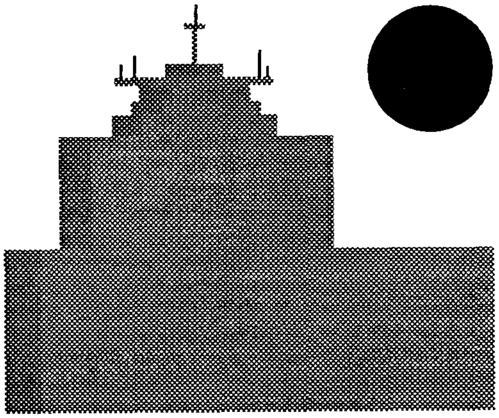
Human and Organizational Errors in Loading and Discharge Operations at Marine Terminals

Reduction of Tanker Oil and Chemical Spills: Development of Accident and Near-Miss Databases

SEA GRANT PROJECT R / OE 28



By

Eliot Mason

and

Professor Karlene Roberts

Professor Robert **Bea**

Marine Technology & Management Group

Haas School of Business and College of Engineering

University of California, Berkeley

November 1995

Abstract

This paper details the strengths and weaknesses of available data and proposes specific expansions to aid studies of Human and Organizational Error (HOE) in the marine environment. It is suggested that analysis of this data will greatly aid spill prevention and mitigation by informing industry and regulators of potential HOE. Although this paper is closely targeted to the marine oil transportation industry and oil spills, it should be considered relevant to all marine activities involving hazardous materials. Applicability of data to the current research in petroleum tanker Loading and Discharge Operations (LDO) is noted; However absence of LDO information does not necessarily imply that the data is not useful for HOE in other operations.

Preface

Approximately one billion barrels of crude oil and products are transported in California waters each year. Based on statistics provided by the California State Lands Commission, tanker discharge and loading operations are the predominate source of industrial oil and chemical spills into California waters. These operations account for a spill frequency that is a factor of 10 more than that associated with offshore platforms, pipelines, and storage tanks.

Spill reports indicate that a significant number of the spills are the result of Human and Organization Factors (HOF) such as poor communications, inadequate training, improper monitoring, inadequate maintenance, improper emergency provisions, and under-staffing resulting in fatigue and excessive stress.

The objective of this project has been to further develop engineering procedures to assist in the definition and evaluation of alternatives to minimize the occurrence and effects of HOF in tanker Loading and Discharge Operations (LDO). As part of a Sea Grant -joint industry sponsored project conducted during the period 1990-93 titled "Reliability Based Management of Human and Organization Errors in Operations of Marine Systems" a general approach was developed to assist in evaluation of the roles of HOE in operations of marine systems[Bea, Moore 1992]. This project has addressed reliability based HOF management technology as applied specifically to tanker LDO.

Two major needs were identified in the initial Sea Grant project on HOF in operations of marine systems. The first concerned the further development and field testing of a classification and evaluation system for HOF. The second concerned the further development of a HOF management system to interface with the marine operations analytical models developed during the first project.

This project has addressed these two needs in the framework of a "hands on" field operations oriented project involving tanker LDO. Testing of the HOF classification and evaluation system has been coordinated with a similar efforts conducted by the United States Coast Guard, the California State Lands Commission, and the Washington State Office of Marine. Safety. The field studies have been concentrated on two 'high reliability' LDO conducted by Chevron Shipping Co. and by Arco Marine Inc.

The results of this project are documented in three reports:

- "Reduction of Oil and Chemical Spills: Engineering to Minimize Human and Organizational Errors," by Susan Stoutenberg, Robert Bea, and Karlene Roberts,

- "Reduction of Oil and Chemical Spills: Organizing to Minimize Human and Organizational Errors," by Thomas Mannarelli, Karlene Roberts, and Robert Bea, and

- “Reduction of Oil and Chemical Spills: Development of Accident and Near-Miss Databases,” by Eliot Mason, Karlene Roberts, and Robert Bea.

This report is funded in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, under grant number NA36RG0537, project number R/OE 28 through the California Sea Grant College, and in part by the California State Resources Agency. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U. S. Government is authorized to reproduce and distribute for governmental purposes.

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1.0 Introduction

The marine transportation industry has developed a growing interest in the role of human and organizational error in marine transportation accidents. Many organizations have undertaken measures to reduce the incidence of such error. These measures may be credited in part with the oil & petroleum transportation industry's recent reduction in the rate and quantity of oil spills. Although progress has been made in this and other industries, questions still remain: How much human and organizational error has been eliminated? How much human error remains and what spill potential does this present? How vulnerable is the industry to such incidents? It may also be asked if our model of human error is correct or requires further refinement.

Regulatory policy, plant design and business organization need these answers to these questions. A greater body of knowledge on HOE in the marine environment is important for risk reduction, safe operation and the development of appropriate rules and regulations. This report pursues the question of how data sources might further advance knowledge of HOE.

1.1 What is Human and Organizational Error?

Human and Organizational Error may occur in many ways. Simply put it is "any human activity, or absence of necessary activity, resulting in an oil spill." (Hermanson, 1994) Human error has also been considered "actions and inactions that result in lower than acceptable quality" (Bea, 1994) The essential characteristic of HOE is error is not limited to individuals performing a task improperly. HOE includes broader errors created in complex systems, even when people perform their jobs properly.

HOE can be observed in many forms. People may fall asleep, make poor judgements or simply be careless. Such error is truly human error. Organizations may issue conflicting instructions, exert pressure, communicate poorly, assign personnel improperly or react inappropriately to a stimulus. Such system based error is considered organizational. Error may also occur between individuals and equipment, such as ergonomic misfits or easily misread gauges, potentially feeding erroneous information into the organizational system. This error may be considered ergonomic (and perhaps human and organizational). These are only some of the possible errors that have been identified. In short form, Human and Organizational Error can be found in all aspects of marine transport: Errors may enter into specification, design, construction, and operation.

1.2 How Does HOE Contribute to Marine Accidents?

Accidents may be viewed as events with many causes. In the case of an oil spill, it is rare that a single cause results in an oil spill. Chains of events are more characteristic, with errors compounding until a spill event occurs. An example LDO error combination could combine the following two contributing causes, leading to an equipment failure as an initiating event, and the absence of a mitigating factor: (1) faulty gasket not checked, (2) pressure is brought up too quickly, (3) a failed gasket results, (4) scuppers have been left open. The spill result is oil leaking from the transfer line, and flowing through the scuppers into a containment boom. In this case the actual spill event (the initiating event) is the gasket failure; however a check of the gasket might have revealed the fault or a slow build up of pressure could have revealed the leak at low pressure. Plugged scuppers would have contained the spill to the deck, instead they are open and may be considered a compounding factor. Were the vessel not boomed off (a mitigating factor), the effect and cost of the spill could be greater.

Thus spills are the product of errors. In the above example, absence of contributing causes 1 or 2 would not have resulted in a spill, and presence of the mitigating factor 3 would have limited this event to a deck spill. A conventional, engineering-oriented investigation would reveal the faulty gasket and list it as the spill cause. This is incorrect: the faulty gasket is only a contributing cause. The three preceding events could have HOE roots. The scuppers may have been open for one or more of the following reasons: the operator forgot to plug them (human); because cold impaired his judgement (environment); a deck box blocked the operator's view of the single open scupper (system); the scupper plugs had been lost and the request for replacements delayed (organization); the operator was rushed to commence the operation (organization); one of two operators is supposed to plug the scuppers, but they did not check with each other to see if the plugs had actually been placed (organization). These are only hypothetical cases, but they demonstrate the range and complexity of errors that may ultimately by classified as "human error". To study HOE in producing oil spills, it is necessary to go beyond examining initiating events and examine the chain of preceding and following events.

Increased vigilance and awareness of oil transportation safety may reduce error from each of the four source areas (environment, procedures, organization, system). Such vigilance, however, is most likely to reduce individual human error by increased attention to procedures and placing more responsibility upon individuals. Phrased differently, vigilance will reduce mistakes. Vigilance however cannot address organizational error, error produced by systemic interactions between operational or organizational components. Organizational error is more difficult to detect, its role as a background curtain upon which operations occur is not immediately apparent. Organizational error is also more complex than individual sources of error, making it harder to correct if found. System errors may be foreseeable, but may be equally difficult to change. Thus there is reason to suspect that only the easiest and most obvious changes have been made, that the industry has "sucked in its gut" and tightened up operational procedures. This is not an accusation of superficial change, only a reflection of the difficulty identifying and correcting system and organizational problems. Analysis of HOE data may identify previously unidentified problems in human, organizational, and system areas.

1.3 How to Study HOE

There are several ways one could study human and organizational error in a marine environment. Trained observations, professional opinion, and data analysis are options considered. Although each has its strengths, it is concluded that data analysis will generate the most widely useful information.

1.3.1 Observation

Observation of operations could identify potential or existing problems. Such an approach is very limited. Operations generate few incidents, occur in a great variety of geographic, temporal and climatic conditions, requiring an impractical number of observation hours to cover the scope of operations and conditions. If observation were conducted in depth at one location, a lot could be learned about that particular operation’s strengths and weaknesses. Unfortunately application of this site specific information may not be generalizable to other operations and sites.

1.3.2 Professional Opinion

Professional opinion is very valuable, particularly for initial identification of error potential and probability; however, opinion may not span the entire variety of operations and it cannot produce accurate estimates of error probability. It is also possible that professional opinion will entirely miss critical operational factors that have yet to produce a significant spill (that have not been a salient contributing factor). This approach was utilized in the accompanying paper by Stoutenberg & Bea, *Reduction of Tanker Oil and Chemical Spills: Engineering to Minimize Human and Organizational Errors (1995).*

1.3.3 Data Analysis

Data analysis of oil spills and other accidents presents a third method to determine the role of human and organizational error. This approach is of course only as good as the available data, but it has the advantage of covering wide ranges of activities under diverse environmental and geographic conditions.

Unfortunately, data on human and organizational error in marine accidents and spills is scant. Although several researchers have noted the lack of HOE information for marine casualties (e.g. Moore, Nagendran), the lack of data for oil spills, involving casualties or otherwise, is probably worse. Several federal and state government agencies maintain databases, but human error information is either questionable in its detail and accuracy or is simply not included in the database. Industry sources are not much better. This is not a general critique of these databases, only a recognition that many were not designed to serve this purpose.

