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INFORMATION MANAGEMENT SYSTEM DEVELOPMENT FOR THE INVESTIGATION, REPORTING, AND ANALYSIS OF HUMAN ERROR IN NAVAL AVIATION MAINTENANCE.

by

Douglas B. Nelson

September 2001

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The purpose of this research is to evaluate and refine a safety information management system that will facilitate data collection, organization, query, analysis and reporting of maintenance errors that contribute to Naval Aviation mishaps, equipment damage and personnel injury using OPNAV 3750.6R, Human Factors Analysis and Classification System Maintenance Extension taxonomy. The target audience for this information management system tool included safety personnel, mishap investigators, Aircraft Mishap Board (AMB) members, and analysts. A review of three areas was needed to refine the prototype tool: (1) the collection, use and management of accident information, (2) human error theories as related to aviation mishaps and (3) the design of an effective mishap database tool. A usability study was conducted using potential end-users. Fifteen Naval Aviation Safety Officers and Naval Aviators were given written procedures to navigate through the prototype and an exit survey. The survey responses, including objective and subjective responses about the prototype were gathered. The results indicate, that with proper training, the prototype could provide insight into maintenance errors, which could be used to target hazards and develop intervention strategies to prevent future mishaps.

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INFORMATION MANAGEMENT SYSTEM DEVELOPMENT FOR THE INVESTIGATION, REPORTING AND ANALYSIS OF HUMAN ERROR IN NAVAL AVIATION MAINTENANCE

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LIST OF ACRONYMS

AGM	Aircraft-Ground Mishap
AIMD	Aircraft Intermediate Maintenance Department
AMB	Aircraft Mishap Board
ASO	Aviation Safety Officer
CSA	Command Safety Assessment
DOD	Department of Defense
DON	Department of the Navy
FAA	Federal Aviation Administration
FM	Flight Mishap
FOQA	Flight Operational Quality Assurance
FRM	Flight-Related Mishap
FY	Fiscal Year
GPWS	Ground Proximity Warning System
GUI	Graphical User Interface
HCI	Human-Computer Interface
HFACS	Human Factors Analysis and Classification System
HFACS--ME	Human Factors Analysis and Classification System-Maintenance Extension
IFSD	In-flight Shutdown
LAN	Local Area Network
MDA	Maintenance Mishap Data Analysis
ME	Maintenance Extension (see HFACS--ME)
MEDA	Maintenance Error Decision Aid
MEIMS	Maintenance Extension Information Management System
MRM	Maintenance-Related Mishap
NADEP	Naval Aviation Depot
NSC	Naval Safety Center
NPS	Naval Postgraduate School
NTSB	National Transportation Safety Board
OB	Organizational Benchmarking
ORM	Operational Risk Management
HFQMB	Human Factors Quality Management Board
RAM	Random Access Memory
SHEL	Software, Hardware, Environment, and Liveware
SIMS	Safety Information Management System
TACAIR	Tactical Aviation
USN	United States Navy

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DEDICATION

I would like to dedicate this thesis to my wife Liz and Son Caleb. I have always received their love, encouragement and support, this being no exception. I am eternally grateful, for without them I would not have achieved nearly as much.

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I. INTRODUCTION

A. OVERVIEW

From Fiscal Year (FY) 1951 to 1999 Naval Aviation has had great success in substantially reducing its Class A Flight Mishap (FM) rate (see Figure 1). Even with this accomplishment, the proportion of mishaps attributed to human error has remained relatively constant at 80 percent (Nutwell & Sherman, 1997). In 1996, a Navy F-14 Tomcat crashed shortly after taking off from Nashville, Tennessee killing both aircrew and three civilians on the ground. Because the cause of this mishap was exclusively human error, Department of the Navy (DON) leaders chartered a Human Factors Quality Management Board (HFQMB) to reduce mishaps by identifying systemic improvements to enhance performance and systems that guard against error. The HFQMB's goal was to reduce human error in the Naval Aviation Class A FMs rate by 50 percent at the start of FY 2000 and to further reduce it by another 50 percent by FY 2006 (HFQMB, 1997).

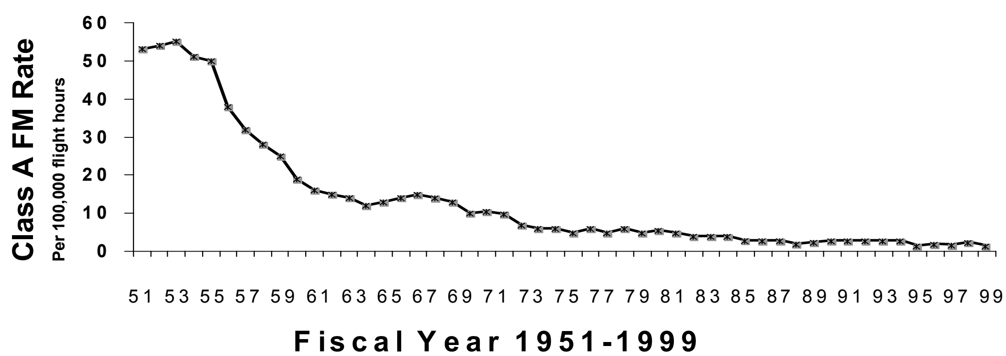

Figure 1. Naval Aviation Class A FM Rates for FY 1951-1999 (From NSC, 2000)

The HFQMB adopted a three-prong approach to tackle human error. The first thrust was to conduct an extensive mishap data analyses focused on human factors. The Naval Safety Center (NSC) developed the Human Factors Analysis and Classification System (HFACS) to capture aircrew errors in Naval Aviation mishaps. This taxonomy identifies areas for potential intervention by fully describing factors that are precursors to accidents. HFACS identifies both active failures and latent conditions within four categories: (1) unsafe acts, (2) pre-conditions for unsafe acts, (3) unsafe supervision, and (4) organizational influences (DON, 2001). NSC adopted HFACS for analyzing aircrew error in Naval Aviation mishaps and targeting appropriate areas (DON, 2001).

Naval Aviation achieved its lowest Class A FM rate in FY 1999 partly due to the efforts of the HFQMB. Even with this reduction, the HFQMB failed to achieve the desired 50 percent reduction in human error (NSC, 2001). A study noted that HFACS could be extended to cover maintenance errors; hence, HFACS was adapted to classify maintenance errors (Schmidt, Schmorrow, & Hardee, 1997).

The maintenance extension (ME) of HFACS contains four human error categories: (1) Management Conditions, (2) Working Conditions, (3) Maintainer Conditions, and (4) Maintainer Acts. A review of 470 Naval Aviation Mishaps by Schmorrow (1998) determined the HFACS--ME taxonomy was an effective classification for determining trends in maintenance mishaps. Building on Schmorrow's research, Fry (2000) developed Maintenance Error Information Management System (MEIMS) for the analysis of maintenance related mishaps. MEIMS lead to a refinement of HFACS--ME, and made the data more comprehensive and accessible.

Fry's rudimentary MEIMS was further refined by Wood (2000) and developed into a working prototype for fleet test and evaluation. A usability study of the MEIMS prototype determined it could not only be effective system in determining trends, but also providing information for mishap prevention efforts. Wood's study identified a need to incorporate HFACS--ME definitions, improve the user interface, simplify data entry procedures, and provide example mishap scenarios. The MEIMS tool was further refined by McCracken (2000), and training incorporated a user tutorial. His study revealed that participants in the tutorial group performed better using MEIMS than the non-tutorial group. Recommendations from McCracken's study include better main menu navigation, improved data error checking, and making and the tutorial available over the Internet.

This thesis is part of ongoing effort to study the feasibility and utility of MEIMS as a tool for investigating, collecting, and analyzing maintenance mishaps and maintenance error. By further refining MEIMS, it is contended that the end user will be able to easily access valuable safety information, which can be used in training, hazard identification and trend analysis to prevent possible future mishaps.

B. PURPOSE

The intent of this study is to refine, expand, and revaluate the MEIMS tool to facilitate the collection, organization, query, analysis, and reporting of maintainer errors that contribute to Naval Aviation maintenance mishaps. The goal is to provide an effective tool to promote the use of HFACS--ME as part of the revised Naval Aviation Safety Program Instruction (OPNAVINST 3750.6R).

C. PROBLEM STATEMENT

In order to continue to reduce the annual mishap rate, Naval Aviation leadership is expanding the focus of their safety initiatives to encompass maintenance errors. The systematic analysis of maintenance mishaps offers an increased opportunity to reduce the mishap rate, save lives and assets, as well as increase fleet readiness. The HFACS--ME as it is incorporated into MEIMS provides a well-designed information management system to effectively identify maintenance error patterns and trends. The current prototype MEIMS is a valuable tool; however, it needs to be refined and enhanced to capitalize on current technologies and to include mishap investigation. This thesis examines the following questions:

1. How can MEIMS be used to facilitate preliminary mishap investigation?
2. How will investigators use this tool?
3. What processes are needed to capture maintenance error under OPNAVINST 3750.6R?
4. What enhancements are needed to make MEIMS more user interactive/friendly?
5. Could this tool be Web-based, making it more easily/widely accessible?

An effective information management system will give the fleet users the ability to quickly access standardized error data relating to aviation maintenance mishaps. Providing an easy-to-access error database will ensure standardization, as well as increase the validity and reliability of the data. Ready access to error data will allow maintainers and safety personnel to quickly identify potential hazards, analyze trends, and ultimately train personnel to avoid future occurrences, thus reducing aircraft mishaps. This reduction in mishaps can save lives, aircraft, and equipment.

D. SCOPE AND LIMITATIONS

Fleet personnel, primarily consisting Aviation Safety Officers, were tasked to evaluate the prototype MEIMS tool. The prototype is intended to be refined for use by Naval Aviation squadrons, but may have some crossover use by other Military Services, government organizations, and the private sector. This study only focuses on maintenance mishaps caused by human error. Material failure, maintenance hazards, and personnel injuries not reaching the threshold of a mishap were not used within this study.

E. DEFINITIONS

This study uses the following abbreviations, terms, and associated definitions:

Aircraft Mishap Board (AMB). Group of officers appointed to investigate and report on an aviation mishap (DON, 2001).

Aviation Safety Officer (ASO). Principal advisor to Naval Aviation squadron commanding officers on all aviation safety matters (DON, 2001).

F-14 Tomcat. US Navy aircraft. Two aircrew, two engines, swing-wing, supersonic fighter with air-to-air, air-to-ground, and reconnaissance capability (Rowe & Morrison, 1973).

Human Factors Analysis and Classification System (HFACS). System designed to help analyze Naval Aviation mishaps focusing on aircrew error (Shappell & Wiegmann, 1997).

Human Factors Analysis and Classification System--Maintenance Extension (HFACS--ME). HFACS adaptation to classify causal factors that contribute to maintenance mishaps (Schmidt, 1996).

Human Factors Quality Management Board (HFQMB). Established by Naval Aviation senior leadership to reduce human error involvement in Naval Aviation Class A flight mishaps (HFQMB, 1997).

Maintenance Error Information Management System (MEIMS). Prototype error management tool examined in this thesis (Wood, 2000).

Mishap. A Naval mishap is an unplanned event or series of events directly involving Naval aircraft, which result in $20,000 or greater cumulative damage to naval aircraft, other aircraft, property, or personnel injury (DON, 2001).

Mishap Categories. Naval aircraft mishap categories are defined below (DON, 2001):

Flight Mishap (FM). Those mishaps resulting in $20,000 or greater DOD aircraft damage or loss of a DOD aircraft, and intent for flight for DOD aircraft existed at the time of the mishap. Other property damage, injury, or death may or may not have occurred.

Flight Related Mishap (FRM). Those mishaps resulting in less than $20,000 DOD aircraft damage, and intent for flight (for DOD aircraft) existed at the time of the mishap, and $20,000 or more total damage or a defined injury or death occurred.

Aircraft Ground Mishap (AGM). Those mishaps in which no intent for flight existed at the time of the mishap and DOD aircraft loss, or $20,000 or more aircraft damage, and/or property damage, or a defined injury or death occurred.

Mishap Rate. Number of aviation mishaps per 100,000 flight hours (DON, 2001).

Mishap Severity Class. Mishap severity classes are based on personnel injury and property damage (DON, 2001):

Class A. A mishap in which the total cost of property damage (including all aircraft damage) is $1,000,000 or greater; or a naval aircraft is destroyed or missing; or any fatality or permanent total disability occurs with direct involvement of naval aircraft.

Class B. A mishap in which the total cost of property damage (including all aircraft damage) is $200,000 or more, but less than $1,000,000 and/or a permanent partial disability, and/or the hospitalization of five or more personnel.

Class C. A mishap in which the total cost of property damage (including all aircraft damage) is $20,000 or more but less then $200,000 and/or injury results in five or more lost workdays.

Naval Aircraft. Refers to US Navy, US Naval Reserve, US Marine Corps, and US Marine Corps Reserve aircraft.

The Naval Aviation Safety Program (OPNAVINST 3750.6R). US Navy instruction outlining Naval Aviation's safety program. (DON, 2001).

Operational Risk Management (ORM). A decision making tool to increase effectiveness (and hence decrease accidents) by anticipating hazards, reducing the potential for loss due to these hazards, and thus increasing the probability of a successful mission (DON 1997).

NATOPS General Flight and Operating Instructions (OPNAVINST 3710). US Navy instruction outlining Naval Air Training and Operating Standardization program to improve combat readiness and achieving a substantial reduction in aircraft mishaps (DON 1997).

F. CHAPTER ORGANIZATION

Chapter II contains a literature review on the development of a prototype database tool to identify human error involvement and patterns in aviation maintenance mishaps. The methods used in this study are discussed in Chapter III. The results of this study are presented in Chapter IV. Lastly, Chapter V contains the study's findings, conclusions, and recommendations.

II. LITERATURE REVIEW

A. OVERVIEW

The literature studied encompasses human error, maintenance error in aviation, and error classification and analysis. It includes work from textbooks, research articles, and master theses pertaining to: (1) management of accident information, (2) human error theories and their relation to maintenance related aviation mishaps, and (3) design and usability of a mishap database tool. This information provides the foundation for the ongoing expansion and refinement of a prototype maintenance error analysis and reporting mishap database tool. While numerous efforts are ongoing to reduce the number of Class A FMs in Naval Aviation, there is potential for further improvement, in particular the area of maintenance error.

B. ACCIDENT INFORMATION

1. Investigation

Grimaldi & Simonds (1984) detailed a four-part process for accident investigations. First the investigator must explore the history, including activities occurring both during and prior to the event. Second, the investigator must collect as many facts relating to the incident as possible, from reliable witnesses, videotapes, maintenance and training records. Next, the physical environment associated with the accident must be studied. Finally, common causal factors can be used to determine probable causal factors of the mishap. This process parallels aspects of that provided by Diehl (1991) in his model of aviation accident investigation.

