Accurate Data Collection:

Roadmap to Proactive Aircraft Wiring Maintenance

Presented To: OSD CBM+ Action Group

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23 Aug 06

Agenda

- Wiring Background
  - Description/Scope
  - Data/Information
  - Safety, Readiness, Cost
  - Scheduled vs Unscheduled MMHrs
- NAVAIR & RCM
  - Maintenance Philosophy Change
- Data Collection
  - Testing & Maintenance
- Wiring Diagnostics Technology
- Summary

Aircraft Wiring Components: Description

- All wiring/cable/harness components which functionally preserve, protect, and ensure the qualitative and quantitative transfer and distribution of power, signals, data, images, etc.

- **Conductor(s)**
- **Insulation (dielectric)**
- **Splices**
- **Contacts/Pins/Sockets**
- **Terminations (lugs, blocks, etc.)**
- **Grounds**
- **Shields**
- **CB's, relays, resistors, capacitors, inductors, diodes, etc.**
- **Connectors**
- **Backshells (strain relief)**
- **Sleeves (marking, etc.)**
- **Braiding & Jacketing**
- **Hardware (brackets, clamps, mounts, etc.)**

Wiring is a **Sub-SYSTEM** and not just a fit-n-forget commodity!

Navy Wiring Data: Safety, Readiness, Cost

- **As of 3rd Qtr FY05**
- 921,658 flight hours / year
- ~ 3,045 aircraft (fixed, rotary)
- ~ 20 yrs old = avg age of all aircraft

- **Safety Data/Impact**:
- 2.5 electrical fires / month
- 401 in-flight aborts / year
- Hazardous Material Reports (HMRs)
  - ***Chafing conditions*** are our **number one safety issue with regard to wiring**
  - **Hazardous incidents** (HMR's) are ***increasing*** as ***aircraft age***

- **Readiness Data/Impact:**
- 1,101 mission aborts / year
- Effectively average 78 NMC aircraft per year due to faulty wiring

- **Cost Data/Impact:**
- Approximately $94M in NFF eqpmt removals due to undiagnosed wiring problems on an annual basis
- 1-2M operational MMHrs / year spent repairing wire problems
- Could be as high as 4M MMHrs / year
- Most time spent trouble-shooting, isolating, & locating wire faults

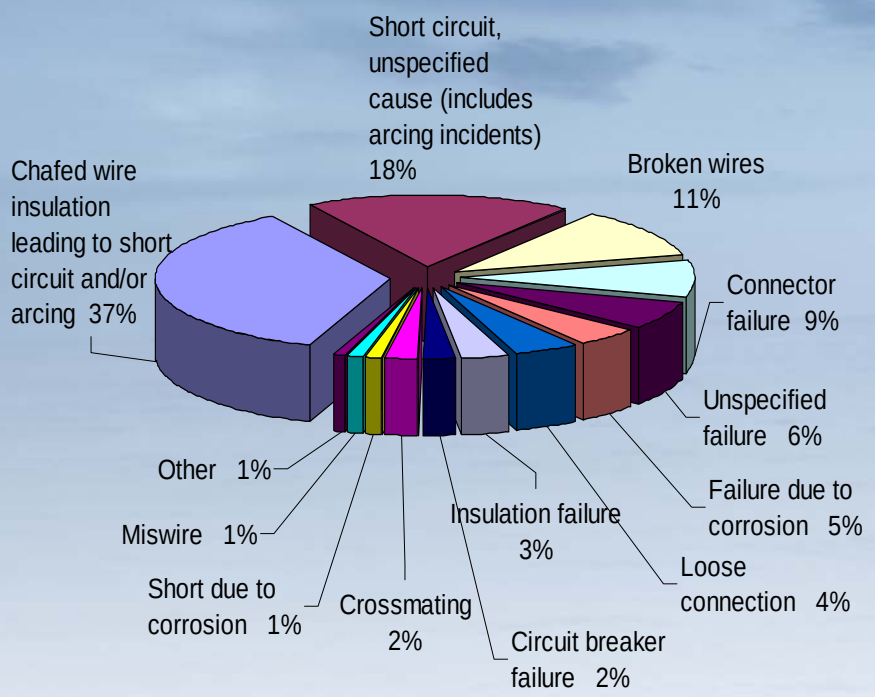
Wiring Fault/Failure Types

- "Hard" faults
  - *Reactive/Diagnostics*
- Opens
- Shorts
- *Functional* failures
- Usually detected and located when aircraft is back on the ground
- Repairs attempted during unscheduled/corrective & scheduled/preventive maintenance

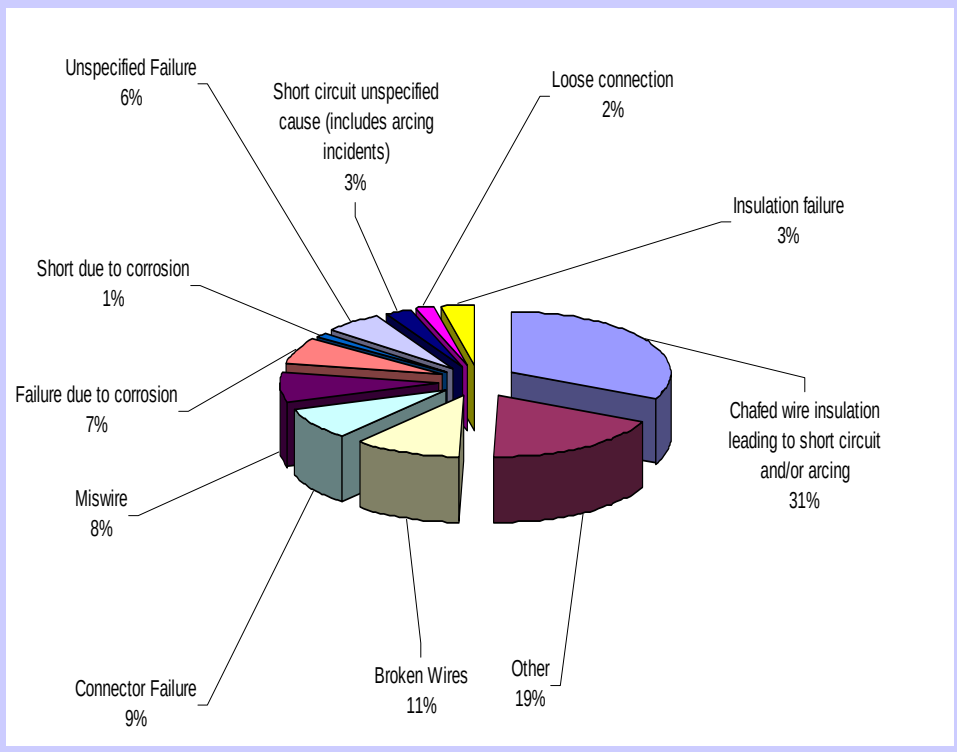
- "Soft" faults
  - *Proactive/Prognostics*
- Chafing, Corrosion, Contamination, Loose Connections
- *Intermittent, conditional,* ***potential*** *failures*
- May **not** occur when aircraft not powered &/or not in-flight
- Repairs attempted during unscheduled/corrective maintenance but should be repaired during scheduled/preventive maintenance