Modification of the collection and storage of information in some of these databases would yield improved information on HOE and, in turn, improved prevention. Paradoxically the great improvements recently made by the oil transportation industry also poses a problem. Simply put, by reducing the number of spills there are fewer data points available to examine. However, this does not mean there is no error left to study. It is possible that many contributing factors are still occurring, only with less probability. Thus the probability of, say, three factors occurring simultaneously is reduced. Fewer spills may indicate reduced error input, not a system that is inherently less susceptible to errors or accidents. This is particularly true for LDO as an LDO spill is likely too small to be included in some data sources.

2.0 Currently Available Data

Data is divided into three categories: Federal, State and Industry. The Federal agencies considered here are the Department of the Interior's Minerals Management Service (MMS), the Environmental Protection Agency (EPA), and the United States Coast Guard (USCG) and National Transportation Safety Board (NTSB). Information from California, Oregon and Washington state agencies are considered[1]. Industry sources are primarily an assortment of publications, both newsletters and annual publications. Industry sources are the most international of all sources considered. Other sources of data on human error outside of the marine industry are not considered here (for references to such sources, consult Fleishman et.al (1990) pgs 19-25). A brief description of each data source follows. The potential use in HOE, particularly LDO, is also considered.

2.1 Industry Sources

A number of industry sources were considered. First are publicly available publications and databases, then publicly available databases and finally private corporate investigations.

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[1] Other states of the U.S. and Canada may also collect information. Time and resource constraints have prevented a poll of all possible states for information on marine oil spill databases. Interviews with a number of industry and state agency personnel indicated that the state agencies and databases considered here are a representation of the best implementations in this area.

2.1.1 Oil Pollution Bulletin

Golob's Oil *Pollution Bulletin* (*OPB*) is a regularly published industry newsletters. The scope of this publication is global, the purpose is dissemination of information relevant to the oil shipping industry. Rule changes, spill histories, lawsuits, technology advances and more are reported. The publisher claims to have excellent sources within the oil transportation community. Although spills are reported, the report places little emphasis on cause. Cause may be reported, if known, but it is not investigated. A further weakness from the perspective of this study is the reports are typically limited to spills greater than 10,000 gallons (250 bbl). Loading and discharge operations are, unlikely to generate a spill of this size. The publisher makes a database available. The database contains limited spill information (date, size of spill, product spilled, vessel and owner, location, and cleanup information).

2.1.2 Oil Spill Intelligence Report

The Cutter Information Corporations publishes a very similar newsletter titled *Oil Spill Intelligence Report* (*OSIR*) . This report has the same basic parameters, scope and reporting style as the Oil Pollution Bulletin. A database is also available, with recently added cause information. Unfortunately cause information is limited to events, not contributing causes (e.g. “grounded vessel” is the event that spills oil, but a communication and navigation error causes the grounding). This database has approximately 3250 records.

Though these databases are of little use in an HOE study, the qualitative reports could be coded for information. As these reports are not as detailed as National Transportation Safety Board reports (evaluated below), the quality and utility of such coding is not predictable.

2.1.3 Marine Regulatory Bulletin

The *Marine Regulatory Bulletin (MRB)* is another industry newsletter. Instead of an international scope, this publication focuses only on Pacific Coast (U.S. and Canada) activity. The primary focus is the reporting of proposals and changes to regulations of interest to the marine industry. Oil spills greater than 250 gallons (?) may be reported, but the cause is again not investigated. If *Oil Pollution Bulletin* and *Oil Spill Intelligence Report* are coded, *Marine Regulatory Bulletin* should be included[2].

2.1.4 Guide to the Selection of Tankers

Another publication serving needs of the marine industry is the *Guide to the Selection of Tankers.* This annual publication ranks all tankers greater than 10,000 metric tons displacement. Each tanker and fleet is given a rating based upon the accident history of the vessel. The accidents evaluated include oil spills,

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[2] There are also other industry publications targeted to hazardous materials transport (the *Hazardous Materials Intelligence Report)* and other segments of marine transport. These sources have not been evaluated at this time. They may be useful in a general evaluation of Marine Transport HOE, but have severely limited applicability in an oil spill study.

mechanical damage requiring repair, casualties and other marine incidents[3]. Though some spill information is provided, the publication is designed to assist the charter of tanker vessels, and not as an analytic tool. An analysis of Lloyd's and the Salvage Service data by the publisher demonstrates that tankers with a lower rating in this guide are more likely to experience an oil spill. Spill information is obtained from a variety of sources included in this report.

The Guide provides a wealth of historical information on large tankers, but it provides no information on barges. Barges are often considered to pose a risk at least as great as tankers for oil spills, particularly in LDO. This and the highly limited spill information does not allow use of the *Guide* as a primary source. The Guide's ranking and listing of accidents could be very useful as an additional source of information.

2.1.5 International Maritime Organization

The International Maritime Organization (IMO) has considered or developed several models for the collection of human error[4]. A document was produced in 1993 titled "Role of the Human Element in Maritime Casualties." Although titled a human error study, the IMO report only considers, "accidents where fatigue was a

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[3] This information is collected from a variety of sources, public and private. There appears to be no *a priori* size or damage reporting minimum, so the Guide may contain information on LDO events.

[4] Requests for information have been submitted to the IMO. This section on the IMO should be considered incomplete and somewhat speculative at this time.

contributing factor." Fatigue is certainly a contributing factor of human error, but there are many, many others.

An advantage of IMO's tight focus on fatigue is an excellent list to guide an incident investigator. This list appears comprehensive and should produce data that is more accurate and consistent than most sources. Unfortunately the IMO is only an advisory organization with no provisions for conducting its own investigations. Thus there is no actual data associated with these recommendations.

2.1.6 Det Norske Veritas

The classification society Det Norske Veritas (DNV) has a program, the Safety and Environmental Protection program, which may yield data. An element of this classification is a requirement that all accidents and near misses be reported to and investigated by the vessel owner. The actual reporting mechanism is left to the discretion of the owner. Though this program may produce excellent information for distinct cases, it may be very difficult to use as data. The information is not reported to a single organization and each owner may conduct the investigations differently, thus collection and assembly of the data into a uniform structure may be costly and ineffective. DNV also produces the well known World Offshore *Accident Databank.* This databank is limited to offshore structures (primarily oil platforms) and contains no human error information.

2.1.7 Corporate Investigations

Many of the large oil shippers and refiners have internal data collection. Spill size and date should be replicated in USCG records, but companies may also conduct an in-depth internal investigation. Near spills may also be investigated by shippers and refiners. Corporate investigations may produce a wealth of information, but as in the DNV SEP case, each company probably conducts investigations differently. In both cases, companies may be reluctant to release information for legal or public affairs reasons. Collection of company data, if available, will require large quantities of labor and time to both obtain and then code the data.

2.2 State Sources

The State of California has two agencies to consider: The California State Lands Commission Marine Facilities Inspection Division and the Department of Fish and Game's Division of Oil Spill Prevention and Response. The State of Washington has its Office of Marine Safety and the Department of Ecology. Oregon has one agency, the Department of Environmental Quality. All of these agencies are young organizations, still creating systems and procedures. Some of these agencies are also linked through the States-BC Oil Spill Task Force, an organization designed to aid communication and coordination of oil spill issues among the Western States and British Columbia.

2.2.1 California State Lands Commission, Marine Facilities Inspection Division

The Marine Facilities Inspection Division (MFID) inspects marine terminals and observes LDOs in California. MFID collects information on spills of all sizes, from tablespoons to thousands of gallons, occurring in California waters. MFID presently has two databases. The older database is considered first.

Location, time, product, quantity, source, vessel and terminal are entered into the old system, though accuracy is questionable (impossibly large spills are documented). A narrative field describes causes of the spill. MFID performs spill investigations and also enters information reported by a variety of agencies and the responsible parties (information accuracy is expected to be higher when MFID performs an investigation). MFID contains spills of all sizes so it does not censor the smaller spills typically generated by LDO. Unfortunately it reports only a single cause. Further, there are no choice lists, no description of activity at spill occurrence, and no information on human factors (other than listing “human error” as a cause) is included. There are over 7000 records covering spills from 1988 to the present, although few of these pertain to commercial marine activity and even fewer to LDO. The lack of consistent and comprehensive cause and contributing factor information greatly limits the use of MFID historical spill data.

The new database and collection scheme addresses HOE more comprehensively. In addition to information collected in the old system, events at time of spill are determined. Both the evolution (e.g. bunkering, LDO, ballasting) and specific event (e.g. startup, topping off, etc) are collected. Personnel, mechanical, and organizational causes are presented in tiered choice lists. Causes are also identified as primary or contributing. The 9 types of personnel and 6 types of organizational error are not exhaustive (see section on MSIS) but they capture the basic identity of the error.

This new system is still under development. Terminal accidents from 1992 on have been coded under this scheme and entered into the system. Future terminal spills will be investigated and entered using this scheme. Although this system still has a few problems, such as inter-coder reliability of the fairly subjective causes, it is a promising development. At present there are approximately 130 records, with a portion related to LDO.

MFID also collects information oriented not to spills but to compliance with LDO procedures. MFID regularly visits all terminals during LDO operations. During this visit the inspector completes a checklist detailing compliance with legally mandated procedures. The checklists could be used to infer the probability of human error, based upon the premise that strong systems reduce human error. Taken alone this data is not useful for HOE studies; However, combined with terminal spill data it could be very important as an indicator of terminal operation quality.

2.2.2 California Department of Fish & Game, Oil Spill Prevention Response

Oil Spill Prevention and Response (OSPR) division of the California Department of Fish & Game does not collect spill and cause information at this time. The division is considering developing a database to capture this information.

2.2.3 Washington State Office of Marine Safety

The Washington State Office of Marine Safety (OMS) recently began collecting a broad range of information on commercial marine activity, including spills. OMS's purpose is the reduction of human and organizational error, making OMS information particularly valuable despite its limitations to vessels. Vessel boarding checklists are designed to assess the potential for human and organizational error first, and compliance with equipment regulations second. In the case of oil tankers, the boarding officer verifies vessel compliance with company spill prevention policies (submitted to and approved by OMS). The database constructed to hold this information is very modern in its capabilities and very comprehensive in its scope, containing human factor information, vessel and crew histories and even near misses and near spills (the importance of which is explained in Appendix B).

Accuracy is expected to be high as OMS uses its own personnel to collect information (by culling industry reports, boarding vessels) while integrating information from the United States Coast Guard's Marine Safety Information System (evaluated below). Although integrating information from potentially problematic sources (such as the Coast Guard), the process of integration and the blending on new information should produce data that is better than most.

