Fleet Readiness Center Southwest

From Brain to Brawn:
Enabling Maintenance Via The Digital Thread

Captain Timothy Pfannenstein, USN
"The use of IETM/ETMs has shown great promise in terms of reduction of distribution costs, data access times and reducing data mean time to repair.” Navair 4120.11

“Implementation of ETMs has caused a significant change in that contracted deliverables are digital rather than paper pages.” Navair 4120.11

“The primary motivation for contracting ETMs should be to provide cost effective, maintenance-aiding tools to the war fighter.” Navair 4120.11

Today

• About Fleet Readiness Center Southwest (FRCSW)
• S1000D and Navy Fleet Readiness Center products
• Taking things a step farther
• Leveraging the “Digital Thread” (Connecting entities, processes)
• Achieving results and closing the loop
Department of Defense

MRO

- Maintenance
- Repair
- Overhaul

- Navy and Marine Corps Aircraft and Weapons Systems
- Components and Engines
- Manufacturing and Processing

PMO Precision Maintenance Organization
Naval Aviation Enterprise

Production

FRCSW

Speed to the Fleet, Innovation & Agility

S1000D
MIL-STD-3001
MIL-STD-81310

IETMs/ETMs XML SGML??

Engineering & Logistics

NAVAIR

Data Modules XML SGML??

Supply Chain

DLA
Organizational Level (O)
- Squadron Level
- Servicing
- Replace Parts

On-Aircraft Maintenance

Off-Aircraft Maintenance

Depot Level (D)
- Overhaul
- Rework

Intermediate Level (I)
- Component Repair
  - Afloat & Ashore

Fleet Readiness Centers

IETMS  ETM  TM
Robust?
Major Navy/Marine Product Lines

- SH-60
- AH-1/UH-1
- H-53
- F/A-18A-G
- AV-8B
- LM2500
- E-2C/C-2A
- F-35/V-22
- USMC MMF
Established in 1919
2,100 In-Service Repair Requests Worldwide
Voyage Repair Team (Support all CVN/Surface ALRE)
1/3 of Workload is Marine Corps Aircraft/Systems
FRCSW Support Architecture

PRODUCTS

AIRCRAFT
- F/A-18
- E-2C
- C-2A
- AV-8B
- EA-6B
- P-3 (ISR)
- V-22 (ISR Future Depot Workload)
- H-60
- H-53
- H-46
- UH-1Y/AH-1W/Z
- F-35 (JSF)
- UAV (MQ-4 Triton/8 Fire Scout)

ENGINES
- LM2500
- T700
- T56

SERVICES
- Maritime
- Paint

COMPONENT REPAIR
- AVIONICS & INSTRUMENTS
- RADAR
- CSD / ROTATING ELEC
- COMPOSITE REPAIR
- CALIBRATION
- HYDRAULICS

MANUFACTURING
- WET PROCESSING
- FORMING / DROP HAMMER
- MULTI-AXIS MACHINING
- COMPOSITE FABRICATION

Site Japan
Iwakuni & Okinawa
FRCSW Det Japan

Site Whidbey Island
FRCSW Det Whidbey Island

Site Pt. Mugu
FRCSW Det Pt. Mugu

Site Hawaii
FRCSW Det Kaneohe

Site Lemoore
FRCSW Det Lemoore

Site Yuma
FRCSW Det Yuma

Site Miramar
FRCSW Det Miramar

SOUTHWEST
FRCSW North Island: Homplate

Red = Marine Corps MAG/MALS relationships

Distributed Maintenance
Distributed Data?
Component Partners

F/A-18
TEF & Stab Actuators

H-60 “Tip-to-Tail”

EA-6B  CSD

Cockpit Displays & E/F HUD

Performance Based Logistics Workload for Components = 18%
25 Active Public-Private Partnerships
New Products/Emerging Technology