Diehl's (1991) three-stage model of accident investigation and prevention focuses on human performance and systems safety considerations (see Figure 2). The Accident Generation stage involves hazard identification. The mere existence of hazards has the potential to lead to an incident, or worse, an accident. A study of thousands of accidents by Heinrich (1941) determined that for every major accident, there are approximately 30 minor accidents, and 300 hazardous incidents. This relationship among hazards, incidents, and accidents also applies to aviation safety (Diehl, 1991)

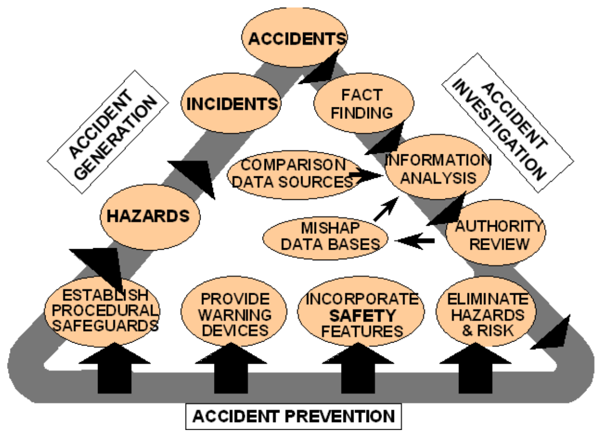

Figure 2. Accident Generation, Investigation, and Prevention Elements (From Diehl, 1989)

The Accident Investigation stage includes the collection, analysis, and review of accident data. Mishaps rarely result from a single, sudden event, but rather they are tied to a series of events degrading equipment and crew performance until an accident is inevitable (Nance, 1986). Aircraft accident investigation procedures require investigators to determine *what happened*, and subsequently *what caused* the mishap. The analysis is captured in a final report containing accepted findings, root causes, and prevention recommendations. This phase is subjective in nature, but is based on examining comparative data, on aircraft performance, and on human capabilities/limitations.

The Accident Prevention stage details the methods used to avoid future accidents. There are four categories of accident-prevention measures: (1) eliminating hazards and risks, (2) incorporating safety features (3) providing warning devices, and (4) establishing procedural safeguards. As one travels from right to left along the bottom leg of Diehl's triangle (see Figure 2), the measures become less expensive, less effective, and less restrictive (Diehl, 1991).

2. Reporting

Accident reports generally centered on number of episodes and observations per unit of time (Brown, 1990). Frequencies and rates, however, do not provide a sound basis for understanding accidents. The traditional reporting format does not normally capture human factors information (Adams, Barlow, & Hiddlestone, 1981). Ensuring collection, classification, and data recording methods are accurate and reliable will significantly assist in the determination of causes and prevention of future mishaps and overall increase the usability of the mishap report.

Three elements critical to ensuring accurate and reliable mishap reports are (Chapanis, 1996): (1) properly trained investigators, (2) good accident reporting forms, and (3) a centralized facility for dealing with reports. Analyzing typical reporting systems data is accomplished through the following process (Wood, 2000):

- collecting data on past accidents within a population;
- dividing the sample into groups with and without accidents;
- obtaining measurements of individual characteristics on all participants;
- statistically comparing the two groups; and
- identifying any significant difference between the two groups, associating the differential characteristic with accidents.

These methods result in a more complete and thorough analysis effort.

3. Data Management

In order for data to be useful in the prevention of accidents, it must be collected and properly cataloged and stored for future inquires (National Safety News, 1975). Coding the data and the use of databases to store the information have become universally accepted methods. In 1975 the National Safety Council established a method where numerical codes are assigned to the different classifications in the mishap (National Safety News, 1975). This aggregation of mishap data permits trend identification and factor concentration to focus on specific causal factors. Obtaining data alone will not prevent future mishaps; the conditions contributing to the incident must be corrected. Further, it can be argued that not only should accidents be analyzed, but "near-miss" situations should be addresses, as well (Pimbel & O'Toole, 1982). Recognition of near-misses identify potential conditions or practices that are accident-producing types and prevent their future occurrence.

Setting up a computer analysis program can reduce man-hours involved in reviewing mishap histories (Kuhlman, 1977). Computer analysis tools can significantly aid reviews of mishap histories (Grimaldi & Simonds, 1984). To be a truly effective system in reducing future accidents and incidents, the tools must be well organized and tabulate the data logically. The user interface to the data must be presented sensibly and in a easy to understand user-friendly format.

4. Accident Prevention

Accident prevention began in the first part of the 20th century when employers realized that it was less expensive to prevent accidents than to pay for their consequences (Petersen, 1978). Initially accident prevention was based on a notion that people committing unsafe acts, not their working environment, were to blame for most accidents (Heinrich, 1959). This accepted wisdom fostered a preoccupation with assigning blame to people; a practice, which hindered the development of systematic accident prevention well into the latter half of this century (Manuele, 1981). Focusing on people and not on the environment in which they operate tended to obscure a subset of associated causal factors. This is especially true with systems that persistently expose individuals to hazards (Schmidt, 1996). The practice of blaming the individual and not the environment still exists even with advances in accident prevention over the past decades. In order to prevent future accidents, they must be analyzed in terms of the environment in which they occur and not point all the blame to the individual.

Organizations confronted with the challenge of how best to protect themselves and their employees from accidents have two options: (1) insurance, and (2) accident prevention programs (Pate-Cornell, 1996). Organizations typically employ both options (Kanis & Weegels, 1990). The most effective accident prevention strategies employ systems engineering (Hawkins, 1993). Developed in the 1950s the system engineering approach was a part of the United States military's large-scale weapons programs. It transforms operational needs into a description of system parameters and integrates them to optimize overall system effectiveness (Edwards, 1988). Systems engineering focuses the level of analysis on the smallest identifiable system components and how they interact (Bird, 1980). The strategy of focusing on the system through the development of well-defined system components exposes information that would have remained unknown without a system-level evaluation (Miller, 1988). System engineering not only breaks down the system, but also pays attention to the strengths and limitations of the human operator as an integral part of the system (Heinrich, Peterson, & Roos, 1980).

Numerous reviews suggest that 80 to 90 percent of accidents are attributable to human error (NSC, 2001). Therefore, to totally understand way a system failed, human factors associated with the accident must be evaluated.

C. HUMAN ERROR

Analyzing and correcting for human error in aviation can greatly increase safety. There are numerous theoretical approaches to examine mishaps involving human error (Goetsch, 1996). Some of these approaches have their roots in industrial safety, while others are viewed from a more complex systems perspective, with an emphasis on human factors and the operator. Three well recognized approaches are outlined in Table 1.

Table 1. Theoretical Approaches to Defining Accident Processes (From Schmidt, 1998)

Source	Model	Approach
Industrial Safety	Heinrich's Domino Theory	Linear
Systems Safety	Edwards' SHEL Model	Interface
Human Factors	Reason's Swiss Cheese Model	Vertical

1. Heinrich's "Domino" Theory

Heinrich's Domino Theory views accidents as a linear sequence of related factors (see Figure 3) or chain of events that lead to an actual mishap (Bird, 1980). This theory is built upon two central precepts: (1) injuries are caused by the action of preceding factors, and (2) removal of the central factors negates the actions of the preceding factors, and in doing so, prevents accidents and injuries (Goetsch, 1996). Domino Theory encompasses a five-step sequence (Heinreich, Petersen & Roos, 1980):

1. Lack of Control: This is a management issue where the emphasis is placed on the control exercised in a situation for an array of factors.
2. Basic Cause(s): This identifies the origin(s) of the causes and includes aspects such as human factors, environmental factors, or job-related factors.
3. Immediate Cause(s): This includes substandard practices and conditions that

are symptoms of the basic causes.

4. Incident: This typically involves contact with the hazard, and for example, results in a fall or impact with moving objects.
5. Person Injury and Property Damage: This includes lacerations, fractures, death and material damage.

Much like falling dominos, each step causes the next to occur. If factors from any of the first three dominos are removed, the chain of events will be broken and the accident will be prevented.

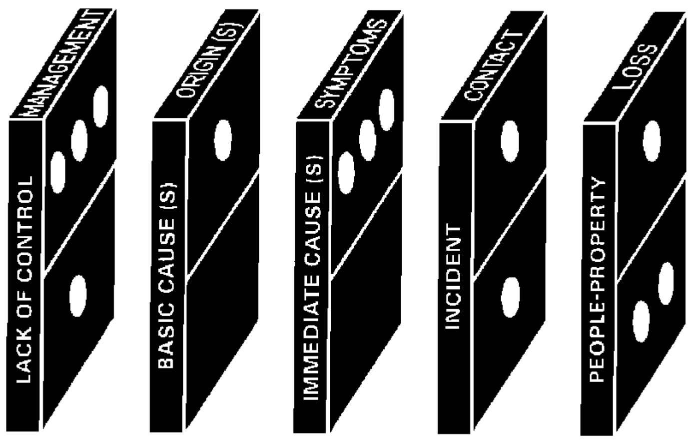

Figure 3. Domino Theory Model (From Bird, 1980)

2. Edwards' SHEL Model

Developed in the early 1970s, the SHEL Model provides an effective means to evaluate human-machine systems failures (Edwards, 1988). The model describes systems, problem areas, and provides a framework for accident investigation. Furthermore, the model identifies human-machine systems failures and classifies them into four dimensions: (1) Software, (2) Hardware, (3) Environment conditions, and (4) Liveware.

- Software: Typically a collection of documents including rules, regulations, laws, orders, standard operating procedures, customs, practices, and habits that govern how a system operates and information is organized
- Hardware: Buildings, vehicles, equipment and materials of which the system is comprised and the operator works with/in.
- Environmental conditions: Weather, lighting, space, etc.

- Liveware: People involved directly with/in and tied to the system.

The SHEL model (Edwards, 1988) is composed of these four basic components and the interface between them (see Figure 4). Failures may occur in the system when one component or the connections between them fail. Mishaps are rarely associated with only one component or interface; they are in fact caused by the interaction of many factors (Shappell & Wiegmann, 1997). This is affirmed in the Naval Aviation system program, that is based on necessitarianism -- mishaps are the inevitable result of their antecedent causes which preceded them (DON, 2001).

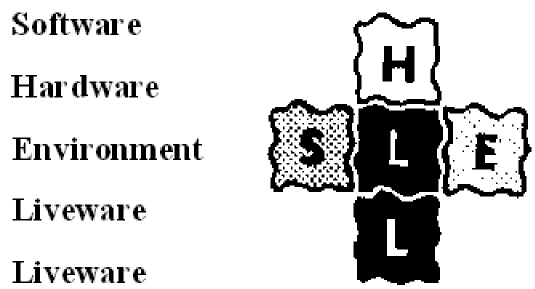

Figure 4. SHEL Model of System Design (From Hawkins, 1993)

3. Reason's "Swiss Cheese" Model

Reason's (1990), Swiss Cheese Model is an internationally accepted perspective on accident causation. It employs a human factors approach to view the vertical association of a collection of factors that eventually lead to an accident. The Swiss Cheese Model distinguishes errors into two types: 1) active failures -- the effects felt immediately, and 2) latent conditions, where effects may lie dormant until triggered by other mitigating factors. Put simply, latent conditions set "the stage" for an accident while active failures are the final catalyst when a mishap occurs. Defenses or safeguards in a system can prevent latent conditions from taking effect, thus reducing the probability for an active failure to occur. The model can be seen as a row of Swiss cheese slices, each vertical slice representing a defense layer, and each hole representing a failed or missing defense. At times the holes may be enlarged and can be aligned leading to a mishap (see Figure 5).

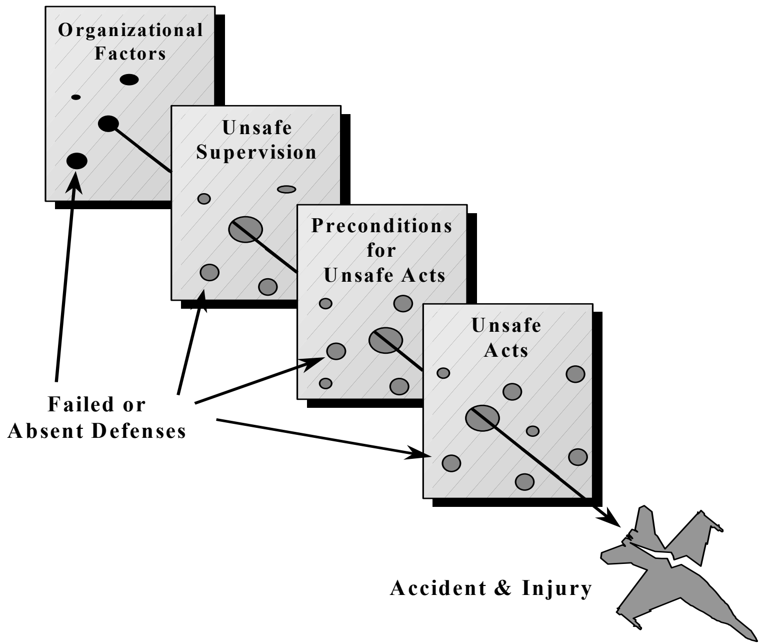

Figure 5. Swiss Cheese Model (From Reason, 1990)

4. Human Factors Analysis & Classification System (HFACS)

In order to capture human errors in Naval Aviation mishaps, NSC staff developed the HFACS taxonomy (DON, 2001). The goal of this taxonomy is to identify areas for potential intervention by fully describing factors that are precursors to accidents. HFACS evolved from the expansion of Reason's Swiss Cheese Model and incorporated features of Heinrich's Domino Theory and Edwards' SHEL Model (Shappel & Wiegmann, 1997).

The resulting HFACS taxonomy focuses on aircrew errors and identifies both active failures and latent conditions within four categories: 1) Unsafe Acts, 2) Pre-conditions for Unsafe Acts, 3) Unsafe Supervision, and 4) Organizational Influences (DON, 2001). NSC has adopted the HFACS Model for analyzing human error in Naval Aviation mishaps and uses it as a targeting tool for appropriate prevention.

5. HFACS –Maintenance Extension (HFACS--ME)

Although very useful, the HFACS taxonomy only focused on aircrew errors. Schmidt, Schmorrow, and Hardee, (1997) noted that this taxonomy could be extended to include maintenance errors; hence, they developed HFACS--ME to classify maintenance mishaps causal factors. This new classification system captures maintenance human factors by facilitating the recognition of absent or defective defenses at four levels: (1) Unsafe Management Conditions, (2) Unsafe Maintainer Conditions, (3) Unsafe

Working Conditions and (4) Unsafe Maintainer Acts (see Figure 6). This taxonomy visibly addresses Marx's (1998) legitimate concern that human error has been under served by traditional maintenance error analysis systems. Effectively employed, HFACS--ME is used to identify maintenance errors and their causes and target intervention strategies to avoid possible future mishaps.

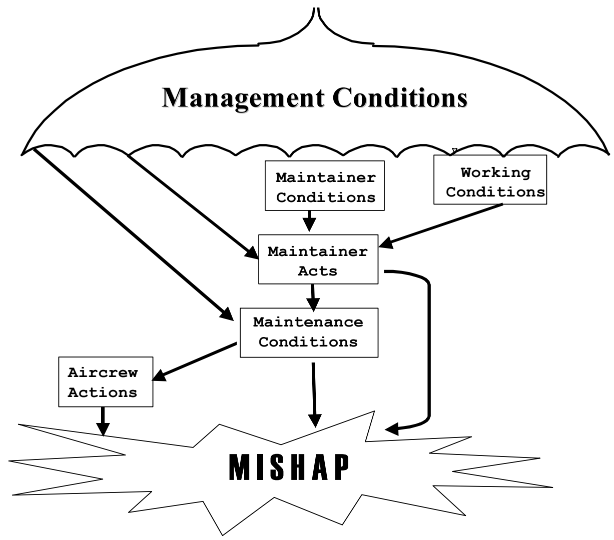

Figure 6. HFACS--ME Model (From DON, 2001)

Management, Maintainer, and Working Conditions are latent conditions that can impact the performance of a maintainer (Schmidt, Schmorrow, & Hardee, 1997). These latent conditions may contribute to an Unsafe Maintaner Act, an active failure, and directly lead to a Maintenacne incident, personal injury, or an unsafe maintenance condition. Unsafe Maintainer Acts are active failures, which directly or indirectly lead to a latent condition that the aircrew will have to deal with during flight. Maintenance conditions have the potential to become a latent condition, which will manifest into an active failure in flight that the aircrew will then have to address. Maintainer working conditions, as compared to those of the aircrew, will often play a more significant role in errors observed during maintenance evolutions (DON, 2001). The three orders of maintenance error: (1) first, (2) second, and (3) third order, reflect a decomposition of the error type from a macro to a micro perspective (see Table 2).

