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High Reliability Tanker Loading and Discharge Operations: Cheveron Long Wharf, Richmond, California

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Abstract

This paper summarizes the results of a two-year study of tanker loading and discharge operations at the Chevron wharf located at Richmond, California. The primary objective of this study was the application of knowledge developed in previous research that addressed human and organizational factors in operations of marine systems. This application was intended first to identify strengths and weaknesses of this technology, and second to identify how the reliability of the operations at the wharf could be improved.

The study involved a review of oil spill databases, data and information gathering in the field at several tanker loading and discharge facilities, interviews with key operations and management personnel, qualitative assessments of the physical and human aspects, and quantitative evaluations of these same aspects. Results from the interviews and field operations observations were used to develop qualitative and quantitative models to address the reliability characteristics of the operations. In the end, the qualitative assessments were found to be much more elucidating than the results from the quantitative models. The reasons for this finding are summarized in the paper. Hardware, procedure, crew selection and training, and management oversight were all found to be of very high quality. The study identified four important areas for potential future improvements: 1) management of organizational change, 2) operations communications, and 3) development of near miss and accident databases. These potential improvements are discussed in this paper.

1. Introduction

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 higher 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 organizational Errors (HOE) 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 the project summarized in this paper was to further develop procedures to assist in the definition and evaluation of alternatives to minimize the occurrence and effects of HOE in tanker Loading and Discharge Operations (LDO). As part of a joint industry - government agency sponsored project conducted during the period 1990-1993 titled *Reliability Based Management of Human and organizational 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 [1]. Two major needs were identified in this project. The first need was the further development and field testing of a classification and evaluation system for HOE. The second need was the further development of an HOE management system to interface with the marine operations analytical models developed during the first project.

The project summarized in this paper addressed these two needs in the framework of a 'hands-on' field operations oriented project involving tanker LDO. The project focused on *high consequence - low probability spill accidents*. Testing of the HOE classification and evaluation system was coordinated with similar efforts conducted by the U. S. Coast Guard, the California State Lands Commission, and the Washington State Office of Marine Safety. The field studies were concentrated on two high reliability organization LDOs conducted by Chevron Products Co. and by Arco Marine Inc. This paper addresses the work conducted with Chevron at their long wharf in Richmond, California.

2. Study Approach

The project was organized into three studies. The first study addressed the organizational aspects of the wharf operations [2]. The second study addressed the engineering assessment aspects [3]. The third study addressed tanker spill accident and near-miss databases and how these might be further developed and utilized in engineering assessments [4].

Meetings with representatives of Chevron's corporate and local management teams were held during the course of the project. In addition, multiple meeting were held with local representatives of the agencies that have primary responsibilities for LDO including the U. S. Coast Guard and California State Lands Commission. The authors were present during multiple LDO and crew shift changes. The project involved LDO observations both on the wharf and on the tankers.

The study of oil spill accident databases involved a large number of Federal, State and industry organizations that have developed or are developing such databases [4]. The organizations included the U. S. Coast Guard, the U. S. Minerals Management Service, Oregon Department of Environmental Quality, the California State Lands Commission, the Washington State Office of Marine Safety, and Chevron Shipping. Access to these databases were provided together with interviews with personnel experienced in accident investigations, reporting, and analyses.

Following the initial information gathering phase in the project, a detailed process analysis of the LDO were developed. The process analysis addressed *hardware, procedures, operating team, organizational, and environmental* aspects. Two questionnaires were developed to address wharf operations and management / organization aspects of LDO. These questionnaires were then used as an instrument to gather information on LDO risks and mitigation measures from management and operations representatives. Results from the questionnaires, individual interviews, and group meetings were used to identify the high consequence - low probability aspects of the LDO. This information then served as the basis for development of qualitative and quantitative evaluations of the LDO.

In the remainder of this paper we will summarize some of the primary insights developed from the study performed at the Chevron long wharf at Richmond, California.

3. Chevron Long Wharf

The Richmond refinery long wharf is located on the northeast side of San Francisco Bay. It is 4200 feet from shore, accessible by a causeway. The long wharf has four ship and two barge berths (Fig. 1).

All ship berths except Berth 2 have dual counter weight marine loading arms. Berth 2 has a large hose riser system for the transfer of refined products.

3.1 LDO Process

Loading and discharge operations follow a basic seven step process. These steps are similar for both loading and discharge, independent of whether loading arms or hoses are used. The steps are: *1) approach and berthing, 2) connection, 3) start up, 4) steady rate, 5) topping off (stripping), 6) disconnection, and 7) departure.*

Approach is the movement of the vessel from the maneuvering basin to the pier. Berthing is the securing of the vessel to the pier. The connection process is the part of the operation associated with the attachment of the ship and shore cargo manifolds. The pre-transfer conference is also considered as part of connection. Start up is the gradual increase in flow rate up to the steady rate agreed upon at the pre-transfer conference. If the ship is being loaded, it will alert the shore when its tanks are nearly full and topping off should commence. Flow is gradually decreased until it is stopped completely. Products are allowed to drain by gravity, aided by pressure in the lines, out of the connecting hoses or loading arms. The vessel can then be disconnected and depart.

Fig. 2 is an event tree characterization of each step in the LDO process. Each of the steps is described in more detail in later parts of this paper. The five steps from connection to disconnection result in six primary opportunities for spills.

3.2 Approach and Berthing

This step was defined to only include the final docking of the ship. Six steps are associated with approach and berthing: 1) berth selection, 2) approach with escort tug, 3) ship positioning, 4) berth approach, 5) line handling, and final positioning.

For vessels that have come to the long wharf before, there is a berth that is typically used based on the size of the vessel and the product(s) that she carries. If a vessel has never been to the wharf before, the berth to be used is planned in advance and the vessel is made aware of this plan so that there are no surprises when the ship arrives.

3.3 Connection

Connection is the process of attaching the shore piping system to the vessel piping system so that the flow of oil may commence in the appropriate direction (Fig. 3). There are four primary steps in the process of connection: 1) pre-transfer conference, 2) flange preparation, 3) hose or loading arm connection, and 4) alignment check.

One of the most important steps in LDO is the pre-transfer conference. During the pre-transfer conference, all details of the transfer of oil are discussed by the personnel that will be involved in the cargo transfer operations and agreed upon. Details of critical communications during the process are defined. Table 2 lists the items that must be covered during the pre-transfer conference that are required by the U. S. Coast Guard and the California State Lands Commission. Similar guidelines and training protocols have been developed and implemented by the Washington State Office of Marine Safety [5]. The Declaration of Inspection is a document that is completed and signed by all parties involved to verify the proper execution of the pre-transfer conference.

Table 2 Pre-Transfer Conference

Product Identity, Quantity and Type
Sequence of Transfer Operations
Amount of Notice Needed Before Stopping or Changing Flow Rate
Arrangement of Transfer Systems
Special Precautions at Critical Stages
Initial, Maximum, and Topping Off Rates
Federal and State Regulations
Signals for Stand-By, Slowdown, and Stop Transfer
Emergency Procedures
Spill Reporting Procedures
Watch and Shift Change Schedules
Shut Down Procedures
Anticipated Cargo Stoppages and Delays
Declaration of Inspection is Completed

The connection is made after the pre-transfer conference. The loading arms or hoses are moved to the vessel. If loading arms are used, the drains are opened and any product remaining in the arms is emptied. The face plate can then be removed. The face plates are removed by loosening the bottom connections first so that any remaining oil will be drained. The o-rings are examined before attachment to the ship flanges and are replaced if they are worn or damaged. The arm or hose flanges are then secured to the ship flanges, ensuring that all connectors are tight or that there are bolts in every hole, respectively. If the vessel is a Chevron ship that uses the port often, this process is performed by the vessel personnel without supervision. If the vessel is not from Chevron Shipping, an observer from the terminal is present on deck to witness the proper execution of this step.

3.4 Start Up

During start up, the most critical components are communication and monitoring. As a part of the pre-transfer conference, the LDO plan is communicated among the vessel person in charge, the berth operator, and the pump operator. The receiving party opens its valves first. This is the ship in a loading operation and the shore in discharge. After the receiver’s valves are opened and verified, the initiating party opens its valves. After the path of the product is verified, the initiating party requests permission to commence pumping.

Flow is started at a slow rate and all connections are checked for leaks or other problems. Loading arms and hoses are observed to verify the absence of excessive cyclic loading due to fluctuating rates or line hammer due to sudden valve closure. After both parties are certain that their side of the system is functioning properly, flow is increased gradually to the agreed upon steady rate. During this process, communication is constant between the vessel and the berth to verify the steps in rate increase on both sides.

Fig. 4 is an event tree characterization of the start up process for discharge operations. The three sub-step process results in three primary opportunities for spills.

3.5 Steady Rate

There are no subsequent steps during the steady transfer of petroleum. Monitoring and communication are crucial during this time so that both the ship and the terminal keep track of the operation. This is important so that neither party will be surprised by the topping off of tanks as well as for the detection of spills. Flow rates and tank levels are monitored. The volume of transfer is calculated continuously and verified periodically to make sure that the ship and the berth agree and that all oil is accounted for. Some deviation is to be expected, but if it is unusually high it is possible that the missing oil is spilling somewhere.

3.6 Topping Off

Topping off is the most complex and difficult step in the loading process. It requires precisely timed communication and perfect control of critical equipment. The timing of the notification of topping off is crucial. Because the large motor operated valves at the berth move very slowly, it is very important that the operators be warned in advance. The recommended time of notification is thirty minutes before the transfer is to be completed. At this time the vessel will alert the berth operator to the planned topping of tanks and the berth operator will stand by the valves for further notification.

Beginning fifteen minutes before the end of the transfer the valve is slowly closed incrementally. The careful and slow manipulation of these valves ensures that no hydraulic shock will result in line rupturing if the valves are slammed shut when the shore-side pumps are still operating. The pumps are slowed and then stopped in response to back pressure on the line as the valve is closed. When the final notification to stop the flow is received, the valve is closed completely and flow is ceased. The ships valves are left open so that lines can be allowed to drain in preparation for disconnection.

Fig. 5 shows the relationship between the different substeps in the topping off procedure. The process results in three primary opportunities for spills.

Stripping is a much more simple process from the standpoint of the terminal. Because the terminal has an effectively unlimited capacity for oil, flow does not have to be stopped at a precise point. The same guidelines for notification are usually followed. The vessel will inform the berth when it is nearing the bottom of the tanks

3.7 Disconnection

Disconnection procedures vary based on whether hoses or loading arms are used or whether crude oil or refined products are transferred. If the ship is being loaded, at this point in the operation she will be quite low in the water and most of the product will simply drain by gravity. To facilitate this process, some suction is provided in the tanks to draw oil out of the lines. The bolts in the connecting flanges are removed beginning from the bottom. If there is any product left in the line, it will drip into the containment and drip pans under the vessel's cargo manifold. If the hose was used to transfer refined product, face plates will not be replaced so that any remaining vapor will evaporate. If black oils are transferred, face plates will be secured so that any product adhering to the inside of the hose will not ooze out later.

If loading arms are used, the lines are drained using drain taps in both the headers and arms. Flanges are disconnected from the bottom around to the top connectors to allow any remainder to drain into the containment. After the arm is disconnected from the ship, the o-ring is carefully examined and replaced if there are any signs of wear before the face plate is secured. After everything is re-secured, the blanked off arms are covered with a plastic bag to catch any possible drips and the loading arms are returned to their rest position at the berth.

3.8 Departure

Departure is not strictly part of the loading and discharge process, but it is included here for completeness. Departure is similar to approach, but in reverse. The ships lines are let go and it is pulled away from the wharf by the assisting tugs. The only danger for oil spill in departure is due to navigation. The hazards most closely related to departure are the possibilities of grounding or collision with a loaded tanker. Grounding or collision is not likely to happen close to the wharf because vessel traffic and draft are very closely regulated.

4. Organization Assessment

When organizations address actions they must take, particularly strategic actions to minimize risk, individual operators become one of several components they must manage. The basic model used in this project is illustrated in Fig. 6. It consists of five components: 1) Organizations (Chevron, U. S. Coast Guard, etc.), 2) Individuals (LDO operators), 3) Procedures (software and processes used in LDO), 4) Hardware (LDO facilities), and 5) Environments (internal, external, sociological). These five components comprise the LDO 'system.' There are error or accident producing potentials within each of these five components and at their multiple interfaces. Error is defined as an action or inaction that results in an unanticipated and undesirable result.

The organization in this model represents the central decision-making and strategizing unit, related to each of the components to which it is linked. Hardware (systems, equipment, facilities) are indeed operated by individuals, but the organization must develop the systems, make decisions as to the type of hardware to be used, subsequently install the agreed-upon hardware, and ultimately make repairs, adjustments, upgrades, and changes.

Similarly, procedures, while given to the end-user/operator (i.e., the individual) to put into practice, must be developed, disseminated, implemented, and even enforced by the organization. Use of procedures must be consistent among operators within an organization and can only be so with the existence of an organizational system capable of implementing and monitoring such uniformity.

The organizational environment is represented by two forms: internal and external. The internal organizational environment refers to the network of groups within a single organization (or in the case of this project, a single corporation) relevant to the existence and operations of a particular group. The external organizational environment pertains to the system of external (i.e., outside the corporation) organizations relevant to the existence and operations of a particular organization (this distinction and its relevance with respect to this project will be addressed in greater detail later in this paper).

Finally, the individual (or operator) is the fourth factor that influences and is influenced by management-level human and organizational error. However, individuals are a particularly important component in the model because they interact with each of the other components. Organizational decisions and strategies with respect to systems, procedures, and environments are made by individuals and are made with the end-user, the operator, in mind. Once those decisions or strategies are made and implemented the operators must continue to perform their duties with them, and their ability to do so in a functional manner determines any possible future changes to the original decisions or strategies.

This model does not assert that individuals are not 'connected' to hardware, procedures, and environments. Rather, the model posits that in the context of organizational issues and managerial recommendations, organizations serve as the conduit between individuals (operators) and the hardware, procedures, and environments that exist inside the organization.