F-35 Components
- Electro Hydrostatic Actuator System (EHAS)
- Leading Edge Flap System (LEFAS)
- Lube and Scavenge pump
- EU portion of the Electro Hydrostatic Actuator System (EHAS) (Moog)
- EU portion of the Electro Hydrostatic Actuator System (EHAS) (Parker)
- Electrical Power Generation and Conversion System (EPG&C)
- Electrical Power Management System (EPMS)
- Nose Wheel

H-1 Components
- Aircraft Wiring Integration Remote Terminal Assy. (AWIRT)
- Cockpit Wiring Integration Remote Terminal Assy. (CWIRT)
- Flight Control Computer (FCC)
- Optimized Top Owl (OTO)
- Inverter (AH-1Z)
- Inverter (UH-1Z)
- Air Data Computer (HIADC)
- Mission Computer (Tech Refresh)
- Multi-Function Display (MFD)
- Standby Air Data Computer (SADC)
- Stores Station Electronics (SSE)
- Memory Loader Verifier (UH1Y)
- Memory Loader Verifier (AH1Z)

Triton Components
- 36 Structures components

E2-D Components
- Radar
- On Board Oxygen Generating System (OBOGS)
- Fire Extinguishing System
- Electronic Liquid Cooling System (ELCS)
- Radar Pressurization and Cooling System (RPCS)
- Electronic Generating System (EGS)
- Communications Suite (COMM)
- Identify Friend or FOE (IFF)
- Integrated Navigation Controls and Display System (INCDS)

P-8A Components
- Computer Data Link (CDL)
- International Maritime Satellite (INMARSAT)
- Inter-communications system/Communications Switching Unit (ICS/CSU)
- V/UHF ARC-210
- Link 11
- High Frequency Radio
- Mission Computing and Display System (MCDS)

Leveraging S1000D constructs within weapon system maintenance plans enables speed and agility in technical data delivery
Enablers

Certifications

FRCSW Environmental Management System Standard – ISO 14001 Registration

FRCSW Quality Management Certification

AS9100 & AS9110 Quality Management Certification

FRCSW Occupational Health and Safety Standard/Safety Management System SMS 18001 Registration

In development FY-16 anticipated
Supporting the Warfighter

- F/A-18 Hornets / Super Hornets
- E-2C Hawkeyes & C-2A Greyhounds
- Ground Support Equipment (GSE)
- Training & Field Service Teams
- Aircraft Catapults & Arresting Gear
- Components & Manufacturing
- Intermediate Maintenance (AIMD)
- H-53 Super Stallion
- AH-1 Super Cobra
- UH-1 Huey
- AV-8B Harrier
- SH-60 Seahawks
You have seen who we are and what we do and why we do it, so…

What enables us to do it?
NAVAIR, S1000D and MIL-STD-3001

Fundamentals for Navy Technical Manuals:

• Migrate to Interactive Electronic Technical Manuals (IETM) in all acquisition and when cost effective on legacy systems

• Employ S1000D when functionality not obtainable with MIL-STD-3001. May employ MIL-STD-3001 when cost effective

• IETM/ETM not always the best choice (MRC decks/NATOPS)

• Ensure functionality

• Employ Integrated Data Environment (IDE) common database

• Maintain common “Look and Feel” among IETMs

• NMCI Compatible

• Employ Common Source Data Base (CSDB), Extensible Machine Language (XM/SL), Standard General Mark-up Language (SGML)
## IETMS Reality in the Depot

