



# ***The Naval Aviation Approach to Error Management***

CAPT John K. Schmidt, MSC USN  
Naval Aerospace Medical Institute

NASA 5<sup>th</sup> Risk Management Conference  
October 26-29, 2004

Glenn Research Center, Ohio

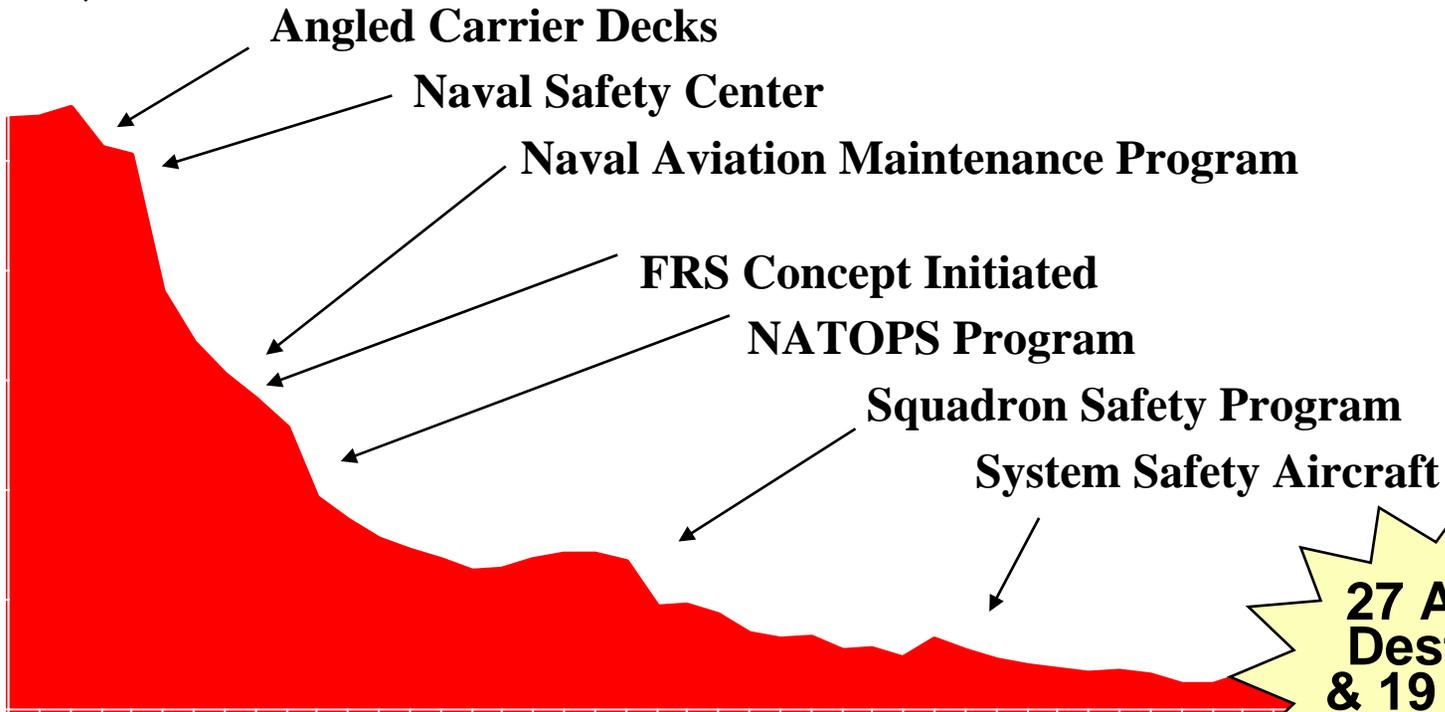
*“Risk Management in the Renewed Spirit of Discovery.”*

# Naval Aviation Class A Flight Mishaps

FY50-04

**776 Aircraft  
Destroyed  
in 1954**

Class A Flight Mishaps /100,000 Flight Hours



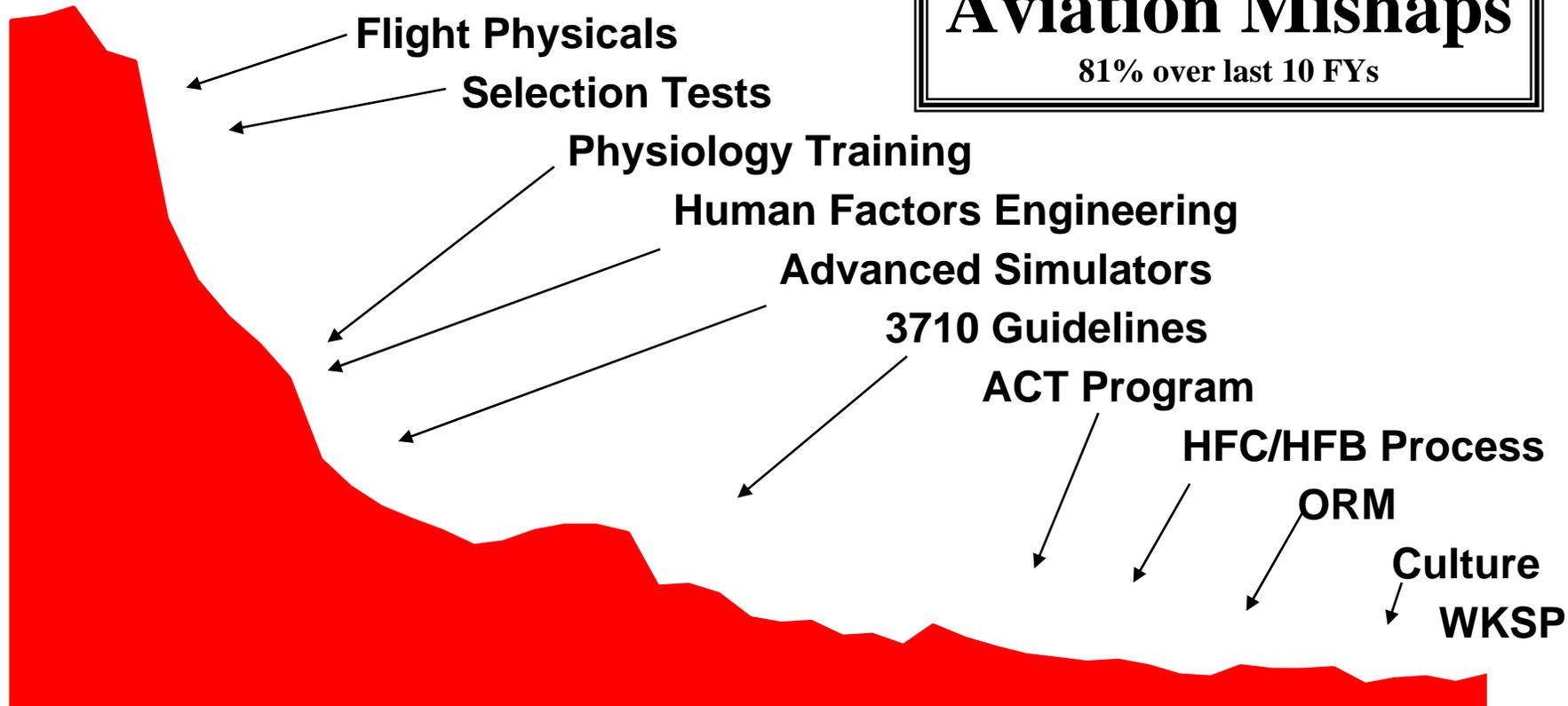
**27 Aircraft  
Destroyed  
& 19 Deaths  
in 2004**

**Predominant Use of Engineering & Administrative Controls**

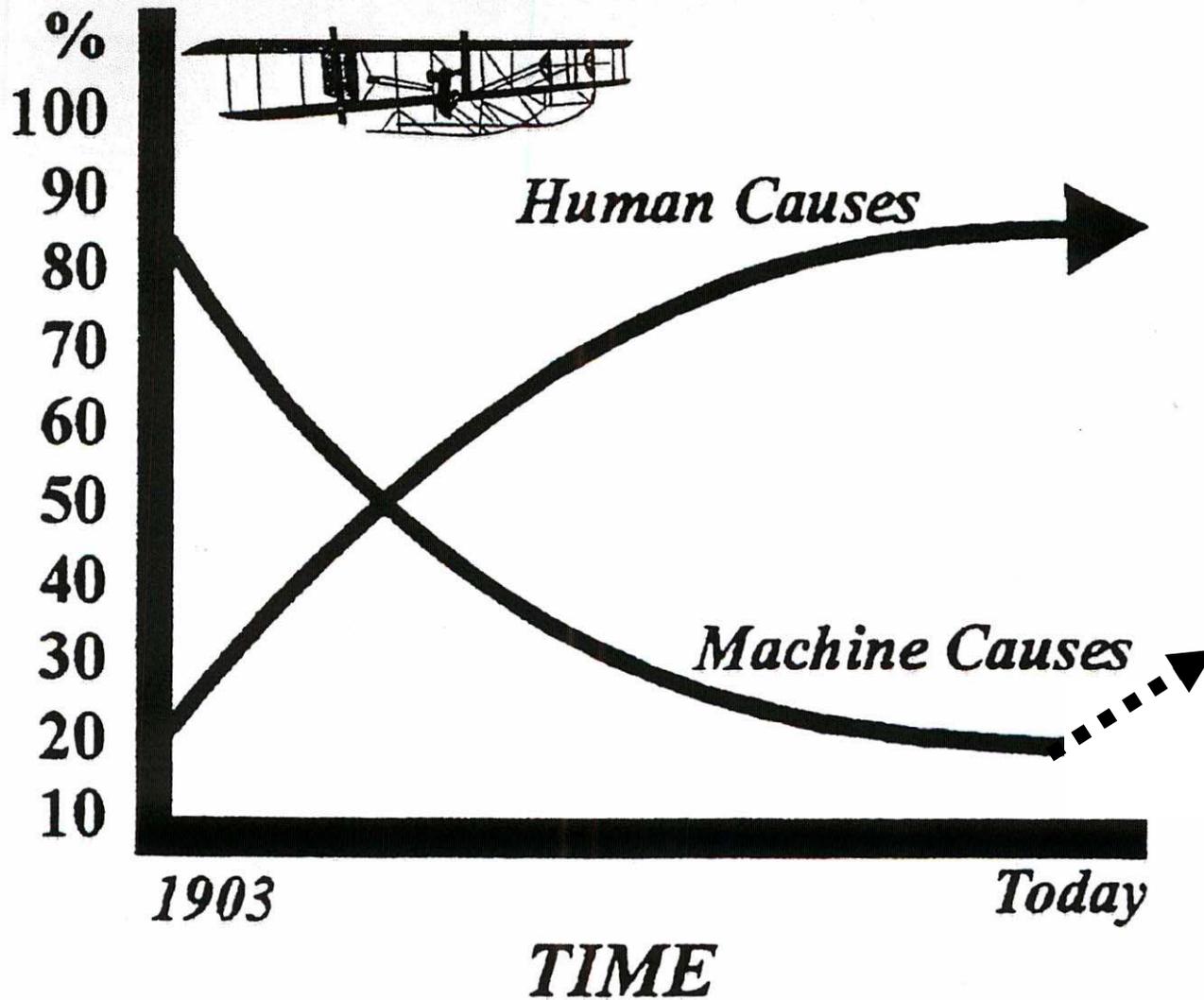
# Naval Aviation Human Factors Control Measures