Aircraft Wiring System Failure Modes Chart

Jan 1980 to Dec 1999



Jan 1999 to Jun 2004

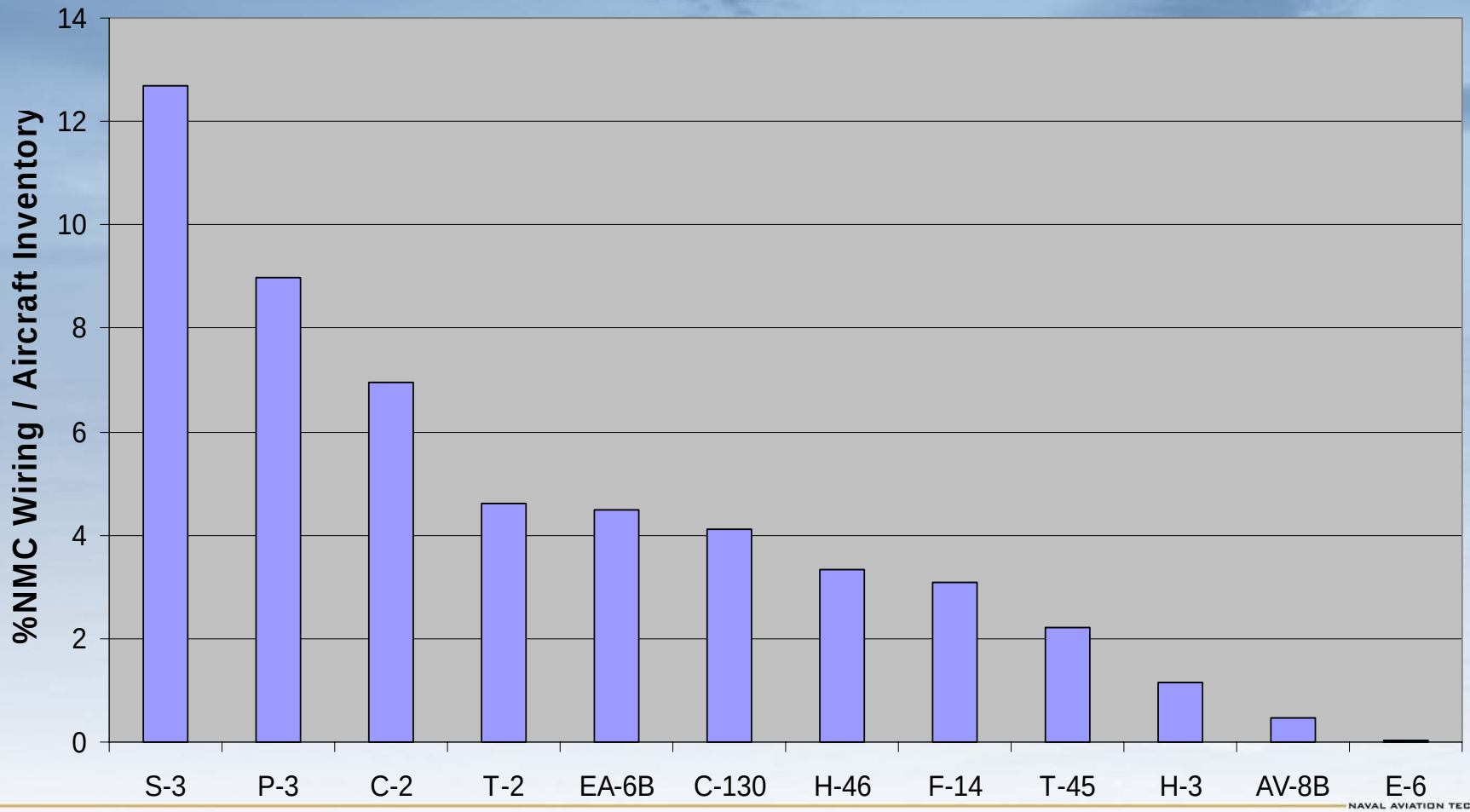


Circuit Breaker Failure - 0% (-2), Crossmating - 0% (-2)

(Source: Navy Safety Center Hazardous Incident Data)

Aircraft Readiness - Wiring Related

%NMC (Wiring) / Aircraft Available (9 years total)



Work Unit Codes (WUC)