4.1 Chevron Long Wharf

The Chevron long wharf at Richmond is owned and operated by the Refining Department of Chevron Products Company. Chevron Shipping personnel were also included in our assessment. The contact in the Shipping Company was made through the headquarters offices in San Francisco, California. The companies, while part of the same corporation are operated separately and structured in different manners. While the main office of the Shipping Company is located centrally at the headquarters in San Francisco, the operation offices for each of the Chevron refinery locations are housed on the premises of each individual refinery. Chevron Shipping has a field contingent located in offices at the long wharf to facilitate and assist in coordination of the terminal operations. Therefore, with respect to this study, the refinery personnel, both at the terminal and in the offices, are located on site at the Richmond long wharf.

In this study, specific attention was given to LDO. Therefore, the focus was on activities and management at the Chevron long wharf and less attention was given to shipping operations. Based on extensive field visits and pilot studies, a group of organizational concepts were identified and selected for in-depth analysis. The concepts are: 1) organizational culture, 2) the organizational environment, 3) human-resource management, and 4) management strategy. Within each concept, other related concepts or phenomena specific to this project are also identified, defined, described, and elaborated on.

4.2 Organizational Culture

Organizational culture has long been a topic of considerable interest among scholars and practitioners of business and organizations. Anthropologists were among the first to address culture as an issue, but many of the definitions they used were applicable to societal cultures, such as race, ethnicity, or religion. Malinowski [6] defined culture as comprised of "inherited artifacts, goods, technical processes, ideas, habits, and values."

When organizational researchers began to study culture in organizations, they sought to define it in more pragmatic ways. Van Maanen and Barley [7] describe organizational culture as the "values and expectations which organizational members come to share". A more crude, yet highly popular definition comes from Deal and Kennedy [8] who claim that organizational culture is simply "the way we do business around here". While both definitions offer insight into what is meant by culture, they have been criticized as being too broad while offering little managerial usefulness [9].

Perhaps a less crude and more operational definition that is more appropriate to the topic of this project was offered by Schwarz and Davis [10], who define culture as "a pattern of beliefs and expectations shared by [an] organization's members. These beliefs and expectations produce norms that powerfully shape the behavior of individuals and groups." This definition is preferable because it avoids pinpointing specific criteria that define organizational culture, while also ambitiously illustrating the behavioral components and effects that other, more abstract definitions do not. It also introduces norms as a component of organizational culture, which other definitions inappropriately ignore.

Culture is in many ways the cornerstone of the study of organizations because it recognizes differences between industries and firms. Some of its components operate to differentiate among organizations in a single industry, or even divisions or departments in a single company. The concept is also very elusive in attempts by many to identify significant aspects of culture, particularly those that are objectively positive or negative. In fact, it is the very nature of the concept, that it cannot be universally applied, that may make such objectivity-seeking goals virtually impossible. At the same time, it is possible to identify cultural components, under specific circumstances or within specific industries, that could have identifiable positive or negative consequences for the firm.

One of the most salient findings to emerge about the organizational culture of Chevron is that it is in a period of marked and rapid transition. Prior to the Exxon Valdez accident, like most of its industry counterparts, Chevron paid limited attention to environmental safety issues. Government regulations required little, and the perceived consequences (environmental and financial) of an oil spill were not considered as devastating as they later proved to be. Locally, the collision of two Standard Oil vessels in San Francisco Bay twenty-five years ago prompted significant concern and action regarding vessel traffic safety, however it was the catastrophic nature of the Exxon-Valdez disaster which served as a national and industry-wide watershed event.

The Exxon Valdez disaster had an enormous impact on the industry, permanently altering the organizational environment. Organizations initially resisted external forces tinkering with their operations; but over time it became clearer that the forces were not going away, and cultural changes in the industry and the separate organizations were necessary to successfully adapt.

A more recent cultural trend that affects the development of a safety culture relates to a re-engineering of the organization. In the context of the larger business environment in the United States, demands for lean operations are dominant. An increasingly legitimized transformation of organizations, striving to improve operating efficiency through down sizing, out sourcing, and other cost-cutting techniques has gained institutional favor. Chevron, while confronting these new re-engineering demands, is struggling to maintain its focus on safety in the face of increased resource constraints. Top management feels that the balance is currently being maintained satisfactorily and that the organization is and will remain committed to safety [11, 12]. However, some managers expressed the hope that the focus on safety would not be a casualty to future corporate cost-cutting and down sizing decisions.

Based on our research, four organizational areas were identified as crucial to Chevron's operations and directly impacted by organizational culture issues. These areas were addressed in detail through interviews and discussions with operators and other employees on the wharf and in the shipping division. The areas identified are: 1) the goals and objectives of the organization, 2) prevention and response activities, 3) near-miss phenomena, and 4) organizational demographics. An analysis of our findings on each of the identified areas follows.

4.2.1 Organization Goals and Objectives

An organization is defined as a "consciously coordinated social entity, with a relatively identifiable boundary, that functions on a relatively continuous basis to achieve a common goal, or set of goals" [13]. It is therefore assumed goal attainment is done in an organization setting because objectives are either unattainable by individuals working alone, or if attainable individually, are achieved more efficiently through group effort.

Although it is not necessary for all members to fully endorse an organization's goals, there should be an understanding of what the mission of an organization is; not simply as stated, but also as legitimated through action. Often changes occur in an organization, or situations arise that require modification of company objectives. In these cases, the dissemination of these changes can be a difficult and lengthy process. The marine industry has been subjected to immense external pressures to modify objectives and has experienced first-hand many of the difficulties that coincide with goal-adjustment.

The predominant cultural change required in the wake of Exxon Valdez was the adoption of environmental safety as a top organizational priority. Chevron, like many top industry counterparts, rapidly moved in that direction, and eventually arrived at the point at which it now stands: an organization which proclaims operational safety as a top priority.

The clearest message to come from the interviews of Chevron operating and management personnel conducted during this project regarding the organizational culture at Chevron was the relative newness of these changes. A recurring theme from upper management was one of patience. One manager indicated that the full dissemination of cultural changes as severe as those Chevron has undergone could require up to ten years. Given that Exxon Valdez occurred in 1989, followed by a period of resistance before even the more progressive industry participants (like Chevron) adopted a more safety-conscious cultural orientation [11, 12], Chevron could still be several years away from full realization of these changes. However, the fruits of the changes made thus far have come to bear at least somewhat. Most middle level managers and operators note the visibility of these gradual changes. One wharf supervisor said:

> *"The emphasis (placed on accident prevention) is extremely high. But it's only been in the last four or five years that I've felt this way...Before they just talked the talk, but didn't back it up....It used to be more of a dichotomous, 'Get the unit running and be safe.' But now safety comes first."*

4.2.2 Prevention and Response

Organizations in which the consequences of error could bring about substantial (financial or otherwise) costs, allocate a great deal of resources to the identification and reduction of risks in their operations that could lead to such a disaster. In this context, risk is defined as the extent to which a potentially harmful state of affairs [14] exists, the probability that the risk will lead to an accident, and the likely consequences of such an occurrence [15].

Conceptually, risk has two major components, that while related, are at their base, quite different. The first component is prevention. Simply defined, prevention is the act or ability to preclude an event (in this case risk potential) from occurring. It includes the ability to pre-identify a risk, to anticipate its threat at a given moment, and to intercede to nullify the hazard before it occurs. In practical terms appropriate to this project, prevention refers to all of the activities undertaken to keep oil products from escaping their intended routes and ultimately entering the water.

The second component is response, which is defined as an action which constitutes a reaction to a preceding event (in this case, the occurrence of an error or the realization of a hazardous condition). It is the sum of activities after an incident has occurred, that are intended to minimize its consequences. With respect to LDO at marine terminals, response refers to all of the activities undertaken to minimize the impact of an oil-spill threatening incident. This includes efforts to halt the flow of spill, as well as efforts to trap and clean up that product which has already escaped its intended route.

In other words, prevention and response are separated by temporal factors. Prevention activities occur prior to and up to the occurrence of an incident, while response activities kick in immediately upon the onset of the accident, incident, or error. This does not mean they are necessarily mutually exclusive. Once an incident occurs, response activities begin, but it may be necessary to simultaneously continue prevention activities to avoid a widening of the crisis.

Prevention is the pro-active component of risk, while response is more re-active. Based on results from interviews of both regulators and industry participants conducted during this project, often organizations, in their efforts to manage risk, fail to sufficiently recognize the distinction between prevention and response, training for them simultaneously or in the same manner. It is also common for organizations to focus their attentions on one component (generally, response / clean up), while neglecting the other.

Much criticism has been aimed at industry and regulators alike that the focus of safety and risk mitigation in oil transport operations is on response, and that prevention is neglected. This accusation was borne out during our project by the admission of all parties. For example, participants from the Oil Spill Prevention and Response Unit at the California Department of Fish and Game conceded that while their goal is to focus more heavily on prevention, they have made significantly more progress on response efforts [16]. For some, prevention is completely incorporated with response as one concept, and risk reduction efforts are identical for both.

At Chevron, the delineation between prevention and response is not particularly simple, because prevention activities have been incorporated as a part of the overall operator training program [11]. Prevention is seen as achieved by means of having all operators adequately selected and trained to do their job and having an adequate understanding of the importance of following procedures Prevention is viewed as the outcome of operating well, and in that sense, is seen as an integral portion of operator training. The better trained the operator, the lower the risk that the operator will cause an error that could lead to a spill.

Conversely, response activities are treated separately. They have been undertaken a corporation-wide program to create a distinct unit, i.e.., the *Oil Spill Clean-Up Crew*. No like effort has been advanced in oil spill prevention, although they have recently begun an *Incident-Free Operations* program. It is more pro-active in dealing with prevention issues, but it is newer and not as advanced as the response program. Commendably, the prevention program has been developed in conjunction with a regulator, the California State Lands Commission:

> *"...based on regulations coming from the State Lands Commission, we have begun to pull out prevention as its own entity. In the past we had people just dedicated to response training, but no comparable prevention training personnel....In essence, we have a core operator training, and slowly we have teased out a specific prevention training that is driven by CSLC regulations."*

Chevron has taken two of the three crucial steps with regard to the prevention-response issue. First, they have not made the mistake of lumping the two concepts together, recognizing the distinction between prevention and response, and with that in mind, implementing different plans to deal with each [11, 12]. Second, they have instituted a corporate sponsored comprehensive program to address response issues. The third step has begun, but has not been carried out fully: the institution of a corresponding corporate-sponsored comprehensive program to address prevention issues. With the assistance of the State Lands Commission, the realization of this objective is underway and should be achieved in the near future.

Finally, while the distinction between programs to deal with prevention and response is important and has been made, the complete separation of those programs may be causing the company to miss an opportunity. Although prevention and response are separate and risk reduction activities are different for each, there seems to be little communication between those individuals responsible for the implementation of each of the training programs.

Prevention and response, while distinct, are related and can inform one another, and some combined training could prove beneficial. In addition, more communication between those individuals responsible for each type of training could ensure consistency between the two.

4.2.3 Near-Miss Phenomena

A near-miss refers to a situation in which an incident, accident, or catastrophe is narrowly averted. The aversion can be the result of any number of factors including the specific prevention or response activities of the organization, the specific prevention or response activities of an external, third party, or possibly sheer good fortune. The term itself is a bit of a misnomer, since it is in fact a miss, and the concept is more accurately described as a near-incident, near-accident, or near-catastrophe. However, this is the conventionally used term both in current literature and by operators, and will therefore be used here.

The importance of near-misses and an organization's policies about dealing with them is crucial for the purposes of information-gathering. A closely averted incident provides an opportunity for an organization to learn without having to bear the consequences of an accident. The information gained from near-misses is also a vital component in the development of a complete incident database [4].

Chevron's policy is that management is to track all incidents with a computer system and incident reports are completed on all near-misses. If it is deemed serious, a root cause analysis is conducted. However, both top and middle management concede that the policy is not always carried out as specified. One representative from top management offered:

> *"There is still some reluctance among operators (ship and shore) to report a near-miss. There still exists mis-trust of management. Of the ones we do hear about, I don't know if they were in fact reported by the operator, or if the wharf master just happened to see it."*

A wharf supervisor relayed:

> *"(Operators) have come to me many times, but I suspect many have slipped by without being reported. But I do get a lot of reports."*

Finally, an operator provided support for management's concerns by frankly conveying an attitude that implied a certain level of representativeness:

> *"If nothing happened, if no oil spilled or nobody got hurt, then it pretty much didn't happen."*

Although there appears to be a certain trust issue, the problem is acknowledged and the organization is making efforts to reduce the level of mis-trust. One other concern regarding the near-miss issue is how an organization defines the concept. There did not seem to be a consensus on the definition of a near-miss among operators and management. One contact stated that a near-miss at the Richmond long wharf is considered to be oil that spills on deck, but does not enter water. While this could certainly constitute a near-miss, it appears to be too narrow a definition. It is not difficult to imagine a hypothetical situation where a severe accident involving large amounts of oil spilling into the water was averted, yet no oil spilled on the deck at all. Such a situation may be much more a threat, and consequently much more informative, than a less severe threat in which a few drops of oil spilled on deck. Yet it may not fall under the current definition. Therefore, it was recommended that a clearer, and more inclusive definition of a near-miss be adopted by management, and that that definition be effectively communicated to all relevant employees [2].

4.2.4 Demographics

An additional cultural challenge confronting organizations that directly affects the organizational culture is labor force demographics. In virtually all industries the United States labor force is undergoing significant demographic changes, and the case is no different in oil and marine industries. By the year 2000 it is estimated that 26% of the U. S. work force will be composed of citizens of black, Latin, or Asian descent [17]. In addition, the role of women in the work force continues to grow. While in 1976, only 37.7 % of women were employed, today 65 % of all new jobs are filled by female employees. It is also projected that 47.3% of the U. S. civilian work force will be female by the year 2000 [18].

Another demographic trend occurring is the aging of the U. S. labor force. This is occurring primarily for two reasons: First, the baby-bust (a drop in birth rates) that followed the baby boom of the post-World War II era has simply made fewer people available [19]. Second, largely due to health care advances, people are living healthy longer and many are working further into what were traditionally regarded as retirement years.