**Human Factors  
Involved in 4 of 5  
Aviation Mishaps**

81% over last 10 FYs



# AVIATION ACCIDENTS

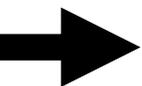


# United Space Alliance Board of Directors Brief

(27 JAN 03\*)

- Recent Trends in Naval Aviation & Aerospace Industry-

- Aircraft Procurements: Quantity & Rate
- Aging Aircraft & Service Life Extensions
- Greater Demands on Overhaul & Repair
- Greater Need for Preventive Maintenance
- Increased Inspection Requirements
- Increased Maintenance Requirements
- Personnel Shortages & Experience Gap



FOCUS: Naval Aviation Human Factors in  
Maintenance and Error Prevention Efforts



**STS-107**  
**January 16 -**  
**February 1, 2003**



# Maintenance Lessons Learned from the Columbia Accident Investigation

**2004 Department of Defense Maintenance Symposium & Exhibition**  
Houston, TX  
25 Oct 2004

**LtCol Chris Mardis, USAF**

86<sup>th</sup> Maintenance Squadron Ramstein AFB, Germany

**LtCol Larry Butkus, USAF**

Aeronautical Systems Center, Wright-Patterson AFB, OH

**Col Dave Nakayama, USAF**

Warner Robins Air Logistics Center, Robins AFB, GA

**Col Tim Bair, USAF (Ret)**

Applied Research Laboratory Pennsylvania State University, State College, PA

**CAPT John Schmidt, USN (Session Chair)**

Naval Operational Medicine Institute, NAS Pensacola, FL



# **Human Factors Quality Management Board: Aviation Maintenance Working Group**

## **Three Prong Approach**

### **Human Error Analysis**

**Adopted MX Extension of the Human Factors  
Analysis & Classification System (HFACS-ME)  
For Investigating, Reporting, & Analyzing Mishaps**

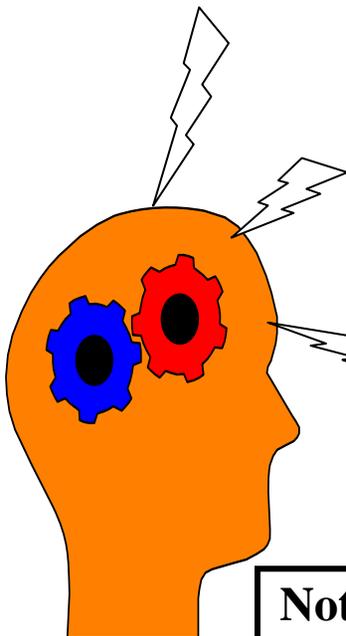
### **Safety Climate Assessment**

**Developed On-Line Maintenance  
Climate Assessment Survey (MCAS)  
to Proactively Assess MX OPS**

### **Best Practices Benchmarking**

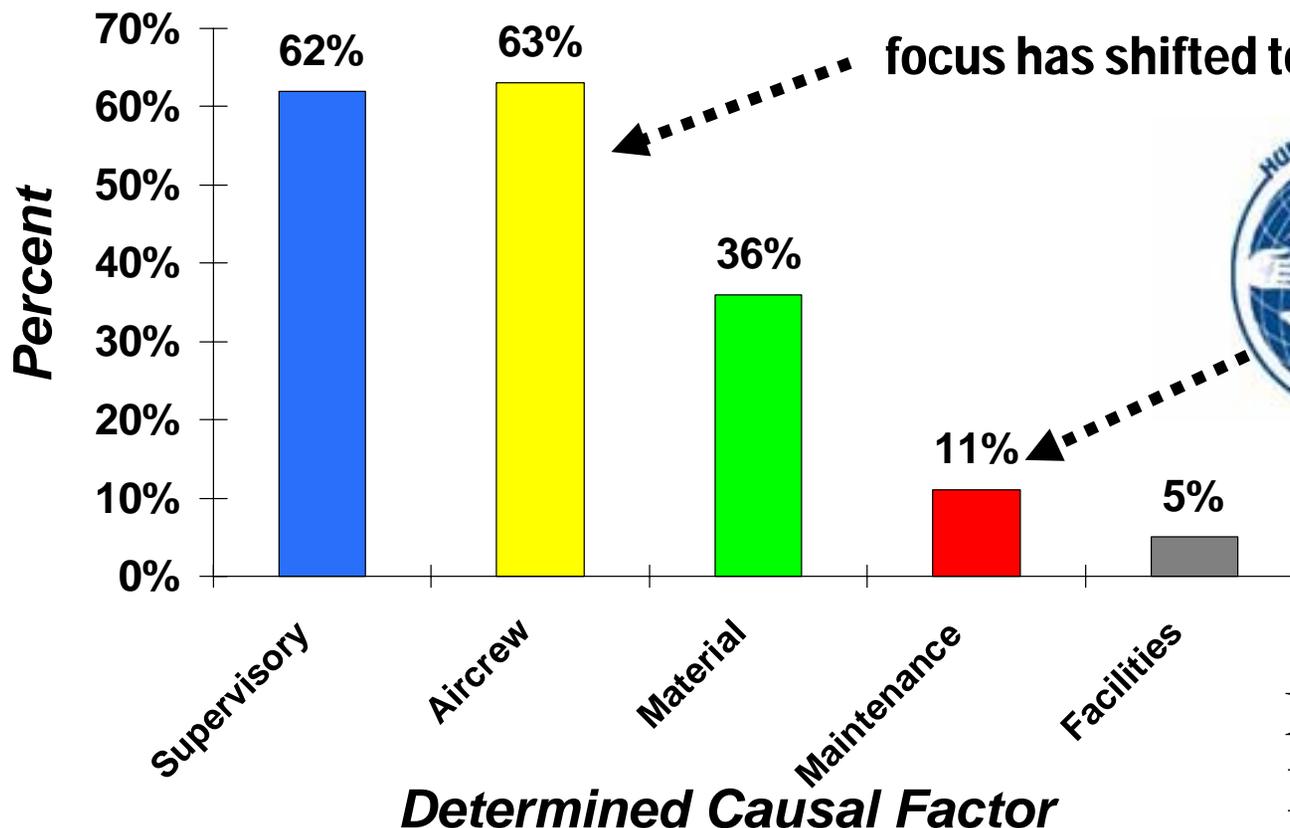
**Adapted Crew Resource Management  
Training for MX (MRM) to Enhance  
Teamwork & Hazard Awareness**

**Note: Meets ATA SPEC 113 Maintenance Human Factors Program Guidelines**



# Mishap Data Analysis Focus: Naval Aviation Class A FM Causal Factors FY 95-04

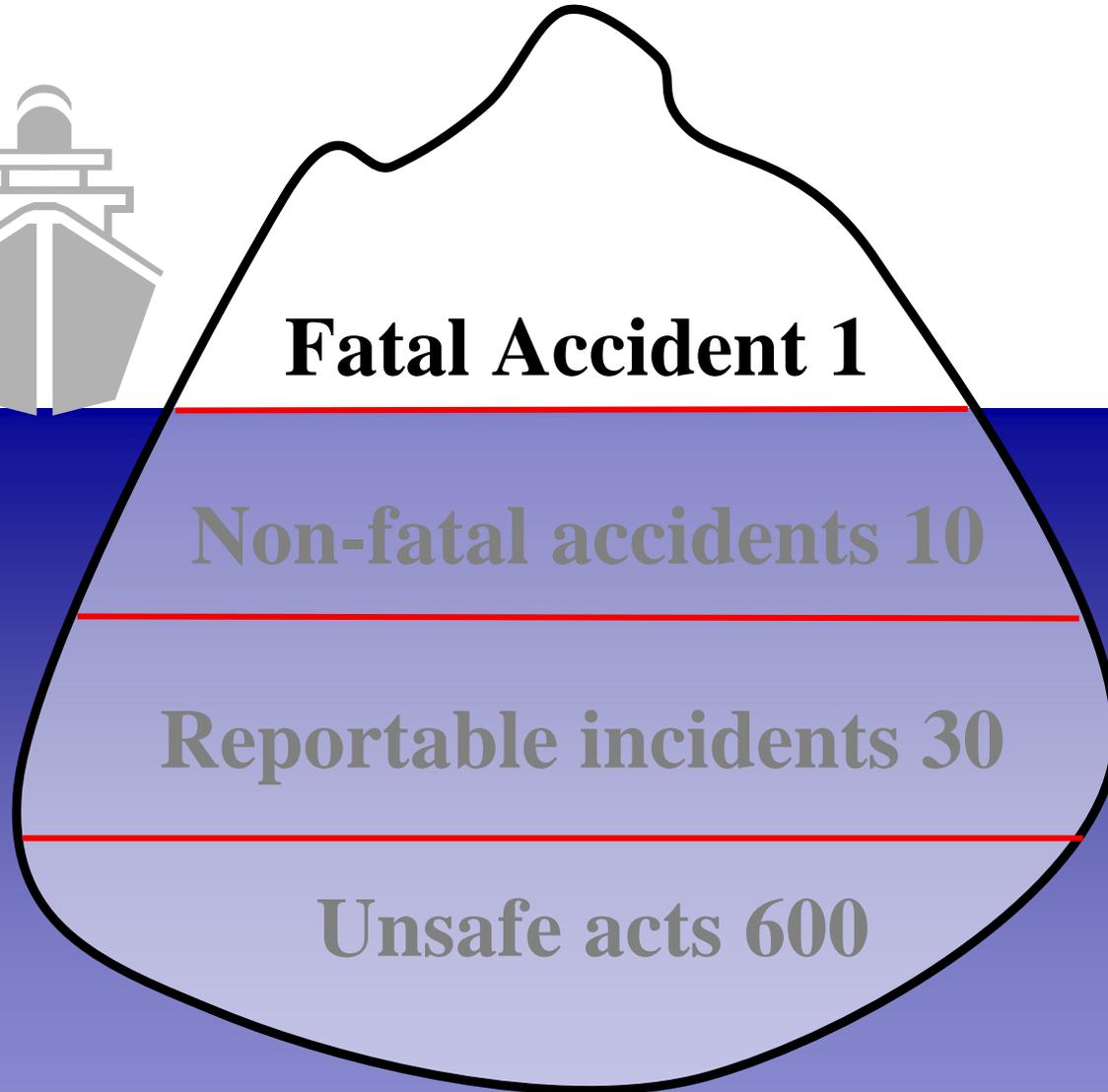
Initial emphasis on "Pilot Error,"  
but to continue cutting mishaps the  
focus has shifted to:



MX in 24% of All  
FY95-04 Mishaps

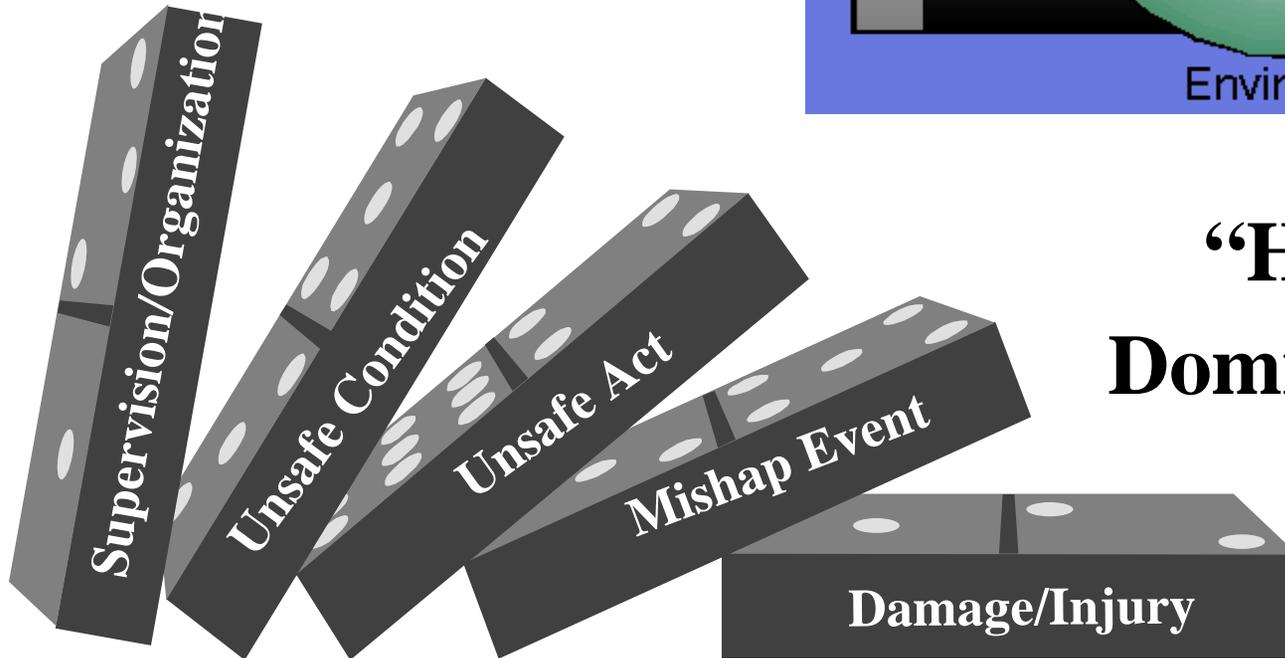
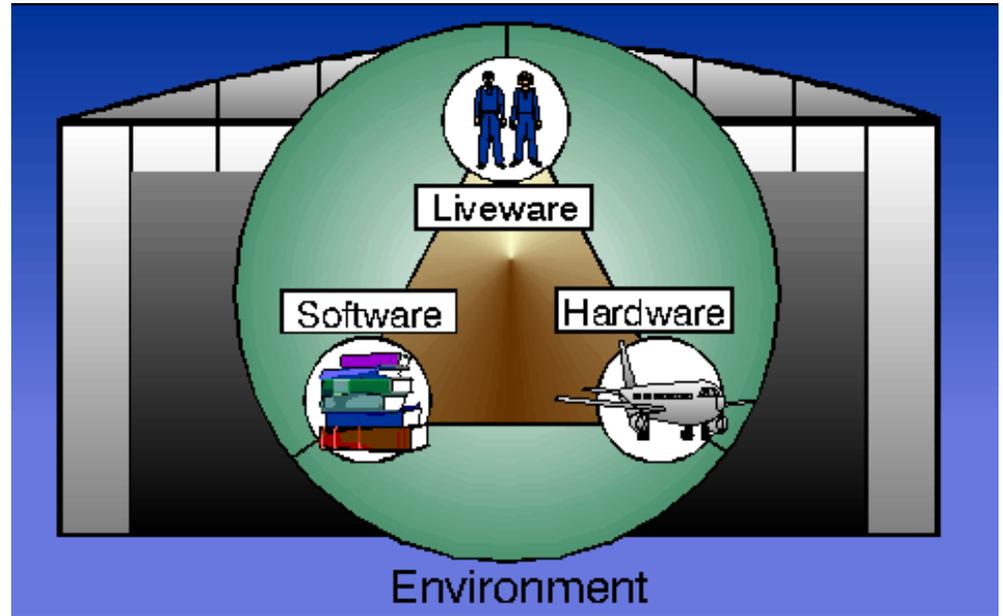
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# The Heinrich Ratio



# Accident Models

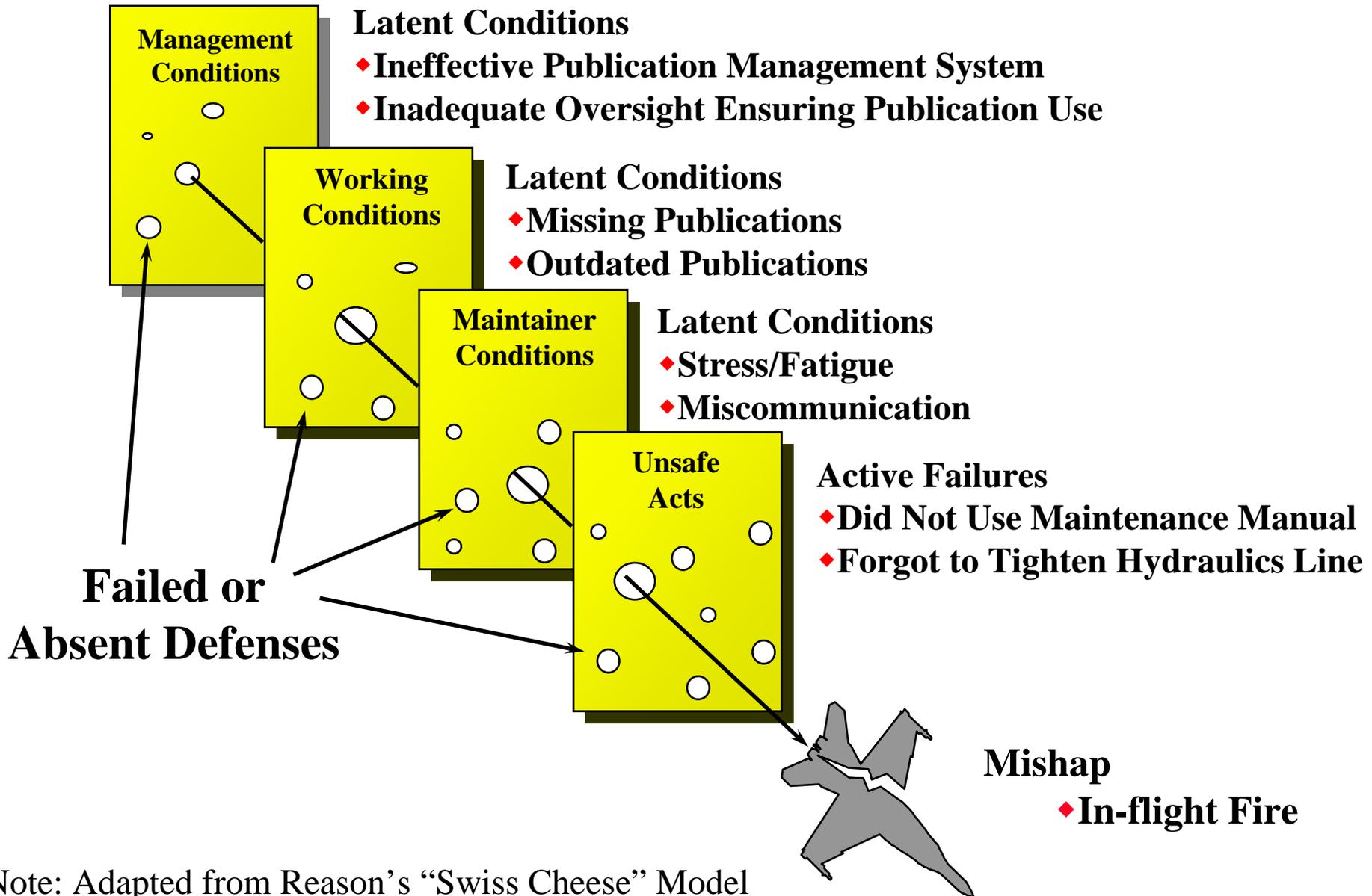
## “Edward’s Shell Model”



