need to be carefully cleansed so that people and organizations remain anonymous but the data still must result in useful safety information. Those are the keys to a successful system.

The real key is to enable voluntary confidential reporting. We hope to convince the Department of Justice to permit protections that are really needed in our industry. Such protection was not as needed in the aviation industry to make things happen.

In a robust system that has adequate protections, people will report and come back as they learn its utility. We are at the point where the industry group has met a number of times. We have a draft blueprint to be published soon that is the basis for the entire system. We hope to put it within a nonregulatory party in the year 2000, but that depends on funding levels, industry leadership, and the Department of Justice really approving where we are headed.

One other thing I want to mention is that the Department of Transportation recently held its first ever Intermodal Safety Conference. One key recommendation that came from the event was to look at the safety data being collected. Are we collecting the right data? How can we get the data we need? Are we using the data in the right way? We concluded that we really need to have a good workshop that ties together intermodal interests and tries to compare and get the best practices in each; in particular we need to gather the information necessary for developing a good incident reporting system for the maritime industry.

We want to have practical, accurate, useful tools with which to assess safety levels. Our goal is an efficient and environmentally friendly waterway system in which we hope and are planning for trade to double or triple in the next 10 years. There are a lot of challenges and we need to do these things right away!

MTS TASK FORCE PRESENTATION

Using Risk Assessment in Inspection Programs

Douglas L. Slitor, *The Minerals Management Service*

My agency, the Minerals Management Service (MMS), has three primary responsibilities: leasing offshore lands for mineral exploration; regulating exploration, drilling, and production; and collecting royalties associated with production.

I am going to talk very directly about some ways we have been using risk assessment. Several studies in the late 1980s and early 1990s suggested that MMS should use risk assessment in some fashion in their inspection program, the program that I am in. These recommendations were made because of the following conditions. There has been offshore oil and gas exploration and production since the late 1940s, and these facilities have grown tremendously in that 50-year period. We have a wide range of facilities—nearly 4,000. Regulations require that we inspect these facilities once a year and we have a very limited inspection workforce to do that. We are barely able to get to each facility each year.

We have some very good facilities and we also have some facilities that are poor performers. We have nearly 1,500 single-well caissons, which are merely pipes sticking out of the water. We also have very large structures with 60 wells—complex equipment that can house 100 people.

Our traditional approach has been compliance strategy. We have developed 600 potential incidents of noncompliance. Our inspectors land, they go through a checklist based on the equipment there, and, if they see an infraction, they issue an incident of noncompliance (INC). We created a huge database with this information. Part of it is very useful and, as many of you are aware, part of it is faulty. But it has been useful for us.

What we want to do though, because we have an annual requirement to inspect facilities, is to focus on those facilities that are poor performers. We needed to find a way to do that. We started out by playing with semantics to try to buy ourselves some time and we redefined the term "facility." We came up with a cluster arrangement that reduced the number of inspectable facilities from almost 4,000 to fewer than 2,000.

We have yet to implement the next part, which is a sampling methodology. We have made revisions so that we can take a look at a statistically significant sampling of components and walk away with the knowledge that we have 95 percent assurance that a particular facility is in compliance. These two efforts have increased the time available to our inspectors, so hopefully we can focus on the facilities with more problems.

We started by developing a list of risk factors. We did this in concert with our inspection workforce. We did an initial survey that allowed inspectors to rank specific risk factors, which gave us a starting point for looking at our data and deciding what to do first.

After that, Dr. Paul Fischbeck introduced me to one of his graduate students, who has taken our database and taught us some things about what goes on in the database; he also developed a model that we can use to predict where accidents are likely to occur. He took 10 years worth of data (basically compliance data), INCs, infractions, accident data, and a host of other fields of information and put it into a NeuralNet software. This software learns about patterns among data and gives weights to certain things as it learns about the data. It came up with some very interesting findings.

Along with the NeuralNet, some logistical regression work was also done, and we looked at the number of INCs received by a given facility. The three correlated very strongly. The NeuralNet itself looked at data for a 5-year period, took that data, and tried to predict the facilities that were likely to have some type of incident the following year. It was fairly successful. When we rank-ordered the facilities by the risk the NeuralNet had predicted, we found that, typically, 55 percent of the accidents occurred on 20 percent of the platforms; sometimes up to 70 percent of incidents occurred on 20 percent of the platforms. This was exciting from our standpoint, because we had a method that we could use to focus our inspection workforce on some facilities that were having problems.

One of the drawbacks is that there are a lot of false positive results. Certain facilities were predicted to have accidents and they did not. What we take from this is basically that false positives might be a near-miss situation brewing. Our inspector workforce could still be validly used to check on all these facilities.

How do we plan to use these data? We have some things in mind now and we hope in 1999 to get to a point where we can run a pilot program. We want to use the NeuralNet to determine inspection frequency. It gives a value between zero and one; the higher numbers are those that the model considers more likely to have some kind of incident. We want to take that value and delineate what we believe would be a low-risk area, a medium-risk area, and a high-risk area. This tells only part of the story of the risk. A lot of things happen daily—new applications being applied for construction or welding or a particular operation where risks are higher than other operations. At that point, we want our district supervisors to take the value the model has generated and overlay it with some more specific and more recent information that they know. It may be information that is not in our database.

One of the things that the inspector workforce indicated was that we have a lot of new operators. The number of people has grown along with the number of facilities. Some are brand new and do not have a good grasp on our regulations; that is a cause for concern and it is a red flag to our workforce that is not in the database. It is something that can be used when making a final determination on what kind of inspection strategy to use for a particular platform. Also, the manpower and logistics vary—we have facilities that are very close, and we have some that are very far offshore. All this has to be factored in for the district supervisors' attention and for figuring out a particular strategy.

Where we really want to go from this point is to work with our pilot program and learn some lessons from it. We think we are on to something, but we cannot foresee the problems; we want to work this out in the field and see how it works with the inspection workforce. They have been very receptive to it because they are involved with it. They help determine the inspection frequency and the three surveys we've conducted with them indicate that they believe they have a vested interest in this.

This is a part of three programs that dovetail fairly nicely. The risk-based inspection is one. We also are working with performance measures of operators. This is facility specific, regardless of the operator, but we also look at performance of operators, and that becomes another factor that we would like to fold into this—how that operator is doing. We are beginning to talk to those operators who are doing well about alternative compliance—we are receiving proposals from them on how they can still meet the intent of the regulations but through their own means, giving them the flexibility to act on their own in terms of their own efficiencies and manpower needs.

MTS Task Force Presentation

The Marine Transportation System and Environmental Concerns

Craig Vogt, *U.S. Environmental Protection Agency*

The marine transportation system (MTS) presents a myriad of negative risks to the environment and a myriad of positive economic benefits for the American standard of living. The age-old question has been how to balance those risks and benefits. We have been making these decisions for many years; the wisdom of some of the decisions is now coming into question, but choices were made based on the information that was available at the time. Today's risk assessment and risk management models/procedures attempt to quantify available information providing a systematic framework for decision making, and their use in MTS planning should bring long-term health to the economy and to the environment.

The message in this presentation is captured in Exhibits 1 and 7; however, the reader is encouraged to examine Exhibits 2 to 6 and the text to understand the risk assessment/management framework as it is applied to the MTS.

The concepts in Exhibit 1 are not original or new, but they do represent the consensus of the National MTS Conference in Warrenton, Virginia, in 1998. The take-home message here is the first bullet—let us consider environmental concerns from the beginning in every one of our decisions. The challenge before us is how we can best integrate environmental concerns with MTS planning, which should help us achieve an efficient and effective MTS. The premise of this paper is that, if environmental concerns are not addressed up front, the vision for the MTS will not become a reality.

The second bullet in Exhibit 1 talks about stakeholders. It is essential for stakeholders to be brought into the planning and decision-making process early and to be kept informed as MTS plans are developed. Without the "help" of the stakeholders early and throughout the planning and decision-making process, a system that invites "late hits" evolves, which can stifle project time lines and create serious inefficiencies and very ineffective decision making. The final bullet in Exhibit 1 recognizes that environmental issues are seldom single faceted and broad-scale planning efforts should address the long-term aspects of the proposed action.

The risk assessment model presented in Exhibit 2 is the model that is used at the U.S. Environmental Protection Agency (EPA) in the various programs; it is the same model that Dr. Todd Bridges presented earlier. It is fairly simple, and I will not go into the technical details in this paper. The key is to recognize that this is a procedure to put the information into a decision-making framework that identifies the problem, assembles information on effects, assesses exposure, and then characterizes the risk. Risk characterization tells how good the information is and whether it can be used in the risk management decision.

As shown in Exhibit 3, EPA uses risk assessment in regulatory programs. These are frequently chemical-by-chemical assessments and are formal/traditional risk assessments. Many of these regulatory programs already deal with the MTS, such as in Superfund sites at ports, in air-quality standards and water-quality criteria, or in dredged material management. Risk assessment traditionally has been used in the MTS to prevent accidents and spills. The National MTS Conference recommended that the use of risk assessment be broadened in its appli-

EXHIBIT 1 MTS National Conference: Recommendations on Environment

- Environmental concerns must be consistently incorporated into MTS decision-making processes from the beginning.
- Decision-making processes must bring all interested parties to the table.
- Processes must focus on long-term planning on a broad scale.

EXHIBIT 2 Components of Risk Assessment

- Hazard identification/problem formulation
- Dose-response assessment for toxicity/effects
- Exposure assessment
- Risk characterization

EXHIBIT 4 Typical Environmental Considerations for Port Development Projects

- Underground/aboveground storage tanks
- Chemical storage
- Spills and leaks
- Water resources
- Wetlands
- Cultural resources
- Air emissions
- Wastewater discharges
- Storm water discharges
- Construction impacts
- Fisheries
- Traffic
- Noise
- Endangered species
- Public outreach/access
- Mitigation
- Hazardous wastes
- Sediment and erosion control
- Dredging and dredged material placement

cation to the MTS by addressing a multitude of potential environmental concerns, such as those presented in Exhibits 4 and 5 from port development projects and port operations, respectively.

Despite major progress in controlling pollution since the early 1970s, we have not achieved a healthy coastal environment, and there are a number of serious problems before us. We have certainly made progress in controlling wastewater discharges from sewage treatment plants and industries, but the most difficult problems remain: toxic chemicals damage ecological resources and public advisories to not eat fish are very common. Other indicators of the challenge before us include unsafe shellfish and unsafe swimming beaches due to pathogens, algae blooms,

EXHIBIT 3 Sample Regulatory Programs in EPA That Use Risk Assessment

- All EPA regulatory programs use some form of risk assessment.
- Formal/traditional chemical-by-chemical risk assessments are the basis for decisions in numerous programs.
  - Superfund
  - Pesticide registration
  - Drinking water standards
  - Hazardous waste disposal siting
  - New chemical assessments
  - Air-quality standards
  - Water-quality criteria
  - Dredged material management

EXHIBIT 5 Port Operations with Related Environmental Concerns

- Automobile transport
- Building/grounds maintenance
- Cargo handling
- Chemical storage and handling
- Fueling
- Painting
- Paint stripping
- Public access and recreation
- Rail maintenance
- Ship liquid discharges
- Ship ballast water discharges: invasive species
- Ship air emissions
- Ship breaking
- Vehicle and equipment maintenance
- Vessel repair and maintenance

and hypoxic conditions (i.e., lack of oxygen) in our coastal waters from excessive nutrients from storm water runoff, loss of habitat/wetlands, and the decline of our fisheries. The MTS is a contributor to these coastal conditions. The question is how much the MTS contributes to these effects, how much each one of the concerns in Exhibits 4 and 5 contributes, and what can reasonably be achieved in terms of application of controls. This is where risk assessment can help.

One very well-known example of port development or port operations that can pose risks to the environment is the deepening or maintenance of channel depth by dredging and placement of dredged material, as noted in Exhibit 6. Dr. Bridges pointed out in his paper that the environmental evaluation of dredging and placement operations by the Corps of Engineers and EPA has been consistent with risk assessment but efforts are ongoing to provide a more formal risk assessment approach; in this regard, it is important to understand that risk assessment is a model (some prefer to call it a framework) and that "one size does not fit all." The intensity and effort put into the risk assessment for each project or component of a project should reflect the extent of the problem, the potential risks to the environment, and the amount of data and information that are needed to reach a decision. A formal risk assessment for a Superfund site can be very complex, expensive, and time-consuming, whereas some other risk assessments, such as the risks of the actual dredging operation, can reach conclusions with much less effort.

EXHIBIT 6 Potential Impacts from Dredging and Placement of Dredged Material

- Wildlife and fishery impacts during dredging
- Physical impacts of placement of dredged material
- Contamination of dredged material and potential adverse impacts to ecological resources and human health
- Beneficial use of dredged material

EXHIBIT 7 Major Factors That Affect Decision Making: Risk Management

- Scientific factors
- Economic factors
- Laws, regulations, and legal decisions
- Social factors
- Technological factors
- Political factors
- Public values

Risk assessment provides a model or framework to organize data and information and to characterize the data/information to determine whether it is an adequate basis from which to make a decision. The actual decision-making process is termed risk management and it embodies all aspects of factors that influence the decision, such as the factors indicated in Exhibit 7.

Traditional approaches in the MTS have been to balance economic needs with environmental concerns. There have been major environmental issues over the years. Some of the problems that have been experienced were a result of not considering potential environmental impacts until late in the project evaluation process and a lack of stakeholder involvement. In addition, there has not been sufficient use of risk assessment models to assist in the analysis and evaluation of environmental concerns. The learning curve has reached a point where decision makers now understand that environmental concerns must be consistently incorporated into MTS planning from the beginning and that use of risk assessment and risk management can provide an efficient approach to reach the most efficient and effective decisions.

Thus, I believe the environment will not stand in the way of achieving the vision for the MTS if we use the tools before us, if we recognize that all interested stakeholders need to be brought in early, and if we all understand that a healthy MTS cannot be achieved without a healthy environment and that the concept of balance should be replaced by the concept of harmonization.

Keynote Presentation

Risk Management in the Marine Transportation System

Vice Admiral James Card, *Vice Commandant, U.S. Coast Guard*

I am pleased to be here today and to have a chance to spend a little time with you talking about the marine transportation system (MTS) and risk management as it relates to that. We have heard several good discussions this morning, and I know there will be more good discussions in this area.

I want to talk about what is going on in the Department of Transportation with the MTS and about what the U.S. Coast Guard and the Department are doing in risk management.

The MTS is vital to our country and to our national interests. There are some impressive numbers that I want to cite that many of you probably already know, but I want to make sure we don't forget them. Over 2 billion metric tons of cargo, worth over $1.0 trillion, transit our waterways every year. Ten million barrels of oil are imported daily, almost all of it by water. Excluding Mexico and Canada, 95 percent of our foreign trade and 25 percent of our domestic trade depends on marine transportation. Over 90 million passengers embark on ferries, cruise ships, gaming vessels, and tour boats from U.S. ports every year. Over 26,000 documented commercial fishing vessels harvest food from the sea. Probably 100 million Americans use the nation's 20 million recreational boats. The MTS and its infrastructure contribute $78 billion to the U.S. gross domestic product. I challenge that number because I think it is low. And it generates 16 million jobs. Ninety-five percent of all the weapon supplies and U.S. forces during Desert Storm were transported by ships. So, we clearly depend on the MTS as an element of the overall national transportation system to provide safe, secure, environmentally sound, and effective transportation.

However, the United States is at a critical point with respect to the future of our ports and waterways infrastructure. Many of our ports and waterways have aging infrastructures, which most of you already know, and we are not world class. This probably reduces our competitiveness and increases the safety risk as well as the risk to the marine environment. Our system is under stress. Some of the projected trends, some of which you have already heard, are that world maritime trade will double or triple by the year 2020. There is increased use of passenger vessels, including ferries and commuter ferries; recreational and leisure use of the waterways is growing; and there is increased concern about public safety and the environment—that concern grows all the time. There is a threat or a concern for a threat that we will see in our transportation infrastructure from cargo crime, smuggling, and terrorism. We are fairly vulnerable in that regard to anybody who would like to do us harm.

Meeting these challenges is difficult because we are unlike many other countries. We have lots of ports and our ports and waterways are managed by a host of federal, state, and private sector organizations. Federal agencies, like the ones you've seen here today, as well as St. Lawrence Seaway Development Corporation and a lot of other people are involved in marine transportation. Sometimes we are compared with Rotterdam and Singapore. If 50 percent of your gross domestic product comes from a port, you probably have a national entity to look at what is going on in the port, as does Rotterdam.

So, with all this background and with all these trends, there is a need to look at our transportation system and that is what is being done.

Last spring, as you have heard, the Coast Guard along with the Maritime Administration and many other federal agencies held seven 2-day regional listening sessions around the country to find out what issues concern our MTS. The goal was to start the dialogue, to have input from a variety of people who were involved, and to hear about the issues they considered to be most critical. During the listening sessions, we received hundreds of comments and recommendations, which formed the basis for the national conference on U.S. marine transportation that was hosted by Secretary Slater last November. The two and a half-day conference was attended by 144 senior leaders in government and the private sector, and the importance of this can be told by the fact that, although there were 144 attendees, many others wanted to be there at the conference and we just couldn't work them in. This included people from the federal government, state governments, industry, and a broad range of stakeholder groups.

The conference was structured around several key areas. The goal was to develop a vision for the MTS for this more demanding future I've talked about; to develop a framework for national and local coordination; and to develop goals and recommended actions to address the challenges and achieve the marine transportation vision in safety, security, environment, competitiveness, and infrastructure.

I'm going to focus on a few of those today. The vision is very important. Secretary Slater opened the conference by voicing his support and challenging the group to develop a bold, forward-looking vision, one that ensures that the MTS in the 21st century lives up to its potential as an intermodal engine for economic growth, while preserving safety, security, and the environment.

The reason it is important to mention Secretary Slater is that there have been several secretaries of transportation. They have all been very worthy and good public servants, but I don't think any has taken on the chore of a MTS as Secretary Slater has. He is absolutely committed to this now and it is an important part of his leadership in this area. We have continually explained to him that as he puts together a national transportation system, he needs to have one from the water side that is not the weak link—it is at least equivalent to the others.

Having said that then, the following vision came from our conference: The U.S. MTS will be the world's most technologically advanced, safe, secure, efficient, effective, accessible, globally competitive, dynamic, and environmentally responsible system for moving goods and people.

That is a tall chore but that is the vision and visions are supposed to be tall chores. The guiding principles are systems integration, federal leadership, shared responsibility, balance among diverse interests, technology development and deployment, and recognition that people are critical to the success of the vision.

Lack of coordination was a topic of great interest at both listening sessions and the national conference. It was identified as a problem not only at the national level where agencies don't always coordinate, even though we are working hard to do that today, but also at the local level, between state, local, and private stakeholders. The conference participants endorsed the idea of a national council to coordinate federal efforts and eliminate barriers between agencies. However, they were careful to note that private sector stakeholders must have an avenue to communicate with this council and be able to participate.

Secretary Slater is seeing the need for national leadership in the MTS, as I mentioned, and he has responded to the challenge. In his closing remarks, he said, "I want to personally assure you that I will do my part, working with all of you in carrying out the leadership role." The call for leadership was not limited to the national level. Participants also clearly saw the need for local coordination and leadership. They endorsed existing local harbor safety committees as models for other ports. Their harbor safety committee concept was also identified as the model for possible expansion beyond safety to security, environmental transportation infrastructure improvements, and economic issues as appropriate.

As you might expect, there was also a consensus that the national council should not be overly restrictive in its guidance and direction to the local coordinating committees. The Coast Guard is intimately involved with most of these local committees and believes that local activity is the key, not just to safe operations but to ensuring environmental responsibility, mobility, and other efficiencies as well as to ultimately achieving that MTS vision. We are looking for ways to foster local coordination and gain a level of consistency among these groups.

The proceedings you have in your packet have been published on the Internet and we asked for comments on them in the *Federal Register*, which was published on March 11th. This is a national dialogue we are trying to have.

Another piece of our rollout in the MTS is the Task Force. Congress mandated formation of a national task force through our 1998 Coast Guard Authorization Act. The task force is an advisory body whose purpose is to assess the adequacy of the nation's MTS to operate in a safe, efficient, secure, and environmentally sound manner. The task force members, representing 23 federal agencies and 44 maritime industry organizations, were appointed by the Secretary of Transportation. The Commandant of the Coast Guard and the head of the Maritime Administration serve as co-chairs. Secretary Slater convened the first meeting of this task force on March 12th. In his remarks, he spoke about the strategic nature of the MTS, which he called the country's first interstate, and its importance to the overall transportation system in the national economy. He also reiterated his commitment to leading the MTS effort.

The output of the task force will be a report to Congress that examines the critical marine transportation issues and develops strategies, recommendations, and plans of action to advance the national interests, including global economic competitiveness and national security in the marine transportation arena. The report is due July 1, 1999. I know they are working hard to make that deadline.

The task force is tasked by Congress to (*a*) take into account the capability of the MTS and, specifically, the adequacy of depth of approach channels and harbors and the cost to the federal government to accommodate projected increases in foreign and domestic trade over the next 20 years; (*b*) consult with senior officials in the public and private sectors, including users of the system such as ports, commercial carriers, shippers, labor, recreational boaters, fishermen, and environmental organizations; (*c*) sponsor and provide participation in public and private sector activities to further refine and implement, to the extent possible under existing authority, the strategies, recommendations, and plans for action; (*d*) evaluate the capability to dispose of dredged materials that will be produced to accommodate the projected increases; and (*e*) evaluate the future of the navigational aids system, including the use of virtual aids to navigation and electronic charts.

Those are the two big things that are going on right now in the MTS. Now I want to talk about risk management and what we have done, what we are doing, and what we hope to gain.

The process we've embarked upon, conducting all these sessions, gathering leaders from all facets of the maritime transportation community, and evaluating the needs of the system, is linked to risk management, which is the purpose of this meeting.

Risk-based decision making was a recommended action that came from the regional listening session and for both the environment and safety sessions at the MTS conference. Our goal is not only to increase the efficiency of the system but to make it as safe as possible. Risk and risk management have been defined several different ways today. Risk management is not new to us. It is not new to the Coast Guard, nor is it new to the people in the marine transportation industry. But increasing our understanding of risk management and increasing the use of risk management to make it effective are important.

We are trying to apply these principles. We have applied risk-based decision making in the Coast Guard in the past, everything from transportation of liquefied natural gas to looking at fire safety on tankers and passenger vessels. But now we need to be able to take some more positive steps. Most of those were material solutions to the problems. We have all heard that most of the problems and the solutions are ones that you find in the people and not, for example, in a redesigned steering gear. Every year marine-related accidents cause about $1.5 billion of damage. I think that is a conservative estimate. If most of these accidents are people related in some way, then by applying the actions we've taken in the past and fixing the systems wherever they may be, the steel and the hardware, and now even the information hardware, are not going to solve the problem. Earlier in my career, when I had Bob North's job, we put together an effort called Prevention through People; one of the many guiding principles was to manage risk.

The human element includes everyone—those in government, marine organizations, port authorities, classification societies, the maritime industry, and the mariners themselves. It is not limited. In fact, there may be things we put out in regulations and processes and procedures from the government that actually hurt instead of help what we want to do. One might suggest that the way we've crafted regulations is not necessarily helpful or customer focused and that is an area that can be improved. But it is important to look at all these things under the umbrella of partnerships. Hence, the Coast Guard has nine formal partnerships with industry associations. The first was with the American Waterways Operators, followed by Innertanco, BIMCO, API, the old Aimes, the Spill Control Association of America, PVL, ICCL, and the American Pilots Association. These partnerships have yielded positive, nonregulatory solutions, although they do not prevent us from coming up with areas where regulations need to be changed. I will give two examples of ones I think have been successful, but many others have also succeeded.

1. Analysis of the causes of spills associated with tank/barge cargo transfers and applying these results to reduce spills during these evolutions and development of a program targeting the human element, reducing personnel casualties aboard tugs and barges—effectively, that means people falling over the side. Every year, more mariners die from falling over the side and drowning than from any other single cause. I suppose you can regulate against that and tell them not to fall over the side, but that doesn't work. So, we had to pay attention to that, and it is working.

2. A risk guide providing U.S. passenger vessel owners and operators with a tool for better assessing and managing risks inherent in their operations and avoiding accidents. We hope these efforts will reduce the risks associated with human error in maritime operations and encourage public stakeholders and all to have a common understanding, to share information, and to work together. All these are foundations of prevention through people. Actually, the concept initially started also with applying quality principles in what we were doing in this regard.

You may remember that in the early 1990s much of what we talked about was that if people were the problem, then they needed more training. Anyone who has studied the situation will recognize that training may be an element, but it is not the answer.

The same principles are at work as we pursue an MTS that is technologically advanced, safe, secure, efficient, effective, accessible, globally competitive, dynamic, and environmentally responsible.

The physical boundaries of our ports and waterways are not going to change much, so maritime traffic congestion is going to increase. You're going to have technological changes. In fact, not only are the boundaries not going to change, there are going to be more claims on those resources. You've heard some today—areas to be avoided—marine sanctuaries, and so forth. Unless you believe that Antarctica is going to melt and there will be more coastline, and look at the population projections and the concerns, you're going to have more and more people using the same body of water and it is going to have to be sorted out in a way that hasn't been done so far. The principles you're talking about are going to be very important in that regard.

One concept where we are using risk management in navigation safety that you'll see more of has to do with safety analysis of our ports and waterways. We intend to look at each of the ports from a navigational safety perspective and then identify, at the local level, port-specific risk factors and examine current and available navigation safety activities that offset these risks. We intend to identify the best logical mix of risk mitigation measures, including measures such as traditional aids to navigation, traffic separation schemes, vessel traffic services, and pilotage requirements.

There is an old saying that, if the only tool in your toolbox is a hammer, then every problem looks like a nail. We want to make sure that we have a well-stocked toolbox that allows us to choose the right tools for the job at hand. I would say that, after *Exxon Valdez*, that hammer was a Vessel Traffic Service 2000 system. So, everybody had to have one. When it came to paying for that and looking at it, we determined that maybe we couldn't afford it. That has been reracked and now we are going to have a toolbox of things we look at; the ports and waterways safety system will be one of those.