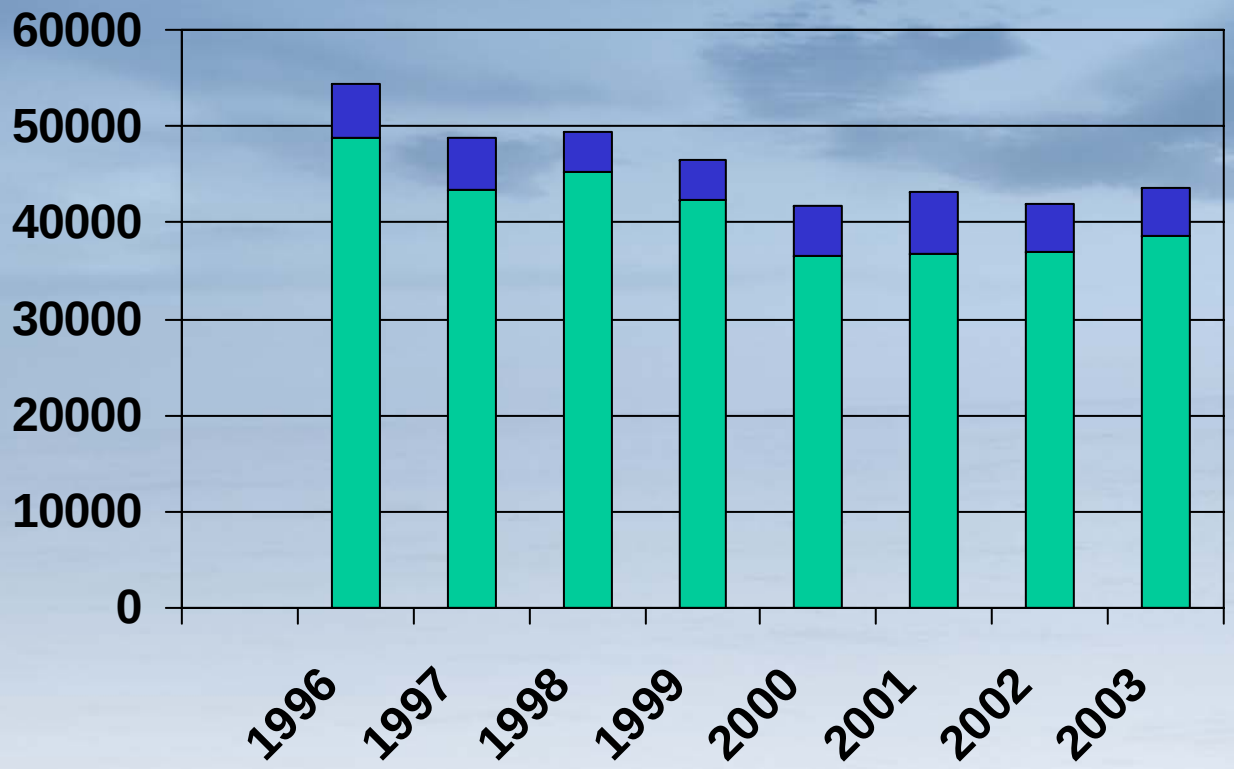
- 11000 Airframe
- 23000 TurboJet Engines
- 24000 Auxiliary Power Systems
- **44000 Lighting System**
- **46000 Fuel System**
- **51000 Instrument System**
- **57000 Int Guidance/Flight Control System**
- **65000 IFF System**
- **72000 Radar Navigation System**
- 81000 Airborne Guided System

- 42000 Electrical System
  - 42A6A CSD/Engine Starter/Generator
  - 42A6E Aircraft Battery
  - 42800 Aircraft Wiring
  - 42820 Lighting Systems Wiring
  - 42830 Fuel & Oil Systems Wiring
  - 42840 Avionics Systems Wiring
  - 4284T Radar Nav Systems Wiring
  - 42850 Engine Performance Indication Wiring
  - 42860 Landing Gear Systems Wiring

Maintenance Manhours (One Navy Platform)

Scheduled/Preventive vs Unscheduled/Corrective

(WUC 42xxx - Electrical System)



Scheduled / Preventive Maintenance MHrs

Unscheduled / Corrective Maintenance MHrs

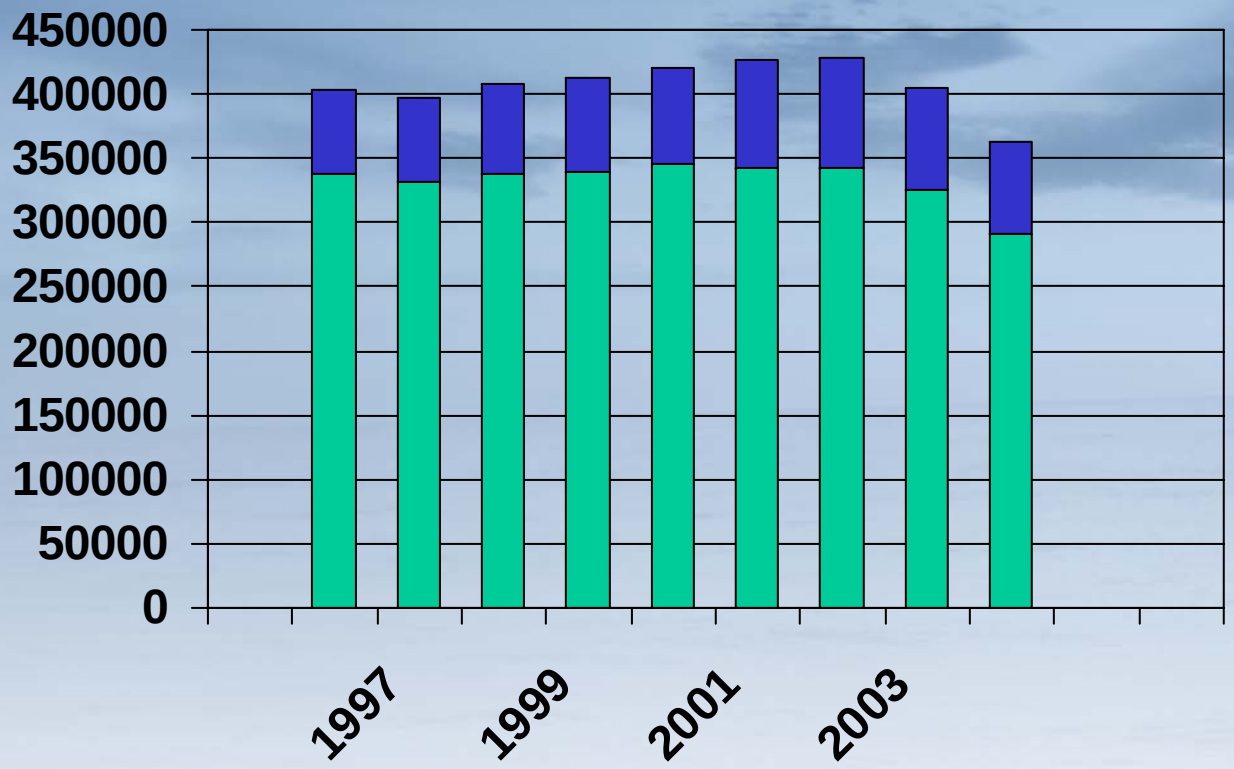
~1 to 9 ratio Scheduled (~10%) to Unscheduled (~90%)

•No Defect Data (Action Taken Code A and Mal Codes 799 thru 814, 877) were removed
All actions that did not reflect maintenance actions (NFF A-799, admin driven, removal for cannibalizations, SRC forced removals, etc.) were removed (Source: AI-ES, Inc., May 2004, OP, FL)

Maintenance Manhours (10 Navy Platforms)

Scheduled/Preventive vs Unscheduled/Corrective

(WUC 42xxx – Electrical System)



Scheduled / Preventive Maintenance MHrs

Unscheduled / Corrective Maintenance MHrs

~2 to 8 ratio Scheduled (~20%) to Unscheduled (~80%)