OMS may conceptually be divided into three segments. The first, and smallest, segment contains violation or incident information investigated by OMS. The second section contains boarding summaries of vessels. The accident and casualty histories of all vessels entering Washington waters are researched and entered into the third segment. Together these three segments feed information into a risk matrix that returns a risk rating for each vessel (in comparison with the Guide, OMS bases this rating on more and different information). Each of these segments must be considered individually for data potential.

Presently an evaluation of incidents in Washington is unlikely to contain enough cases to conduct data analysis. As time passes and more cases are investigated this limitation will erode. On the other hand, OMS incident investigations are likely to contain high quality, accurate human and organizational information on the involved vessels. As with other sources, these investigations may be most appropriate for case study methods of research.

By year's end close to 1,000 vessels will have been boarded. This is absolutely invaluable data for conducting a human and organizational error analysis, Similar to the MFID data on terminals and LDO, this information could be used as an assessment of ship operational quality. As OMS has background information on incidents (including spills), comparison of boarding ratings and vessel histories would more closely reveal the links between many sources of human and organizational error and incidents. Unfortunately, OMS has only recently begun boarding oil tankers so there is little data on tankers as of now. Tanker LDO will probably constitute only a minority of the boardings as tanker traffic is less frequent than other types of cargo in the state. However, there may be ample information on the bunkering of ships to determine the extent and causes of HOE in bunkering operations.

The historical incidents are of interest. These incidents are carefully entered into the database. Indeed, an incident is not officially logged in the system unless all information' (date, location, specific violations) is available. Additional information that cannot be officially logged is entered into a comments field. Because this information is entered by a small number of experienced mariners, it should be highly consistent. Unfortunately, this strength is undermined by most incident information coming from sparse sources that do not provide enough information to accurately code the role of human or organizational error.

Although both the historical and Washington incident reports allow for extensive entry of human and organizational factors, there is no taxonomy to place these errors into. Users of the system may add and delete error categories from the choice list as appropriate. Further, one factor may be flagged as the initiating event while all others are listed only as contributing factors, with no differentiation of compounding factors.

The mentioned limitations do not pose serious difficulty for the analysis of HOE, they simply must be considered in the analysis. As will be seen, OMS offers some of the best analysis potential of all sources considered here. One of the greatest strengths of OMS data is the very small size of and high levels of training in the organization. As already mentioned, the historical backgrounds on vessels are researched and entered by a small number of people. These same people also perform and report the boardings of vessels. These characteristics greatly limit the idiosyncrasy of the data, maintaining high standards in all areas of the database. Furthermore, scheduled improvement to the system will allow improved data collection.

2.2.4. Washington State Department of Ecology

Washington State's Department of Ecology also records oil spills. This system appears to contain only limited information on spills, recording only date, location, violator, medium, material, source, quantity and "cause." Causes are not elaborated upon, only identified as an event (e.g. equipment failure, operator error) with no elaboration.

At this time the Office of Marine Safety is scheduled to merge into the Department of Ecology. It is not believed that this merger will have a detrimental effect on the data system, and it may actually improve the scope of the system by integrating both marine and shore sources of spills. However any such predictions are speculation at this time.

2.2.5 Oregon Department of Environmental Quality

The State of Oregon's Department of Environmental Quality (DEQ) compiles information from the Coast Guard's Marine Safety Information System. The agency has plans to collect improved HOE information, unfortunately these plans have not been implemented at this time. Present DEQ databases are duplicates of the Coast Guard and Washington Department of Ecology.

2.3 Federal Sources

Four sources were considered at the federal level. These are the Department of the Interior's Mineral Management Service, the Environmental Protection Agency, the Coast Guard and the National Transportation Board.

2.3.1 Department of the Interior, Minerals Management Service

The Minerals Management Service (MMS) of the Department of the Interior periodically compiles spill information. The most recent report contained 1100 spills since 1974. Information is collected on all tanker and barge spills of greater than 1,000 barrels (42,000 gallons) throughout the world. Adequate information is given to location, size, and vessel identification. MMS also includes other data relevant to understanding and predicting oil spills: year vessel built, vessel size, load size prior to spill, role of heavy weather, and a sequence of casualties leading to the spill. Environmental damage assessments are also included.

The great weakness of MMS is the limitation to spills of 1,000 barrels or greater. Human error is likely a factor in spills of this size, though probably no more than in smaller spills. This arbitrary boundary limits the size of the database, and it may also censor causes which tend to result only in small spills. The cause sequence is valuable, but is again limited more to events (e.g. EXPLOSION - FIRE - FOUNDER - SPILL) than the cause of each event leading to a spill. Finally, MMS is collected from many sources including USCG sources and various industry publications (including those evaluated here). Information and accuracy likely suffer in duplication.

2.3.2 Envirdnmental Protection Agency

The Environmental Protection Agency has limited data collection capability in its PIES system. Data is reported to the EPA as soon as any spill occurs, thus the data will indicate the frequency of spills. Information is typically reported by the responsible organization and contains little more than estimated spill size, location, product and source. Follow-up or investigative information is not collected or entered into the system. This system is nearly useless for human and organizational error research.

2.3.3 United States Coast Guard

The United States Coast Guard operates the Marine Safety Information System (MSIS). The largest and most complex of the databases considered here, MSIS contains well over 200,000 records on oil spills. Information is collected by the many Marine Safety Offices throughout the United States in completion of its oversight, regulation, inspection and investigation duties. The amount of information collected is truly formidable. MSIS contains qualitative and quantitative data on the spill, including vessel and terminal histories, historical inspection information (including records of infractions or violations), training information, operation at time of spill, operator information (age, education, time on shift, hours of sleep), responsible party information (may be corporate), initiating cause of spill and contributing factors (including human and organizational error). Any spill, regardless of its origin, creating a sheen on the water is reported (although spills of less than 1 gallon are recorded in the system as 1 gallon spills). It is also possible to link spill information from a particular vessel to recorded infractions by that vessel.

MSIS also has an extensive human factor recording capability. An extensive (though not exhaustive) choice of human factors are allowed as causes and contributing factors (as detailed in the CFRs). The system also classifies vessel operation at time of spill, including some of the stages of a loading, discharge, bunkering or lightering.

Although it would seem that the siie, geographic scope and depth of detail make MSIS the ideal database, there are many problems to be considered. These problems are access, orientation, consistency and accuracy.

Access to MSIS is difficult, primarily because the legal nature of many Coast Guard investigations is not compatible with public access. Reports and data files can only be constructed at headquarters and may require filing under the Freedom of Information Act. The complexity and scope of MSIS make it difficult to assemble an information request. Terminal access to MSIS could alleviate this difficulty, however this is also difficult to gain.

MSIS also poses problems for the entry of spill data, not just retrieval. The system is divided into many different modules Each module is devoted to an MSO activity area (Pollution, Investigation, Inspection, etc) and information does not automatically relate across all modules (e.g. an event description may need to be entered once in each of two modules). System fragmentation makes spill entry very time consuming, as much as two hours or more of computer time may be necessary to enter a basic case. This is expected to reduce the entry of information that may be considered spurious to the Coast Guard's investigation but would be essential to HOE research, particularly for minor occurrences.

MSO pollution investigations are oriented towards identifying the source of the spill. In this case, "source" is not the root cause of the spill but an identification of the physical source of the spill, and thus the responsible party. Busy and under staffed MSO offices thus cannot always engage in the luxury of pursuing causal investigations once a spill is linked to its physical source. Thus even for spills in which human error is clearly a major contributing factor, human factor information may not be collected, analyzed or entered. If human error is the cause (the initiating event) this information will be investigated and recorded.

The accuracy of MSIS is expected to be as good as any information reported. That is, identifying data on spill size, location, material, date, vessel, etc will be very accurate (as is necessary for the prosecution of pollution and violation cases). However cause information, particularly human factors (if reported), has little or no consistency. This lack may be traced to several factors. First, investigators are not extensively trained in human factors. Second, the military billet and career structure hinders development of investigators into highly experienced "experts." Third, a lack of definitions and a clear taxonomy further compounds the problem, reducing determination of the causal factor code to a near random process. Each individual may report an incident differently, choosing or neglecting to complete "supplementary" information as human factors. The idiosyncratic nature of the information is increased by turnover of personnel, the large number of personnel involved and the geographic diversity of the Coast Guard offices.

A further limitation of MSIS are the huge number of “source unknown” sheens that are entered. Many entries address sheens or spills generated by from sources ranging from the recreational boater, storm drains, and underground pipelines to natural seepage, commercial vessels and shore facility fires. This will greatly deflate the number of cases relevant to commercial HOE. A review of one MSO's current cases (totalling perhaps 450 cases for an eight month period) found approximately 20 cases relevant to commercial shipping and even fewer cases related to oil carriers and terminals. Thus the 200,000 records might be reduced to less than 1,000 commercially relevant records, with an optimistic estimate of one or two hundred related to LDO.

The above limitations of MSIS lead us to the unfortunate conclusion that despite its many attributes the HOE data is neither consistent nor reliable enough to use as a sample in a rigorous data analysis. Other information contained in MSIS, as violation information, could be very useful if combined with other sources of HOE data.

The USCG does maintain a publicly available database, the Port Safety Information Exchange (PSIX). PSIX allows access to some public information contained in MSIS. Coast Guard transactions, inspections and equipment violations are listed. Because pollution and accident case information are not public, PSIX contains no information on spills, accidents or other casualties.

2.3.4 National Transportation Safety Board

The National Transportation Safety Board of the Department of Transportation examines marine accidents. The NTSB does not maintain a database, but produces highly detailed analytical reports. An attractive feature of NTSB reports is the common use of human factors specialists (who may also work on airplane, train or highway accident reports). These specialists consider and analyze human and organizational error, making NTSB reports the premier available human and organizational error data sources. Though qualitative, these reports could be coded to produce highly consistent data.

NTSB reports do however present some drawbacks. The NTSB investigates accidents involving the loss of 5 lives or more, vessels over 100 gross tons, accidents of a recurring nature, or accidents involving Coast Guard vessels. Discretion is also used to determine the accidents investigated, so not all accidents fitting the above criteria are investigated, nor do all investigations fit the criteria. There are not a sufficient number of reports done (or there are not enough accidents fitting the NTSB investigation criteria) to generate a sample for study: From 1985 to present there are 62 reports available, 25 of which pertain to tank vessels, tank barges, chemical carriers or offshore oil drilling and pumping equipment. There appears to be but one report during these years directly related to loading and discharge operations. Although useful for a general study of Marine Transportation HOE, there is almost no available data for an analysis of HOE in LDO.