Although demographic changes have occurred regarding the racial make-up of the work force on the wharf, these changes are not perceived to be a major problem by most Chevron operators and managers. The reason may be due to other demographic changes and situations which are more salient. While there has been an increase in minority participation at Chevron, it has not been drastic, and perhaps less drastic than in the general work force. Traditionally, a large proportion of the marine industry's work force came from the military, a work force that was more integrated earlier than most private sector industries.

The increased role of women on the wharf, however, was noted as a challenging demographic shift. One manager commented:

> *"...there are a lot of guys who think, 'women don't belong.' They don't go out of their way to undermine their work; but there is an undercurrent of discontent. It's improving, but it takes time and we have a ways to go yet."*

Chevron faces a cultural challenge due to the increased presence of women on the wharf. It is likely that women will continue to enter traditionally male-dominated work situations, like those at oil terminals. The increasing presence of women brings to bear issues of physical ability, as well as the difficulties some operators may have adjusting to role transformations. Much like the adjustments that have been undertaken in the military, Chevron is actively working to smoothly make that transition. It may be unwise to assume that the mere presence of more women is sufficient to eventually allow the problem to solve itself. Often the process can be assisted through diversity training exercises, and other means that directly address the problems and feelings of all of the workers involved.

The other situation that arises is the demographic diversity that exists on the ships; particularly the increasingly high percentage of non-English speaking crews. Many terminal operators and managers perceive this diversity as a direct threat to safety, due to potential mis-communication:

"Currently, only six of thirty-plus ships are U. S. All others have multinational crews. This has resulted in a dramatic cultural change because officers of different races and nationalities must work together."

As in the case of gender diversity, management must actively address the issue of language diversity on ships and between ship and shore personnel. However, the perceived threat to communication is not solely due to language differences, but also to the diversity of cultures. Differences due to cultural norms based on the birth country of operators can also pose risk to communication, even if the language barrier is eliminated. The company has undertaken training efforts with this regard and some policies have been changed and implemented. Related to the near-miss concept, a similar tracking of missed communications could be beneficial in pre-identifying (before an accident) sources of communication breakdowns that could potentially lead to negative consequences.

4.3 Organizational Environment

Organizations do not exist in a vacuum. On the contrary, every organization operates in a network of systems that make up the organizational environment. Miles [20] describes the environment in simple and broad terms: *"Just take the universe, subtract from it the subset that represents the organization, and the remainder is environment."* Although quite illustrative, this definition is not very useful without qualification. Robbins [13] makes an important distinction between the general environment and the specific environment. The general environment encompasses conditions that may have some impact on an organization but are unlikely to, and their relevance is minor and not overtly clear. Whereas the specific environment is that part of the environment that is directly relevant to an organization's ability to operate and achieve its objectives (Fig. 7).

The specific environment was addressed in this project because of its concern to organizations. The survival of every organization depends heavily on the connections they have to the players in their specific organizational environment. It becomes the organization's task to manage its environment by both adapting and creating linkages [21].

The specific environment can be broken down into two categories: the internal environment and the external environment. The internal environment refers to all members of the environment with direct links to the organization that are a part of the organizations operations. Some examples of internal environment members of marine products and shipping companies include the customers, competitors, labor unions, and port authorities. In addition, some *within-corporation* entities could be considered internal environment members. In other words, different companies or divisions under a single corporation are a part of an organization's internal environment.

The external environment refers to entities that, while having a direct impact on an organization, operate independently and are not an objectively essential part of an organization's operations. Some examples of external environment members of marine products and shipping companies include the media, state and federal legislators, municipalities, regulatory agencies, and the public. Naturally, the degree of relevance an external environment member possesses varies greatly, as the more distant an external entity, the more it becomes less a member of the organization's specific environment and more a member of the general environment.

In addition, the internal/external distinction is not always clear, with some entities exhibiting both internal and external qualities. For example a regulatory agency, like the California State Lands Commission, does indeed interact with operators at the Richmond long wharf on a regular basis, and the agency creates policies and regulations with the assistance of corporate management at Chevron, USA.

This seems to imply that its relevance is internal. However, the agency is not an essential component of the objective goals of oil products loading and discharge operations. Rather, it is institutionally constructed to address socio-political concerns associated with the organization's operations. Therefore it is ultimately defined as external.

Factors in the organizational environment of the Chevron long wharf are undoubtedly much more important today than they were in the past. Many participants, who were members of the general environment then, have entered the specific environment today. Not only are they now represented in the specific environment, but in many cases, they have come to play crucial and defining roles with regard to many of the organization's operations.

One of the most significant ways an organization contends with its environment is by adapting to it by controlling relevant resources and acquiring power in the environment. Referred to as *resource-dependency*, this approach has as its primary focus, the organization, and its relations with other organizations operating in its environment [23].

Because organizations are not self-sufficient, they must engage in exchange relationships[1] to obtain important, but scarce resources. The need to acquire resources creates dependencies upon external forces (or organizations), which often creates power differentials. As a result, organizations actively seek opportunities, attempting to strike good deals which optimize resource acquisition, while minimizing dependencies. Those organizations which are most successful at this gain power, defined as the ability to control or influence, i.e., the flip side of dependence [24]. This conception of power and dependencies opens the door to political problems which can, and often do, result in political solutions [21]. This is certainly relevant in the oil industry, arguably one of the most politicized industries of the 20th century[2].

4.3.1 Regulatory Agencies

Most of the new participants in the specific environment came in through the external environment. The most critical and involved participants are the regulatory agencies. Three main external participants are typically identified as having the most direct interface with organization members at the Chevron wharf: The California State Lands Commission (CSLC), The California Department of Fish and Game's Oil Spill Prevention and Response Unit (OSPR), and the United States Coast Guard (USCG).

For the most part, these organizations are seen in a dual manner, both negatively and positively. They are viewed in some ways as necessary and beneficial, but there is also a feeling that they are often mis-informed or mis-guided and serve as a hindrance to operations. For example,

> "*There is tension between us, but the tension is in some ways beneficial. We've learned a lot from them, and I think they've learned a lot from us too....(But) sometimes they come up with rules that they don't understand what it requires to implement, often at the risk of employees' safety. Sometimes ideas are not well thought out.*"

or

> *"...a lot of the inroads we've made on safety have been helped along by regulations. At the same time, we're over-regulated. The pendulum is swinging too far where they get in the way of business. But we wouldn't be where we are (in terms of safety) without them."*

In addition to the problem of the specific regulations they enforce, their presence creates other problems as well. The regulators are also seen as large consumers of time, both in terms of on-site inspections and physical interface with the inspectors, and the paperwork they create as the result of mandated checklists and forms which must be completed. Relatedly, there is a general feeling that they must contend with too many regulators. Although the three aforementioned regulators are the primary organizations Chevron must deal with, there are also a number of other federal, state, and local agencies[3] with specific mandates to control or oversee a variety of operations including vessel traffic, noise levels, radio communications, and occupational safety and health, to name a few. During this study, we identified 23 separate organizations that have some degree of influence over the Richmond LDO.

As a result, upper management finds itself struggling to manage the relationships with each of the regulators, while attempting to maintain as much power and control as they

1 Exchange relationships are not necessarily exchanges of physical goods or services, but might also include exchanges of less tangible assets such as information or power. They also may be non-monetary exchanges.

2 See *The Prize: The Epic Conquest for Oil, Money & Power* (Yergin, 1991; New York: Touchstone, Simon and Schuster) for an excellent account of the oil industry.

3 As well as some private watchdog agencies and groups

can over their operations. The sheer number of regulatory agencies makes the management of these dependencies a costly and time-consuming undertaking. Resources could arguably be better spent on developing safety programs, offering additional training, purchasing additional and more modern equipment, hiring increased or back-up personnel, developing advanced technology, etc. But these and other internal, bottom-line enhancing expenditures are fruitless if the organization cannot survive in its environment. The efforts directed toward power maintenance and dependency management support Aldrich and Pfeffer's [22] suggestion that in many cases these activities are more crucial to the success and survival of an organization than are internal management activities.

Based on the results developed during this project, one organization stands out as being more beneficial and less of a hindrance than any of the others: The California State Lands Commission (CSLC). When discussing the positive aspects of the regulators, informants repeatedly mentioned CSLC as the organization that most embodied the positive characteristics[4]. In addition to the praises given to CSLC for their efforts in aiding Chevron to develop an oil spill prevention program, one manager commented:

> *"The State Lands Commission is the organization that we have the most interface with. They are trying to help us do the job and do it safely. Admitting a problem is no longer a doomed effort. State Lands has now gone out of its way to work with us when there is a problem."*

The relationship is clearly viewed as one of mutual assistance, collaboration, and cooperation. As a result, Chevron management views the relationship between the two organizations as one based on trust and respect, with common interests as their objectives. Another manager added:

> *"We (CSLC and Chevron) end up reinforcing each other. Chevron clearly understands the aversiveness of having an oil spill. They (CSLC) came on the scene, but we were already wanting to do this. The relationship is not adversarial. They've helped us, but we've done it."*

The more positive attitudes toward, and the limited praises of, CSLC are clearly unique. The level of enthusiastic praise directed to CSLC compared to other regulators was unparalleled[5]. The positive relationship Chevron's long wharf operators and managers have developed (and are developing) with CSLC is one that should serve as a model for other similar organization-regulatory agency relationships, and should be examined more closely.

One initial characteristic that stands out about the relationship is its more democratic, cooperative nature. Regulations offered by CSLC are typically formed after close consultation with industry participants. Suggestions are noted and incorporated into eventual policies. This form of regulator-regulatee relationship is particularly beneficial for the regulated organization because it allows it to maintain some power and control over the policies and rules that it will be required to implement.

One of the major complaints about regulators that we heard from operators during this project concerned the quality of some of their rules and requirements. They are often seen as outsiders who make arbitrary decisions that are not well thought out or based on an insufficient level of field experience. The CSLC has made strides at circumventing that problem by giving industry a greater voice in decision-making and breaking down the relationship as one of rule-maker to rule-follower. It would be beneficial to the safety of operations as well as to all parties involved for other regulators to strive for adopting a strategy similar to that of CSLC.

Despite the special case of the CSLC, the overall analysis of the relationship between Chevron and its regulators comes out as negative in the eyes of most operators and management:

> *"There is still a lot of concern that the regulators are out to get us. Overall there is a feeling of 'Be careful what we say, be careful what we agree to. Give 'em in inch, and they'll take a mile.' They're seen mostly as an impediment."*

And this recognition is not interpreted as unique to Chevron but considered to be industry wide:

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4 The USCG was also mentioned positively by many informants, along with CSLC, but in each case it was indicated that the level of actual direct interaction with the USCG is much less than with CSLC, due to that organization's more limited resources and less directly related mandated objectives.

5 Several comments combined praises for CSLC and the USCG, although even in those cases, it was clarified that CSLC played the more active positive role (again, it is noted that the USCG has a more limited direct involvement due to its resource availability and mandated function).

> *"Yes, we've been put on the defensive. Following the Exxon Valdez, the whole industry has been put on the defensive."*

4.3.2 The Public and the Media

Other participants in the specific external environment whose roles have increased significantly are the public and the media. Again, as a result of the Exxon Valdez disaster, public interest and scrutiny of oil operations multiplied exponentially. It is not clear, and beyond the scope of this report to identify whether, following Valdez, public interest spurned media scrutiny or vice versa. Suffice it to say that they probably influenced one another, leading to an industry which at least perceives itself as being extremely scrutinized and feels its survival threatened:

> *"The public is far more aware of environmental problems than they used to be. They're not educated nearly as well as they should be about (our) operations. We're very fearful about anything that might bring down their wrath. And sometimes, in my view, they make demands which are not based on knowledge of the facts. Sometimes it feels like some groups are not concerned about getting rid of the problem, but rather getting rid of the industry."*

The feeling is largely that public scrutiny is driven by media coverage, which is seen as biased and one-sided.

Although a solution to this problem is also beyond the scope of this effort, this information is included because of the strength of the finding. It is nearly universal that members of the organization at all levels feel this threat and are significantly concerned about it. In addition, there is a feeling that the efforts management undertakes to mitigate these threats are time- and resource-consuming and that they get in the way of the organization's ability to solve more pressing problems and operate safely and effectively. In lieu of a major shift in public perception and the media's role, those resources expended toward contending with those constituents may be necessarily well-spent, especially if the threat is as real as it is perceived to be. This serves as further evidence to support Aldrich and Pfeffer's postulate regarding the importance of managing the environment [22].

4.3.3 The Competition

Although oil companies are in direct competition with one another in their business of selling oil to the public, they all face approximately the same issues with respect to safety of operations and the consequences of an accident. However, the interaction among them, at least on the prevention side, seems to be non-existent. In general, safety managers and trainers at Chevron are not in contact with individuals who perform the same functions for other companies, and as a result, are unfamiliar with the programs and policies utilized by competition in their risk reduction efforts:

> *"I don't know anyone at another company who does my job. I don't get any information from other companies. There is, to my knowledge, no cross-company communication about safety issues. But it would be valuable to learn about problems at other organizations....It's difficult go get all of the information. But I would love to see some communication between companies in the industry."*

Interestingly, when several top managers and safety managers at Chevron were asked to compare their operations to industry standards, they were unable to do so. While we had no problem finding out who the regulators identified as those setting the industry standard for safety, that information has apparently not been disseminated to industry participants.

These findings represent a potential missed opportunity for information gathering and sharing. It would behoove Chevron and its competitors to know who is setting the standard with respect to operational safety. From that knowledge they could then identify the reasons for the standard, and implement programs based on the standard model. In addition, communication between companies on safety issues could greatly increase information and enhance overall safety industry-wide. It is certainly not unreasonable to assume that this type of intra-industry communication and cooperation is feasible. Similar efforts have already been successfully undertaken in some ports with the formation industry coalition oil spill response teams, and a corresponding program aimed at sharing prevention knowledge would likely enhance safety of operations.