Ultimately, our assessment efforts will concentrate on waterway safety improvements in those areas with the greatest need. These improvements will include a system based on voiceless transponder technology known as the automatic identification system (AIS). AIS consists of transponders and displays carried on board vessels, which provide information such as the name, position, course, and speed to all equipped vessels. AIS will significantly expand the information available to mariners in a more timely manner and it will eliminate some of the distractions associated with excess VHS voice radio traffic, although I don't think that will probably change down in the Gulf of Mexico because they really like to talk on the phone down there.

It is perhaps worth mentioning that the purpose of this is to provide better information to the people onboard ship so they can make better, informed decisions. They are the people who really need to make those choices. No one else can do that from outside.

Let me close with this. We've talked about risk management and we've talked about the principle that all of you know; many of you know more about it than those of us in the Coast Guard. We've sent people to school on this. We have some of your students who are part of the Coast Guard and looking into it. We need to take this capability and these approaches to the step where they become practical, decision-making tools in all our decision makers' pockets. Simply from the captain of the port perspective for the Coast Guard, we have one that Jack Harrell put together for us, which is helping somewhat. But it needs to be reinforced. We in the Coast Guard intend to spend some money sending people to school to learn more about this. We intend to integrate it not only into our external operations but into our internal operations as well.

Karlene Roberts had a good perspective when she talked about looking at a situation and figuring out what is done right and improve upon that instead of focusing on what is being done wrong. My Coast Guard experience tells me you can learn a lot more from something that went right than you can from something that went wrong, because when you do an operation right, there will still be lots of things you can learn from that and the defensiveness barriers as well as the legal barriers are brought down. So that is something that is worthy of your consideration.

The second thing I want to say is that leadership is key. Leadership is crucial. Gus brought that up as well. What do leaders do? They do the right thing. What is that? It is hard to know sometimes, but you have to tackle the tough problems, those intractable problems that no one else seems to be able to solve, and in the marine industry there are lots of those, ones that we don't go there because we can't do that because of whatever it may be. We stay away from that. But leaders can't do that. Leaders have to go where those things are and be willing to stand up to the popular but the wrong answer if that is the case. Leaders need to be committed, which means they have to double their efforts. We recently wrote a book that says, why don't things work, why do things fail? One reason is really lack of communication by a factor of 10—no, by a factor of 100—no, by a factor of 1,000. That level of communication is very important. If you are going to step up the leadership, you have to step up to that requirement for communication.

I said it before and I'll say it again—commitment. You can't let it go. You have to keep after it. If you believe something is the right thing to do, then you have to keep going on with that.

While I agree that our process must be objective and nonpolitical, the world does not always operate that way. The best assurance of a rational process is to ensure that we are wisely addressing the risk and preventing bad things from happening, including all the stakeholders being involved in this solution process. Government and industry, public and private, including, as the gentleman from EPA said, the environmental concerns, because they are real and they won't go away. Success then depends on the trust of all involved as well as the best analysis and applications. Building that trust, again, while it may not be in the equations you have in risk management, is also very important because without that, the solutions are different. You might have the right answer, but if you can't convince the people it is the right answer, if you don't have trust in the process, then it won't work.

Case Studies

Practical Application of Risk Analysis in Development of Harbor Safety Plans

Prince William Sound Risk Assessment: System Risk Analysis by Simulation and Expert Judgment

Oceans Risk and Criteria Analysis

Practical Application of Risk Analysis in Development of Harbor Safety Plans

Suzanne M. Rogalin, *Office of Oil Spill Prevention and Response, California Department of Fish and Game*

I am going to discuss an example of how people have applied concepts of risk in the real world—a practical, nonscientific application of risk management by California Harbor Safety Committees in the development of harbor safety plans. For those of you who are not familiar with Harbor Safety Committees, and I suspect there are fewer and fewer of you, I will provide a little background. Then I will present a brief overview of the risk analysis process we used, describe two very different examples of issues to which we applied the process, and conclude with an evaluation of the effectiveness of the process.

In California in 1990 the Lempert, Keene, Seastrand Oil Spill Prevention and Response Act, the Act for short, required formation of Harbor Safety Committees for the five major harbors in the state. These local committees were to include representatives of the ports, tanker operators, pilots, dry cargo vessel operators, commercial fishing or recreational boaters, labor, tug or barge operators, environmental organizations, and the California Coastal Commission, or, in the case of San Francisco, the San Francisco Bay Conservation and Development Commission. In addition, nonvoting representatives of the U.S. Coast Guard, the U.S. Army Corps, and the U.S. Navy were invited to participate. This is a representative cross section of the port community. The entity charged with establishing these committees and keeping them running was the Office of Spill Prevention and Response (OSPR).

The five committees, in Humboldt Bay, San Francisco, Port Hueneme, Los Angeles/Long Beach, and San Diego, were responsible under the Act "for planning for the safe navigation and operation of . . . vessels within each harbor" and for preparing "a harbor safety plan encompassing all vessel traffic within the harbor."

Although the mandate of the five committees was the same, the differences between the harbors were vast. Vessels entering San Francisco Bay may travel 43 mi (69.2 km) upriver to the Port of Sacramento. By contrast, it's about 4,300 ft (1311 m) from the entrance to Port Hueneme to the back of the harbor. The petroleum traffic varies from a few barges a year in one port to over 700 tankers per year in another. Some have world class vessel traffic systems, and others have none. Winds, wave heights, currents, visibility—all vary greatly from one harbor to another. And, as I know from having served on the Humboldt, Port Hueneme, Los Angeles/Long Beach, and San Diego Committees, the cultures of the committees varied as well.

Despite these differences, the process used to develop harbor safety plans was basically the same for all five harbors.

Committees were required by the Act and its implementing regulations to examine specific issues and propose pertinent recommendations in the harbor safety plans. For instance, committees were to determine when tankers must have tug escorts of sufficient size, horsepower, and pull capability when entering, leaving, or navigating in the harbor. Other issues to be addressed included anchorage designations, communication systems, navigational aids, traffic routing during construction and dredging projects and emergencies, channel design, sounding checks, conflicts with small vessels, and whether to establish or expand a vessel traffic system within the harbor.

All these issues were first to be examined in terms of the current environmental and operational conditions in the harbors and not just in some idealized, hypothetical context. For instance, what were the present channel depths, navigational aids, anchorages, and contingency routing plans? What were the types of vessels and cargoes, the weather, tidal ranges, and geographic boundaries? Also required was a 3-year history of accidents and near accidents. The list ends with "any additional issues that could impact safe navigation." And that was all just a summary.

This checklist in the Act amounted to a de facto risk inventory, and our informal application of risk review included a modified "what-if" analysis. None of us thought at the time that we were doing a risk analysis. Indeed, a pilot recently told me that the term risk analysis was scary and that the pilots had never done a formal risk analysis before. After thinking about it, however, he decided that pilots do informal risk analyses every day.

Using this checklist from the Act, we began to work together to develop our first harbor safety plan. Basically, we used the expertise of committee members for brainstorming. And as you might deduce from the list of representatives, that expertise spanned a wide range. Slowly, one of the most important aspects of the process began to develop: the building of trust between representatives of industry and government. From the viewpoint of several industry representatives, trust was essential so that members of industry could speak honestly of problems without fearing that government would, in their eyes, "overreact." As they put it, they were able to describe the problem without having a new regulation come down the next week. They came to believe that they could use the committee as a forum for developing workable regulation packages.

The trust that developed between environmentalists and industry representatives was also essential, because, although environmentalists cannot throw new regulations at industry, they do have a good deal of influence in the arena of public opinion. Speaking for the four Harbor Safety Committees on which I served, the trust that developed among representatives of government, industry, and the environmental movement allowed them to constructively work cooperatively on even highly charged, politically sensitive safety problems. A critical element in the building of this trust was the continuity of the committees. Members were appointed for 3-year terms and many were reappointed.

We used the expertise of committee members from the maritime industry with the added benefit of the perspective of those outside the industry. I am overgeneralizing, but industry came to the table with the attitude that "we've been doing it this way for years and haven't had an accident yet." The nonindustry members, on the other hand, came to the table with memorable past events in mind for ports with a history of disasters: Halifax Harbor, 1917, two ships collide, 1,600 dead, 6,000 injured; Texas City, 1947, two ships collide, 500 dead; Los Angeles Harbor, 1976, a ship explodes, 10 dead and about 100 injured. Although such disasters are by no means commonplace, just as oil spills the size of the *Exxon Valdez* are hardly commonplace, they are all memorable enough to color the public's perception. In discussing these different frames of reference with industry representatives, I was gratified to hear that at least some of them grew to value the exchanges that took place among committee members. These industry representatives considered the committee a "good forum for discussion which made everyone step back and look at what their interests and biases were." An example one member gave was the establishment of a formal Vessel Traffic Service in Los Angeles/Long Beach. During initial discussions within the Harbor Safety Committee, dating back to 1991, many in industry did not see the need for mandatory vessel traffic services, but the Coast Guard, OSPR, and many ship masters favored development of such a system. Through the ensuing discussions among various parties, though, industry came to recognize the value of the Vessel Traffic Information System to facilitate communication in the port complex and supported its installation, which occurred in 1994.

I'll now describe two very different issues that two of the committees addressed. The first is a relatively simple success story, and the other is the most complex issue with which we dealt.

For years, many San Francisco pilots and ship masters entering the Bay felt uneasy coming under the Golden Gate Bridge in conditions of poor visibility. Such conditions were not infrequent, because San Francisco Bay typically has 1,500 h of fog annually, and visibility is often less than 500 ft (152 m). The collision of two tankers in heavy fog in the Golden Gate in 1972, which caused massive environmental damage, certainly added to this concern. When the first racon was installed in San Francisco Bay on the sea buoy by the pilot station, the pilots saw its value and wanted one installed on the bridge. As you may recall, two of the items on our lengthy checklist of issues to review were bridges and aids to navigation. Shortly after the San Francisco Harbor Safety Committee was formed, the problem was discussed by the committee. A member described it as an issue looking for a venue. In the ensuing discussions, some expressed the "haven't had a problem yet" approach. Others used the example of a San Francisco pilot who was coming from upriver and approaching the Richmond-San Rafael Bridge, which had a racon installed. He had a strong current behind him when a large sudden squall caused the bridge to be obscured by rain on his radar return. The only way to determine the bridge opening while making the critical approach was with the racon signal. In contrast, in

Tampa Bay when a sudden squall obscured a vessel's radar return of the Skyway Bridge, which was without a racon, the ship hit the bridge and killed over 30 people. Ultimately, the San Francisco Committee agreed that a racon placed on the Golden Gate Bridge would reduce the risk of collision under conditions of reduced visibility. The recommendation was forwarded to the Golden Gate Bridge District.

Here, once again, the diversity of the Harbor Safety Committees was valuable. A nonindustry member was active in local politics, acquainted with members of the Bridge District, and familiar with its procedures and politics. This person shepherded the proposal through the various subcommittees for over a year, and the racon was eventually approved and installed. Since that time, racons have been installed on other bridges throughout the state at the request of local Harbor Safety Committees.

In contrast to this simple, apple-pie issue is my other example: Harbor Safety Committees' development of tug escort recommendations. This represents the single instance when Harbor Safety Committees hired an outside consultant to perform a formal risk study. Even in this case, however, the value of the consultant's study depended on the practical, real-world expertise of the committee members, whose input determined the assumptions on which the consultant's model was based.

The Act mandated that development of tug escort regulations was of the highest priority, especially for San Francisco Bay. The San Francisco Committee quickly adopted interim regulations and about 1 year later submitted suggested permanent regulations to OSPR. These recommendations were rejected because the guidelines developed to match tugs to tankers lacked a scientific rationale.

Glosten Associates, the consultant then contracted to provide technical data on the issue, at first adopted a dual-failure standard—in other words, simultaneous loss of both propulsion and steering—as the basis for measuring the amount of tug power needed to safely stop a tanker within the available reach. Industry reacted strongly against the dual-failure assumption. They contended that such a scenario was so unlikely as to be unreasonable, that the force required to be brought to bear was so great that it created other problems, and that there was not a pattern of dual failures in other risk areas.

The Tug Escort Subcommittee, after reviewing failure probability, requested that Glosten calculate demands based on single failure, which the second Glosten study did. The study was based not only on computer modeling but also on full-scale trials. After many meetings, much discussion, and two Glosten studies, the San Francisco Harbor Safety Committee voted 12 to 1 to adopt a single-failure standard for development of matching criteria. The dissenting vote was by the representative of an environmental organization, who contended that, although dual failures were rare, the consequences could be so catastrophic that it was prudent to base the criteria on that eventuality. OSPR promulgated permanent tug escort regulations for San Francisco Bay based on the committee's recommendations and using the single-failure standard.

The Los Angeles/Long Beach Committee had early on called for tug escort/assist inside the breakwater. As we began to look at marine casualties in the harbor area, we saw that 1 in 100 commercial vessels, or one per week, sustained some type of steering or propulsion failure during the inbound or outbound transit. I might add, this is a good example of the value of collecting and analyzing incident or near-miss data.

The committee decided that this mechanical failure rate, combined with the decreasing amount of navigable waters inside the breakwater because of fill projects, was a risk to tankers transiting the relatively narrow breakwater entrances. We decided the risk justified requiring tug escorts outside the breakwaters, which had not been considered before. Implementation of the scheme was delayed, however, until the second Glosten study was completed in San Francisco, because we believed that the study might provide helpful technical insights.

The subcommittee developed a tug escort scenario of stopping a tank vessel within 3,000 ft (914 m). After extensive technical analysis and debate, the subcommittee determined that the Glosten single-failure study was transferable to the conditions in the approaches to Los Angeles/Long Beach Harbor. Glosten was hired to validate this conclusion and determined that the results were not transferable. As part of this third report, Glosten provided examples of braking forces needed to stop a tank vessel within 3,000 ft. These braking forces were extremely high and were neither practical nor workable in Los Angeles/Long Beach Harbor. It would have taken a significant portion of the harbor complex's entire tug fleet to escort a single tank vessel. Furthermore, the number of tugs that would be needed to provide the required braking force could not simultaneously be applied to a tank vessel. A new scenario was needed.

Before Glosten could proceed further with the third report, it was necessary for the Harbor Safety Committee to develop some basic assumptions. What goes into a model determines what comes out, and the Tug Escort Subcommittee worked long and hard to come up with a set of assumptions about tanker speeds, tug capabilities, currents, and transfer and reach distances. Again, according to both industry and government representatives, the key was the ability to see the issue through someone else's eyes. The Los Angeles/Long Beach Tug Escort Subcommittee decisions were always consensus based, which was not always easily attained.

In the previous studies, the goal was assumed to be the ability to apply enough force to stop a disabled tanker, and Glosten did not specifically address turning forces.

Los Angeles/Long Beach Subcommittee members determined that, based on the geography of the Los Angeles/Long Beach Harbor and the location of the federal breakwater, it might be a safer option in many cases to try to turn a disabled ship outside the breakwater instead of trying to stop it. If the vessel was within 3,000 ft of the breakwater, then the recommended procedure would be to guide it through the entrance as there was adequate reach inside to stop the tanker before it reached the dock. We proposed that Los Angeles/Long Beach require tugs to have adequate braking capability to meet an inbound speed-restricted tanker far enough outside the breakwater to either halt the tanker before it grounded on the breakwater or help steer it through an opening if it failed closer to the breakwater.

The third Glosten study provided a force matrix for both turning and stopping, and the committee recommended that state regulations be amended to incorporate tug-to-tanker matching requirements as specified in that matrix. These regulations are now in force. An interesting footnote is that the Los Angeles/Long Beach criteria could cover a dual as well as a single failure, even though that was not the intention.

Now for a quick evaluation of the effectiveness of the process as a risk analysis mechanism, albeit from a prejudiced source.

The process was successful in that it resulted in plans that were accepted and implemented. In addition, there is an ongoing forum in which emerging safety issues can be addressed. Unlike some formal risk analysis documents that just sit on a shelf, the Harbor Safety Plans positively affect the day-to-day safety operations of the ports. Some plans are even on the Internet.

The diversity of the group contributed to the success of the process in several ways. The wide-ranging experiences and expertise of those on the committee were critical in identifying problems and developing solutions. Through the process, members developed a more holistic view of the port operations and gained an appreciation for the complexities of the workings of the port. For instance, recreational boaters, through working with pilots on the committee, came to realize that it was often impossible to see small boats from the pilothouse of large vessels. Both groups believe the resulting improvements in communication are responsible for a decrease in the number of small recreational boats interfering with large vessels in shipping channels.

By bringing these diverse parties to the table in a proactive way, we solved problems that otherwise would have had these groups meeting on opposite sides of the barricades by the time the issue became public. A pilot stated that input from outside of industry was good because, without it, industry could not always see the forest for the trees.

The committee was a forum for discussion of what risks we were willing to tolerate. The risks we were looking at were not only to commerce but also to the environment and to public safety. Because industry was not the only party at the table, decisions were not determined solely by cost-benefit analysis.

When we had to call the outside scientific experts, we did, but one cannot do an entire Harbor Safety Plan in that manner. Individual committee members thought that decisions that were taken regarding risk-benefit analysis and risk assessment were based on their input and therefore reflected their particular concerns. This is not to say that Harbor Safety Committees are a panacea for port safety problems. The diverseness of the group certainly led to occasions when the conflicting interests could not be reconciled. Those occasions, however, were amazingly few and far between. It was a practical, reality-based process that, within the constraints posed by time and money, was a very effective way of improving harbor safety.

Prince William Sound Risk Assessment
System Risk Analysis by Simulation and Expert Judgment

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Martha Grabowski, *Rensselaer Polytechnic Institute*

The use of dynamic simulation as a risk modeling tool was a unique aspect of the Prince William Sound (PWS) risk assessment. The simulation technique enhanced the estimation of risk due to situational interactions (such as adverse weather, traffic) and allowed the systemwide impact of dynamic interventions such as closure restrictions and escort requirements to be measured. The PWS risk assessment project was a joint project of Det Norske Veritas, Rensselaer Polytechnic Institute, and The George Washington University (GWU). The project was directed by a steering committee composed of the PWS shipping companies (ARCO, Sea River, British Petroleum, Chevron, and Tesoro), the PWS Regional Citizens Advisory Committee, the Alaska Department of Environmental Conservation (ADEC), and the U.S. Coast Guard (USCG). The involvement of all TAPS shippers, the Regional Citizens Advisory Council, Alyeska, the Coast Guard, and the ADEC in management of the project provided the study team with unique access to individuals and information and ensured that all viewpoints were considered in the analysis.

The risk of an accident is defined as the product of the probability of occurrence of the accident and the consequences of that accident. An accident is an event that has adverse consequences (injury, loss of life, economic loss, environmental damage). Seven accident types were considered in the PWS risk assessment: collision, powered grounding, drift grounding, foundering, structural failure, allision (i.e., a ship running into a stationary ship), and fire or explosion. An incident is an error such as a wrong course change or a failure such as a loss of propulsion that creates an unsafe condition that may result in an accident. The USCG uses the term vessel casualty to describe both incidents and accidents. The PWS risk assessment differentiates between triggering events (incidents) and events with direct adverse consequences (accidents).

The study scope addressed the risks of marine oil transportation from the Valdez Marine Terminal to 20 mi (32.2 km) outside of Hinchinbrook Entrance. It examined causal and contributory factors such as marine traffic, weather, external environmental variables, human error, and mechanical failure. The study included technical and operational aspects of the tanker fleet, regulatory requirements, and operating company management. Excluded from the scope of the study were events that could occur within the terminal itself or events that could be caused by certain extremely low probability natural phenomena (lightning strike, earthquake). The project approach integrated a system-oriented simulation-based methodology with more traditional statistical and event-oriented probabilistic methods. Historical data analysis and structured expert judgment were used to support each element of the modeling process.

Risk Assessment Framework

The first objective of the risk assessment was to quantify the probability of the following accident types:

- Collisions: colliding or striking of two under way vessels because of human error or mechanical failure and lack of vigilance (intership collision) or the striking of a floating object by an under way vessel (ice collision);

- Drift grounding: contact with the shore or bottom by a drifting vessel not under control because of a propulsion or steering failure;
- Powered groundings: contact with the shore or bottom by an under way vessel under power because of navigational error or steering failure and lack of vigilance;
- Foundering: sinking of a tanker because of water ingress or loss of stability;
- Fire or explosion: occurrence of a fire in the machinery, hotel, navigational, or cargo space of a tanker or an explosion in the machinery or cargo spaces; and
- Structural failure: failure due to hull or frame cracking or erosion and serious enough to affect the structural integrity of the vessel.

The second objective was to identify, evaluate, and rank proposed risk reduction measures; thus, a single statistical estimate of the current probability of an accident was not sufficient. A comprehensive probabilistic model was developed that allowed such risk interventions to be evaluated. The model had to incorporate the effect of the major contributors to risk.

The probability of an accident depends on the organizational and vessel attributes of a tanker and the situational or waterway attributes that describe its environment. Vessel characteristics, such as size, age, material and hull type, and crew characteristics, such as years of service, training and bridge team stability, were considered, whereas situational factors included location and type of nearby vessels, wind speed and direction, visibility, and ice.

Accidents involving oil tankers are rare events. However, low-probability, high-consequence events lead to difficulties in the risk assessment process. Because such accidents occur infrequently, large accident databases are not available for a standard statistical analysis of the causal effect of each risk factor. Garrick (1984) notes that an accident is the culmination of a series of events and not a single event. Figure 1 shows the causal chain for the occurrence of a maritime accident.

The assessment framework differentiates between the triggering events (incident) and causal events (either basic or immediate causes). Triggering events were separated into mechanical failures (called vessel reliability failures) and human errors (called vessel operational errors). The mechanical failures considered to be triggering events were propulsion failures, steering failures, electrical power failures, and hull failures. The concept of classifying human errors is more complex. Harrald et al. (1998) discuss the full treatment of human error in the PWS risk assessment. The basic classifications of human errors used were diminished ability; hazardous shipboard environment; lack of knowledge, skills, or experience; poor management practices; and faulty perceptions or understanding.

As mentioned previously, the probability of an accident involving a particular vessel depends on vessel attributes and waterway attributes that describe its situation. A set of vessel and waterway attributes defines an opportunity for incident (OFI). The accident model used was based on the notion of conditional probability. The levels of conditional probability in the accident model were as follows:

- *P*(OFI): the probability that a particular set of vessel and waterway attributes occur in the system,
- *P*(incident/OFI): the probability that a triggering incident occurs given the opportunity, and
- *P*(accident/incident, waterway): the probability that an accident occurs given that a triggering incident has occurred.

Figure 2 shows how this approach is applied to drift grounding accidents caused by propulsion failures. First, a tanker, with given vessel attributes, is in the system for 5 min. There is a certain probability that the tanker will

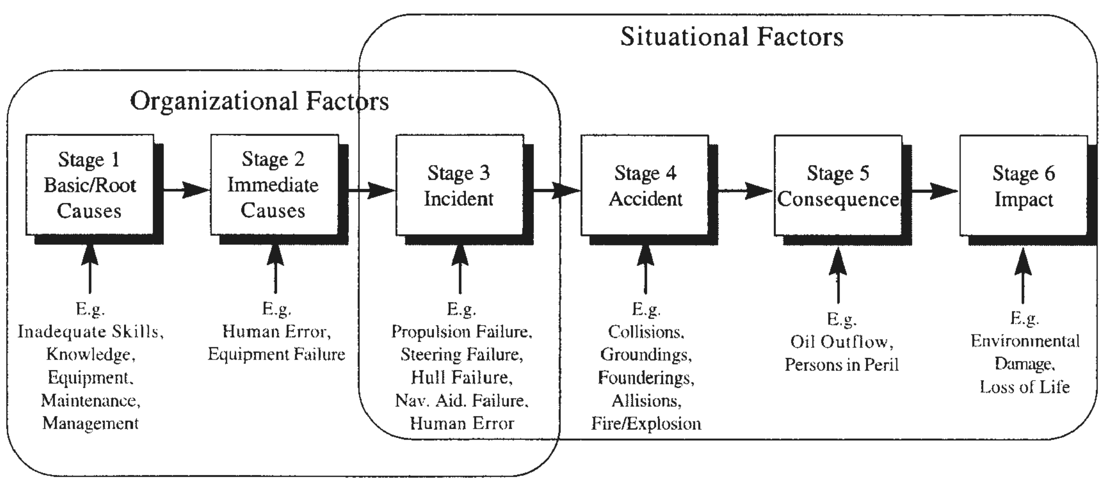


FIGURE 1 Accident event chain.

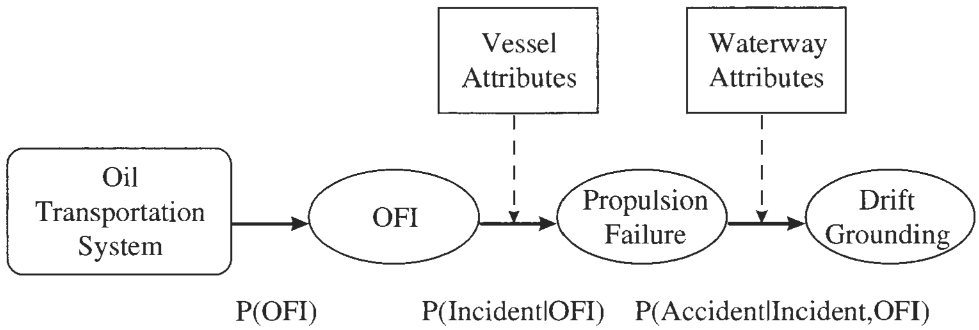


FIGURE 2 Accident probability model for drift grounding accident.

experience a propulsion failure. Once the propulsion failure has occurred, there is a certain probability that the tanker cannot be saved and cannot perform a self-repair and so it runs aground. This probability depends, for example, on the waterway attributes of the OFI, wind speed, and current.