2.4 Evaluation Summary

A accident database is made from three steps. First the accident occurs. Next it is investigated. Finally, the results of the investigation are then reported to the database. The sources considered above are lacking in at least one of these three steps, as discussed below.

None of the current sources of data contains the full range of HOE information necessary for a comprehensive study. The data sources can provide excellent information on the frequency, size and location of spills. Only MFID, OMS, NTSB reports and the USCG's MSIS are designed to capture HOE information. However, MFID has not fully implemented the new system and OMS is still developing a track record and collecting information. It may be some time before either system contains enough data to permit analysis. NTSB reports are highly detailed, but they detail only actual accidents not near misses. NTSB reports are further limited by lack of established HOE similarity between large and small accidents; there may be distinct differences in type and number of causes in large and small accidents. The lack of similarity is important for LDO analysis. MSIS contains fields for recording HOE though department priorities, a difficult computer system and lack of training in HOE inhibit collection and recording of HOE.

Outside of the general accuracy of the available data, there is also the problem of data scope. LDO is inherently a mating of ship and terminal, both physically, organizationally and procedurally. The USCG is the only organization with the prerogative to consider both ship and shore installations: MFID is restricted to terminals, while OMS is limited to vessels. Although the merger of Washington's

Office of Marine Safety and Department of Ecology may ultimately result in a merged dataset, there is certainly no available data at present.

Present data collection systems can generally be characterized as deficient in accuracy, taxonomies and completion of information. Accuracy is questionable, if only because many systems rely upon initial report information only. This initial information may be erroneous, inaccurate or incomplete, and is often not corrected or checked by an investigation. The systems have unclear taxonomies (particularly for human factors), allowing contradictory or incompatible information to be entered. Finally, completion of some information (specifically human contributing factors) is not required to enter a case. It is possible that MFID or OMS will overcome these inherent problems. If so, the value of their data will be greatly enhanced.

Beyond these factors associated with computer based systems, there is a greater weakness with all information sources: a spill must actually occur to notice the event. "Near spills[5]" are not included (excepting information required under DNV's SEP, OMS and possibly related information collected by MFID facility inspections). Other highly safety sensitive industries, particularly the nuclear power industry and most classes of aviation, are required to report and investigate near misses. The importance of near spill information is discussed in Appendix A.

The lack of near spill information in these data bases is not a fault of the responsible agencies. Rather, it reflects that maritime and oil industries are not

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[5] "Near spill" as used here includes navigational or other "near misses" of maritime accidents (e.g. grounding, collision) that have the potential to produce a spill, and narrowly avoided spills (e.g. a contained deck spill).

required to report near misses and spills. It is also a reflection of the absence of an accepted definition of a near miss/spill in the marine environment (see Appendix B). Both reasons may be attributed to a historical orientation towards response and citation, not prevention.

All of these systems are also artifacts of the legal, commercial, social and engineering histories of marine transport. These histories have led us to focus on the ship as an entity unto itself: crew belong to a ship, a ship spills oil, ships represent large amounts of capital and earnings potential. When we speak of a ship we may mean not only the vessel, but also its complement and cargo. A ship and its name are (relatively) enduring while the crew are temporary. A ship's age is considered a more important risk factor than the current crew levels or crew training. Crew are considered interchangeable, though some are better than others.

The problem of this conception of "ships" as a collective cause of accidents is that information is collected only on vessels and facilities, while the personnel are mostly ignored.6 In none of these systems (excepting OMS) can information on relevant individuals be entered or recalled. HOE evaluation would be more effective if information on crew composition, experience, violations and incidents were recorded. Although identification of individuals may be very interesting for prevention, it also serves a role in understanding how crew characteristics, in addition to ship and company characteristics, explain HOE.

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[6] This is not necessarily the case when legal action is taken: Captain Hazelwood was tried in court for negligence leading to the Exxon Valdez spill. However, researchers have not been able to address the potential for crew composition as a source of error because no data is available.

Also conspicuously absent from an HOE perspective is information on the relevant organization. Again this is not a criticism of any of the systems, only a limitation that must be understood in advance of analysis. Organizational features are difficult to categorize in meaningful ways, change frequently and may have little relation to actual operations. This may make any ex ante coding of organizational policies and procedures (as provided to OMS & MFID) difficult to evaluate. However, it is generally recognized that these policies, procedures and cultures may have a large impact on such organizational outcomes as the number of HOEs. Thus it may be sensible to collect some general organizational data during an investigation. This data can be very general, such as a consideration of the procedure characteristics (e.g. was an action an automatic response, an involuntary response to a request from a superior to perform a specific function, or a voluntary response to a request from a superior to correct a general situation). Such distinctions between voluntary and involuntary actions may seem arcane, but are important when considering how to best advise companies on the reduction of error.

3. Utility of Current Data

How could the current information be used to examine human error in oil loading and discharge operations? The discussed available databases could have limited use. It may be possible to analyze the data as is, accepting the discussed limitations, or by combining data sets to generate proxies for HOE risk.

Using proxies for human error presents four basic analyses. The assumption could be made that training levels are negatively related to human error and thus spills. Examination of vessel flag or classification society requirements could yield differences in training standards that might be related to spill frequency. Another possibility is a comparison of the frequency of cargo transfers (indicative of familiarity and competence) with the number of spills per transfer? Weather records could be correlated with spill data to find possible links between time of day, temperature, rainfall, etc. A final option is identifying procedures that are organizationally or technically complex, and perhaps more prone to human and organizational error. The number of spills occurring during such procedures could be examined.

The problem with each of these make shift approaches is the lack of new information provided. It is already established that human error plays a large role in oil spills, transforming the questions from "Does it play a role?" to "What role does HOE play?" These methods may also be considered as demonstrating correlations, not causation. An analysis of training requirements and topics may

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[7] Such an analysis would require assembly of transfer frequency and size information as it is not included in any of the databases addressed here. Company and port arrival records contain this information.

reveal a negative correlation between training and spills, but it is too coarse a measurement to indicate the topics that are effective or ineffective in prevention, and cannot identify topics that may actually increase the probability of spill. A training analysis also does not address the individual level'of training a causal individual may have, only the average or prescribed training. A transfer frequency analysis limits itself to simple correlational results because it cannot control for causes, complexity of equipment, and perhaps not the size of transfer. Weather analysis does not describe the mechanism nor is it likely to go beyond common knowledge of human performance in adverse conditions An examination of high risk procedures is probably the best of these options though it faces two problems. First, it is not clear that there is sufficient data available on the activity at time of spill to conduct such an analysis. Second, there would be no indication as to which part of the activity presents the highest risk of human error.

Limited analysis may be more useful than use of proxies. NTSB reports may be limited to high cost accidents and rarely involve spills but they contain a wealth of information. Coding these reports could reveal consistent similarities in causal factors. LDO or other operations could then be examined (by observation for instance) for evidence of these factors. MSIS data could be analyzed with the caution that results could be statistically meaningless, although there may be emergent patterns to investigate in the field. Of these approaches, the NTSB coding is more reliable and more likely to produce relevant results,

4. Solutions

One must ask if the currently available data could not be fixed, or if existing systems could amended or improved to provide better HOE data in the future. Failure of these options suggests the need to develop a new system.

Retroactively fixing data is improbable. The primary deficiency in existing databases is a lack of human factor information, information that would be nearly impossible to accurately and consistently investigate months or years after an event. Advancing knowledge of HOE in marine operations additionally requires precise identification of the procedure and the error. Intensive interviews could reconstruct some of this information at great cost. Accuracy, particularly for small spills with low saliency, will be low. Near spills would also be completely missed as there are no records of such events to reconstruct.

Database modification could improve the ability of systems to record information; however the problems of collection (primarily trained investigators) are not overcome by the addition of fields to a database. MSIS is an example of this problem.

A third possibility is the development of a new database. This database could be wholly independent of the sources considered here, independent with ties to information in other databases, or an integral part of another database. However, the same collection problems facing a modified database will confront a new database. The ultimate placement of a new database will require an analysis of collection methods for the proposed human error information. Links with existing databases may ease the burden of collecting background information (company and crew information for instance).

It is much easier to state what HOE information should be included in a modified or new database. Don Hermanson of the Marine Facilities Inspection and Management Division, California State Lands Commission has suggested an improved oil spill database as part of his *Marine Oil Pollution Prevention Strategies.* In addition to information concerning the time and date, location, product and quantity of a spill he suggests the following minimal information be collected:

Process at time of spill
Equipment involved
Employees involved and:
-experience
-training
-tenure
-time on duty
-physical condition
Environmental conditions (including physical and work environment)
Injuries incurred
A specific and complete narrative of the spill cause
Contributing factors
An assessment of spill costs (lost product, overtime, injuries, cleanup, repairs, liability, etc).

The availability of this information would greatly enhance human error analysis. We go further and suggest the following general additions:
Number of people present at event, arresting and mitigating factors limiting the spills and near spills, potential spill size if the arresting or mitigating factor fails (see Appendix B), and a detailed description of the event, including a description of any HOE. It is also preferable to not just name contributing factors, but also to determine the conditions under which each contributing factor occurred (as an error leading directly to a spill).

Further detail on a proposed contents of a database are given in Appendix C.

4.1 Difficulties Implementing a New Marine HOE Database

Recording HOE in a computer database is a simple task many inexpensive computers and programs are capable of today. The difficulty is found in maintaining an HOE system with other databases (witness the USCG's MSIS) and devising an easy entry system (again, witness MSIS). Merging HOE information with regulatory and legal information may pose collection problems, though there are no technical reasons rendering this impossible. .

The greatest difficulty is collecting the information. The marine industry poses several challenges to collection. It is a diffuse industry with many countries, organizations and locations, without a strong unifying organization. It is a diverse industry, transporting many goods through a wide, and extreme, variety of conditions using a multitude of vessel and terminal designs mated with a multitude of personnel, utilizing a multitude of vessels (tugs, barges, tankers). It is also an industry that has, with diminishing success, maintained relative freedom from regulation. On the other hand, terminal operations are generally limited to a select number of products, employ a stable group of workers and have come under increasing local regulation. The terminal information might be easier to collect, but it does not resolve the difficulties associated with vessels. Both vessel and terminal operations share a distrust of regulation, perceiving it as some combination of unnecessary, ill-conceived, costly or simply threatening. It might be added that some regulators view industry in equally poor light, and the mixture of various regulatory agencies, crew nationalities and ship registries only complicates relations between industry and regulators. Thus there are several logistic and cultural problems impeding collection of meaningful information.