Table 2. HFACS--ME Categories (From DON, 2001)

First Order	Second Order	Third Order
Management Conditions	Organizational	Inadequate Processes Inadequate Documentation Inadequate Design Inadequate Resources
	Supervisory	Inadequate Supervision Inappropriate Operations Uncorrected Problem Supervisory Misconduct
Maintainer Conditions	Medical	Adverse Mental State Adverse Physical State Unsafe Limitation
	Crew Coordination	Inadequate Communication Inadequate Assertiveness Inadequate Adaptability/Flexibility
	Readiness	Inadequate Training/Preparation Inadequate Certification/Qualification Personnel Readiness Infringement
Working Conditions	Environment	Inadequate Lighting/Light Unsafe Weather/Exposure Unsafe Environmental Hazards
	Equipment	Damaged/Unserviced Unavailable/Inappropriate Dated/Uncertified
	Workspace	Confining Obstructed Inaccessible
Maintainer Acts	Error	Attention/Memory Knowledge/Rule Skill/Technique Judgment/Decision
	Violation	Routine Infraction Exceptional Flagrant

Management Conditions, either organizational or supervisory, may contribute to an active failure due to unforeseen events or lack of proper leadership. Maintainer Conditions that can contribute to an active failure include: (1) medical, (2) crew coordination, and (3) readiness factors by the maintainer. Working Conditions that can contribute to an active failure include: (1) environment, (2) equipment, and (3) the workspace the maintainer operates. (DON, 2001)

6. Maintenance Error Information Management System (MEIMS)

Using the HFACS--ME taxonomy as a framework, a MEIMS prototype database tool was developed (Fry, 2000). MEIMS is intended for fleet users to collect, catalog, collate, and analyze human error in Naval Aviation maintenance mishaps. Wood (2000) after refining MEIMS, conducted a usability study and demonstrated the tool was effective, yet lacking in some areas. Specifically, MEIMS was hard to navigate, required HFACS--ME familiarity/training, and had poor data entry configuration. Woods (2000) concluded that for MEIMS to reach its full potential, it needed design refinements and more usability testing.

McCracken (2000) further refined MEIMS by developing a user tutorial. He administered the tutorial to half of his test subjects. The tutorial group found MEIMS to be of more interest than the non-tutorial group. Both groups, those given the tutorial and those without, advocated MEIMS relevance to maintenance operations and strongly endorsed it, but they also pointed out additional potential problem areas, to include: (1) improve the graphical user interface, (2) include the tutorial as part of MEIMS, (3) develop normal graph presentations, (4) bring the database up to date, and (5) make MEIMS (and the tutorial) available on the World Wide Web. It was concluded that once available online, and with the proper training, MEIMS should be a useful tool in the effort to preserve lives, material and readiness (McCracken, 2000).

D. TOOL DESIGN CONSIDERATIONS

1. System Design

The usability of any software product can be linked directly to its user interface (Wickens, Gordon & Liu, 1997). An easy to understand and manageable user interface will have postive usability evaluations. Cleary, the user interface is the most important factor in determining the success or failure of a software application (Wickens, Gordon & Liu, 1997). To maximize the usability of an interface, Shneiderman (1997) proposed eight golden rules of graphical user interface design: (1) strive for consistency, (2) enable frequent users to use shortcuts, (3) offer informative feedback, (4) design dialogs to yield closure, (5) offer error prevention and simple error handling, (6) permit easy reversal of actions, (7) support internal locus of control, and (8) reduced short-term memory load. Designing an effective interface will increase the usability of any program.

Consistency is the rule most frequently broken when designing a user interface. In similar situations the same action sequence should be required. These consistencies include; identical terminology, menus, and help screens as well as layout, color, capitalization and fonts. Fast display rates and short response time are attractions for *frequent users*. To increase the pace of interaction, shortcuts should be provided; this can be accomplished with abbreviations, special keys, hidden commands and macros. For every action, weather minor or major, there should be varying degrees *of information feedback* to the user. This allows the user to fully understand their current status. Every event should have a beginning, middle and end. *Information feedback* at the completion of an event will give the user closure, a sense of accomplishment that the action was complete. (Shneiderman, 1997)

A system should be designed such that a user cannot make a serious error. In *handling error* the system should detect the error and provide simple and specific instruction for recovery. To relieve user anxiety and encourage exploration the system should permit *reversible actions*. Designing an internal *locus of control* allows the user to feel in charge of the system and that the system respond to their actions. This is accomplished by making the user the initiator of action rather than the responder to actions. Lastly, to *reduce short-term memory,* system displays need to be kept simple, multiple page displays to be consolidated, training time allotted for new programs and integrated assistance information. (Shneiderman, 1997)

2. Usability Study

According to Nielson (1998) the usefulness of a system is determined by two components: (1) the utility, and (2) usability. Utility is a measure of relevancy; if the system is irrelevant to the user it will be a poor system regardless of its design. Usability is a measure of how effective the user can navigate the system. Usability is the measure of the quality of the user experience when interacting with a system, such as a Web site, software application, or any user operated device. Nielson further breaks usability into five characteristics: (1) ease of learning; how fast can a new user sufficiently learn the program, (2) efficiency of use; once the system is learned, how fast the user can complete tasks, (3) memorability; how effective can previous users accomplish tasks without relearning the system, (4) error frequency and severity; how many errors occurred and how were they recovered, and lastly (5) subjective satisfaction; the users approval with the system. All systems have all five of the usability characteristics and all need to be considered in any design project. (Nielson 1998)

Frokjaer, Haertzum and Hornbaek (2000) adopted the International Standardization Organization definition for usability, which consists of three distinct aspects. First is effectiveness, which is the accuracy and completeness with which users achieve certain goals. Indicators of effectiveness include quality of solution and error rates. Second is efficiency, which is the relation between the accuracy and completeness with which users achieve certain goals and the resources expanded in achieving them. Measures include task completion time and learning time. Third is satisfaction, which is the user's comfort with and positive attitudes toward the use of the system. A successful software tool will be effective, efficient as well as satisfying to the users (Frokjaer, Haertzum & Hornbaek, 2000).

Usability testing can ensure all contractual requirements have been completed, help maximize the usability of the system, and provide evidence of testing in cases where legal issues may arise. Dependant on the need to bring the system to full production, varying degrees of system errors will be tolerated during testing. However, as the number of system inputs increase, the testing becomes more difficult yet these tests are increasingly needed. (Shneiderman, 1997)

Informal demonstrations to colleagues or customers can provide useful feedback, but formal reviews by experts have proven to supply more effective feedback (Nielsen & Mack, 1994). Thus, system design and test should include expert reviewers who usually can offer comprehensive report on system problems and make recommendations. Expert reviews can be heuristic evaluations, guidelines reviews, consistency inspections, cognitive walkthroughs, or formal usability inspections (see Table 3). Expert reviews can be scheduled at project milestones in the development, when experts are available, or when the project team is ready.

Table 3: Expert Review Methods (From Shneiderman, 1997)

Expert-Review Method	Description
Heuristic evaluation	Expert reviewers critique an interface to determine conformance with a short list of design heuristics such as the eight golden rules.
Guideline review	The interface is checked for conformance with the organizational or other guidelines document.
Consistency inspection	Experts verify consistency across a family of interfaces, terminology, color, layout, input/output formats, within the interfaces, in the training materials and online help.
Cognitive-walkthrough	Experts simulate users walking through the interface to carry out typical tasks. Simulating the day in the life of the user should be part of the evaluation.
Formal usability inspection	Experts hold courtroom-style meeting, with a moderator to judge, to present the interface and to discuss its merits and weaknesses.

When planning to conduct a usability study an important consideration is the length of the study (Dumas & Redish, 1994). If the study is integrated with the design process, then the length can be reduced to a manageable level so as to not impose a burden on the expert and still provide useful feedback. Formal testing, with comprehensive test reports requires eight to twelve weeks, if a strong collaboration is exhibited among team members and a shortened report format is used, then four to six weeks are required. If a particular part of the system is to be studied with well-established procedures, then one week may be appropriate. Although discouraged, just-in-time testing can provide useful information in a few days, if necessary. The length of the study is also a critical part of the usability study and can impact results.

3. Computer-Human Interaction Design Issues

Human Factors Engineering existed long before computers were developed and examines the relationship between humans and all types of machines (Carey, 1991). With the advent of computer systems, Human Factors in Information Systems (HFIS) became an area of interest. According to Carey (1991) several disciplines contribute to and overlap with HFIS: (1) Computer Science, (2) Management Information Systems, (3) Human Factors Engineering, and (4) Computer-Human Interaction. Each of these areas of study has a focus, which overlap with HFIS. Carey (1991) uses a VENN diagram to illustrate the differences and similarities between the disciplines and the nature of HFIS, (see Figure 7). A circle represents each of the four disciplines; the intersection of the circles represents HFIS. The portion of each circle that overlaps with HFIS indicates how closely each area is related to HFIS.

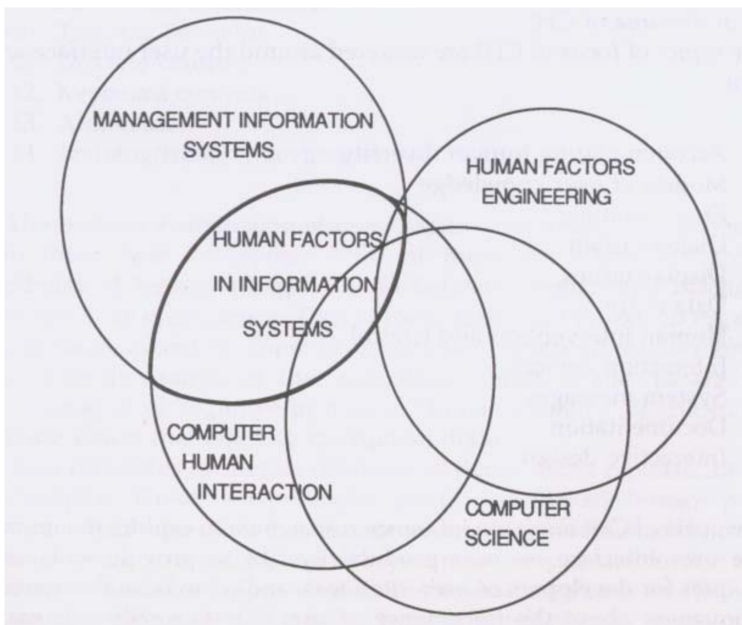

Figure 7. Disciplines Contributing Knowledge to Human Factors in Information Systems (From Carey, 1991).

The following statements reflect the goals and purposes of each of the disciplines: (1) Computer Science is about optimizing computer efficiency, (2) Management Information Systems is about maximizing organizational effectiveness through information, (3) Human Factors Engineering is about increasing system performance by reducing human error, (4) Computer-Human Interaction is about increasing user effectiveness by enhancing the user interface, and finally (5) HFIS is about increasing user effectiveness within an organization by enhancing the user interface and other human-to-computer contact such as training and user involvement in development (Carey, 1991).

Brown (1989) states that a useful design philosophy for developing user-oriented human-computer interfaces is to consider the computer as a tool to aid the user in accomplishing tasks. A tool, which requires more time, training and effort to use than the task requires without the tool, is a poorly designed system. Brown recommends an eight-step strategy for developing an effective computer-human interface: (1) establish the human-computer interface role in system development, (2) know the users, (3) define the tasks, (4) incorporate design guidelines, (5) train software designers in computer-human interface design, (6) develop user interface software tools, (7) prototype and user testing, and lastly (8) designing by interactive refinement. "The most important thing to know regarding your user is that he is not interested in using your product. He is interested in doing his work, and your product must help him do it more easily" (Heckel, 1994). A well-designed computer interface will aid users in completing assigned tasks.

In *establishing the computer-human interface role* in systems development, management support, participation as team members, and appreciation for design tradeoffs are critical to the success of the design. Users must be directly involved in the design process from its infancy, *knowing the users* are critical to successful system design. Design must be based on an understanding of the *tasks* the users will perform with the system, and the environment in which it will be used. User interface *guidelines* must be developed, documented, revised, maintained and customized to the context and constraints of the project. Systems analysts, programmers, and other developers often need to be *trained* to the concepts and philosophy of computer-human interface design. Interface *software tools* can enhance the consistency in the interface and provide an environment where interactive design is simple. It also benefits in program modularity, data independence, and development time and cost. *Testing* early in the development cycle can reveal flaws in concepts or assumptions about what users need and want. Design features and concepts must be tested on people from the population of users for which the system is targeted. Finally, as ongoing tests reveal needed changes and refinements the design must be *updated*. Early testing of the design will prove to keep updating costs low. The problems discovered in a test cycle must be resolved in a revised design. Then to assure the flaws are corrected, the revised design must be tested. (Brown, 1989)

E. SUMMARY

Over the last half century, Naval Aviation has made significant strides in reducing the mishap rate. This reduction can be attributed to standardized reporting and investigation system, the use of systems engineering, the application of human error causation theory on mishap cause factors. Mishap data is currently being collected, cataloged and stored for future reference. This data is useless in preventing future fatalities unless a well-defined, systematic accident investigation, analysis, and reporting process is developed and tested. No single universal system currently exits (Marx, 1998). Current technology exists that make organization of data relatively simple for the program and the user. For Naval Aviation to further increase its safety record, a robust system for analyzing stored data for trend analysis and prevention is needed.

HFACS was developed to provide a more useful data analysis system. With its success, HFACS was expanded to cover maintenance error, and HFACS--ME was developed. Both have proven to be effective in capturing the nature of, and relationship among, latent conditions and active failure. MEIMS was developed as a tool to capture maintenance error trends in aviation maintenance using the HFACS--ME taxonomy. In limited usability studies, MEIMS proved to have great potential to increase safety awareness. However, to fully reach its potential, MEIMS must be proven to be a user-friendly system that users embrace. In order to achieve this goal, MEIMS is undergoing further systems development and more rigorous usability testing. With proper advances, MEIMS has the potential to analyze data, find trends, save taxpayers money, and ultimately save lives.

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III. METHODOLOGY

A. MEIMS APPLICATION DEVELOPMENT

The original version of MEIMS was programmed in Microsoft Access 97 using Visual Basic for Applications (VBA). This prototype had very little documentation. The FAA required that it be upgraded to Access 2000. Because of the lack compatibility between Access 97 and Access 2000 a completely new version of MEIMS had to be developed.

Flanders and Tufts, two Computer Science graduate students at the Naval Postgraduate School, developed a revised version of MEIMS prototype for their research using Access 2000. The authors' contribution to the new MEIMS application was requirements generation, functional assessment, and program development support. The author also developed a decision support investigation module based on the HFACS--ME taxonomy. The investigation module assists the user in determining mishap causal factors and builds a preliminary investigation report. A detailed description of the MEIMS application prototype can be found in Flanders and Tufts (2001) - *Software Re-engineering of the Human Factors Analysis and Classification System – (Maintenance Extension) Using Object Oriented Methods in a Microsoft Environment.*

B. RESEARCH APPROACH

The MEIMS prototype tool was circulated to a representative sample of prospective end-users. Participants were provided a prepared task list that required them to enter fictitious mishap data information, as well as navigate through and utilize features of the tool. The participants navigated through the entire system and completed an exit survey. The exit survey instrument included demographic background information, as well as quantitative and qualitative survey items designed to elicit users' views and ideas. The resulting data was inserted into a Microsoft Excel spreadsheet for analysis. Content analysis was conducted on the qualitative survey questions.