4.3.4 Ship - Shore Relationships

As stated earlier, Chevron Corporation is divided into a number of companies including Chevron Products Company, which operates the Richmond refinery and long wharf. Other companies under the Chevron Corporation umbrella are a part of the wharf's internal environment. Chevron Shipping (the company responsible for the marine transportation of Chevron products) is very actively involved with operations on the wharf.

Perhaps the most common threat to safety, as perceived by terminal management and particularly terminal operators, is from errors made on the ship side of the transfer process. Operators routinely identified the causes of most problems as the result of an error on the part of ship operators, or a communication breakdown between ship and shore personnel. This was perceived to be a problem regardless of whether the ship was under a Chevron Shipping flag or not[6]. Although we did not speak directly with Chevron Ship personnel, a project conducted with Arco Marine, Inc. (AMI) shipping allowed us to evaluate the opinion from the other side [2, 3]. As expected, many ship personnel felt the threat to spill during loading or discharge operations was likely to come from an error on the terminal side.

We can only hypothesize whether Chevron Shipping personnel hold a similar belief. However, we did have contact with Chevron Shipping management located in the Corporate Headquarters in San Francisco, California [11]. Although they did not place a greater degree of responsibility for errors on the terminal side of operations, when we conveyed terminal operators' concerns about communication problems that may result from language barriers under foreign flagged ships, the response was essentially that it was their (Chevron Products') problem. This may be an indication that Chevron, like AMI, still faces the challenge of bridging its team-building strategy between ship and shore personnel.

The structuring of the corporation and the separate companies may make strategic sense financially, but it may make less sense for other objectives. Ultimately, a spill involving a Chevron ship and/or a Chevron terminal during a loading or discharge operation is detrimental to Chevron Corporation's finances as well as its reputation and goodwill. Both companies have the Chevron name, and members of the external environment (e.g., the regulators, the media, the public) do not care whether the accident was caused as the result of an error on the part of Chevron Shipping or Chevron Products Company.

In many instances, the wharf operators think the problem lies on the ship and the ship operators think the problem lies on the wharf. They both can be right because they are too busy pointing fingers at each other to tackle the problems. Again, opportunities to exchange information and increase knowledge may be missed if there are not formal channels of communication among companies with respect to safety issues. An us-and-them attitude, while perhaps not prevalent, appears to exist, and does not serve well efforts to open up those channels. Surely complete integration of ship and shore safety programs is impossible, but some integration could prove invaluable, and this can best be pursued if top management facilitates the breakdown of the cultural separation of the different companies.

4.4 Human Resource Management

A human resources approach to management emphasizes participation as a means of productivity improvement, through better, more informed organizational planning and decision-making [25]. It focuses on the individual as the key resource in an organization. Human resource management (HRM) refers to the practical management programs an organization adopts to maximize the productivity of its human resources. A number of HRM topics have been identified as particularly relevant with respect to risk reduction and organizational reliability. Among them, deemed crucial in our project and included herein are selection and training, and reward and punishment systems.

4.4.1 Selection and Training

Selection is the process by which an organization chooses individuals. This includes the identification of minimum qualification requirements, implementation of recruitment strategies (e.g., newspaper advertisements, headhunters, employee referrals), and preliminary and secondary screening processes. Screening processes may include interviews, tests, or both. In addition, a variety of tests may be utilized including aptitude tests, skills assessments, drug and alcohol tests, and honesty evaluations (i.e., lie-detector test).

Once an individual is selected by an organization, some amount of training is almost always required to bring him or her to a knowledge level necessary for operation. An organization can provide training in a variety of ways. The most common distinction is between formal training and on-the-job training. Formal training typically refers to classroom training. It can be conducted by full-time instructional staff or by persons with other functions in the organization as well. Often outside consultants are brought in to conduct classroom instruction, or employees may be sent to courses or seminars conducted outside the organization.

On-the-job training usually entails the employee working with a trainer, or a more experienced employee, actually performing the job and learning its particularities "as you go along". The degree of supervision during on-the-job training can vary significantly, usually depending on the difficulty of the task, and the risk posed by a failure.

An increasingly common mode of training is in many respects a hybrid of formal training and on-the-job training: simulator training. This involves a simulation or

6 Non-Chevron ships *are* seen to pose a *greater* risk than Chevron flagged ships, although the risk was still felt to be present with the owned vessels. The greatest risk factor is perceived to be based on the nationality and primary language of the crew, regardless of ship ownership.

facsimile of an actual on-the-job experience, while avoiding the potential negative consequences of failure that could be associated with inexperience. Like classroom training, this can be offered both within an organization or through an outside source.

When the Chevron Long Wharf in Richmond looks to hire additional operators, they utilize several methods of recruitment including newspaper want ads and references from current employees. A large number of the applicants are typically close friends and family members of current operators. All applicants are given basic tests in math, writing, reading comprehension, and science skills. A drug and alcohol screening is also required.

For those who qualify past the first round of tests, an interview process begins, where more screening and testing occurs including a battery of computer skills tests and a new *control board operator test* which is a simulation of a control board. The simulation is an effective test of mechanical thinking ability and control under pressure. The trainers believe the screening process is successful in identifying individuals with sufficient skills to be trained as terminal operators.

One additional screening for all new refinery applicants is a test that classifies individuals on a dimension of complexity (intricacy, complicated nature). Depending on their performance on the instrument, applicants are categorized as either *complex* or *semi-complex.* The *complex* individuals are typically assigned to the abstract positions in the cracking and refining units, while those classified as *semi-complex* are sent to wharf operation jobs. This may be a potential area for policy re-evaluation considering concerns about individual complexity needs of operators during crisis situations on the wharf [2].

The training of operators at the Chevron refinery has undergone significant changes in recent years, with a greater emphasis on front-end and classroom training. Each operator first attends a minimum two-week classroom training. That is followed by an on-the-job form of training, monitored closely by the trainer. This lasts a minimum of six months and consists of classroom training, observation, and hands-on operations. Based on the trainer's judgment, once the operator is up to qualification, he or she will be put on a crew and will 'piggy-back' with one member of the crew. During this period the trainee is never left alone to operate. At such time as the 'piggy-back' crew person, the head operator, and the trainer deem the trainee ready, he or she will be given a final written, oral, and hands-on examination.

Enhancement training is also offered to existing operators if one feels the need for additional training in a particular job or function. Enhancement training generally is voluntary, although it can be recommended or mandated by a supervisor.

A third type of training is provided: Refresher training is a form of re-training for all operators that is part of an OSHA (Occupations Safety and Health Administration) regulation. OSHA requires refresher training be conducted every three years. Although it could be an opportunity, the training department feels that it is more of a burden, done only to satisfy federal regulations and their emphasis and efforts are more directed toward the initial training and enhancement training.

Overall, the company has made significant strides at developing a detailed and comprehensive front-end training program. The training department is working much harder than in the past at getting its operators trained at all levels of operations. There seems to be a greater emphasis on the front-end training versus re-training (enhancement and refresher training). The same individual is in charge of all of the training, and there may be an issue of limited human resources. On the other hand, the department does not feel strapped financially from top management:

> *"They give us all we need. They don't limit us at all in terms of training for prevention."*

4.4.2 Reward and Punishments

In the traditional human resource management sense, rewards and punishments can refer to compensation, as well as other incentive systems. However, with respect to this project, rewards and punishments are used in the context of more specific actions than those that simply relate to good or bad performance. First, as the evaluative criteria for rewards or punishments, we do not simply define it as 'performance'. Because the objective of this project was to identify concepts that will aid in the reduction of human and organizational error, the criteria used for evaluation are the 'safeness' or 'unsafeness' of operations. With that as the criteria, reward systems refer to the organizational response to safe or unsafe operations by its members. The emphasis is on the feedback given to organization members and how they may be informed and subsequently rewarded or punished, if desired or necessary.

A key cultural change Chevron is trying to instill in its employees is one of increased trust. Particularly they are concerned with communicating to operators that their commitment to safety extends to being tolerant of errors and threats, as long as they are acknowledged appropriately. Although the tolerance is supported by offering positive reinforcement for honesty, top management recognizes its intentions have not been fully realized:

> "We are now giving rewards[7] for coming forward with information; admission of errors and mistakes. But the investigation process is

> still painful. There is still a lingering fear among wharf operators. It takes a while for the culture to disseminate."

Operators have at their disposal multiple methods of reporting problems or errors, ranging from informing their head operator or wharf master to filling out safety forms (both public and anonymous). As an incentive to fill out a *Safety 620 (*the name given to a particular safety reporting form), every quarter four of the forms are pulled out randomly and those individuals who completed them are awarded $150 gift certificates.

Awards are also given to operators and departments that go long periods without accidents or injuries. In addition, recognition awards in the form of cash or gift certificates are given to individuals who exhibit extraordinary effort, going above and beyond the duties of the job.

The company has changed its strategic approach in dealing with incidents, focusing on trying to increase trust and openness among operators [11, 12]. The term used is one of 'progressive discipline' where significant mistakes are dealt with through a progression of warnings, retraining, and other forms of rational discipline, rather than immediate negative reinforcement. However, some behaviors, such as drug use, alcohol use, or blatant disregard for safety are (still) considered just cause for immediate dismissal.

4.5 Management Strategy

The management of an organization's environment, efforts to control crucial resources, and the positioning of a firm to maximize power are all accomplished, at least in part, through the development and implementation of an organizational strategy. Goals and objectives were defined above as, in essence, the ends of the organization; strategy is the means by which an organization strives to achieve them.

Based on an organization's determination of basic, long-term goals and objectives, strategy is defined as the adoption of courses of action and the allocation of resources necessary for attaining goals [26]. Although the thrust of the definition focuses on two components (the selection of a course of action and the distribution of resources), the determination of organizational goals and objectives is a crucial third element, a necessary pre-cursor to the existence of a strategy.

This conceptualization of strategy implies that it is always a well-thought out, pre-meditated plan. Mintzberg [27] suggests this is not always the case. He distinguishes between two types of strategy. The planning mode describes strategy as a series of explicit guidelines formulated in advance and followed meticulously. The other, labeled the evolutionary mode, acknowledges that strategy is not necessarily a well-thought-out, systematic plan. Instead, it evolves over time, in part taking on a life of its own, influenced by a number of factors including both significant internal decisions and more uncontrollable external incidents and factors.

Although some aspects of strategy are significantly stable[8], strategies can undergo many changes and transformations. Typically environmental factors are at the source of such a change. External conditions, such as new opportunities, needs, or threats can force an organization to re-evaluate its goals and its strategy to achieve them. A determination is first made as to the appropriateness of the goals, and then the strategy must be similarly evaluated to judge its applicability in the face of a changed environment, and perhaps even a new objective. These strategy transformations can also occur in both planning mode and evolutionary mode, as discussed above.

Each of the previous sections has outlined the concepts deemed relevant either to influence strategy formation (organizational culture, organizational environment) or are tools by which strategy is implemented (human resource management). The strategy section of this report summarize the most salient findings and suggest courses of action for the organization to consider as part of an overall strategy.

Prior to the formulation of an effective strategy, an organization must identify the primary goals and objectives the strategy is intended to facilitate. Chevron has taken the crucial first step in recognizing the dramatic changes that have occurred in its organizational environment in the six years since the Exxon Valdez disaster. As a result it has specified and backed up as a primary objective the imperativeness of environmentally safe operations.

Repeatedly operators, supervisors and management stressed the development of a strong, primary commitment to safety. Many acknowledged that lip service had been paid for years, but only recently (in the past 2 to 4 years) had they begun to put the teeth behind the words.

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7 "Rewards" here generally refers to recognition and positive reinforcement rather than monetary incentives.

8 Particularly, strategies based on the most rudimentary organizational goal or objective do not fluctuate. For example, an organization's mission is typically an extremely stable objective, and the general strategy implemented to achieve it can be relatively unchanging.

Such a transformation is, more than anything, a cultural transformation; one that challenges what had long been a different operating system of shared values and beliefs. Such a major transformation cannot happen overnight and that fact is well recognized by top management. Strategically, the organization will and must continue to emphasize its commitment to safety and allow the cultural transmission to evolve injecting consistency of management behavior with facilitative actions.

Some actions that may help to facilitate this transformation are already underway and others have been suggested in this report. For example, the development of a separate devoted unit to oil spill response has proven beneficial, and the further development of a like effort in prevention should be continued. At the same time prevention and response are (appropriately) separated, some links between the two may be necessary to improve communication and information dissemination between the two activities.

The importance and priority placed on near-misses must be further stressed, to the point where top management commitment is perceived at the operator level. Also, operators must be able to trust that coming forward will not be met with reprisal and will be fruitful to maximizing system reliability, without imposing an overly burdensome reporting system. In addition, a clearer and more encompassing definition of what constitutes a near-miss must be specified.

Demographic challenges must be actively confronted, particularly with respect to the increased participation of women on the wharf, as well as on ships. Language barriers due to increased ethnic and national origin diversity, particularly on ships must also be dealt with. Both of these issues are perceived as problems and potential threats to safety of operations and unless management-led efforts are made to resolve them actively, the likelihood is minimal that they will simply take care of themselves.

A nearly universal perception among operators and management is the negative role that regulators play in the ability for the Richmond long wharf to function effectively. At the same time, some positive benefits are noted, and the specific relationship with one agency (the State Lands Commission) is lauded as being one of mutual respect. Although success is dependent on the reaction and actions of the other regulators, efforts should be made to create similar links to other key agencies, using the CSLC-Chevron relationship as a model.

Enhancing relations with competitors should also be considered. Although Chevron competes with other oil companies along product lines, all of the organizations have a vested interest in operating safely. Links to competitors for the purposes of sharing information with regard to safety could prove extremely beneficial. It would help to eliminate some of the duplication of effort in identifying risks and programs, an activity that is already strapped for resources.

A breakdown in the internal walls among different Chevron companies (esp. Chevron Shipping and Chevron Products) could also have positive safety consequences. An 'us' and 'them' characterization may not only be detrimental, it is inaccurate, and would be better replaced with a characterization that is all 'us'.