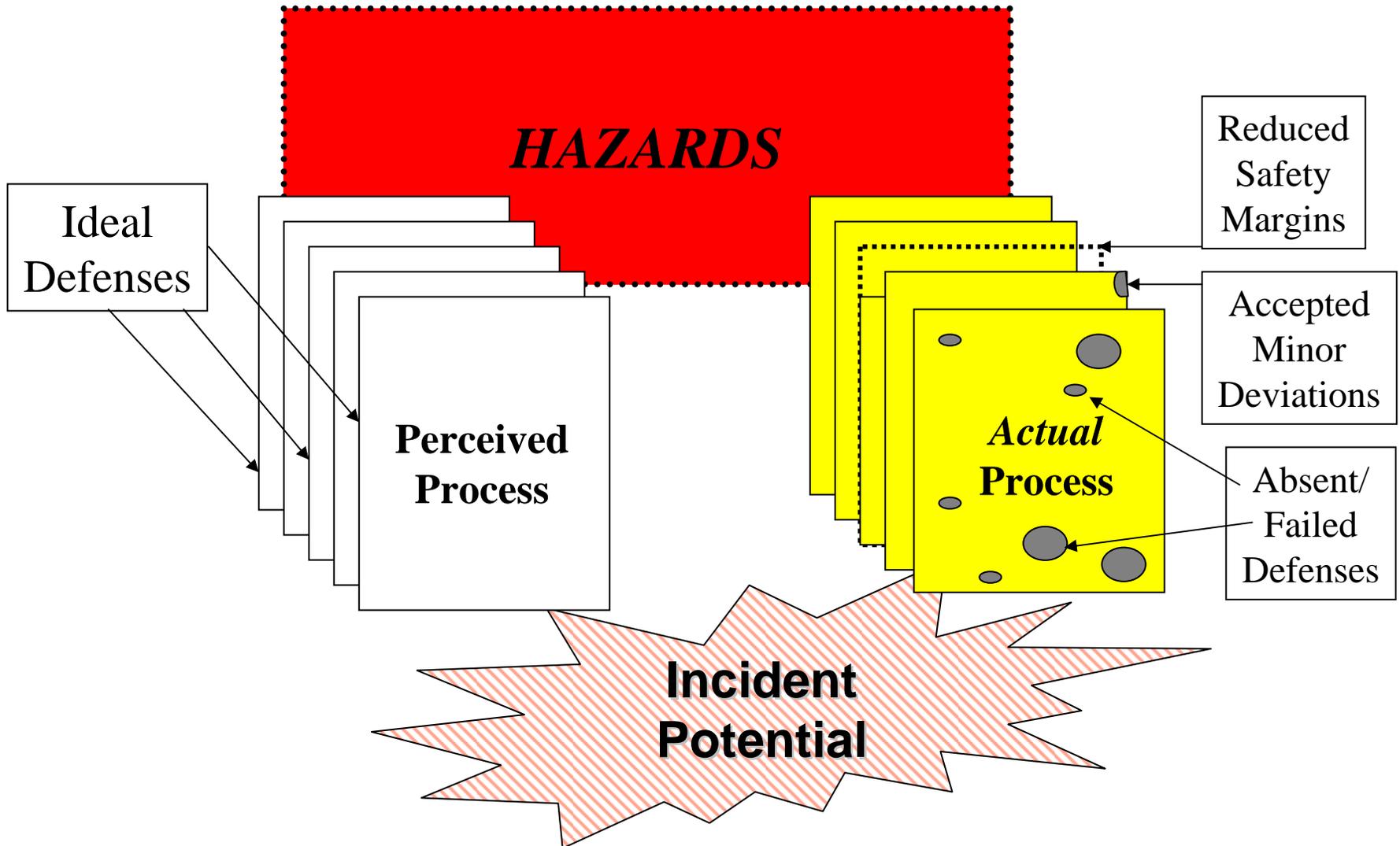
## “Heinrich’s Domino Theory”

# Human Factors Analysis & Classification

## *System Maintenance Extension*



# Potential for Defense Breaches



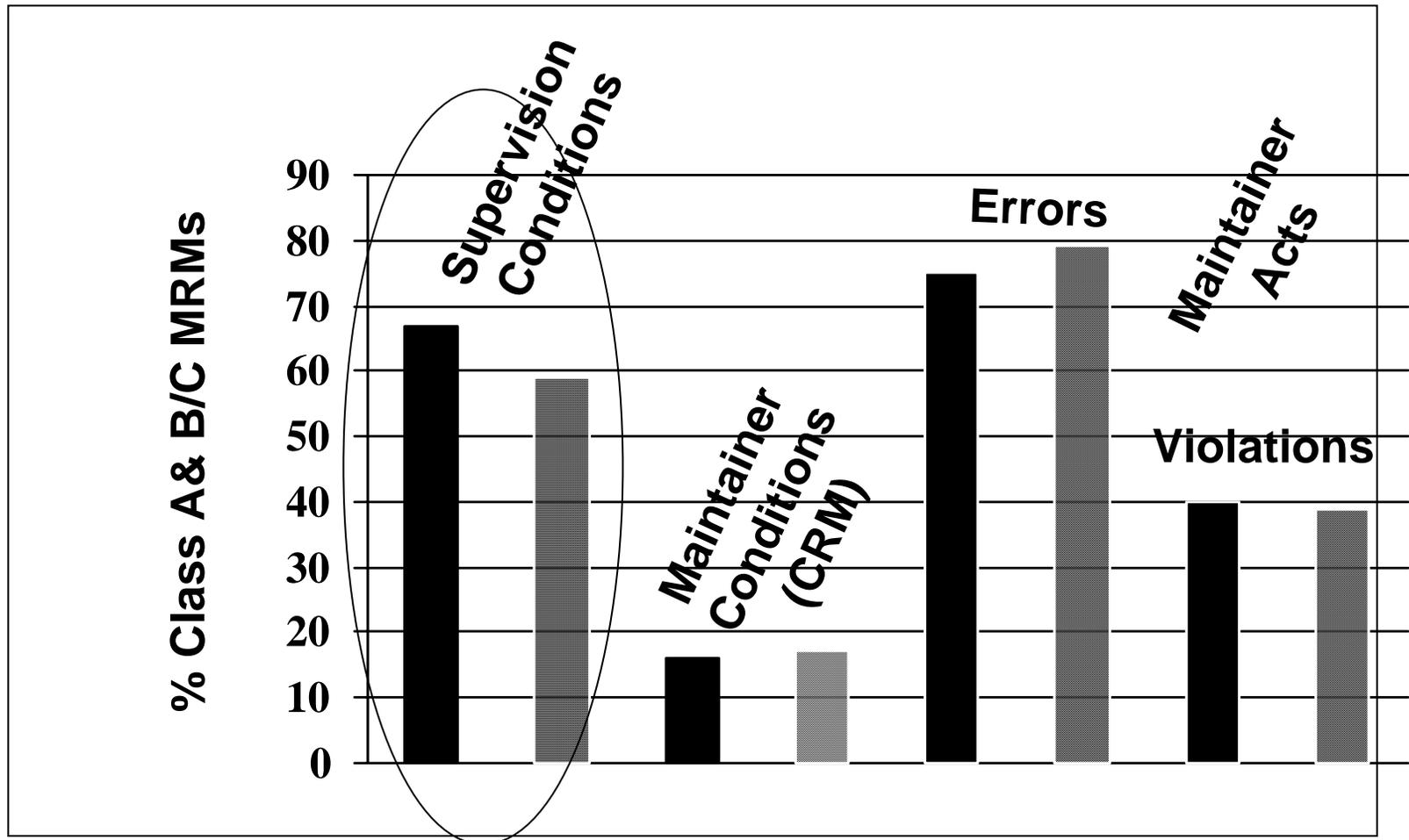


# Maintenance Lessons Learned

## Losing Focus – Culture as a Factor

- Inadequate concern over deviations (foam loss)...
  - Repeated occurrences; most serious on STS-112
  - Violated original design requirement, but never fixed
  - With each successful landing, NASA became more accepting of foam loss as inevitable and unlikely to jeopardize safety
  - Had become “in-family” over time; connotation of less seriousness
  - Nearly identical w/o-ring seal problems resulting in Challenger’s loss
  - Diane Vaughn, noted sociologist: the “normalization of deviance”
- A silent safety program
  - NASA’s safety culture had become reactive, complacent, and dominated by unjustified optimism
- Bureaucratic accountability
  - An allegiance to hierarchy, procedure, & chain of command
  - Diffused accountability through extensive coordination, no one person in-charge

# HFACS-ME Profile: Class A vs. B/C Maintenance Mishaps





# Preliminary HFACS-ME Analysis of All FY 90-02 Maintenance Mishaps

- 294 of all Naval Aviation Maintenance Mishaps Involved a Publications Problem (28%)

TPDs	#	%
Technical data is inaccurate or not established	134	46
Maintenance procedures unclear, incomplete or out of sequence	93	32
Inspection procedures are inadequate or not established	54	18
Hazards/Warnings not included in maintenance procedures	13	4



# Maintenance Mishaps Involving Publications Activity Breakout



- Inspection 31%
- Installation 23%
- Troubleshoot 10%
- Servicing 08%
- Repair 05%
- Removal 04%
- Assembly 04%