The probability of an accident can be found by summing the product of the conditional probabilities over all types of accidents and triggering incidents and all combinations of vessel and waterway attributes. Thus, to perform an assessment of the risk of an accident with this model, one must estimate each of the terms in the probability model.

Dynamic Nature of Risk in an Oil Transportation System

The system risk simulation approach relies on the premise that risk is a dynamic property of the system. Harrald et al. (1992) discussed the need for dynamic modeling in the assessment of risk in the maritime area. The system risk at any given time is the risk of all vessels in the system. As vessels pass through the system, the waterway and organizational characteristics of the vessels (the OFIs) in the system change with time and thus the risk changes.

To calculate the system risk, one must first estimate the frequency of occurrence of each combination of waterway and vessel characteristics. Although data are collected on vessel arrivals and environmental conditions, combinations of these events are not. Use of a discrete-event simulation of the system captures the complex dynamic nature of the system and accurately models the interactions between the vessel and waterway attributes. The first step in creating a realistic simulation of the PWS oil transportation system was to collect data on the traffic movement and weather conditions. The simulation was used as an event counter. The simulation sampled traffic arrivals once every 5 min of simulation time, and the weather was sampled once an hour. The state of the system in the simulation was calculated once every 5 min based on traffic arrivals, the weather, and the previous state of the system. The simulation was run for 25 years of simulation time.

Need for Expert Judgment in Maritime Risk Assessment

The next step in risk estimation was to estimate the two levels of conditional probability of triggering incidents and accidents. These are the conditional probability of a triggering incident occurring given that a set of vessel attributes has occurred and the conditional probability of an accident given that a triggering incident has occurred, with a defined set of waterway attributes. The preferred method for estimating these probabilities is with data. In the PWS risk assessment, there were insufficient data to estimate the probabilities as the number of explanatory variables that described each vessel were required to be reasonably large.

Cooke (1991) cited the use of expert judgment in areas as diverse as aerospace programs, military intelligence, nuclear engineering, evaluation of seismic risk, weather forecasting, economic and business forecasting, and policy analysis. The need for expert judgment in performing risk analysis was discussed by Paté-Cornell (1996), whereas Harrald et al. (1992) proposed the use of expert judgment in the analysis of risk in ports and waterways.

Expert judgment was used in the PWS risk assessment to assess the relative probabilities of incidents for different sets of vessel attributes and the relative probabilities of accidents for different sets of waterway attributes, whereas data were used to calibrate these relative probabilities. This approach relies on the premise that the judgments of the experts who have a deep understanding of the system provide a more accurate basis for calculating risk than do the sparse, and possibly unreliable, data. It must be noted, however, that all available, reliable data were used to estimate the conditional probabilities. Figure 3 shows the format of one of the primary questionnaires, and two similar scenarios are described.

In each situation there is an inbound tanker, greater than 150,000 deadweight tons (DWT) in size, that has just experienced a propulsion failure. It is within 2 to 10 mi (3.2 to 16 km) of a tug with tow in winds over 45 mph (72 km/h) blowing on shore to the closest shore point, with visibility greater than half a mile (0.8 km) in the central PWS. The only difference between the two situations is that the situation on the left includes an iceberg, and that on the right has no iceberg. The expert is asked to determine which is more likely to result in a collision. In each question, to enable the experts to estimate the difference in relative risk between the two situations, only one attribute is changed. The experts found these questions possible to answer and could answer a book of 120 questions in a 1- to 1.5-h session. To minimize response bias, the questions in the books were asked in random order. The parameters of the probability model were estimated by statistical regression.

Results of Risk Assessment

The first objective of the risk assessment was to identify and evaluate the risks of oil transportation in PWS. An accident scenario was defined to be an accident type in a given location. Before the risk assessment, there was a common belief that the most likely accident scenario was a drift or powered grounding in the Valdez Narrows or Hinchinbrook Entrance. Figure 4 presents a ranking of the expected frequency of the accident scenarios as a percentage of the total expected number of accidents.

Figure 4 indicates that the first seven accident scenarios account for 80 percent of the total expected number of accidents, with 60 percent coming from collisions in the port, Valdez Narrows, and Valdez Arm locations. A further analysis was performed to find the primary cause of the accidents. It was found that the primary risk was collisions with fishing vessels, which operate in large numbers in these locations. Although this introduces a relatively high risk of a collision, very few of the fishing vessels are large enough to penetrate the hull of a tanker. Thus, the expected oil outflow from these events was relatively low. The perceived high-risk scenarios of drift or powered groundings contributed about 15 percent of the expected frequency of accidents.

The risk models also estimated the expected volume of oil outflow as a measure of risk. A surprising result was discovered with this metric. Collisions with Sentinel Emergency Response Vessels (SERV) tugs were a large contributor to the total expected oil outflow. The tugs are intended to save disabled tankers, but they introduce a risk of collision and can cause enough damage to tankers to spill oil. It was found that the frequency of interactions with tugs returning from an assignment led to this high risk. Less surprising, however, was confirmation of the risk of drift or powered groundings in the Valdez Narrows or Hinchinbrook Entrance.

The second objective of the risk assessment was to identify, evaluate, and rank proposed risk reduction measures. Extensive modeling was required, but, because of the level of granularity incorporated in the model, pa-

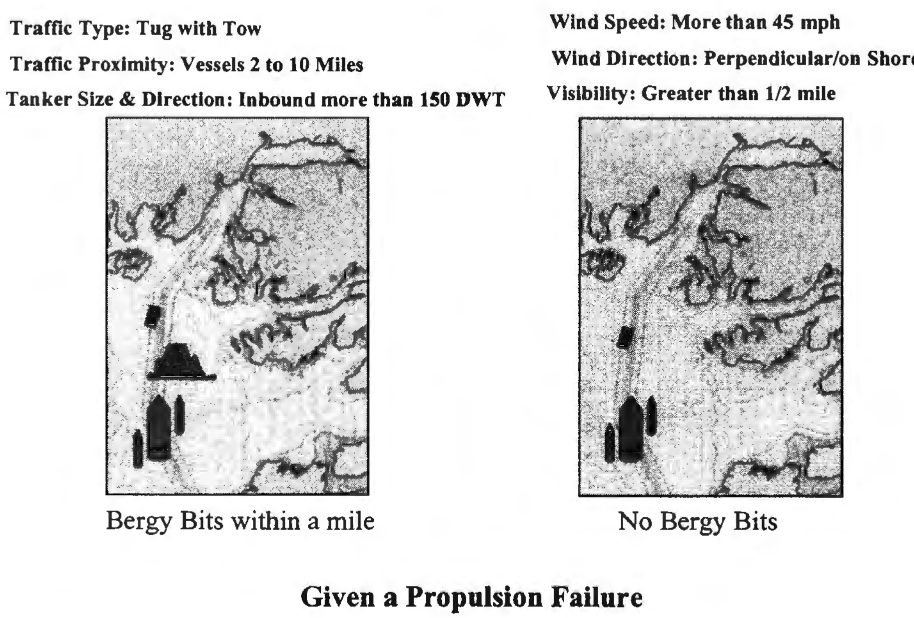


FIGURE 3 Example of a scenario pictured in the questionnaires.

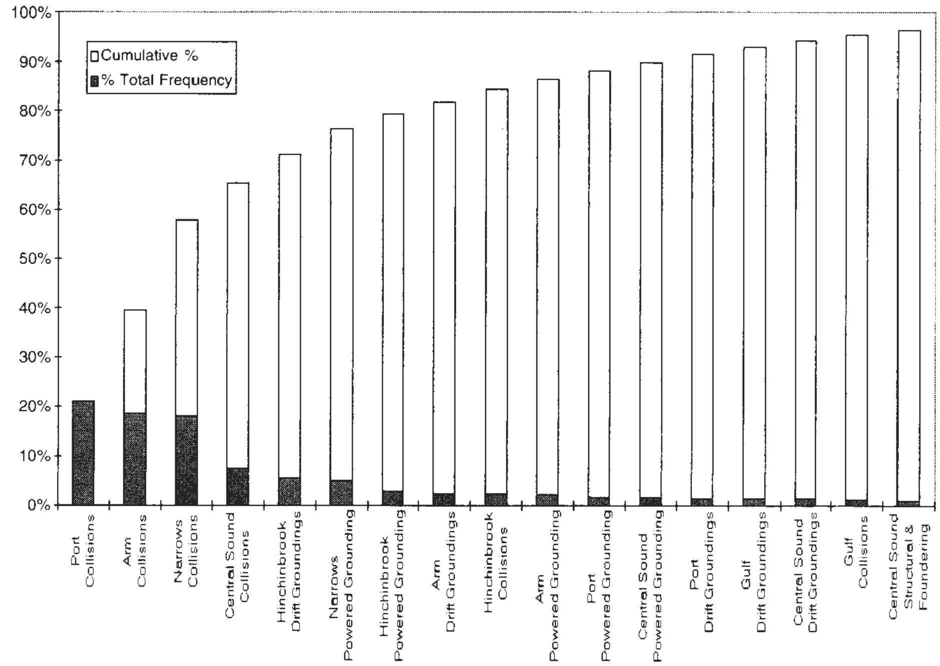


FIGURE 4 Ranking of accident scenarios by expected number of accidents.

rameters could be changed to reflect the effects of risk reduction measures. By stripping away previously implemented risk reduction measures, an estimate of the risk before the *Exxon Valdez* accident was calculated. When this was compared with the baseline case, representing the PWS system during the study period, the risk models indicated a 75 percent reduction in risk since the *Exxon Valdez* accident.

The analysis demonstrated that a major reduction in risk can be realized by modifying the escort scheme to reduce interactions with tankers and by managing the interactions of fishing vessels and tankers. The model also enabled estimation of the risk reduction resulting from improvement of human and organizational performance through the International Safety Management program.

Study Recommendations

At the conclusion of the study, the contract team delivered a final report to the steering committee. This report included technical documentation of the methodology used in the study, the results of the modeling performed, and a set of recommendations based on these results. After the risk assessment project, the steering committee separated into risk management teams charged with implementing the recommendations in specific areas of operation. To date, the risk management teams have taken the following actions:

- To avoid collisions with fishing vessels, the Coast Guard Vessel Traffic Service manages interactions between fishing vessels and tankers.
- To avoid collisions with SERVs, a further analysis was completed to find an improved escort scheme. This analysis is described below.
- To avoid drift groundings in Hinchinbrook Entrance, an enhanced capability tug called the Gulf Service is now used to escort oil-laden tankers through the entrance.
- On board the escort tugs, the required bridge crew has increased from one to two to add additional error capture capability.
- The shipping companies have made long-term plans for quality assurance and safety management programs.

Analysis of Alternative Escort Schemes

The PWS risk assessment determined that, under certain conditions, the escort vessels would not be able to "save" a disabled tanker at Hinchinbrook Entrance. An enhanced capability tug was stationed at Port Etches on Hinchinbrook Island to guard against this possibility. The presence of a tug at Hinchinbrook led to the question of whether an escort made up of one continuous escort, a second close escorting tug through the Valdez Narrow, Valdez Arm, and Hinchinbrook Entrance and standby escorts covering the transit through the central PWS would provide a more effective escorting scheme.

This escorting scheme is presented in Figure 5. The objectives of the analysis of this scheme performed by GWU were as follows:

- To verify that the proposed escort system was an improvement from the baseline, and
- To serve as a new baseline for future risk reduction measures assuming the implementation of the proposed escort scheme.

The analysis used to answer the following questions needed to verify the proposed escort scheme is described in detail in a 1999 Oil Spill Conference paper (Harrald et al., 1999):

- What is the effect on the expected number of drift groundings of having a single close escort and a standby escort through the central PWS for outbound laden tankers?
- What is the expected number of drift groundings for inbound tankers under the proposed escort scheme?
- What is the change in collisions from the revised base case provided by the proposed escort scheme?

The system simulation was used to determine the "save" effectiveness of the standby escorts. Thus, a drifting tanker simulation was used to count drift times for hundreds of drift scenarios. Figure 6 presents one such scenario. Two counts were kept in the simulation: the time until the standby escort reaches the drifting tanker and the time until the drifting tanker runs aground, assuming no assistance from the escorts.

Figure 7 presents the distribution of times sampled between the occurrence of the propulsion or steering failure and the standby escort reaching the disabled tanker.

The response times are almost always less than 1.5 h. In Figure 8, the distribution of times sampled between

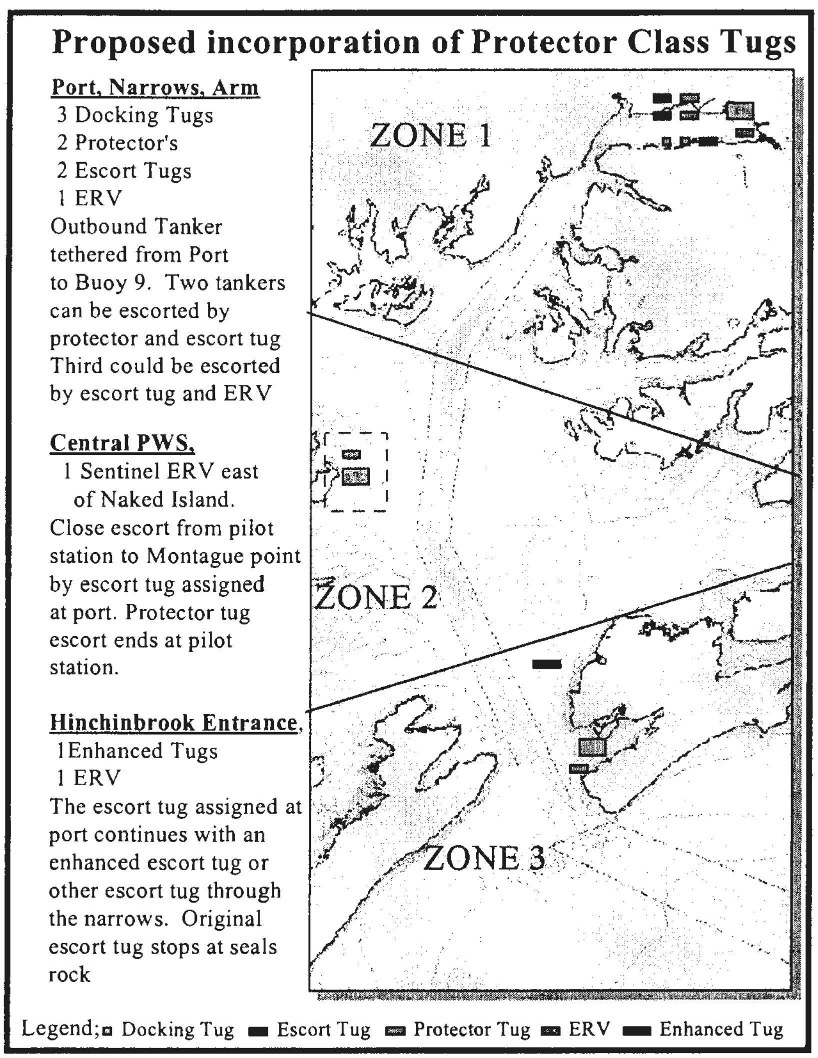


FIGURE 5 Proposed escort scheme (ERV = emergency response vessel).

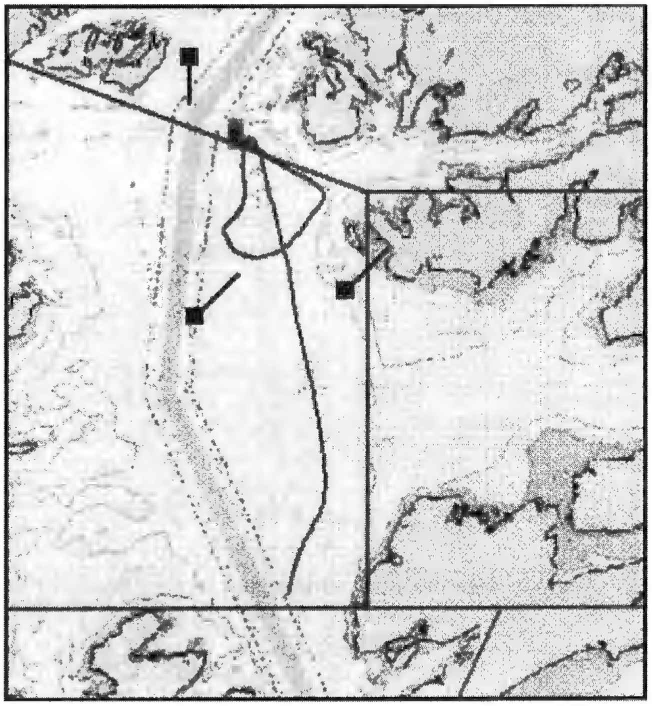


FIGURE 6 Long drift time scenario.

the occurrence of the propulsion or steering failure and the disabled tanker running aground (assuming that no assistance was given by the escorts) is presented; 15 percent of the drift times are >12 h and thus are not shown.

The time of interest is the difference between these two times; this represents the time that the standby escort has before the disabled tanker runs aground. This is the time available to assist the close escort in making a save. Even assuming that the tanker is not being slowed at all by the single close escort, the second escort will be with the drifting tanker for at least 1 h 96 percent of the time. In almost all situations sampled, the second escort will reach the disabled tanker with much longer than an hour to assist in the save.

To summarize the effect of the proposed escort scheme:

- The long-term average of the total number of accidents for outbound tankers is the same as the revised base case and may be better if the new escort vessels are shown to give better save capability; and
- The long-term average of the total number of accidents for inbound tankers is reduced by at least 18 percent.

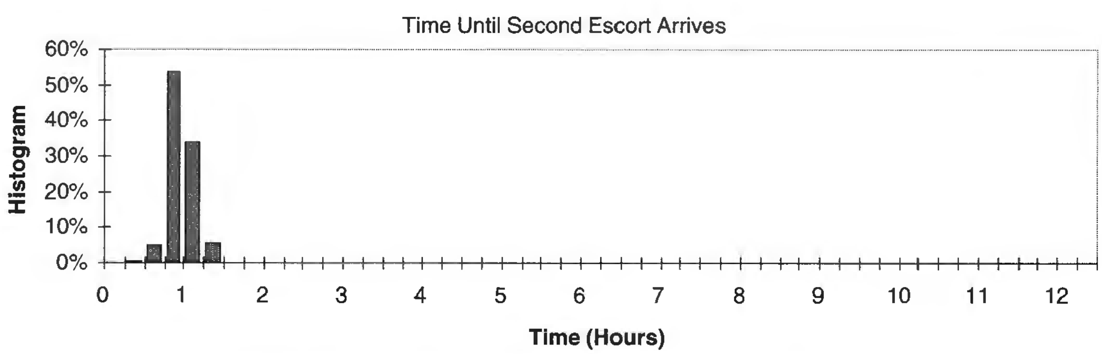


FIGURE 7 Distribution of times the standby escort took to reach the drifting tanker.

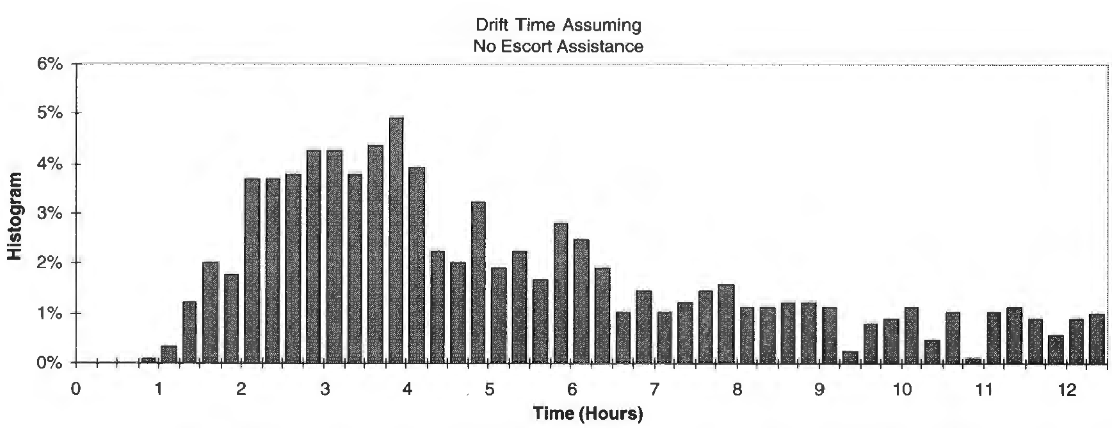


FIGURE 8 Distribution of times between the failure event and the tanker running aground (15 percent of the sampled drift times were >12 h).

The reduction will be significantly larger if simulations of inbound tanker drift paths can verify the degree of coverage given to inbound tankers in areas other than central PWS. The reduction justified thus far in the total number of accidents is 13 percent, and the reduction in the total oil outflow is 4 percent.

The recommendations of the basic study and the additional analysis have been implemented by the sponsor, enhancing the level of safety in PWS.

REFERENCES

Cooke, R. M. *Experts in Uncertainty: Expert Opinion and Subjective Probability in Science.* Oxford University Press, 1991.

Garrick, G. J. Recent Case Studies and Advancements in Probabilistic Risk Assessment. *Risk Analysis,* Vol. 4, No. 4, 1984, pp. 267–279.

Harrald, J. R., T. A. Mazzuchi, and S. M. Stone. Risky Business: Can We Believe Port Risk Assessments? Proceedings, Ports '92 Conference, 1992.

Harrald, J., T. Mazzuchi, J. Merrick, R. van Dorp, and J. Spahn. Using System Simulation to Model the Impact of Human Error in a Maritime System. *Safety Science,* Vol. 30, 1998, pp. 235–247.

Harrald, J. R, T. A. Mazzuchi, J. Merrick, and J. R. Van Dorp. The Analysis of Escort Requirements for Tank Vessels in Prince William Sound. Proceedings, International Oil Spill Conference, 1999.

Paté-Cornell, M. E. Uncertainties in Risk Analysis: Six Levels of Treatment. *Reliability Engineering and System Safety,* Vol. 54, 1996, pp. 95–111.

Opinions or assertions expressed in this paper are solely those of the authors and do not necessarily represent the views of individuals or organizations composing the PWS Risk Assessment Steering Committee or other members of the PWS Risk Assessment contract team.

Oceans Risk and Criteria Analysis

George E. Bushell, *Consulting and Audit Canada*

Given scarce resources and a continuing emphasis on a business approach, the Canadian Coast Guard (CCG) is striving to better allocate resources among waterways, programs, and users in order to achieve the best possible level of marine safety. In this regard, the CCG has used, and is continuing to use, risk analysis and risk management tools on a project and program basis. However, to better match resources to risk (both geographically and by program) the CCG still would like an estimate of overall marine risk by program and waterway.

Technically, such an estimate of risk would be given by the expected annual dollar losses by geographic area for all those hazards and associated impacts addressed by CCG programs (the annual dollar value of marine fatalities and injuries, environmental damages, clean-up effort, vessel damages and losses, cargo losses, fishery impacts, and so forth, given that no CCG services existed). Knowing the expected dollar losses by geographic area and hazard type, the CCG could then attempt to allocate available resources to each geographic area and program in a way that would optimize the reduction of these losses (i.e., maximize risk-reduction results).

Although the above risk-based approach is theoretically the method of choice, many practical problems exist. To derive a geographic distribution of expected dollar losses requires a multitude of activity, probability, and value estimates for vessels, cargoes, human life, birds, mammals, and so forth. Furthermore, the past and current risk-reduction effectiveness of every existing program is needed if residual or observed risk is to be blown up into total annual risk.

If applying values to life, birds, mammals, ecosystems, and so forth is too problematic, counting expected physical losses is the next desirable level of analysis. Even here, however, the analysis is time-consuming and not without controversy (e.g., each program's historical risk-reduction effectiveness still must be estimated in order to convert observed physical losses into total estimated losses). The CCG and Consulting and Audit Canada (CAC) have conducted a number of traditional risk-based analyses on a project and program basis in the past [e.g., the Confederation Bridge Risk Analysis, the Port of Hong Kong Risk Study, and various Vessel Traffic Services (VTS) Risk Studies across Canada]. However, these types of studies are relatively expensive and take considerable time to complete.

The next level of analysis involves creating an index from those factors or criteria that the marine community now uses, both explicitly and implicitly, to rank risk and to allocate resources across waterways and by program [the explicit form of this approach, called *Multi-Criteria Decision Analysis (MCDA)*, is commonly used to order complex requests for proposals, alternative policies, options, and strategies]. CAC created a display and risk index computer system with about 150 columns of risk-related data covering 100+ waterways/ports. The data were subdivided into four categories:

- Frequency (e.g., number of cargo vessel movements, number of ferry movements);
- Impact (e.g., metric tons of petroleum transported, number of passenger trips);
- Modifiers (e.g., visibility, windspeed); and
- History (e.g., vessel collisions, loss of life).

The computer system (called ORCA—Oceans Risk and Criteria Analysis) allows a user to automatically display data in bar chart, map, or scattergram format and to weigh and combine criteria data in a risk index. Data can be modified to conduct "what if" analyses. Study area risk index values for a given safety program can be compared with study area expenditures or other activity measures for the program and potential anomalies can be identified. However, detailed analysis of any apparent anomalies is necessary before any resources can be reallocated. Furthermore, a minimum level of waterway service may be required for some programs regardless of the measured level of a program risk index. Finally, it should be noted that considerable resources must be dedicated to ensuring that risk criteria data are kept up-to-date and that costs are properly allocated to programs and waterways.

Examples of ORCA displays are presented in Figures 1 through 6.

