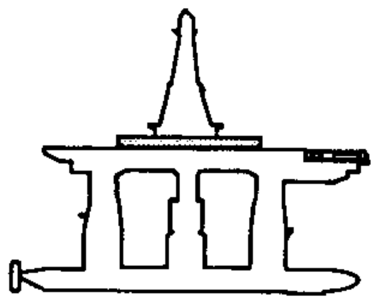
CUIMR-T-91-001 C3

CALIFORNIA SEA GRANT
(Bea; R/OE-17)

MANAGEMENT OF HUMAN ERROR IN OPERATIONS OF MARINE SYSTEMS



REVIEW OF EXISTING MARINE RELATED CASUALTY REPORTS, AND DATABASES FOR HUMAN AND ORGANIZATIONAL ERRORS

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Report No. HOE-91-1
July, 1991

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1. INTRODUCTION

The effects of tanker and offshore platform accidents can be quite evident by their catastrophic consequences such as the Exxon Valdez and Piper Alpha accidents. However while examining the causes of marine casualties such as these, we find a complex and integrated set of human and organizational operating conditions whose catastrophic consequences may or may not have been evident before the fact. Most catastrophic marine accidents are the event of compounded human and organizational errors (HOE) during operations (generally more than 80%) [1, 2]. These types of errors can be distinguished as active errors or "initiating" errors, which normally result in immediate consequences and latent errors which can lie dormant within systems for indefinite periods of time and becoming evident only when combined with active errors under unique circumstances [3].

Existing casualty database such as the U.S. Coast Guard (USCG) marine casualty database CASMAIN or the World Offshore Accident Database (WOAD) present the effects of marine casualties (loss of life, discharge of hydrocarbons, economic loss, etc.). At times, they present limited information on active errors that may have immediately caused the accident. However, there are no existing marine casualty database systems which provide comprehensive and integrated data to identify and correlate human and organizational factors related to marine casualties [2, 4, 5].

One of the major challenges is developing a comprehensive, standardized and generally accepted taxonomy that can adequately identify and describe HOE related factors [2, 6]. Yet, there have been recent developments to address this problem such as the USCG's Annotated Human Factors Taxonomy (AHFT) which will be used by CG marine casualty investigators in the coming months [2].

This report addresses the limitations and advantages of existing HOE marine casualty reports, and databases. In addition, it reviews existing & proposed HOE taxonomies for the development of a commonly used and accepted taxonomy and database system for both tankers and platforms to be implemented by operators, regulators, and designers of offshore platform and tanker operations.

2. BACKGROUND & WORK TO DATE

The taxonomy examination and development is the second primary task of the approach for the project: *Management of Human Error in Operations of Marine Systems*. The five primary tasks of the research are:

<u>Task 1</u>: Identify, obtain and analyze well documented case histories and data bases of tanker and offshore platform accidents whose root causes are founded in HOE. *(August 1990 - present)*

<u>Task 2</u>: Develop an organizational classification framework for systematically identifying and characterizing the various types of HOE. *(April 1991 - present)*

<u>Task 3</u>: Develop general analytical frameworks based on real-life case histories to characterize how the HOE's interact to cause accidents. *(June 1991 - present)*

<u>Task 4</u>: Formulate quantitative analyses for the case histories based on probabilistic risk analysis (PRA) procedures using influence diagrams. Perform quantitative analyses to verify that the analyses can reproduce the results and implications from the case histories and general statistics of marine accidents. *(Projected starting date: December 1991)*

<u>Task 5</u>: Investigate the effectiveness of various alternatives to reduce the incidence and effects of HOE. Evaluate the costs and benefits in terms of risk reduction (products of likelihoods and consequences). *(Projected starting date: August 1991)*

As shown in Figure 1 the role of the case histories and database development are important to four tasks in the HOE research. First, case histories and databases are critical to the development of HOE taxonomies. Second, they are critical to the development of the analytical framework to maintain checks and balances to whether the models are consistent with the operational procedures of the accidents being modeled. Third, case histories and databases are important to determine if the results of PRA models are consistent with the available casualty statistics and case history implications. Finally, the recommendations which follow each accident report can be analyzed to determine optimal cost-benefit schemes for HOE alternatives.

2.1 Case Histories and Database Sources

In August of 1990, we initiated an extensive search for offshore platform and tanker accident investigation reports and casualty databases. This information has been obtained from a number of sources.

1.) The USCG has supplied 30 written accident reports for tanker and mobile offshore drilling units (MODU's) casualties dated from 1979 to 1989. In addition, they have supplied the marine casualty data base (CASMAIN) which include 62,228 marine casualties dated through 1990.

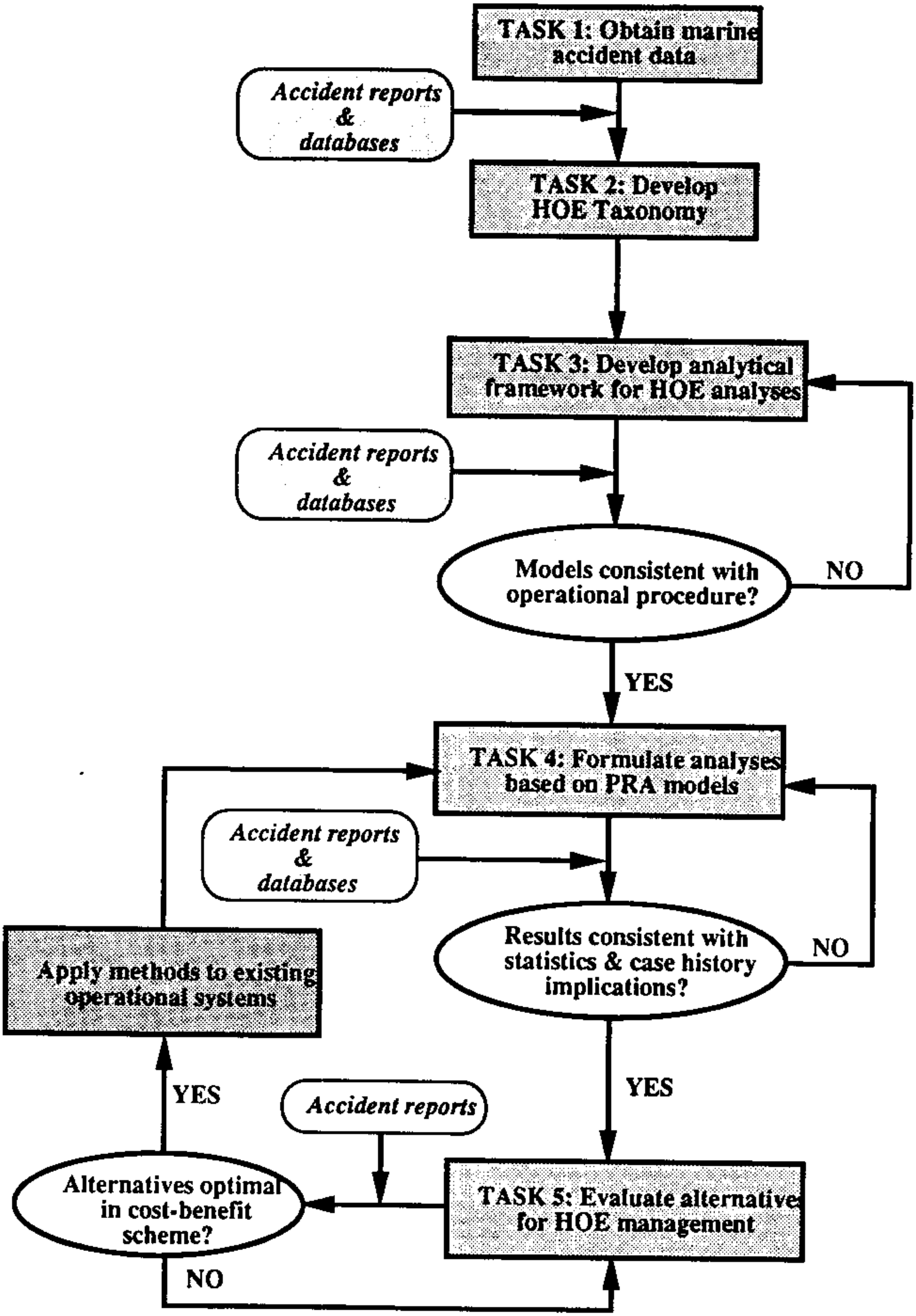


Figure 1: Flow chart of HOE study tasks

2.) The National Transportation Safety Board (NTSB) has supplied 60 written accident reports dating from 1980 to the present. The NTSB updates us with important accident reports as they become available.

3.) The Minerals Management Service (MMS) has supplied us with 42 written accident reports dating from 1979 to 1989 and offshore continental shelf accidents associated with oil and gas between 1956 and 1986. In addition, reports on risk analysis for offshore welding and crane accidents have been obtained.

4.) Independent accident reports and inquiries have been obtained for the *Piper Alpha* and disaster, including the Lord Cullen and Petrie reports. These reports have information on potential accident sequences, pre and post disaster design, operations, and regulations offshore. We have found *Piper Alpha* to be the most well documented offshore accident, these reports are to form the basis for Task 3 of the study which is discussed below.

5.) Approximately 7500 records of offshore casualty data has been obtained from WOAD up through 1988. Data consists primarily of events and not related causes.

6.) Bureau Veritas has offered access to the Institut Francais Du Petrole's (IFP) database for offshore platform (850 accidents covering 1955-1988) and tanker accidents (1,150 accidents since 1955).

7.) Offshore reliability data (OREDA) provides reliability information on safety, process, electrical, utility and crane systems, and drilling equipment.

3. WRITTEN ACCIDENT REPORTS

Case histories are invaluable in that the study of a single case can provide insight into circumstances leading up to catastrophic events. It allows us to examine causal factors involved which would be difficult to determine and identify by other means. Some catastrophic events are the result of a truly unique set of causal circumstances which allow us to examine the effects of contributing error factors and the limitations of human performance under various operating conditions [3].