C. DATA COLLECTION

1. Participants

Fifteen students attending either the Naval Postgraduate School (NPS), or the Aviation Safety Office (ASO) course, within the School of Aviation Safety at NPS, severed as participants in the research. The NPS is comprised of officers from the Army, Navy, Air Force, Marine Corps, and Coast Guard, as well as several foreign Services. Student demographics represent a wide cross section of Naval Aviators, Naval Flight Officers, DOD officers, Flight Surgeons, Aeromedical Safety Officers, and foreign nationals from a variety aircraft communities and platforms. ASO course graduates are responsible for implementing and managing squadron safety programs and mishap investigation and reporting. NPS graduates, who are designated aircrew, typically return to aviation units in department head positions and play an integral role in safety initiatives.

2. Apparatus

Participants were introduced to the HFACS--ME taxonomy and the MEIMS prototype mishap database tool through the use of a multimedia demonstration. Participants had access to three computer laboratories at the School of Aviation Safety via login ID and password to a group account. Each computer system in the labs is a Pentium I, with a Windows 2000 operating system, and 15-inch monitor of 800 x 600 resolution (or better). All systems had a fully functioning MEIMS prototype mishap database tool loaded onto the hard drive. After gaining access to the computer, the "MEIMS Tool" icon was selected to open the MEIMS prototype (see Appendix A).

3. Instrument

The author constructed a participant usability survey consisting of three parts: (1) Participant demographics, (2) Likert-type quantitative assessment statements , and (3) Open ended qualitative items. Demographic information was collected by participants selecting from a list of descriptors (rank, branch of Service, number of years in Service, and total flight hours). Survey questions were designed to determine if the prototype tool meets user investigation, reporting, and analysis requirements. Likert-type statements used a five-point rating scale: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree, to capture the participant's opinions. The open ended questions were constructed to elicit the subjects overall impression of the prototype software tool, recommendations for improvement, and an area for additional comments not adequately covered by the first two portions.

4. Procedure

The MEIMS application containing a database derived from compiled NSC maintenance mishaps was loaded on computer systems in the labs with 24-hour accessibility. There was a MEIMS icon on each computer desktop to allow easy access to the application. Before logging on, participants were given a training tutorial and instruction manual for MEIMS.

Testing was conducted over a one week period. All participants were given a group orientation on the purpose, goals, and procedures for the prototype including a computer demonstration, and materials necessary to carry out the user test. These materials included:

- Instructions for accessing the Prototype tool – information to log on and open the prototype (See Appendix B).
- MEIMS Evaluation – A series of planned navigation routes for every area of the prototype. (See Appendix B).
- MEIMS Exit Survey – Participants completed an exit survey composed of demographic background questions, impressions of MEIMS and the investigation module and open ended questions requesting participant's opinions (See Appendix C).

All participants performed the following actions: (1) accessed the prototype tool, (2) navigated the system using the prototype task list, and (3) provided feedback on the system by completing the exit survey. The anonymously completed exit surveys were all submitted through a drop box provided in a common area.

D. DATA TABULATION

The collected data were transcribed from the survey into a Microsoft Excel 2000 spreadsheet. The Likert-type statements, based on a five-point scale, are coded into the software using number 1 through 5 to correspond respectively with (1) Strongly Agree, (2) Agree, (3) Neutral, (4) Disagree, and (5) Strongly Disagree.

E. DATA ANALYSIS

Descriptive statistics were generated using functions within Excel to include: (1) mean, (2) standard deviation, (3) range, and (4) frequency distribution of the collected data. Content analysis was conducted on the responses provided from the open-ended survey questions. The data were used to assess the viability of the MEIMS prototype.

IV. RESULTS

A. TEST SAMPLE

A usability test was administered to 15 students at the Naval Postgraduate School. All participants were designated Naval Aviators or Naval Flight Officers and represented a cross section of the aviation commands that make up the squadrons in the Navy and Marine Corps. No foreign Service students participated in the survey. Each participant was given a MEIMS tool evaluation package with 10 tasks to complete and a brief tutorial on HFACS--ME. After completing the tasks, participants were asked to complete an exit survey. The survey consisted of demographic information and queries regarding their satisfaction with MEIMS.

B. TEST TASKS

The tasks were designed to introduce the participants to MEIMS and exercise some of its capabilities. The tasks required the participant to access all functional areas of MEIMS. Test performance is summarized in Table 4.

Table 4: Test Task Performance

TASK	n	NUMBER CORRECT	PERCENTAGE
1 - Access Program	15	15	100%
2 - Main Menu Opinion	15	11	73%
3 - Aircraft Query	15	15	100%
4 - ID Factors	15	15	100%
5 – Access Information	15	14	93%
6 – Access Information	15	13	87%
7 – Access Information	15	14	93%
8 – Graph Information	15	15	93%
9 – ID Mishap	15	15	100%
10 – Investigation Opinion	15	13	87%

The first task was accessing the program; all participants (n=15; 100%) were able to access MEIMS without difficulty. The second task requested the participants' opinion of the main menu (See Figure A1, Appendix A). The majority of participants (n= 11; 73%) responded that the menu was easy to understand. Other participants noted that the average computer user might not understand "query". Tool tips would help in understanding what each function does, and one participant commented that he thought there would be a number of graphs under the graph menu. One participant did not answer this question. The third and forth tasks required the participant to query a type of aircraft, from the multiple criteria menu (See Figure A3, Appendix A), and then determine how many mishaps exist in the database for that type aircraft and how many factors existed for the first mishap. All participants (n=15; 100%) were able to correctly accomplish these tasks. The fifth, sixth and seventh tasks required the user to draw mishap information from the HFACS--ME Summary Form (See Figure A5, Appendix A) regarding the total number of mishaps and factors within the database. Fourteen (93%) were able to correctly identify the answers for the fifth and seventh tasks. On the sixth task thirteen (86%) were able to correctly identify the answer. One participant had the right answers down for his specific aircraft, but not the total number of mishaps in the database. The eighth task required the user to properly graph (See Figures A6 & A7, Appendix A) the mishap types versus the organization and determine how many aviation ground mishaps the U.S. Navy has had by clicking on a portion of the graph. All participants (n=15; 100%) correctly identified the value. Several participants commented on the difficulty of having to click on just the right spot on the graph and that some sort of roll over value would greatly enhance this function. The ninth task required users to open up a specific report from the report menu (See Figure A8, Appendix A) and identify the number of total number of Class B mishaps. All participants (n=15; 100%) were able to correctly identify the value. The last task requested the participants' opinions of the investigation portion (See Figures A10 to A20, Appendix A) and whether it helped them identifying the causal factors associated with the mishap scenario. Thirteen participants (87%) felt that the section helped them in identifying the causal factors. Two participants (13%) did not answer the question.

C. DEMOGRAPHIC INFORMATION

The data collected in part one of the exit survey consisted of demographic information concerning participant's computer and aviation experience levels. This information was used to determine if the participants' level of experience effected their satisfaction with the MEIMS prototype database tool. Demographic information is summarized in Table 5.

Table 5. Demographic Information

Demographic	n	Number of Participants	Percent
Squadron level maintenance	15	15	100%
2 + years computer experience	15	15	100%
Use Microsoft Office	15	15	100%
Use word processing programs	15	15	100%
Use word spreadsheet programs	15	15	100%
Use presentations programs	15	15	100%
Use graphic related software	15	10	66%
Use E-Mail	15	15	100%
Use Database programs	15	10	66%
Use Windows (3.1-2000)	15	15	100%
Use Windows NT	15	11	73%
Use Macintosh	15	1	6%
Use Linux	15	2	14%
Use Unix	15	3	20%

Question one determined that all participants had been or are members of aviation units that performed squadron level maintenance (n=15; 100%). Question two indicated that all participants had at least two years of experience using a computer (n=15; 100%). Question three determined that all participants (n = 15; 100%) were users of Microsoft

Office. Question four established a participant's familiarity with different software applications; all participants (n=15; 100%) were familiar with processing, spreadsheet, presentation, and e-mail. A third (n=10; 66%) of the participants were familiar with both graphic and database applications. Question five revealed what operating system the participates are familiar with working with. All participants (n = 15; 100%) are familiar with Window 3.1, 95, 98, or 2000 while several (n=11; 73%) were familiar with Windows NT, one (6%) worked with Macintosh and few (n=3; 20%) and (n=2; 14%) were familiar with Unix and Linux respectively.

D. PARTICIPANT SATISFACTION WITH MEIMS TOOL

1. Responses to Impressions of MEIMS

The information gathered in Part II of the exit survey requested the participants' impressions of the MEIMS tool and its value to Naval Aviation. Participants responded to five statements using Likert type responses selecting from one of five responses: (1) strongly agree, (2) agree, (3) neutral, (4) disagree, and (5) strongly disagree. Values of five through one respectively were assigned to the statements. Additionally, participants could make subjective comments on any of the statements.

Statement one asked whether or not a participant found MEIMS to be presented in a logical form. Almost all of the participants either strongly agreed (n=7; 47%) or agreed (n=7; 47%) that the MEIMS prototype was in a logical form while only one (6%) was neutral on whether it was logical. Figure 8 depicts the results for "being in a logical form".

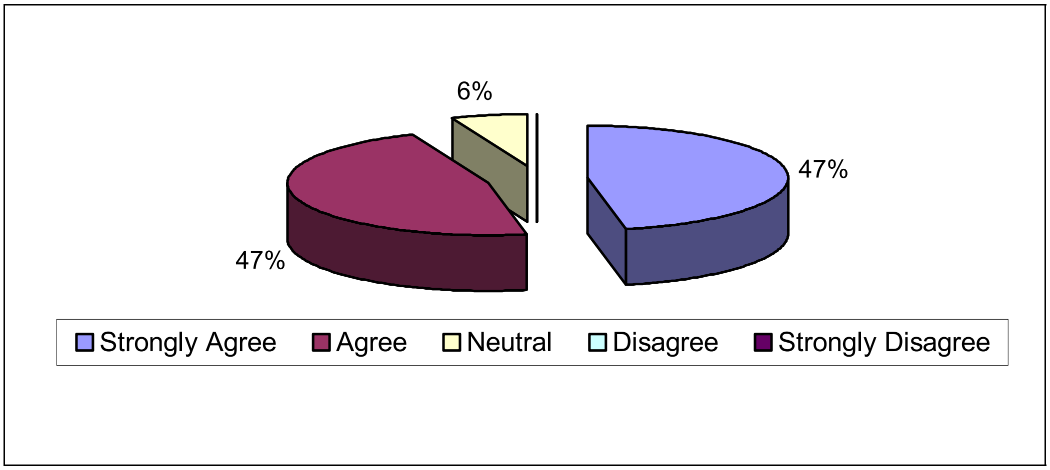

Figure 8. MEIMS is "In a Logical Form"

Statement two asked about the ease of navigation of the prototype. Almost all of the participants strongly agreed (n=8, 54%) or agreed (n=6, 40%) that the MEIMS prototype tool was easy to navigate. Only one (6%) was neutral on the ease of navigation. The results for easy navigation are depicted in Figure 9.

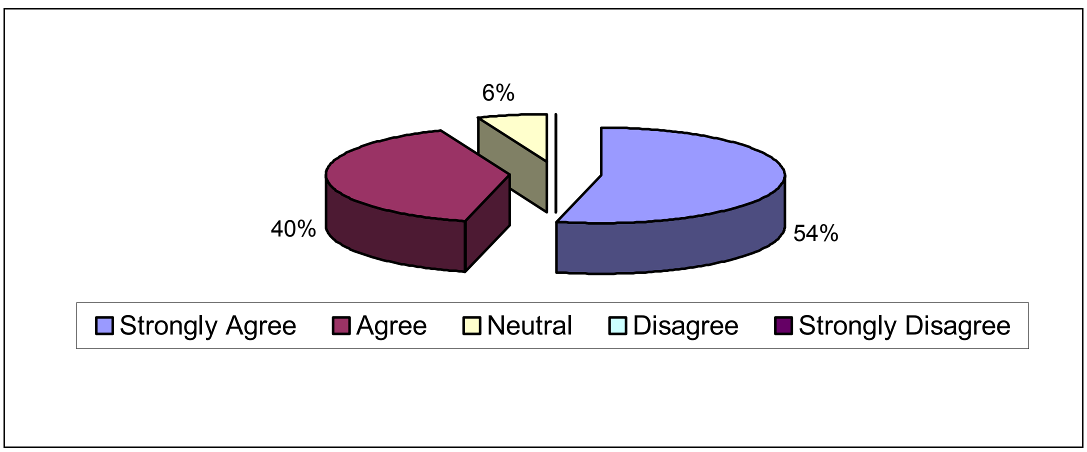

Figure 9. MEIMS is "Easy to Navigate"

Statement three asked the participants if MEIMS was interesting. Almost all of the participants strongly agreed (n=7; 47%) or agreed (n=6; 40%) that MEIMS was interesting. Two (13%) of the participants were neutral on the whether MEIMS was interesting. The results for being very interesting are depicted in figure 10.

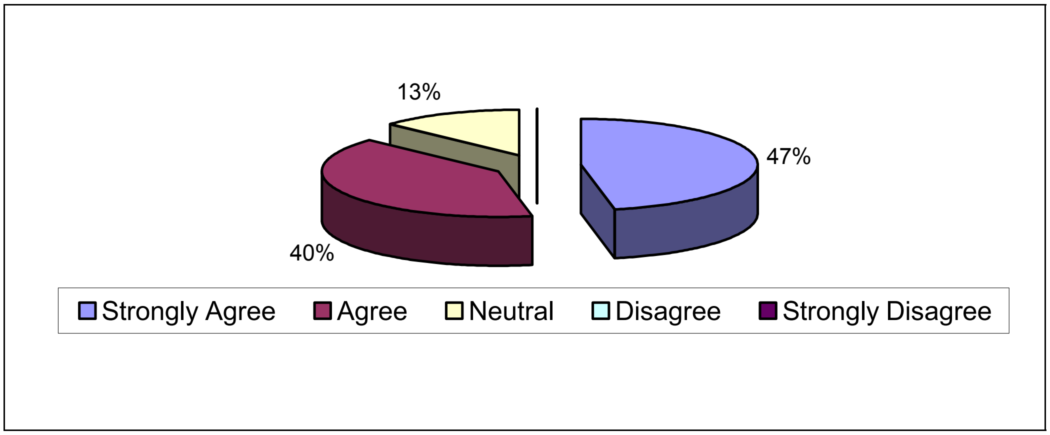

Figure 10. MEIMS is "Interesting"

Statement four asked about the relevance of MEIMS to aviation maintenance operations. All of the participants either strongly agreed (n=8; 53%) or agreed (n=7, 47%) that MEIMS is relevant to maintenance operations. The results for maintenance operations relevance are depicted in figure 11.