# **NATEC Technical Manual Status**

## ***As of 20 DEC 01***

### **■ Outstanding Actions**

**■ 2,761 Interim Rapid Action Changes**

**■ 18,780 Tech Pub Deficiency Reports  
(including 218 CAT I)**

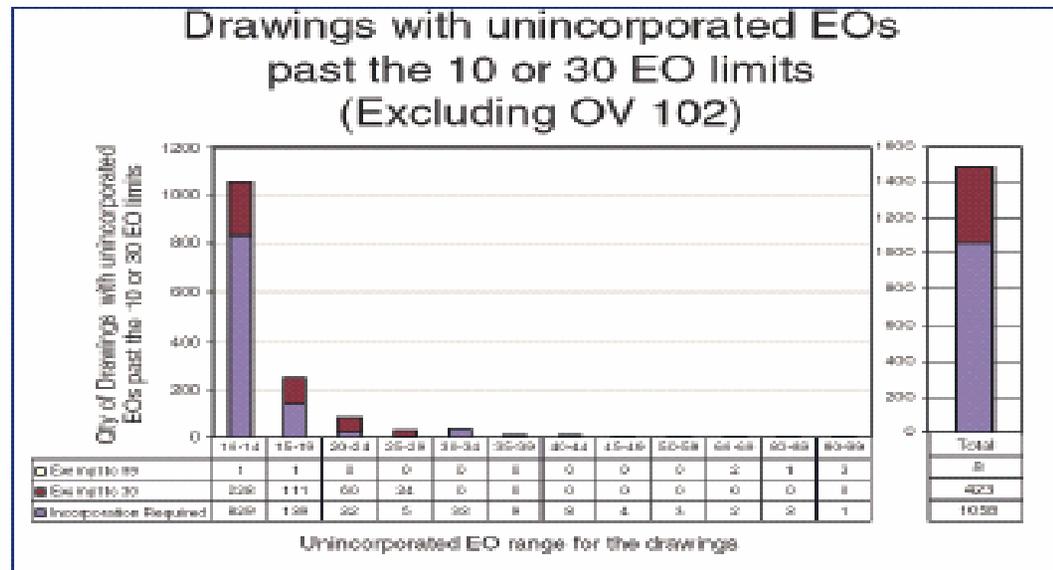
**■ 5,683 Publications Require Update**



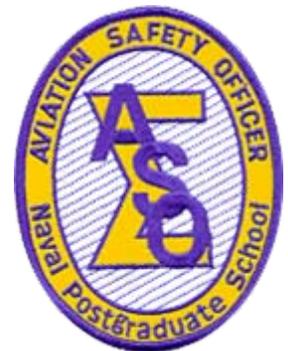
# Maintenance Lessons Learned

## ...Tech Data

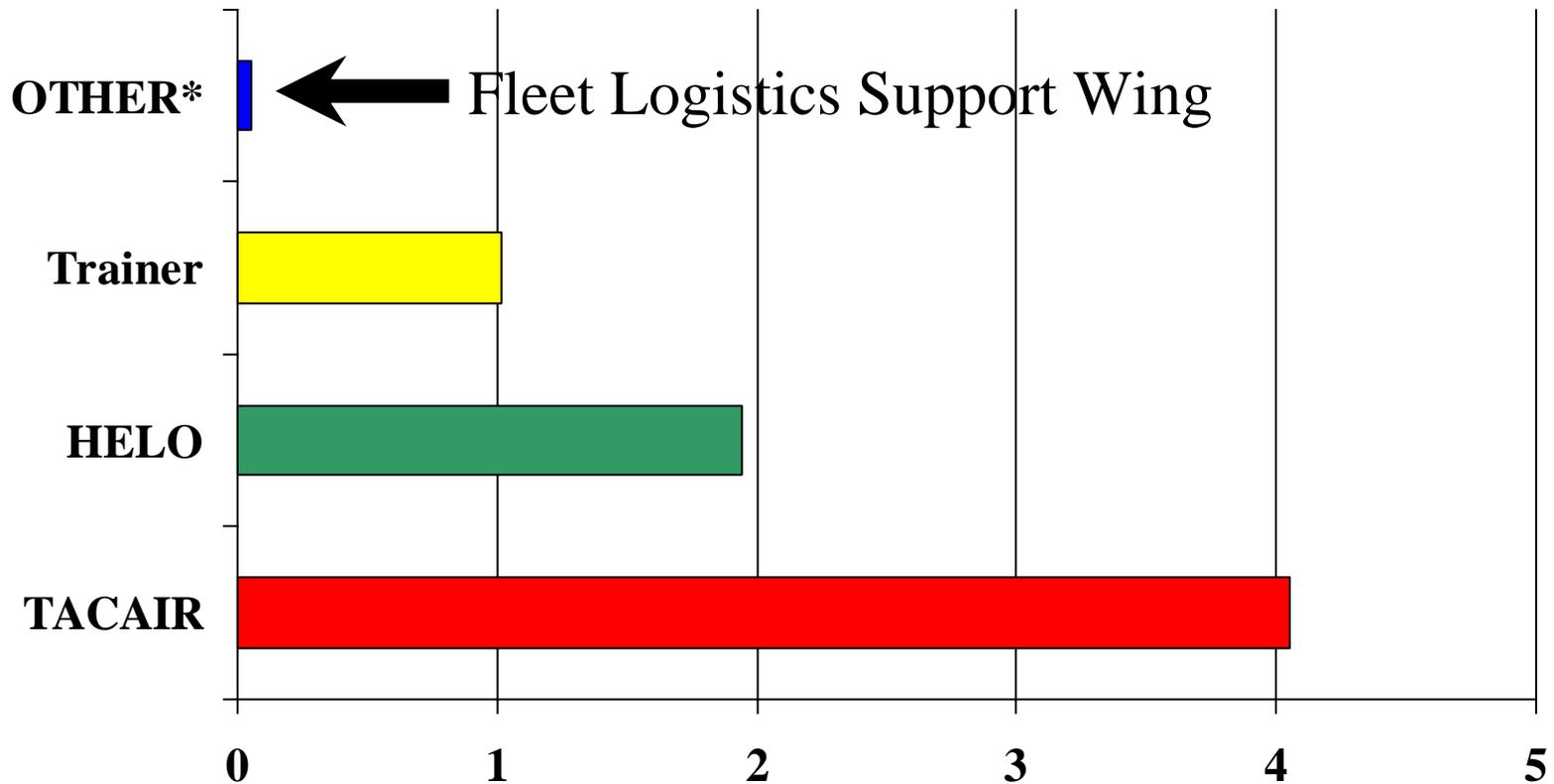
- Engineering drawings are used as source data for WADs.
- The CAIB found a significant backlog of Unincorporated Engineering Orders (UEOs)
  - Significant challenge to work with numerous UEOs
  - Plan to incorporate changes based on highest use and complexity was hampered by funding



# Benchmarking VR Community Maintenance Operations

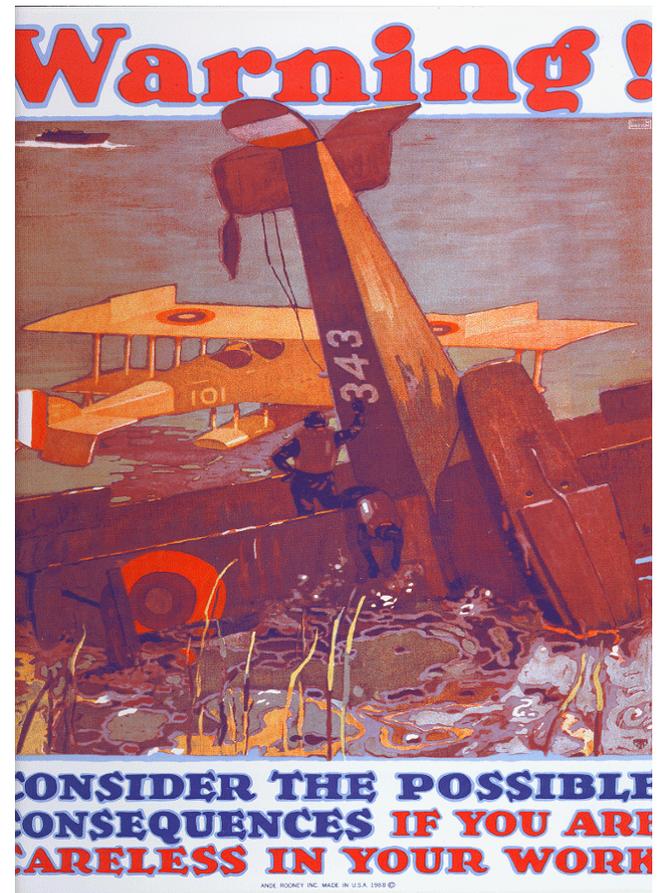


# Class A FM Rate Community Comparison

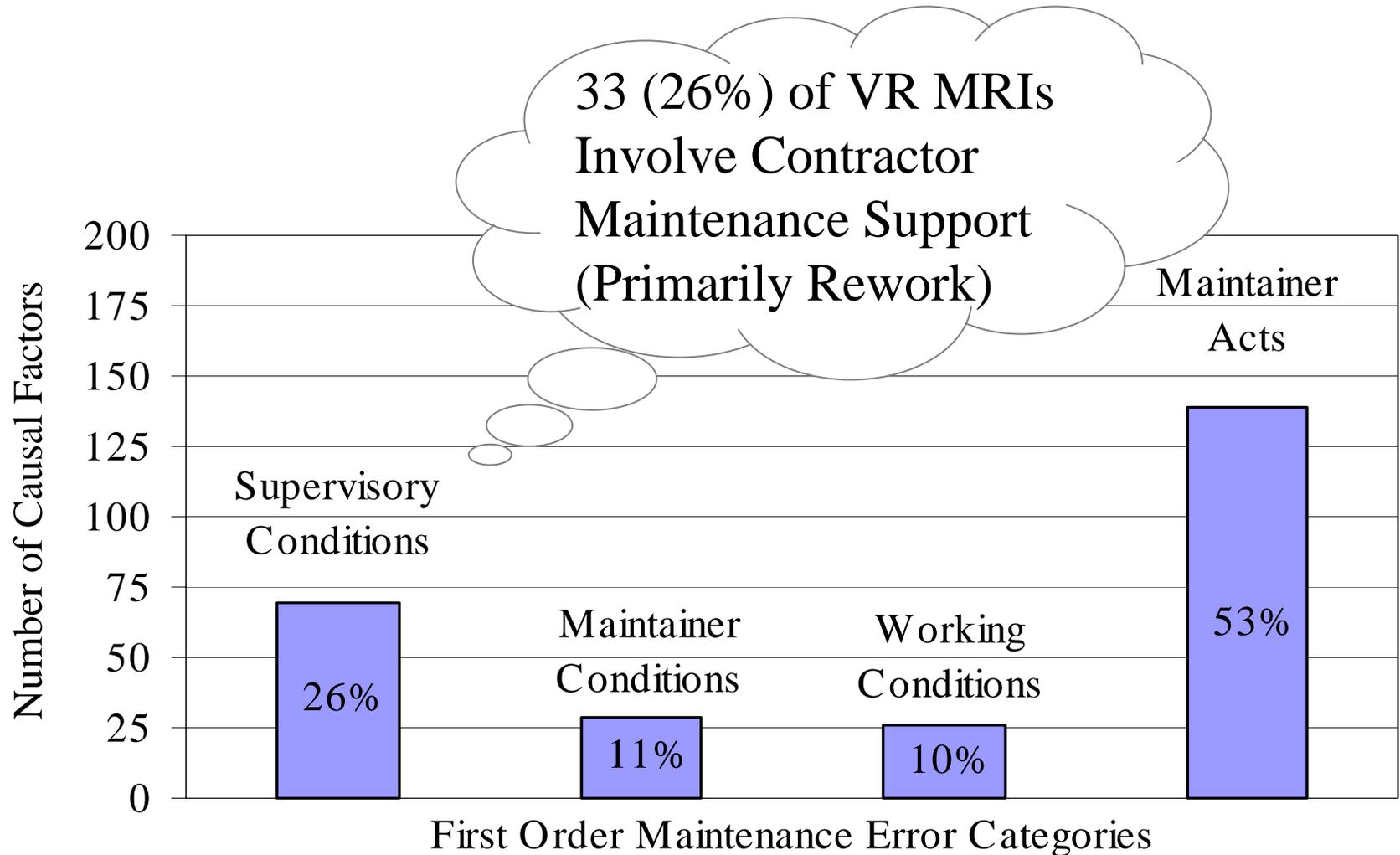


# Analysis of VR Wing MRIs (FY 90-98)

- **124 Maintenance Related Incidents (MRIs) Involving VR A/C Were Analyzed**
- **Classification Performed by Maintenance & Safety Staff**