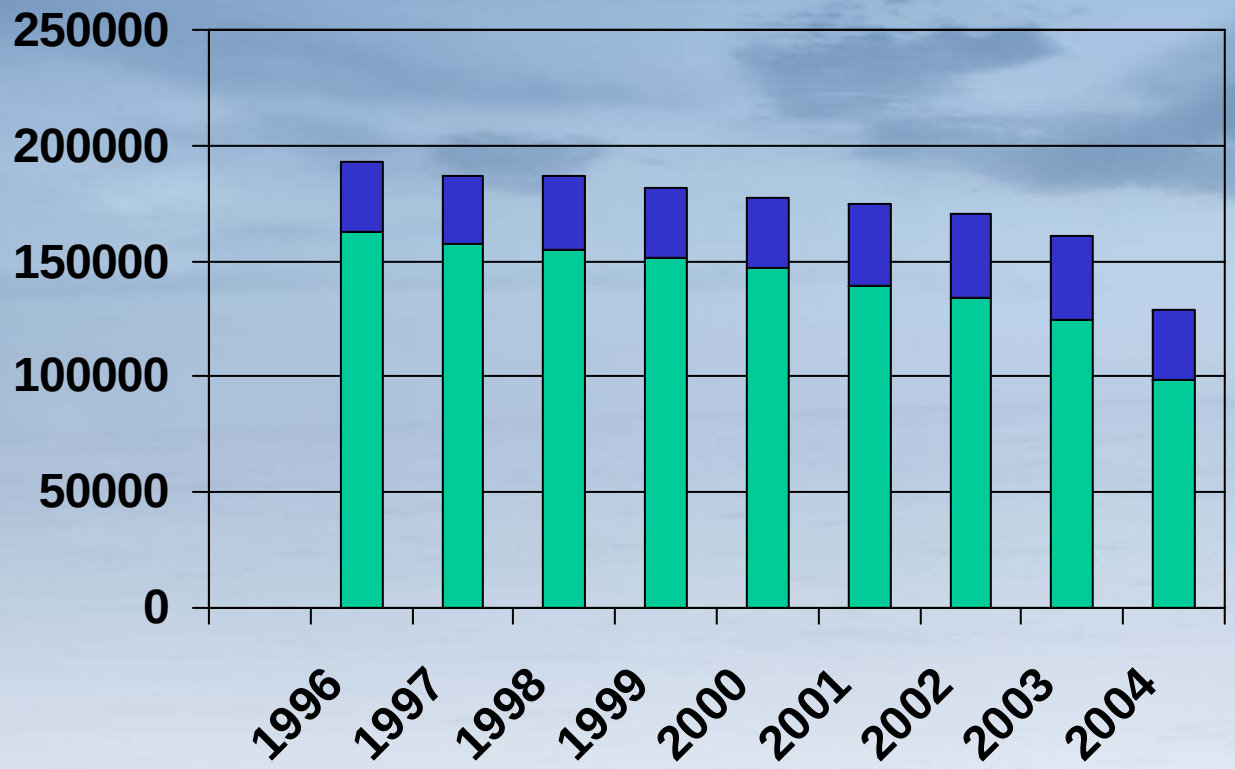
***WUC 42xxx includes all data return for WUC 42. Scheduled Maintenance = when discovered codes J, K, L, & M. Unscheduled Maintenance = all other when discovered codes. Action taken codes: A, N, & T removed; Malfunction codes: 799 & 800 series (admin) removed.**

(Source: Wyle Laboratories, Inc., Orange Park, FL, June 2005)

Maintenance Manhours (10 Navy Platforms)

Scheduled/Preventive vs Unscheduled/Corrective

(WUC 428xx - Wiring-Related)



Scheduled / Preventive Maintenance MHrs

Unscheduled / Corrective Maintenance MHrs

~25 to 75 ratio Scheduled (~25%) to Unscheduled (~75%)

***Wiring includes only data with WUC's indicating a wiring discrepancy. Scheduled Maintenance = when discovered codes J, K, L, & M. Unscheduled Maintenance = all other when discovered codes. Action taken codes: A, N, & T removed; Malfunction codes: 799 & 800 series (admin) removed.**

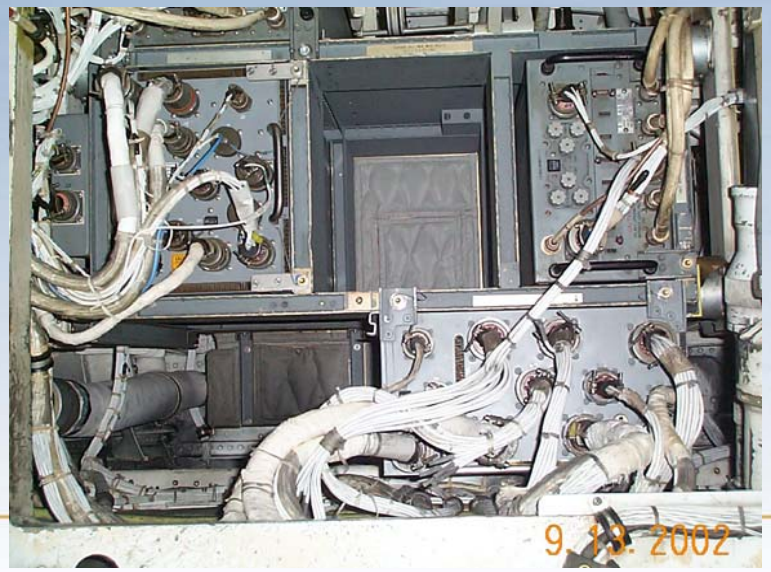
(Source: Wyle Laboratories, Inc., Orange Park, FL, June 2005)

Safety, Readiness, Cost & MMHrs

Why Should You Care About Wiring Systems?

- An Indispensable System
- Impacts Safety and Mission Readiness
- High Cost Of False Equipment Removals
- Complexity and Density Is Increasing
- Experiences Degradation & Aging Effects

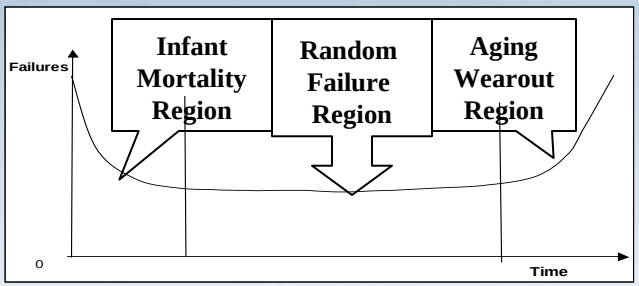
- **Safety Degrader**
- **Readiness Degrader**
- **Millions Of MMH**
- **Escalating Cost**