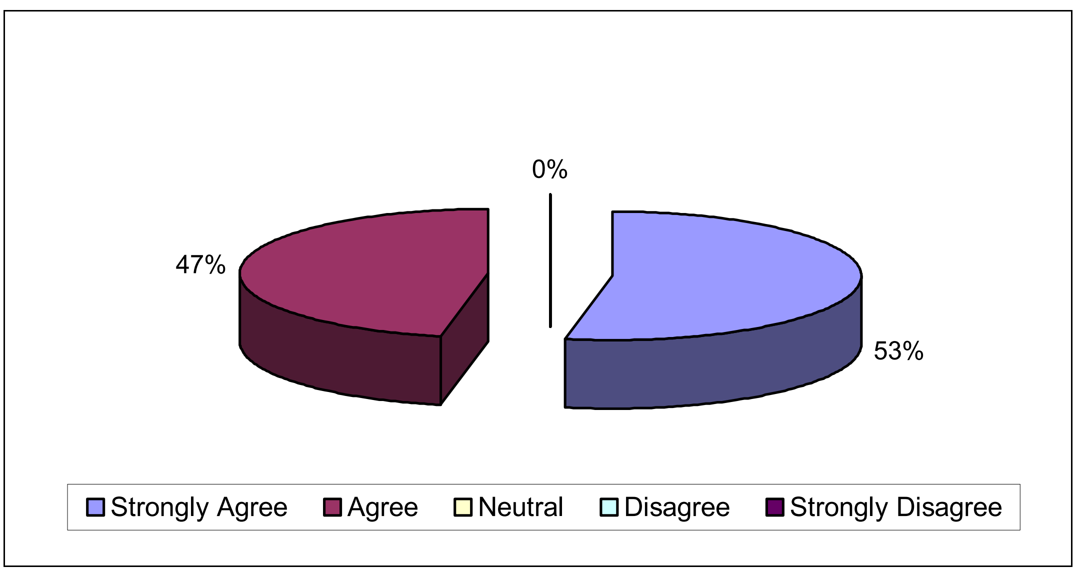

Figure 11. MEIMS is "Relevant to Maintenance Operations"

Statement five asked whether prototype concept was a good one. All the participants either strongly agreed (n=13; 87%) or agreed (n=2; 13%) that the MEIMS concept is a good one. Figure 12 depicts the result for the concept goodness.

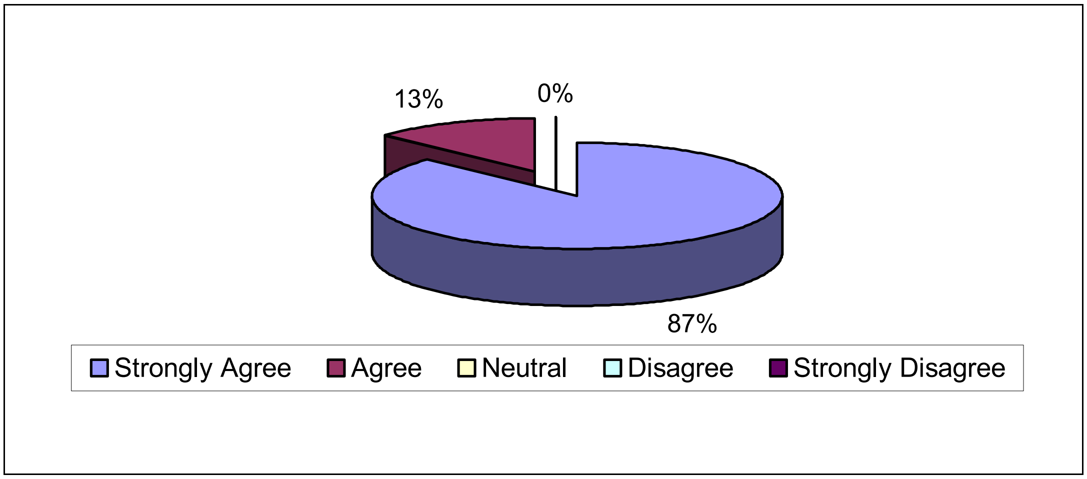

Figure 12. MEIMS "Concept is Good"

Statement six asked whether the participants found the investigation tool helpful. All of the participants either strongly agreed (n=11; 74%) or agreed (n=4; 26%) that the investigation tool was helpful. The results are depicted in Figure 13.

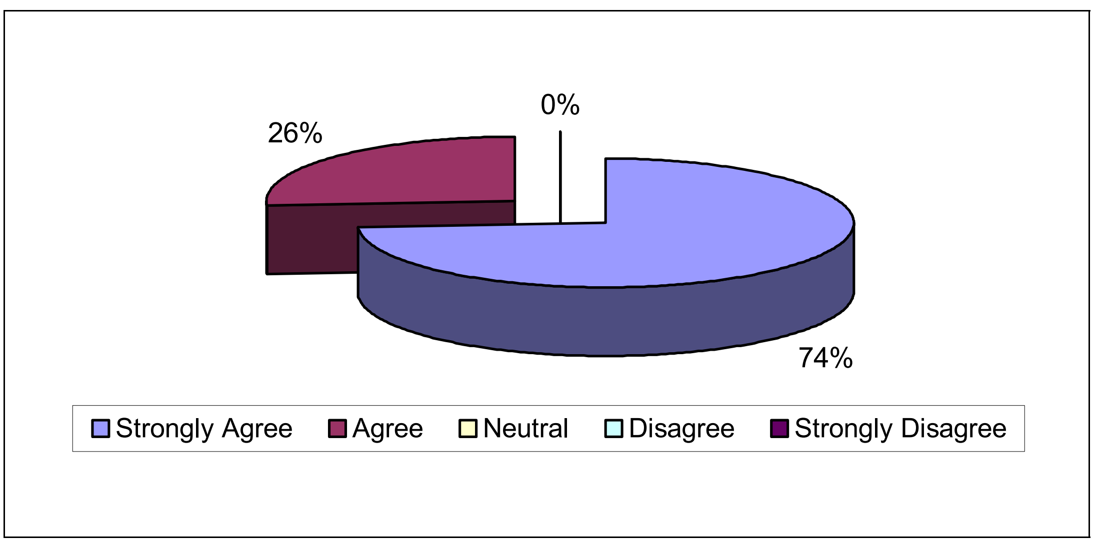

Figure 13: Investigation "Tool is Helpful"

2. Responses to Open-ended Questions

Part III of the exit survey contained four open-ended questions regarding the participants overall satisfaction with MEIMS. All participants took the opportunity to make comments. The majority of comments were positive and indicated that MEIMS was a good tool that has the potential to be extremely valuable instrument in the prevention of mishaps

Question one asked the participant to list the most positive aspects of the prototype. Overall, the response was positive. Six participants commented on MEIMS ease of use and ease of navigation. Five participants commented on layout of MEIMS, the quantity of information and the thoroughness. Several commented on the features that the user has the ability to capture trends. Some sample inputs include:

- "*Quantifies other factors of a mishap beyond the aircrew.*"
- *"It helps the ASO identify factors they may not have thought of."*
- *"Allows quick and easy input of data by trained Safety Officer/Individual."*
- *"Ability for maintenance supervisors to query for specific 3rd level factors for briefing and training maintance personnel."*
- *"The fact that it brings together all the mishap data in one place for easy access."*

Question two asked for the most negative aspects of the prototype. Most comments were problems or suggested improvement to the interface. A few left this area blank and some comments made had merit, but were beyond the scope of this study. Several of the comments focused on the users lack of understanding with the HFACS--ME taxonomy terms and the fact that potential users would need some training. Some sample comments include:

- *"A little cumbersome to use at first."*
- *"An explanation of the 1st, 2nd, and 3rd level factors may be helpful. Often the factors seem so similar that it almost get confusing as to which one is most appropriate. If there was possibly something to go back to see some key words then it might help."*
- *"No interface for retrieving NSC data."*

- *"Learning curve once past that everything is great."*

Question three requested suggestions for changes to MEIMS. For the most part participants reiterated what they had stated previously and centered on training or their lack of knowledge of HFACS--ME. Several participants left this area blank. A few of the comments include;

- *"Add a few standard icons to selection Menu."*
- *"Add Help Menu"*
- *"Add tool tips."*
- *"Online tutorial to get started."*
- *"Spend the time to make it a little more user friendly without the aid of tool evaluation package, it would be difficult to use*."

Question four requested suggestions for changing the investigation section of MEIMS. Some participants' comments again focused on their lack of understanding with the HFACS--ME taxonomy and the definitions of all its terms. Several participants had no comment. Two participants suggested that the user should have the option to go through the factor input wizard or manually enter the factors. They felt that once the user became familiar with the taxonomy the factor input wizard would only slow them down. Several others responded positively about the ability to import the preliminary report into a Microsoft Word document. Some comments include:

- *"I can't say I would add anything more to this one particular portion, it certainly gives the database a lot more functionality."*
- *"Investigation module portion helpful but not as a stand-alone application, it would need to be integrated."*
- *"Possible examples of descriptions."*
- *"Add help menu that incorporate the legal and layman's descriptions of mishap categories."*
- *"Should be able to skip the factor input status if factors are known."*

Lastly there was a space for additional comments, they include;

- "*Great for a safety standown to look at the trends instead of always glossing over on a case by case basis."*

- *"Good addition to the ASO tool kit."*
- *"Good training to give the maintenance department – so they know."*
- *"Good to go!"*

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

Naval Aviation has always had great demand for high levels of operational readiness, equipment availability, and personal training. These trends continue today, despite reduced budgets and aging aircraft. To continue to meet this operational demand, it become vitally crucial to protect our assets, as replacement airframes are not likely in the foreseeable future. In this financially strapped environment, costs of Naval Aviation mishaps, in terms of operational readiness, material resources, and operational capability are too high. Therefore, reducing the number of mishaps is crucial to the continuing success of Naval Aviation. Although not all mishaps are avoidable, reducing the mishaps involving human error becomes imperative.

In an effort to reduce human factor errors in Naval Aviation mishaps, recent efforts have targeted aircrew error. This emphasis has resulted in the comprehensive HFACS taxonomy. These early efforts resulted in a reduction of mishaps, but not to the extent Naval Aviation had hoped to achieve. It was soon realized that the scope of mishap prevention must be expanded beyond aircrew error to included maintainer errors. This expanded scope resulted in the HFACS Maintenance Extension, or HFACS--ME. This taxonomy proved to be an acceptable method for classifying maintainer errors. Using the HFACS--ME taxonomy, a clear picture of the human factor errors contributing to maintenance mishaps could be formulated.

To fully tap into the potential of the HFACS--ME taxonomy, an existing prototype database tool, Maintenance Error Information Management System (MEIMS) was developed and refined. This enhanced MEIMS prototype mishap database tool, based on the HFACS--ME taxonomy, is a safety information management system used to facilitate the characterization and analysis of human error in Naval Aviation maintenance mishaps. Users are able to query data, custom make graphs, view reports, conduct a preliminary investigation, as well as download and updated database file. A Tool such as MEIMS has the potential to identify human errors patterns or trends and assist safety personnel in intervention development.

B. CONCLUSIONS

The participants' high level of satisfaction with the MEIMS prototype mishap database tool indicated a need for quick, accurate mishap data information for use in training, analysis, and investigations. Participant feedback demonstrated that MEIMS is beneficial to fleet safety. However, as with any new major software program, there are areas that need improvements.

According to the quantitative survey items, the MEIMS prototype type received its highest ratings in ease of navigations and logical format. For MEIMS to reach its full potential the following items must be completed:

- Incorporate definitions of the HFACS--ME taxonomy terms into the application, this will enhance the users understanding of the taxonomy.
- Create a users manual and help function. These will increase the user's ability to understand the functions of MEIMS and increase their ability to access information quickly.

Increasing the users knowledge of the MEIMS program, and all it functions, as well as providing more detailed information on the HFACS--ME taxonomy will make MEIMS a valuable program tool for any fleet unit.

C. RECOMMENDATIONS

1. Recommended Prototype MEIMS Tool Improvements

- Incorporate HFACS--ME definitions within MEIMS. Better descriptions of the HFACS--ME causal factors will also improve usability and understanding.
- Include a detailed description for each mishap to augment the brief description.
- Include mishap data prior to 1989 and from 2000 to the current
- Include maintenance related Hazard Reports.

- Change the aircraft identifier to include aircraft nickname in addition to type/model to avoid similar names.
- Separate AH-1 and UH-1 into two categories, due to the aircraft's differences.
- Provide a link to the date-time-group of the Mishap Investigation Report. This will give the user the option to obtain the complete details surrounding a mishap.
- Incorporate a help menu within the program and a user manual. This will improve the end-users knowledge of HFACS--ME and make MEIMS a more productive tool.
- Expand this program to other areas with in the armed forces where maintenance is performed.
- Develop a program similar to MEIMS using the aircrew factors taxonomy, HFACS.
- Make MEIMS available over the World Wide Web. This will ensure that everyone, regardless of location, will have access to the data.

2. The Future of MEIMS

MEIMS has developed into a comprehensive information management database tool for accessing mishap data information for use in training, analysis, and investigations. This tool has the potential to save the Naval Aviation money, increase combat and personnel readiness, and, ultimately, save lives. Even with this enormous potential, this program is only in its infancy. Expanding the MEIMS concept to other areas within the Service where maintenance is performed could further enhance the safety impact. Moreover, MEIMS could be further expanded to civil aviation where there is also a record of human error, including maintenance related human error, in mishaps.

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APPENDIX A

PROTOTYPE MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) TOOL REVIEW

1. MAIN MENU

The Main Menu appears after HFACS-(ME) ICON is selected (see Figure A1).

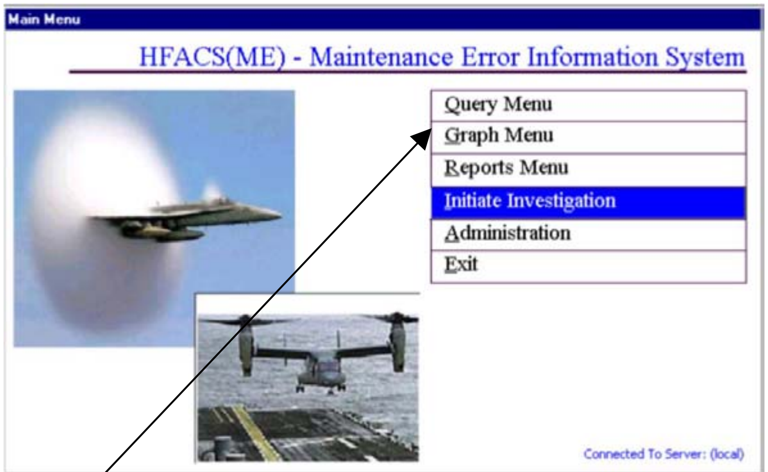

Figure A1. Prototype MEIMS Tool Main Menu

Select the "Query Menu" command button to view Query Menu (see Figure A2).

2. QUERY MENU

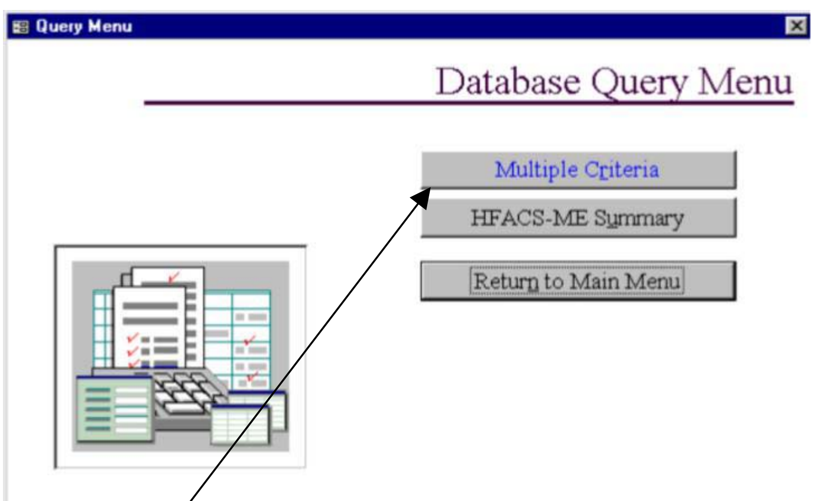

Figure A2. Query Menu

Select the "Multiple Criteria" command button.
The Multiple Criteria Query menu appears (see Figure A3).