# 1st Order HFACS-ME Category Distribution for All VR MRIs



# VR MRI Analysis General Findings

- **Contractor Rework** (e.g., tool control, FOD, etc.)
- **Crew Coordination** (e.g., pass-down, shift turnover, etc.)
- **Maintenance Publications** (e.g., outdated, missing, etc.)
- **Maintenance Procedures** (e.g., non-existent, not clear, etc.)
- **Procedural Violations** (e.g., not following policy, checklists, etc.)
- **Maintainer Training** (e.g., OJT, community transition, etc.)





# Maintenance Lessons Learned

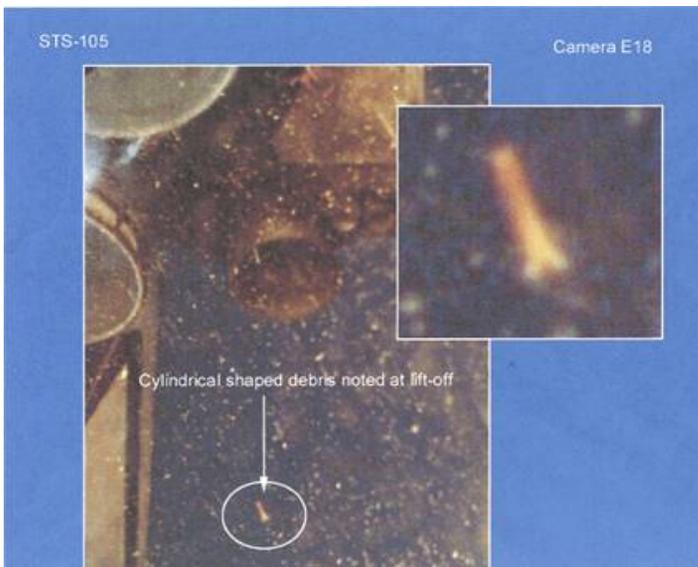
## ...FOD VS PROCESS DEBRIS

FOD prevention is highly emphasized in USA/NASA daily operations and assessment of responsibility is delineated: S&MA (NASA) responsible for FOD and SQ&MA (USA) primarily responsible for Process Debris

**“FOD” -- After job is stamped**

**“Processing Debris” -- before job signoff or end of shift**

NASA inspects and assesses FOD failures only after USA has closed a WAD



“FOD” is an industry standard term – basis for prevention programs and immediately recognized as critical part of mishap prevention

Commonly expressed opinion: FOD was redefined to accommodate SFOC award fee determination



80%

3.50

R.O.I.

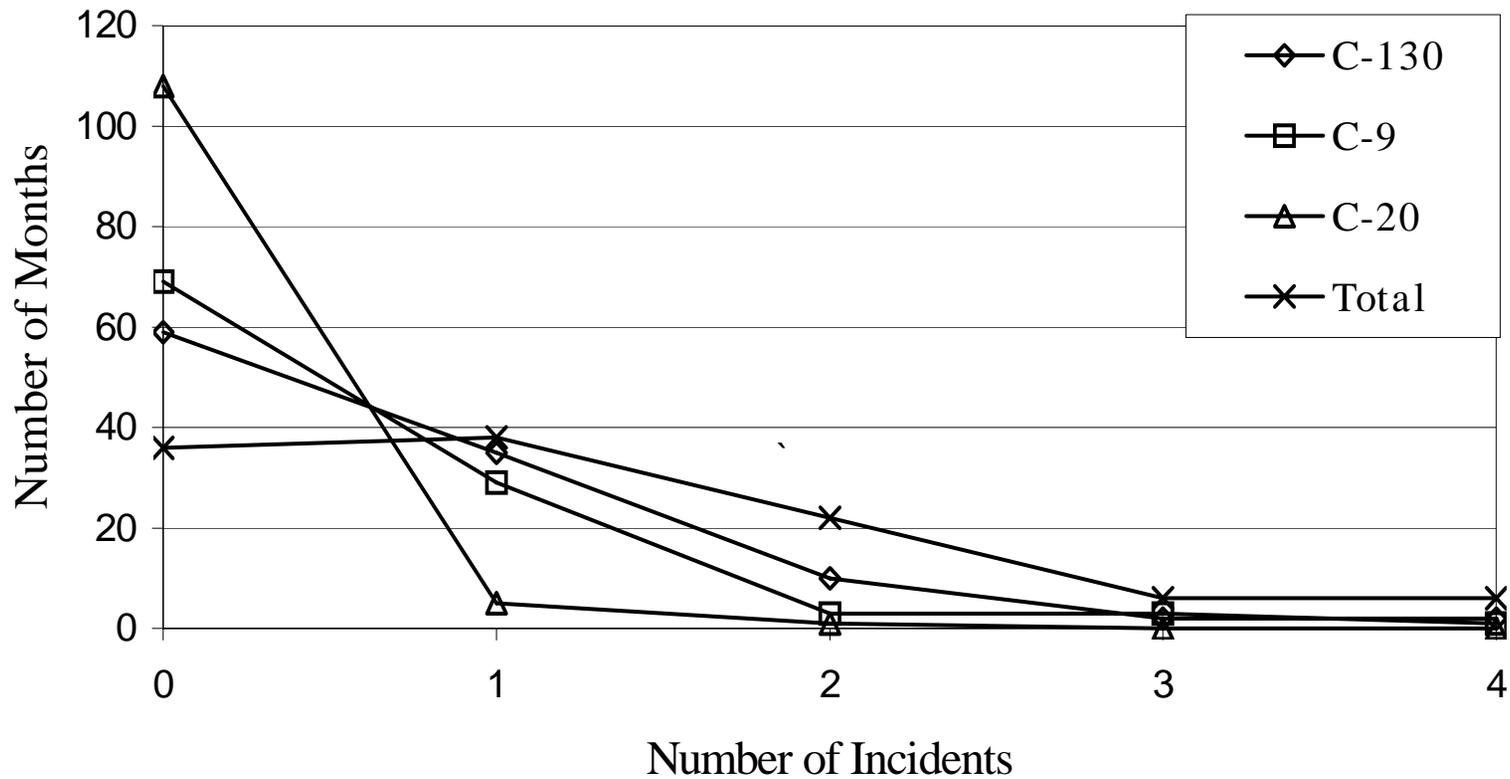
\$89 = \$72,000

\$

5,000  
20,000  
50,000  
80,000,000

100,000,000!!!!  
25,000 + 52,000

# Monthly MRI Distribution by Community



# Predicted Incident Rate for Reductions in Contractor Errors

Model	1st Year		2nd Year		3rd Year		Total	
	Rate	Incidents	Rate	Incidents	Rate	Incidents	Rate	Incidents
Status Quo	13.30	14	13.27	14	13.39	14	13.32	41
30% Reduction	12.41	13	12.38	13	12.50	13	12.43	38
50% Reduction	11.65	12	11.62	12	11.73	12	11.67	36
70% Reduction	10.99	11	10.97	11	11.07	11	11.01	34

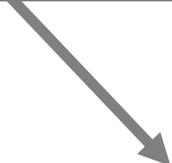
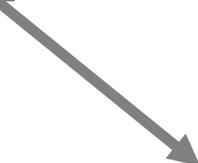
# Risk Assessment Matrix

			PROBABILITY				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
SEVERITY	Catastrophic	I	Extremely High		High		Low
	Critical	II	High	High		Low	
	Moderate	III	Medium	Medium		Low	
	Negligible	IV	Low	Low		Low	

Other factors may warrant consideration (e.g., cost, morale, perceptions, etc.)

# Human Factors Intervention Strategy Matrix

Most Mishap  
Recommendations  
Fall into Just Two  
Categories!!!!!!