However case study analysis of marine casualties have potential drawbacks. Case reports possess a limited amount of the information that is available and "digitize" the set of complex events and circumstance which lead to casualties [3]. An overall picture of the complex processes and circumstances involved in the casualties are difficult to determine and present. Marine investigators may have biases toward addressing technical factors involved or not possess the expertise or knowledge to determine and report HOE factors. There is a tendency to focus on the system failures and not the human operators as exemplified by the many of USCG, MMS, and NTSB accident reports. In addition, there can be a substantial amount of uncertainty involved in these casualty reports due to inaccurate or incomplete information.

Accident investigations and reports tend to focus on visibly "solvable" problems. It is presumed to be in the best interest to formulate "feasible" solutions and recommendations even at the expense of excluding valuable information. The majority of these solutions tend to be remedial in nature, non-effective, and can create unforeseeable operational problems.

3.1 USCG & NTSB

The written casualty reports provided by the USCG and NTSB have been valuable in examining a number of human and organizational factors involved in marine casualties. Though many of the reports tend to be technical in nature, most reports pay particular attention to problems resulting from operator or management errors as well as point out failures of operators to stay within the guidelines of marine regulations. The advantages of using the USCG and NTSB for HOE analysis are:

1.) Many of the accidents are of sufficient detail to formulate PRA analyses to verify that the analyses can reproduce the results and implications of operations and general statistics of marine accidents (Task 3).

2.) Each accident report is followed by recommendations to ensure the reduction in the possibilities of similar accidents in the future. Alternatives for HOE management suggested in these recommendations can be used to determine their effectiveness using the cost benefit analysis.

3.2 MMS REPORTS

Offshore platform casualty reports by the MMS are less detailed than those provided by the NTSB and the USCG particularly in the technical aspects. The reports make little mention of human factors which have contributed to the accidents, though some human factors information can be drawn from the reports such as various concurrent activities which may have contributed to the hazardous environment (e.g. cold-cutting maintenance on a riser resulting in a hydrocarbon leak due to the riser not being properly bled while welding operations were being conducted nearby resulting in an explosion and fire).

Two reports on OCS accidents do make mention of HOE factors involved in casualties. The first report, *Risk Analysis of Welding Accidents: Gulf of Mexico OCS Region* from 1967 to 1984 categorize operator errors by:

1.) Lack of proper site preparation, coordination and supervision.

2.) Failure to properly isolate potential source of fuel and/or flush/inert the work area.

3.) Improper layout or design.

4.) Employee negligence.

5.) Protective devices not used.

6.) Poor housekeeping.

7.) Improperly prepared work area.

Ninety accidents were recorded for the 1967 to 1984 time period of which 88 accidents were the result of the causes listed above. Table I describes the causes of OCS welding accidents and the consequences:

Table I: HOE factors resulting in OCS welding accidents [7]

Cause	Fire	Explosion	Pollution spill	Injury	Fatalities	Total # of accidents
Lack of proper site preparation	25	3	1	30	17	26
Failure to isolate fuel source	34	8		22		37
Defective equipment	1					1
Improper layout or design	1					1
Employee negligence	7	2		9		8
Protective devices not used				2		2
Poor housekeeping	3					3
Improperly prepared work area	9			1		9
Equipment failure	2			1		2
Unknown		1			1	1
Total	82	14	1	65	18	90

The second report *Risk Analysis of Crane Accidents* from 1970 to 1984 categorizes 35 of 55 (64%) crane accidents resulting from human errors by:

1.) *Unsafe procedures* (19 accidents)

2.) *Error of judgement* (5 accidents)

3.) *Crane overload* (11 accidents)

No further differentiation of accident causes were given [8].

An additional report, *Accidents Associated With Oil & Gas Operations: Outer Continental Shelf 1956 - 1986* has documented all OCS accidents during that time period. This report provides accident location, date, duration, type of accident, corrective action, volume of pollution spilled, fatalities, injuries, and damage to property or environment but make no mention of accident causes [9].

In general, documentation of OCS casualties is limited and does not yield much detail to provide a solid basis to examine accident causes rooted in HOE. Attempts to provide empirical risk analysis for offshore operations have been curtailed by lack of reliable data to examine HOE factors [5, 10]. In response to the *Piper Alpha* disaster, the MMS has established a task group to review information on the tragedy to examine alternative regulatory responses to ensure similar events will not occur in the domestic offshore operations [11]. However, no mention is made of establishing an effective database to examine HOE factors.

3.3 PIPER ALPHA DISASTER: PETRIE & CULLEN REPORTS

Both the Lord Cullen and Petrie Reports provide detailed analysis of the *Piper Alpha* disaster. The Petrie Report focuses primarily on technical aspects of the disaster and makes little mention of the human and management factors though some mention of operational procedures is included [12, 13]. The Lord Cullen Report is a detailed study examining technical, fire, and human and management errors in both design and operations [14, 15]. In addition, the report gives recommendations for future platform operations along the United Kingdom OCS.

For Task 3 of the project which entails development of an HOE framework for real-life case histories, we find *Piper Alpha* as the ideal platform accident to study for the following reasons:

1.) In addition to the Petrie and Cullen reports, more information and data is available on *Piper Alpha*. This information includes design strategies for the replacement structure *Piper Bravo*, new design, operational, and regulatory requirements currently being implemented in both the British and Norwegian sectors of the North Sea and the United States.

2.) The Cullen Report proposed 106 future recommendations for UK OCS operations. Task 5 of the project calls for the investigation of the effectiveness of various alternatives to reduce the incidence of the effects of HOE. These recommendations can be examined through the HOE framework to be developed using the cost benefit analysis in Task 6 of the study.

4. DATA BASES

4.1 CASMAIN

CASMAIN has been developed by the USCG to document both marine related vessel and personnel casualties. A variety of information is available through CASMAIN as seen in Appendix 1 and Appendix 2. The primary sources of information to be used for the HOE study are the "nature" (event) and "cause" (reason) for the casualties. Both the nature and cause categories have designations for human errors in their taxonomies. As seen in Appendix 3 the "nature" of the casualties include variations of collision, disappearance, explosions, fires, grounding and material failure. Appendix 4 gives reference to the "cause" of the casualty which include human factors, structural and equipment failure, maintenance, weather, navigational obstacles, and management and regulatory factors.

The general structure of CASMAIN has a maximum of three fields for the "nature" and a maximum of seven fields for "cause". Each of the nature fields are labeled Nature 1-3, and cause fields CAUSE 1-7. The nature of the incident moves through various stages of events which lead to a final outcome. Generally, each accident has a set of causes associated with that event as observed in Figure 2.

For example, Figure 3 shows the three nature fields in CASMAIN representing the *Ocean Ranger* accident (84 men killed). Nature 1 "Material failure, electrical control systems", led to Nature 2 "Capsizing", and finally Nature 3 "Foundering, sinking". The cause associated with Nature 1 was stated as "averse weather", the cause associated with Nature 2 was "improper casualty control" and, no cause was stated for Nature 3.

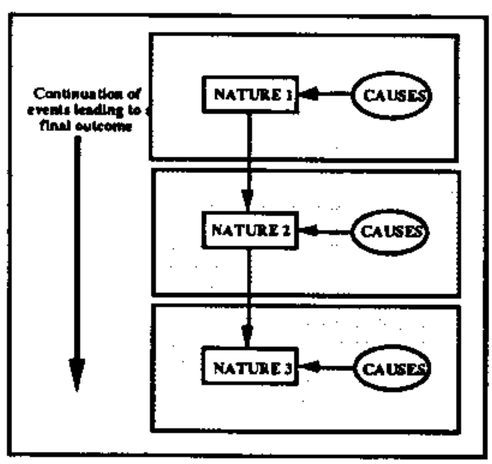


Figure 2: CASMAIN database accident nature and cause relation

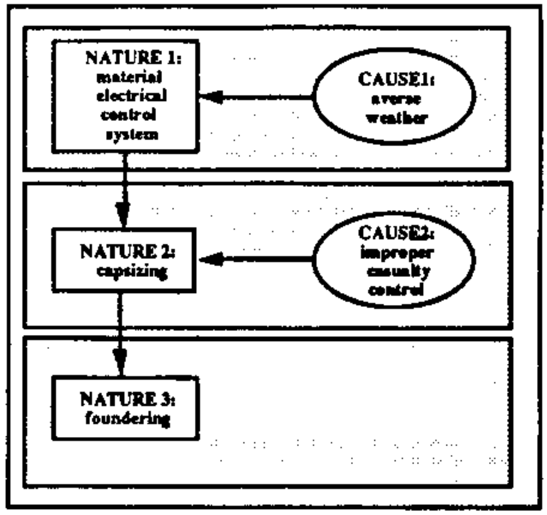


Figure 3: CASMAIN database accident nature and cause relation for the *Ocean Ranger* accident

4.1.1 Advantages of CASMAIN

In general, CASMAIN can be used to address the following HOE factors:

1.) Given the limited human factors related data for marine casualties available, CASMAIN provides the basis for establishment of empirical models and can be used to assist in development for statistical models for various HOE error forms.

2.) Though limited in assessing the cause of the events in the incidents, the framework for determining the process of the accidents and their causes can be used to a limited extent. Again empirical and statistical models can be developed for conditional statistics based upon specific events. For example, conditional probabilities for various causes that are human factor related can be established for various events in a sequence:

$$P[nature_i|cause_j] = p_{ij}$$

Table II shows the conditional probabilities of various human factors related to collision data. This data was obtained from a sample of 7,915 CASMAIN marine accident reports dated from 1980 to 1984 of which 2,018 casualties were collision related (25.5%).

Table II: CASMAIN collision probabilities for various human related causes[1]

Given...	Cause	P[Cause | Collision][2]
Collision	Inattention of duty	.01
"	Intoxication	1.0×10^{-3}
"	Calculated risk	8.9×10^{-3}
"	Carelessness	.013
"	Judgement error	.129
"	Lack of knowledge	.01
"	Lack of training	.003
"	Lack of experience	.005
"	Operator error	.142
"	Fatigue	.006
"	Stress	0.0
"	Failure to comply with rules and regulations	.06

4.1.2 Limitations of CASMAIN

There are four particular shortcomings involved with the CASMAIN documentation in examining HOE factors:

1.) error sequences are "digitized" from what was initially a set of complex and continuous events into a limited number of events. Much of the error sequences and interactions cannot be analyzed through this database in addition to being inaccurate and incomplete even if written by experienced casualty investigators.

