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A Preliminary Human Factors Analysis of Naval Aviation Maintenance Related Mishaps

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ABSTRACT

Naval Aviation has expanded its efforts to eliminate mishaps; especially those linked to human error. This focus was expanded to cover not only aircrew error, but maintainer error as well. To examine maintenance error, the Naval Safety Center's Human Factors Accident Classification System (HFACS) was adapted to analyze eight fiscal years of major maintenance mishaps. The HFACS Maintenance Extension effectively profiled the nature of maintenance errors and depicted the latent supervisory and maintainer conditions that "set the stage" for subsequent unsafe maintainer acts.

INTRODUCTION

Since the fall of the Berlin Wall and the Coalition's victory in Desert Storm, the U.S. Armed Forces have faced budgetary constraints and manpower reductions despite a need to sustain mission readiness and meet operational requirements. Naval Aviation, which asserts U.S. National Policy around the world through power projection, has been affected by this trend. Today, the conservation of resources is emphasized and the loss of assets due to mishaps is heavily scrutinized.

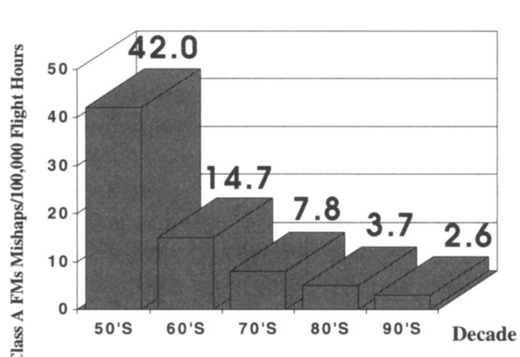

Figure 1. Average Flight Mishap Rate by Decade

Naval Aviation dramatically reduced its Class A Flight Mishaps (FM) over the past 50 years, and in fact has cut the rate in half each decade since 1950 (see Figure 1). [1]

This decline is mainly attributed to the adoption of several engineering and administrative controls (see Figure 2).[2]

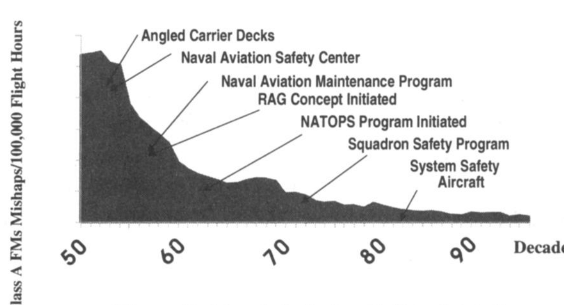

Figure 2. Naval Aviation Safety Initiatives

Unfortunately, it appears that the declining rate has leveled off in the mid-90s and that the much anticipated 50 percent reduction would not be realized this decade (see Figure 3).[1] Some view, in economic terms, that the present FM rate is a "fixed cost" of doing business that cannot be reduced.

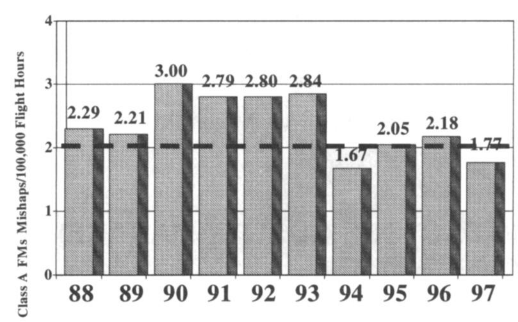

Figure 3. Class A Flight Mishap Rate for Last 10 FYs

In examining Naval Aviation Class A FMs for FYs 90-97, it was determined that Aircrew Error (58%) was a predominant causal factor, followed by Material Failures (38%) and Maintenance Error (16%). Supervisory Failures (60%), including aircrew management, aircraft design, maintenance management, and logistical support, were very pervasive (see Figure 4).[2] It is now accepted that 80% of Class A FMs are in part due to human error. For example, 23 of the 27 Class A FMs for FY 97 (85%) were directly attributable to human error.