	Engineering Control	Administrative Control	Personnel Control
Error Prevention	<b>X</b>	<b>X</b>	
Performance Enhancement			

1st YR Result:  
87% Reduction in  
Ground Damage

*"We Need to Start Thinking Out of the Box"*



**NADEP Cherry Point employs over 3,000 personnel & supports aircraft, engine, and component overhaul**

# ADDED NADEP CHALLENGES

- **Related Staffing Concerns:**
  - Aging Workforce - Retention & Retirement
  - Worker Attrition & Replacement
  - Worker Qualifications & Certifications
- **Qualified Personnel Shortage Implications:**
  - Overtime (Productivity, Quality, Work-life, Cost, & Scheduling)
  - Shift-Work (Productivity, Quality, Work-life, Cost, & Scheduling)
  - Short-Run Staffing (Qualification, Certification & Experience)
  - Cross-Training/Multi-roles (Productivity, Quality, & Work-life)
  - OJT/Mentoring (Standards, Resources, & Timeliness)
  - Outsourcing (Control, Procedures, Standards, & Timeliness)

# F-402 ENGINE LINE



Objective: Trial Effort to Apply Human Factors in Maintenance Error Investigation Processes and Associated Interventions to Tackle Quality Issues in DEPOT Overhaul and Repair Operations

# Actions Taken



- F-402 Engine Area Pilot Study
  - ✓ Maintenance Error Investigation Training (QA, Safety, Engineering, ISO 9000, & Management)
  - ✓ QA Adoption of HFACS-ME & Implementation
  - ✓ Post Hoc Analysis of F-402 Incidents
  - ✓ MCAS Adaptation for NADEP Workforce
  - ✓ MCAS Administration to F-402 Personnel
  - ✓ Development of Tailored MRM Training
  - ✓ Trained All SBU Associated Personnel



# Heinrich Ratio Adapted

**Major Quality Escape/Severe Injury**

The way to manage this risk:

**Minor Quality Escapes**

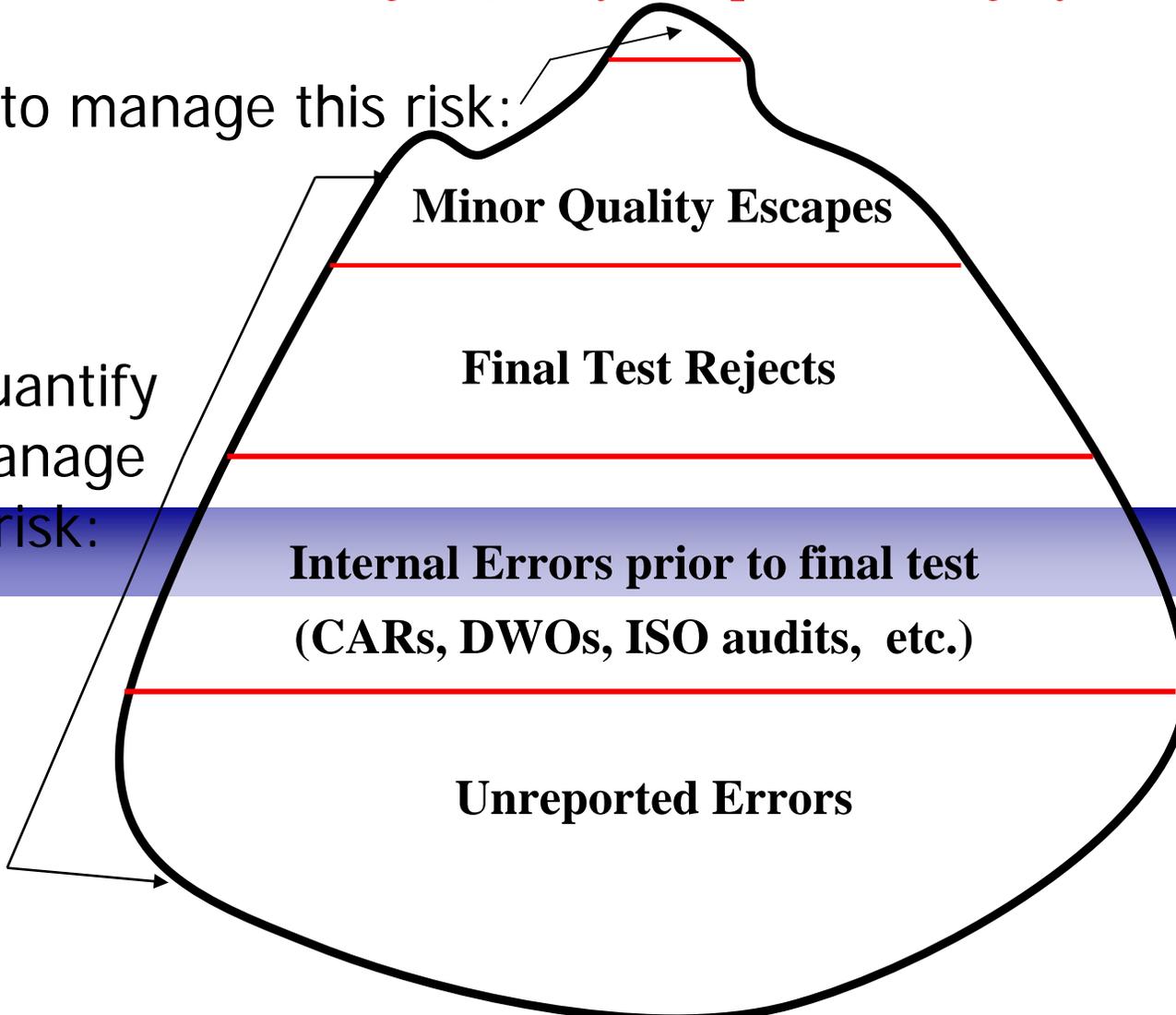
Is to quantify  
and manage

This risk:

**Final Test Rejects**

**Internal Errors prior to final test  
(CARs, DWOs, ISO audits, etc.)**

**Unreported Errors**

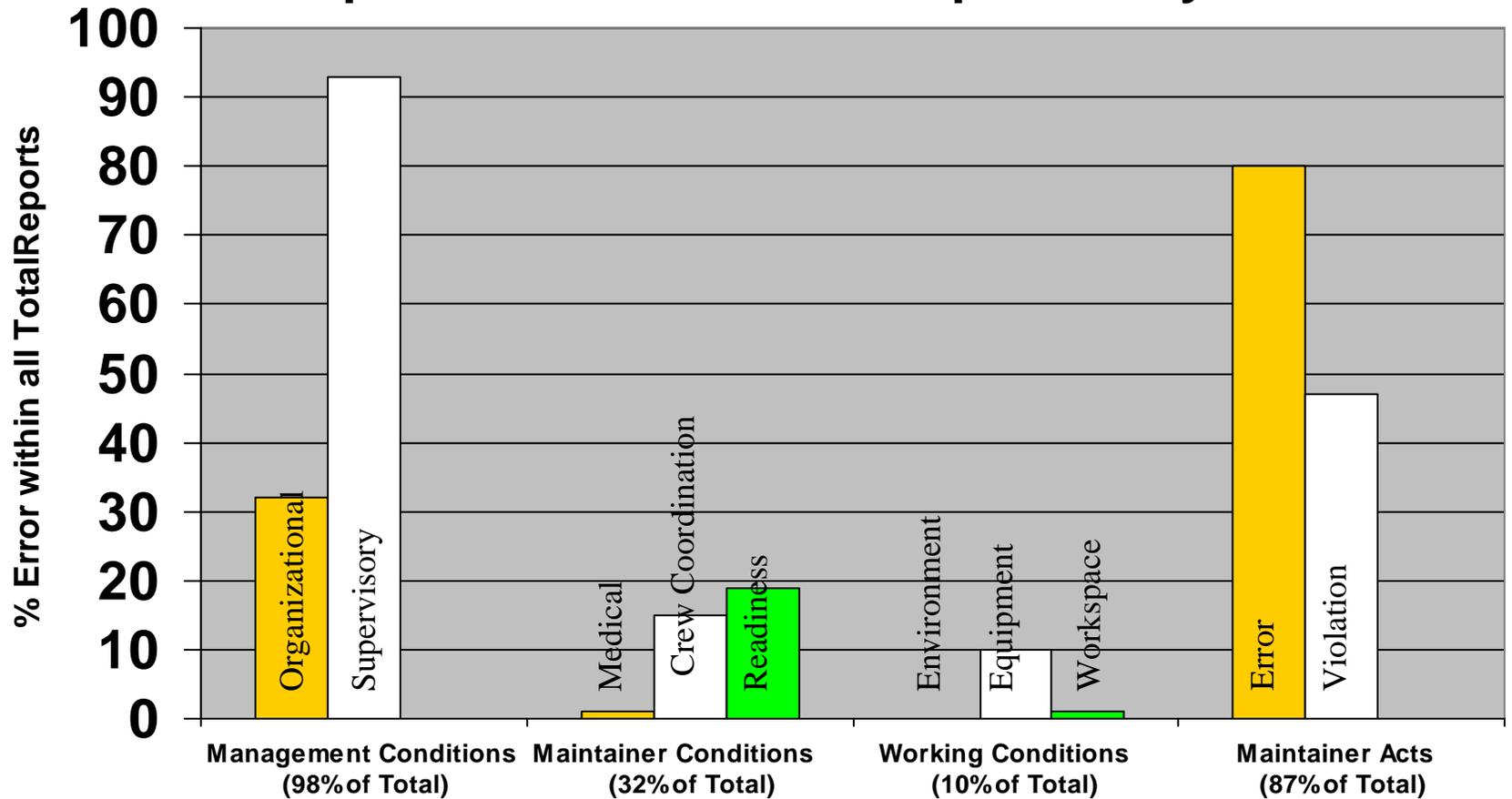


# HFACS-ME-Framework

..HFACS-Investigation-on-00000

Error Categories of HFACS-Framework				
First Order	Second Order	Third Order		
<input type="checkbox"/> Management Conditions	<input type="checkbox"/> Organizational  <input type="checkbox"/> Supervisory	<input type="checkbox"/> Inadequate Processes <input type="checkbox"/> Inadequate Resources  <input type="checkbox"/> Inadequate Supervision <input type="checkbox"/> Supervisory Misconduct	<input type="checkbox"/> Inadequate Documentation  <input type="checkbox"/> Inappropriate Operations	<input type="checkbox"/> Inadequate Design  <input type="checkbox"/> Uncorrected Problem
<input type="checkbox"/> Maintainer Conditions	<input type="checkbox"/> Medical  <input type="checkbox"/> Crew Coordination  <input type="checkbox"/> Readiness	<input type="checkbox"/> Mental State  <input type="checkbox"/> Communication  <input type="checkbox"/> Training/Preparation	<input type="checkbox"/> Physical State  <input type="checkbox"/> Assertiveness  <input type="checkbox"/> Certification/Qualification	<input type="checkbox"/> Limitation  <input type="checkbox"/> Adaptability/Flexibility  <input type="checkbox"/> Infringement
<input type="checkbox"/> Working Conditions	<input type="checkbox"/> Environment  <input type="checkbox"/> Equipment  <input type="checkbox"/> Workspace	<input type="checkbox"/> Lighting/Light  <input type="checkbox"/> Damaged/Unserviced  <input type="checkbox"/> Confining	<input type="checkbox"/> Weather/Exposure  <input type="checkbox"/> Unavailable/Inappropriate  <input type="checkbox"/> Obstructed	<input type="checkbox"/> Environmental Hazards  <input type="checkbox"/> Dated/Un-certified  <input type="checkbox"/> Inaccessible
<input type="checkbox"/> Maintainer Acts	<input type="checkbox"/> Error  <input type="checkbox"/> Violation	<input type="checkbox"/> Attention/Memory <input type="checkbox"/> Skill/Technique  <input type="checkbox"/> Routine <input type="checkbox"/> Flagrant	<input type="checkbox"/> Judgment/Decision-Making  <input type="checkbox"/> Infraction	<input type="checkbox"/> Knowledge/Rule-Based  <input type="checkbox"/> Exceptional

# Example Corrective Action Report Analysis



## First and Second Order Analysis



**School of  
Aviation Safety**  
Naval Postgraduate  
School

SURVEY OVERVIEW

SAMPLE SURVEY

TAKE A SURVEY

SURVEY ADMIN

C.O. ACCESS

SAMPLE C.O. ACCESS

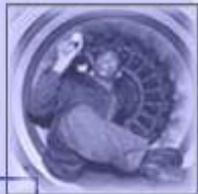
SITE MAP

HELP/FAQ

CONTACT US

SUGGESTIONS

# Command Safety Climate Assessment Surveys



**-- On-line Diagnostic Tool**

**-- Based on HRO Theory**

**-- Designed for Maintenance Personnel**

**-- Focuses on Key Maintenance Issues**

**-- Results are Confidential (Password Protected)**

**-- Data Available in Aggregate Database**

**-- Can Compare Your Data with Other Data**

# SAMPLE SURVEY (MCAS/NADEP)



## PART I. DEMOGRAPHIC INFORMATION

The following survey is a **SAMPLE**. No actual responses will be recorded.  
For the actual survey, no individual's demographic data will be made available to any CO.