Demonstration Risk Index for VTS and Other Programs

Oil spills and the threat of oil spills were the major impetus for creation of Canadian VTS systems starting in the 1960s. Today, 12 high-level VTS centers are in operation covering 14 distinct zones [Vancouver, Tofino, Prince Rupert, Sarnia, Montreal, Quebec, Les Escoumins, Saint John (with remote coverage of Northumberland Strait), Halifax (with remote coverage of Canso), Placentia Bay, Port-aux-Basques, and St. John's]. The following VTS index was developed in an effort to reflect, as much as possible, the current distribution of VTS centers:

$$\text{VTS Index} = \Big\{0.9\times(D8\times 0.6+E8\times 0.1+F8\times 0.3)+0.1 \times\Big[(I8+J8)+(G8+H8+K8+L8+Q8)^{1/2} +(M8+N8+O8+P8+R8)^{1/3}\Big]\Big\}\times \text{if}\,\big[S8/2 + T8/2)<1,1,(S8/2+T8/2)^{1/2}\big]\times U8\times V8$$

where

D = metric tons of petroleum cargo arriving, departing, and transiting;

E = metric tons of chemical cargo arriving, departing, and transiting;

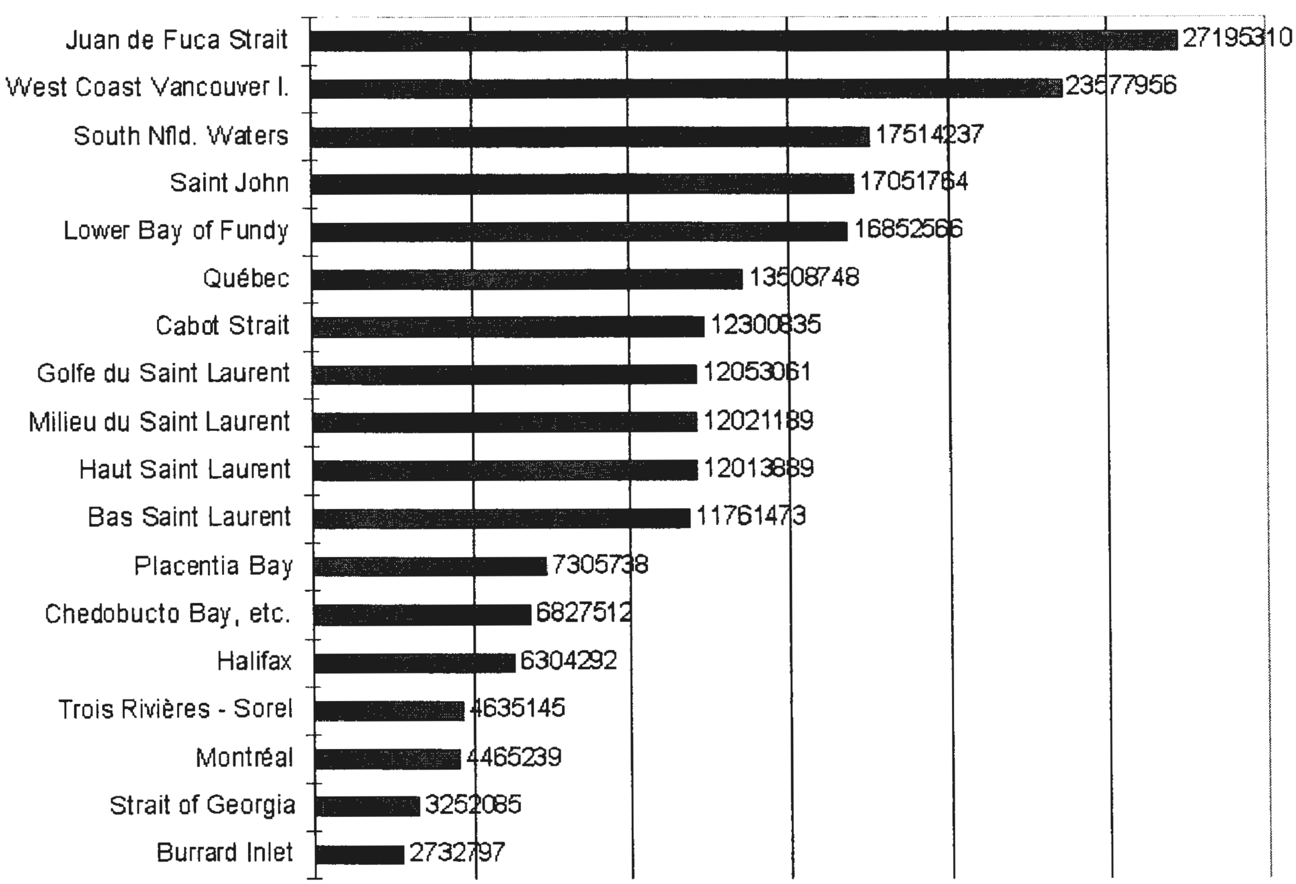


FIGURE 1 Metric tons of petroleum transported by vessel in 1996 (Source: Statistics Canada and U.S. Waterborne Commerce).

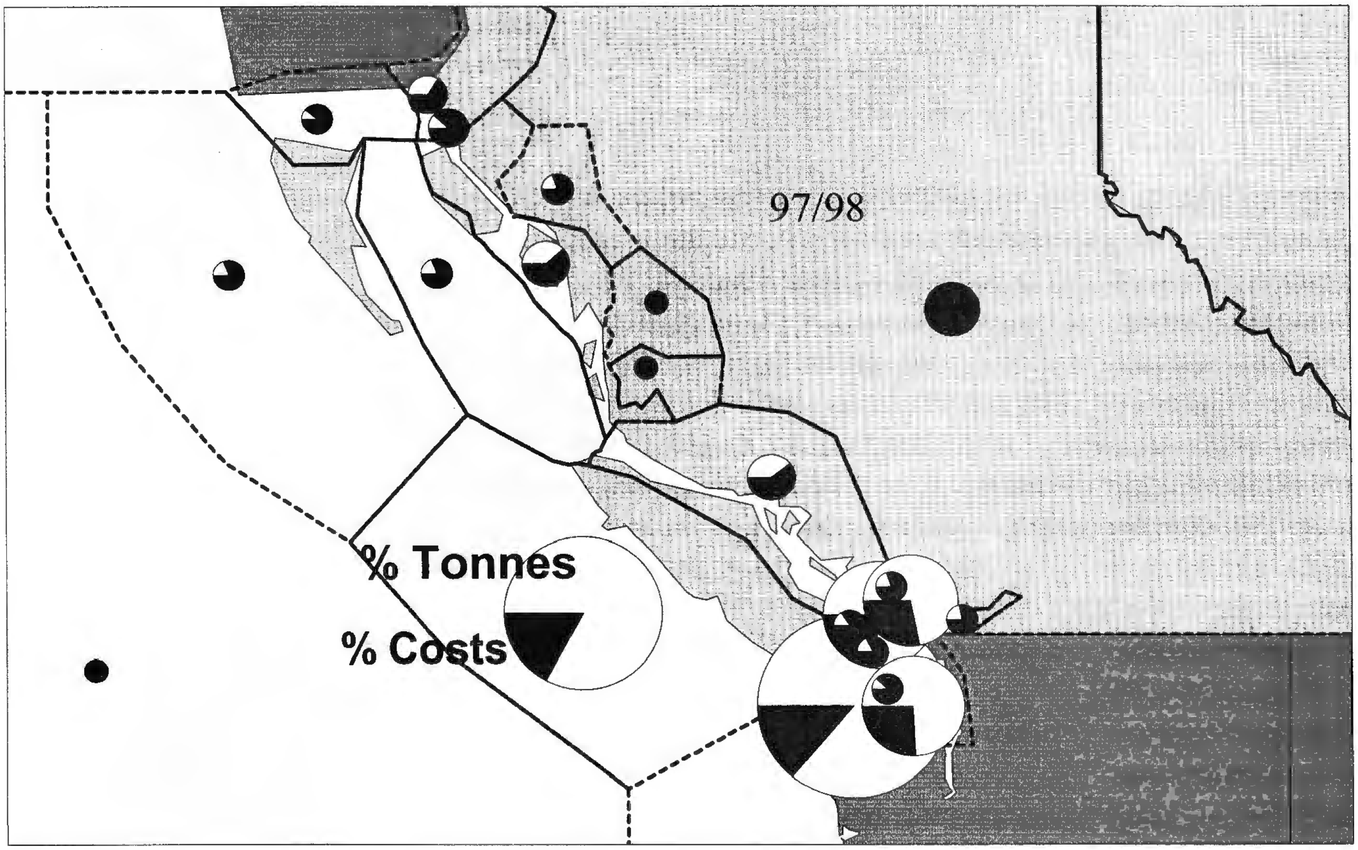


FIGURE 2 **Total polluting cargoes versus rescue safety and environmental response costs (example only).**

F = metric tons of onboard bunker fuel arriving, departing, and transiting;
G = crews arriving/departing on tugs and tows;
H = crews transiting on tugs and tows;
I = crews arriving/departing on tankers, lakers, and other cargo vessels;
J = crews transiting on tankers, lakers, and other cargo vessels;
K = crews arriving/departing on cruise and passenger vessels;
L = crews transiting on cruise and passenger vessels;
M = crews arriving/departing on large ferries;
N = crews transiting on large ferries;
O = crews arriving/departing on small ferries;
P = crews transiting on small ferries;
Q = passengers arriving/departing/transiting on cruise and passenger vessels;
R = passengers arriving/departing/transiting on all ferries;
S = percent of time in January visibility <0.5 nautical mile (NM);
T = percent of time in July visibility <0.5 NM;
U = waterway type measure; and
V = traffic pattern measure.

In keeping with the main risk-reduction goals of VTS, the index can be interpreted as follows:

- First, add the tonnage of petroleum cargoes, chemicals, and bunker fuels, weighted by 0.9 (a 90/10 split between polluting cargoes and people is assumed based on the apparent historical reasons for establishing VTS systems).
- Then, add the number of passengers and crew onboard, weighted by 0.1^2. Cargo vessel crews are added directly but the impact of crews and passengers on other vessel types is reduced to reflect the apparent historical consideration given these vessel types when considering the need for VTS (i.e., by taking the square root for tugs, cruise ships, and passenger vessels, and the cube root for ferries). These vessel types appear to have been considered less in need of VTS.
- Next, the above base VTS index is multiplied by
  - The square root of January and July mean visibility conditions minus percent of time visibility is less than 0.5 nautical mile [the square root is used to reduce the effects of very high measures relative to low values; mathematically, a measure of 36 percent is 36 times as large as a measure of 1 percent, but, in

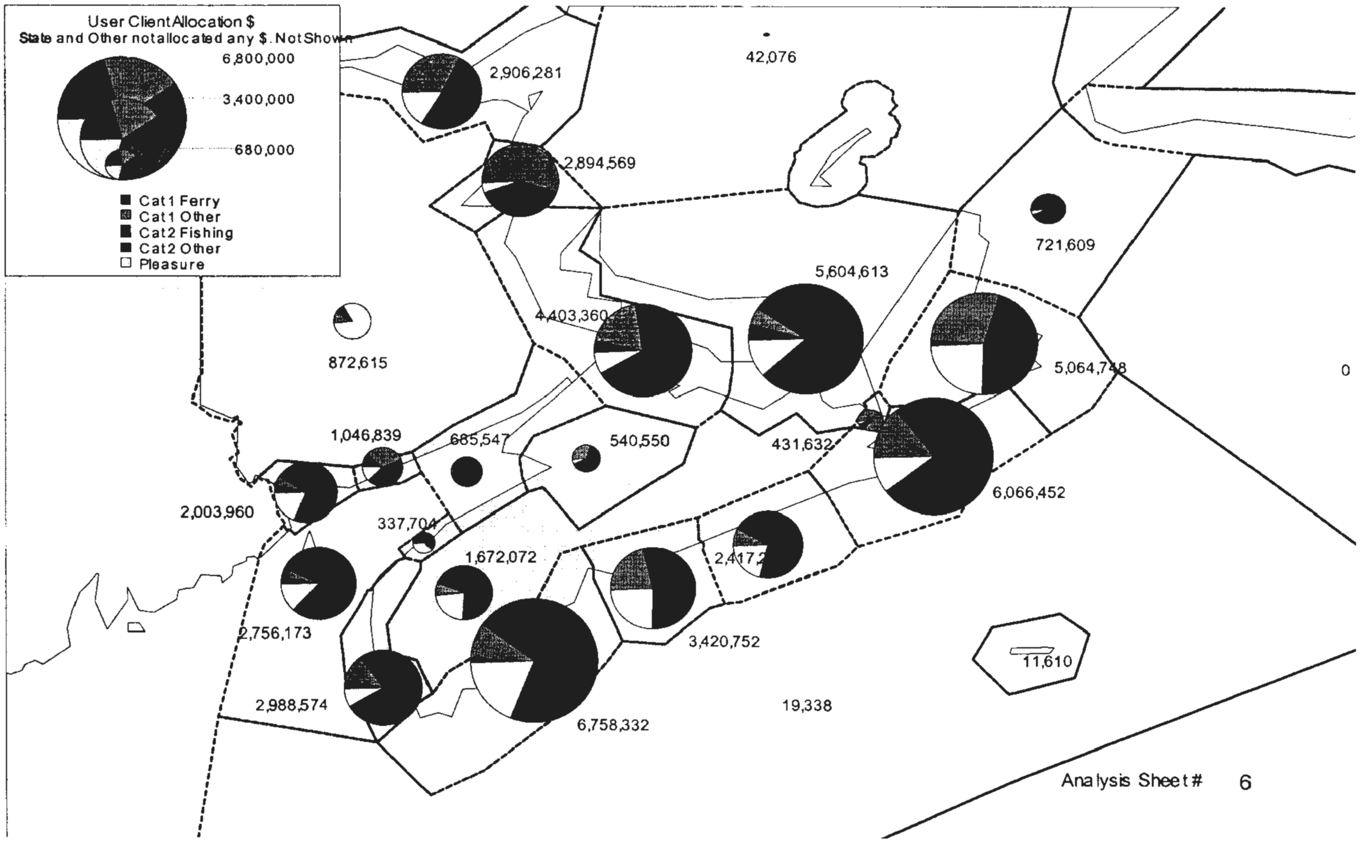


FIGURE 3 Short-range navigation aids: cost by client group (example only).

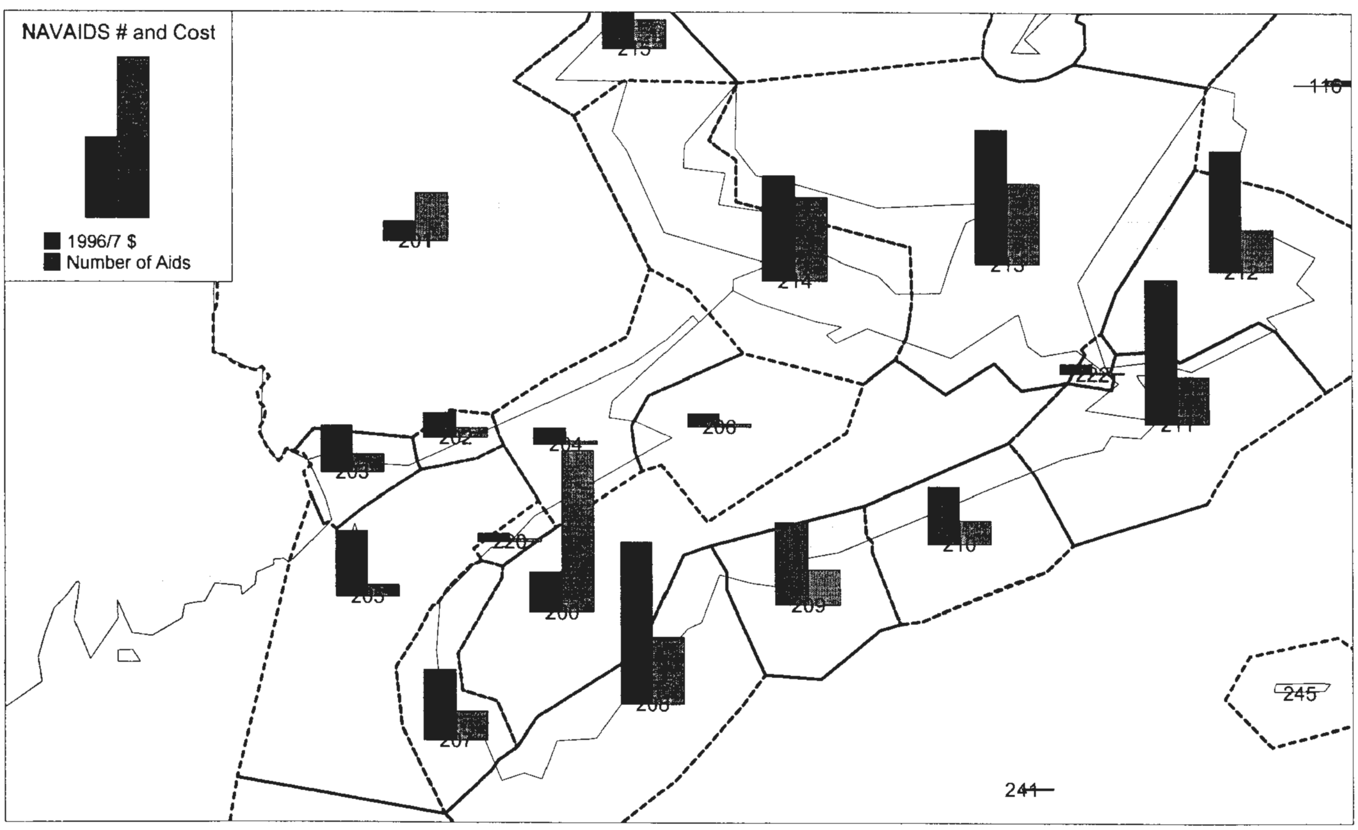


FIGURE 4 Short-range navigation aids: total cost versus number (example only).

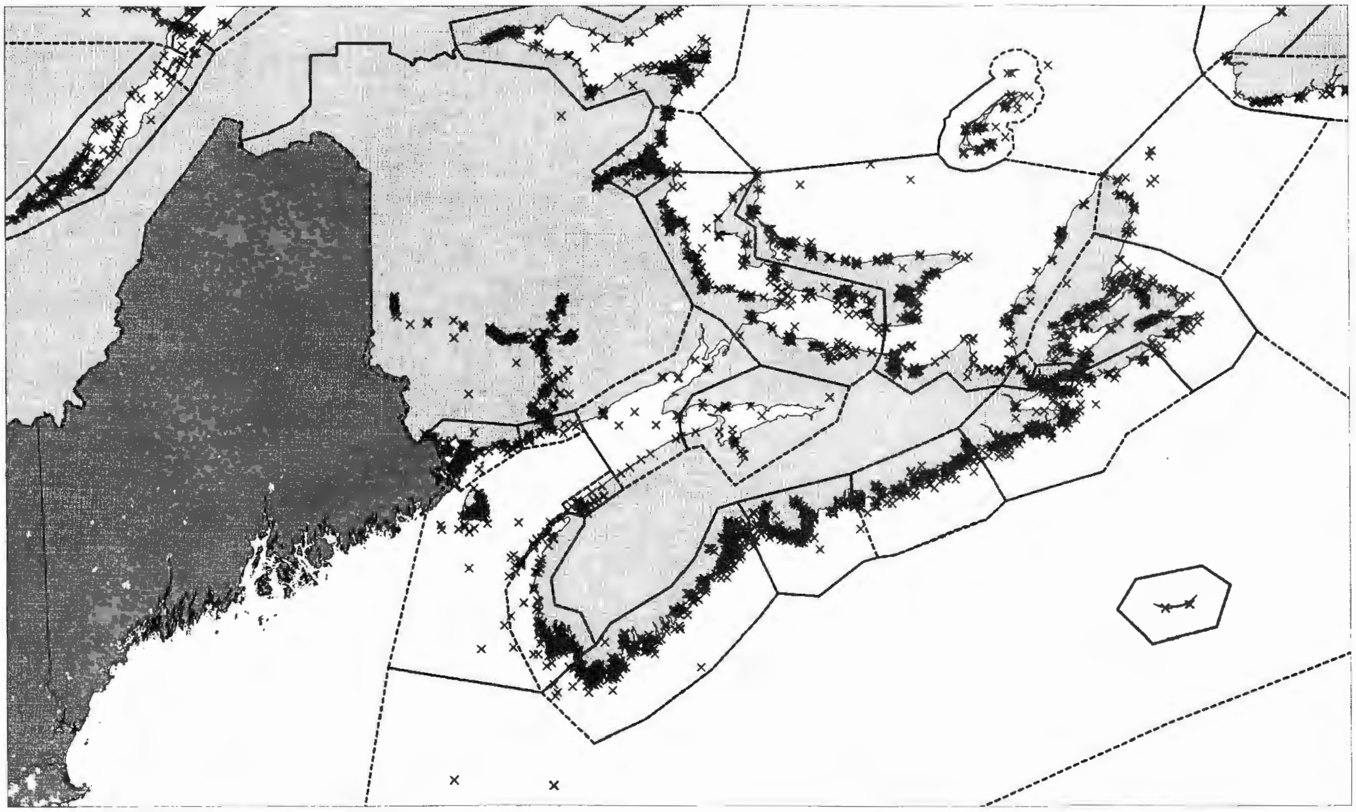


FIGURE 5 Location of CCG navigation aids (as of November 1998).

terms of risk, it is not likely 36 times as dangerous to the mariner—taking the square root reduces a measure of 36 percent to only 6 times as dangerous as a measure of 1 percent (values less than 1 percent were set to 1)];

- Our assigned measure for waterway type (where confined waters receive a higher, or riskier, value than open waters); and
- Our traffic pattern measure (where areas with complex vessel movement patterns receive a higher value than areas with simple patterns).

StatCan records for 1997 show about 8 million metric tons of petroleum movements for Placentia Bay. However, the new transhipment depot at Whiffen Head near the Come-by-Chance refinery in Placentia Bay started receiving offshore crude oil in 1998 and could handle over 30 million metric tons annually in 3 or 4 years. Next year, Placentia Bay is expected to record 15 million metric tons (combining Come-by-Chance and Whiffen Head). Thus, we assumed 15 million metric tons for Placentia Bay in this VTS risk index analysis.

Figure 7 presents the resulting VTS index on a map of Canada. The top 20 study areas account for 80 percent of the risk as measured by the index. Ten of the current 12 VTS centers include at least one of these areas in their zone. Figure 8 presents a demonstration index for search and rescue (SAR).

Other Risk Management Issues

Individual Versus Societal Risk

One must be clear about the kind of risk that is being addressed/ranked. A risk-based approach almost always looks at total or societal risk (e.g., the expected mean cost of all casualty impacts in a waterway during a 12-month period). Individual risk, on the other hand, addresses the particular losses experienced by a particular entity, person, group, region, and so forth—for example, the expected loss from one vessel transit through a specific waterway or the expected losses for a single ship during a given year (this is the risk that an insurance company would cover). Most recent government initiatives relate to an attempt to minimize societal risk. However, while theoretically producing the greatest overall good for society, the implementation of societal risk-reduction initiatives often conflicts with the equitable delivery of individual risk-reduction services.

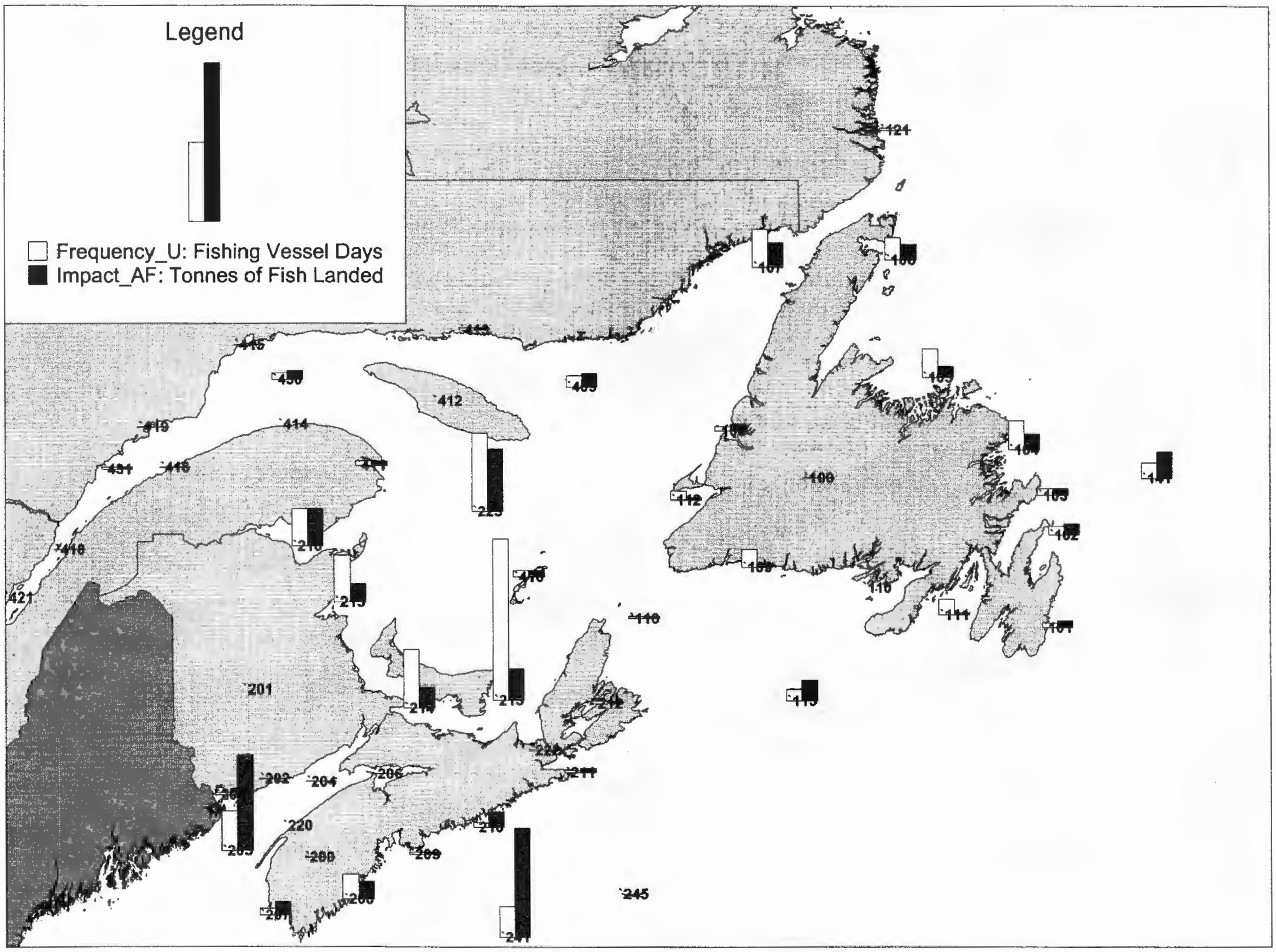


FIGURE 6 Fishing vessel days versus metric tons of fish landed (Source: F&O Canada Data, 1995 and 1996).