Accuracy in HOE reporting requires the assistance of companies and individuals. This assistance may be difficult to obtain in the United States' litigious environment, particularly if HOE investigation is conducted simultaneously with legal or regulatory investigations. At the same time, the investigators must be associated with an organization powerful enough to command assistance and cooperation of a company, or companies must provide the information voluntarily and in a uniform manner. It may be preferable to develop a community of investigators that spans these various roles. Not unlike the Bar Pilots, these investigators could serve all facilities in an area. This solution develops high skill, familiarity with local facilities and personnel, consistent reporting and the exchange of information.

If individual crew level information is to be collected an entire new approach to identification will be required. The present norm is to classify incidents by the legally definable entities of company, ship or terminal. There is no precedent for identification of an entire crew so an approach will need to be developed. Although not intended to place blame upon individuals, any effort to identify such crew characteristics as training, hours of sleep, experience, etc may be misunderstood, generating strong resistance (see below). In addition to a history Collection of such information will also be more difficult for the itinerant ship crews than for the stable terminal crews, and even more difficult for crews of foreign vessels.

Further collection complications arise when trying to classify HOE information. HOE is not necessarily easy to determine in simple systems, in the complex system just described determination will almost always be difficult. The NTSB requires 9 months[8] to research and write its reports. Development of a clear and easy to use taxonomy (discussed below) will simplify this process.

Finally, there must be considerations of a near spill or near miss reporting system. Other systems of this sort, as the system operated by NASA to report commercial air problems, have provisions for confidentiality or indemnity. In the LDO context, this may require that not only are individual employees reporting near spills protected from any company action against them, but also that the individual or company be given some level of protection against legal or regulatory action. Some of the difficulty in implementing such a system within corporate boundaries is identified in the accompanying report by Stoutenberg & Bea (1995), with wide disagreement among employees as to the existence of a near miss reporting program.

4.2 Difficulties in Design of a New Marine HOE Database

Marine transportation is also an industry with a wide range of technologies, matching computer controls with essentially primitive machinery and a wide range of operations (e.g. petroleum transport presents different operational procedures for different cargoes). This range creates special considerations for recording accurate information of each operation in marine transportation. Although a simple design

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[8] From start to finish. This is a time frame, not a count of labor.

can accept all sorts of information given to it, narrowing down the specifics of events requires a larger, more discriminant structure. For example, the accompanying report by Stoutenberg & Bea (1995) details the many complexities of LDO: LDO may be characterized as a seven step process, with each process requiring a multitude of tasks that must be performed correctly to prevent a spill. A database designed to capture LDO information would have to accept and positively identify spill information from each of the seven steps. This allows a separation of errors not only by type, but also by procedure, generating insights into the interactions between errors and procedures. Exhaustive identification of errors would require a full explication of all the substeps of each procedure. Of course there will be simplifying similarities across tasks, procedures and operations. The complication comes from developing a system that can accept the unique or idiosyncratic tasks, procedures and operations.

A thorough taxonomy of event factors is critical. Clear taxonomy, choice lists and decision trees will be necessary to develop the database, produce usable forms, and train personnel. The more developed the taxonomy, the easier collection (considered above as a difficult task) will be. A well developed taxonomy may also require less investigation training, increasing the likelihood of industry adoption.

Taxonomy development will be the first major step in developing a collection and recording program. Years of marine casualty investigation have identified most, if not all, physical initiating events. There are now two more steps in taxonomy development. The first is developing a clear and transparent HOE taxonomy. The next stage is identifying possible sequences of events in error chains and better identification of HOEs. Ideally, the knowledge of such sequences could be used to develop a reliable entry program. Although the development of a better HOE taxonomy is necessary, the development of interactions and chains is less easily completed because of the amount of data that is required (see Appendix C).

Taxonomy development is already underway. HOE taxonomies have been developed for design and construction of marine structures (Bea, 1994), the NTSB has developed their thorough "Classification of Human Performance Analyses Variables" and Fleishman et.al 's 1990 review describes no fewer than 11 generic human error taxonomies. Together these taxonomies possess both the basics of a genera1 HOE and Marine system, a good starting place for the development of an LDO specific system. Although these taxonomies may offer good theoretical coverage of events, they are not easily applied to an investigation. Work by Boniface (Boniface, 1995) also suggests taxonomic coding options. Coding of NTSB and MFID research will aid the refinement of existing taxonomies for application in LDO.

5. Conclusion

If our understanding of Marine HOE is to advance, it will be necessary to collect improved HOE information. Existing data is neither sufficient for a general survey of HOE nor for any specific operation. Study and prevention of HOE will require collection of more accurate data. This collection may require the modification of an existing database or the creation of a new database. Collection will also require wide ranging changes in public agency orientation, industry support and participation, collection methods and regulations. The goal of any changes should be to create a unified system that can both collect and return data (for preventative purposes), operate without seeking blame, and be easy to use.

The changes necessary for effective collection of data are beyond the scope of this paper; however recommendations are given for developing a taxonomy to guide the development of a database and collection system. Continued study through observation and professional opinion is warranted at all stages of development. Focus groups might be added to the methods used to collect professional opinion.

Analysis of existing data will also aide development. In particular NTSB reports should be coded and analyzed. The NTSB reports should help delimit possible HOE errors and, more importantly, begin to demonstrate the sequence in which these events may occur. NTSB report coding should not be limited to marine reports. Air, Railroad and Pipeline accidents occur in complex systems not unlike marine accidents, although in different physical, technical and regulatory environments. NTSB reports will not directly further knowledge of HOE in LDO, but indirectly through a contribution to the knowledge of HOE in complex systems.

Beyond the basics of data collection, high quality HOE information can only be collected through changes to increase trust and openness in the entire operational environment. The potential for blame is a strong source of distrust, suggesting corporate, regulatory and public policy must change culture, policies and practices to make the placing of blame secondary to disclosure. Such changes could ultimately lead to savings by decreasing the probability and magnitude of spills, reduced response costs and an appropriate level of regulation.

HOE is an important cause of accidents in the marine transportation industry with environmental, commercial, personal and social costs. Its reduction could have a profound impact on marine operations. The best way to reduce HOE is to understand it thoroughly and focus on improving prevention. A comprehensive understanding may be obtained only through increased study that requires improved data.

Appendices

Appendix A: Attempting to Define Spills & Near Spills

It is difficult to define an "accident." We tend to think of accidents as both single events and the resulting combination of events. Examining the oil spill example introduced earlier in this paper (pg 2), where does the "accident" occur? Is the "accident" created when a crew member fails to close the scuppers or fails to notice the faulty gasket when coupling hoses? Is the "accident" caused by bringing the pressure up too quickly? If the scuppers were plugged and the oil was contained on the desk, is this series of events even considered an "accident?" If the replacement scupper plugs were not ordered in time is this part of the "accident"? We can further complicate the issue by adding organizational variables such as pressure to complete work quickly. If time pressure were the cause of any of the events preceding the spill was it an "accident" for the company to exert these pressures?

Accidents then can be considered as the application of an arbitrary standard. Is it an accident if the oil escapes deck containment but is captured in the boom with a 90% recovery rate? A common definition of a spill is contact of oil and a body of water. This is as arbitrary as defining it as a deck spill, an uncontained spill or in the category of "a spill would result if one more valve were open." Thus an "accident" is not bounded by time or a single event. The question may then become not "Is this an accident?" but "Is this close to an accident?" The latter can be considered a near spill.

If the oil spill example is placed on a time continuum, the classification of each cause may change. Using the contact of oil and water as our spill definition, the open scuppers, improper connection, and improper start-up flow are contributing causes. The initiating event is the gasket breaking. The containment boom is a mitigating factor. We can suppose a stop factor in the attention of the crew member that observed the oil flowing from the hose connection and shutoff the pump.

The classification is very different if the scuppers are closed. The contributing and stop factors are the same except the scuppers are now a mitigating, perhaps a stop, factor. If we redefine a spill as “loss of flow” the closed scuppers are still a mitigating factor. If the scuppers are open, they become a compounding error. The incorrect hose coupling could also be considered the initiating event, with all other events classified as compounding factors.

Using “contact with a water body” definition we can also see that many errors can occur without creating a spill. These errors may be sequential and propagate until the chain is broken (e.g. the closed scuppers), or they may accumulate until an initiating event releases the chain. (e.g. bringing pressure up too quickly). A spill may not occur, but has an accident occurred if all of the events except bringing pressure up too quickly occur?,

Although accidents are not bounded by time, it may bound the categorization of factors. Once an initiating factor has been fixed, events preceding and following may be classified using the following definitions. Contributing factors clearly precede in time the initiating event, while the placement of compounding and mitigating factors is not as apparent. *Compounding factors* are a type of contributing factor that are not required to cause an accident, but do worsen the accident once it occurs. It makes sense to define *Mitigating factors* as events prior to the initiating event that have the effect of restricting the chain of events. *Propagating factors* are events occurring after the initiating event that actively advance the chain of events, either accelerating the chain or increasing its scope. *Arresting factors* are events that occur after the initiating event that actively halt the advancing chain. Thus preceding the initiating event are Contributing, Compounding and Mitigating factors, and following the event are Propagating and Arresting factors.

These classifications suggest a theoretical definition for the near spill. A near spill will have a set of contributing factors that allow an initiating event to occur. The difference between the near spill and an actual spill is then the presence of mitigating factors and the absence of propagating factors. It is not expected that there would be no mitigating factors in play during an actual spill, however there may not be enough present to entirely prevent a spill. By definition a propagating factor would rarely be found in a near spill *(in LDO)*. An operational definition of a near spill *in LDO* could then be "the last mitigating factor functioned as planned." Technically this could be converted to considerations of containment (if one valve were opened...). It might be more correct to consider cases in which the first, second and third mitigating factors operated properly; however such an extensive approach applied to human error would severely test cognitive limits.