NAVAIR RCM Paradigm Shift: Aircraft Maintenance Philosophy

Traditional Maintenance Overhaul/Rework Concept

- OEM provided standard overhaul maintenance plan
  - "Fix it whether its broken or not"
- Assumes infant mortality and aging wear out failures for all (100%) aircraft components
  - UAL, Broberg, and MSP Data shows only ~ 8% to 23% components fail by wearout



Reliability Centered Maintenance (RCM)

- Integrated Maintenance Concept/Plan IMC/P
  - "If it isn't broke, don't fix it."
  - Phase Depot Maintenance (PDM)
  - Enhanced Phased Maintenance (EPM)
  - Performance Based Logistics (PBL)
- Based on reliability (MTBF/R) data
  - Actual data collected/analyzed
  - FMECA/FMEA => root cause analysis
  - Assumptions are made depending on the amount of "accurate" failure & corrective action data available
- Mid/Late 1990's – Navy Incorporated RCM

NAVAL AVIATION TECHNOLOGIES

RCM & IMC/P – Current Navy Platforms

- RCM/IMP Program Phases
  - Development
  - Implementation
  - Sustainment

- Engines/Propulsion
  - F-402
  - F-404
  - F-405
  - F-414
  - J-52
  - T-56
  - T-58
  - T-64
  - TF-34
  - others

- Aircraft Platforms
  - Trainer:
    - T-45
  - Helos / Rotary Wing:
    - H-1
    - H-46
    - H-53
    - H-60
  - Fighter / Attack:
    - AV-8B
    - EA-6B
    - F/A-18A/D
    - F/A-18E/F
  - Patrol / Cargo / Surveillance:
    - C-2
    - C-130
    - E-2
    - E-6
    - P-3
    - S-3

NAVAL AVIATION TECHNOLOGIES

RCM/IMP Scope

- **Past/Current**
  - Applied to primarily mechanical & structural aircraft components
  - Historical abundance of maintenance & failure data collection (lessons learned)
    - Flight Critical
    - Safety of Flight
    - Critical Single Point Failure
  - Traditional Non Destructive Inspection/Testing (NDI/T)
    - Proven & reliable
  - Airworthiness determination
    - "Go" or "No Go"

- **Current/Future**
  - Reliability & Root Cause Analysis application to electronics & avionics
    - "random electrical failures & random failure modes" assumption & debate
    - Where's the data to support this claim?
    - How about this claim?
    - All electrical failures are a result of mechanical failure modes
  - Goal: RCM application to aircraft electrical wiring
  - Reliability of electrical, electronics, & avionics directly impact capability & readiness

NAVAIR Wiring & RCM

- **VADM Massenburg's NAVAIR Goals:**
- **Balance Current, Future Readiness**
- **Reduce Cost of Doing Business**
- Improve Agility
- Ensure Alignment
- **Implement Fleet Driven Metrics**

- **Priorities (Wiring & RCM)**
- Promote aircraft wiring as a Sub-System
  - Should NOT be considered a "commodity"
- Reactive to ***Proactive*** Maintenance
  - Need to apply RCM to aircraft electrical/wiring (WUC's 42)
- Reduce electrical/wiring unscheduled maintenance events/actions
  - New wire diagnostics technology & testers for trouble-shooting wiring problems
  - Collect "accurate" electrical/wiring maintenance/failure data for RCM
  - Analyze this RCM data to incorporate into scheduled maintenance events
- Fleet driven metrics implementation is critical for VADM Massenburg's goals

Accurate DATA Collection

- **Test & Measurement Data (on tester HW)**
  - Specific, Quantitative
  - Baseline/comparisons
  - Taken & collected on the tester/hardware
    - Depot Artisans
    - Depot Contract Maintainers
    - AE, AT, AO
    - QAS, CDI
  - Data Mgmt issues
    - storage/transfer/etc.

- **Maintenance Data**
  - Optimized NALCOMIS
    - O & I Level
  - MRP II, ADCS, etc.
    - Depot Level
  - Descriptive, qualitative
  - Maintenance Action Form (MAF)
  - Failed/removed component
  - Corrective action/repair
  - Supply/replacement part data

Data Collection – Maintenance

- Maintenance Action Form
  - *BUNO*
  - *Work Unit Codes (WUC's)*
  - *Aircraft/Electrical System*
  - *Reference Designator*
  - *Connector P/N*
  - *Failure/Malfunction Codes*
  - ***MAF Control Number (MCN)***
  - ***Job Control Number (JCN)***
  - Harness Number
  - Wire/Cable Number
  - Pin/contact info
  - **Location/zone/area**
- Wiring & Wiring Components Malfunction Codes ("W")
- ***Potential*** Failure – Inspections
  - Harness/Wire Chafing
  - Circuit Breakers/Relays
  - Connectors
  - Dielectric (Insulation)
  - Installation/Security
  - Terminal Boards/Modules/Points
- ***Functional*** Failure
  - Broken
  - Arced/burned/shorted
  - Damages/defective

Wire Diagnostics, Data Collection & RCM

DIAGNOSTICS TOOLS

- **FIND FAULT FAST**
- **VALIDATE REPAIR FAST**

IMPLEMENT INTO:

- **Unscheduled (On A/C)**
- **Scheduled (O, I, D)**

Wiring/Electrical Trouble-shooting Test Measurement Data

AGING SYSTEMS RESEARCH

INDUSTRY

RECOMMENDATIONS

Test Measurement Data Collection LINKED TO Maintenance Action Forms (MAFs) (MCN & JCN)

ENGINEERING & RCM (PREVENTIVE MAINTENANCE)