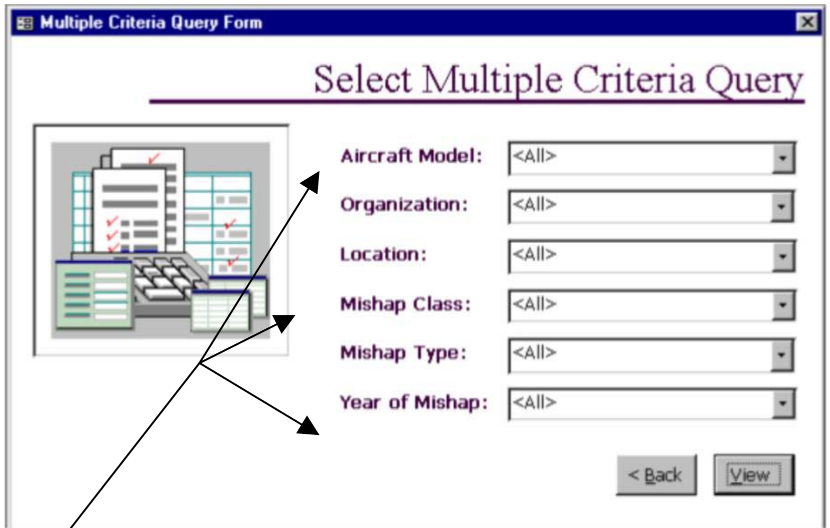

Figure A3. Multiple Criteria Query

Select one or multiple categories in the drop down boxes then click “View”, and the Summary of Mishap form appears (see Figure A4).
Selecting the Back button will take you back to the Main Menu.

Figure A4. Summary of Mishap Form with F14 selected as Aircraft Type and US Navy as Organization.

Select the inner right arrow after “Record:” to view additional Mishap Factors.
Select the outer right arrow after “Record:” to view additional Mishaps.
Select “Print” to view a printable record.
Selecting “Done” will take you back to the Multiple Criteria Query (see Figure A3).
Selecting the “HFACS--ME Summary” from the Query Menu (see Figure A2) will display the HFACS--ME Summary page (see Figure A5).

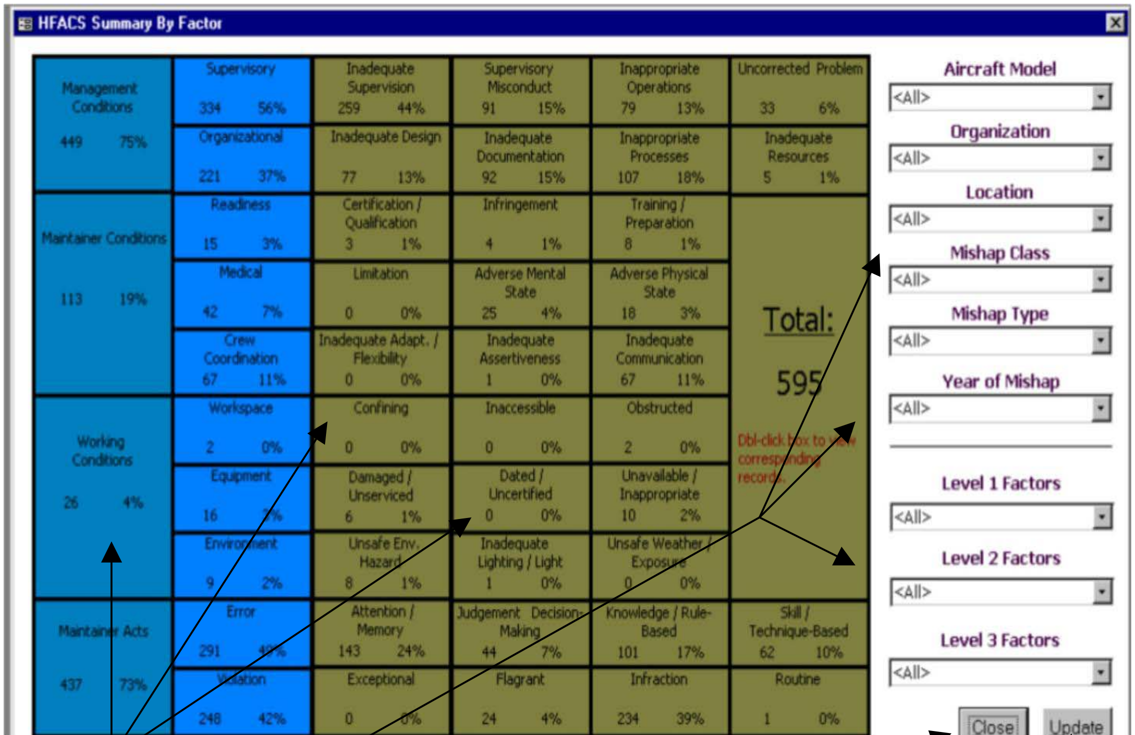

Figure A5. HFACS--ME Summary Form

Selecting one or multiple criteria from the drop down boxes and then selecting “Update” will recalculate the values in each of the factors boxes.
Clicking on any factor box will bring up the Summary of Mishap Form (see Figure A4) for desired user input.
Selecting Close will return the user to the Query Menu (See Figure A2)

3. GRAPH MENU

Selecting the “Graph Menu” from the Main Menu (see Figure A1) will display the Graph Menu (see Figure A6)

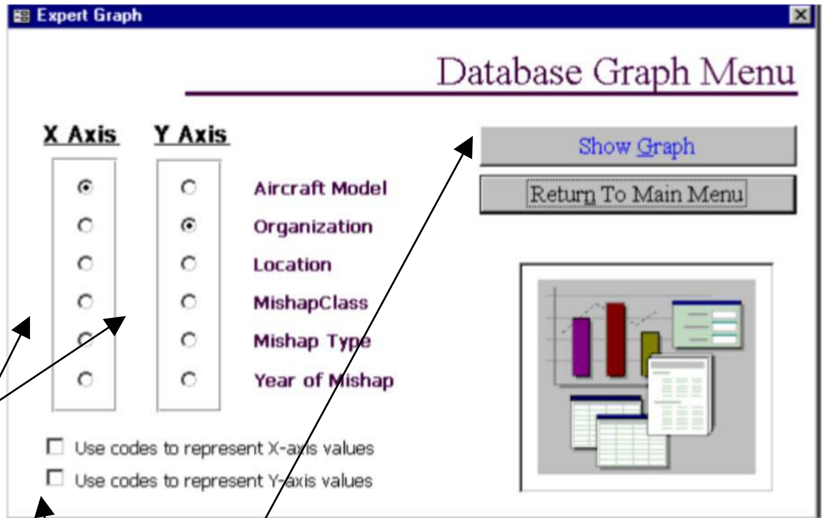

Figure A6. Graph Menu

Select one of the radial buttons to determine the value of the X-axis, and one of the radial buttons to determine the value of the Y-axis.
Select "Show Graph" to display the Graph (see Figure A7).
Checking the "Use codes to represent X-axis/Y-axis values will display the code vice the full definition in the X and Y values area of the graph

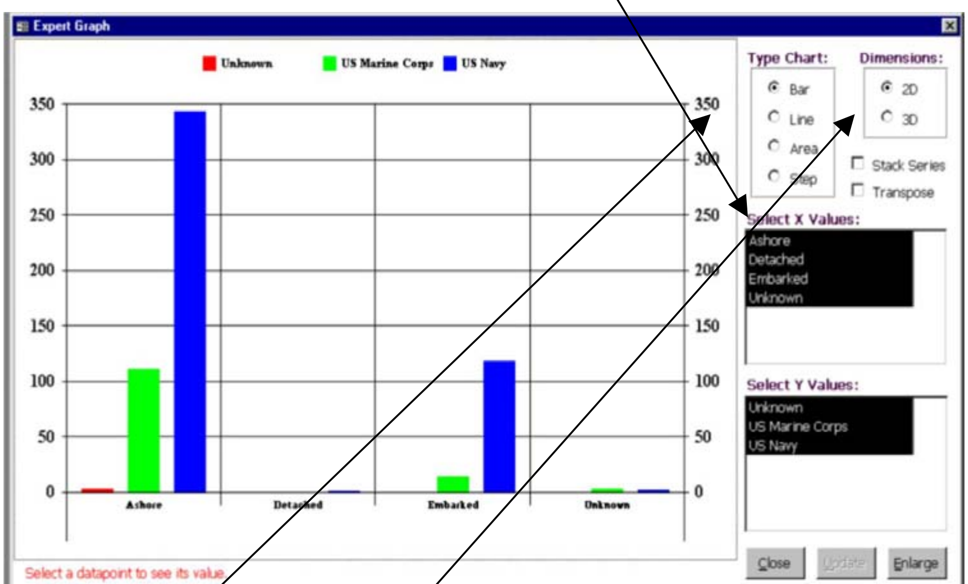

Figure A7. Graph Form

Select "Type Chart" or "Dimensions" to change the type and style of chart.
Choosing different X and Y values and then selecting "Update" button will update the graph.

4. **REPORT MENU**

Selecting the "Report Menu" from the Main Menu (see Figure A1) will display the Report Menu (see Figure A8).

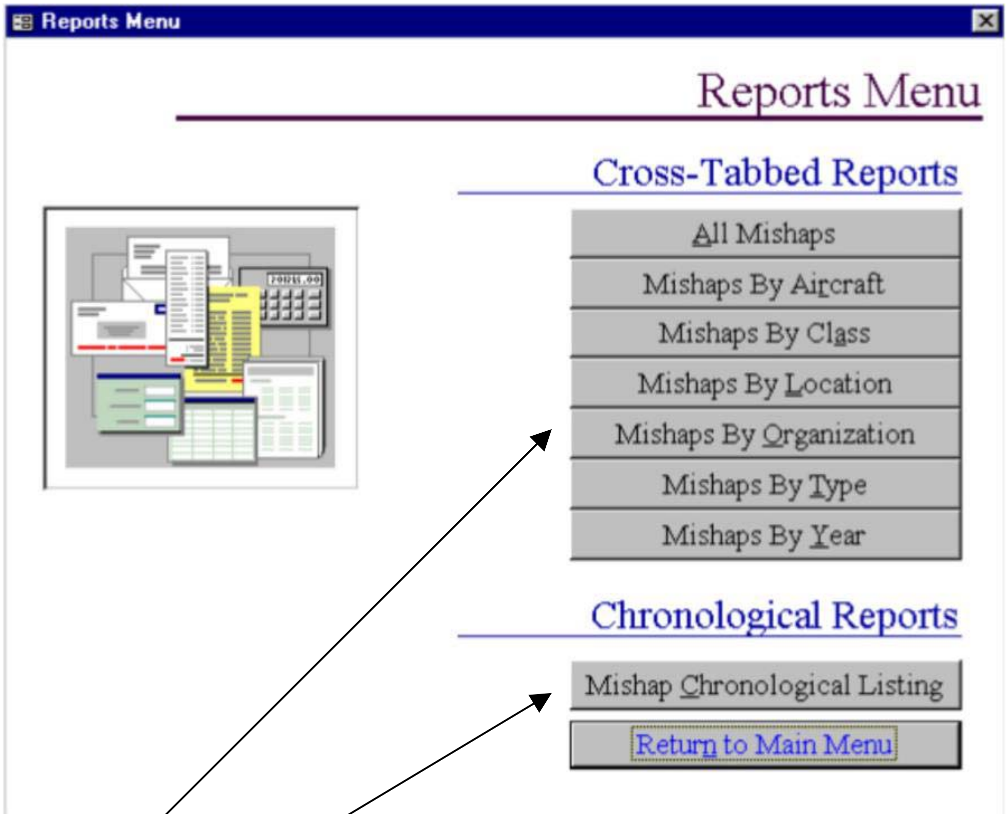

Figure A8. Report Menu

Selecting one of the "Cross-Tabbed Reports" will display the selected reported (see Figure A9).
Selecting Mishap Chronological Listing will display a chronological list of all mishaps in the database.

HFACS-ME Summary Report

Aircraft

As Of: Sunday, August 19, 2001 12:54:20 PM

Aircraft: A4 **Total Mishaps** 6

1st Level Factor	Number of Factors	% of Total	2nd Level Factor	Number of Factors	% of Total	3rd Level Factor	Number of Factors	% of Total
Unsafe Management Conditions	3	50%	Organization	1	17%	Inadequate Processes	0	0%
						Inadequate Documentation	1	17%
						Inadequate Design	0	0%
						Inadequate Resources	0	0%
			Supervisory	2	33%	Inadequate Supervision	2	33%
						Inappropriate Operations	1	17%
						Uncorrected Problem	0	0%
						Supervisory Misconduct	1	17%
Unsafe Maintainer Conditions	1	17%	Medical	1	17%	Adverse Mental State	1	17%
						Adverse Physical State	0	0%
						Unsafe Limitation	0	0%
			Crew Coordination	0	0%	Inadequate Communication	0	0%
						Inadequate Assertiveness	0	0%
						Inadequate Adaptability/Flexibility	0	0%
			Readiness	0	0%	Inadequate Training/Preparation	0	0%
						Inadequate Certification/Qualification	0	0%
						Personnel Readiness Infringement	0	0%
Unsafe Working Conditions	0	0%	Environment	0	0%	Inadequate Lighting/Light	0	0%
						Unsafe Weather/Exposure	0	0%
						Unsafe Environmental Hazards	0	0%
			Equipment	0	0%	Damaged/Unserviced	0	0%
						Unavailable/Inappropriate	0	0%
						Dated/Uncertified	0	0%
			Workspace	0	0%	Confining	0	0%
						Obstructed	0	0%
						Inaccessible	0	0%
Unsafe Maintainer Acts	4	67%	Error	2	33%	Attention/Memory	2	33%
						Knowledge/Rule	0	0%
						Skill/Technique	0	0%
						Judgment/Decision	0	0%
			Violation	3	50%	Routine	0	0%
						Infraction	3	50%
						Exceptional	0	0%
						Flagrant	0	0%

Page 1

Figure A9. Sample Aircraft Report

5. INITIATE INVESTIGATION MENU

Selecting the “Initiate Investigation from the Main Menu (see Figure A1) will open up a separate Access database program and will display the Mishap Investigations form (see Figure A10)

Figure A10. Mishap Investigations Form

Select “Add” to start the investigation decision program (see Figure A11).

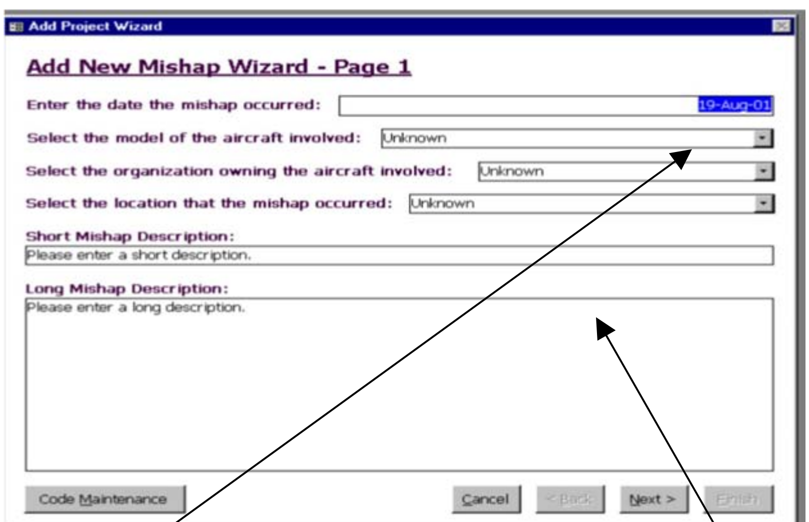

Figure A11. Add new Mishap Investigations Form

Select the appropriate data from the drop down boxes and enter a short and long mishap description. If your data is not present in the drop down boxes select Code Maintenance to add the information. When done select “Next” to continue entering information (see Figure A12).