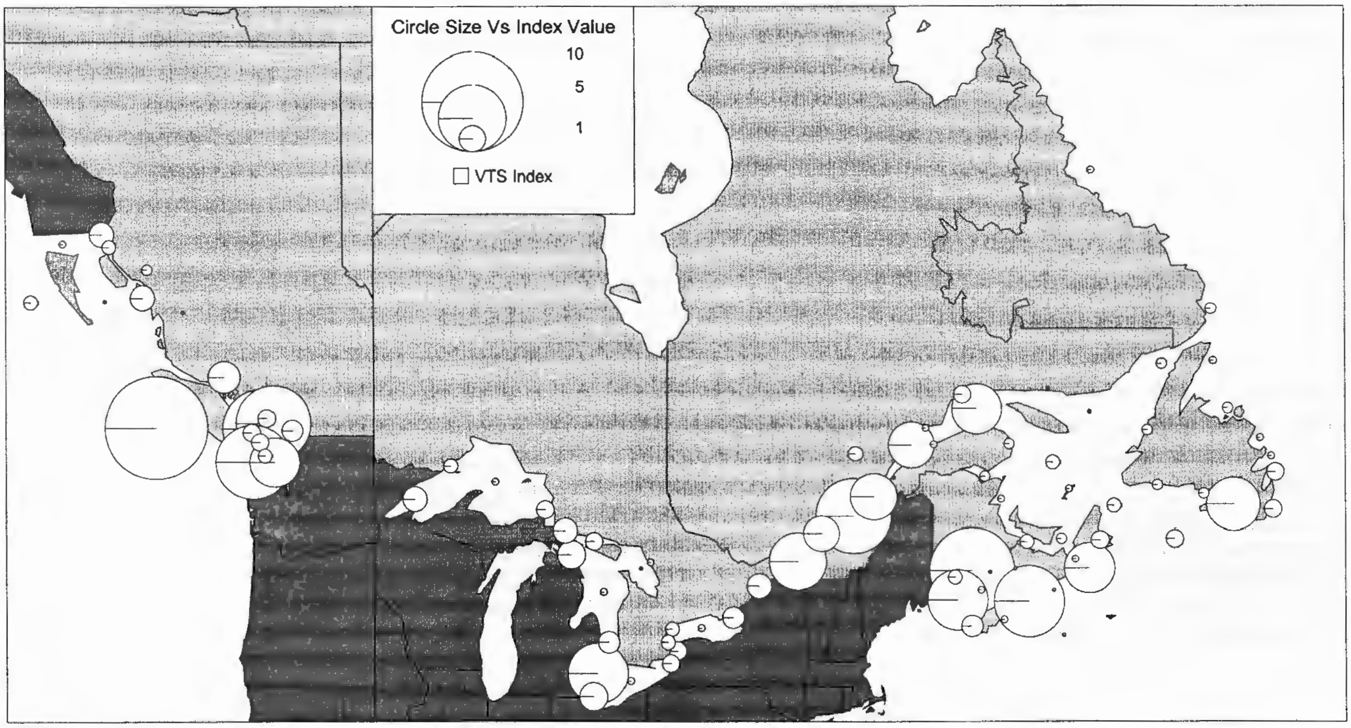
Level of Service

If, as the optimization of societal risk implies, one invests only in those areas that produce the greatest risk-reduction benefits for the resources available, how does one justify the cutoff point to individuals who fall below the line. For example, the greatest societal good might be gained from investing only in heavily trafficked waterways and doing nothing in the remaining ones. However, individuals across the country will receive significantly different safety services and benefits, which often is not acceptable. Consequently, most public services, including health care, postal services, and so forth, attempt to provide a minimum level of access (although not necessarily a similar minimum level of service). For example, SAR in Newfoundland is available to anyone in distress, as it is in the Great Lakes. However, it may take several hours to reach an incident off Newfoundland compared with only a few minutes in the Great Lakes.

In the past, most public safety or risk-reduction services have attempted to allocate resources so that a minimum level of accessibility is available to each individual across the country. Only recently have we attempted to maximize societal risk with any real resolve. However, this strategy can conflict directly with the goal of providing equitable risk-reduction services to all individuals if taken to its logical conclusion where only those individuals above the cutoff point receive services. Not surprisingly then, compromises between individual and societal risk have been and continue to be made.

Risk Perception

Human activity is not, and cannot be, risk-free. Nevertheless, there is no generally acceptable minimum level of risk or risk-reduction service level for any human activity. People accept risk because of the benefits the



$$\text{VTS Index} = \{0.9 \times (D8 \times 0.6 + E8 \times 0.1 + F8 \times 0.3) + 0.1 \times [(I8 + J8) + (G8 + H8 + K8 + L8 + Q8)^{1/2} + (M8 + N8 + O8 + P8 + R8)^{1/3}]\} \times \text{if}\,[(S8/2 + T8/2) < 1{,}1, (S8/2 + T8/2)^{1/2}] \times U8 \times V8$$

FIGURE 7 VTS risk index (example only).

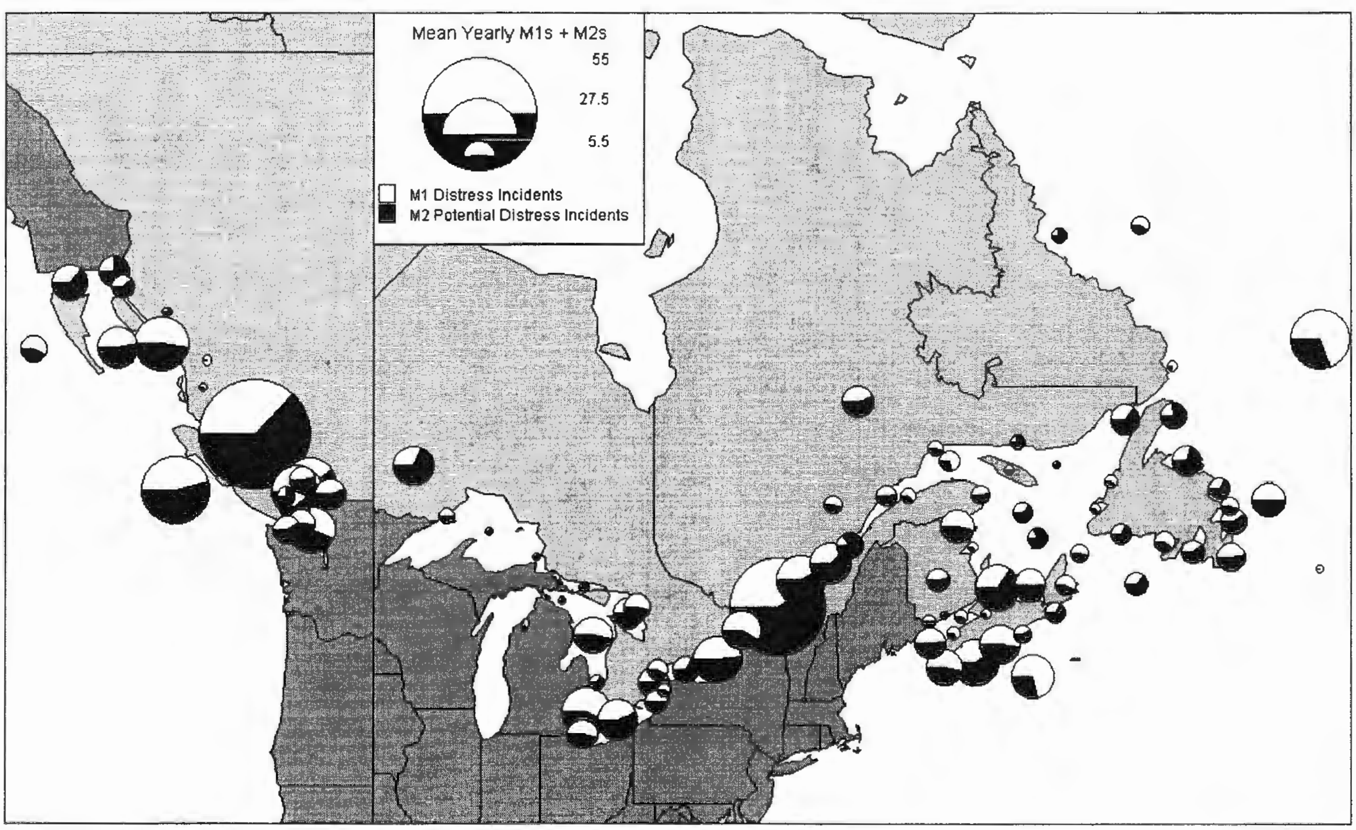


FIGURE 8 Risk Index 2 for search and rescue and distress safety.

risk-producing activity generates. Reducing risk in one area usually means that another area receives less resources for risk-reduction efforts. Furthermore, society has never demanded the same level of risk (i.e., safety) for all activities (Fischhoff et al., 1978).

Experimental psychologists have shown that society ranks risk consequences according to four basic factors (Slovic, 1987):

- Is the risk understood—dying from heart disease is more acceptable than dying from some unknown problem caused by bioengineering;
- Is the risk controllable—people generally accept a much higher level of risk when they are driving their own automobile than when they put their life in the hands of someone else (e.g., airline pilot, vessel master);
- Is the risk potentially catastrophic—most people have more fear of a death that involves large numbers of victims (e.g., a large ferry sinking) than of a fatality related to a small accident (e.g., pleasure boat sinking); and
- Is the risk dreaded—death from radioactive fallout, fires, explosions, and drownings is feared much more than death from natural causes (e.g., stroke).

The public also believes that some hazards occur very frequently even though they are actually quite rare (Fischhoff et al., 1993). For example, botulism, airplane crashes, tanker spills, ferry accidents, and violent crime are often considered to be more common than automobile accidents or strokes because every instance of the former is published in the press, whereas the latter are rarely mentioned.

Accident Cause and Risk Reduction

High breaking waves, strong winds, fog, or busy channels that increase vessel risk can rarely be modified directly. However, the factors that put a vessel in a vulnerable position often can be addressed so that the frequency of future accidents is reduced (e.g., not sailing under such conditions, installing marine aids or VTS, and so forth). Furthermore, the consequences of accidents that do occur can also be addressed so that they are mitigated or made less serious (e.g., wearing life jackets often prevents persons involved in a capsizing accident from drowning before rescue takes place, establishing pollution response centers can sometimes reduce the quantity and spread of spilled oil, and so forth).

Whereas proposed risk-reduction solutions address either accident frequency or accident consequence, solutions themselves can also be categorized as passive or active. Passive solutions include things such as design improvements (e.g., better flotation or a higher free board requirement in a construction standard, double hulls for tankers). Active solutions would encompass ongoing programs such as operator training, licensing, and inspection of vessels.

Compliance is another aspect that must be considered when solutions to reduce risk are being proposed. Again, compliance strategies are often classified as proactive or reactive. Education and publicity that identify a new standard or requirement are considered a proactive compliance strategy, whereas fines or withdrawing licenses are considered reactive.

There is one other consideration that society makes, albeit subconsciously, when demanding or supporting safety improvements. There is often more willingness to spend resources to reduce actual risk than to prevent statistical risk. For example, actual lives can be personally identified—those people rescued from the water after a boat capsizes. Statistical lives involve persons who were prevented from drowning and can never be identified personally—those who did not drown because of the placement of navigation aids. The same applies to oil spills—society appears to be more willing to spend money on cleaning up an actual spill after they see it on television than on preventing statistical occurrences that could happen in the future (through more funding of preventative programs). Of course, preventative strategies usually cost less in the long run.

Conclusion

With a fully supported ORCA system, coast guards and other marine organizations should be able to realize savings while ensuring high levels of safety. ORCA allows easy accessibility to data that managers need for making informed decisions. ORCA promotes a culture of openness in data management and allows all levels of an organization to benefit from the work of others.

References

Fischhoff, B., et al. How Safe Is Safe Enough? A Psychometric Study of Attitudes Toward Technological Risk and Benefits. *Policy Sciences*, Vol. 8, 1978.

Fischhoff, B., A. Bostrom, and M. J. Quadrel. Risk Perception and Communication. *Annual Review of Public Health*, Vol. 14, 1993, pp. 183–203.

Slovic, P. Perception of Risk. *Science*, Vol. 236, 1987, pp. 280–285.

Discussion Group Summaries

Group 1: Risk Assessment Models: Practical Applications and Guidance

Group 2: Data and Information Necessary for Risk Assessment Applications

Group 3: Real-World Applications

Group 4: Agency Integration and Cooperation

Discussion Group 1

Risk Assessment Models: Practical Applications and Guidance

Chair

B. John Garrick, *Garrick Consulting*

Panelists

Robert G. Bea, *Department of Civil Engineering & Naval Architecture, University of California*
David Corbett, *Lloyd's Register of Shipping*
Tom Green, *Washington State Transportation Commissioner*
Willard C. Gekler, *Los Alamitos, California*
Thomas R. Moore, *Chevron Shipping Corporation*
Richard Ranger, *ARCO Marine, Inc.*

Discussion Paper

Weick, Karl E. The Neglected Context of Risk Assessment: A Mindset for Method Choice. (See page 17.)

Description/Objectives

Over the past 50 years, a dizzying array of risk assessment approaches has been developed: among them are descriptive and prescriptive models, analytic and behavioral methods, organizational and system models, statistical and "fuzzy" techniques for risk assessment. In this session, we

- Provide an overview of several of these methods, techniques, and models to provide context and background;
- Explore the appropriate use of differing techniques and models for different types of risk assessment problems and different domains; and
- Conclude with a discussion of lessons learned in applying different risk assessment models, techniques, and methods. Best practices from maritime and other domains are identified in this session.

Summary of Discussion

Presented by B. John Garrick

Our group was asked to discuss risk assessment models, methods, and practical applications. To get the panel discussion going in some sort of systematic and organized fashion, we started with the purpose and objective of the conference. That purpose is to find ways to integrate risk assessment methodologies into the practical world of waterways management. Probably the most important words here are the "practical world." Those of us who are in the analysis and assessment business appreciate that and realize its importance. What we asked here was, why on earth would anybody want to do risk assessment? Here are some of the reasons we cited.

Risk assessment seeks the truth on issues and events about which there is uncertainty. When risk assessment has failed, it is usually because it has not told the truth, especially with respect to uncertainty. Probability is the language of uncertainty. In Karl Weick's presentation, uncertainty is highlighted by his account of general, accurate, and simple explanations. Two of the three descriptors, but not all three, may be applicable to a given risk condition.

Fundamental elements of the risk management field are risk assessment, risk communication, and risk management. Risk assessment leads to the truth, risk communication leads to understanding, and risk management involves making decisions and taking action.

Risk management is proactive and should use multiple risk measures. Risk assessment should look at a greater scope than is customary in the marine field—for example, not just oil in the water. The scope of risk assessments may include health effects, facility damage, external events, human reliability, organizational components, and other attributes. Uncertainty analysis and common cause analysis are used effectively in other industries. Quantifying risk provides an enhanced basis for risk management.

Motivation to use risk assessment in decision making comes from the International Maritime Organisation, the U.S. Coast Guard, and an international emphasis on safety.

Current assessments rely heavily on experienced mariners. Risk assessment in the maritime field lacks a set of common principles and methods. Databases are not well aligned; the risk assessments should be driving the structure and content of databases.

The scope of an analysis depends on the industry. Marine transportation systems have special characteristics:

- Large rotating equipment;
- Confined and isolated;
- 24-hour working conditions, nonstandard conditions;
- Diversity of systems, extremes of the environment; and
- Safety culture—change is slow.

There have been some effective applications of risk assessment—for example, Prince William Sound and other isolated applications—but the marine industry is mostly reactive in nature. There are opportunities for risk assessment to add value to marine transportation safety. It can be conducted in a horizontal mode (multiple performance measures) and a vertical mode (go down to the level where there is information) with respect to scope. Agencies talk about transitioning to risk-based regulations. We need to expand the range of risk measurement.

If we know the risk, we are in a much better position to manage it, especially if we are able to measure it. The single important forward step that risk assessment has provided is that it has extended way beyond the issue of hardware performance in most applications, and it has tried to provide the connection between frontline systems and support systems. Examples of support systems are traffic rules, procedures, software, qualifications and training, human response, and organizational impacts. Of course, part of what we have been discussing here is that some parts of it have been done better than others. Pinpointing risk-reduction measures that have the greatest return and providing a basis for transitioning to risk-based and performance-based regulations appear to be the opportunities.

What we attempted to do was translate what the panel was trying to address into some questions. The questions are presented in Exhibit 1; we did not answer all of them, but they served us well in motivating and stimulating the discussion.

The first question is *Where can we get the greatest return? Where is the value added in using these methods?* What we mean by greatest return here is cost savings through improved risk management. *Are the current activities moving us in the right direction? Who is and who should be leading the way?* We did not discuss this point too much, but it is a very important one. *Is there a basic strategy of risk management and risk assessment for marine transportation? Would a general theory or a set of underlying, overarching principles be helpful in bringing greater order and progress to the process?* Finally, a question such as, *Given the heavy dependence on crew*

EXHIBIT 1 Questions for Discussion

- Where can we gain the greatest return (cost savings from better risk management) through the use of the risk sciences in marine transportation?
- Are the current risk assessments and risk management activities moving us in the right direction—for example, the Prince William Sound Risk Assessment, the U.S. Coast Guard's *Risk Based Decision Making Guidelines,* and the Formal Safety Assessment process?
- Who is and who should be leading the way?
- Is there a basic strategy of risk management and risk assessment for marine transportation?
- Would a general theory (general principles without being too prescriptive) of risk assessment endorsed by an oversight group or regulator of marine transportation provide coalescence and stimulation to more effective use of the risk sciences?
- Given the heavy dependence on crew and support groups for marine transportation safety and the diversity of organizations involved, how do we integrate the human and organizational factors into the risk assessment and risk management process?
- Is it possible to rate the opportunities for greatest gain in application of the risk sciences to the marine transportation system?

and support groups for marine transportation safety—and we heard a great deal about the diversity of organizations involved—*how do we integrate the human and organizational factors into the risk assessment and the risk management processes?* This is one of the reasons we had as our keynote speaker somebody who could speak to organizational issues.

Is it possible to rate the opportunities for greatest gain in the application of the risk sciences? As background in considering this question, I sent out a draft report to the panel and requested their comments on its conclusions. With the draft report as background, we came up with some observations about approaches that would lead to improvements (Exhibit 2).

One of the things that was discussed a lot was the soft issues—in the sense of *How do you interject policy into this process? How do you educate management?* It is true that we are talking about a substantial cultural change here. We are talking about something in which senior managers must become engaged. How do we avoid having this discipline take the form of something that only nerds do, and is it not really an integral and inherent part of the way we think and the way we make decisions? The only justification for doing risk assessment is to help us make better decisions. If we are not successful in convincing people to appreciate that and convincing management to embrace it from the point of view that it is a valuable aid to the decision-making process, we will probably fail.

The other thing that is not said so much here but that is part of the horizontal/vertical communication issue is what I've always believed, and the panel was in agreement with this, that one of the most important requirements of risk assessment is that it have an operations perspective. When I was doing a lot of risk assessment projects, the only person that I said no to was an owner of a large nuclear power plant in a foreign country. He asked us to do a risk assessment, but he did not want us to talk to his reactor operators. We turned it down. You cannot do that. If there is to be value received from these analyses, then you have to do it in such a way that you can enhance one of the most important outcomes of these analyses, accident management. You have to be able to recover from a degrading situation. You want to know what operational options you have for recovery. This is where the quantitative analyses have been enormously insightful in giving alternatives for recovering from specific equipment failures or human errors or external impacts, such as a severe storm or an earthquake.

So, the people element is something that has been emphasized here a great deal—the performance-through-people program—and I agree with that. It is a program we really want to push very hard. Then we laid out some guidelines for the risk assessment process (Exhibit 3).

The first thing we agreed on, not always unanimously, was the need to develop a set of method development principles. In other words, instead of trying to address the question of methods and general theory that would apply, maybe what we ought to be talking about are the underlying principles that guide their development. It is clear that the risk assessments must be flexible in order to accommodate the diversity of this industry. It is a dynamic system. It is a system that involves a wide variety of hardware, various nationalities, and a variety of procedures and regulations. These dynamics have to be in the process.

Everybody agreed that the human element should be a very visible and major input, even in the methods business. If there is a way we can bring human performance into the analysis and make it more specific, more explicit, and more deliberate, then we certainly should try to do that.

A lot of discussion about one of the problems with risk assessment is that its birth and its development came

EXHIBIT 2 Observations

1. Recognize the industry-specific characteristics of the marine transportation system.
2. Early success is more likely using qualitative methods.
3. Quantitative methods are important for special applications, especially those relating to design.
4. Stakeholders must participate and buy into the risk assessment.

EXHIBIT 3 Recommendations

1. Develop a set of method development principles that could be used by the diversified maritime community.
2. To accommodate that diversity, risk assessment methods must be flexible.
3. Incorporate the human element into the process.
4. Emphasize the more likely events in risk assessments instead of the catastrophic.
5. Investigate the use of interactive risk management.
6. Improve communications both horizontally (between industry sectors) and vertically (between management and workers).
7. Let the risk assessment drive the data needs.
8. Consider the total evidence, including the physics and mechanics of the event.
9. Use end state/goal orientation in conducting risk assessment.

about as a result of focusing on very rare and catastrophic events. It has served us extremely well in that regard. But, there is a great deal of interest in having it serve us better in the area of risk activities that happen more frequently.

We talked a lot about management and how to investigate the use of interactive risk management, both vertically and horizontally. Much of this is rooted in what you ought to be doing to enhance communication across and in vertical slices. You cannot neglect the issue of data when you talk about methods, even though another group will cover this subject in detail. Generally what we found about risk assessment is that to develop a database that supports risk assessment, do some risk assessment modeling first and figure out what you need. More programs than you can imagine have been killed by trying to do it the other way around.

Data have to serve purposes other than risk assessment, but, for the purpose of risk assessment, you really must determine what you need. The only way you can find that out is to do some risk analysis. That is not to say that you shouldn't use whatever data you can get.

One of the things that is very important, and I've already mentioned it, is the industry-specific characteristics of the marine transportation system. When you do your modeling, acknowledge those characteristics, especially the dynamics. Yesterday we saw an example of simulation as a way to represent the dynamics. You can also represent a dynamic system in discrete phases. There are a number of ways to do that.

We also agreed that, as far as embracing risk assessment methods, we are more likely to be successful with qualitative methods instead of pushing the large detailed quantitative risk assessment studies. However, I have a strong prejudice in that arena because most of the great strides we have made in understanding safety have come directly from quantitative and not qualitative risk assessments. In other words, we need to be quantitative sometimes to understand the subtleties of what can go wrong. It was sort of agreed that quantitative methods are important for special applications. Maybe there is some percentage of the issues that we're faced with where it would be very constructive and informative to do a much more quantitative analysis. The Prince William Sound Risk Assessment is an example of the quantitative approach. One of the things that is a tremendous asset when you are considering a design change is to be quantitative with respect to the risk implications of that design change. Thus, for design purposes, quantitative methods are much more beneficial.

Finally, stakeholders need to buy in to the process. It is more than that. They must participate in it. They must be a part of the establishment of the risk measures, the database, the parameters that you're actually going to calculate.

Questions and Answers and Discussion

Question: Can I ask whether your panel discussed how you get input from the operators, pilot masters, bridge crews, pilots, and so forth? I work mostly with the tanker industry and a lot of people say, well we get 95 percent of our oil coming in on foreign flag tankers. I don't think that is bad from a safety point of view, but I hear all these risk management words. Where do the rules fit in for the pilots and the pilot masters, . . . characteristics of vessels that to me are the real guts of whether you have safe operations in a marine transportation system in our ports.

Answer: I agree, and if some of the panel members want to help me respond to this, I would certainly appreciate it. I agree with you 100 percent. I think this is an area where the most difficult thing to change is the culture. I know it was in the nuclear field. But it has changed, and the way it has happened is basically a looking-over-your-shoulder process. You don't do any mechanical work on a nuclear plant these days without somebody watching you. It is a little bit like the aircraft industry, although I think it is even more rigid in the nuclear power industry. To talk about somebody watching a mechanic change a valve 10 years ago was absurd, but now it is accepted. All the paperwork that goes with it, all the documentation, and all the quality assurance (and I'm not saying there are not some glitches from time to time) are there and are in place. It took time and it took an accident and it usually takes some sort of a major stimulus to develop a basis for imposing rigid quality assurance procedures (as it is sometimes viewed by operators and crew members).

One of the most important things is, again, to communicate to the operators and the crew what value is in it for them to be a part of this process. Also, we must somehow remove them from the stigma of thinking they will get in to trouble if they expose something that reflects on fellow workers or what have you. It is a difficult area, and the only thing that I have found that works is the agreement to do some training. The performance-through-people program that the Coast Guard is talking about appears to be moving in that direction.

Question: In her talk yesterday morning, Karlene Roberts asked some questions for consideration: one question was "Where do I get my notions about what I think is wrong?" Well, to find out what is going on in the operation, you have to ask the operators. You have to ask them in terms they understand. You start by asking and you start by honoring in some way the experience of the operators. Why is it you do what you do? How is it you learned? Then, you ask more than one operator and you get some comparisons. You get storytelling out of that. You don't initially get a lot of data, but the stories are important and the stories aggregate to a common experience. You acknowledge that this experience has value because it has led to a series of incremental, day-to-day risk management decisions these people are making. They may be making them based on good or bad information. They may be making them based on accurate or inaccurate perceptions. We don't know. But you have to start. If you start communicating to them in this process of thinking "How is it that I, as an operator, make my choices on what's wrong?" then they start listening to each other and they start thinking that way.