2.) no ways to trace individual errors grounded in the organizational structure.

3.) few taxonomies that demonstrate regulatory, management and organizational errors.

4.) no methodologies for differentiating between the various organizational parties at fault for accidents with multiple parties involved.

To illustrate the limitations mentioned above, we can return to the example of the *Ocean Ranger*. There were a particular number of causes for the three "natures" of the events

[1] Excluding fishing vessel as the primary vessel in casualty report.
[2] Conditional probability is based on the events and causes disregarding of the sequence of occurrence.

described above for the *Ocean Ranger* accident. In examining the written accident reports for the disaster, it is evident there were substantially more causes related to the events of the accident than those described in CASMAIN [16, 17].

Using the CASMAIN taxonomy, Figure 4 shows a more detailed version of the causes of the events of the accident. Even in the event of documenting the causes to each nature, there is a loss of the complex and dynamic interactions which have occurred in the incident. It is difficult to determine what human errors are the result of errors rooted in the organization or whether the operators are acting on their own initiative. In addition, there were a number of factors involved regarding the regulatory requirements for manning the vessel which were unable to document such as the government of Newfoundland's persistence in having the platform manned with Canadians though not properly trained [16, 17].

It is impossible to distinguish between responsible parties of various errors in the sequence particularly for offshore operations where there can be many sub-contractors working aboard the vessels. For example, Mobil Oil was the operator and coordinated all aspects of the exploratory drilling program , while ODECO Drilling Company was the contracting company aboard the *Ocean Ranger*. Though both organizations were found to be at fault, the taxonomy does not allow for the differentiation between the management factors to distinguish responsibility for various aspects of the accident.

4.2 WORLD OFFSHORE ACCIDENT DATABASE (WOAD)

WOAD is the worlds largest databank of offshore accidents. Though reports issued by Veritec using WOAD state the need to focus on worldwide operational safety and human factors, the database is limited to documenting events which have initiated the accident chain [18, 19] with no mention of the cause of the event. For example, Figure 5 shows the initiating events leading to severe offshore fixed and jackup accidents from 1970 to 1984. Each of the events can be shown to have causes rooted in HOE as was demonstrated with the collision data from CASMAIN (see Table III).

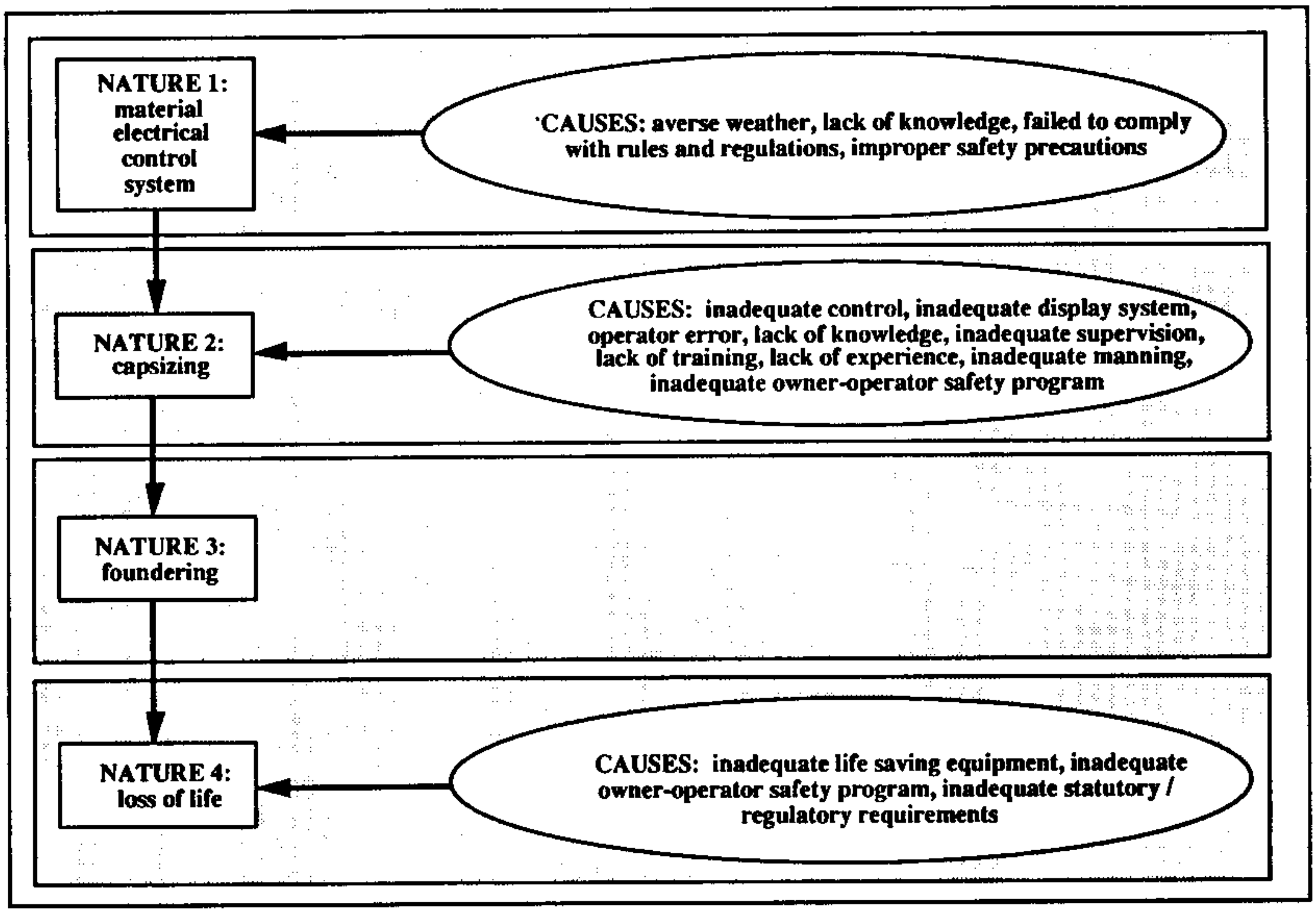
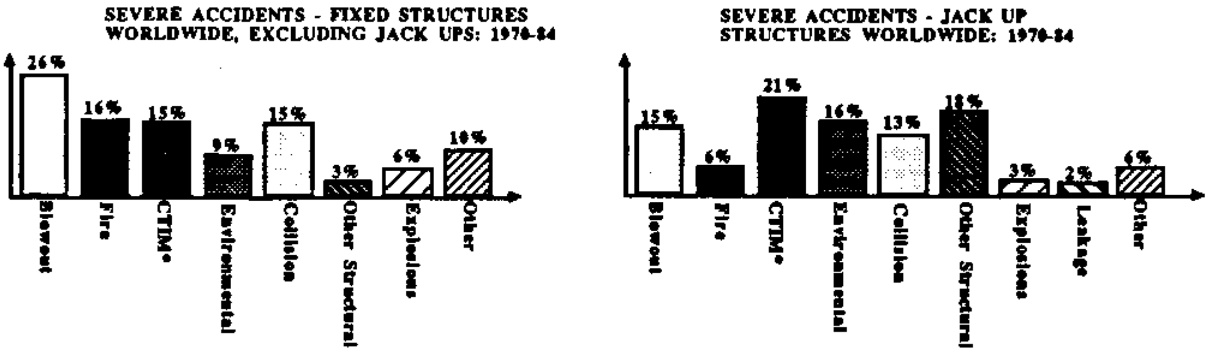


Figure 4: More detailed CASMAIN database accident nature and cause relation for the Ocean Ranger accident



* CTIM: Construction, Transportation, Installation and Mobilization

Figure 5: WOAD severe accident statistics for fixed and jackup structures worldwide: 1970 - 1984

The advantages of using WOAD is it allows for a global analysis of offshore accidents. It allows for comparison between other offshore operations worldwide to those being conducted in US OCS waters and allows for the analysis of time dependent trends in offshore safety for various types of operations (drilling, production, fixed platforms, MODU's, etc.). On the other hand, WOAD is limited in a similar nature to that of CASMAIN. The database does not allow for the examination of the complex interaction of causes with the casualty events.

4.3 INSTIUT FRANCAIS DU PETROLE (IFP)

The IFP has gathered data for tanker and offshore platform accidents worldwide. This database has been divided into two areas: (1) tanker accidents resulting in spills of at least 500 metric tons, and (2) for platforms accidents resulting in the shutdown of activity for a minimum of 24 hours for both drilling and production platforms. These databases exclude some accidents that may have been heavy in human losses but did not result in oil discharge or work stoppage.

Each accident is documented by a series of synthesis data sheets containing all that is known about the accidents from press reports, articles, and reports and documents. These data sheets describe how the accidents occurred and their consequences. The information available through the data sheets include:

1.) the accident (date, cause, weather, place) and its chronology, 2.) the ship (name, type, flag, deadweight tonnage (dwt), age),

3.) the spill (nature of cargo, amount transported, amount spilled),

4.) pollution control measures,

5.) consequences of the pollution,

6.) miscellaneous comments not falling within the framework of the other headings,

7.) for platforms there are other characteristics of the vessel and chronology of the accident.

In addition, the IFP databases have thirty parameters in database form which include:

for vessels-

- ship name
- date of accident,
- its situation at the time of accident,
- stage of the tanks on tanker,
- site of the accident,
- preliminary factors to the accident,
- chain of events making up the accident,
- number of casualties,
- amount of oil spilled,
- details about recovery of cargo,
- nature of oil spilled,
- impact of pollution
- and a means of pollution control.

and additional information for platforms-

- type of craft,
- its builder,
- its age,
- evacuation of personnel.

Similar to the WOAD, the IFP database allows a global analysis of both tanker and offshore accidents. Though much information is in database form, the datasheets allow an accident analysis similar to written casualty reports though not as detailed. However, factors associated with the accidents can be extracted which would not be normally accessible through the casualty database (e.g. event-cause relationships).