**FRCSW IETM Status**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>PEMAs with IETMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/A-18 A-D &amp; F/A-18 E-G</td>
<td>95</td>
</tr>
<tr>
<td>H-60</td>
<td>14</td>
</tr>
<tr>
<td>V-22*</td>
<td>12-24</td>
</tr>
<tr>
<td>MQ-8*</td>
<td>4</td>
</tr>
<tr>
<td>E-2D**</td>
<td>Planned IETM in five years</td>
</tr>
<tr>
<td>F–35**</td>
<td>Planned IETM in five years</td>
</tr>
<tr>
<td>H-1</td>
<td>No IETMs (Planned 2020)</td>
</tr>
<tr>
<td>E-2C</td>
<td>No IETMs</td>
</tr>
<tr>
<td>C-2</td>
<td>No IETMs</td>
</tr>
<tr>
<td>H-53</td>
<td>No IETMs</td>
</tr>
<tr>
<td>AV-8</td>
<td>No IETMs</td>
</tr>
<tr>
<td>Components:</td>
<td>No IETMs</td>
</tr>
<tr>
<td>LM2500</td>
<td>No IETMs</td>
</tr>
<tr>
<td>MMF</td>
<td>No IETMs</td>
</tr>
</tbody>
</table>

*New FY-15 Work Load  
**Planned Work Load

IETMs are not connected to depot administrative / maintenance processes

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**Sharing technical data** in product and process development requires the foundations of S1000D. With regard to Technical Manual Content Requirements (TCMR): “These requirements are used to develop and assemble complete TMs for any level of maintenance through depot.” (Navair 4120.11 IETM Look and Feel Requirements Handbook) **REALLY??**
• FRCSW is a key player in the Navy’s development of new processes that digitally link product design to product manufacturing devices.

• The digital thread ties in key functionalities present in the S1000D construct including:
  – External Processes (Parts, AM/CNC Operations via Common Language)
  – Graphics (Fly-Through)
  – Linkages (Hot-Spotting)
  – Navigation (Drill-Down)

• From *Engineering Design* to *Logistics Technical Data* and linkages to *Material Requirements*, in it simplest form *data sharing* on the *digital thread* enables production machining via Additive Manufacturing (AM) and Computerized Numeric Control (CNC) 2-5 axis devices. *(Brain to Brawn)*

**Current State: Transaction Based**

**Future State: Model Based Enterprise**
“Digital Thread” = Should exist not only for Engineering and Manufacturing, but for every element in Life Cycle Logistics
The Vision of Digital Connectivity in the MRO

Rationale for Enterprise Connectivity

Work Hard Today

Celebrate Tomorrow

Efficiencies Forever
• Mission
  – The Advanced Aircraft Technologies (AAT) IPT team identifies and champions innovative, cost effective solutions, and new business development opportunities to meet the evolving needs of the Naval Aviation Enterprise

• Vision
  – As a recognized leader, AAT IPT advances the collective knowledge in engineering and production capability by:
    • Creating an exciting place to work where services are sought and problems solved through innovation
    • Building an empowered and creative workforce
    • Collaborating effectively with the best in global industry, academia, and government
    • Capitalizing on our wealth of in-service aviation support experience

Empowered and Innovative workforce breeds world class aviation support

Innovating since 2008
FRCSW’s AAT IPT Approach

• Establish and leverage key relationships with Government, Industry, Academia, and Technology Organizations
  – OSD JTEG, ONR, NRL, AFRL, SPAWAR/NAVSEA, NCMS/CTMA, UCSD, SDSU, NGC, LM, and more!!!

• Leverage FRCSW Federal Lab Designation for effective Technology Transfer (T2): See Next Slide
  – Cooperative Research and Development Agreements
    • Intellectual Property and Patents
  – Educational Partnership Agreements (EPAs)
  – Partnership Intermediary Agreements (PIA)

• Engage in DoN SBIR and S&T process and assist PEO(T) in the transition of sustainment related R&D for legacy platforms

• Participate and Influence COMFRC's Advanced Technology Insertion IPT
  – Joint Technology Exchange Group (JTEG)

• Solicit and evaluate suggestions from the maintainers
A PARTNERING APPROACH

Federal Laboratory/CRADA

Cooperative Research and Development Agreements consistent with the mission of the laboratory.

- Job Performance Aides
- Laser Measurement
- Electro Discharge Machining Drill
- Atmospheric Plasma for Bonding

Why Collaborate with FRCSW Federal Lab?