Answer: Let me give you an example. In an early risk assessment we went to people in the plant and we said, "What do you think of this?" They surprised us. They didn't like fault trees. They didn't like logic diagrams. So what we learned from that is that we need to represent the information in a form they can understand or are interested in, and that was really kind of the birth of the idea of a scenario-based approach to risk assessment. They understand scenarios. They understand if you have an initiating event like a pump failure when things can start to go wrong. So, when you put the fault trees in a black box and put the focus on outputs that they can become a part of and that they can correct us on, you can get the kind of input needed.

Question: I think this is all wonderful, but the new word in the '90s is risk assessment. I don't think we're risk assessing anything, because we just continue to avoid the same issue, and that is dealing with people. I've been in this business for 35 years and was involved in the beginning of the Alaska risk assessment, which, frankly, didn't prove anything to anybody except an awful lot of nice words. I have never had anybody come up to me in all these years and say what a wonderful document that was. What I've heard the most from everybody is that it is a lot of paper and the oil companies paid a lot of money.

I wish we could look around for a minute and ask how many people here are truly ship operators. I went through this piece of paper and I count eight. I think I now see five. My whole point is, who are we talking to? The government? Consultants? Academics like me? The issue is dealing with the people. The day this industry or the consultants and the government and so on and so forth get down and talk to people on the ships will be a new dawn. That does not happen. They don't want that to happen. Quite frankly, we are wasting our time.

What should we do to not waste our time? What we ought to do is be out there finding out where the difficult areas are and then proceed from there. That is not what you are doing here. Some people are putting numbers onto things and saying this is this and this is that.

The second thing too, sir, is that we are not talking today about Americans. We are talking about foreign flagships. We need to decide how we are going to deal with them.

Answer: Even though what you say may have a lot of truth in it, we have seen tremendous progress. We understand the mitigation capability of equipment now at levels we had no idea of 20 years ago with respect to some systems. We can put some degree of confidence and measurement in the ability of a high-pressure injection safety system to do its intended job. So, I cannot agree that it is nonsense or a waste of time. I'm basically a great sympathizer to the operations point of view. But I think the scientific process continues to push us to seek ways of measuring things, and I think that is all we are trying to do here. Of course, some of the analyses are going to be ridiculous and some of them are going to be much too narrow in scope, and some of them are going to be off target. But the overall movement is what you have to look at and where the progress has been made. In the refinery, chemical, and power businesses, there have been great strides made in enhancing our understanding of the underlying drivers of how to safely manage these complex facilities. This kind of thought process has made a contribution. I have been one of the most outspoken in support of one of your themes of getting the operators, the crew's perspective, into these processes, because a lot of them do not do that. If we do that and combine the two, we will see great progress.

DISCUSSION GROUP 2

Data and Information Necessary for Risk Assessment Applications

Chair

Paul S. Fischbeck, *Carnegie Mellon University*

Panelists

Martha Grabowski, *Lemoyne College and Rensselaer Polytechnic Institute*
Paul Green, *Washington State Ferries*
Sonja Haber, *Human Performance Analysis Corporation*
Najmedin Meshkati, *University of Southern California*
John (Jay) S. Niederhauser, *Puget Sound Pilots*
Stephen Ricks, *Clean Bay*

Discussion Paper

Connell, Linda J. Aviation Safety Incident Reporting: The NASA Aviation Safety Reporting System. (See page 24.)

Description/Objectives

Reliable data about a range of identified risk factors are needed to support complete risk analyses. However, there are considerable difficulties with data to support risk analyses: data sets and information sources can be incomplete, inconsistent, and of different degrees of accuracy and utility for risk assessment. Data difficulties—incompleteness, inaccuracy, inconsistency, unreliability, unavailability—and the need to integrate data from different sources in order to perform risk assessments are common topics in many risk domains, including the maritime world. This session

- Provides an overview of issues associated with data and information necessary for risk assessment applications,
- Focuses on approaches to overcoming data and information limitations, and
- Summarizes lessons learned from maritime and other domains.

A glimpse of future data needs, sources, and problems is also provided.

SUMMARY OF DISCUSSION

Presented by Paul S. Fischbeck

We looked at data and information necessary for risk assessment applications. As you can see, we had a variety of people from industry, government, and academia. It was a very successful panel.

Why Collect Data?

One point is, if better data are the answer, and we kept hearing that yesterday, we need better data. If that is the answer, what is really the question? What are we really collecting the data for? Why collect the data? What are we going to use the data for?

We started our discussion with why collect data? One of the first key points that emerged was that collecting data is good business. You can make better business decisions if you have good data. Data have many applications other than risk analysis. If you understand what is going on, then you can improve schedules and so forth. With this demonstration, you also get upper management buy-in. They understand the value of collecting data.

Then, once you have data, you can build models, which we just heard about, and those models have applications aside from just doing risk assessment. They can help you prevent accidents and reduce injuries and impacts from accidents; they can also do things such as justify a government program or show why a regulation is a good idea or not a good idea. They can save you money. By having a good model of operations, you can, in fact, save money. You can also demonstrate use scenario generation and do "what if" analyses not only about risk but about other applications as well. So, you get this buy-in and there is more application to data than just risk analysis.

Types of Data

We talked about the types of data we may want to collect (Exhibit 1). There are accident data and there are near-miss or incident data, which we talked about in detail yesterday. But we also need to know about normal operations. We need to know what happens every day. This is often overlooked. A discussion that came up several times was about how it takes a lot of effort and we have to merge four or five databases. Let's find out what normal operations look like. We need to find that out so we can compare how unusual accidents are and how unusual those precursor events are. For instance, for environmental reasons, we also may want to find out what baseline is appropriate. To determine the impact of an accident, we may have to determine the conditions before the accident to know what actually happened.

EXHIBIT 1 Types of Data

- Accident data
- Near-miss (incident) data
- Normal operations
- Baseline (preaccident) conditions
- Real-time ship-specific data
- Reliability of mechanical systems
- Human factors performance
- Environmental conditions
- Organizational norms and procedures
- Causal data
- Need leading indicators (cholesterol) more than deaths (heart attack rates)
- Note: marine data are not aviation data
  - Variety of platforms
  - Controlling agency/organization

There was also a need that was brought up for real-time, ship-specific data. If you have a pilot that is going out to a ship, wouldn't it be nice to know what has happened recently, such as how the engine has been performing in the past 24 to 48 hours? What about the crew? Is there any way to retrieve that kind of information? It would certainly help the pilot make better decisions. The information may not be year-end summary data, but at the same time, getting real-time information could be critical.

Other data types include, for example, the reliability of mechanical systems. Where is that information collected? How is that collected? Who is collecting it? And what about human performance, environmental conditions, and organizational norms and procedures? You have to understand the whole thing. You can't just focus on, for instance, human performance. That has been a focus of a lot of discussion, but without the context of other things it is useless; understanding the ships norms in operating for the ship must be part of the context.

There is a need for causal data. Someone mentioned not wanting to know heart attack rates. I want to know the relationship between cholesterol and heart attack rates. That is what is going to be useful to me to make my decisions. So, reporting in year-end summary data will not be what is useful.

Another thing that came up was that maritime industry and maritime data are not the same as aviation industry and aviation data. They are not the same as nuclear power industry and nuclear power data. These are very different environments. You cannot assume that what works well for aviation will work well for the marine industry.

In particular, the variety of platforms makes the marine industry different from other industries. Linda Connell talked about her NASA database. They were dealing with 200 types of platforms. Two hundred types of aircraft configurations. Well, there are 200 different types of ships that pull into the Los Angeles Harbor every day. So the variety and the variability between platforms and the crews that operate them and the way they are maintained is far, far more variable than it is in the aviation and nuclear power industries. This has to be understood and recognized up-front.

Also, if you look at the overarching controlling agencies, when it comes to aviation there tends to be a very nice structure on top. This is the same for nuclear power. There are some tightly controlled regulatory bodies that sit on top. When it comes to the marine industry, they don't exist at the international or national level. You don't have quite the same control. So, that also makes data collection more important. Other questions arise; for instance, how do you collect data from foreign nationals operating in your waters?

How to Collect Data

How do you collect these data? One thing that came up was that there are a lot of data out there that have already been collected in various ways, shapes, and forms.

But we have to be creative in order to find it. Unfortunately, there is no one-stop shopping. Different people collect different things for different reasons, and to be able to pull it all together and make sense of it is always a very difficult task. The ability to go through and perhaps use the carrots we talked about—the fact that data collection is good business—may be a way to encourage more data collection. At the same time, if you are collecting data from a variety of sources, you must be aware of built-in biases that exist and sometimes hide behind the data.

The data can be everything from low-level data to preprocessed data. There is a hierarchy. When you do census collection, you get every single data point in the population. Then you go to survey data; there was a comment that this is not being done enough. People are always pushing for that complete census. Maybe survey data can be very helpful. Then you fall back on models and then simulation outputs, which we have seen used in the Prince William Sound study. Then there are expert opinions. So, be aware of this continuum of types of data collection.

As was just mentioned, data collection should be rated based on model needs. You don't want to go out and collect data because it is easy and the data are under the lamp post—you have the data, that is great, but does that help you make the decision you're interested in? You have to keep that in focus. There is a technique called the value of information, which is part of decision analysis, that allows you to focus on your data needs.

Then here comes the big guy, which is the incident reporting data. Yesterday Linda Connell talked about the ASRS database and how, hopefully, they will have a real opportunity to get people to report, to put up an immunity deal that allows them to report incidents. So, we can start to capture the concerns that people have on ships. This has to be one of the key ways to do that. If we can't get trust and buy-in from international sources, then we have a real problem; it has to be done. Trust is critical. A system was modeled after ASRS that was started in 1980 for the marine industry. It was a flop. Trust was violated and it was a day of disaster. We are still living with the repercussions and stigma of that particular loss of trust. It has be there; it has to be guaranteed; it has to be a gold standard that cannot be violated.

Data Quality

We have all different types of data and poor data can, in fact, undermine the credibility of the entire analysis. At the same time, perfect data are never going to be available. You have a battle going back and forth between what you want and what you can get. When are data good enough to include or to make a decision? That is where the modeling problem comes into play. So, it is important to state the source and accuracy of what you have. Don't hide it. Be open with it. Let people know what is going on. There are quantitative methods including probability distributions and qualitative methods for doing that. You should seek more sources. Get verification. That is a key element. Don't be afraid to show what you don't know. If you don't know something, don't say that you do. Put uncertainty on it. Allow for the uncertainty to be truly registered.

Who Has Access to What Data?

You've collected the data. Now, who gets to look at it? Different industries have tried different levels of exposure, different levels of access. Nuclear power has some great databases, but they are very tightly held for many reasons; they are very tightly held within utilities. They are shared among themselves, but there is no access to them from outside.

There was a discussion about open and closed databases and here the key was that it was believed that open was better. For this industry, openness is critical. Once again, immunity and trust are critical. Because you have an open database, you can't let people backsolve and figure out who reported what, what is going on. It has to be solid. You have to sanitize the data fields so you can prevent this backtracking. Proprietary databases have to be honored. At the same time, if you can share the carrot and the advantages of sharing data, then that may break down some of the barriers. Don't be surprised if people misuse the data. You are going to collect all these data; you are going to put the data on the web or somewhere to make them publicly accessible. People will do bad analyses. That is going to happen. But, that does not mean it shouldn't be done.

We had a small discussion, with mixed results, about whether we should charge a fee for access to the data.

How Are the Data Maintained?

You've collected the data; you've decided who has access. The question is, how do you maintain the data? Who owns the data? Is it a private or a public ownership—critical question. Is it a central location or do you have a web page that points to the different data sources? Many current databases are in very poor condition so it takes time, effort, and money to go through and clean them up and get them into acceptable form. Who pays for that? Who can afford to pay for that? Who is going to do that? Once that is done, that is when you don't want to throw the data away. That is when you want to really make it available to a lot of other people, once you have cleaned it up. But, how do you do that? Let me turn it over to who are the maintainers. If we standardize fields, data merging is much easier. Working with the offshore platform people, having common IDs that are consistent and reliable allows you to merge data together. That is really important.

The other kicker is—who owns the data and who is liable for errors in the data? Suppose there are omissions—something is missing and you make a decision and the data should have been there. They weren't—you make the wrong decision. Who is liable? Is the data owner liable in some way, shape, or form? Lawyers become involved here. They have to come up with disclosures that say, "Here are data, if you use them, it is your own responsibility." What is legal? What is the legality of data errors and so forth?

What Can Be Done with Current Data?

There are a lot of current data out there and a lot of different sources. To be able to go through and start pulling the data we already have and seeing what is out there is an important first step. But, it is tough. Once again, because of the quality of the data, wouldn't it be nice to know all these different things—how good are those databases, what are they being used for today, what could they be used for, how can owners be encouraged to share, and so forth.

So there are a lot of questions about existing databases. We don't know all these things. It would be nice to know—here is a database and here is a taxonomy, here is a description of each of the databases, and here are the limits and strengths and weaknesses and applicability and previous applications and so forth—so we could know what is out there. Who is going to pay for that?

In summary here are some of the major points. Collecting data is good business. That was a big insight to me. I had not realized how important that was. There is a need for this accident, incident, and normal operations data. We need normal operations data. We need to prioritize collection. Let's help the modelers, let's help the decision makers, let's help the policy makers by giving them the data they need—not the data that are easy to find. There is this . . . where we have "poor data can hurt you, but perfect data is not available." You have to understand that and then be open about data limits, the biases, the quality, and the uncertainties of the data you're using. Let's open the data up to the public.

Questions and Answers and Discussion

Question: How many of these types of data are being collected? How many organizations are collecting them?

Answer: One group with a tremendous amount of data are classification societies. They hide behind the idea of liability. The sad part about that to me is that the shipping people basically own those people. We serve on the boards and so on and so forth. There are a lot of data there. I never see anybody mention what goes on in the Nautical Institute and their simple system of reporting accidents. I don't know if that is going to be included or not, but there is a system that goes on that is voluntary, and the amount of data that come in there is amazing. So there is a platform that people will, in fact, report. How far we take it, I don't know. One thing to do is to really go through and find out what data are out there and find out how big a carrot you need to put in front of that person to open it up. If you want to go through and justify, and you can show a bottom-line improvement in profitability by having better data access, I think doors will open. It can span not only risk and accident prevention but also other things—better maintenance, more reliable systems, less dead-in-the-water time.

Question: I want to get a ship owner's point of view here. Accidents and pollution incidents, and knowing what the definition of an accident is, and knowing what the definition of a pollution incident is, it is very important from our standpoint as ship owners to operators to the industry. Perception of it. So, when we start talking about the data that were collected, I think it is important to make sure that we know what the definitions are of the types of data collected. I haven't heard anything said here about the definition of an accident. We had a discussion about what a fatality is. Different people record fatalities differently. The issue of a pollution incident, and some people may think of pollution incidents as being oil in the water, as opposed to . . . . as opposed to broken glass or whatever it is. So, it is important to make sure as part of the idea of collecting data that we have definitions of the data we are collecting. I think that if data are recorded as an incident, once again, if you have the specific information that describes what is going on, then different people will define things differently. You are absolutely right that you cannot merge apples with oranges. If one person defines a spill as over 10,000 gallons, and someone else says a spill is anything over 5 gallons, and you merge those databases, you have a real problem. So, going back to the various databases and having a clear idea what is already in there—there was some long discussion about how people are going through and pulling data off the web and doing quick, ad hoc analyses through them, making bold statements, and they really don't know what the underlying data were or the definitions of what they are dealing with. This can be very problematic.

What is the alternative? The alternative is to have all the data secret or hidden or password protected, or you pay $1.00 to look at it, and you can control access. So, there are two sides to the coin about how public and how private this should be. But you are absolutely right.

Comment: It is interesting because in the '60s and '70s, the International Chamber of Shipping had an excellent program that had fire and explosion accidents, tanker accidents, navigational accidents, many things like that. It all fell apart around 1980 because of concerns about leaks. You can't overestimate the impact of that on people being willing to even have something reported anonymously. It is a huge problem.

Comment: What you are saying is there are three problems here. One is that we don't really know the status of who has what current data, the reliability of it, and the pluses and minuses to all that is out there. Second, whether they are near-miss data or any other data using some of the existing data sets, there are legal implications on who holds or who releases the data that have to be overcome. That has to come primarily because for the data to be widely accepted and used in risk analysis and decision making, they need to be available to the public. So, there are really three somewhat separate issues. The question I have is this: Did your group discuss who, where, why, or what might be a method base that has the potential to do that sort of thing?

Answer: We talked about the need for a trustworthy organization, one that is, in fact, removed from the biases you might find. So, the IMAS people are going to come here and tell me who that contractor is who is going to maintain that database or how that will be collected. There is a very strong need to make sure the controlling agency is above reproach and that they can be trusted. They have to be shielded from the legal onslaught that is going to occur.

Comment: What I'm hearing you say is that, even if we assume we can overcome the issue to be near-miss systems, there are broader issues relative to currently available data, let alone who we get it from or if we gather from the right sources, that have to be looked at. If we can get one system to work, we have to start somewhere. If we can get the incident material in place and working, that would go a long way to showing everybody else that we can get over these hurdles and the end result is valuable for business, for reduction of risk, for saving the environment, for all these different reasons. You then get real big payback at the end.

Question: I was going to ask if you discussed quality management techniques as a method of incorporating this—if you are an inherently competitive industry and if each company addresses it internally as an industry-wide practice?

Comment: Good data collection is good business and improves performance, absolutely. There was some discussion about some organizations that people had witnessed that had collected no data. They were operating big things in dangerous waters and they had no data. So, there is an amazing variety. Some companies track washers and find out how many have been used. Others operate and don't collect anything.

Question: ASRS didn't start out with 34,000 inputs a year. It took 10 years spool-up time. But, if you look at the previous attempt in 1980 for the ship equivalent incident database, that was about $10 million a year for 4 or 5 years. That was $50 million down the tubes. Not only that, but it hurt the possibility of it ever happening again because people are still around from 1980 and they are the ones who were burned and they are still here. To get them engaged and involved again requires some real guarantees. But, without that, without one of these steps, taking one of these databases and getting it going and demonstrating the availability, the applicability, and the viability of such a database, we're going to be spinning our wheels again and we'll come back in 5 years and have the same discussion again.

Question: One useful point of input, one of the most useful databases that we've found, is in the insurance PMI direction. The investigation reporting of the accidents is good and it incorporates a great deal of the human factors information. . . .

Comment: Analysts know where the data are. But, to know what data are out there, where they are, and the quality of that data and who to call to get that data, it shouldn't be a secret handshake. It has to be opened up and made available to people.

Comment: The first lawsuit that goes after that data is yet to come. Someone is going to sue to find out the data. We have to have things in place. We have to be proactive and understand that now. This is the reality. This is the world we are working in.

Discussion Group 3

Real-World Applications

Chair

Anthony Taormina, *Dames & Moore Group*

Panelists

W. O. (Bill) Gray, *Gray Maritime Co.*
Paul G. Kirchner, *American Pilots' Association*
Rod Vulovic, *Sea-Land Service, Inc.*
David A. Walker, *ABS Group Inc. Risk and Reliability Division*
George F. Wright, *U.S. Coast Guard*

Discussion Paper

Roberts, Karlene H. The Real World: Blooming Buzzing Confusion. (See page 30.)

Description/Objectives

This session covers application of both the theory and the use of data combined with the experience of those on the waterfront in application of risk assessment to specific aspects of waterways management. Some phases of a project may require more exacting compliance to the theories and better data and others may be done within a risk assessment framework to accomplish a balanced and appropriate evaluation of the interrelated risk present in a crowded waterway.

Summary of Discussion

Presented by Anthony Taormina

We are going to change our discussion a little when we talk about the real world. John Garrick talked some about the practical world and Paul Fischbeck talked about data, and I heard normal operations. I was given the task of talking about real-world applications. I'm a port director, so I defined the real world as the waterfront types, and our panel represented what Nancy Foster was saying in yesterday's presentation with NOAA—this puzzle of many different and competing interests coming together, and they all appear to come together at my house, down on the port. So, when I started out in the port business, I came from the public policy side and not from the marine transportation side. In my earlier days in San Francisco, when I was at the Port of San Francisco, we were thinking in terms of urban waterfronts and urban planning but from the perspective that public policy is really formed at the neighborhood level, as we interpret real-life situations on a day-to-day basis and then try to convert that into public policy for the whole. That is what we tried to do in our panel.

Our panel tried to develop products related to areas we thought were key themes for the symposium. Those themes are basically techniques and tools, management approaches, and policy recommendations.

Policies

We classified the themes into three areas. Starting with policy (Exhibit 1), one of the things we talked about early and emphasized was that, in all our discussion of risk management, people are important. As we look at the waterfront and the changing aspects of the waterfronts—issues of the cruise lines and issues of the shared waterways—one aspect that any national policy relating to risk management has to take into account is that at the basic level that I deal with on a day-to-day basis, people are very important with respect to use of our waterways.

To that extent, we see a changing phenomenon. Come to Gulfport, Mississippi, where I am the director, and you will find that not only do we have the normal waterfront activities associated with the port, but we also have things

EXHIBIT 1 Policies

- The Marine Transportation System risk management policies should address all aspects of the system to include people and freight (cruise ships, cargo, shared waterway users), as well as a system of vessel, wharf, terminal, and intermodal connections and it should include all agencies within the Department of Transportation.
- Policies relating to marine transportation risk are needed at the local, regional, state, and federal levels as nonmandatory guidelines as opposed to regulations (e.g., take advantage of local users and knowledge such as the Harbor Safety Committee model with pilots, local regulators, port authorities, port users, and vendors).
- Risk management policies and implementation can be used to broaden the public's understanding of the Marine Transportation System (e.g., the public's perceptions are often built on adverse significant events reported on CNN).
- Risk management policies are most effective when they help define the acceptable level of risk.

such as gaming casinos. One of the things we talked about was having a banana boat and a gaming boat vessel meet in the harbor; suddenly, risk management is a very important aspect of my board and my state.

Another aspect is whether policy should come from a bottom-up approach, taking advantage of the local users' knowledge. This involves the harbor safety committee models that we heard about in California, including the pilots' local knowledge. In this approach, we can see these groups providing guidelines that can be developed at the regional, state, and federal levels, taking advantage of the uniqueness of the waterfronts. We talk in terms of ports and we talk in terms of marine transportation systems, and when you look at the gamut of ports, both inland and coastal, they are quite different; for example, look at New York/New Jersey and look at Gulfport. We need to broaden the public's understanding of what is happening on the waterfront. The public perceptions are often what people see in the news media, on television, whether at the Port of Gulfport or in New Orleans.

The theme of education arose in our discussion in the sense that we need to educate people about the waterfront. That is a theme I have heard previously at many Transportation Research Board activities—that we need to educate people about freight. Effectively, that is a lot of what we are involved in. We hear normally that much of the funding goes to public transit and the highways, because people vote and freight does not. To the extent that we look at our merchandise and our markets, people aren't walking in and saying, "Did this come on C. H. Hunt's truck or which truck and what port of entry?" Basically, people expect merchandise to be there. When it is not there because of an accident or incident, then, in fact, it is the policy people who are trying to find out what happened.

Over the past few days I've heard a lot about our tankers, and I've heard a lot about vessel and risk management. But when I came here to talk about and hear about risk assessment, it was about a marine transportation system. That system involves vessels, it involves our wharves and our terminals, and it is very much conditioned upon our intermodal connections.

In Gulfport, probably the biggest question we will address, as in many ports, is the grade crossing just north of the port where we are bringing our rails and the containers in and out of the port. That is the site of more accidents than occur on the water side. So, whatever we do in the policy areas, all the agencies within the Department of Transportation need to be brought together because effectively we need to address this as a full intermodal/multimodal system.

Someone asked what to do about it once you determine the risk. We need to be able to have some basis of being able to determine what an acceptable level of risk is for the various port authorities. To some extent the harbor safety committees in the California model certainly addressed that issue—look at Port Hueneme and the Los Angeles–Long Beach areas. That kind of discussion needs to elevate above just the people on the committees. It needs to be brought to the policymakers so they will know what level of risk is acceptable.

Management Issues

We tried to define what we call management issues (Exhibit 2). Some of this is relatively repetitive in the sense that, when we look at risk, we need to look at it independently for the various segments of the pipeline. But we also need to look at it collectively.

Risk assessment must include a future state of our marine transportation system. We hear a lot about megaships, particularly at the port authority areas—everybody is looking at what is going to happen to the large containers. One person in our panel said, "Let's remember the megaship and the large container; we also had a period of time where we had the supertanker and what incidents occurred as a result of larger tankers?" Is there a relationship there? In some cases, real-life issues to me mean what we are going to do, how we are going to dredge our channels, and how we are going to dispose of the materials from our channels to be able to maintain that pipeline.

EXHIBIT 2 Management Issues

- Risk managers need to evaluate risk associated with waterways, vessels, terminals, and intermodal connections independently and collectively.
- Risk management assessment should include the future state of the marine system (e.g., megaships, increased cruise ship traffic, redeployment of vessels to new routes).
- Risk management needs to be included in early design phases and to focus on the interrelationships of people, design, organization, and systems.

To that extent, we need to be looking. Today I have to be thinking in terms of not necessarily what the Port of Gulfport should be reacting to today, but what is going to be our 5-, 10-, 15-year horizon. We see different dynamics as larger cruise ships come in. Now, all of a sudden, cruise lines are looking for different ports of call. All of a sudden, Gulfport could be a port of call for a cruise line. So, we may not necessarily even have a system that would be safe or prepared for that type of activity. But, I'll guarantee you this, if I bring the cruise line to the Port of Gulfport as a port director, I've secured myself a contractor for at least 10 years at that particular port because it has a very attractive aspect.