The IFP has the particular drawback of limiting data to accidents resulting in spill or limited shutdown periods and do not account for the major accidents which may not fall within this category such as loss of life, helicopter, or diving accidents.

4.4 OFFSHORE RELIABILITY DATA (OREDA)

The scope of the development of OREDA was to collect, analyze, and present quantitative and qualitative reliability information from failure and repair records already existing for offshore systems in handbook form [20].

For the items covered, OREDA presents generic quantitative information for:
failure modes, failure rates for each failure mode,

1.) Failure modes.

2.) Failure rates for each failure mode with associated uncertainties.

3.) Mean repair times.

4.) Supportive information on such items as number of events, time in service, population, etc.

Qualitative information provided by OREDA include:

1.) Item descriptions.

2.) Offshore application.

3.) Environmental and operational conditions.

4.) Failure causes and additional description of failure modes.

5.) Data sources.

6.) Item boundary specifications.

OREDA has been established in a taxonomy form basis as observed in Figure 6, the first level of consisting of safety systems, process systems, electrical systems, utility systems, crane systems, and drilling equipment. The second level of the taxonomy identifies the subsystems, major equipment and processing equipment. The additional differentiation of subsections are primarily based on function.

OREDA provides a quantitative database system for analysis of offshore systems. The ability to model offshore reliability based on system failure through quantitative risk assessment has been preformed previously. However, this modeling had the disadvantage of limited data at the time [5]. Methodologies for integrating human errors into fault tree analyses has also been suggested [21]. The event in the fault tree can be established then initiating events can take into account the escalating events which are HOE related [21, 22]. Figure 7 shows an event tree for the installation of an ESD valve in an oil pipeline. The event tree distinguishes between decisions and events at various states of the system [22].

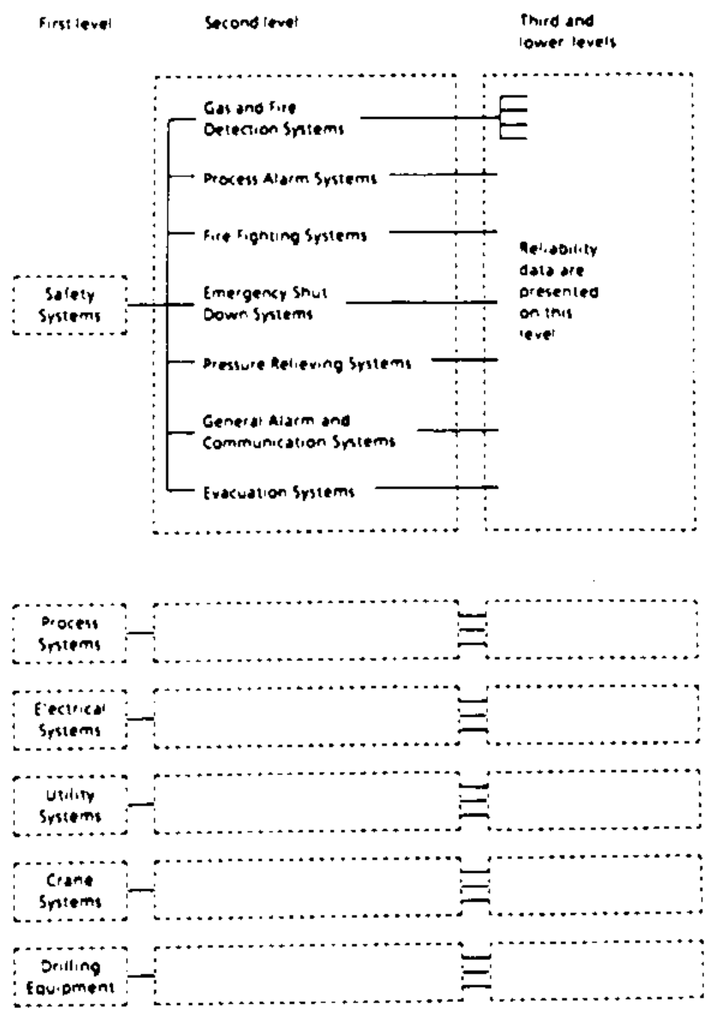


Figure 6: Hierarchal breakdown of OREDA data presentation

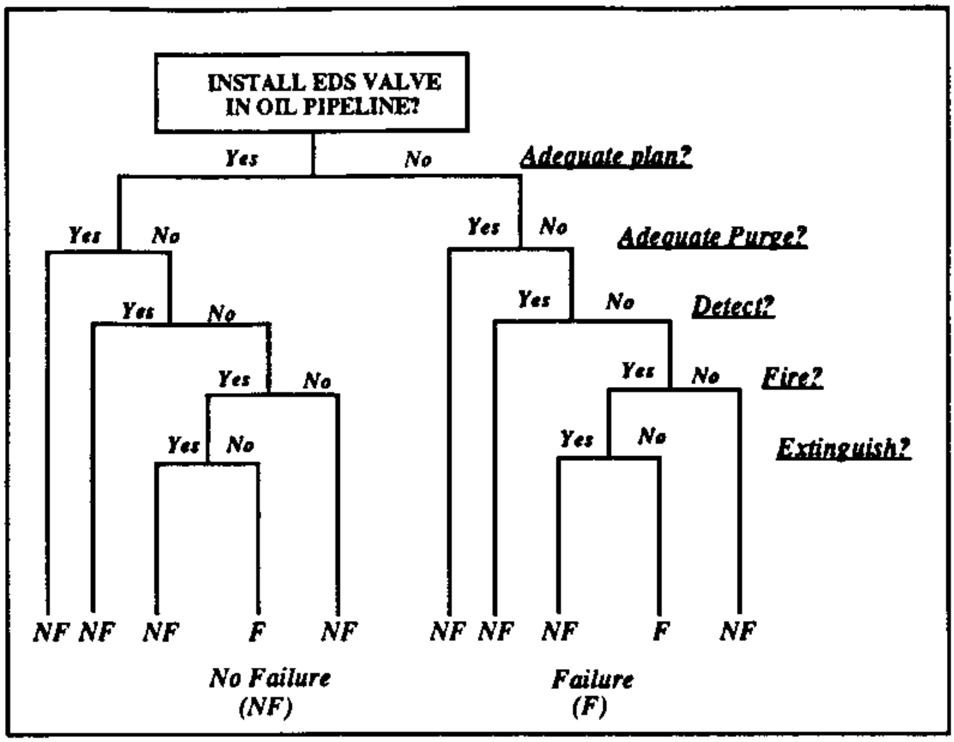


Figure 7: Event tree for installation of ESD valve in oil pipeline [22]

5. PRESPECTIVE TAXONOMIES FOR HOE ANALYSIS

5.1 MARINE BOARD TAXONOMY FOR MARINE CASUALTIES

In 1976, the Maritime Transportation Research Board (MTRB) concluded a five year study on merchant marine safety called *Human Error in Merchant Marine Safety*. The objective of the study was to determine the causes of marine casualties resulting from human errors. The MTRB panel concluded that there were 14 human factors which led to marine casualties or near casualties [4]. These factors were:

1.) *Inattention*: lack of full vigilance to duties and responsibilities assigned.

2.) *Ambiguous pilot-master relationship*: confusion in authority and responsibility.

3.) *Inefficient bridge design*: poor instrumentation and control stations.

4.) *Poor operational procedures*: failure of deck and engine watchstands to observe consistent operating standards.

5.) *Poor physical fitness.*

6.) *Poor eyesight.*

7.) *Excessive fatigue.*

8.) *Excessive alcohol use.*

9.) *Excessive personnel turnover.*

10.) *High level of calculated risk.*

11.) *Inadequate lights and markers: particularly for vessel navigation purposes.*

12.) *Misuse of radar*. Misuse or misinterpretation of radar equipment.

13.) *Uncertain use of sound signals*: general failure to employ sound signals as required for rules of the road.

14.) *Inadequacies of the rules of the road*: when rules are considered to be the source of, rather than the countermeasures to human error casualties.

These conclusions were based upon an intensive literature search as well as 359 in depth interviews distributed to pilots, masters, deck officers, chief engineers, engineering officers, tug and harbor personnel.

In addition to these human factors, the panel concluded there is an inadequate database to maintain statistics on marine casualties and had recommended the development of such a database by the USCG. The MTRB panel also suggested recommendations to address the 14 human factors listed above.

Through examination of the questionnaires and literature search, the MTRB panel defined 13 types of human errors they believed to be detrimental to safe marine operations [4]:

1.) *Panic or shock,*

2.) *Sickness,*

3.) *Drunkenness or drug influence,*

4.) *Confusion,*

5.) *Inattention,*

6.) *Incompetence,*

7.) *Anxiety,*

8.) *Fatigue or drowsiness,*

9.) *Negative transfer of training,*

10.) *Negligence,*

11.) *Ignorance,*

12.) *Calculated risk, and*

13.) *Fear.*

The panel then constructed the casualty flow diagrams shown in Figures 8 - 12 to model a ship casualty [4]. Ship casualties were distinguished into 4 major categories: foundering, fire or explosion, grounding or collision, and death of or injury of personnel. Further differentiation of failures were constructed with mention of where human errors could be contributors to the events.

These flow diagrams do not present the complex sequences and combinations of human errors and material failures. Given the unique nature of many vessels and operations, there are many variations on the vessel flow diagrams. Yet, it had been suggested that this form of flow diagram could be the basis for developing more detailed fault trees for vessel casualties.

In conclusion, the human error taxonomy developed by the MTRB encompasses operator errors and a framework for developing fault tree analyses for merchant marine casualties.