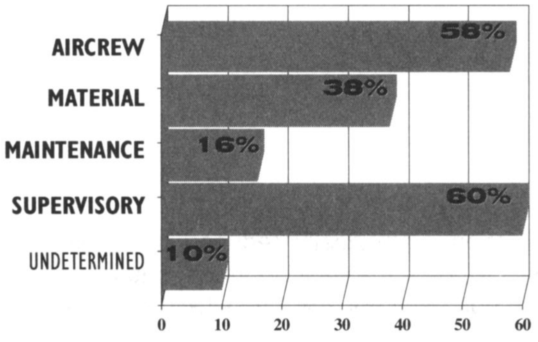

Figure 4. FY 90-97 Class A FM Determined Causal Factors

Partitioning all mishaps for the past three decades into those, which were purely due to material/mechanical failure or in part due to human error, reveals two distinct trends. Human error did not decline at the same rate as material/mechanical failure, and as of late, human error has not only leveled off but may be increasing (see Figure 5).[3] Consequently this recognized leveling off of the Naval Aviation mishap rate underscores the need to more effectively combat all forms of human error.

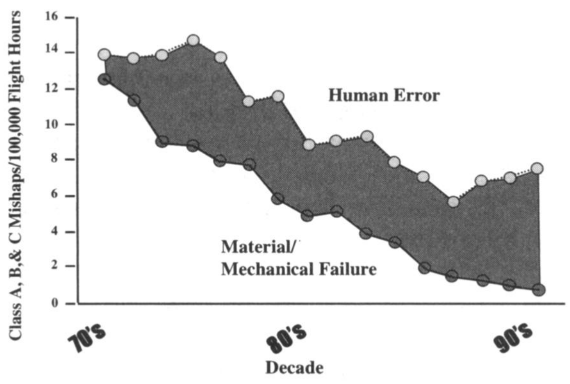

Figure 5. Human Error vs. Material Failure in Mishaps

HUMAN FACTORS QUALITY MANAGEMENT BOARD

Following the 1996 F-14 Mishap in Nashville, TN, the Commander, Naval Air Forces Pacific empanelled a Human Factors Quality Management Board (HFQMB) to identify human factors threats and develop interventions against them. The goal was to cut the mishap rate in half by reducing human error. The HFQMB adopted three processes to study human error in mishaps: mishap data analysis to identify hazards and risks, benchmarking to uncover best practices and find process improvements, and climate assessment to evaluate safety posture. Given the total number of Class A FMs having aircrew error, Naval Aviation leadership targeted it first along with related supervisory error.[4]

The HFQMB had encouraging results in its first 18 months of existence. The Navy FM rate dropped to its lowest point ever, and overall, Naval Aviation had its second best FM rate in history. This success, coupled with a Naval Air Systems Command drive to address issues related to aging aircraft, compelled the HFQMB to examine maintenance related mishaps (MRMs) using the same processes.[5]

HUMAN FACTORS ACCIDENT CLASSIFICATION SYSTEM - MAINTENANCE EXTENSION

The Human Factors Accident Classification System (HFACS) was developed by the Naval Safety Center to analyze human errors contributing to Naval Aviation FMs. HFACS incorporates features of Bird's "Domino Theory," Edward's "SHEL Model," and Reason's "Swiss Cheese Model." Latent conditions and active failures are partitioned into one of three top-level categories (see Figure 6).[6]

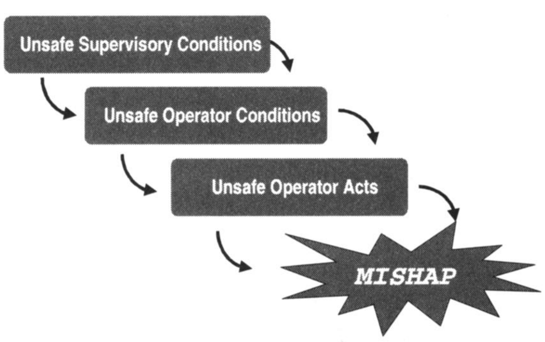

Figure 6. HFACS Top-Level Categories

These categories enable an analyst to identify failures at each of the three levels historically related to accidents: supervisory condition, operator condition, and operator act. These classifications are then used to target appropriate intervention strategies.

A Maintenance Extension taxonomy for HFACS was developed to classify causal factors that contribute to MRMs. This addition to HFACS consists of four broad human error categories: Supervisory Conditions (latent), Working Conditions (latent), Maintainer Conditions (latent), and Maintainer Acts (active). The three orders of maintenance error: first, second, and third reflect a decomposition of the error types from a molar to a micro perspective (see Table 1).[7]