Unscheduled to Scheduled Maintenance Planning RCM Analysis/FMECA

RCM/DATA/TREND ANALYSIS

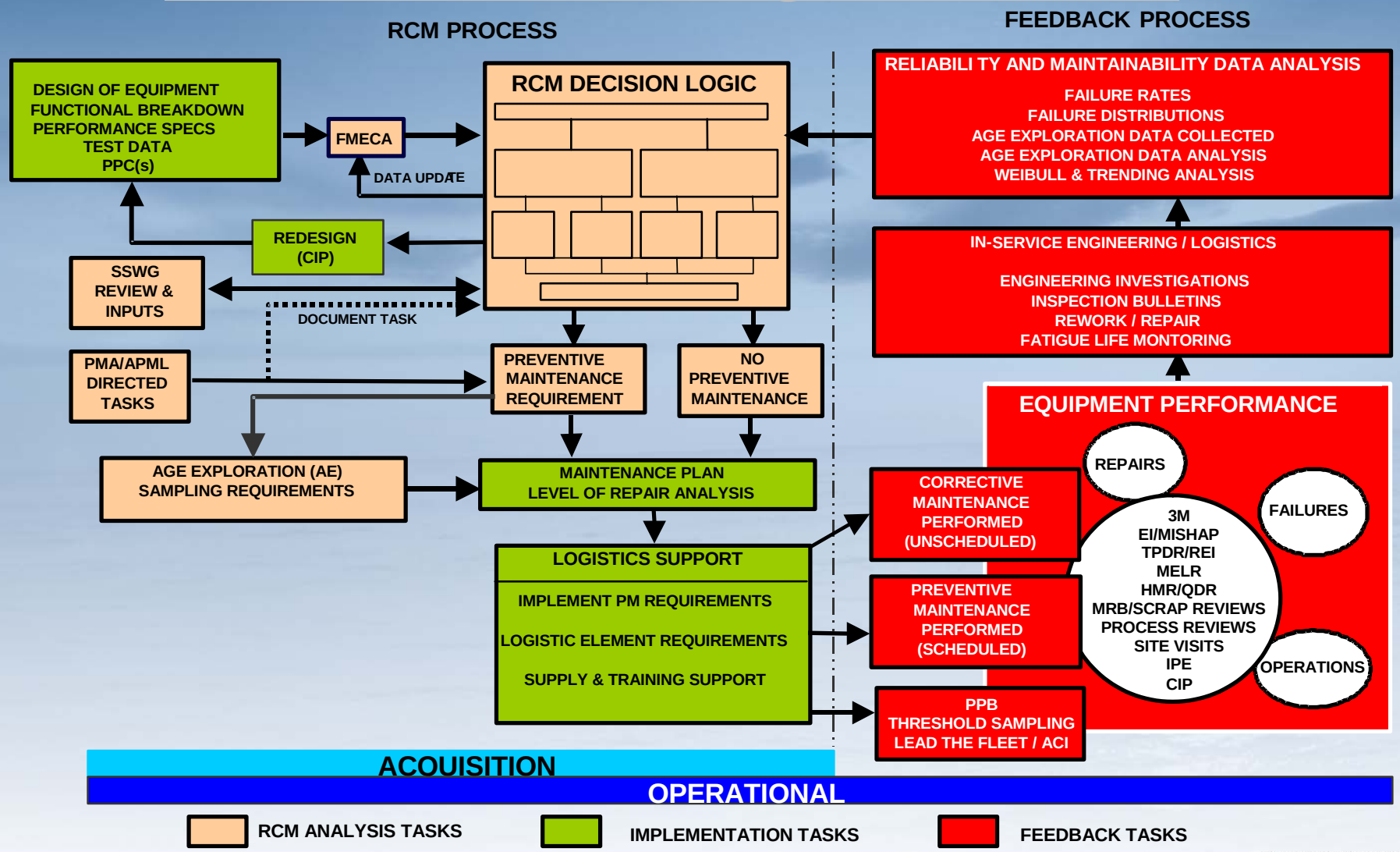
DATABASE NALDA/NALCOMIS OOMA INTERFACE TO ALL LEVELS

RESULTS IN:

REDUCED MAINTENANCE MHRS/$, IMPROVE READINESS & SAFETY

NAVAL AVIATION TECHNOLOGIES

Maintenance Planning/Sustainment



Wire Testing/Technology

- Multi-meters
  - *Digital*
  - Analog
- Automated Wiring or Circuit Analysis
- Resistance
  - *Insulation Resistance*
- Capacitance/dielectric
  - *Dielectric Breakdown*
  - *Excited Dielectric Testing (EDT)*
- Reflectometry
  - *Time Domain*
    - *Spread Spectrum*
    - *Sequential*
  - *Frequency Domain*
    - *Standing Wave*
    - *Phase Detection*
    - *Frequency Modulated Continuous Wave*
  - Other (Noise, Mixed, etc.)
- Partial Discharge Analysis
- On-Board Sensors/Circuits
  - Smart/Embedded Connector

Handheld Wiring Diagnostic/Prognostic Tools

- Handheld Units
  - 3M 900 AST
    - TDR/DMM
  - Goodrich wire integrity system prototype
    - TDR
  - Phoenix Aviation PDA
    - TDR/DMM
  - CM technologies MTDR
    - TDR

Automated Wiring Analysis (AWA) Program: Diagnostic/Prognostic Tools

- **Remote Test Set (RTS) 501** (Two-ended)
- PC & Analyzer is Programmable, Rugged, Portable, Explosive Atmosphere rated (MIL-STD-810 Method 511)
  - Load Box is not rated to MIL-STD-810
- Measures continuity, isolation, resistance, AC & DC Voltage, Capacitance, 4-Wire, 200% OL CB
- D38999 128-pin connector for test adapter cables
- Remote probe for isolated test & troubleshooting
- Latching Energization – activation of discrete components and circuits
- **Handheld ESP +** (Single-ended)
- *Utilizes Standing Wave Reflectometry (SWR) to **locate** opens and shorts (hard faults) within inches*
- *Collects waveforms/test data so could possibly identify & locate "soft faults" with a baseline*
- > 10 hrs on battery power; full recharge ~ 2 hrs
- Ruggedized case and sealed keypad

Scheduled/Unscheduled Maintenance Levels

- **RTS 501 Portable, Ruggedized Analyzer (2-ended)**
- Depot, D-FMT's (includes Contractor-FMT's), & NATEC reps
  - **Scheduled** maintenance
- O & I level maintainers (fleet)
  - Focus on **Scheduled maintenance** actions (but should also be used on **Unscheduled** trouble-shooting maintenance actions)
- ***Automated test data collection***
- **Handheld ESP+ Tester: (single-ended)**
  - Depot, D-FMT, &/or NATEC reps
  - O & I level
    - Focus on **Unscheduled maintenance**
  - ***Manual/hardcopy*** *test data collection*

Automated Wiring Analysis (AWA) Program:

- Each participating aircraft platform identifies top 10 electrical/wiring problem areas
  - New or aging aircraft
  - Addressing systems which are "low hanging fruit" high degraders
  - Not entire aircraft at once, basically piecemeal approach to prove out that the wiring diagnostics technology/tester works
  - Collect "accurate" test, maintenance data, and user feedback/opinions
- By participating in the AWA program, platforms receive the following for one/few problem systems:
  - Tester/technology HW
  - SW test programs
  - Interfaces (test adapter cables)
  - Training (Operator & Programmer)
  - Val/Ver/Integration
- Age Exploration Tasks/Bulletins
  - Continue to gathering data on other/remaining problem systems to incorporate into each NAVAIR platforms' IMC/P & RCM programs

Summary

- **Proactive Aircraft Wiring Maintenance factors**:
  - Proliferation of new detection/sensing technology and wiring diagnostics tools
  - Updated wiring training products
  - Implementation of RCM & IMC/P programs
  - Accurate data collection
    - Test/measurement
    - Maintenance

- **Over The Horizon**
  - Prognostics/Predictive Capability with On-board sensors/detection
  - Better SW algorithms
  - Autonomic Logistics Structure/System (ALS)
    - Joint Strike Fighter
  - PHM integration & proliferation
  - Integrated Vehicle Health Management (IVHM)
  - More progressive "Events Based Maintenance (EBM)" philosophy

Questions?