Strategic choices about crew mixes must take into account the complexity of crisis activities against the less complex normal operations. Screening new hires already includes a test that takes complexity into account, and currently the more complex individuals are assigned to non-wharf duties. A more heterogeneous mix of complex and semi-complex individuals as terminal operators may prove to be a positive influence on behavior during complex crises, and ultimately safety.

Currently the refresher training, required by OSHA, is seen primarily as a burdensome, regulation-fulfilling requirement, and less of a positive influence on safety of operations. Although the training is part of an externally designated rule, it would seem beneficial and cost-effective if it could be turned into a positive opportunity for improving the safety performance of operators. Since the specifics of the OSHA mandate are not known by the study team, only Chevron's Training Department can determine if the requirements are sufficiently flexible to be molded into a highly beneficial component in its overall safety training program.

Chevron should continue to offer rewards and incentives to operators and other employees for reporting potential problems as well as admitting mistakes. This should be further developed to include near-misses, as well [4]. At the same time, its progressive discipline should be followed, with low tolerance for gross misconduct.

Finally, recognizing that the changes the company is undergoing are major cultural transformations, Chevron must maintain its commitment, both in words and actions, to safety [11, 12]. This is particularly crucial as the company struggles through the simultaneous cultural transformation of organization re-engineering. A corporate-wide *management of change* strategy has become necessary as the result of institutional forces in the competitive environment. This strategy involves, among other things, operating more efficiently by reducing or removing excess costs. This has resulted in massive organizational changes including significant down sizing in terms of personnel as well as resource allocation.

As the perceived need to down size dominates, and all expenditures become more carefully scrutinized and subject to re-evaluation, the temptation may be to cut back on resources allocated to the areas of accident prevention and response and safety. One manager coherently summed up this fear:

> *"What I sense as a concern is a continued focus (on safety). Continuing to support and reinforce the importance of training. In other words, don't let business reasons get in the way of our goal of being a 'safety-first' organization. Don't let short-term considerations jeopardize our long-term goals and progress. We need to stay focused and committed on all fronts."*

If top management recognizes this threat, thwarts it, remains committed to its safety objectives, and maintains patience with the cultural dissemination process, the progress for Chevron should continue to bear positive consequences in terms of its safety record [12]. At the same time it must resist allowing its down sizing, cost-cutting, and re-organizing efforts to contradict the organization's ability to develop a fully disseminated and functional safety culture.

5. LDO Questionnaire

Mixed qualitative and quantitative analysis is a way of assigning probabilities without adequate historical data [1, 28]. Soft linguistic variables derived from qualitative analysis can be translated to numerical variables to provide inputs to the quantitative approach [3].

To accurately portray the LDO process for the analytical study of HOE, it is necessary to do as much information gathering in the field as possible. In order to obtain quantitative data and to structure the gathering of information, a questionnaire and interview process was used. Questions in the interview instrument were based on a step-by-step definition of the process and were formulated to elicit numerically valued responses. Respondents were asked to gauge the 'risk' of various steps based on two parameters, importance and grade.

The importance is a gauge of how critical the perfect performance of a step is to the prevention of an oil spill, measured on a seven point scale. This questionnaire asked operators to evaluate the importance and grade of each step and sub-step in the process. The importance of a step is a value of how critical it is from the standpoint of spill prevention, ordered on a seven point scale. An importance of one corresponds to a step which can be virtually eliminated or grossly mis-performed without the threat of a spill. An importance of seven corresponds to a step which must be performed perfectly in order to prevent any oil spill. A score of seven means that the improper completion of the step is very likely to cause a spill. A score of one means that even if the step is performed incorrectly or not at all it would be close to impossible for an oil spill to result.

Respondents were asked to grade how well each step is performed by the operators at their terminal (or crew of their ship), usually their peers. The grade is based on a typical grading scale. The grade is a measure of how well the step is typically carried out. For the purpose of data manipulation, a grade of 'A' is given a weight of one, a 'B,' two, and so on. The product of the importance and the grade is the overall risk. Table 3 shows the first level of the questionnaire. It was based on the basic seven step model described earlier.

Every respondent was asked to answer the questions associated with this first level of the model. Each person was then asked to assess the risk in the performance of the two steps that he defined as the most risky.

Table 3 Chevron Long Wharf Questionnaire

Importance	Grade	Step	Definition
		Approach & Berthing	Vessel approaches terminal, with tug escorts. Vessel is secured to wharf.
		Connection	Pre-transfer conference completed. Hoses or loading arms are connected.
		Start Up	Product begins to be pumped, at increasing rate.
		Steady Rate	Product is transferred at steady agreed upon rate.
		Topping Off	Product flow is slowed and then ceased.
		Disconnection	Hoses or loading arms are disconnected.
		Departure	Vessel leaves the terminal.

A problem with this type of questioning is that the responses are highly subjective and dependent on the experience and biases of the respondent [28 - 30]. This subjectivity causes the range in answers to be very high. The relative risks, however, were fairly consistent from person to person. For this reason the data were normalized or 'anchored' to obtain an average risk value for each step (and sub-step) in the process. The absolute responses were subtracted from the individual's mean risk. These normalized risk values were averaged and the mean of all of the responses added back to this average for each step to obtain the overall risk factor. These overall risk factors were used to establish the relative influence of each step in the operation [29]. In this manner, we were able to identify the most important tasks and elements associated with these tasks, and focus our evaluations on these tasks and elements.

6. Qualitative Evaluation

Eighteen wharf operators responded to the questionnaire. Table 4 summarizes the mean risk values for each of the steps in the loading and discharge process. These risk values had coefficients of variation in the range of 50% to 100%. All operators were asked to respond to questions regarding the overall process. They were then asked to evaluate the risk of each of the sub-steps of the steps which they chose as the most risky.

As shown in Table 4, the wharf operators felt that topping off and start up were the two most risky steps. Topping off is the most risky step because it involves very careful manipulation of tank levels by the ships crew and consequently the precise manipulation of valve positions on shore. In addition, the communication between the ship and shore is very critical so that the manipulation of valves can be done at the proper time. The risk factors for the sub-steps of topping off are summarized in Table 5.

Table 4 Risk Factors for Steps of LDO

Rank	Step	Risk
1	Topping Off	6.89
2	Start Up	4.72
3	Approach	4.67
4	Disconnection	4.28
5	Connection	3.78
6	Steady Rate	3.00
7	Departure	3.00
Number of responses		18

Although there is no direct action involved in the communication of the request to slow the flow and then the request to stop, because the motor driven valves on the shore side move slowly it is important for these commands to be given early enough that the operator and the valve can respond in time. The communications during the topping off phase of the loading and discharge operation are given high risk values because there is sometimes a difficulty with communication between the ship and the shore. This is particularly true of foreign flagged vessels which may not be comfortable communicating in English.

Table 5 Risk Factors for Sub-Steps of Topping-Off

Rank	Step	Risk
1	Request to Slow	5.94
2	Request to Stop	5.13
3	Flow Slowed	4.31
4	Valve Closed	4.13
Number of responses		16

The manipulation of valves are given high risk marks for two reasons. The first reason is that these are the actual action steps in this process. In addition, these large motor operated valves are large and slow moving. It requires a certain degree of finesse to slow the flow precisely as desired. Stopping the flow is somewhat easier to accomplish, but if something goes wrong in this step there will certainly be a spill.

Start up is the second most risky step in the loading and discharge process. This is not because it is inherently difficult or problematic but because if there are any mistakes previously, it is when the flow is commenced that a spill will occur. Table 6 summarizes the risk factors associated with each of the steps of start up.

The increase of flow is nominally twice as risky as any of the other steps. This is because when the flow is first started at a slow rate, it can be stopped quickly and easily in response to any leaks which are detected. At this stage any leak will be small and probably trickle or drip out. If these small leaks are not detected during the slow rate they could rupture further, spilling much more oil when the flow rate is increased.

Table 6 Risk Factors for Sub-Steps of Start Up

Rank	Step	Risk
1	Increase Flow	5.20
2	Communication	2.60
3	Clearance	2.60
4	Slow Rate	2.00
5	Sampling	2.00
6	Checking	1.80
Number of responses		15

Although connection was not observed to be a particularly risky step in the process, it is directly correlated to start up and can therefore be considered to be subsidiary. Connection was not considered to be very risky because there is no flow at this time. Any spill would be the result of the draining of residual oil in the line. In contrast, any problem or mistake that occurs during connection will be directly felt during the start up operation.

Based on our operations observations, our evaluation was that the responses regarding the risks of connection were deceptively low. Proper connection is crucial to the continuation of the loading or discharge procedure. A possible reason for the low risk values is the routine nature of the task (‘risk habituation’). This can have both positive and negative effects. The procedure is very simple and performed often which can lead to perfection of technique. Conversely, the routine nature of this procedure can lead to complacency.

An interesting aspect of connection is that it is performed by the ship’s crew and not by terminal personnel. In the case of vessels which are owned and operated by Chevron Shipping Company, the crew is solely responsible for the proper connection. In the case of other vessels, a witness is provided by the terminal to ensure that everything is done properly. The presence of this individual should mitigate complacency.

Approach was the third most risky step of loading and discharge. This is because of the navigation of the ship in the channel. Navigation is outside the scope of this evaluation because it is not within the strict confines of transfer. Navigation is more risky than cargo transfer because when there is a possibility for vessel grounding there is limited control over the amount of oil lost. If a spill occurs during transfer, systems are in place to stop the flow of oil and limit the amount spilled.

6.1 Operations Communications

Communication is extremely important in topping off. While it is also important to start up, there is not as significant of a hazard when the transfer is beginning at a very slow rate. It would seem that if communication was managed to be optimal to the topping off procedure, problems that would be presented during start up would also be solved.

There are two problems with communication that were identified as a result of the wharf operations interviews and observations. One was identified by terminal operators and the other by vessel crews. Terminal operators are primarily concerned with problems communicating with foreign crews. While all vessels are required to have at least one person who is proficient in English on board to communicate with the wharf, often the most proficient person is not as fluent as would be desired. In addition, this language barrier may cause foreign vessels to be more ‘shy’ communicating with the wharf. This can be a problem where ample notification is concerned in topping off.

The other problem with communication is the use of the same radio channel at all berths. Although this has never caused an accident, it is possible that communications at one berth could be impaired while another berth is talking. Transfer operations are coordinated, loosely, so that two berths will not be reaching critical points in their operations at the same time. This is not, however, a key planning step. It is possible that communication at one berth could be delayed, hazardously, while the radio is being monopolized by another. It was recommended that additional consideration be given to radio communications during transfer operations so that the necessary channels would be open during critical points in the transfer operations.

6.2 Operations Planning

Other human and organizational factors which influence the topping off step are procedures and planning, environmental conditions, and personnel problems. Although operational procedures are well documented and continued training is an important part of an employee’s career on the wharf, topping off involves the use of skills and techniques which cannot be easily mastered using a checklist type of procedure. For the flow to be slowed precisely, some finesse is required. This involves careful attention to the sound of the flow in the lines and the delicate manipulation of the large motor operated valves. This type of precision can only come from years of practice and not through exact completion of easily defined steps.

Topping off also involves careful planning and preparation. It is important for the berth operator to keep track of the rate of transfer so that he is not surprised by the vessel’s warning. The thirty minute warning is meant to alert the operator before he needs to pinch down on the lines. At this time the operator should stand by the valve and await further instruction. Even though he can anticipate that no valve closure will need to be done for a few minutes, it is essential that the operator be prepared, and ready to act in case there has been a miscalculation and flow must be shut down in a hurry.

This is also the time when environmental conditions and the operator’s attitude can adversely affect the operation. If it is raining or cold, or if he is fatigued or simply lazy, the operator may not be inclined to stand by the valve outside of the berth shack for longer than he perceives necessary.

7. Influence Analyses

Influence analyses were developed to understand the correlation between different human factors in the steps of the process. These analyses were concentrated on the most risky steps in the loading and discharge process: 1) start up, and 2) topping off. The influences analyses for these steps (Figs. 8 and 9) show the sub-steps connected by dotted lines. Overlapping dotted lines indicate an iterative process. Solid lines connect human and organizational factors to the appropriate sub-step.

Fig. 8 is an influence analysis of the start up process. The most important component of start up is communication. It is essential that constant contact be maintained between the berth and the ship. If there is a problem with noise in the area, this can interfere with communication. Oil transfer operations are not typically loud enough to cause a problem. The problem most often cited by the wharf personnel is the language barrier between the wharf and foreign flagged vessels. Although all vessels are required to have someone on board who speaks proficient English and can communicate with the wharf, often the most proficient person is not as fluent as desired. A problem with communication which is cited by vessel personnel but not by wharf operators, is the communication between all berths and vessels on the same channel. Terminal personnel maintain that this is not a problem because the radio is only used for essential business so there is little chatter and everyone can reach the berth when they need to. This is not as much of a problem during start up as it can be in other phases of the operation. If one of the berths is going through a critical portion of their process and monopolizing the air, the berth waiting to start up can delay a few minutes until they are able to communicate more easily. During other steps, especially topping off, it is important to be able to communicate at the exact time that is necessary.

Once positive communication has been established, the valves can be opened. When the ship is being loaded, the terminal valves are opened and the cargo moves by gravity. When flow is increased, pumps are added. In discharge, the ship's pumps are warmed up before start up begins and are brought on line when needed to move product. When the valves and pumps are maneuvered, the most likely error factor would be due to the system itself: durability. Durability is the ability of the system to continue to perform its job without excessive need for maintenance or tuning. Although the valves and pumps are well suited to their purposes, over time, without proper inspection and maintenance, they may degrade in serviceability.

After flow begins at a very slow rate, the volume is checked on both sides. In addition the path is verified on both sides. Operators and watch standers walk along the piping watching and listening for leaks. These steps are the mostly likely to find human errors. It is easy in this stage of the operation to simply forget to check one of the components or miscalculate the flow. In addition, because the verification of the path does not require a specific action, it is susceptible to environmental difficulties as well as fatigue. If an operator is tired and not very alert it would be possible to miss a problem which may be more subtle to the observer. If it is dark out or if it is raining visibility may be limited. If it is cold or raining, the operator may be in a hurry to get back in doors.