- Gain access to FRCSW expertise, intellectual property and facilities
- Perform mutually beneficial R&D
- Government lab could successfully develop commercial product
- DoN may grant a patent to the CRADA collaborator

Sharing technical data in product and process development requires the foundations of S1000D. With regard to Technical Manual Content Requirements (TCMR): “These requirements are used to develop and assemble complete TMs for any level of maintenance through depot.” (Navair 4120.11 IETM Look and Feel Requirements Handbook) CAN WE?
Setting the Stage

circa 2009 - 2010

Advanced Measurement Systems & Reverse Engineering Lab

- Joint Lab with FRCSW Tooling Engineering Code 8.1 and Research & Engineering Code 4.0
- Exploit Reverse engineering work/3D opportunities
- Enhance repair design & analysis capability
- First article verification
- Rapid 3D models for Fleet Tech Directives & Job Performance Aids
- FRCSW makes $800K investment w/ NIPR funds for procurement of new equipment & software

Advanced Composite Rapid Tooling

- Need for rapid and inexpensive layup tooling for complex contoured composite parts fabrication
- Evolution of AMB/RE and AM Tooling
  - AAT (PT) proof of concept on F-16 E/F engine bay door fairing fin after section
  - Laser scan to form 3D Model
  - Strategies creates FDM tooling female mold
  - Nevada Composites fabricates “Green Sand” layup tool for autoclave
- Approved PIP Project $80K (FY10)
  - Material, contract & organic labor
  - Plan to verify process on section then full size part

Begin with the End in Mind


AMS/REL Capabilities

• Joint Lab with FRCSW Tooling Engineering Code 6.3 and Research & Engineering Code 4.0
  – Exploit reverse engineering workload opportunities
  – Enhance repair design & analysis capability
  – Verify first article manufactured items
  – Validate 3D Models from Legacy 2D B/Ps
  – Generate 3D models for Tech Directives, Animations, & Job Performance Aids, Model Based Instructions
  – Digital Tooling Verification

• Equipment
  – 7 axis CMM Arm w/Laser Line Unit
  – Portable API Laser Tracker System
  – Surphaser Spherical Scanner
  – Konica Minolta Stationary Scanner
  – Stratasys Dimension FDM

• Software
  – Verisurf, Polyworks, and Rapidform

Precision Measurement Tools Deliver Rapid Technical Solutions
AMS/REL Influence

AMS/REL

Rapid Prototyping
“3D Printing”

Training
3D GD&T
MBD
Lasers
CMMs

3D Models
for MFG
support, suppliers &
DLA via 3MS

Engineering &
Mfg support
Quality -
CSI / FAI
3MS

Stakeholders
6.8
7.2
5.4

Field Service
Support and
Engineering
Support

Tech Data
Animations
Job Performance
Aids (JPAs)
Model Based
Instructions (MBI)

Industrial
Tooling
Certification

RDT&E
Network
Certification

AMS/REL provides Tools for Transformation
Current FRCSW AM Capabilities

- Selective Laser Sintering (SLS)
- Fused Deposition Modeling (FDM)
- Stereo Lithography Apparatus (SLA)
Emerging Technology/Happening Now

Additive Manufacturing – 3D Printing

“Rapid Tooling”: 3D printed composite layup tooling.

Printed testing apparatus for Navy Primary Standards Lab (NPSL).

Printed computer controlled testing apparatus for NPSL.

3D Printed F/A-18 Super Hornet Environmental Control System duct.

3D Printed adapter to attach canopy peck drill to a “Zero-G” arm.

3D Printed tooling for forming sheet metal.
We can make it!!! But with what???

AMS/REL

Case Studies at Fleet Readiness Center Southwest
• C2 Wing fold Issue.
   – Determine Mechanical Issue, if any, and report results to Aero engineers in group.