Table 1. HFACS Maintenance Extension Categories

First Order	Second Order	Third Order
Supervisory Conditions	Unforeseen	Hazardous Operations Inadequate Documentation Inadequate Design
	Squadron	Inadequate Supervision Inappropriate Operations Failed to Correct Problem Supervisory Violation
Maintainer Conditions	Medical	Mental State Physical State Physical/Mental Limitation
	Crew Coordination	Communication Assertiveness Adaptability/Flexibility
	Readiness	Preparation/Training Qualification/Certification Violation
Working Conditions	Environment	Lighting/Light Exposure/Weather Environmental Hazards
	Equipment	Damaged Unavailable Dated/Uncertified
	Workspace	Confining Obstructed Inaccessible
Maintainer Acts	Error	Attention Memory Rule/Knowledge Skill
	Violation	Routine Infraction Exceptional

The following paragraphs provide a brief illustration of the HFACS Maintenance Extension taxonomy levels:

Latent Supervisory Conditions that can contribute to an active failure includes both unforeseen and squadron.

Examples of unforeseen supervisory conditions include:

- An engine that falls off of a stand during a change-out evolution due to an unforeseen hazard of a high seas state (Hazardous Operation)
- A manual omits a step in a maintenance procedure, such as leaving out an o-ring that causes a fuel leak (Inadequate Documentation)
- The poor layout of system components that do not permit direct observation of maintenance being performed (Inadequate Design)

Examples of squadron supervisory conditions include:

- A supervisor who does not ensure that maintenance personnel are wearing required personal protective gear (Inadequate Supervision)
- A supervisor who directs a maintainer to perform a task without considering risks, such as driving a truck through a hangar (Inappropriate Operations)
- A supervisor who neglects to correct maintainers who routinely bend the rules when they perform a common task (Failed to Correct Problem)
- A supervisor who willfully orders a maintainer to wash an aircraft without proper safety gear (Supervisory Violation)

Latent Maintainer Conditions that can contribute to an active failure include medical, crew coordination, and readiness.

Examples of maintainer medical conditions include:

- A maintainer who has a marital problem and cannot focus on a maintenance action (Mental State)
- A maintainer who worked for 20 hours straight and suffers from fatigue (Physical State)
- A maintainer who is short can not visually inspect aircraft before it is launched (Physical Limitation).

Examples of maintainer crew coordination conditions include:

- A maintainer who leads a taxiing aircraft into another due to improper hand signals (Communication)
- A maintainer who performs a task, not in accordance with standard procedures, because the maintainer was overly submissive to a superior (Assertiveness)
- A maintainer who downplays a downing discrepancy to meet the flight schedule (Adaptability)

Examples of maintainer readiness conditions include:

- A maintainer who is working on an aircraft skipped the requisite OJT evolution (Training)
- A maintainer who engages in a procedure that they have not been qualified to perform (Certification)
- A maintainer who is intoxicated on the job (Violation)

Latent Working Conditions that can contribute to an active failure include environmental, equipment, and workspace.

Examples of environmental working conditions include:

- A maintainer who is working at night on the flightline does not see a tool he left behind (Lighting/Light)
- A maintainer who is securing an aircraft in a driving rain fails to properly attach the chains (Weather)
- A maintainer who is working on a pitching deck falls from the aircraft (Environmental Hazard)

Examples of equipment working conditions include:

- A maintainer who is using a defective test set does not precheck it before troubleshooting (Damaged)
- A maintainer who starts working on landing gear without a jack because all in use (Unavailable)
- A maintainer who uses an old manual because a CD-ROM reader is not available (Dated)

Examples of workspace working conditions include:

- A maintainer who is working in a hangar bay cannot properly position the maintenance stand (Confining)
- A maintainer who is spotting an aircraft with his view obscured by catapult steam (Obstructed)
- A maintainer who is unable to perform a corrosion inspection that is beyond his reach (Inaccessible)

Maintainer Acts are active failures, which directly or indirectly cause mishaps, or lead to Latent Maintenance Condition, they include errors and violations.

Examples of errors in maintainer acts include:

- A maintainer who misses a hand signal and backs a forklift into an aircraft (Attention)
- A maintainer who is very familiar with a procedure may reverse steps in a sequence (Memory)
- A maintainer who inflates an aircraft tire to a pressure required by a different aircraft (Rule)
- A maintainer who roughly handles a delicate engine valve causing damage (Skill)

Examples of violations in maintainer acts include:

- A maintainer who engages in practices, condoned by management, that bend the rules (Routine)
- A maintainer who strays from accepted procedures to save time, bending a rule (Infraction)
- A maintainer who willfully breaks standing rules disregarding the consequences (Exceptional)