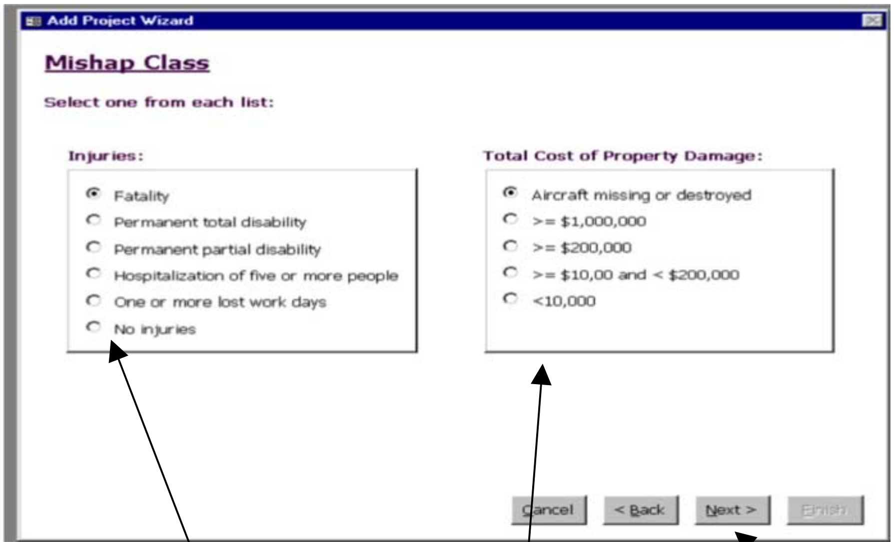

Figure A12. Mishap Class Form

Select one radial button for injuries and one radial button for cost and then select "Next".

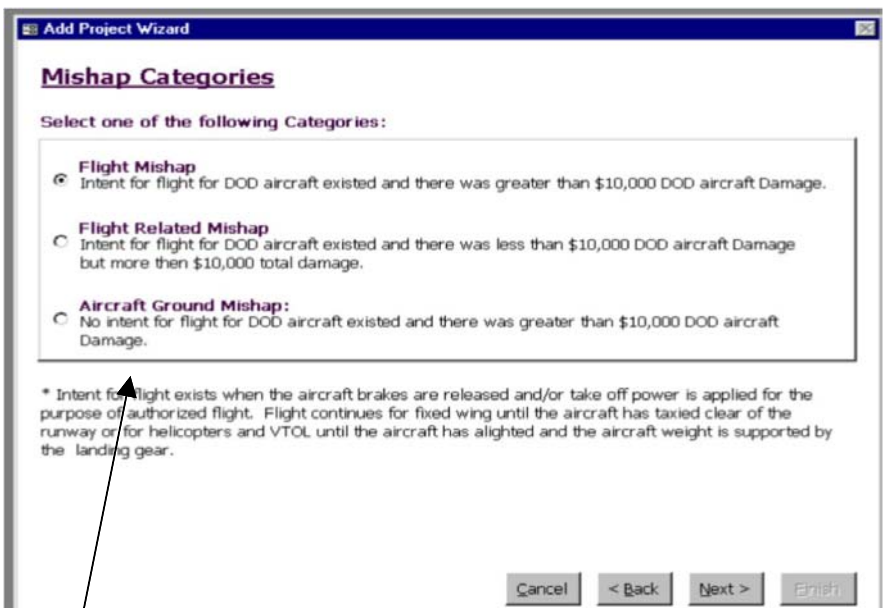

Figure A13. Mishap Category Form

Select one radial button for the appropriate mishap category and then select "Next".

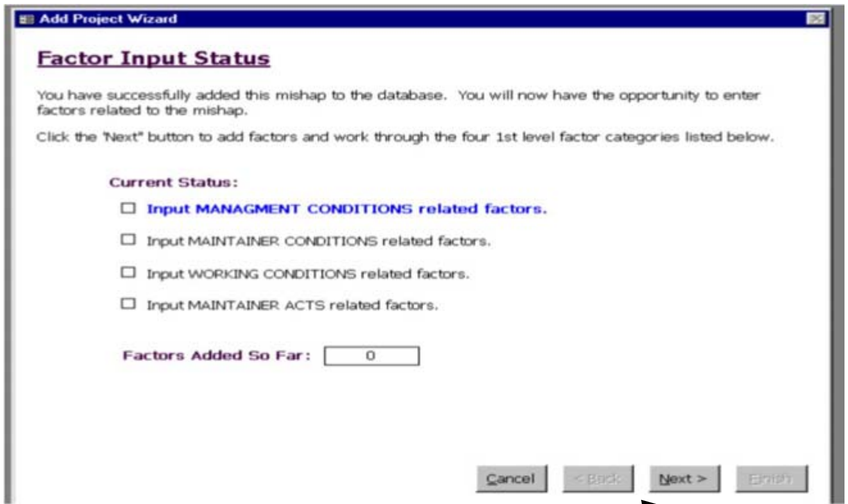

Figure A14. Factor Input Menu

Select "Next" to start adding factors for the mishap.

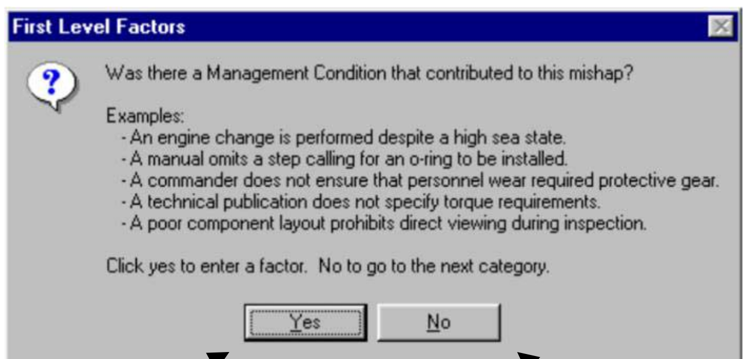

Figure A15. First Level Management Factor form

Select "Yes" to add a factor for first level factor that is stated on the form (see Figure A14).

Select "No" if there is no factor for the first level factor that is stated on the form and return to the Factor Input Menu (see Figure A14).

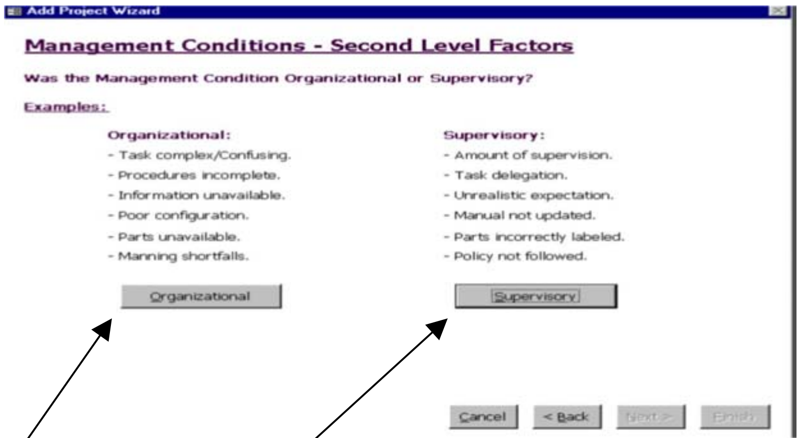

Figure A16. Second Level Management Factor form

Select "Organizational" or "Supervisory" depending on the type of factor.

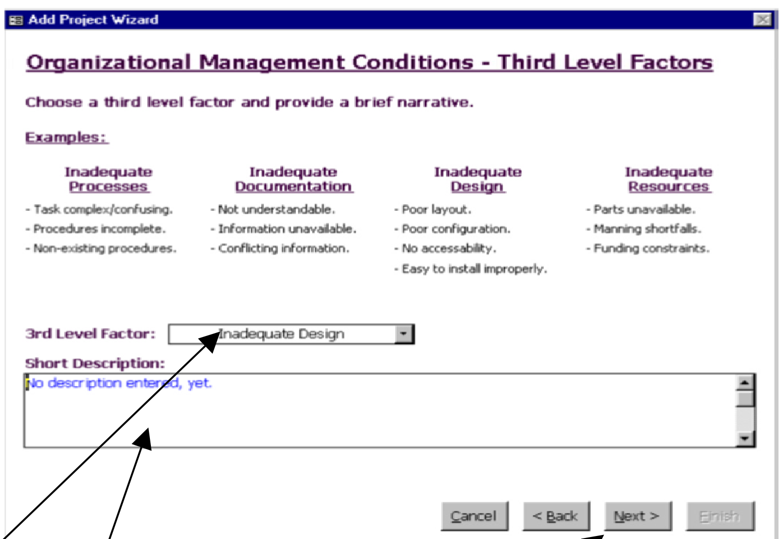

Figure A17. Third Level Management Factor form

Select the appropriate third level factor from the drop down box.
Write a brief description of the factor.
Select "Next" when completed filling in the form. The program will take the user back to the Factor Input Menu (see Figure A14) to continue entering factors until all factors for the mishap are entered into the program. Once all factors are entered the user will get the finished form (see Figure A18).

Figure A18. Finished Form

Select "Back" if there are more factors to add.
Select "Finished" to view the mishap data entered (see Figure A19).

Figure A19. Mishap Data Entered Form

Select "Print" to view the Investigation Mishap Report (see Figure A20).
Selecting "Save" will save the data and return the user to the Mishap Investigations Form (see Figure A10)

Mishap ID #27

Organization: US Marine Corp

Aircraft Type: AV8

Mishap Date: 19-Aug-01

Mishap Type: Flight Related Mishap

Mishap Severity Class: $1 Million > X > $10000

Mishap Location: Ashore

Short Description:

Aircraft departed runway

Factors:

Description Of Factor	3rd Level	2nd Level	1st Level
Maintenance Chief directed improperly trained mech to change brakes.	Inadequate Supervision	Supervisory	Management Conditions
Mech not qualificated to service brakes without supervision.	Certification / Qualification	Readiness	Maintainer Conditions
Mech used wrong tools to perform brake job.	Damaged / Unserviced	Equipment	Working Conditions
Mech knew that he was not qualified to change the brakes.	Knowledge / Rule-Based	Error	Maintainer Acts

Long Description:

Aircraft departed runway at MCAS Yuma due to improperly installed brakes.

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Figure A20. Mishap Investigation Report

6. ADMINISTRATION

Selecting “Administration” on the Main Menu (see Figure A1) will bring up the login in form (see Figure A21).

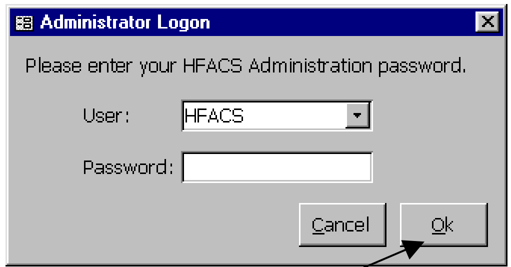

Figure A21. Administrator Login Form

Fill in password and press "Ok"

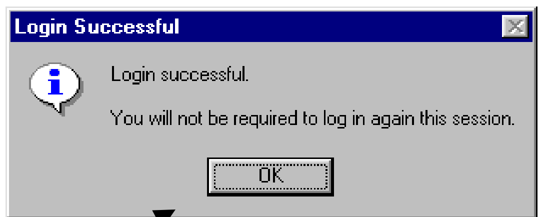

Figure A22. Successful Login Form

Press "OK" to view the Administration Manage Mishaps Form (see Figure A23)

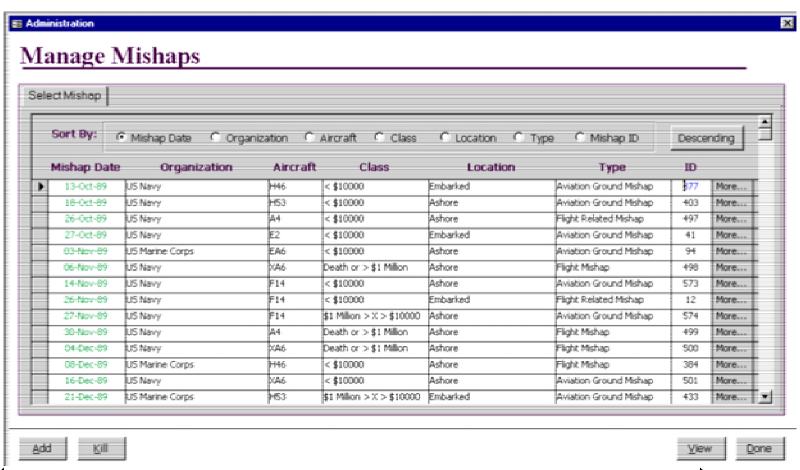

Figure A23. Administration Manage Mishaps Form

Select "Add" to add a mishap and its associated factors.
Select "Kill" to delete the highlighted record and its associated factors.
Select "View" to see the mishap and its associated factors in the Mishap Data Form (see Figure A24).

Figure A24. Administration Manage Individual Mishaps Form

Select "Print" to view the Investigation Mishap Report (see Figure A18).
Select "Save" to change any data that has been changed.
Select "Cancel" to either close the form or to cancel any changes you have made.

7. EXIT

Selecting "Exit" from the Main Menu (see Figure A1) will close the program.

APPENDIX B

PROTOTYPE MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) TOOL EVALUATION

Background. Thank you for participating in a usability study (evaluation) of a prototype tool for the Maintenance Error Information Management System (MEIMS). This tool was developed at NPS and has been modified based upon previous usability studies. This study is being conducted by Capt Doug Nelson, USMC as part of a thesis project for his Master of Science program in Information Technology Management. MEIMS was developed to address and identify patterns of human error in Naval Aviation maintenance-related aircraft mishaps. The Human Factors Analysis and Classification System Maintenance Extension (HFACS--ME) taxonomy is the foundation of MEIMS and is an effective method for classifying and analyzing the presence of human error in maintenance operations leading to major mishaps, accidents of lesser severity, incidents and maintenance related personal injury cases. Given the capability of the previous MEIMS systems an improved information management system was needed to fully capture Maintenance related factors and bring the system to the next level.

MEIMS captures maintenance error data, facilitates the identification of common maintenance errors and associated trends, and supports understanding of how to identify human errors in the future. The target audience for this information management system tool includes safety personnel (data entry & retrieval by unit safety officers, other safety & training personnel, maintenance officers, maintenance supervisors), mishap investigators-for data retrieval (Aircraft Mishap Board members, squadron safety officers), and analysts (from the Naval Safety Center, the command's safety officer or one from its higher headquarters). This tool can directly lead to a decreased mishap rate and overall increased mission readiness due to the training and analysis opportunity it provides.

Usability Study. You will be given a packet of instructions to guide you through MEIMS. You will be asked to make comments on the effectiveness and usability of the prototype system during your testing phase. Additionally, you will be asked to complete an "exit survey" after completion of your testing. Questions will include demographic information, objective questions about MEIMS usability, and subjective questions and comments for areas not covered in the objective section. The study should take no more than 20-30 minutes.

Completion of Study. Upon completion of your testing and survey you will be asked to return your packet of instructions to Capt Doug Nelson. Thank you again for your participation.