Fig. 9 is an influence analysis of topping off. Communication is again very important during topping off. The ship must notify the berth one half hour before they anticipate stopping. At this time the operator will stand by the valve for further instructions. Fifteen minutes before shutting down, the ship will again signal the berth at which time the operator will close the valve half way. The valve is then closed incrementally with the ship giving proper warning and the operator manipulating the valve. It is important that the operator receive ample warning for each step because the valves are slow-moving and do not react immediately. This is where a particular problem lies with non-English speaking crews and berths all communicating on the same channel. Some crews with particularly poor English skills may be reluctant to call the berth. This can result in the berth operator not standing by the valve a full thirty minutes prior to shut down. If more than one berth is talking on the same channel there may be difficulty in getting through when necessary. Communication can be impaired after the beginning of topping off because once the operator begins to pinch off the flow, the noise in the lines becomes much louder than usual. Because this is always true, the communication system is designed so that it will always be heard.

Planning and preparation are also very important. If the operator is surprised, the valves may not be manipulated at the correct time or as quickly as need be. It is essential that the operator be standing by the valve and be prepared to act as soon as the ship gives the word. This is also where fatigue and environmental conditions are felt. If he is tired or it is cold or raining outside, the operator may not be eager to stand by the valve for a full thirty minutes. Also, if he is tired he may have some difficulty acting as quickly as necessary if the topping off occurs sooner than expected.

System error can cause trouble in topping off as well. Because the valves are slow moving, it is very important to have prior warning and to anticipate the precise moment when flow needs to be stopped. In addition, in order to pinch down on the line slowly, finesse is required to get the flow to be at just the precise rate. This can be difficult because as the flow is slowed, back pressure will cause the pump to kick off slowing the flow much more than intended.

This need for finesse in slowing the flow can be impacted by procedural problems. Because the variation in flow must be heard or felt, it is very difficult to teach and to

Table 7 Calculation of P_f in Topping Off Step

Operators	Organization	Procedure	System
Communication: $2x10^{-2}$	Communication: $2x10^{-2}$	Incomplete: $3x10^{-3}$	Serviceability: $1x10^{-2}$
Impairment: $2x10^{-2}$		Poor Documentation: 3x10-3	Durability: 4x10-4
Total: $4x10^{-2}$	Total: $2x10^{-2}$	Total: $6x10^{-3}$	Total: $1x10^{-2}$
			Total: 8 %

document. The only way that it can be learned is through tutoring and practice. This can lead to each operator improvising his own way of doing things.

8. Quantitative Assessments

Two methods were used to perform quantitative assessments of the Chevron LDO [3, 31]. The first method used influence diagrams to identify contributing, initiating, and compounding events (Figs. 8 and 9) [32]. Heuristic judgment was used with conditional probabilities to define the probability of failure (major spill) of the LDO system. The second method used an event / fault tree approach. Errors were classified by their source and the probability of each type of error is evaluated. [32]

Existing spill statistics regarding the number of occurrences were used to verify the results of the quantitative analysis [4]. This is more useful when viewed in an objective manner in terms of the number of spills per year versus the number of operations. While significant spill reporting is in place, virtually no high consequence accidents have occurred in recent years. A reportable spill is enough to create a sheen on the water which means that the database is dominated by spills of a cup or less of oil. Most of these spills do not occur during transfer operations. Most of the spills at Richmond have been due to pinhole leaks in hydraulic lines of loading arms or to grease from other apparatus. Several of the hydraulic leaks occurred during a construction project and are therefore not a consistent indicator. Nonetheless, spills on the Chevron long wharf have been quite infrequent and small.

8.1 Influence Analyses

Influence analyses were used to define contributing, initiating, and compounding events that could lead to LDO accidents [31]. This method was used to calculate the probability of an oil spill during the start up phase of the operation. Five categories of factors were included in the analysis: individual, organization, environment, procedures, and system (Fig. 10) [32].

The operator error rates were based on task error rates developed by Swain and Guttman [33] and Gertman and Blackman [34]. These error rates were modified with the results from the first generation of wharf questionnaires and interviews [31].

Scenarios were developed for 322 potential accidents that could lead to significant (reportable) spills (failures) during start up. The analyses indicated that the probability of failure per start up operation on the Chevron long wharf was 8%.

The contribution of errors initiated in organization, system, procedure, and environmental factors was 3%, 2%, 2%, and 1%, respectively. Organization culture and communications factors accounted for one-third of the initiating errors related to the organization issues that influenced the wharf operations during start up operations.

An assessment was developed of the influences of additional monitoring during the start up step. Based on available information [33, 34], it was assessed that the additional monitoring would result in a 25% reduction in the HOE. This modification resulted in a 37% reduction in the spill rate.

Based on the recent experience with spills that have occurred during the start up at the Chevron long wharf, the quantitative results indicate spill rates that are far too large.

The source of this error must be in the input operator error rates. In general, they would have to be lowered by a factor of 10 to 100 to result in a predicted rate of spills approximate the historical rate of LDO spills.

The predicted spill rates are more in agreement with the historical spill rates for all types of LDO [4]. Compared with general LDO experience, the Chevron long wharf is obviously a ‘high reliability organization’ operation.

8.2 Fault Tree Analyses

The second method of quantitative analysis used fault trees to calculate probabilities of failure. The probabilities were derived from task performance data developed for the nuclear power industry [33, 34] modified based on expert judgment and the results from the LDO questionnaires and observations. The fault tree structure was based on the HOE classification system summarized in Fig. 10 [32]. Critical limbs were identified from the qualitative analysis of the topping off step (Table 5, Fig. 9). This included factors from both the terminal and vessel.

The base tree (Fig. 10) associated with errors in each of the sub-steps of the topping off step was pruned to isolate those primary sources of errors which were identified in the qualitative analyses. Based on the rare event analysis formulation developed by Bea [32], the probabilities from each of the HOE were summed to give the probability for each category of error. These values were again summed to yield the total probability of a major spill for the operation. Table 7 summarizes the probability of failure for the topping off phase of the transfer operation.

The probability of experiencing a significant spill during the topping off step was indicated to be 8% per operation. If one assumed that the components that were involved in the topping off system were highly correlated, the probability of experiencing a significant spill was indicated to be 2% per operation. Again, however, the predicted probabilities of failure are far too large when they are compared with recent experience at the Chevron long wharf.

The largest single contributor to the probability of failure is communications errors developed by the organization and the wharf operators. This observation is consistent with the results from the wharf observations and the questionnaires completed by the operating personnel. Failures due to system failures account for about 10% of the total probability of failure. This is consistent with general experience associated with marine and non-marine systems [32].

As noted earlier, the Chevron long wharf operators related the occurrence of many more near-misses than accidents. In general, it has been found that there is a ratio of 1 accident to about 10 near-misses and about 100 alerts [35]. This observation indicated that the primary problem associated with the foregoing analysis was in its lack of recognition of the effects of 'checking' and failure to recognize the probabilities of early detection and correction.

A simple analytical model has been developed to permit evaluation of the effects of detection and correction on the probability of failure [32]. In this analysis, based on the information in references [33, 34] and the Chevron LDO observations, it was assumed that the Chevron LDO would result in a probability of detection of developing spills of 95% (5% would not be detected), and that when detected, there would be a 95% probability of correction. This resulted in a 10% of non-detection and correction of an HOE during the topping off operation (the general ratio of accidents to near misses) [35]. Application of the additional'checking' effects resulted in reducing the probability of spills to 0.8% to 0.2% per operation (uncorrelated and correlated errors, respectively), much more in line with Chevron's current experience.

Conclusions

What did we learn from this project? We learned that the HOE classification and evaluation approaches developed during the first phase of this work were workable. Improvements were identified and these were implemented in ongoing projects.

We learned about practical HOE management strategies that can be and are being implemented to improve the safety of field operations. These management strategies are summarized at the end of Section 4.

We learned that in field operations qualitative assessments are much more productive than the quantitative assessments. The processes of defining tasks and systems; interviewing management, supervisory, and operating personnel; observing the operations; and then developing a logical structuring of the LDO 'system' was able to identify those elements that could be further improved to reduce the likelihoods of significant spills.

Although valuable, the questionnaires had limitations. They provided a structured basis to conduct interviews and record the results from interviews and operations observations. They helped provide consistency among the student and faculty 'assessors.' However, in some settings, the questionnaires were not effective, inhibited communications, and were not able to capture the important factors. The quantitative expressions of likelihoods, consequences, and risks had to be posed in terms that could be readily understood by the wharf operating personnel.

The quantitative assessments that were performed during this project were not able to fully capture the complexities and 'dynamics' of the LDO system. The quantitative evaluations developed on the basis of the interviews had very large variances. It was difficult to properly 'anchor' the responses and integrate the responses to develop meaningful quantitative evaluations. The assessments showed the importance of integrating 'checking' (detecting and correcting errors) into the analytical models. Experience indicates that it is this 'checking' that results in many more near misses than accidents.

The quantitative analyses became an instrument to demonstrate what the qualitative evaluations had indicated to be important. Given the meager appropriate 'hard data' on HOE in marine operations (and, perhaps in any operations), the numbers that are supplied to the analytical models must represent 'judgment.' The critical challenge is to assure that the judgment represents qualified, informed, realistic, and honest evaluations. It became painfully clear during this project that the purpose of quantitative analyses of complex systems that involve people can not be prediction. These analyses are not able to capture the complexities of people's future interactions with technological systems. Although frequently tempting for the engineering analyst, it is important to recognize that people can not and should not be treated in the same manner as a component of equipment or the structure. The experience in this project demonstrated that the purpose of quantitative analyses must shift from an objective of prediction to an objective of producing insights to help improve quality and safety in marine systems.

We learned that interfacing students and faculty with management and operating personnel in the field is very daunting and challenging. We were fortunate that the organizations that assisted with this project were patient and cooperative. We are fortunate that the students were able to deal so well with the intellectual, emotional, and physical challenges associated with the 'real world' in which this project was conducted.

Did we do anything that was or could be beneficial to safety of the operations we worked on? We hope so. Practical suggestions regarding improvements in management of change, communications during LDO, and development of accident and near-miss databases were developed [2, 3, 4].

Chevron Products Company is a leading organization with respect to developing and implementing a highly prioritized safety culture. Chevron clearly has recognized the importance and necessity of safe operations. Chevron has acknowledged the financial and reputation costs and the threats to survival posed by operating carelessly, and is actively seeking to minimize the risk of HOE [11, 12].

In sum, it could be argued that the three participating organizations in this project (Chevron Products Company, chevron Shipping, and Arco Marine) are among the best in the industry with respect to their commitment to safety of operations. Despite that, it is clear from the facts, policies, opinions, and examples shared by organizational contacts that the threat to safety is still present, and the organizations still have room to further reduce the risk of HOE. Although the improvement in this area has been exponential in these organizations over the past quarter-century, the pro-active opportunities are still significant and warrant continued and increased commitment to safety issues, particularly in these times of down-sizing, out-sourcing, and re-engineering.

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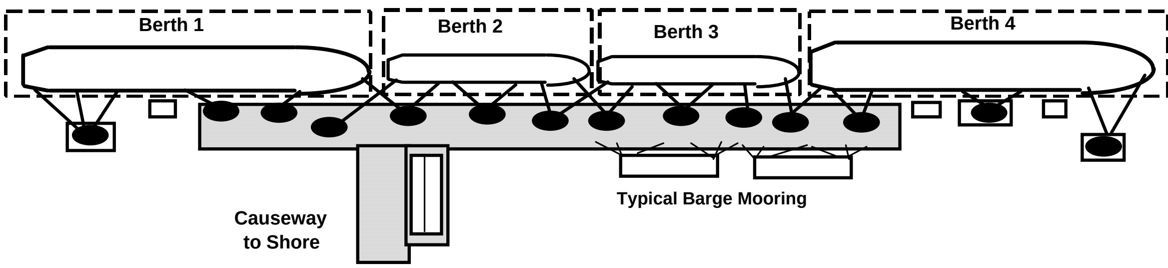

Figure 1
Chevron Long Wharf Berthing Layout

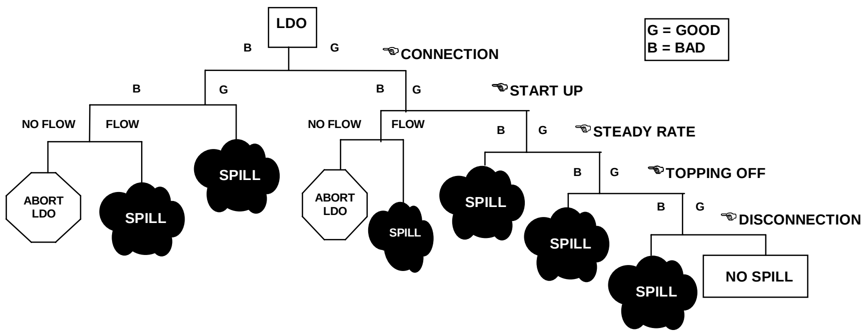

Figure 2
Event Tree of LDO

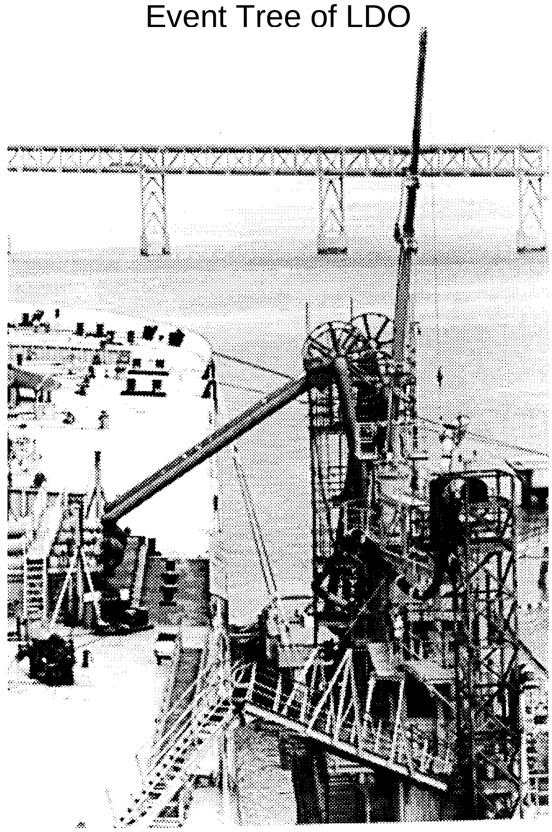

Figure 3
Loading Arms at Berth 4 Connected to Vessel Cargo Headers

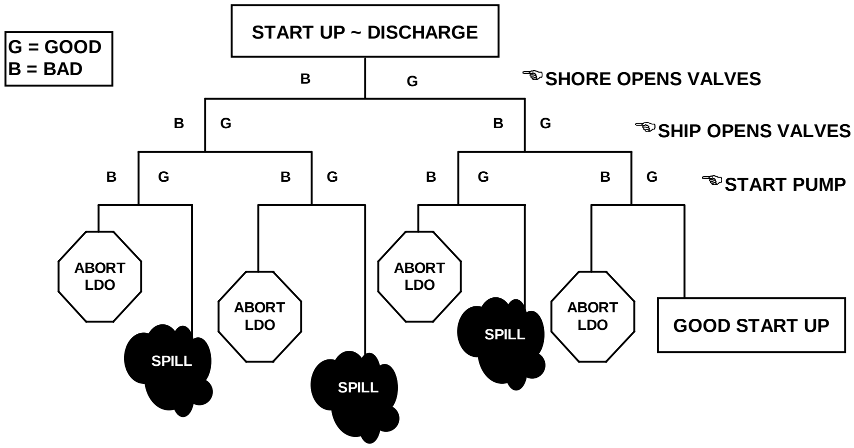

Figure 4
Event Tree of Start Up Process (Discharge Operation)