Following the HFACS Maintenance Extension Model Supervisory, Maintainer, and Working Conditions are latent factors that can impact a maintainer's performance and can contribute to an active failure, an Unsafe Maintainer Act (see Figure 7).[7]

Figure 7. HFACS Maintenance Extension Model

An Unsafe Maintainer Act may lead directly to a mishap or injury. For example, a maintainer runs a forklift into the side of an aircraft and damages it. The Unsafe Maintainer Act could also become a latent Maintenance Condition, which the aircrew would have to deal with on take-off, in-flight, or on landing. For example, an improperly rigged landing gear that collapses on touchdown or an over-torqued hydraulics line that fails in flight causing a fire. It is important to note that Supervisory Conditions related to design for maintainability, prescribed maintenance procedures, and standard maintenance operations could be inadequate and lead directly to a Maintenance Condition.

HFACS ANALYSIS OF CLASS A FY 90-97 MRMS

During FY 90-97 there was a total of 63 Class A Mishaps, of which 61 were Flight, 0 were Flight Related, and 2 were Aircraft Ground. Two Navy Maintenance Officers and two Navy Chiefs used the HFACS Maintenance Extension to classify the human factors causes reported in these mishaps (see Figure 8).[7]

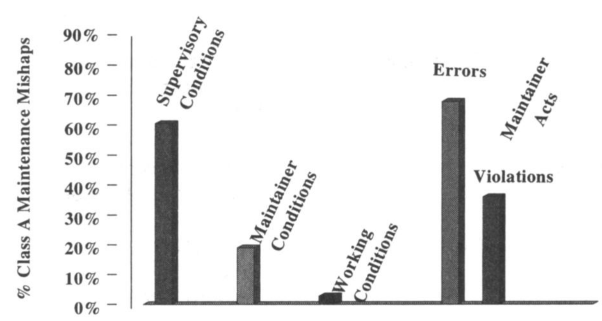

Figure 8. HFACS Profile Of Class A MRMs

They discovered the following profile of human errors in MRMs:

Supervisory Conditions – 67% of all Naval Aviation Class A MRMs reported Squadron Supervisory Conditions, whereas 21% had Unforeseen Supervisory Conditions (not shown).

Maintainer Conditions – 21% of all Naval Class A MRMs reported Medical, CRM, or Readiness Maintainer Conditions. *Note: Maintainer Conditions were under reported, more are likely present and have an effect.*

Working Conditions – 3% of all Naval Class A MRMs reported Environment, Equipment, or Workspace Working Conditions. *Note: Workspace Conditions were under reported, more are likely present and have an effect.*

Maintainer Acts – 75% of all Naval Aviation Class A MRMs reported Maintainer Errors, whereas 40% had Maintainer Violations.

Clearly, latent conditions in the form of Supervisory, Maintainer, and Workspace factors are present that can impact maintainers in the performance of their jobs. However, many Maintainer and Workspace Conditions are not reported due to the reporting system in place, perceptions of accident causation, or culture/climate issues. Specifically, inadequate supervision of maintenance evolutions, not ensuring personnel are trained and/or qualified, not enforcing rules, and poor communication characterize the majority of latent Supervisory Conditions. Poor passdown, coordination, and communication; non-use or lack of publications, policies, and procedures; and fatigue comprise most latent maintainer conditions. Finally, most Maintainer Errors reflect a lack of training, experience, and skill, whereas Maintainer Violations consist of routine non-compliance with standard procedures and practices, and infractions, bending the rules in order to meet mission requirements and the flight schedule.

CONCLUSIONS

The HFACS Maintenance Extension was effective in capturing the nature of and relationships among latent conditions and active failures present in Class A MRMs. The insights gained provide a solid perspective for the development of potential intervention strategies. The major mishaps analyzed were primarily FMs, meaning that many imposed in-flight Maintenance Conditions on aircrew. During FYs 90-97 there were almost 500 MRMs in Naval Aviation, many of which were of lesser severity and were either Flight Related or Aircraft Ground Mishaps. Such mishaps involve primarily ground and ramp activities and can lead directly to a mishap or injury. Consequently, the present profile and observed relationships only hold for the mishaps considered and cannot be generalized to all MRMs. Further, it can be contended interventions developed for major mishaps that primarily involving maintenance activities such as engine repair are likely not appropriate for ones of lesser severity that involve other activities such as loading ordnance or towing aircraft. Presently, an in-depth analysis of all MRMs is underway and it is planned to contrast major vs. minor MRMs, MRMs occurring during maintenance, stores, and ramp activities, and MRMs for specific communities.

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