Doug Nelson

Instructions for Prototype Maintenance Error Information Management System (MEIMS) Tool Evaluation

Start-up

1. Go to a room E-322.

2. When Log-in menu appears, Log-in using ASO ID and password.

3. When Desktop (main Icon screen) appears, double click on the HFACS-(ME) icon. This will start the MEIMS application using Acess 2000 as an interface and SQL server as the database engine.

Question 1: Did you have any problems accessing the program? Y / N (circle one)
If so, please describe:

Main Menu

4. You will now have the Main Menu displayed with the Supersonic Hornet and Osprey photos.

5. Note the six categories on the right portion of the screen.

Question 2: Is the terminology clear enough to understand what each of the six command buttons does? If not, what could be changed to make it clearer?

6. Select (click) <Query Menu>

Query Menu

7. Note there are two sections on the Query Menu. Multiple Criteria and HFACS--ME Summary

8. Select (click) Multiple Criteria

9. Another form appears: “Select Multiple Criteria Query”. Select your type aircraft, and then select <View >. The “Mishap Data” form appears. Note the number of maintenance related mishaps is on the bottom of the outer box and the number of factors for that mishap are on the inner box. You can cycle through mishaps or factors by selecting the (>) to the right of the number box. Review the “Short Description” of the mishap and the “Mishap Factor Summary” . Note

selecting print will show you a printable report.

*Question 3: What aircraft did you select?*__________

*Question 4: How many separate mishaps of that aircraft type are in the database?*______________

Question 5: How many factors are there for the first mishap? ______________

10. Select "Done" when you are through.

11. You are now free to choose other mishap information if you wish, or continue to step 12.

12. Select "< Back".

13. Select "HFACS--ME Summary"

14. HFACS summary by factor form appears. This page will first display all the mishaps in the database and can be narrowed down by the user with the drop down boxes on the right and then selecting "Update" in the lower right hand corner. The form displays the total number of mishaps (right center), as well as the number of mishaps for each factor and what percent that factor is to the total number of mishaps.

Question 6: How many total mishaps are in the database? __________
Question 7: How many mishaps have a level one category of Management Conditions? ________

Question 8: What is the percentage of mishaps that have a 3rd level factor of Inadequate Design? _______

15. Conduct further queries as desired or continue to step 16**. Note:** you can click on any factor box to bring up detailed information.

16. Select "Close"

17. Select "Return to Main Menu"

Graph Menu

18. Select "Graph Menu"

19. The Database Graph Menu will appear. Select "Mishap Type" for the X-axis value and "Organization" for the Y-axis value.

20. Select "Show Graph"

21. A graph form will appear for the values selected. You can click on the top center of any bar and the total number of mishaps for your selected values will show up on the bottom left.

Question 9: How many total Aviation Ground Mishaps does the US Navy have? ______

22. You are free to play with the graph menu or go onto step 23.

23. Select "Close"

24. Select "Return to Main Menu"

Report Menu

25. Select "Report Menu"

26. The Report Menu Form will appear.

27. Select "Mishaps By Class"

28. A HFACS--ME Summary report will appear. Mishaps are organized by mishap class and the total number of mishaps will be displayed for that class. Each level factor will display the total number of mishaps that have that factor as a cause of the mishap as well as a percent compared to total mishaps. To cycle through the other mishap classes click the right arrow (>) to the right of Page: in the bottom left corner.

Question 10: How many total class B mishaps are there? _________

29. Select "Close" at the top of the report to return to Report Menu.

30. You can choose other reports if you wish, or go to step 31.

31. Select "Return to Main Menu".

Initiate Investigation

The following scenario will help you in completing the following section; During a turnaround inspection the plane captain fell off an aircraft and broke his arm as well as damaged the aircraft. Due to his injuries the plane captain missed two workdays, also there was aircraft damage in excess of $10,000. After a brief investigation of this incident you discover that the maintenance chief directed the plane captain to get the turnaround done despite the pouring rain outside. You also discover that the plane captain had duty the night before and had been up all night.

32. Select “Initiate Investigation”

33. A new database program will open in Access 2000 and the Mishap Investigation form will appear. This section is for the user to enter mishap data using the HFAC-ME taxonomy. Select “Add”

34. Add new mishap wizard will appear. Fill in the appropriate information using your personal information and the scenario above. You can fill in the same information for short and long description. Click “Next >” when done.

35. Mishap Class screen appears; check the appropriate injuries and cost boxes. Click “Next >” when done.

36. Mishap Categories screen appears; check the appropriate category. Click “Next >” when done

37. Factor Input screen appears. You are now going to be guided through the HFACS--ME taxonomy with a series of questions until all possible factors for your mishap have been entered. Click “Next >” to continue.

38. At the 3rd level screen you will select one of the third level factors and write a brief description of the factor that contributed to the mishap. Click “Next >” when done.

39. Factor Input screen appears. Click “Next >”, you will again be asked if there were any Management Conditions. If you have no more Management Conditions to enter select “NO”. Click “Next>” and continue this cycle until all factors have been entered for your mishap. Notice that a check will appear before each first level factor when you have completed that factor.

40. When all factors are entered Click “Next>”. You will be at the finished screen and select “Finished”

41. The Mishap Data form will now have the data you entered. Click on “Print” in the lower left section of the screen.

42. The data is now arranged in report format suitable for printing.

Question 11. Do you feel this section helped you in identifying all possible factors for this mishap? Yes/No (circle one), If not please describe.

43. Select “Close” on the top left.

44. Select “Cancel”

45. Select “Done’

Administration

50. The Administration section is for Adding, Deleting or modifying existing data in the database and is not a testable portion.

Exit

51. Select “Exit”

52. Select “Yes”

53. Please fill out an Exit Survey Questionnaire.

APPENDIX C

PROTOTYPE MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) TOOL EXIT SURVEY

User's Impression of the Maintenance Error Information Management System (MEIMS) Prototype Tool

Purpose: This survey evaluates a user's overall satisfaction of the Maintenance Error Information Management System (MEIMS) prototype tool. It consists of three parts.

Part I: *Demographic Information.* Part I provides the user's aviation background, computer experience, and availability of software and hardware systems used in the Navy and Marine Corps.

Part II: *User Satisfaction with the Four Sections of the MEIMS Prototype Tool.* Part II deals directly with user feedback as they use the prototype tool.

Part III: *User Overall Satisfaction with the MEIMS Prototype Tool.* Part III allows users to give general feedback about the prototype tool.

Part I. Demographic Information

Follow the instructions after each numbered question or statement.

1. I am currently/was attached to a command that **primarily performs maintenance** (military and/or civilian) at the:

(Select one from the list and check the box)

- ❑ Squadron Level
- ❑ Intermediate Level (AIMD)
- ❑ Depot Level (NADEP)
- ❑ Command does not perform aircraft maintenance
- ❑ Other (describe if other) ____

2. **How long** have you been using a computer?

(Select one from the list and check the box)

- ❑ Less than one month
- ❑ One month to less than one year
- ❑ One year to less than two years
- ❑ Two years or more

3. What **software** do you normally use?
   (Check all boxes that apply)

- ❑ Microsoft Office (Word, PowerPoint, Excel, Access)

What version?
   (Check all boxes that apply)
- ❑ 97
- ❑ 2000
- ❑ not sure of version
- ❑ other (describe if other)__________________________

4. What **software application categories** are you familiar with?
   (Check all boxes that apply)

- ❑ Word Processing (MS Word, Word Perfect, Word Pro...)
- ❑ Spreadsheet (Excel, Lotus 123, Quattro Pro...)
- ❑ Presentations (PowerPoint, Harvard Graphics...)
- ❑ Graphic Software (Corel Draw, Adobe Photoshop...)
- ❑ E-Mail (Outlook, Eudora, AOL...)
- ❑ Database (Access, DBase...)

5. What computer **operating systems** do you use?
   (Check all boxes that apply)

- ❑ Windows (3.1, 95, 98, 2000)
- ❑ Windows NT
- ❑ Macintosh
- ❑ UNIX
- ❑ Linux
- ❑ Other (describe if other) ____

Part II. User Satisfaction with the Four Sections of the MEIMS Prototype Tool
Select the category that best matches your impression of each of the below categories (and check the box).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I feel the information on the MEIMS tool was in a **logical form**	☐	☐	☐	☐	☐

(comments)____

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I found the MEIMS tool **easy to navigate**	□	□	□	□	□

(comments) ____

My tour of the MEIMS tool was **very interesting**	□	□	□	□	□

(comments) ____

The information presented on the MEIMS tool is **relevant to maintenance operations**	□	□	□	□	□

(comments) ____

The **concept** of the MEIMS tool is a good one.	□	□	□	□	□

(comments) ____

I found the investigation tool to be helpful	□	□	□	□	□

(comments) ____

Part III. User Overall Satisfaction with the MEIMS Prototype Tool
Please make any comments you may have on the MEIMS Prototype Tool not reflected in your comments in sections 1 and 2. Please use back of paper if you need more room.

The most positive aspects of the MEIMS prototype tool were:

The most negative aspects of the MEIMS prototype tool were:

I would make these changes (if any) to the MEIMS prototype tool:

I would make the following changes (if any) to the investigation portion:

Any additional comments:

Thank you! Your participation is greatly appreciated!

APPENDIX D

PROTOTYPE MAINTENANCE ERROR INFORMATION
MANAGEMENT SYSTEM (MEIMS) ENTITY RELATIONSHIP DIAGRAM

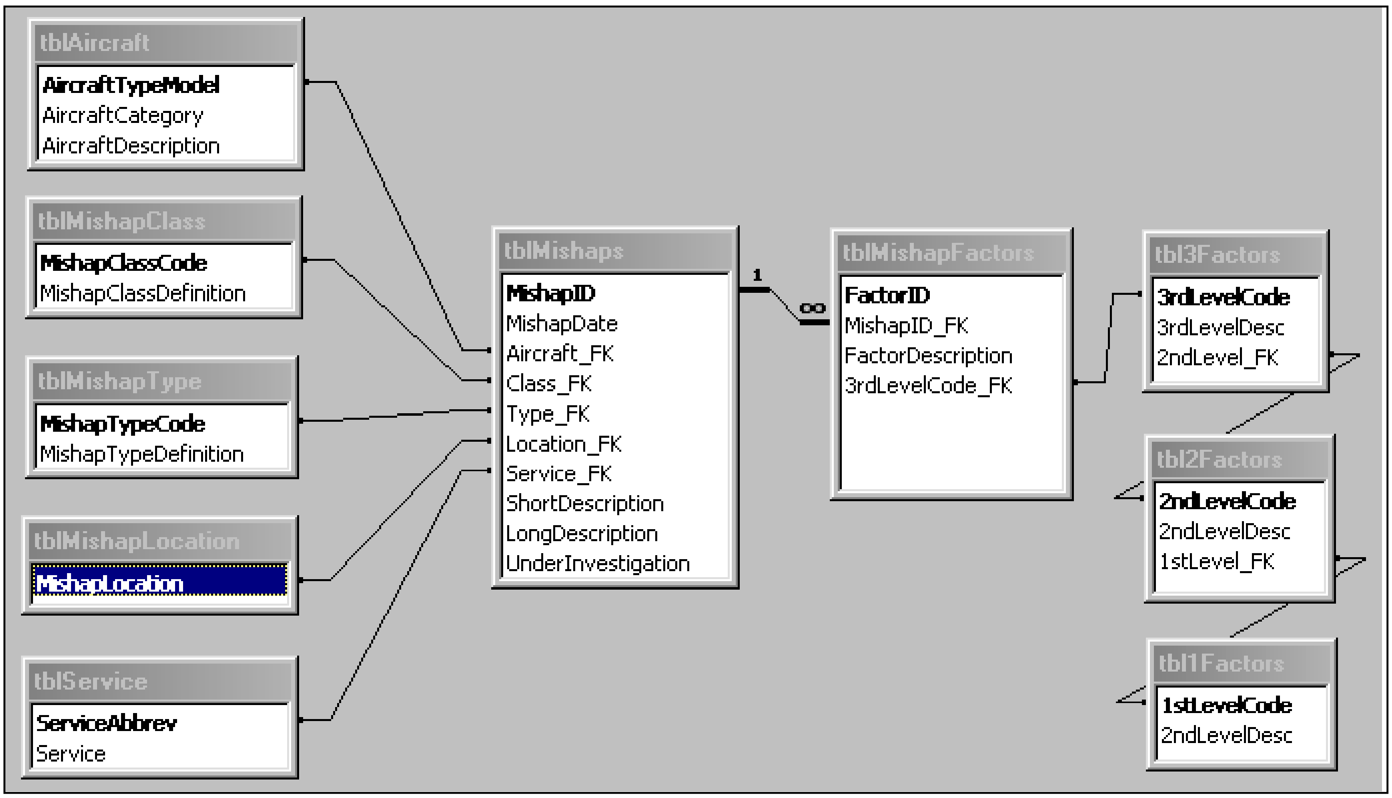

Figure D1. Entity Relationship Diagram

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APPENDIX E

PROTOTYPE MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) METADATA

Table 6: HFACS--ME Tables

Table Name	Number of Columns	Primary Key
tblMishaps	11	MishapID
tblMishapFactors	5	FactorID
tblFactors	6	3rdLevelCode
tblAircraft	3	AircraftTypeModel
tblMishapType	2	MishapTypeCode
tblMishapClass	2	MishapClassCode
tblOrganization	3	OrgID
tblMishapLocation	3	MishapLocationID
tblDatabaseType	1	DatabaseType

Table 7: HFACS--ME Columns

Column Name	Table Name	Data Type	Length
MishapID	TblMishaps	int	4
MishapDate	TblMishaps	datetime	8
Aircraft_FK	TblMishaps	nvarchar	50
Class_FK	TblMishaps	nvarchar	5
Type_FK	TblMishaps	nvarchar	5
LocationID_FK	TblMishaps	nvarchar	50
OrgID_FK	TblMishaps	nvarchar	50
ShortDescription	TblMishaps	nvarchar	255
LongDescription	TblMishaps	nvarchar	4000
UnderInvestigation	TblMishaps	bit	1
DatabaseType	TblMishaps	nvarchar	5
FactorID	TblMishapFactors	int	4
MishapID_FK	TblMishapFactors	int	4
FactorSummary	TblMishapFactors	nvarchar	255
3rdLevelCode_FK	TblMishapFactors	nvarchar	3
FactorDescription	TblMishapFactors	nvarchar	4000
3rdLevelCode	TblFactors	nvarchar	5
3rdLevelDesc	TblFactors	nvarchar	50
2ndLevelCode	TblFactors	nvarchar	5
2ndLevelDesc	TblFactors	nvarchar	50
1stLevelCode	TblFactors	nvarchar	5
1stLevelDesc	TblFactors	nvarchar	50

AircraftTypeModel	TblAircraft	nvarchar	15
AircraftCategory	TblAircraft	nvarchar	50
AircraftDescription	TblAircraft	nvarchar	255
MishapTypeCode	TblMishapType	nvarchar	5
MishapTypeDefinition	TblMishapType	nvarchar	255
MishapClassCode	TblMishapClass	nvarchar	2
MishapClassDefinition	TblMishapClass	nvarchar	255
OrgID	tblOrganization	nvarchar	10
OrgName	tblOrganization	nvarchar	50
DatabaseType	tblOrganization	nvarchar	1
MishapLocationID	tblMishapLocation	nvarchar	50
MishapLocation	tblMishapLocation	nvarchar	50
DatabaseType	tblMishapLocation	nvarchar	1
DatabaseType	tblDatabaseType	nvarchar	50

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