Near spills may also occur during non-LDO. The definition may be different in such cases, possibly involving compounding factors, because it is not the failure of a piece of the LDO system, but perhaps the total failure of a larger system. For instance tankers underway may suffer mechanical problems that result in grounding. In this case defining a near spill as having but one final valve closed or the rupture of the outer but not inner hull equates the risk in two very different areas of operation. Not only do the two present different probabilities of failure given the other circumstances or contributing factors, they also present very different magnitudes spills. Subsequently is may be appropriate to have definitions of near spills that are appropriate to the evolution.

Simplicity requires that we make a firm, though perhaps arbitrary, judgement about initiating effects and "accidents." While sliding a definition along a time line highlights the temporal quality of causes and demonstrates the nature of error chains it does not help a general classification of such events. This paper suggests that the general definition of factors be reconsidered to more accurately reflect the role of the various factors in an unfolding accident chain. Although these suggestions may not be feasible for many types of investigation, they are helpful when considering how to define events.

Appendix B: The Importance of Studying Near Spills

Unfortunately the accepted definition of a spill does not capture all relevant information. Simple probability can demonstrate this. Assume Contributing Event A occurs with a probability of .8, Contributing Event B with .7 and Compounding Event C (the initiating event) with probability of .2. The chance of A, B & C occurring to create a spill is .112. If only C is observed and associated with spills, we will incorrectly calculate the probability of a spill. The result will be a reduction in the probability of compounding event C. However if we instead observe the relation between A, B &C, we notice the high probability of contributing events A or B occurring. What is observed is a stage set (with probability .56) awaiting compounding event C to cause a spill. If these contributing factors can also be reduced in probability, the chance of a spill will be greatly reduced.

Near spill reporting may capture data on events A&B, and most importantly the likelihood of interaction between events A, B & C. Near spill investigation is important because there is as much to learn, if not more, from near spills as from actual spills. This is true even with an arbitrary definition of a spill. Evaluation of actual spills yields only the negative factors (contributing, compounding and initiating factors), while evaluation of near spills yields positive factors (mitigating and stop factors). Thus near spill investigations can reveal not only causes of potential spills, but comparisons to actual spills highlights preventive factors. This allows study not only of potential human errors, but also of improved stop and mitigating factors. Such prevention factors can then become part of the wider knowledge on oil spill prevention.

Near spill reporting could also aid in predicting sizes of spills, an important component of spill response planning. More accurate spill prediction may emphasize the need for prevention.

The temporal nature of accidents suggests that mitigating and stop factors should also be collected for actual spills (not just near spills). These are probably the factors that prevent a minor spill from escalating into a major spill. The value of such information is again the study of the positive "stop" mechanisms, potentially highlighting the most effective and least effective responses to spills. It is possible that some "stop" mechanisms actually increase the length and magnitude of the error chain in events under different conditions. Only by studying the positive and negative effects of each mechanism can prevention be improved.

It is important to remember that most of the systems involved in LDO already have integrated many mitigating and stop factors while eliminating compounding factors as they have been learned through the years. The prohibition on smoking removed a compounding factor, watchstanders and flow meters are mitigating factors (allowing the diversion of the accident chain) while emergency shut off switches are a stop factor.

Appendix C: Proposed Database

The above evaluation of databases concluded no single sources contain enough accurate HOE information to conduct a thorough analysis of HOE in LDO, much less for marine transport generally. These sources also do not have the ability to collect (with the exception of OMS) any near spill data. It was then proposed that some sources could be reconfigured or a new database and collection system designed.

Recurring themes in the evaluation section were the skill and training of the investigator, and the sources of information. The data sources that interpret or cull other sources as well as those that do not use trained, career investigators are generally found lacking. There are two possible fixes for this general problem. The first is creating a highly sophisticated data collection system to guide relatively unskilled investigators through the data collection process. This will be referred to as the “strong system.” The second approach uses a less sophisticated data collection design and relies instead upon well trained investigators to produce accurate data. This will be referred to as the “weak system.”

Both approaches have their benefits. The strong system is characterized by high levels of interaction between the data collection system and the investigator. For instance, a spill occurs when the tanks of a barge are overfilled during topping off. If the spill initiating event is determined as “overfill” the program and taxonomy will need to prompt for more information on procedure (e.g. topping off or steady rate?), source of error (sounded wrong tank, sounding reading misinterpreted, failure to shut off pump, miscalculation of fill time, etc), contributing factors and compounding factors (misunderstanding of the DOI, scuppers not closed, flow rate increased or not decreased, etc). Such a system would not only make HOE classification simple, consistent and reliable, it would also highlight unidentified sources of error when an new type of error or sequence occurs and cannot be entered into the system.

The strong system makes collection easy in widely dispersed locations, especially when the events occur with low frequency. Terminals or ships could simply keep the system available and assign a person to complete the case information when the rare event occurs. This approach also produces highly consistent data. Unfortunately an immense amount of development is required for such a system to be completely exhaustive. Not only must all possible outcomes be considered (and known) in advance, but all possible processes must also be considered (and known). Thus although a strong system is able to collect highly detailed and objective data, it is not easily adapted to new procedures, new technology or simply new applications (e.g. LDO and bunkering). Such an approach must therefore be considered appropriate for monitoring of processes that are well known, not for the study of processes that are still only weakly understood.

The weak system is so named for its lack of constraint upon the investigator. Instead of requiring the investigator to collect information, the investigator is trained to use judgement. Only information judged relevant is collected. Such a weak systems approach requires only the training of investigators. During the investigation, the investigator can use previous knowledge of the system and process with training in the types of HOE to best identify to various contributing, compounding, propagating and mitigating factors. Although not well suited for isolated facilities, where an investigator may have little to do, larger facilities or concentration of facilities (such as in major ports) would allow for a shared investigator. The greatest difficulty in such a system is training the investigators to identify factors similarly. As an example of this difficulty, the California State Lands Commission, Marine Facilities Inspection Division recently had two staff members examine the same incident reports. Although they were working from identical reports, their attributions of HOE factors were significantly different. If investigators are not trained to objectify, then each report is strictly a subjective review with no consistency at all.

What is needed then is a system that freely allows trained investigators to follow the various leads in an incident investigation yet provides some sort of a structure to help collect objective information. Such a system provides both the objective quantitative data as well as qualitative descriptions of the accident.

The proposed system is such a mating of systems. First, the common incident identifiers are collected (e.g. spill size, location, time of day, weather, etc). Next the incident is broken into the phases (if a linear sequence) or elements (if a non-linear sequence) of the event chain: Contributing, Compounding, Propagating, Arresting and Mitigating factors. Each event may have any number of factors, allowing for multiple Contributing or other factors. Each phase is then compared against a checklist of basic HOE errors, with each factor indicated as present or absent in the phase. The phase is then briefly described. This is shown schematically in Figure 1. Note that the design can accept near spill information.

This simple structure is easily enriched with stronger taxonomies. For each factor involved in the particular phase, an additional choice list could be added. Thus, the identification of "Hardware" as a factor would lead to a choice list containing "Design" "Construction" "Maintenance" etc, while "Individual" factors could lead to a taxonomy of "Mistake" "Ignorance" "Fatigue" etc. All or some factors could have such a taxonomy attached? The system can also be adapted to different systems or procedures. When the evolution (the general activity at the time, e.g. loading cargo, bunkering, underway, LDO) is identified, greater detail about the evolution can be prompted for. In the case of LDO, the investigator could be prompted to identify one of the 7 primary stages of the LDO, and then even the step within the LDO (see accompanying report by Stoutenberg & Bea, 1995). Until such choice lists are developed, the information can still be entered into the description, perhaps for later recoding. This is shown in figure 2.

The advantages of these systems is they allow for the collection of basic identification information. The information required by regulators is still collected, but there is additional information to help understand such events. Although this design cannot explicitly locate a particular factor within the chain of events, it does place a factor in the appropriate phase. Thus while other systems can only indicate the presence of a particular type of error and if it was an initiating or contributing

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[9] Furthermore, because some factors may have error chains completely separate from the chain leading to the accident (i.e. there is an error chain that produces a contributing factor), this design could be looped to allow entry of information for all levels of the chain. This would allow, if desired, for each contributing or other factors to be considered an event, without losing ties to other events in the chain.

factor in an event, this system could identify *for* each *human error* the presence of and the type of the error and its effect on the error chain (e.g. as a contributing or compounding factor).