Your Grade/Rank:

Total years aviation maintenance experience:

Total years Naval Aviation Depot experience:

Your current job/trade:

Total years in your current job/trade:

Your primary shift:

Your primary program:  
(Select all that apply)  
 A-4  
 AH-1  
 AV-8  
 C-130

Your status:

Your Service:

Your parent command:

Your unit's location:

## The following survey is a **SAMPLE**. No actual responses will be recorded!

1. The NADEP adequately reviews and updates safety procedures.

<input type="radio"/>					
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A Don't Know

2. The chain of command monitors artisan qualifications and has a program that targets training deficiencies.

<input type="radio"/>					
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A Don't Know

3. Supervisors use safety and medical staff to identify/manage personnel at risk.

<input type="radio"/>					
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A Don't Know

4. Quality Assurance routinely monitors rework/repair/maintenance tasks.

<input type="radio"/>					
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A Don't Know

5. Tool Control and support equipment licensing are closely monitored.

44. The next quality defect will be caused by.... (200 words max.)

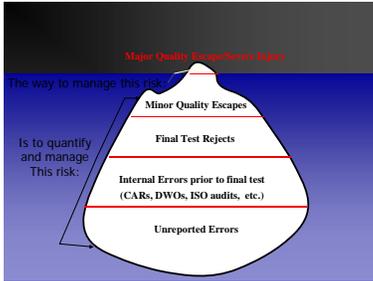
No comment  My response is:

45. The next quality defect can be prevented by .... (200 words max.)

No comment  My response is:



**NEXT STEP: Form a MGMT, ENG, QA, ISO9000, & Artisan focus groups to “triangulate” HFACS-ME analysis, MCAS results, and work experience to develop tailored intervention strategies**

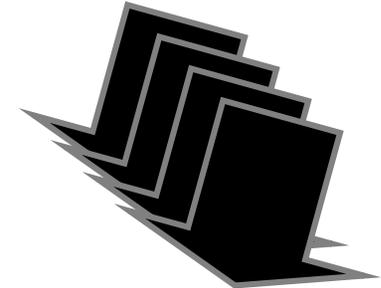
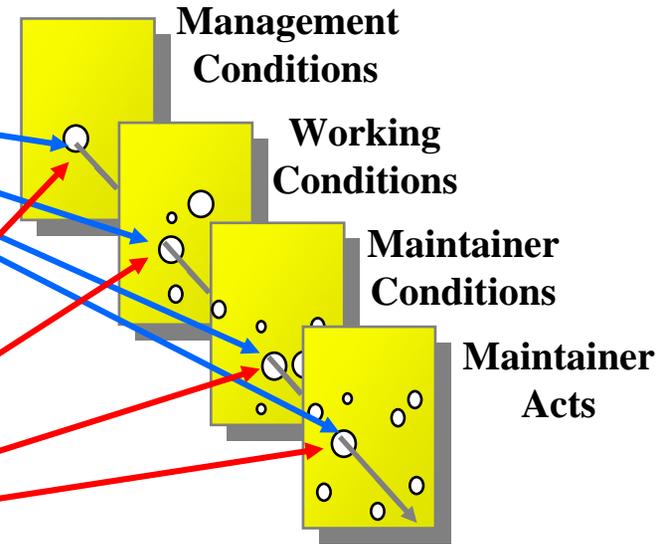


**HFACS-ME**

- ID Causal Factors (Hazards)
- Risk Assessment/Prioritization
- Target Intervention Areas
- Safety Performance Metric

**MCAS**

- ID Potential Factors (Hazards)
- Risk Assessment/Prioritization
- Target Potential Risk Areas
- Safety Performance Metric



**INTERVENTION**

**-How close are we to an HRO?**



## Early Results

- Increased Quality in CARs, DWOs, & QDRs
- Significant Decrease in Quality Departures
- External NAVAIR Process Audit Noted Significant Reduction in “High Risk” Areas
- Engine Overhaul Manager Desire to Expand

# Maintenance Lessons Learned

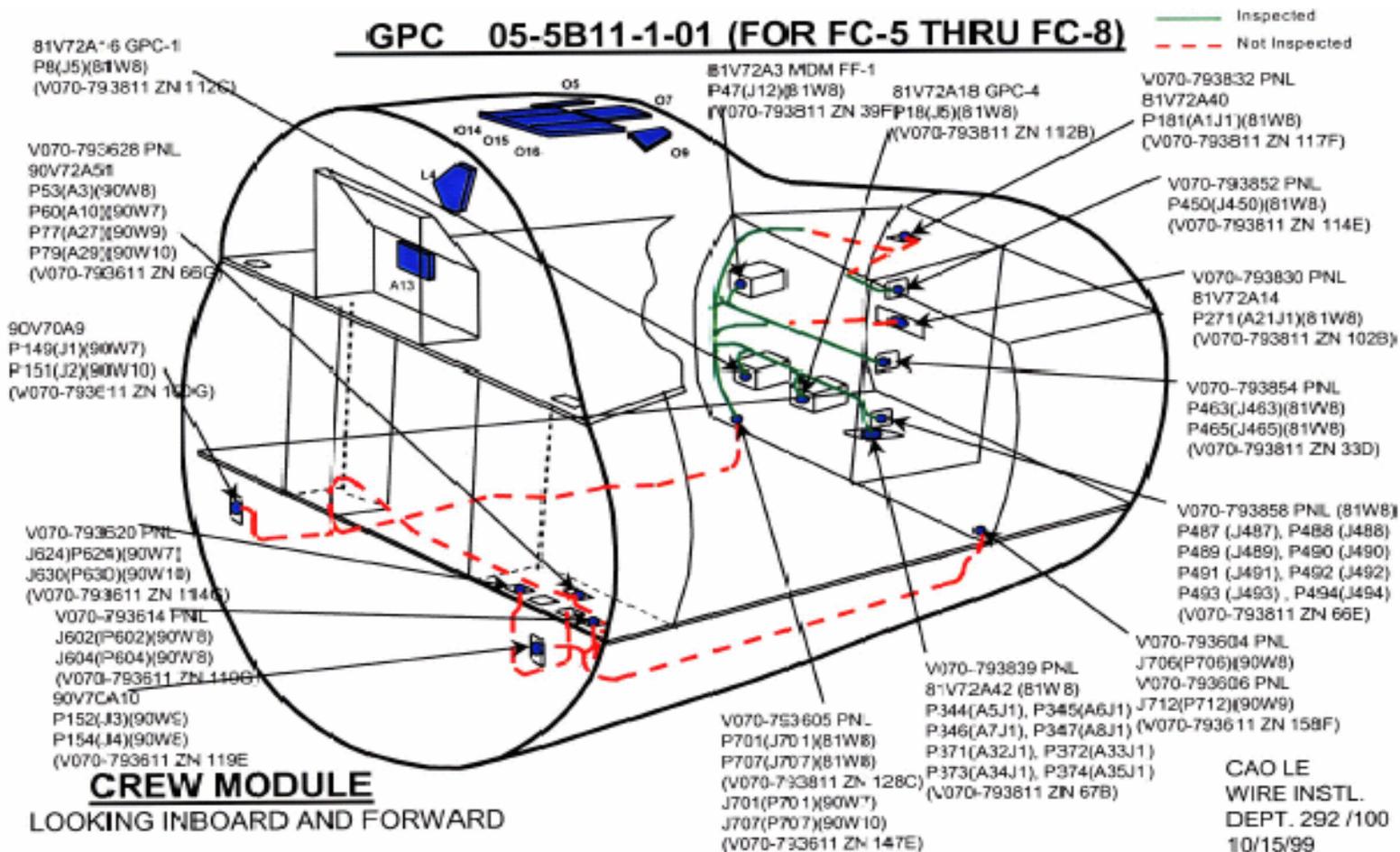
## ... Kapton Wiring

- Each orbiter contains ~ 852,000 feet of (mostly) Kapton wiring
  - Major concern is arc tracking
    - A phenomenon in which broken insulation causes overheated wiring and carbonizes
    - Carbonized Kapton results in a “soft short” which continues to conduct below the tripping threshold of circuit protection
  - Approx 2,000 feet of orbiter wiring is inaccessible
    - No plans to inspect over the life of the orbiter
    - NASA confirmed, no Crit 1 wiring in inaccessible areas

# Maintenance Lessons Learned

...Indications Missed

## Red Dashed Lines Indicate Inaccessible Wiring



# High Reliability Organizations

**HROs -- Organizations have less than their “fair share” of failures despite:**

- managing complex & demanding technologies**
- meeting peak requirements & time pressures**
- routinely handling significant risks & hazards**
- executing dynamic/intensely interactive tasks**

(Roberts,1990)

## **Components:**

- Process Auditing
- Reward System
- Quality Assurance
- Risk Management
- Command & Control
- Functional Relationships