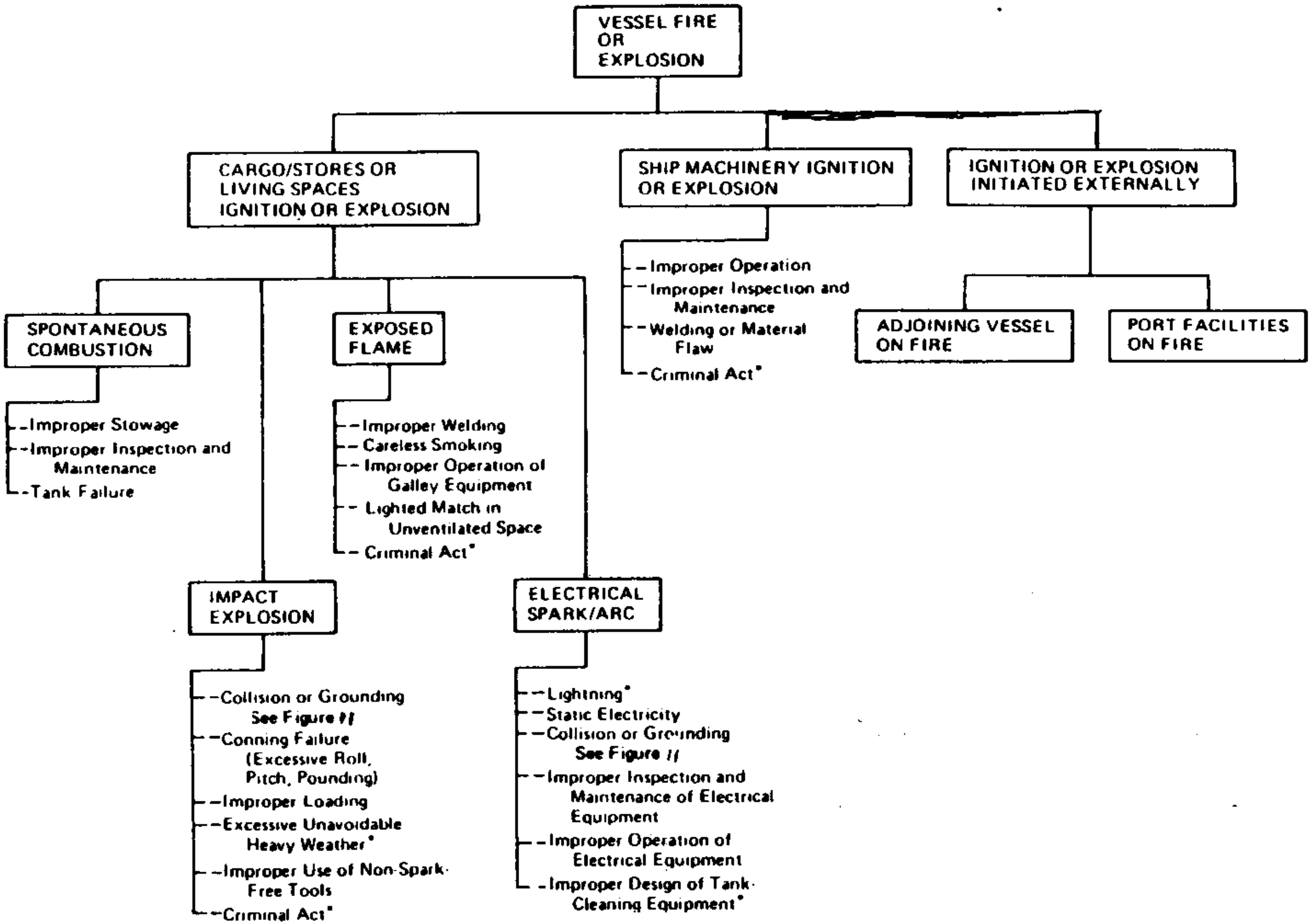


FIGURE 10

CASUALTY FLOW DIAGRAM FOR FIRE OR EXPLOSION [4]

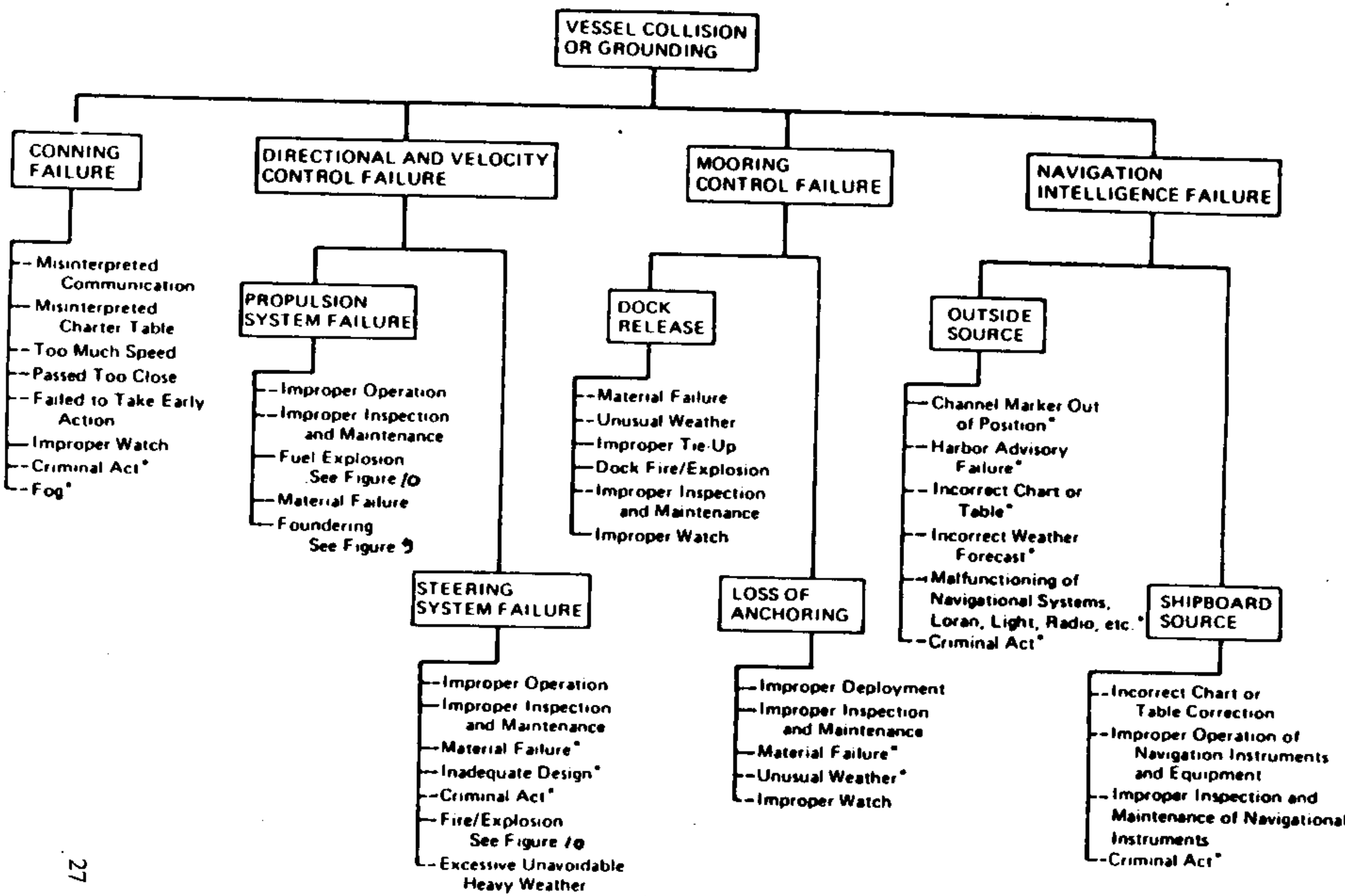


FIGURE 11

CASUALTY FLOW DIAGRAM FOR COLLISION OR GROUNDING [4]

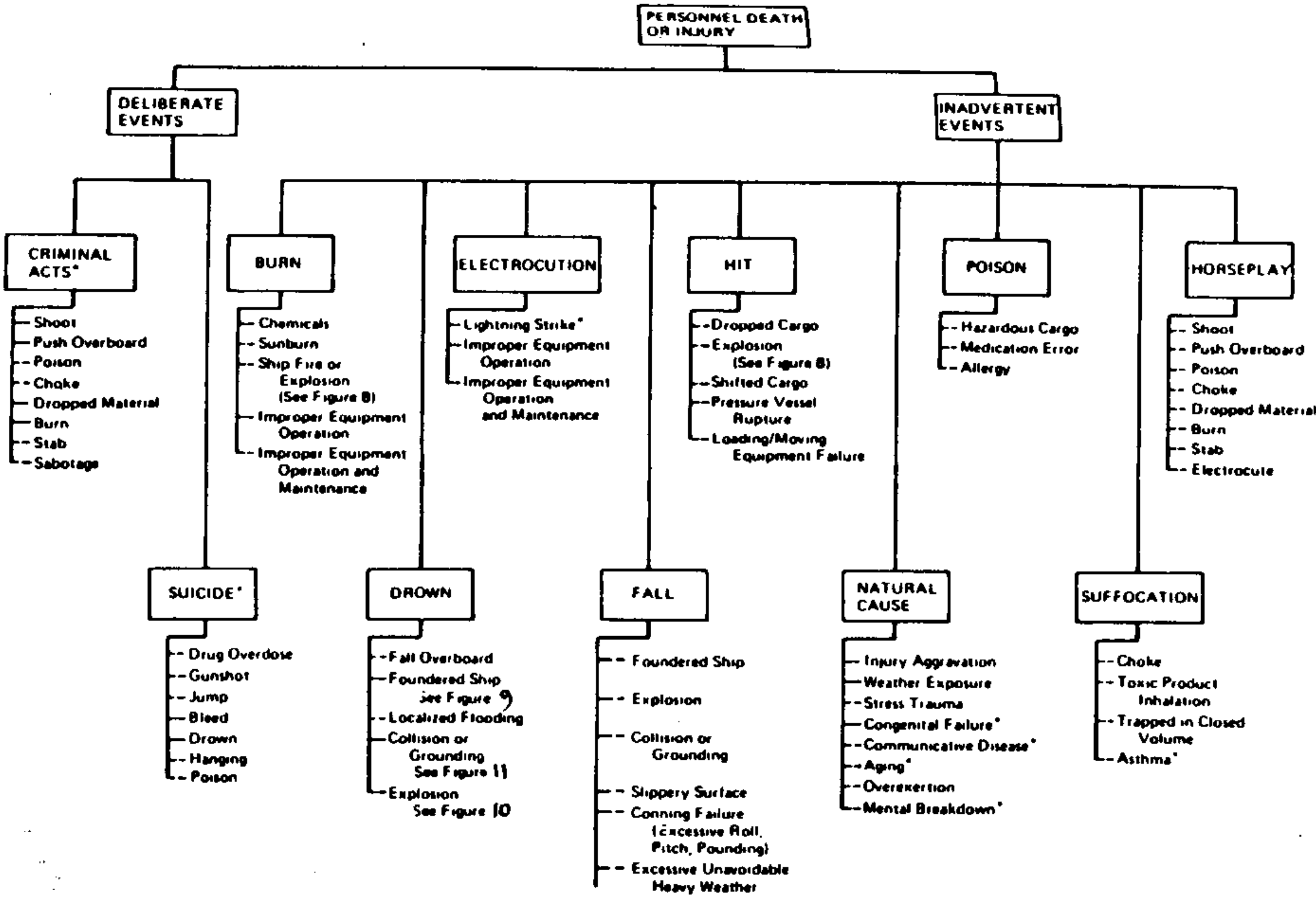


FIGURE 12

CASUALTY FLOW DIAGRAM FOR PERSONNEL DEATH OR INJURY [4]

Further development of the taxonomy and casualty flow diagram could integrate a more detailed human error taxonomy to include organizational factors and detailed fault trees for analysis.