We all agreed in our discussion that management needs to be early in the design phase, whether in the instruction of our vessels or in the construction of our terminals. We need to be able to look at how to incorporate that in the early aspects in all phases and to focus on the relationship of people designing an organization system. Dr. Karlene Roberts had a great line when she presented her paper—I won't try to repeat it here, but the aspect that I took from it was an interrelationship. We have to be able to put human elements into the areas that we are looking at in our design, whether it is the bridge design of our vessels or the terminal design of our facilities.

Tools and Techniques

This is the third element I was asked to talk about (Exhibit 3). Some of the tools already exist, so we don't necessarily need to go out and reinvent them. We need to enhance, to educate, and to raise understanding of tools. The captain of the port at our session talked about the port's state control system. Bill Gray talked about the need to step up inspection of our marine terminal facilities to the extent that we may have the greatest ships in the world, but the connection between the vessel and the terminal is as much of a risk as the vessels themselves. To some extent, if we have many different types of vessels calling at our ports, we have many different types of terminals and levels of expertise in management at those terminals throughout the United States, both in the inland waterway system and in our coastal areas.

EXHIBIT 3 Effective Tools and Techniques: Existing and Proposed

- Utilization of the U.S. Coast Guard Port State Control and inspection of marine terminals (existing).
- Improvements in vessel traffic systems in association with the local Port Safety Committee System. American Pilot Association course training and better communications at the port and harbor level (existing).
- Better hydrographic information on our channels and harbors and application of international positioning standards and redundant systems (existing).
- A national reporting system for vessel incidents that includes human systems within the databases (new).
- Implementation of risk analysis that fits the situation and organization (existing).

Vessel Traffic Systems

Basically, vessel traffic systems are very important and are part of our overall risk management at the port level. Again, the California model for oil spill response, harbor safety committees, is a prime example of that to the extent that the vessel traffic system does not necessarily have to be the same for all ports. What kind of communications exist? What kind of pilot training? How do you use the pilots? At a port authority, we see the pilots as an extension of our risk management and activities and tools and techniques. We rely on them to be able to tell us what is happening in the channels.

One of the comments we made at our discussion groups was whether at the same time the port authority acts as the licensing board for that pilot, are they reporting all the incidents to us? Or are there some issues that we must look at and address?

Hydrographic Information in Channels and Harbors

We need to have good information—good data for our channels and harbors. This appeared to be a theme that came very strongly from some of the vessel operators' aspect of looking at the ports—looking at some type of international positioning standards and ensuring that we have a set of redundant systems.

One of the things we talked about was pilot incidences and near-collision incidents and we know the vessel traffic systems have some way of reporting this information, but again that is unique for some ports: Gulfport, Mississippi, or Mobile, Alabama, or in some cases the Mississippi Sound—there are a lot of shrimp boats out there. But we have a lot of other types of activities. There are cruise ships going into other markets. There are ferries. We need to have some type of national reporting system for these vessel incidents, and we must ensure that the human system is basically developed within the databases.

Finally, risk analysis needs to fit the situation and the organization. Too often I'm in a situation in which I have to make a decision. I have a commission meeting every 2 weeks. Someone says, "We want to know what the risk is in making a particular decision. Should we allow this to occur at the port?" Generally, they ask that question with political motivation. Too often, if we begin using risk assessment and management as a political tool to make decisions at the port level, then, in effect, we are going to be influencing people's views and attitudes toward risk management. To that extent, we need to have practical tools and applications that I, on a regular basis, can apply at my level and at all levels that meet the real-world situation that has some credibility, some truth that stands behind it, so that we can make credible public policy decisions about whether we want an ammonia nitrate vessel to call at the Port of Gulfport. Clearly, when the U.S. Coast Guard looks at regulations, they don't have the discretionary ability to say, "We won't allow that to occur." They can only say, "Here are our regulations." But I have to determine whether it is good public policy for that vessel and that activity to occur within my port.

Questions and Answers and Discussion

Comment: I want to respond to something you said about policy and implementation in risk management. I think it is important to acknowledge that, in the real world, broadening public understanding is neither swift nor inexpensive. We tend to talk about that in conferences like this, and then we go away and don't allocate resources in our organizations to accomplish that task. Using the risk assessment study in the Prince William Sound as a case study, part of the reason why it has exceeded its original budget by multiples is because it was a multistakeholder process. Multistakeholder processes are not cheap. The analogy I want to draw is to consider General Grant's campaigns in Northern Virginia in 1864 and 1865. They were incredibly wasteful in Fredericksburg, Spotsylvania, and Chancellorsville, yet he won the war. But it was an incredibly wasteful effort to get there. I'm not saying that waste is justified. I'm just saying that a certain component of it is inevitable.

The other thing I want to say is that the use of the term stakeholders, which we have talked about, has come to validate the participation and role of self-appointed spokespeople for the public who may not represent many and are accountable to few. I think as we talk about stakeholders, particularly in a local setting but also in a statewide setting, we have to ensure we are talking about the people who in fact represent somebody. There is no reason why environmentalists as a category should have standing in decisions over, say, single mothers.

Comment: Our port has already started a K-12 curriculum that we introduce in our school system about freight and about transportation. We are basically forming strategic partnerships with the University of South Mississippi to begin putting our issues on the table, . . . as an intermodal transportation. I think we have to start it from the bottom up, and it is going to be a long process.

One of the things I want to build on is your comment about fitting the risk analysis to the situation or the organization. In that context, the diversity of the marine transportation system has been well discussed, at least at one level. In a tactical sense, you might need to do some analysis to help you make your individual decision, but it is not a one-round game. A set of decisions will be made by a set of players and the risk analysis needs to be fit to the situation that crosses those organizations and those decision makers. Those decisions are mutually dependent. If you make a decision about a cruise ship, and then the cruise ship operators make a decision about how to maximize their efforts in that port, then there is another series of decisions and another series of mutually dependent decisions—it is not just a risk analysis for the one decision.

Question: In those decisions, who is leading the way?

Answer: Generally, at the port level, the market is leading the way. We are market-driven individuals. For example, Carnival Line comes to me and says, "It is less safe for me to go up the river; I've got to go up the river to New Orleans to make a port of call. If you can meet my commercial criteria, we'll bring our vessel in there." Generally, that is, it will reduce overall costs. They don't come and say, "Is it safer in Gulfport?" No. So, the market drives the machine.

DISCUSSION GROUP 4

Agency Integration and Cooperation

Chair

Rear Admiral Robert C. North, *U.S. Coast Guard*

Panelists

Lillian C. Borrone, *Port Authority of New York and New Jersey*
Todd Bridges, *U.S. Army Corps of Engineers*
Gus Elmer, *SeaRiver Maritime, Inc.*
Nancy Foster, *National Oceanic and Atmospheric Administration*
Alexander C. Landsburg, *Maritime Administration*
Douglas L. Slitor, *Minerals Management Service*
John Torgan, *Save the Bay*
Craig Vogt, *Environmental Protection Agency*

Description/Objectives

The federal agencies charged with various aspects of the marine transportation safety and regulatory regime are seeking ways to measure and quantify the level of risk in any waterway and the risk reduction value of various safety interventions. Several risk assessment models are in use or are planned for use soon. This session addresses some of these plans, their goals and objectives, their methodology and data requirements, their strengths and weaknesses, and the underlying policy that supports them.

SUMMARY

Presented by Jeffrey P. High for Rear Admiral Robert C. North

Rear Admiral North, leader of this panel, sends his regrets this morning. He would love to have been here, but pressing business drew him away.

The panel consisted of the federal members you heard from yesterday, with additional participation of Tom Wakeman of the Port of New York and New Jersey, Gus Elmer of SeaRiver Maritime, and John Torgan from Save the Bay.

Admiral North opened the session by referring to the remarks of the federal panel and the lunchtime speaker Vice Admiral Card. Then Admiral North led a group discussion by posing the following questions:

- How do we begin to build risk-based culture where none exists?
- How do we get the Prince William Sound risk management back on track?
- How should we document lessons learned? Best practices?
- How should we treat very low-probability/high-consequence accidents?
- Should risk models focus on narrow or broad issues or both?
- How often should risk analysis be reviewed/updated?

- What kind of protections/encouragement should we have for vessel owners to participate in near-miss incident tracking?
- How can we use risk when a catastrophe occurs and public pressure is intense?
- What are some other examples of risk assessment and lessons learned?

After the discussion session, Admiral North and I were deputized to take our discussion topics and divide them into three categories: tools and data, management approaches, and policy. Because we had some other good thoughts to capture, we added a category called discussion and observations.

Tools and Data

- Definition and standardization/tools and compare results,
- Methods to obtain accurate/honest data (data quality objectives),
- Standards for data collection,
- System to deal with uncertainty of data values (variability),
- Broadly focused tools (mission impacts and business interpretations), and
- Look at other databases (National Safety Council, OCIMF condition reports, Department of Energy data).

A lot of things here are very similar to what you heard before. We had a lot of comments about data standardization. The data ought to be standardized; we have to find some way to make them more accurate; there must be some definition to them. We have heard these themes this morning. For the purposes of getting the tools right, for getting the terms right, for comparing results, we needed to have some standardization or methodology.

We also talked about a system to deal with uncertainty of data values. The problem is that when data points are averaged they tell one story, but the picture may be different when you look at specific data. Sometimes, the data values vary considerably. We have to find better ways to compare things.

Broadly Focused Tools

We concluded that we need something that can help us look at mission impacts and business interruptions, something a little bit broader. We need a tool set that will give us broad as well as narrow indicators.

Looking at Other Databases

The data group did a great job listing various databases. We had another—OCIMF, the Oil Carriers International Maritime Forum. I think the data group had all the others. The Department of Energy has some data as well.

Management Approaches

- Local coordinating committees (area committees), nonregulatory guidance;
- Measures of effectiveness;
- Investigate concept of index (positive) based on a set of criteria; and
- Refocus risk from avoiding loss to enhancing performance (anchor to vision).

We talked about a number of potential management approaches. This is a list of just a few. One of the things we talked about, and this is a theme that came from the Marine Transportation System (MTS) national conference that keeps coming up, we need some sort of local coordinating committee—an area committee or a harbor safety committee. We need some sort of scheme that helps folks at the local level and gets all the stakeholders involved to come together and talk about common issues. Another thing we talked about is that it would be great to have nonregulatory guidance coming from these groups. It does not have to be a government entity—state, local, federal, or whatever—giving out regulations; it should be the real stakeholders, if we can identify them, who come up with the guidance.

We talked about measures of effectiveness. We talked about investigating a concept of an index—an index to get us at 20,000 ft and looking down. And maybe a positive index instead of a negative index. There is a fear of always citing problems. That index ought to be based on some sort of criteria. We did not have a scheme on how to do that. That would be difficult. Nevertheless, we talked about that as something we ought to have.

Then we talked about refocusing the discussion from avoiding a loss, the negative, to enhancing performance, a positive. For example, there is a vision statement for the MTS that has a very positive tone to it. Perhaps we need to use that as our objective. Those are the management approaches we discussed.

Policy Implications

- Emphasize International Marine Incident Safety System (IMISS), confidentiality (capture all), use third party;
- Long-term waterways management through continuous updates;
- Cooperative reviews;
- Identify a responsible and accountable party (champion) to focus on data integration, provide resource support;

- Address ongoing operational environment;
- Consider environmental issues up front;
- Consider more complete record keeping and disclosure—for example, incident response forms should be fully filled out, and traffic should be reported periodically (monthly-daily);
- Risk assessment for all federally significant plans (Environmental Impact Statement trigger);
- Risk assessment to enhance competitiveness worldwide;
- Teach risk assessment (or the positive version of it) to all in the industry—for example, a U.S. Coast Guard roadshow to all harbor safety committees.

Again, there is no specific order to our policy ideas. These were the things that resulted from the brainstorming. For example, the IMISS—the whole idea of finding ways to capture information and providing confidentiality (and all those things you need to do to try to get the information that they enjoy on the aviation side, as we heard earlier in this symposium).

We need to use a third party. Maybe even NASA is a place to do that. We need someone who can be trusted to provide confidentiality.

We talked about managing the waterways over the long term by using some sort of continuous update to risk assessments. In other words, it is not just a specific assessment and then it is over and done with. You must keep after these things to determine trends.

Cooperative reviews means that we ought to involve all the right players. We talked about identifying some responsible and accountable party, perhaps a champion but, more than that, someone who is going to actually take this job and focus on integration of the data. That doesn't mean own the data, it doesn't mean do the job, and it doesn't mean it has to be a federal entity. But it also doesn't mean that it must be a commercial activity. This simply means someone has to be responsible and accountable. Because the Coast Guard was mentioned, I'll let you know that the Coast Guard has a strategy that says that we wouldn't mind being an "information broker." However, we understand that there are lots of players—for example, the National Oceanic and Atmospheric Administration and the Corps of Engineers—who are providing data. We're not out to capture any parts of those organizations or to capture any commercial activities. But we see this as a responsible role. It will not be cheap, as someone said earlier, so there are some resources that have to go with that.

We discussed the idea of addressing the ongoing operational environment. It is not just the catastrophes. We also need to focus on the constant risk management and risk assessments of what is happening on a daily basis.

Then we wanted to reemphasize an MTS national conference recommendation that environmental issues need to be considered up front. After the fact is too late. We want to find them in the beginning.

One specific suggestion was related to availability of the data—who gets them. We need to make data more complete and to disclose them more widely. A specific idea was to fill out the incident response forms more fully and maybe even provide traffic data to some of the players other than the ports and the shippers. For example, maybe people with environmental interests would like to see this information more frequently.

Risk assessment for the federally significant plans was another specific point. The idea here is that events like Environmental Impact Statements might trigger the need to do a specific risk assessment.

Next we discussed the idea of using risk assessment at the very grandest scale to enhance U.S. competitiveness around the world. Again, no answers about how to do that, but that is certainly something we thought someone should be looking at.

Our group also discussed teaching risk assessment, the whole idea, to the public and to industry. Someone suggested that the Coast Guard take a road show out to the harbor safety committees—another great idea and it can be done. In fact, the Coast Guard is looking at resources in future budgets to try to make sure we can handle things like that.

Observations and Discussion

- Research on double hulls (structures and alternatives),
- Tell the public what we are planning to do on risk assessment,
- Dialogue on overall risk assessment (determining priorities on MTS),
- Need to foster commitment to the process (national and local), and
- Liability (civil and criminal) in marine industry inhibits data gathering.

Admiral North and I pulled these things out as additional observations and discussion items. My sense was that the group did not quite reach consensus on all these points, but they are worthy of discussion. Again, these are in no particular order. For example, we talked about needing risk-related, but relatively specific, research on double hulls. I thought this was kind of a special item.

We talked about telling the public, in general terms, what we are planning to do with risk assessment. That is a little more than just educating people about how it works; it includes pointing out that we are going to go and apply these kinds of tools out there. That is something we should be doing.

The third point—dialogue on overall risk assessment—means the whole idea of discussing what it means from an overall national perspective to have, perhaps, 300 deepwater ports around the country. We are not advocating that any of the government agencies, or anyone really, should be in the business of deciding who is going to have what kind of port. We are not talking about that. But, we are suggesting that maybe there should be some groups who get together and talk about national issues. Maybe we need some dialogue on that. I'm not sure we had consensus on that.

Of course, we need to foster commitment. Again, I heard this in other sessions. If we are going to use risk assessment, if we are going to apply a process, and if we are going to have some common definitions, then we need some commitment to this process. Then when we apply it, we have some basis for making decisions. So, that is a key. That requires education. It requires trust, and I think it is the key to success.

Finally, something we have talked about a lot—the liability issue. There are no limits on liability in the marine industry. Aviation has some limits. There are criminal as well as civil liabilities, and that certainly inhibits the data gathering, and so we talked about that as an observation.

That concludes my briefing, and I'll be happy to address your questions. I also invite the other members of my group, and/or anyone in the audience, to address any of these additional observations.

Questions and Answers and Discussion

Comment: The notion of giving some sort of immunity for industry reporting on near-miss and other casualty data has come up in everyone's panel so far, and I think there may be a perception that there are folks out there to get these shippers—people or other companies. I can say, at least on behalf of my group, we absolutely support some sort of amnesty or immunity in that a reporting system should come through a third party or independent agency. If data are given anonymously, they are not disclosed in a way that would affect competitive practices and reliability for prosecution. Getting a creative strategy like that might actually get the data we are talking about. That is one point where I think there would be consensus. There should be no disagreement about the fact that it is a freedom that should be afforded to the industry.

The other thing is that there was some sort of discussion about whether risk assessment comes as a nonregulatory advisory set of guidelines or whether risk assessment is mandated in the process in one way or another. I heard in our panel that local and regionally specific risk management is key to a particular port situation and that some sort of enforceability and some sort of guidelines for risk assessment are needed. There is also a demand for risk assessment lessons learned, which come from planning projects or which come after a major collision incident or grounding. For it to be really effective, it needs to have some enforceable provisions, but it should be incorporated into the planning process on a local or regional level.

Comment: That is a very helpful statement. I would also like to add—and maybe Alex Landsburg will comment on this too—we should make a distinction between so-called hazardous condition reporting (where no one has been injured, no life has been lost, no oil has been spilled, or something like that) and some actual incident or accident in which obviously you don't have a blanket immunity if something has actually happened. I would also like to suggest this: just as the aviation people have NASA to be the honest broker, the maritime industry needs something like that. I don't know that much about it, but the National Transportation Safety Board has a separate charter that allows them to do some things in a different way. They also have marine activity there, which has improved a great deal and is very helpful to the industry. That might be the consideration to draw them into the discussion.

Comment: The concept of the IMISS system is to be anything that is not already reported, such as accidents or incidents, to gather the entire scope of things including some safety thing that somebody identifies or believes in their mind is important.

Comment: Anyone who walks around at an industrial application or on a ship or a terminal or something like that can see hazardous conditions that nobody is doing anything about. That is the very thing that is needed. Liability-free reporting of incidents is a very positive way to do it—to encourage that to happen, just as it is happening in aviation.

Comment: From the harbor safety committee point of view, I thought your point about having environmental issues looked at earlier on, up front, really makes sense. It certainly did for us, and I think others here from the harbor safety committees will agree. It is very valuable having that kind of input and back and forth going on early on.

Comment: I request that Jerry Aspland share with us, if you can, a vision of how to engage the mariners in this process. Are we looking at government regulations through the Coast Guard or that type of thing?

Comment: To the gentleman in the back, you can do risk assessment in your port area today without all the numbers and things. If you sit with a group of people who, in fact, believe in protecting your port area and you get people from all aspects, and you very carefully look at your area, you can pick out those places where you have problems from a risk standpoint. It has worked a lot. It works a lot in California, and it has worked in the state of Washington. And, believe it or not, it also worked in the state of Alaska for a while. So, you can bring people together if you come with the right attitude to sit down and put these things together. It is not that difficult.

Comment: There is one thing we talked about yesterday but haven't heard too much about elsewhere, and that is the other level of risk management that exists. We can call it the micro level. There are individuals who do risk management every day as part of their job. It is not just pilots—there is certainly the captain of the port and there are people in the nuclear reactor facilities. They follow the model that we have been talking about here for larger types of risk assessment and risk management. They collect data. They analyze data. They assess the risk and evaluate the risk, and they choose an appropriate course of action from among the alternatives. One of the things we are seeing is that in the training of individuals who do this type of work, we are trying to get them to think about what they do in terms of risk management. They are not really doing anything they didn't do before other than looking at issues in a different light. Frankly, I don't know if there is a value in that. But, that is where we are going—to think about what they do in terms of managing risk.

Comment: If you can explain what people do in a different light, maybe they can see things more clearly. If we apply what is taught in the mariner's resource management courses, it will reinforce the idea that they assess the quality of the resources of the ship from the moment they head out to a ship. That is a technique they have used all their careers. If they think about it in a different way now and think about other techniques, they will be able to improve other practices as well.

Comment: It would be helpful if there were some standard terminology or a standard way of looking at things, even informal kinds of things. If everyone thinks in the same terms, it is easier to share information.

Comment: The big issue is to teach tactical risk decision methods and risk analyses. All the things people talk about appear to focus very much on detailed quantitative risk analyses, but we need to apply our risk analysis to all the different types of decisions we need to make. On the model from the chemical industry, they are not doing detailed quantitative risk analyses on all the processes. They are using more informal things where they bring subject matter excellence to people who run the units and maintain the units, capturing their information. I think that is going to be a good model for the marine industry as we look for a broad spectrum.

Comment: I want to clarify one point on the cooperative reviews. You had that under policies. When I brought it up in the discussion, it was more in the context of a proactive tool that might be used. Just to give you a quick context, it refers to an existing program. We challenged the industry to develop a safety and environmental management program and to develop some components that would be useful for them to manage their industry in a safe manner. It wasn't a regulation. They wanted to stay away from that. They did that. API came out with RP75, and it was a good document. People used that to model a safety management program. Well, we also didn't want it to just sit on a shelf. So we got together with some of the companies and we said, "Let's try to do some cooperative reviews. We are a regulator and we will not give you any penalties or infractions or anything like that. We will go to a facility that doesn't know we are going to go there, we will work with the platform foremen, we will walk through the entire process there—looking at how they communicate and how they deal with hazardous operations and all the other components in there." That has been a very useful experience for both our agency and the industry itself. They have found out a world of information. They were assuming certain things that were just incredible. To be able to actually talk about it and see how it worked in their facility has been a great benefit.

Symposium Summary

Thomas H. Wakeman III, *Port Authority of New York and New Jersey*
Peter F. Bontadelli, *PFB and Associates, Sacramento, California*
Jeffrey P. High, *U.S. Coast Guard, Washington, D.C.*

Variations on the Risk Management Theme

Thomas H. Wakeman III

Initially when I became involved with this symposium, I thought risk management was something out of the ordinary. I thought it was a complex formal process that was implemented under special conditions or in specifically selected circumstances, like an accident. I did not realize that I already used it in my job.

Over the past 2 days, I have learned that there are many variations to the risk management theme. One observation is that I have a different way of seeing some of the material that has been presented. I found that I actually took a different point of view than my colleagues who sat at the same table and listened to the presentations. We each distilled what we heard in different ways and from different perspectives depending on our positions and responsibilities. I want to share what I heard.

What I heard from the first group, I heard as a manager. I learned that I can embrace risk management as a way to improve decision making, as a way to allocate resources, and as a vehicle to assess the utility of contingency plans. Everything has a risk aspect. It is just that, in my case, I count it in terms of dollars. How can I use risk management in a way to formally help me improve and provide credibility in decision making? So, for me, the first group was about how I could use risk assessment and management to improve my decision making.

What I took from the second group's presentation was that I must determine when the data are good enough to make a decision and at what level of uncertainty. I sometimes fool myself about uncertainty when I make an absolute decision because then I have to defend that decision. But, I would like to know how good the data are and what their level of certainty is so I can know when to back down, because sometimes that is the best decision.

The third group illustrated to me that risk management is all about tradeoffs. Risk management is not just about the risk of a vessel collision on a waterway. There is the risk in a whole bunch of competing aspects of the vessel's movement. For example, megaships are an economic risk. If we don't take steps as a business and a labor conglomerate to address the coming of megaships in the Port of New York and New Jersey, then we run an economic risk. But at the same time, to service that megaship, we must address increased dredging requirements and increased congestion in the harbor because we are expecting a 300 percent increase in dinner boats and recreational users. If we don't deal with these aspects of megaship movement, that is a risk. There is an environmental risk. If we modify the harbor with deeper channels and new expanded terminals, what are the environmental tradeoffs? There is no free lunch. Someone has to make the decision, and risk management is an important tool to help improve the quality of that decision making. It also improves our ability to establish credibility in those decisions among competing demands and political realities. Political realities are part of the real world.

The fourth group illustrated to me that we need a change in our bureaucratic culture. The narrow communications of the stovepipe process used in federal agencies or within individual regions doesn't work anymore in the global network. That change has to begin with something, and risk management appears to be a good place to start. What do I mean? Not long ago, I participated in a national contaminated sediment conference focusing on how to deal with the problem. The discussion began around 1980 regarding the issue of contaminated sediments and the need to deepen our harbors. The National Research Council came out with a report on the subject in 1984, another one in 1989, and another one in 1994. They all said the same thing. The sediments are contaminated, and the harbors need to be deeper. What are we going to do about it? Well, while we are struggling in ports on an individual basis about these issues, there is no national risk assessment of the tradeoffs regarding either the sediments or the requirements for dredging. It appears that all these things are too complex; if they were simple, we would hold only one conference and write one report. But, they are not, so I guess we have to be optimistic about it—we also could apply a risk management approach.

We've all been using risk management—some of us in a formal fashion, some of us in an informal fashion. But, to gain the good that can come from this symposium, the opportunities, we must synthesize the essential recommendations from our discussions. The foremost recommendation was that we need to have a more standardized process for the maritime industry. That was a strong theme that came from the first group's comments. We need to get a consistent set of methods, standards, and data definition, and this needs to be done up front and should include the environment, the stakeholders, and all the other good things we have talked about. So, this is very broad and encompassing, but it needs a methodology that is defined and that we can follow.

When you sift through the various things that were said about data, one thing that reverberated again and again was that we need to go ahead and get this incident reporting system in place, and it needs to have liability protection. I don't know exactly how to do that, but it is very clear that a comprehensive database is the starting point for doing things differently.

The third group said, "We have to look at the real world." The real world is about a lot of these things. For example, many ship crews don't speak English, and they are going to have a tough time filling out questionnaires. But the real world is also about competing demands. The stakeholders must participate and buy in to the process. They need to be educated about the value of the process. To do this, we have to have the ability to present it in a transparent fashion so people can understand what is being done.

The fourth group looked at federal entities. But, recognize that it is really a series of tiers—international, national, regional, and local—that do decision making and therefore need to use risk management as the tool. The synthesis of that group was that we need an entity that is responsible and accountable for gathering all the data and making them available widely to all the decision makers, regardless of their tier. The Coast Guard was mentioned as a possible agent.