NAVAIR

Joint Services Wiring Action Group

(JSWAG)

- June 2005, Combined Naval Aerospace Vehicle Wiring Action Group (NAVWAG) and USAF Aging Aircraft Wiring Working Group (AAWWG)
- Semiannual Conferences/Meetings (150+ attendees)
  - Virginia Beach, VA
  - Civilians & Soldiers (airmen, sailors, marines, etc.)
  - Committees address
    - Maintenance/Data Analysis
    - Training
    - Quality Wiring Components
    - Design/Installation
  - Vendor briefings
- USN and USAF take turns coordinating & funding two JSWAG conferences in May and November
  - Attendees from USAF, USN/USMC, USA, USCG, NASA, Canada, Mexico, British AF, Australia, etc.

Systems Engineering Approach: Wiring Objectives/Challenges

- Technical/Engineering
- Provide to the O, I, & D level the wire diagnostic tools to trouble-shoot the aircraft maintainers' wiring problems
- "Hard" faults - diagnostics
- "Soft" faults - prognostics
- Specific wire types
  - Single Conductor (non-shielded), etc.
  - Branching ($\leq$ 3)
- Software/GUI
- Coordination & Miniaturization of Hardware and Physical Packaging

- Programmatic/Logistics
- Data Collection
  - Trending (Experience into hard data)
  - RCM Analysis (Proactive/Predictive)
    - Scheduling Electrical Wiring Maintenance Actions
  - Cost Benefit
- Budget/Planning
  - TYCOM/CNAF/PMA's ECP/TD (APN-5 & 5I funds)
  - Acquisition/Procurement (APN-7)
- Training
  - New Wire Diagnostic tester operation
  - WUC & Malfunction Code updates
- Supply Issues
  - Forecasting consumables & repairables

WUC 42 - One Navy Platform
Wiring is #1 Readiness Degrader

Microsoft Access - [TOP 25 SYS BREAKDOWN]