5.2 ORGANIZATIONAL ERROR TAXONOMY FOR PLATFORMS

Bea & Patè-Cornell [1, 23] have suggested an organizational error taxonomy for design, construction, and operations of offshore platforms defining organizational errors as being: (1) individual errors that are "grounded" in the organizational structure, and (2) legitimate and rational decisions by the individual which are in variance with the standards of the organization. This taxonomy of operator errors can be used to relate individual errors with those rooted in the organizational structure. Previous analysis on organizational errors in design, construction and operations of platforms have resulted in quantitative results [1].

Organizational errors can be the result of three major sources: (1) human limitations (e.g. fatigue, seasickness, etc.), (2) lack of communication and transfer of relevant information to decision makers at appropriate management levels, and (3) incentive problems resulting from incompatibility of goals and preferences between various levels of management and specific actors.

Figure 13 shows the taxonomy developed to address organizational errors. The taxonomy distinguishes errors between *gross errors* and *errors in judgement.* Gross errors are those resulting from a lack of knowledge, understanding, and the inability to respond under various circumstance. Gross errors are also errors in which there is little controversy or ambiguity and the individual would take notice of the error if brought to his attention. Errors in judgement are interpretations of available information which may be incomplete or uncertain and decisions are ambiguous in nature.

Gross errors can be further distinguished into communication and cognitive problems and human limitations. Communication errors are those where information is not available to the decision makers at specific levels because the information may not have been gathered or the proper communication channels do not exist between involved parties. In addition, the goals may not be communicated to illicit proper actions.

Cognitive problems can be divided into accidental slips, wrong models, and genuine ignorance. Accidental slips are those errors resulting from such aspects as work overloads, stress and improper job design. An individual in the organization may firmly believe in a wrong model because of errors in interpreting incomplete information. In the third case,

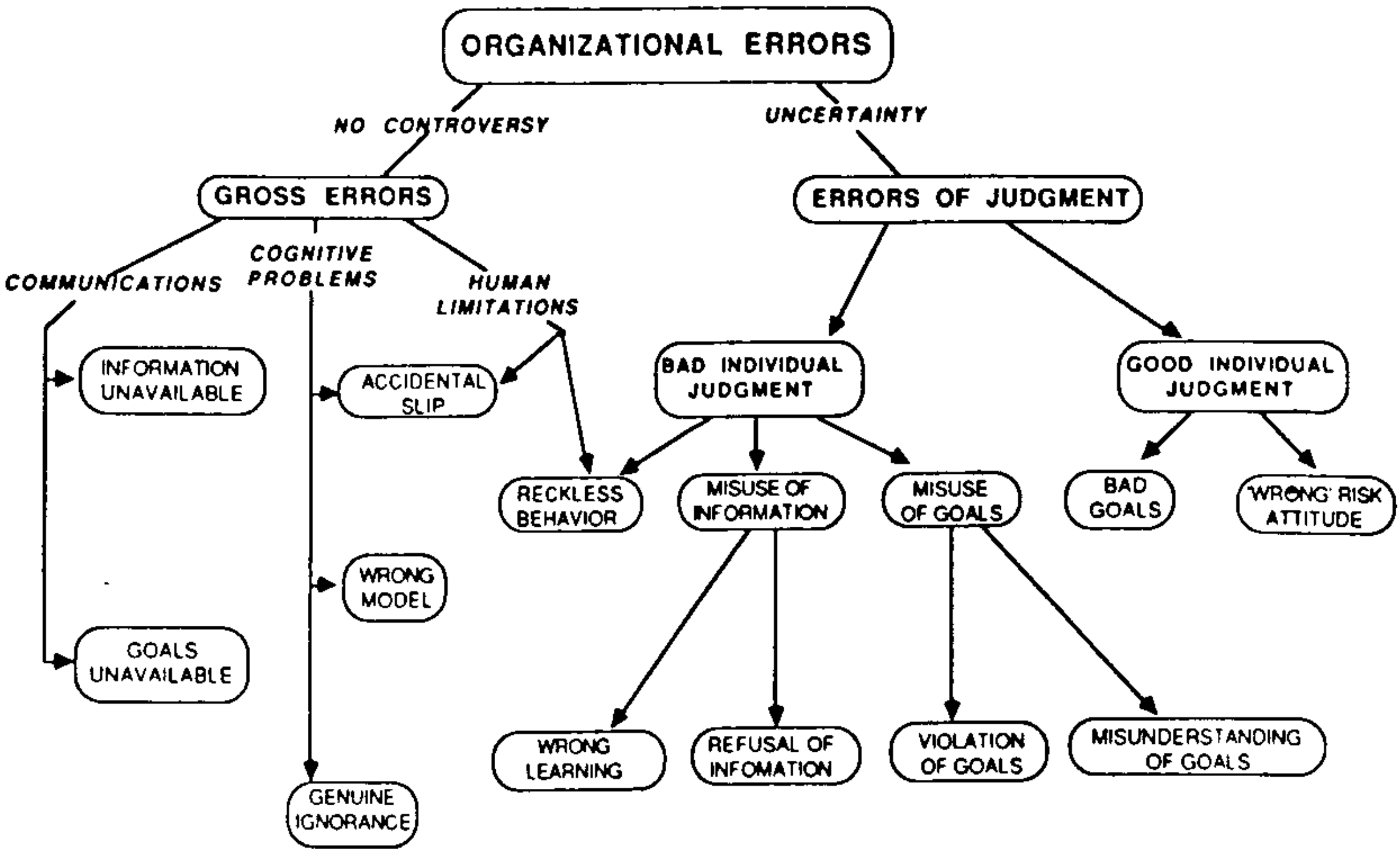


Figure 13: A taxonomy of organizational errors [23]

the individual may be unable or unwilling to acquire additional information and thus is genuinely ignorant to the situation. Human limitations can be the result of either physical or psychological factors which can be the result of inadequate hiring practices or bad individual job design.

Errors of judgement can be distinguished into bad individual judgement and good individual judgement. Bad individual judgement can be in operational behavior, misuse of information and goals of the organization. Errors of judgement may also occur when inadequate procedures and organizational structures lead to rational decisions which are at odds with the overall objectives of the organization.

6. CONCLUSIONS

As described in Figure 1, development of these taxonomies for integration into database systems are an important task to the examination of marine casualties. However, as discussed by Marton & Purtell, there is currently no database which provide comprehensive data needed to identify and correlate human factors in the concerning HOE factors and their role in marine casualties [2]. This is the result of no commonly accepted and comprehensive taxonomy of human factors in marine casualties. Marton & Purtell also conclude that:

1.) There is no comprehensive standardized, validated and commonly accepted taxonomy of human factors to adequately identify human factors involved in the casualty process.

2.) There is no standardized, hierarchally organized, concept or format for identifying human factor casualty data so it can be used to identify and link direct causes of such a casualty to the underlying and contributing factors that shape the behaviors responsible for its initiation. However, as mentioned previously, effort is being placed on assessing a taxonomy to organizational errors to allow the analysis of relations between individual decisions to organizational features [1].

3.) There is no commonly accepted data collection concepts or methodology that assist marine casualty investigators to accurately detect, describe and record the key human error elements associated with the cause of marine casualties.

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Appendix 1: CASMAIN vessel casualties control file