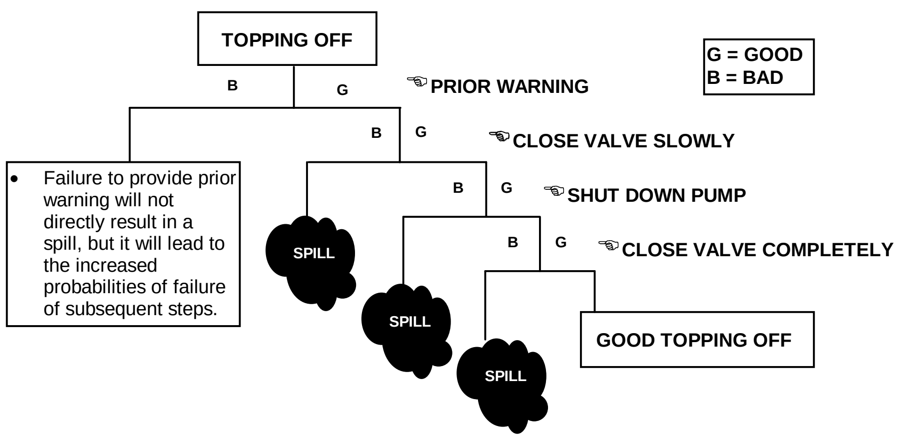

Figure 5
Event Tree of Topping Off Process (Loading Operation

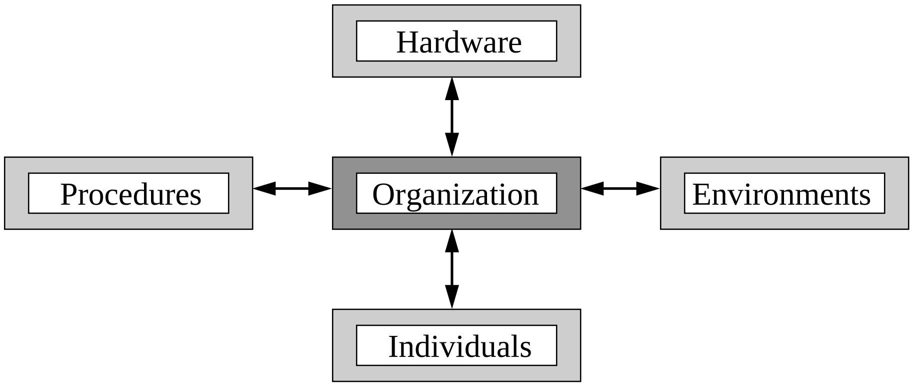

Figure 6
Primary Components that Comprise the LDO System

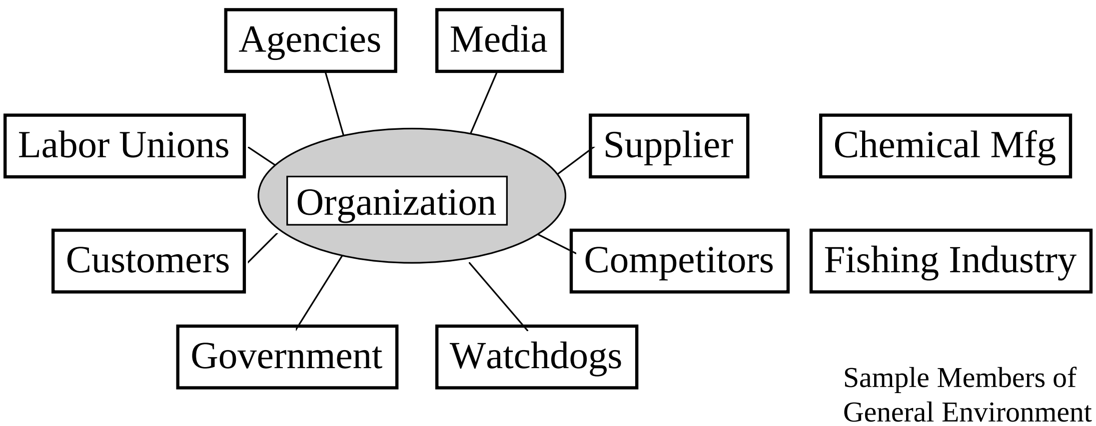

Figure 7
Illustration of the Specific Environment

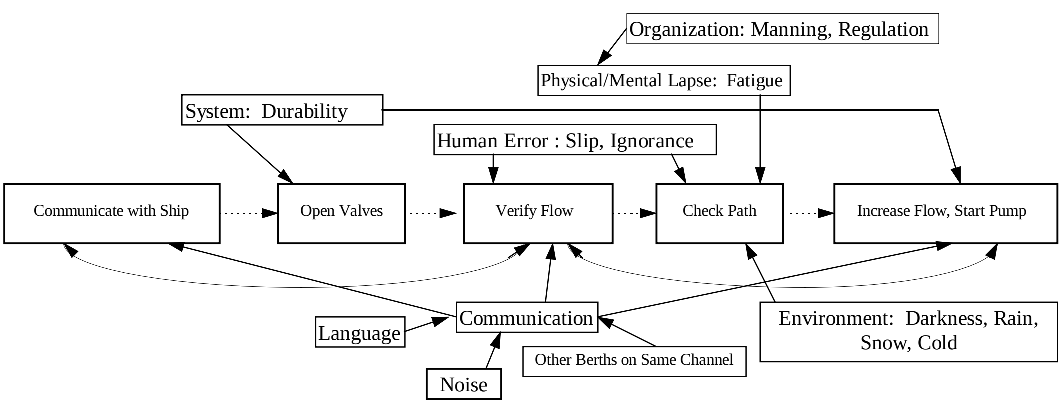

Figure 8
Influence Analysis — Start Up

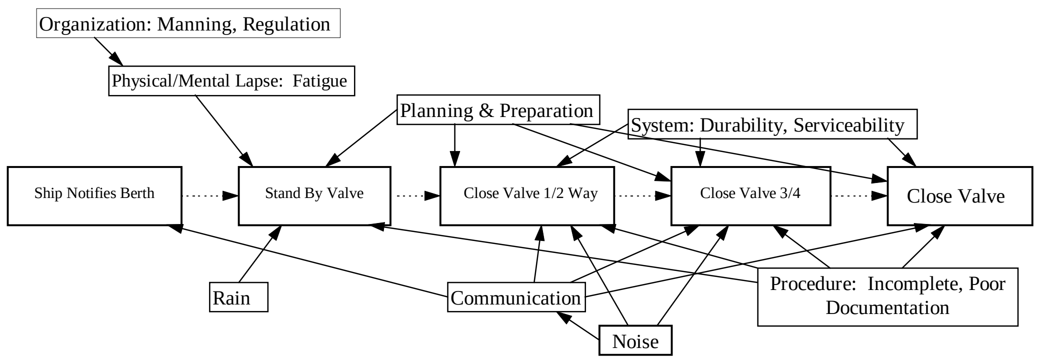

Figure 9
Influence Analysis — Topping Off

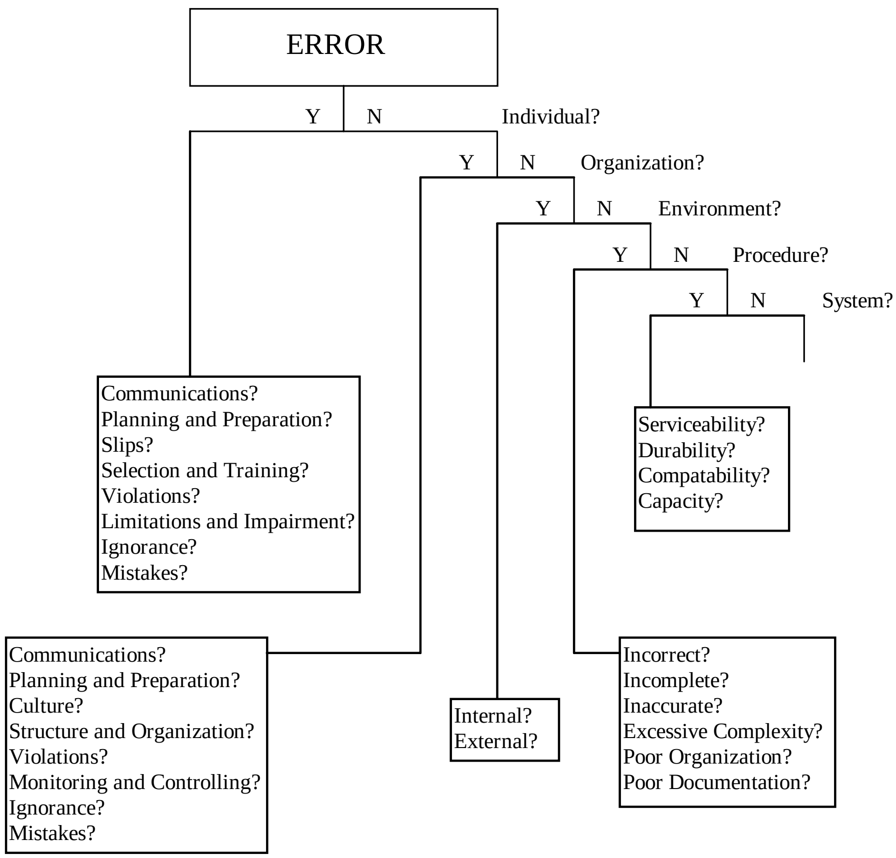

Figure 10
Error Analysis Event Tree

Discussion

by Admiral Rea (USCG retired) and Lt. CDR Buie (USCG)

You commented on the general unreliability of information in marine accident databases and that present investigations were not an effective way to achieve safety in marine systems. Why? How might this situation be improved?

Reply

Yes, our experience with the major marine accident databases and accident investigating and reporting protocols that underpin these databases indicates that generally they do not adequately capture the important human and organizational factors that underlie the majority of these accidents. We have not been able to locate and access one fully functional near-miss and incident reporting and database system. This is due to a variety of reasons that are firmly rooted in the history, culture, and organization of the industry, its regulatory agencies, and the societies in which the systems of marine activities exist. This is not unique to the marine industries. Other industries (e.g. commercial aviation, nuclear power, chemical refining, insurance, medicine, finance) have recognized many of these same problems. Most of these industries are taking important steps to improve the situation.

This attention to accidents, near-misses, and incidents is clearly warranted. Studies have indicated that generally there are about 100+ incidents (oop's), 10 to 100 near-misses (that was close), to every accident. The incidents and near-misses can give "early warnings" of potential degradation in the safety of the system. The incidents and near-misses, if well understood and communicated provide important clues as to how the system operators are able to rescue their systems, returning them to a safe state, and to potential degradation in the inherent safety characteristics of the system.

Incident and Near-Miss Information System

Our research indicates that different approaches, protocols, and information systems need to be developed to properly understand and utilize this important information. In particular, the near-miss databases need to be call-in or write-in systems that encourage operator participation and that are designed to protect the information and sources of the information. The Aviation Safety Reporting System (ASRS) provides some good experience on how to establish, maintain, and utilize such an early-warning system.

The ASRS possesses "elegant simplicity." The developers and users of this system recognize that it is not perfect, but it has proven to be very useful in providing early warnings of potential system degradation. Even at the present time, efforts are underway to further expand and improve the ASRS (e.g. to include ground and maintenance operations). Studies are being conducted on a Ôworld wide web version of this system that would permit integration of information from the international commercial aviation community.

All of the ASRS operations are conducted *outside* the FAA and in a "secure facility." Much attention is paid to avoiding conflicts of interest between the regulatory agency/ies and the sources of the information. Even more attention is paid to protecting the information sources. The ASRS is Federally funded.

When information is initially submitted to the ASRS, a structure and protocol is provided for the source of the information. Initially, the information source is identified. If a "scan" of the incoming reports indicates that a "call-back" is necessary to develop further information, the source is contacted. The scan and the call-backs are conducted by a small team of very experienced pilots (generally retired, well trained, and highly motivated). The number of call-backs is dependent on the availability of personnel and funding for hiring that personnel. The call-backs are intended to develop a more complete understanding of the incident or near-miss. Once the information has been verified and completed, the source identification is destroyed. "Cry wolf" (false) reports have not proven to be a problem in the ASRS.