An Integral Part of Decision Making

Peter F. Bontadelli

One of the points I want to make is that the three of us come from slightly different points of view, like many of you in the audience. As a result, I think we might have heard some slightly different things out of the summations that came in this morning and in the groups we participated in. One issue stood out for me, and maybe it was an item that was said in our group, and that is that risk management and risk assessment, contrary to what may have come across, are not new. They are done every single day by every active mariner, every pilot, and every player in the field. What we haven't done is to put them down and analyze them and use them as integral parts of decision making. Although we can learn lessons from what has come from other industries, in the maritime community we also have to rely on that expertise and opinion and find a way to integrate that as part of our data sets and in helping to shape the political framework in which the risk management decisions are made.

Group one emphasized that we need to pull out the information on methods and methodologies, and we need to find, coming out of this, a recommendation on how to accomplish that. That will be part of the follow-up that we will be working on.

The data information group was very clear on two points—not only the near-miss reporting, which is a great first step, but the fact that there are a lot of excellent data out there. However, there are real questions about the data. They probably need to be looked at from the standpoint of how useable they are, how reliable they are, what types of things can be put into the data, so that every time, individually at a port level, industry level, or government level, you start going through one of these, you aren't starting from scratch, as if there were no yesterday. Some of the points that Jerry made are critical to us. The fact that there are qualitative as well as quantitative data is a critical issue. Jerry, that is one of the key points that I think you were trying to make. Until we start learning to use some of that qualitative understanding of the people who use risk-based decision making in their day-to-day activities and integrate that into our shaping of the framework for risk management decision making, we won't be able to do the job effectively and well.

Group three made clear something that jumped out, and that is that it all has to be done in the real-world context. The decision making, as Tony pointed out to us from his standpoint, is not a problem as long as he can count to three on his five-member board; everything else seems to work. The issue of integrating risk management into the whole decision-making train of thought for every phase is critical and something that comes across all the way through.

Decision making and risk-based use of the decision making are integrated in a multiple series of things: individual decisions made by shipping companies, individual decisions made on a decision to cite something at a port or not accept it, the larger process of using a vessel traffic information service or other method of adjusting waterways management, and the larger picture of the overall marine transportation system all revolve with a degree of risk and risk tradeoffs that get made every single day. Understanding that and putting it into context, pulling out, building on some of the things that came out of this conference, is a lesson that made sense.

The fourth group talked about the federal agencies' roles—my view was that they are the poor folks who get stuck figuring out how to integrate and use some of this stuff. We hope each of you got something positive from this and that the proceedings that you get later will be useful to you. So, those were the issues that jumped out at me, and I think they build on what Tom gave you.

Compiling the Efforts

Jeffrey P. High

I want to use my time to tell you the context in which this information will be used for the marine transportation system initiative. First, the marine transportation system effort has been a series of events. We started with regional listening sessions last spring. There was a national conference in November. Since then, a task force has been formed at the direction of Congress. The first meeting of the task force was March 12, 1999, and there will be one more meeting. From that effort, we expect that a national advisory council will be established. Certainly we are going to build on the success of various harbor safety committees and the other local committees that can and do use risk-based decision making.

So, what is going to happen here? Here is the time line: the report to Congress is due from the national marine transportation system task force on July 1, 1999. That is fairly soon. To prepare for that, the final meeting of the task force is the middle of May. Basically, at that time, the task force, which includes about 70 public and private sector (two-thirds are private sector) members, will get together and look at a draft report, bless it (we hope), and then send it forward. Then we will try to get it through all the various stages of administrative review.

This report is going to deal with dredging. It is going to deal with the future condition of the marine transportation system, the current condition, and the strategic plan. How do you write a report like that in just a few weeks? The answer is that this is not all new work. It is really a compilation of all the effort that has been invested up to this point. What I'm telling you is that what I heard coming out of this conference and what we wrote down as the summary statements here—certainly the things that came out of each of those working groups—I'm going to take back with me. I will bring these ideas back to the working groups that are putting the marine transportation system report together and say, "Here are some good ideas, find a way to fold these in."

Note

The report of the task force, *An Assessment of the U.S. Marine Transportation System: A Report to Congress* is available on the Internet at http://www.dot.gov/mts/report.

APPENDIX A

Symposium Program

Risk Management in the Marine Transportation System

March 29–30, 1999
Beckman Center, Irvine, California

MONDAY, MARCH 29

0830 **Opening of Symposium**
Peter F. Bontadelli, Jeffrey P. High, Thomas H. Wakeman III

0845 **Keynote Speakers**
Thomas H. Wakeman III—Port Authority of New York and New Jersey
A. Elmer—SeaRiver Maritime, Inc.

0930–0945 Break

0945–1200 **SESSIONS ON MAJOR ISSUES**
(Prepared Papers and Presentations)

Session 1: Risk Assessment Methods and Data Needs

Methods and Techniques for Risk Assessment
"The Neglected Context of Risk Assessment: A Mindset for Method Choice"
Karl Weick—University of Michigan

Data and Information Needs/Sources (Integration, Missing, Limitation)
"Aviation Safety Incident Reporting: NASA Aviation Safety Reporting System"
Linda J. Connell—NASA/ASRS

Session 2: Practical Applications and Implementation of Risk Assessment Methods and Techniques

Practical Applications of Risk Assessment Methods and Theory to Real-World Settings
"The Real World: Blooming Buzzing Confusion"
Karlene Roberts—University of California, Berkeley

Sessions on Major Issues (*continued*)

Agency, Port, Industry Overview of Implementation of Risk Assessment:
Marine Transportation System Task Force
U.S. Coast Guard, Army Corps of Engineers, National Oceanic and Atmospheric Administration, Maritime Administration, Environmental Protection Agency, Minerals Management Service

1200 Lunch in Refectory

1300 **Address on Marine Transportation System Initiative**
VADM James C. Card—USCG

1330 CASE STUDIES

Practical Application of Risk Analysis in Development of Harbor Safety Plans
Suzanne Rogalin—California Office of Oil Spill Prevention and Response

Prince William Sound Risk Assessment: System Risk Analysis by Simulation and Expert Judgment Study
John Harrald—George Washington University

Oceans Risk and Criteria Analysis
George Bushell—Consulting and Audit Canada

1530 PANELS/DISCUSSION GROUPS

Group 1: Risk Assessment Models/Practical Applications and Guidance
Chair: *B. John Garrick*

Description/Objectives: Over the past 50 years, a dizzying array of risk assessment approaches has been developed: among them, descriptive and prescriptive models, analytic and behavioral methods, organizational and system models, and statistical and "fuzzy" techniques for risk assessment. In this session, we (*a*) provide an overview of several of these methods, techniques, and models to provide context and background; (*b*) explore the appropriate use of different techniques and models for different types of risk assessment problems and different domains; and (*c*) conclude with a discussion of lessons learned in applying different risk assessment models, techniques, and methods. Best practices from maritime and other domains are identified in this session.

Group 2: Data and Information Necessary for Risk Assessment Applications
Chair: *Paul S. Fischbeck*

Description/Objectives: Reliable data about a range of identified risk factors is needed to support complete risk analyses. However, there are considerable difficulties with data to support risk analyses: data sets and information sources can be incomplete, inconsistent, and of various degrees of accuracy and utility for risk assessment. Data difficulties—incompleteness, inaccuracy, inconsistency, unreliability, unavailability—and the need to integrate data from different sources in order to perform risk assessments are common topics in many risk domains, including the maritime world. This session (*a*) provides an overview of issues associated with data and information necessary for risk assessment applications, (*b*) focuses on approaches to overcoming data and information limitations, and (*c*) summarizes lessons learned from maritime and other domains. A glimpse of future data needs, sources, and problems is also provided.

Group 3: Real-World Applications
Chair: *Anthony Taormina*

Description/Objectives: This session covers application of both the theory and the use of data combined with the experience of those on the "waterfront" in the application of risk assessment to specific aspects of waterways management. Some phases of a project may require more exacting compliance to the theories and better data, whereas others may be done within a risk assessment framework to accomplish a balanced and appropriate evaluation of the interrelated risk present in a crowded waterway.

Panels/Discussion Groups (*continued*)

Group 4: Agency Integration and Cooperation
Chair: RADM *Robert C. North*

Description/Objectives: The federal agencies charged with various aspects of the marine transportation safety and regulatory regime are seeking ways to measure and quantify the level of risk in any waterway and the risk reduction value of various safety interventions. Several risk assessment models are in use or are planned for use soon. This session addresses some of these plans, their goals and objectives, their methodology and data requirements, their strengths and weaknesses, and the underlying policy that supports them.

1730 Recess

Tuesday, March 30

0830–1030 **PLENARY SESSION**
Chairs present summary of group discussions; recommendations for action

1030–1100 Break—Panel chairs confer with symposium co-chairs

1100–1200 **CLOSING PLENARY SESSION**

Development of Action Plan/Next Steps
Thomas H. Wakeman III, Peter F. Bontadelli, Jeffrey P. High

- Technical (tools)
- Management (local, regional, national)
- Policy

1200 Adjournment and Lunch

1300 **FIELD TRIP/TOUR**

1300 Marine exchange vessel traffic information service presentation in the auditorium

1400 Board vans for tour of the port of Los Angeles/Long Beach Harbor complex

Appendix B

Steering Group Member Biographical Information

Peter F. Bontadelli is founder and president of PFB and Associates, an environmental and maritime consulting firm. Mr. Bontadelli served as administrator of the Department of Fish and Game's Office of Oil Spill Prevention and Response from 1992 to1999, where he had the lead for the governor in oil spill prevention and response activities for California's marine waters. In that position, he headed a program that included a wide range of activities such as law enforcement, natural resource damage assessment, and education outreach to marinas, with a heavy emphasis on prevention. He was also a member of the U.S. Coast Guard Negotiated Rulemaking Committee and a member of the National Academy of Pollution Act of 1990 (Section 4115) Implementation Review. He is currently a member of the Marine Board and serves on the executive committee. He also coordinated a Memorandum of Agreement between the State of California and the U.S. Coast Guard, the first of its kind, which set the stage for a cooperative working future for both.

From November 1987 to January 1992, Mr. Bontadelli was director of the Department of Fish and Game. For 22 months before that, he was chief deputy director of the department and was responsible for the department's overall operations. As a special assistant to the director of the Department of Fish and Game from June 1984 to January 1986, he was responsible for legislation, coordination of special task forces, and the department's budget. He worked in a variety of capacities for the California State Legislature from 1970 to 1984. Mr. Bontadelli graduated from the University of California, Davis, with a B.A. degree in political science.

George E. Bushell is a principal consultant with Consulting & Audit Canada, a Special Operating Agency of the Canadian federal government. Mr. Bushell has managed and conducted a broad range of projects for Canadian and other government clients, including vessel traffic services studies for the Canadian Coast Guard and the Hong Kong Marine Department; he has worked with the U.S. Coast Guard and the Volpe National Transportation Center in the same area. He specializes in marine and rail transportation issues, environmental impact assessment, and risk analysis, and he has written a number of papers and reports in these areas, including a risk assessment related to the recently constructed Confederation Bridge linking Prince Edward Island to the mainland. Mr. Bushell received an Honorary B.A. from the University of Western Ontario and a Master's degree from the University of Toronto; he is a Woodrow Wilson Fellow.

Vice Admiral James C. Card became Vice Commandant of the United States Coast Guard on July 24, 1998. VADM Card previously served as Commander, Coast Guard Pacific Area, Eleventh Coast Guard District, U.S. Maritime Defense Zone Pacific; Regional Emergency Transportation Coordinator, Assistant Commandant for Marine Safety and Environmental Protection at Coast Guard Headquarters, Washington, D.C.; and Commander of the Eighth Coast Guard District in New Orleans. As the Pacific area commander, he directed Coast Guard operations from the West Coast to the Far East and from the North Pole to the Antarctic in support of the Strategic Goals of Safety, Protection of Natural Resources, Mobility, Maritime Security, and National Defense.

VADM Card's earlier assignments include serving as chief of staff, Thirteenth Coast Guard District in Seattle; chief of operations for the Eleventh Coast Guard District in Long Beach, California; and commanding officer of the Marine Safety Office/Group Los Angeles/Long Beach, California. Other assignments include sea tours aboard the Coast Guard cutters *Winona*, *Dexter*, and *Barataria*. He was also commanding officer of the Marine Safety Office, St. Louis, and has had tours at Coast Guard headquarters as chief of the Merchant Vessel Inspection and Documentation Division and chief of the Ship Design Branch in the Marine Technical and Hazardous Materials Division.

A 1964 graduate of the U.S. Coast Guard Academy, VADM Card earned two Master's degrees, one in naval architecture and one in mechanical engineering, from the Massachusetts Institute of Technology. He is also a graduate of the Industrial College of the Armed Forces. His decorations include the Distinguished Service Medal, three Legion of Merit awards, four Meritorious Service Medals, and a U.S. Coast Guard Commendation Medal. He is the 1997 recipient of the Society of Naval Architects and Marine Engineers' Vice Admiral Jerry Land Medal for outstanding accomplishments in the marine field. He also received the prestigious Rear Admiral Shepherd Award from the Chamber of Shipping of America in recognition of his achievement in merchant marine safety. Throughout his career, Vice Admiral Card has represented the United States as a member of delegations to the International Maritime Organization (IMO) in London and headed the delegations to the IMO Maritime Safety and Marine Environmental Protection Committees.

Linda J. Connell is director of the NASA Aviation Safety Reporting System and Research Psychologist for NASA Ames Research Center. Ms. Connell has been working at NASA Ames Research Center since 1981 and has participated in numerous studies with domestic and international research teams exploring human factor issues in aviation environments.

Ms. Connell continues to investigate aviation incident reports on a variety of topics, including pilot/controller voice communication, emergency medical service operations, cabin safety, aviation maintenance, and technology applications in aviation operations.

During her graduate work at San Jose State University, Ms. Connell completed her Master's degree in experimental psychology. She completed her graduate thesis on physiological countermeasures to jetlag at the NASA Ames Human Research Facility.

Ms. Connell is a pilot and a registered nurse. She is a member of the Aerospace Medical Association, Human Factors Society, National EMS Pilots Association, Helicopter Association International, and SAE, G-10 Human Performance Committee.

A. Elmer III is president of SeaRiver Maritime, Inc., and a native of New Orleans, Louisiana. He received his B.S. in mechanical engineering in 1962 and his M.B.A. from Tulane University. He has done postgraduate work at New York University's Graduate School of Business. Gus joined Exxon Research & Engineering Company in 1963. For the next 18 years, he held increasingly responsible assignments with Exxon affiliates in both the United States and overseas.

In 1981, he became marine manager of Exxon International's Tanker Department and in 1985 vice president and manager of that company's Transportation Department. When Exxon Company International was formed in 1986, he became manager of the Operations, Supply Department.

Gus was elected director and president of Exxon Shipping Company in April 1990. On August 1, 1993, Exxon Shipping Company changed its name to SeaRiver Maritime, Inc., and Gus remained as president. In 1972, he received the Harold A. Levy award from Tulane's School of Engineering; he is a member of the Engineering School Advisory Board.

Paul S. Fischbeck is an associate professor in the Department of Engineering and Public Policy and the Department of Social and Decision Sciences at Carnegie Mellon University, Pittsburgh, Pennsylvania. His general research involves normative and descriptive risk analysis. Past and current research includes development of a risk index to prioritize inspections of offshore oil production platforms, an engineering and economic policy analysis of air pollution from international shipping, a large-scale probabilistic risk assessment of the space shuttle's tile protection system, and a geographic information system designed to evaluate the environmental risk, economic potential, and political factors of abandoned industrial sites. Dr. Fischbeck was a member of the National Research Council (NRC) Marine Board Committee on Risk Assessment and Management of Marine Systems and was a technical advisor to the NRC Ship Structure Committee. Dr. Fischbeck received a B.S. in architecture from the University of Virginia, an M.S. in operations research and systems analysis from the Naval Postgraduate School, and a Ph.D. in industrial engineering and engineering management from Stanford University. He has written extensively on various applications of decision and risk analysis methods and has won several awards from the Institute of Operations Research and Management Sciences. He is a retired Navy Captain.

B. John Garrick was a founder of PLG, Inc., a consulting firm of engineers, applied scientists, and management consultants, from which he retired as president and chief executive officer in 1997. Currently, he has an active consulting practice in the development and application of the risk sciences to nuclear power, space, chemical, and marine systems. His accomplishments include a Ph.D. thesis on unified systems safety analysis that first advocated what is now known as probabilistic risk analysis and establishment of the first consulting team to perform initial comprehensive and quantitative risk assessments for the commercial nuclear power industry. He is past president of the Society for Risk Analysis and recipient of that society's highest honor, the Distinguished Achievement Award. Dr. Garrick is a Fellow of three professional societies and was elected to membership in the National Academy of Engineering in 1993. He has been a major contributor to the analytical methods and thought processes used in quantitative risk assessment. He holds a Ph.D. and an M.S. in engineering and applied sciences from the University of California at Los Angeles and a B.S. in physics from Brigham Young University in Provo, Utah.

Martha Grabowski is professor of Management Information Systems in the Business Department at LeMoyne College in Syracuse, New York, and Research Associate Professor in the Department of Decision Sciences and Engineering Systems at Rensselaer Polytechnic Institute. Dr. Grabowski was a member of the Marine Board and served on the Marine Board Committee on Human Factors. She chaired the Marine Board study that investigated advances in marine navigation and piloting. She also served as a member of the U.S. Coast Guard's Navigation Safety Advisory Council from 1993 to 1994.

Dr. Grabowski's educational background includes a B.S. from the U.S. Merchant Marine Academy, Kings Point, New York; she has M.S., M.B.A., and Ph.D. degrees from Rensselaer Polytechnic Institute, Troy, New York. After graduation from the Merchant Marine Academy, Dr. Grabowski served as a shipboard merchant marine officer for El Paso Marine Company, Exxon Shipping Company, and Hvide Shipping, serving around the world in shipboard assignments and working in shipyards in France and Greece. After her shipboard experiences, she spent 10 years at General Electric as a marketing and advanced programs manager.

Dr. Grabowski has developed for MARAD and the U.S. Coast Guard, and in concert with a variety of shipping organizations and ship's pilot associations, intelligent piloting systems that are embedded within integrated ships' bridge systems and vessel traffic systems. She has participated in a number of maritime risk assessments over the past 5 years.

John R. (Jack) Harrald is director of The George Washington University (GWU) Institute for Crisis, Disaster, and Risk Management and a professor of engineering management in the GWU School of Engineering and Applied Science. He is also co-director of the GWU/Virginia Technical Institute Center for Disaster Mitigation and Management and associate director of the Louisiana State University/GWU National Ports and Waterways Institute. Dr. Harrald has been actively engaged in the fields of maritime safety, emergency management, and crisis management as a researcher in his academic career and as a practitioner during his previous career as a U.S. Coast Guard officer. He has written and published in the fields of crisis management, management science, risk and vulnerability analysis, and maritime safety.

Dr. Harrald is co-coordinator of the Corporate Crisis Management Roundtable, a founding member, director, and secretary of The International Emergency Management Society, and a director of the Disaster Recovery Institute. Dr. Harrald was the principle investigator for recent maritime risk studies in Prince William Sound, Alaska, the Port of New Orleans, and Washington State and for earthquake vulnerability studies funded by the National Science Foundation (NSF) and the American Red Cross. Funded by NSF quick response grants and Red Cross projects, he studied the response to the *Exxon Valdez* oil spill, the Loma Prieta earthquake, Hurricane Hugo, Hurricane Andrew, and the Northridge earthquake. Dr. Harrald received his B.S. in engineering from the U.S. Coast Guard Academy; his M.S. from the Massachusetts Institute of Technology, where he was a Sloan Fellow; and an M.B.A. and Ph.D. from Rensselaer Polytechnic Institute.

Jeffrey P. High was promoted to the Senior Executive Service and began his current position as director of waterways management on 14 June 1998. His specific responsibilities include U.S. Coast Guard waterways management plans and policy, port security, vessel traffic management, and Great Lakes pilotage. In this position, he is a U.S. delegate to the International Maritime Organization's Navigation Subcommittee, a member of the National Port Readiness Network Steering Committee, and co-chair of the Interagency Working Group on the Marine Transportation System.

Mr. High attended the U.S. Coast Guard Officer Candidate School, and was commissioned as an ensign in January 1971. After 3 years as a junior officer, he was assigned to the Civil Engineering Division in headquarters, and he became a civilian employee of the Coast Guard. Since then he has advanced through a wide variety of jobs in Coast Guard Headquarters, including positions in civil engineering, planning, acquisition, programming, budgeting, information management, logistics, and organizational analysis. His assignments included senior reviewer with the Programs Division, assistant chief of the Logistics Management Division, and chief of the Management Effectiveness Staff in the Office of the Chief of Staff. From 1996 to 1998, he held the Department of Transportation Chair as an instructor at the Industrial College of the Armed Forces.

Mr. High holds an undergraduate degree in civil engineering from the University of Michigan (1970), a Master's degree in systems management from the University of Southern California (1974), and an M.B.A. from George Mason University (1982). He is also a graduate of the Industrial College of the Armed Forces (1991), the Federal Executive Institute (1994), and the Department of Transportation Senior Executive Service Candidate Development program (1995), which included a 4-month assignment as special assistant for research and technology in the office of the Secretary of Transportation.

Mr. High's professional honors include the Secretary's Award for Meritorious Service (DOT Silver Medal), Commandant's Superior Achievement Award (DOT Bronze Medal—two awards), Coast Guard "Unusually Outstanding" Merit Award, and Department of the Army Commander's Award for Public Service, plus several other individual and team awards.

Rear Admiral Robert C. North assumed the duties of Assistant Commandant for Marine Safety and Environmental Protection at U.S. Coast Guard headquarters in Washington, D.C., in May 1997. In that capacity, he directs coordinated national and international regulatory programs for commercial vessel safety, port safety and security, and marine environmental protection. Previously RADM North served as Assistant Commandant for Acquisition at Coast Guard headquarters with responsibility for directing programs for the acquisition of major systems, products, and services to support Coast Guard mission requirements worldwide. RADM North came to Coast Guard headquarters after serving as Commander, Eighth Coast Guard District, New Orleans, Louisiana, where he was responsible for all Coast Guard operations over a 26-state area from the Gulf of Mexico to the Canadian border.

RADM North chairs the Interagency Ship Structure Committee and is a member of the Society of Naval Architects and Marine Engineers, American Bureau of Shipping, Lloyd's Register of Shipping, the Sealift Committee of the National Defense Transportation Association, Det Norske Veritas North America Committee, and Marine Engineering Council of Underwriters Laboratories. He heads the U.S. delegation to meetings of the Maritime Safety and Marine Environmental Protection Committees of the International Maritime Organization.

Karlene Roberts is professor of business administration at the Walter A. Haas School of Business, University of California at Berkeley. She received her undergraduate degree in psychology from Stanford University and her Ph.D. in psychology from the University of California at Berkeley. Dr. Roberts teaches cross-national management and organizational behavior. She has done research on job attitudes, organizational communication, and cross-national management, and she has contributed to the literature on research methodology. For the past 10 years she has researched the design and management of organizations and systems of organizations in which errors can have catastrophic consequences. This work is at the heart of what has come to be known as the study of high reliability organizations (HROs) and spans industries and organizations and includes studies of U.S. Navy aircraft carrier aviation, the Federal Aviation Agency's air traffic control system, the commercial nuclear industry, community emergency services, patient safety, the commercial marine industry, and banking.

Dr. Roberts has published numerous books, chapters, and articles. She has served on the editorial boards of the major academic journals in her field and is a Fellow in the American Psychological Association, the American Psychological Society, and the Academy of Management. She is on the Human Factors Standing Committee of the National Academy of Sciences; the Advisory Panel of the Decision, Risk, and Management Science Group of the National Science Foundation; the Research Committee of the National Patient Safety Foundation of the American Medical Association; and the Human Factors Quality Management Board of the U.S. Navy.

Suzanne Rogalin was a founding member and served for 7 years on the Los Angeles/Long Beach, San Diego, Humboldt Bay, and Port Hueneme Harbor Safety Committees. She has been on the staff of the California Coastal Commission for 21 years, and she has expertise in vessel safety, transportation of oil and hazardous cargoes, ports and marine terminals, oil spill prevention and response, risk management plans, commercial fishing facilities, and environmental conflict resolution.

Thomas H. Wakeman III is the program manager, Dredging Division, Port Commerce Department, for the Port Authority of New York and New Jersey. He is responsible for the bistate agency's multimillion dollar dredging program at its maritime terminals and facilities. Before he joined the Port Authority in September 1994, Mr. Wakeman was with the U.S. Army Corps of Engineers for over 20 years. His last assignment with the Corps was as special projects manager, Programs and Projects Management Division, for dredging and navigation projects. His other experiences include being the director of the San Francisco Bay delta hydraulic model in Sausalito from 1985 to 1990; he was also the president of an engineering consulting firm, Earth Doctors, from 1982 to 1984. His professional memberships include the International Navigation Association (PIANC), where he is vice president for the eastern region and the U.S. representative to the Permanent Technical Committee on ocean navigation; the American Society of Civil Engineers, Western Dredging Association (member of the board of directors); and the Transportation Research Board. Mr. Wakeman's formal education includes studies in mechanical engineering, marine biology, and civil engineering. He holds a B.S. from California Polytechnic State University and an M.S. from San Francisco State University in marine biology. In 1979, he was advanced to candidacy for a Ph.D. in engineering at the University of California (Berkeley/Davis). Currently, Mr. Wakeman is a doctoral student at Columbia University in earth systems engineering.

Karl E. Weick is the Rensis Likert Collegiate Professor of organizational behavior and psychology and professor of psychology at the University of Michigan. He is a former editor of *Administrative Science Quarterly*. Dr. Weick studies processes of organizing and how people make sense of equivocal information when they are under pressure. His current work focuses on wildland firefighting, marine navigation, medical errors, and ways organizational learning and collective minds produce error reduction in these settings.

APPENDIX C
List of Symposium Participants

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