VESSEL file: CAS

Control File positions/lengths

Field	Start Posit	Int Fmt	Int Len	Ext Len	Field Definition
CASE	1	C	10	10	CASE NUMBER OF VESSEL CASUALTY
CASEYR *	8	C	2	2	CALENDAR YEAR CASUALTY OCCURRED
VIN	11	C	8	8	VESSEL DOCUMENTATION NUMBER
VIN1-2	11	U	2	2	FIRST 2 CHARACTERS OF VIN
NUMVSDAM	21	U	3	3	NUMBER OF VSLS DAMAGED IN CASE
CAUSE7	31	C	7	7	SECOND CAUSE NATURE 3, DRUG FACTO
CASDATE	41	U	6	6	DATE VESSEL CASUALTY OCCURRED
CY	41	U	2	2	CALENDAR YEAR OF CASUALTY
MONTH	43	U	2	2	MONTH OF CASUALTY
PERIODAY	51	C	1	1	DAY, NIGHT, ETC.
WEATHER	61	C	2	2	WEATHER
WATER	71	C	6	6	BODY WATER CASUALTY OCCURR/IN
WATER1-2	71	U	2	2	DISTRICT BODY WATER OF CASUALTY
WATER3	73	C	1	1	THIRD CHARACTER OF WATER
WATER4	74	C	1	1	FOURTH CHARACTER OF WATER
WATER5	75	C	1	1	FIFTH CHARACTER OF WATER
LATITUDE	81	C	10	10	LATITUDE
LONGITUD	91	C	10	10	LONGITUDE
REPTYP	101	C	6	6	ROUTINE LETTER XMIT, FORM 2692
TDAM *	111	U	10	10	TOTAL DAM ENTIRE CASUALTY CASE
OFFICE	121	C	3	3	MSO OFFICE INVESTIGATING CASE
MILEPOST	131	C	5	5	RIVER MILEPOST
CAUSE6	141	C	7	7	FIRST CAUSE OF NATURE3
ENTERDBY	151	C	10	10	USCG EMPLOYEE RECORDING CASE
WINDDIR	161	C	3	3	WIND DIRECTION
WIND	171	C	3	3	WIND SPEED
VISIBLTY	181	C	4	4	VISIBILITY
INVVSL	191	U	3	3	NUMBER OF VSLS INVOLVED IN CASE
NATURE1	201	C	6	6	FIRST NATURE OF CASUALTY
NATURE1A	201	C	3	3	FIRST THREE CHARACTERS OF NATURE1
NATURE2	211	C	6	6	SECOND NATURE OF CASUALTY
NATURE2A	211	C	3	3	FIRST THREE CHARACTERS OF NATURE2
NATURE3	221	C	6	6	THIRD NATURE OF CASUALTY
NATURE3A	221	C	3	3	FIRST THREE CHARACTERS OF NATURE3
CAUSE1	231	C	7	7	FIRST CAUSE OF NATURE1
CAUSE1A	231	C	1	1	FIRST CHARACTER OF CAUSE1
CAUSE2	241	C	7	7	SECOND CAUSE OF NATURE1
CAUSE2A	241	C	1	1	FIRST CHARACTER OF CAUSE2

* DO NOT USE THESE FIELDS!!!

con't.

VESSEL file: CAS

Control File positions/lengths

Field	Start Posit	Int Fmt	Int Len	Ext Len	Field Definition
CAUSE3	251	C	7	7	THIRD CAUSE OF NATURE1
CAUSE3A	251	C	1	1	FIRST CHARACTER OF CAUSE3
CAUSE4	261	C	7	7	FIRST CAUSE OF NATURE2
CAUSE5	271	C	7	7	SECOND CAUSE NATURE2
SEACON	281	C	4	10	SEA CONDITIONS
CONFIG	291	C	3	3	TOW CONFIGURATION
VSLNAME	301	C	10	10	FIRST TEN CHARACTERS OF VSLNAME
FLAG	311	C	2	2	FLAG OF VESSEL
YRBUILT	323	U	2	2	YEAR VESSEL BUILT
SERVICE	331	C	4	4	TYPE OF VESSEL: MODU, BARGE
ABC	341	C	1	1	HOW SEAWORTHINESS WAS AFFECTED
USE	351	C	4	4	HOW VESSEL WAS BEING USED
LENGTH	361	U	4	4	LENGTH
GTON	371	U	6	6	GROSS TONNAGE
HULL	381	C	2	2	HULL MATERIAL
PROP	391	C	2	2	TYPE OF VESSEL PROPULSION
HORSEPWR	401	U	6	6	HORSEPOWER
DESIGN	411	C	4	4	HULL DESIGN
VDAM	421	U	10	10	VESSEL DAMAGE
CDAM	431	U	10	10	CARGO DAMAGE
ODAM *	441	U	10	10	OTHER CASE DAM BESIDES V/C DAM
CREWD	451	Z	3	3	CREW DEATH
PASSD	461	Z	3	3	PASSENGER DEATH
OTHERD *	471	Z	3	3	OTHER DEATHS OCCURR/IN CASE
CREWI	481	Z	3	3	CREW INJURY
PASSI	491	Z	3	3	PASSENGER INJURY
OTHERI *	501	Z	3	3	OTHER INJURIES IN CASUALTY
VSLSTATE	511	C	2	2	AFLOAT, AT ANCHOR, ETC.
PIC	521	C	4	4	PERSON IN CHARGE OF VSL MOVEMT
SOCIETY	531	C	3	3	VESSEL SOCIETY CLASSING VESSELS
OPERCO	541	C	10	10	NAME OF COMPANY OPERATING VSL
PILOT	551	C	4	4	VERIFICATION OF LICENSED PILOT
VSLNAMEA	561	C	10	10	SECOND TEN CHARACTERS OFVSLNAME
VSLNAMEB	571	C	10	10	THIRD TEN CHARACTERS OF VSLNAME
VSLNAMEC	581	C	10	10	FOURTH TEN CHARACTERS OFVSLNAME
IND *	591	C	1	1	INSPECTION INDICATOR: Y, N, U
INSPECT *	591	C	10	10	VESSEL INSPECTION VERIFICATION
COIDATE.*	592	C	6	6	INSPECT CERT ISSUE DATE: YYMMDD
IMSO *	598	C	3	3	MSO ISSUING CERTIF of INSPECT

* DO NOT USE THESE FIELDS!!!

Appendix 2: CASMAIN personnel casualties control file

PERSONNEL file: PCAS

Control File positions/lengths

Field	Start Posit	Int Fmt	Int Len	Ext Len	Field Definition
CASE	1	C	10	10	CASE NUMBER OF INJURY/DEATH
CASENAME *	1	C	20	20	COMBINATION OF CASE AND LNAME
LNAME	11	C	10	10	FIRST TEN LETTERS PER LAST NAME
FNAME	21	C	10	10	FIRST TEN LETTERS PER. 1ST NAME
BIRTH	31	U	6	6	BIRTHDATE
STATUS	41	C	02	10	POSITION PERSON HELD ON VESSEL
NATACCID	51	C	10	10	NATURE PERSONNEL ACCIDENT: FALL
NATINJ	61	C	10	10	NATURE OF INJURY/DEATH: BURN
BODPART	71	C	10	10	PART OF BODY INJURIED
RESULT	81	C	4	10	RESULT INJ/DEATH: MISSING-NVC
CAUSE1	91	C	5	10	PRIMARY CAUSE OF INJURY/DEATH
CAUSE2	101	C	5	10	SECONDARY CAUSE OF INJURY/DEATH
OFFICE	111	C	3	3	MSO OFFICE INVESTIGATING
PLOC	121	C	4	10	LOCATION OF PERSON ON VESSEL
ACTIVITY	131	C	2	10	TYPE OF ACTVTY PERSON UNDERTKNG
WATER	141	C	6	10	BODY WATER CASUALTY OCCURR/IN
WATER1-2	141	U	2	2	DISTRICT BODY WATER OF CASUALTY
WATER3	143	C	1	1	THIRD CHARACTER OF WATER
WATER4	144	C	1	1	FOURTH CHARACTER OF WATER
WATER5	145	C	1	1	FIFTH CHARACTER OF WATER
YRBUILT	151	U	4	4	YEAR VESSEL BUILT
CASDATE	161	U	6	6	DATE PERSONNL CASUALTY OCCURRED
CY	161	U	2	2	CALENDAR YEAR OF CASE
INDTIME	171	C	7	10	INDUSTRY TIME OF PERSONNEL
COTIME	181	C	7	10	COMPANY TIME OF PERSONNEL
VSLNAME	191	C	10	10	FIRST TEN CHARACTERS OF VSLNAME
OPERCO	201	C	10	10	NAME OF COMPANY OPERATING VSL
VIN	211	C	10	10	VESSEL DOCUMENTATION NUMBER
VIN1-2	211	U	2	2	FIRST TWO CHARACTERS OF VIN
FLAG	221	C	2	10	FLAG OF VESSEL
SERVICE	231	C	4	10	SERVICE OF VESSEL: MODU, FISH
USE	251	C	4	10	HOW VSL WAS USED: FERRY, CHEM
DESIGN	261	C	4	10	DESIGN OF VSL: BARGE, CONV
LENGTH	271	U	4	4	LENGTH OF VESSEL
GTON	281	U	6	6	GROSS TONS OF VESSEL
DUTYTIME	291	C	3	10	NUMBER HOURS PERSON WAS ON DUTY
LSTNAME	301	C	10	10	SECOND TEN LETTERS VICTIMS NAME
FSTNAME	311	C	10	10	SECOND TEN LETTERS PER.1ST NAME
VSLNAMEA	321	C	10	10	SECOND TEN CHARACTERS VSLNAME
VSLNAMEB	331	C	10	10	THIRD TEN CHARACTERS OF VSLNAME
VSLNAMEC	341	C	10	10	FOURTH TEN CHARACTER OF VSLNAME

* DO NOT USE THIS FIELD!!!

Appendix 3: CASMAIN accident nature control file taxonomy

WIND DIRECTION		CODE	DATA LIMIT
"North	(000.0 Deg)"	"N"	"WIND"
"North northeast	(022.5 Deg)"	"NNE"	"
"Northeast	(045.0 Deg)"	"NE"	"
"East northeast	(067.5 Deg)"	"ENE"	"
"East	(090.5 Deg)"	"E"	"
"East southeast	(112.5 Deg)"	"ESE"	"
"Southeast	(135.0 Deg)"	"SE"	"
"South southeast	(157.5 Deg)"	"SSE"	"
"South	(180.0 Deg)"	"S"	"
"South southwest	(202.5 Deg)"	"SSW"	"
"Southwest	(225.0 Deg)"	'SW"	"
"West southwest	(247.5 Deg)"	"WSW"	"
"West	(270.0 Deg)"	"W"	"
"West northwest	(292.5 Deg)"	"WNW"	"
"Northwest	(315.0 Deg)"	"NW"	"
"North northwest	(337.5 Deg)"	"NNW"	"
"Variable"		"VAR"	"