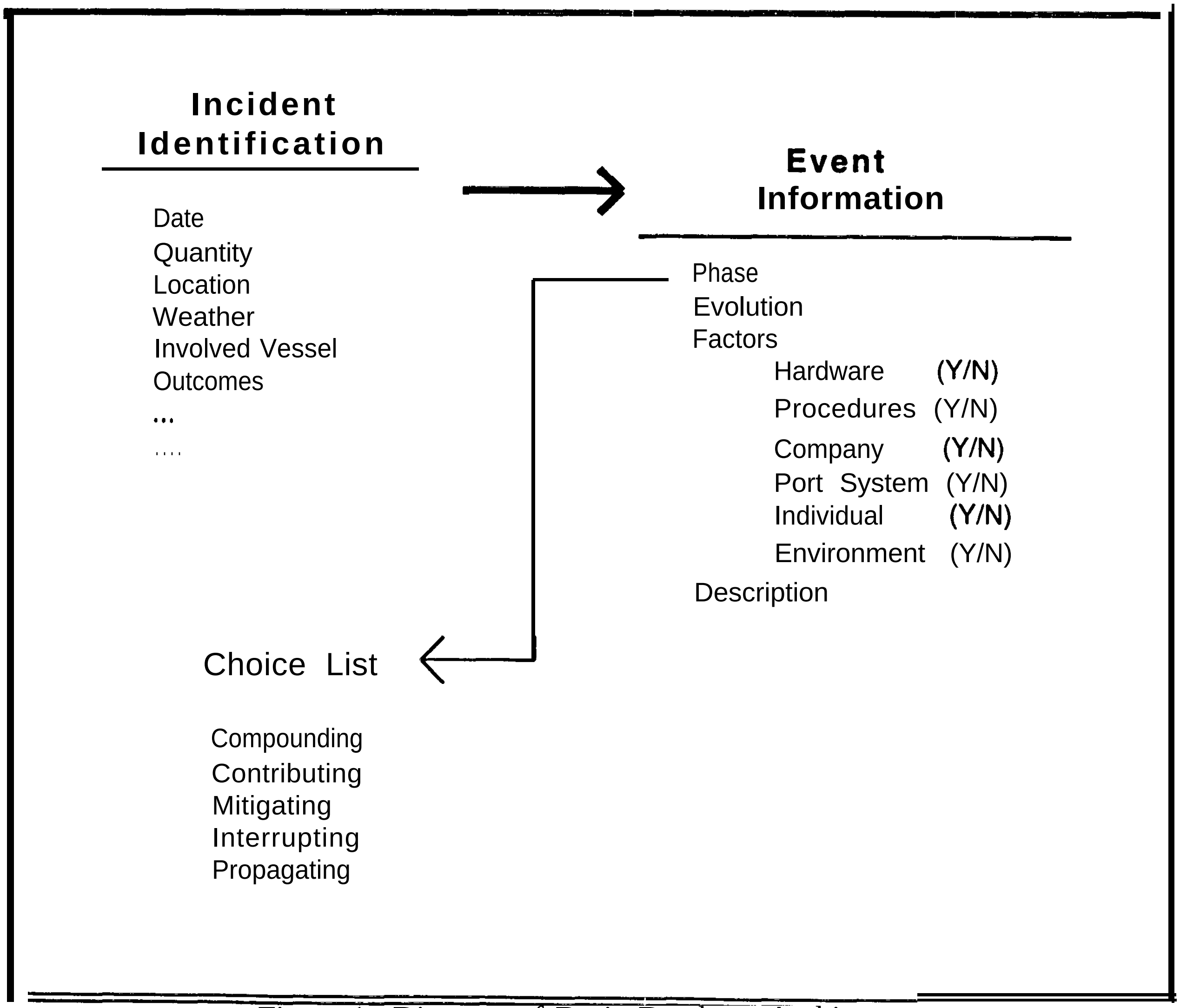

Figure 1 : Diagram of Basic Database Architecture

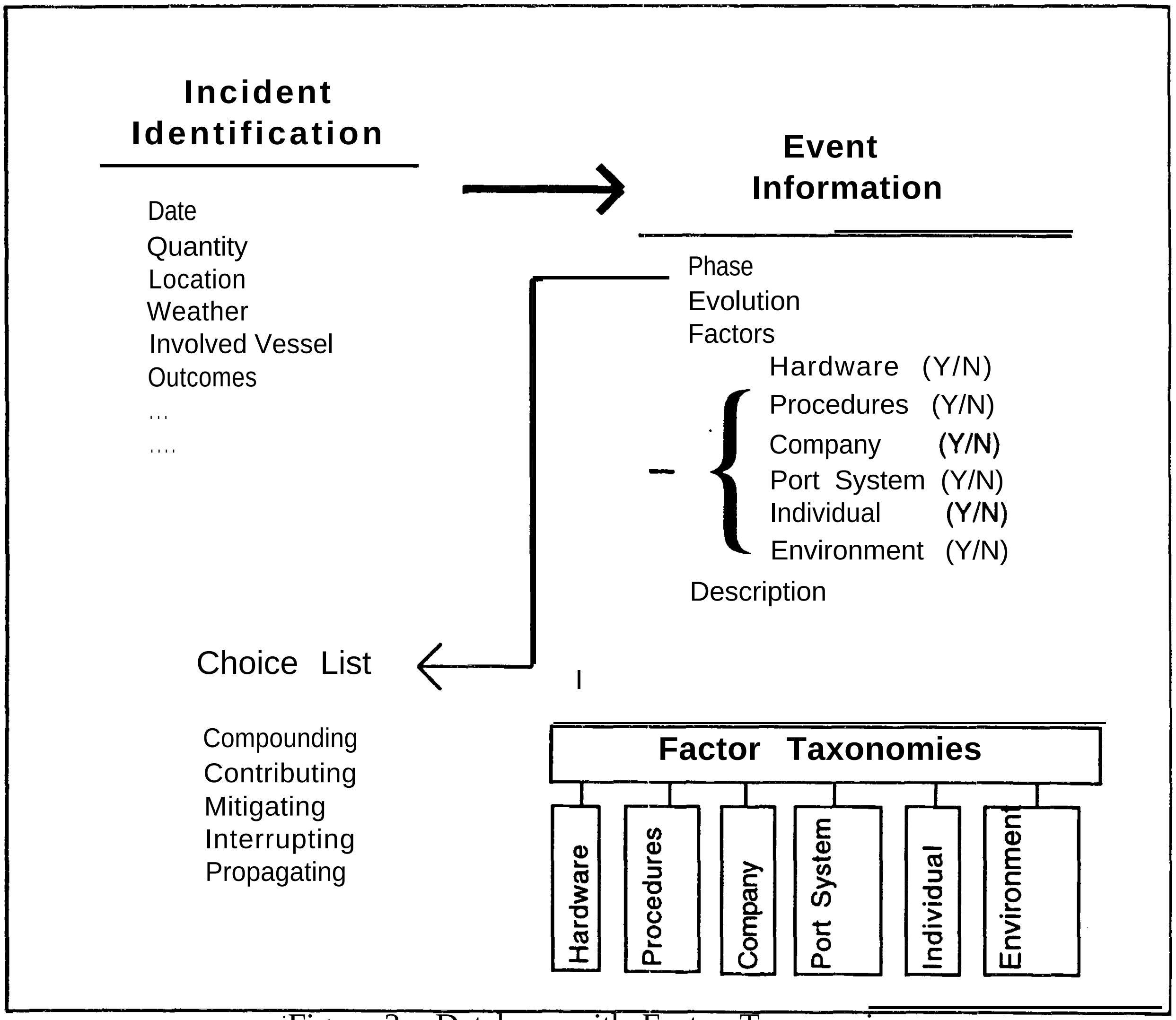

Figure 2 - Database with Factor Taxonomies

Because the system is not tied to a particular hardware system (i.e. only LDO), it could accept information on all types of events. The taxonomies may require some refinement or redefinition for certain systems, but the information could still be collected and entered.

The descriptions are a potentially time consuming part of the database. It is not suggested that each entry in the proposed database contain the voluminous information in NTSB reports, but that the description give a brief recounting of the particular phase of the event. If the investigator determines there is only one factor for the given phase (e.g. the only contributing factor was a fatigued operator), the description may be very brief. However, if the phase involves multiple factors (particularly if they are not linear) the description may become very involved.

The description process can be made richer and easier with the ability to accept both photographs and sketches relating. Further, a basic template could be provided in the database, prompting the investigator for information. This inclusion of this qualitative information frees the investigator from intensive coding and entry of the data and provides a source to verify the coding of the factor variables. Researchers could then also search the database for examples of certain types of combinations of errors and then use this qualitative information in various ways, including recoding with a different taxonomy.

An integral part of the database is a feedback function. Analyses of previous entries should help inform the investigation and reporting of future events. The analyses should also be available to prevent recurrences of events. Analysis of accidents is only as good as the investigationand reporting, but a database is only as good as the information it can provide. Useful output from a database is also critical to ensuring continued input.

Following are the lists of the basic identifiers that should be considered. The list is intentionally broad to suggest the variety of information that is potentially available. Any implementation will require serious consideration of information availability and resources required to obtain it. More detailed information on human error taxonomies is available in Fleishman et.al (1990) and Boniface (1995).

C.1 Facility Information

Facilities (both shore facilities and ships or barges) need to be uniquely identified. Identification provides an event record for regulatory or legal actions and informs future entries (as history). Characteristics as flag, year built, class (for vessels), building code, construction date, tidal influences (for terminals) can yield important information about the physical design of a facility. The historical information is important to attempt to link the likelihood of a particular error with a particular organization's history and relations with other organizations in the port system. This is important to determine the existence of intra-corporate induced errors and inter-corporate induced errors.

Violations, Citations by regulatory and class agencies
Accidents, spills, casualties, near misses, near spills
Major events (ownership change, rebuild, reclassification, etc)

C.2 Personnel Information

Personnel information is important for determining the effects of crew training and experience as well as such factors as fatigue or stress. Personnel information may also point to demographic sources of error. A secondary result of the data is identification of specific individuals as recurring sources of error.

Name
Age
Training
Tenure
Experience (types and amount)
Physical, Mental Condition
Time on shift, in week
Sex
Nationality
Language skills
Recorded violations, citations of regulatory code
Violations of facility policy
Accidents, spills, casualties, near misses, near spills (even if not at fault)
Crew engaged in task
Crew in previous shift (if applicable)

C.3 Spill Identification

Characteristics of a spill are important for regulation. Near Spill quantities inform policy, engineering design and organization changes.

Quantity
Material
Near Spill Potential Quantity (minimum expected, expected, maximum expected)

C. 4 Evolution & Procedure Information

Data on procedures is important. Continuing with the LDO example, there are many stages and steps within stages of an LDO. Better identification of the error in relation to procedures can inform procedural change.

Evolution
Procedure
Point of Procedure
Frequency of inspection
Time since last inspection
Communication method & network
Equipment Involved

Appendix D: Data Source Comparison Tables

A comprehensive set of tables follows, comparing the sources of data considered in this paper. The EPA's PIES, USCG's PSIX system, DNV's SEP and corporate sources have been excluded from these comparisons as they are not directly applicable to studies of Marine HOE. No information on OSPR's proposed system were available at the time of writing, so it is also excluded from the tables. All systems considered are actual data recording systems, excepting IMO which is a recommended format.

The source abbreviations used are as follows :

Proposed	The proposed Marine HOE database.
MSIS	U.S. Coast Guard, Marine Safety Information System
MMS	U.S. Department of the Interior, Minerals and Management Service, *World Wide Tanker Spill Database*
NTSB	U.S. Department of Transportation, National Transportation Safety Board, Marine Accident Investigations
MFID	California State Lands Commission, Oil Spill Database
OMS	Washington Office of Marine Safety, Vessel Screening Database
DEQ	Oregon Department of Environmental Quality
IMO	International Maritime Organization
OPB	World Information System's *Golob's Oil Pollution Bulletin*
OSIR	Cutter Information Corporation's *Oil Spill Intelligence Report*
MRB	Marine Publishing's *Marine Regulatory Bulletin*
Guide	Tanker Advisory Center's *Guide for the Selection of Tankers*

Presence of information is indicated by "Yes" ; In primarily quantitative systems this indicates that a field exists for this information or that the information may be found in the system; In primarily qualitative reports this indicates that the information is reported. Qualitative Reports (or portions) may also be indicated "Possibly." This indicates the idiosyncratic as opposed to systematic reporting of information. "N/A" is used to indicate that the type of information is outside the scope of the source.