42 - ELECTRICAL SYSTEM

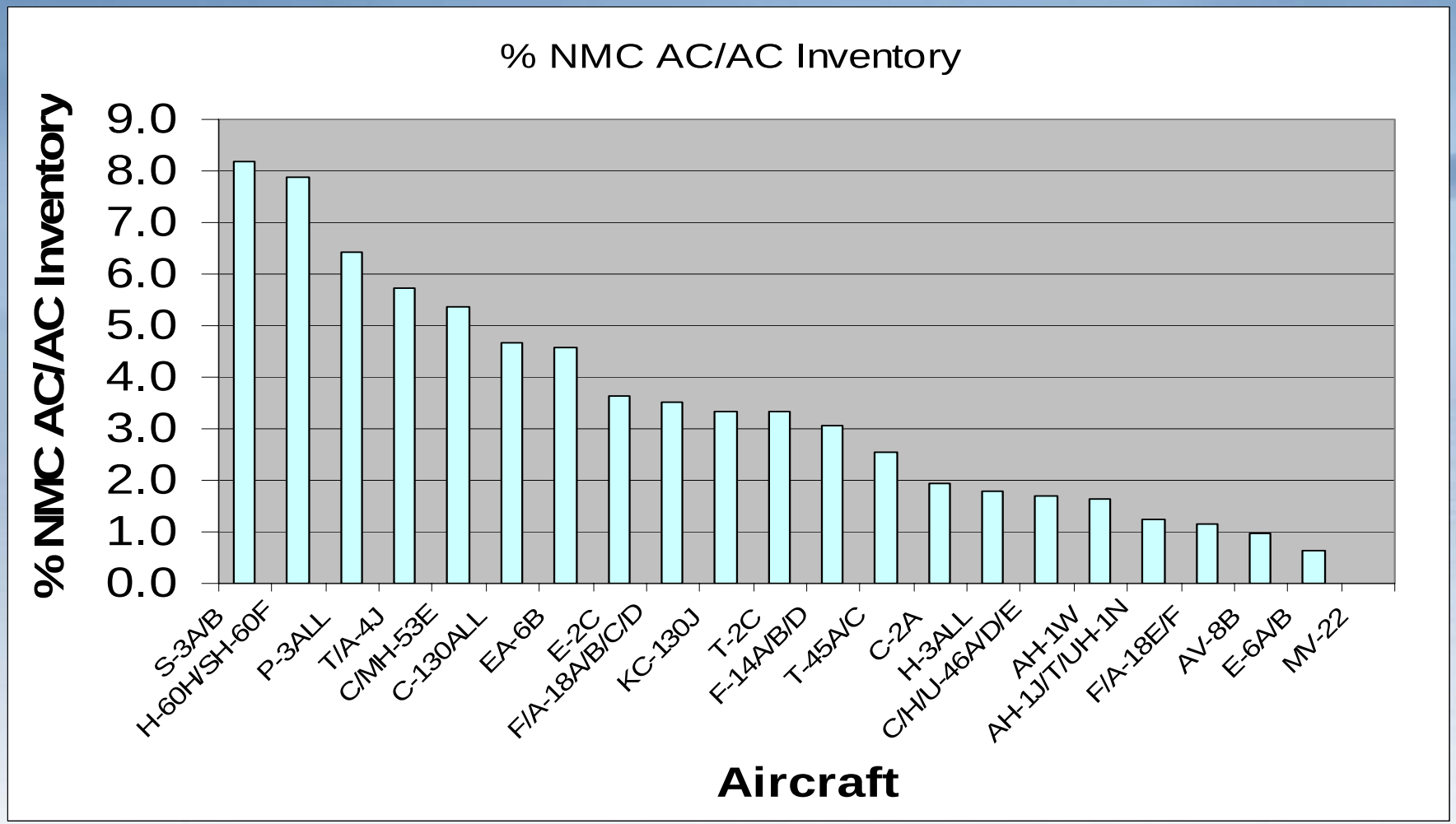
EA-6B

COMPOSITE RANK	SCORE	WRA	NOMENCLATURE	READINESS TOTAL	NMC/PMC MAINT	SUPPLY	SUPPORTABILITY ORGANIZATIONAL RPR	CANN	RMVL	INTERMEDIATE RFI	BCM	AFFORDABILITY MAINTENANCE LABOR COST ML-1	ML-2	AFM	AVDLR
1	24.8%	42A6E	AIRCRAFT BATTERY	12.8%	9.3%	21.5%	1.0%	27.9%	44.2%	38.0%	24.5%	5.9%	66.6%	46.2%	0.0%
2	14.7%	42A6A	CSD/ENGINE STARTER/GENERATOR EA6B ON	11.9%	13.7%	7.3%	7.0%	8.5%	9.2%	4.7%	34.4%	9.2%	5.7%	1.6%	63.3%
3	6.6%	42A65	SUPERVISORY REGULATOR CONTROL PANEL	5.1%	6.0%	2.9%	0.9%	10.2%	10.2%	15.4%	8.8%	3.8%	7.9%	0.3%	7.2%
4	4.5%	42845	ECM SYSTEMS AIRCRAFT WIRING	6.3%	7.2%	4.3%	8.3%	1.8%	1.3%	1.5%	0.8%	8.7%	1.2%	12.6%	0.0%
5	4.3%	42B6J	RT CKPT RELAY BOX ASSY 65A6 EA6A/EA6	2.8%	2.7%	3.0%	0.3%	6.0%	7.1%	18.3%	0.3%	2.5%	7.9%	0.7%	0.7%
6	3.8%	42B6K	EXTERNAL POWER MONITOR	6.1%	2.7%	14.6%	3.4%	8.5%	0.7%	0.0%	0.0%	1.9%	0.0%	7.7%	0.0%
7	3.7%	42A6D	TRANSFORMER RECTIFIER	4.8%	4.8%	4.9%	0.8%	5.3%	7.8%	6.6%	2.1%	2.1%	2.9%	2.3%	0.0%
8	3.7%	42A6B	AIR TURBINE GEN SET AND ENGINE START	1.2%	1.3%	0.8%	1.4%	0.4%	3.2%	0.5%	14.0%	2.4%	1.5%	0.2%	17.1%
9	3.5%	42800	AIRCRAFT WIRING	5.8%	7.4%	1.8%	13.9%	1.1%	0.1%	0.1%	0.0%	9.5%	0.1%	2.6%	0.0%
10	3.2%	42840	AVIONICS SYSTEM WIRING	5.7%	3.8%	10.5%	6.3%	1.4%	0.3%	0.2%	2.3%	4.4%	0.0%	1.5%	2.1%
11	2.9%	42A6M	TOP DECK RELAY MODULE BOX ASSEMBLY	3.5%	3.4%	4.0%	0.7%	4.6%	3.8%	6.9%	0.8%	2.5%	2.4%	1.0%	1.2%
12	2.7%	42000	ELECTRICAL SYSTEM	5.4%	6.7%	2.2%	4.7%	2.1%	1.2%	0.4%	0.5%	4.2%	0.2%	5.1%	0.0%
13	1.7%	42A67	VR AND SUPERVISORY PANEL EA-6B ONLY	0.9%	0.5%	1.9%	0.3%	3.2%	1.5%	1.9%	5.2%	0.4%	1.5%	0.0%	2.8%
14	1.1%	42830	FUEL AND OIL SYSTEMS AIRCRAFT WIRING	2.3%	3.1%	0.3%	2.9%	0.4%	0.5%	0.0%	0.0%	2.1%	0.0%	1.2%	0.0%
15	0.9%	42858	ENGINE PERFORMANCE IND ACFT WIRING	1.5%	2.1%	0.2%	2.4%	0.0%	0.3%	0.2%	0.5%	3.7%	0.1%	0.0%	0.3%
16	0.8%	4282L	INTERIOR LIGHTING AIRCRAFT WIRING	1.5%	2.1%	0.0%	2.9%	0.4%	0.4%	0.1%	0.0%	2.0%	0.0%	0.2%	0.0%
17	0.8%	4284T	RADAR NAVIGATION SYSTEM ACF WIRING	1.6%	1.4%	2.0%	1.6%	1.4%	0.3%	0.1%	0.0%	1.0%	0.0%	0.1%	0.0%
18	0.8%	42820	LIGHTING SYSTEMS WIRING	1.5%	0.7%	3.6%	1.6%	0.4%	0.0%	0.0%	0.0%	1.1%	0.0%	0.2%	0.0%
19	0.7%	42832	FUEL SYSTEM AIRCRAFT WIRING	0.9%	0.5%	2.1%	2.2%	0.0%	0.3%	0.0%	0.0%	1.3%	0.0%	1.2%	0.0%
20	0.6%	42A6T	EXTERNAL POWER PANEL ASSEMBLY	1.0%	0.7%	1.7%	1.1%	1.4%	0.1%	0.0%	0.0%	0.5%	0.0%	0.9%	0.0%
21	0.6%	42844	WEAPONS CONTROL AIRCRAFT WIRING	1.0%	1.4%	0.0%	2.3%	0.0%	0.1%	0.0%	0.0%	2.2%	0.0%	0.1%	0.0%
22	0.6%	42A61	MASTER ELECTRIC PANEL ASSEMBLY	0.7%	0.7%	0.8%	0.5%	2.5%	0.4%	0.5%	0.0%	0.4%	0.1%	0.1%	0.0%
23	0.5%	42A68	GENERATOR LINE CONTACTOR	0.5%	0.4%	0.7%	0.6%	2.1%	0.0%	0.0%	0.0%	1.1%	0.0%	1.1%	0.0%
24	0.5%	4284V	INTERPHONE SYSTEM AIRCRAFT WIRING	0.6%	0.8%	0.0%	1.7%	0.7%	0.4%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%
25	0.5%	42868	NOSE LANDING GEAR AIRCRAFT WIRING	0.4%	0.3%	0.8%	0.9%	0.0%	0.1%	0.0%	0.0%	1.2%	0.0%	2.0%	0.0%
	88.5%	TOTAL	PERCENT OF EFFECT FOR SYSTEM	85.9%	83.6%	91.9%	69.6%	90.1%	93.7%	95.4%	94.1%	76.0%	98.2%	89.0%	94.6%

RANKING COLOR CODE 1 2 3

JAN 03 THROUGH DEC 03

Sum Total Top 25 - Wiring System: ~29.1% => #1 Readiness WUC 42 Degrader

Non-Mission Capable Aircraft – Wiring Related

(Naval Aviation Platforms)