THE NATURE OF CASUALTY - Screen 1

"Allision (collisions involving stationary vessels)	"ALLIS"	"NATURE1+"
"Barge Breakaway"	"BRGBWY"	"
"Capsizing"	"CAPSIZ"	"
"Collision, Meeting"	"COLMTG"	"
"Collision, Crossing"	"COLCRS"	"
"Collision, Overtaking"	"COLOTK"	"
"Collision, Special circumstance"	"COLSPC"	"
"Collision, w/ice"	"COLICE"	"
"Collision, w/aid to navigation"	"COLATN"	"
"Collision, Submerged object"	"COLSUO"	"
"Collision, Floating object"	"COLFLO"	"
"Collision, Bridge"	"COLBDG"	"
"Collision, Pier/Dock"	"COLDOC"	"
"Collision, Offshore drlng unit"	"COLMOD"	"
"Collision, Fixed object NOC"	"COLFNC"	"
"Collision, NEC"	"COLNEC"	"
"Collision, Unknown"	"COLUNK"	"
"Collision, w/dike, lock or dam"	"COLLDM"	"
"Disappearance, w/trace"	"GONETR"	"
"Disappearance, wo/trace"	"GONENT"	"
"Explosion, Cargo - no fire"	"EXPCGN"	"

SCREEN 2	CODE	DATA LIMIT
"Explosion, Mach space - no fire"	"EXPMSN"	"NATURE1+"
"Explosion, Pressure vel-no fire"	"EXPPVN"	"
"Explosion, Pumproom-no fire	"EXPPRN"	"
"Explosion, Boiler-no fire"	"EXPBNF"	"
"Explosion, Fuel-no fire"	"EXPFUN"	"
"Explosion, Cargo-fire"	"EXPCGF"	"
"Explosion, Mach space-fire"	"EXPMSF"	"
"Explosion, Pressure val-fire"	"EXPPVF"	"
"Explosion, Pumproom-fire"	"EXPPRF"	"
"Explosion, Boiler-fire"	"EXPBOF"	"
"Explosion, Fuel-fire"	"EXPFUF"	"
"Explosion, NEC"	"EXPNEC"	"
"Explosion, Unknown"	"EXPUNK"	"
"Fire, Vessel furnishing"	"FIRFUR"	"
"Fire, Vessel cargo, freight"	"FIRCFT"	"
"Fire, Machinery space"	"FIRMCS"	"
"Fire, Pumproom"	"FIRPMR"	"
"Fire, Vessel structure"	"FIRSTR"	"
"Fire, Vessel fuel"	"FIRVFU"	"
"Fire, Electrical"	"FIRELC"	"

SCREEN 3		
"Fire, Vessel cargo, fuel"	"FIRCFU"	"NATURE1+"
"Fire, Vessel cargo, HAZMAT"	"FIRCHZ"	"
"Fire, NEC"	"FIRNEC"	"
"Grounding, accidental"	"GRNDGA"	"
"Grounding, Intl w/damage-hazard"	"GRNDGI"	"
"Matl Failure, main eng/motor"	"MATMEN"	"
"Matl Failure, boiler"	"MATBOL"	"
"Matl Failure, main steam sys"	"MATMSS"	"
"Matl Failure, aux steam sys"	"MATASS"	"
"Matl Failure, feed and condens sys"	"MATFCS"	"
"Matl Failure, cooling water sys"	"MATCWS"	"
"Matl Failure, fuel oil supply"	"MATFOS"	"
"Matl Failure, lube oil supply"	"MATLOS"	"
"Matl Failure, main generator"	"MATMGN"	"
"Matl Failure, aux generator"	"MATAGN"	"
"Matl Failure, elec control systems"	"MATECS"	"
"Matl Failure, elec dis sys"	"MATEDS"	"
"Matl Failure, hyd contl sys"	"MATHCS"	"
"Matl Failure, phuem contl sys"	"MATPCS"	"
"Foundering, sinking"	"FNDRNG"	"
"Flooding, w/out sinking"	"FLDING"	"

SCREEN 4

	CODE	DATA LIMIT
"Matl Failure-Bilge Sys"	"MATBLG"	"NATURE1+"
"Matl Failure-Reduction Gear"	"MATRED"	"
"Matl Failure-Shaft System"	"MATSFT"	"
"Matl Failure-Propeller"	"MATPRO"	"
"Matl Failure-Cargo Hndlng-Tnkr"	"MATCGT"	"
"Matl Failure-Cargo Hndlng-Frt"	"MATCGF"	"
"Matl Failure-Salt Water Sys"	"MATSWS"	"
"Matl Failure-Venting System"	"MATVNT"	"
"Matl Failure-Inert Gas System"	"MATIGS"	"
"Matl Failure-Crude Oil Wshng Sys"	"MATCOW"	"
"Matl Failure-Navigation Eqpt"	"MATNAV"	"
"Matl Failure-Ground Tackle"	"MATGTK"	"
"Matl Failure-Lifesaving Eqpt"	"MATLSG"	"
"Matl Failure-Firefighting Eqpt"	"MATFFG"	"
"Matl Failure-Pers Protect Eqpt"	"MATPPE"	"
"Matl Failure-Hull, Structural"	"MATHST"	"
"Matl Failure-Hull, Deterioration"	"MATHDT"	"
"Matl Failure-NEC"	"MATNEC"	"
"Steering Sys Fail, Contl Sys"	"SSFCSS"	"
"Steering Sys Fail, Rdr and Shaft"	"SSFRAS"	"

SREEEN 5

"Steering sys fail, aux pwr sply"	"SSFAPS"	"NATURE1+"
"Steering sys fail, NEC"	"SSFNEC"	"
"Cargo, loss or damage"	"CARGLD"	"
"Disabled"	"DISABL"	"
"Wake Damage"	"WAK"	"
"Swamping"	"SWAMP"	"
"Weather Damage"	"WTHRDM"	"
"Well Blowout"	"WELBLO"	"

Appendix 4: CASMAIN accident cause control file taxonomy

"Unknown"	"UNKNOWN"	"CAUSE1+"
"P Bypassed avail safety devices"	"PBPSASD"	"
"P Inattention to duty"	"PINAAT"	"
"P Intoxication (Alcohol/Drugs)"	"PDRUNK"	"
"P Calculated risk"	"PCALRSK"	"
"P Carelessness"	"PCRLSNS"	"
"P Error in Judgment"	"PERRJDG"	"
"P Lack of Knowledge"	"PLCKKNO"	"
"P Lack of Training"	"PLCKTNG"	"
"P Lack of Experience"	"PLCKEXP"	"
"P Operator Error"	"POPERER"	"
"P Fatigue"	"PTIRED"	"
"P Smoking"	"PSMOKD"	"
"P Open Flame"	"POPNFL"	"
"P Stress"	"PSTRESS"	"
"P Physical Impairment"	"PPHYSIM"	"
"P Psychological Impairment"	"PPSYCHO"	"
"P Failed comple w/rule,reg,pro"	"PFALRUL"	"
"P Inadequate Supervision"	"PINADSP"	"
"P Improper Casualty Control pro"	"PIMPCCP"	"

SCREEN 2

"P Improper safety precautions"	"PIMPSFP"	"CAUSE1+"
"P Failed to acct for crnt/wx"	"PFALACW"	"
"P Failed to acct for tide/riv sg"	"PFALATR"	"
"P Failed to ascertain position"	"PFALPOS"	"
"P Failed to use avail nac equip"	"PFALANE"	"
"P Failed to use charts and pubs"	"PFALCAP"	"
"P Failed to use radiotelephone"	"PFALRTE"	"
"P Relied on floating ATON"	"PRELFAN"	"
"P Failed to yield right of way"	"PFALTY"	"
"P Failed to est passing agreement"	"PFALEPA"	"
"P Failed to keep to right of chnl"	"PFALKRC"	"
"P Failed to proceed at safe speed"	"PFALSPD"	"
"P Failed to stop"	"PFALSTP"	"
"P Failed to keep proper lookout"	"PFALKPL"	"
"P Improper/faulty lights/shapes"	"PIMPFLT"	"
"P Improper/missing whistle signals"	"PIMPMWS"	"
"P Improper maintenance"	"PIMPMNT"	"
"P Used defective equipment"	"PDEFEQT"	"
"P Design creteria exceeded"	"PDSGCEX"	"
"P Service conditions exceeded"	"PSVCCEX"	"

SCREEN 5	CODE	DATA LIMIT
"E Debris"	"EDEBRIS"	"CAUSE1+"
"E Suction bank/bottom/vsl"	"ESUCBBV"	"
"E Ice"	"EICE"	"
"E Lightning"	"ELITNIN"	"
"E Shoaling"	"ESHOAL"	"
"E Submerged object"	"ESUBOBJ"	"
"E Channel not maintained"	"ECHNMNT"	"
"E Uncontrollable channel hazard"	"EUNCCHZ"	"
"E Unmarked channel hazard"	"EUNMCHZ"	"
"E Hzrdus bridge/dock/pier lctn"	"EHZBDPL"	"
"E Hzrdus bridge/dock/pier config"	"EHZBDPC"	"
"E Inadequate bridge/dock/pier ID"	"EINBDPI"	"
"E Inadequate equip available"	"EINADEA"	"
"E Inadequate reg, rule, proc, plcy"	"EINADGP"	"
"E Inadequate manning"	"EINADMN"	"
"E Inadequate WX info available"	"EINADWI"	"
"M Faulty design"	"MFLTDSG"	"
"M Sys maint functions improper"	"MSYSMNT"	"
"M Improper AID location"	"MIMADLO"	"
"M Inadequate AID display/type"	"MINAIDD"	"

SCREEN 6

"M Inadequate AID maintenance"	"MINAIDM"	"CAUSE1+"
"M Inadequate statutory/reg rqmnts"	"MINREGS"	"
"M Inadequate owner/op safety prog"	"MINSAFT"	"
"Not elsewhere classified"	"NEC"	"
"Result of previous nature"	"PREVNAT"	"
"Vandalism"	"NVANDAL"	"

SEA CONDITIONS

"Calm .... 0-1' "	"CALM"	"SEACON"
"Choppy .... 1-3' "	"CHOP"	"
"Moderate ...... 4-12' "	"MOD"	"
"Heavy .... 12-20' "	"HVY"	"
"Very Heavy ... 20-40' "	"VHVY"	"
"Precipitous .. GT-40' "	"PREC"	"
"Strong current"	"SCRT"	"
"Freshet/Flooding"	"FRFL"	"
"Flood tide"	"FLTD"	"
"Ebb tide"	"EBBT"	"
"Ice"	"ICE"	"
"Not specified"	"NA"	"
"Unknown"	"UNK"	"