The information is then encoded into a database. All information introduced to the database is anonymous. If the information indicates some potentially important emerging trends, the information is distributed to all of the concerned sectors of the aviation community. Users can contact the administrators of the ASRS and have special searches and studies performed. The database can be made available to researchers that are conducting studies to improve air safety. Given sufficient Federal funding, the ASRS administrators are able to conduct research with information from the database. All of this information is distributed freely to those that "have a need to know." Only in the case where there are clearly legal violations are the violations reported in any formal way, still preserving the anonymity of the sources of the information.

The system is obviously successful. There are demands to expand its scope. There are demands to improve its protocols. The primary demands come from those that use the system on a daily basis and have daily responsibilities for the safety and integrity of air safety. A few devoted and highly qualified people make this remarkable system work, it is really not "high tech." The system is spelled "integrity."

We have seen some efforts by the marine community to develop incident and near-miss information systems. In some cases, early indications are that the system can be useful. Our experience with several of these systems indicates that they likely can not be successful in the long-run. Reporting, verification, archiving, and analysis protocols are seriously flawed.

This system provides a good starting point for development of a Marine Safety Reporting and Information System (MSRIS). We would encourage the U. S. Coast Guard to lead the industry (and yes, even IMO) in development of such a system as part of the Prevention Through People (PTP) program. The need for elegant simplicity, experienced verifiers (it takes one to know one and understand one), protection of the sources and information from legal and employment repercussions, and an active reporting system that possesses integrity are key aspects of such a system. This system was reviewed as part of the Ship Structure Committee MSIP (Marine Structural Integrity Program) research (see SSC 361). A simple (not dumb) MSRS system needs to be developed, detailed, tested, and implemented.

Those that act safety in the face of pressures for production ("on-time," "on-budget," and "happy customers") need to recognized in positive ways so that compromises in the safety of the system are avoided by the people responsible for the safety of these systems. I have heard it said over and over at this Symposium that "productivity" is the primary goal. Our experience clearly indicates that the primary goals should be "safety" and the "quality of the system and its processes." Integrity and trust should be built, earned, and recognized. Productivity, profitability, and the other goals of organizations need to get in line behind the goals that can help ensure the viability and longevity of the marine industries.

We need to configure our marine systems and infrastructure so that we do not merely catch-up with the rest of the world by trying to mimic their productivity developments. By the time we do, we will be behind again. Rather, we need to establish leadership for the next Century of the world's marine industries that will take full advantage of the talents that the members and leaders of the U. S. based marine industries bring to this enterprise. We need to overhaul the entire system if this is to be accomplished. Not merely patch it. A viable "life cycle" (design, manufacture, operate, maintain, decommission) Safety and Quality Information system can be a help in getting this leadership re-established.

Accident Information System

Our research indicates that there is also a need for an industry wide accident information system. Here, I will call it the Accident Assessment and Reporting System (AARS). However, this system needs to be designed from the ground-up taking full advantage of private industry, Classification Society, insurance, U. S. Coast Guard, and other regulatory accident information systems. Patch jobs based on existing systems should not be encouraged. We have seen some very good starts at good accident information systems. But, also, we have not encountered one system that is really working or entirely workable.

When the accident occurs and must be reported and investigated, a wide variety of complex issues spring up. Most of these issues represent reactionary responses to the event. I have heard it as "kill the victim." I have personally experienced some of this killing and it is no fun. There are some remarkable ways to kill the victim that include exiling, shaming, persecuting, threatening, making believe that the accident never happened (covering it up), placing blame where it does not belong, terminating career development and promotions, and of course, monetary "restrictions." Given these kinds of reactions, it is little wonder that the lessons of accidents are not rapidly understood and "sensible" measures put in place to manage the lessons learned to help prevent future accidents. Our work clearly indicates that many major accidents are happening over and over again, and in almost the same way. We need to learn how to break this chain.

The tendencies to "find the root cause," call lawyers and police, review the contract clauses, place blame, and other similar reactions are very counterproductive to truly understanding situations that caused failure or failures of the system. Given the litigious nature of the U. S. society, it is important that this nature be recognized and measures put in place not to encourage unnecessary or unwarranted legal action. We are spending too much time in unproductive legal action, maneuvering, and avoidance. The accident information system needs to recognize these challenges at the outset. Formal protocols need to be developed to help guide the DAAR team and process to avoid as many of these pitfalls and traps as is possible.

In our opinion, the accident information system needs to again focus on the life-cycle phases of a marine system, and major compromises in the quality attributes of a marine system. The accident information system that our research indicates needs to be fleshed-out, detailed, tested, revised, and then implemented is outlined in Figure 1. We have tried to take the best practices and experiences from other accident information systems. At this stage of our work, no claims can be made for the completeness or the utility of this system. A lot of work is need before these claims can even be discussed. And, again, we would suggest that this be a flag ship project of the PTP program.

The system is triggered with the recognition of the need for an "accident (incident) assessment" (not investigation please) (Figure 11). An accident assessment team is assembled. The team members would represent experienced, trained, qualified, DAARs (Designated Accident Assessment Representatives) whose expertise and integrity are widely recognized. Ideally, the team members would include DAARs from the sectors that had primary responsibilities for the safety of the particular system or systems involved in the accident. It would be extremely important that the DAAR team have the "requisite variety" to understand the causes and sequences of events that could lead to the accident. Deductive and inductive thinkers are needed on such a team.

A protocol needs to be established for qualification and requalification of DAARs and for selection of DAARs to form an assessment team. Strict confidentiality of the members and organization of the team needs to be preserved in so far as possible and necessary. If a DAAR receives "excessive" pressures that could sway or cloud their judgment and analysis, then he should be able to be relieved and a replacement DAAR appointed.

The next step in the process is to gather all available pertinent information on the accident and the life-cycle of the marine system. This information can be obtained from data and background on previous similar accidents involving similar systems. This information can be obtained from the MSRIS (there may have been early warnings). This information should address three categories of events and factors:

1) **Initiating** events and factors that may have triggered the accident sequence,

2) **Propagating** events and factors that may have allowed the accident sequence to escalate and result in the accident, and

3) **Contributing** events and factors that may have encouraged the initiating and propagating events.

The information developed in the three foregoing categories needs to address seven categories of factors:

1) The **personnel** (operating team) directly involved in the accident,

2) The **organizations** that may have had influences on the accident events and factors,

3) The associated **procedures** and "software" used at the time of the accident (formal, informal),

4) The associated **hardware** (equipment),

5) **Structure** (physical life and equipment support),

6) The associated **environments** (external, internal, social), and

7) The **interfaces** between the preceding five categories of factors.

This is no trivial undertaking, and it needs to be done as thoroughly as possible.

The information needs to address the life-cycle characteristics and history of the system including:

1) **Design,**

2) **Construction,**

3) **Operation,**

4) **Maintenance**.

The information that is gathered at this stage is intended to lead to a number of plausible scenarios for the accident, starting with its incubation and ending with the final event in the accident sequence. An objective is to progressively gather more information until one scenario can be designated as "most probable". The reasons for this designation need to be clearly documented and the reasons for the lower probabilities of the other scenarios need to be clearly documented. The intent is to avoid premature conclusions and a rush to the wrong judgment and scenario. The intent is to develop as complete as possible a most probable picture of why and how the accident happened and unfolded. It is realistic to recognize that the complete understanding may not be possible. It is realistic to recognize that "violations" may have taken place. These violations need to be carefully defined and the reasons for the possible violations understood. The objective is to understand as much as possible about the most probable scenario so that valid and beneficial learning can take place. The worst case is to come up with the wrong scenario, attempt to fix the wrong things, and divert scarce resources from attention to the real problems or challenges to quality, including safety.

The next step is to go the "field" where the accident happened. This step needs to be reached as soon as is possible so that valuable "clues" and factors are not lost, obliterated, or modified. The "site" or locale of the accident needs to be preserved as well as possible. On site during or after audio, photographic, and/or video evidence can be very important. All documentation possible needs to be preserved. This is why flight data and ground operations recorders have proven to be so important for the safety of commercial aviation (more improvements are presently being made to these systems to increase their scope and fidelity). The field could involve an office (design), construction yard (manufacture), operating site, maintenance facility, or decommissioning facility or a combination of these. Everything possible needs to be done to alleviate defensive and evasive postures on the part of all involved in this step. The objective of the assessment needs to be continually stressed: to understand how to make the system or systems like it safer in the future for those that are responsible for its operation to operate. This is really a tough one to create and is a primary talent and sensitivity required in the DAAR team.

A protocol or procedure needs to be developed to help guide the DAAR team activities during the field assessment phase. This protocol needs to address how things should or might be done, the factors and structuring that needs to be developed, and very important how information is recorded and reported. The confidentiality of the proceedings needs to be maintained as much as possible. Leaks should not be tolerated. Credibility and trust takes a life time to create and an instant to destroy.

Again, the DAAR team may need to gather additional information from databases, interviews (confidential and nonconfidential), qualified consultants and experts, and may need to have additional DAARs added to the team to develop the necessary requisite variety. Testing and simulations may need to be done.

The next stage is the assessment phase. It is here that scenarios are constructed and documented. It is here that evidence is assembled and evaluated in the attempt to identify the most probable scenario, or scenarios. It is here that the majority of the documentation is developed. At this stage, it may be desirable to bring in a "fresh" DAAR to help verify and validate the process. This is intended to help avoid "group think" problems and identify any significant "biases" that may be diverting the team from the most probable scenario/s. Again, more information may be necessary to help the DAAR team identify the most probable scenarios.

Perhaps, the most important step in this phase is the development of suggestions to help improve the safety of the system. The suggestions need to be prioritized, effective, detailed as much as possible, justified, and practical. Nothing will destroy the system quicker than a scatter gun approach to the suggestions, ineffective measures, insufficient detailing (to enable understanding what can be done), and unjustified - impractical "pie-in-the-sky" suggestions. Protocols need to be developed for the conduct of this stage.

The next stage is the formal and general reporting phase. This is the formal report that will be distributed to the concerned industrial, classification, and regulatory groups. Concerned parties are those that have daily and continuing responsibilities for the safety of marine systems. Unnecessary exposures of information from the assessment should be avoided whenever possible, and the DAAR team needs to understand the importance of unnecessarily polarized and inflammatory media exposure. Given today's society in the U. S., some exposure probably cannot be avoided in some instances. And, it is impossible to avoid media distortions. This is a significant hazard that needs to be carefully managed for the good of the AARS. Organizational protocols need to be developed to prevent unnecessary and unwarranted legal entanglements. Congressional and or legal privileged information systems need to be developed. There are several precedents for such systems.

The next stage is the encoding phase. This phase is intended to develop the information that will be eventually incorporated into an AARS database. This is intended to be a computer based system that will archive the most meaningful information, insights, suggestions, and other events and factors that influence the basic objectives of AARS. This is not an easy task. Much of the "richness" of the information developed by the DAAR team can be lost if this is not done correctly. This is precisely one of the major problems of existing marine and non-marine databases. Some very experienced and thoughtful study is needed to establish the system (hardware, software, procedures, personnel, organizations, and environments) to capture all of the richness from the information that has been developed. This will probably be an evolutionary process (as most of the rest of this system should be). It should be regarded as a "live" system that needs continual maintenance and adaptations to evolving needs and problems.

The information developed during the encoding phase is input to an archiving relational database system that should contain information on the results of the assessments and the background developed to arrive at these assessments. The information input to the system should be verified.

The last phase of the process is the information analysis and reporting phase. Correlation studies of information in the database should be conducted to detect emerging safety problems. If the information analysts detects an emerging safety problem that high widespread implications, then an alert is output to the system users. The objective of this phase is to understand the available information so that early warnings are developed so that corrective action can be taken before additional accidents are developed.

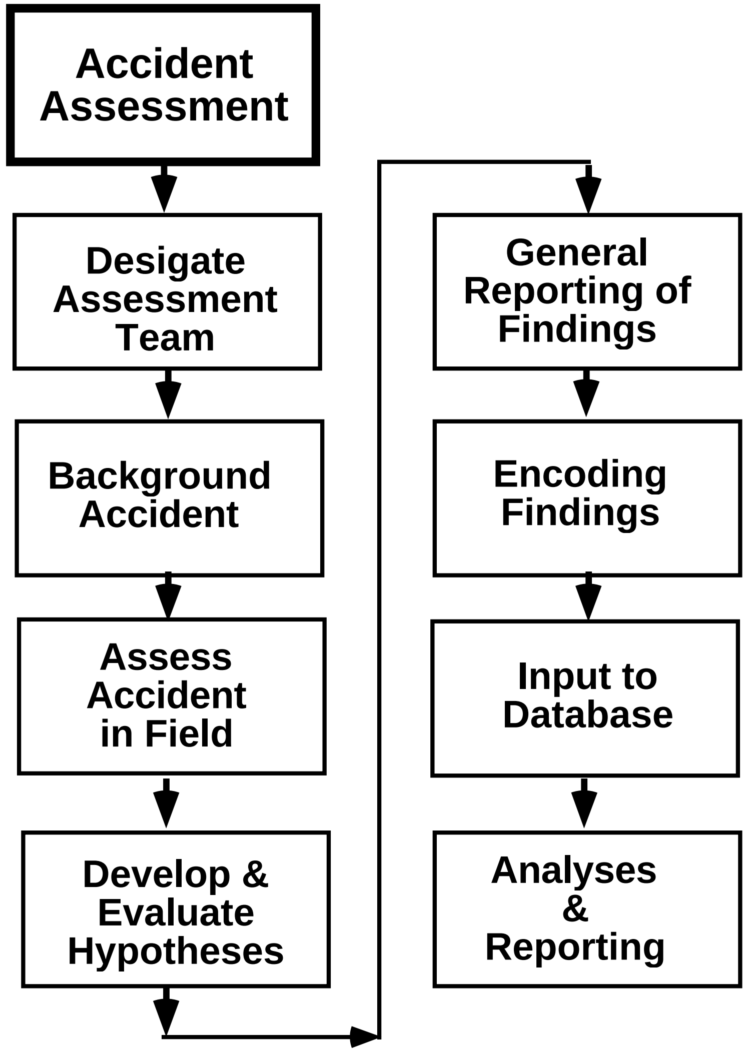

Figure 11
Accident/Incident/Near-Miss Assessment System