In the working draft of this paper question marks indicate the information is not yet known. In the case of OSPR and DEQ this is because the systems are under development.

Table D1: Database Parameters

	Min. Spill Size	Location	Materials	Tankers/ Barges	Terminals	Platforms	Near Spill
Proposed	N/A	Yes	All	Yes	Yes	Yes	Yes
USCG/ MSIS	Sheen	U.S. Navigable Waters	All	Spills from any source entering to navigable waters; includes inshore facilities.			No†
MMS	42,000 gallons (1,000bbl)	World-wide	Oils	Yes	No	No	No
NTSB	Not a criteria	US waters/ vessels	Not a criteria	Yes	No‡	Yes	No
MFID	Tablespoon	CA waters	All	Yes	Yes		No
OMS	Not a criterion	WA (+Worldwide*)	All	Yes	No	No	Yes**
DEQ	Sheen	OR waters	All	Spills from any source entering OR waters			No
IMO	Not a criterion	International	Not a criterion	Yes	No	No	No
OPB	10,000 gallons	World-wide	Oils***	Yes			No
OSIR							
MRB	250 gallons	Pacific Coast U.S., Canada	All				No
Guide	Not a criterion	World wide	Not a criterion	Yes/ No	No	No	No

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†The Coast Guard does record some accidents as "potential spills"; however this is limited to damaged vessels that could discharge hazardous material - typically from fuel tanks.

‡If a vessel accident occurs at a shore facility, the facility will be included in the investigation.

* A unique feature of OMS is vessel screening. This process captures international historical information on all vessels entering Washington waters.

**OMS collects Near Miss information. Presently this is defined as a navigational near miss only.

*** The publishers also produce newsletters for other products, as World Information Systems Hazardous *Material Intelligence Report.*

Table D2: Spill Identification

	Size	Material	Location†	Weather	Date	Time
Proposed	Yes	Yes	Yes	Yes	Yes	Yes
USCG/ MSIS	Yes	Yes (highly detailed)	Yes	Yes (if a factor)	Yes	Yes
MMS	Yes	Yes	Yes	Yes (if a factor)	Yes	No
NTSB	Yes	Yes	Yes	Yes	Yes	Yes
MFID	Yes	Yes	Yes	No	Yes	Yes‡
OMS	Yes	Yes	Yes	Yes (extensive)	Yes	Yes
DEQ	Yes	Yes	Yes	Yes	Yes	Yes
IMO	Yes	Yes*	Yes	Yes	Yes	Yes
OPB	Yes	Yes	Yes	Possibly (if a factor)	Yes	?
OSIR						
MRB						
Guide	Yes	Yes	Yes	No	Yes	No

†Each database reports locations to varying degrees of precision.
‡Time reported. This may differ greatly from the time of the spill.
* Limited to oil or chemical designation.

Table D3: Vessel Information

<table>
<tr><th></th><th>Name</th><th>Flag</th><th>Size</th><th>Year Built</th><th>Type</th><th>Owner-ship</th><th>Class Society</th><th>Equip-ment</th><th>Design</th></tr>
<tr><td>Proposed</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>USCG/ MSIS</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Possibly</td><td>Possibly</td></tr>
<tr><td>MMS</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>NTSB</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes†</td><td>Yes</td></tr>
<tr><td>MFID</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>OMS</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes
(extensive)</td><td>Yes</td></tr>
<tr><td>DEQ</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>IMO</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>Limited</td><td>Yes</td></tr>
<tr><td>OPB</td><td rowspan="3" colspan="2">Yes</td><td rowspan="3" colspan="2">Possibly</td><td rowspan="3">Yes</td><td rowspan="3" colspan="4">Possibly</td></tr>
<tr><td>OSIR</td></tr>
<tr><td>MRB</td></tr>
<tr><td>Guide</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td></tr>
</table>

†Affected or involved equipment is described in great detail, often down to the model number

Table D4: Vessel/ Facility/Crew History

	Vessel		Facility		Crew		
	Violations	Accidents	Violations	Accidents	Deck Crew	Dock Crew	Violations/ Accidents
Proposed							
USCG/ MSIS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MMS	No	No	N/A	N/A	No	N/A	No
NTSB	If the history is relevant to the accident investigation.						
MFID	No	No	No[†]	No	No	No	No
OMS	Yes	Yes	Yes	Yes	Yes	No	No
DEQ	No	No	No	No	No	No	No
IMO	Possibly						
OPB							
OSIR							
MRB							
Guide	Yes	Yes	N/A	N/A	No	N/A	No

[†] MFID field visit checklists may detail procedural violations, but not violations cited under law.

Table D5: Cause/Investigation

			Cause Factors				
	Procedure	Load Level	Human	Contributing	Compounding	Physical events	Mitigating/ Stopping
Proposed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
USCG/ MSIS	Possibly	Possibly	Yes	Yes	Yes	Yes	No
MMS	No	No	No	Yes[†]	No	Yes	No
NTSB	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MFID	Possibly	No	No	No	No	Yes	Possibly
OMS	Possibly	Possibly	Yes	Yes	Yes	Yes	Possibly
DEQ	Possibly	Possibly	No	No	No	No	No
IMO	No	No	Yes	Yes	Yes	Yes	Yes[‡]
OPB	Possibly						
OSIR							
MRB							
Guide	No	No	No	No	No	No	No

[†] Limited to a chain of initiating events leading to a spill.

[‡] Limited to use of safety equipment - life saving, fire fighting, communications.

Table D6: Response Information

<table>
<tr><th></th><th>How/ When noticed</th><th>How Contained</th><th>Damages</th><th>Minimizing Actions</th></tr>
<tr><td>Proposed</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>USCG/ MSIS</td><td>Possibly</td><td>Possibly</td><td>Possibly</td><td>Possibly</td></tr>
<tr><td>MMS</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>NTSB</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td>MFID</td><td>No</td><td>Possibly</td><td>Yes</td><td>Possibly</td></tr>
<tr><td>OMS</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>DEQ</td><td>Yes</td><td>Possibly</td><td>No</td><td>Possibly</td></tr>
<tr><td>IMO</td><td>No</td><td>Yes</td><td>Yes†</td><td>No</td></tr>
<tr><td>OPB</td><td rowspan="3" colspan="4">Possibly</td></tr>
<tr><td>OSIR</td></tr>
<tr><td>MRB</td></tr>
<tr><td>Guide</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
</table>

† Limited primarily to equipment or structural damage and individual injury or death.

Table D7: User Concerns

	Sources	Number of Records	Year Coverage Begun	Type of Info	Computer based
Proposed	Primary	N/A	N/A	Quantitative with extensive Qualitative	Yes
USCG/ MSIS	Primary, Secondary, Legal	≈210,000	≈1973	Quantitative with limited Qualitative	Yes
MMS	Tertiary Public, Industry	≈1,100	1955	Quantitative	Yes
NTSB	Primary	≈180	1973	Qualitative	No
MFID	Secondary Legal	≈7,000	1988	Quantitative with limited Qualitative	Yes
OMS	Primary, Secondary, Tertiary	≈1,200	1993*	Quantitative with limited Qualitative	Yes
DEQ	Primary, Secondary,	≈700	1995 (new system)	Qualitative with Quantitative summary	Yes
IMO	Primary	N/A	N/A	Quantitative with limited Qualitative	N/A
OPB	Secondary	≈80	1978	Qualitative with Quantitative summary	Yes‡
OSIR	Secondary	≈3250	1978		
MRB	Secondary	N/A	1991	Qualitative	No
Guide	Secondary, Tertiary	≈3,400	≈1984	Quantitative with limited Qualitative	Yes

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[*] Information on self-reported tanker incidents from approximately 1988 have also been entered for all tankers operating in Washington waters.

[‡] The databases offered by these organizations provide only the quantitative information.

Appendix E - Method

The information presented in this paper was obtained from a variety of sources. When possible actual data was examined, failing this we used printouts or samples of the data. Complete lists of fields were also requested, though the complexity of some systems did not make this a feasible request. Interviews were conducted with a variety of people, both the custodians of the databases as well as users in and outside of the parent organization. The interviews were conducted primarily between August 1994 and October 1994, with updated interviews in September of 1995. Publicly available newsletters and reports were reviewed for content. Not at all information was verified so there exists the possibility that some information is incorrect.

All interviews are listed in the references, as are all publications. Untitled or informal publications, printouts, et cetera are not referenced as they were effectively part of the interview process.

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Interviews

Cheryl Anderson, U.S. Department of the Interior, Minerals Management Service

Eric Brest, Editor, Golob's Oil Pollution Bulletin

Lou Burris, Information System Manager, Washington Office of Marine Safety

Jean Cameron, Executive Coordinator, States British Columbia Oil Spill Task Force

Nina Carter, Director of Operations, Washington Office of Marine Safety

Bob Diaz, Investigator, Washington Office of Marine Safety

Lt. Cmdr T. G. Falkenstein, Marine Safety Office San Francisco Bay

Ray Fayles, Classifications, Det Norske Veritas

Mike Gobal, Senior Vetting Officer, Sea River Maritime

Lawrence Hope, Chief of Field Operations, Southern California, California State Lands Commission

Dexter Halligan, Management Information Services, Oregon Department of Environmental Quality

Don Hermanson, Marine Terminal Safety Specialist, California State Lands Commission

Rick Holly, Marine Terminal Safety Specialist, California State Lands Commission

Ron Holton, Safety Specialist, Chevron Shipping

Mike Hughes, W.P.I. Coordinator - Richmond Refinery, Chevron Products

Ronald Kelleher, Safety Specialist, Chemical Tankers of America

Dodge Kenyon, Vessel Inspector, Washington Office of Marine Safety

Roy Mather, Marine Terminal Safety Specialist, California State Lands Commission

Cora McCauley, Database Manager, California State Lands Commission

Arthur McKenzie, Director, Tanker Advisory Center

Lt. Rick Naccara, USCG, Marine Safety Office San Francisco Bay

Stan Norman, Policy & Planning, Washington Office of Marine Safety

Capt. Bob Sands, Office of Oil Spill Prevention and Response, California Department of Fish & Game

Gary Schmidt, Field Office Director, Washington Office of Marine Safety

‘Laura Stratton, Vessel Screening Specialist, Washington Office of Marine Safety

Paul Slyman, Oil Spill Specialist, Oregon Department of Environmental Quality

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Bernie Weber, Inland Structures, Det Norske Veritas

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