• C2 Wing fold Issue.
   – Scan data set created using the Surphaser Spherical Scanner
Data Comparison of Multiple Scans
Rendered Scan Cloud of Aircraft

Note the detail of the “scan” and rendering of the data for visual confirmation.

Can a Blue Print give you that?
Meshing of Data for Comparison

Separate scanned data sets merged into a unified mesh
Modeled Areas Compared to Scan

Granularity like this NOT achievable in Blueprints or an IPB

Parametric CAD, Features and Primitives from Scan Data
These Features Generated are Parametric

Primitives or Features (CAD)
Interference Analysis

Interference
In Tolerance

Interference
Clearance
Tolerance
Interference
Interference Analysis

This Pin will Drag based on the Best-Fit Alignment & Deviation Map

Interference/Acceptable!!!!!

Where is this data today, how is it accessed, who can see it, what can we learn?

This level of Interference was “Acceptable” and the Pin would drag and lock. This level of granularity allowed the “real” culprit to be discovered. Improper Lubrication and Hydraulic system cavitation were the root causes.
Corrosion Mapping

Circa 2010

Corroded Wing Rib Location

Leading Extension

Where is this data today, how is it accessed, who can see it, what can we learn?
3D CNC Tube Bending

Features extracted from tube scan data to generate 3D CAD models used to drive CNC tube bending machines.

Where is this data today, how is it accessed, who can see it, what can we learn?
Aircraft Mishap Investigation

Damage noted from scan data.
Granularity/Comparisons allowed
SFF determination

Determined to be within SFF limits for one-time flight and repair at Depot

Where is this data today, how is it accessed, who can see it, what can we learn?
Manufacturing Model Management System (3MS)

2D Blueprint

Build 3D Solid Model
Drawing Reconstruction
Advanced Metrology

Validated 3D Solid Model

Advanced Measurement Verification
3D Printed Part (Fit Check & CMM program)

Produce the Part
Numerical Control (NC program)

2D to 3D Model Conversion Process

Distribution Statement A: Public Release (FRCSW SPR# 14-0001)
Status Today…We Have this!!!

Complicated, Hundreds of Dimensions and Drawings

Accessible to Few, Transferable to Fewer

Accurate? Current? Available?
MODEL BASED DEFINITIONS (MBD)

Accessible, Current and Deliverable to Anyone, Anywhere

Status Tomorrow....We Want This!!!
# NAVAIR 6.0 – Functional Alignment

## Integrated Logistics Elements

<table>
<thead>
<tr>
<th>ELEMENTS</th>
<th>DEFINITION</th>
<th>SME</th>
<th>STAKE-HOLDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Planning</td>
<td>To ensure that the system can be maintained effectively and economically at the desired level of readiness after it is placed in operational use. Ensures that all required maintenance assets are placed to support deployment.</td>
<td>AIR-6.7</td>
<td>Fleet, FRCs, CNAF, OPNAV, HOCM, NAVSUP/NAVICP, DLA, NAVFAC, Commercial Industrial Activities</td>
</tr>
<tr>
<td>Design Interface</td>
<td>Ensures there is a relationship between the design parameters such as reliability and maintainability, and readiness and support requirements. Early focus should result in the establishment of support-related design parameters.</td>
<td>AIR-6.7</td>
<td>Fleet, FRCs, PMAs, CNAF, OPNAV, HOCM, NAVSUP/NAVICP, DLA, NAVFAC, Commercial Industrial Activities</td>
</tr>
<tr>
<td>Supply Support</td>
<td>Having the right part in the right place at the right time in the right quantity at the most economical cost.</td>
<td>AIR-6.7</td>
<td>NAVSUP/NAVICP, DLA, Fleet, CNAF, FRCs, PMAs</td>
</tr>
<tr>
<td>Training &amp; Training Devices</td>
<td>Include the processes, procedures, techniques, and equipment used to train civilian and military personnel to operate and support the system.</td>
<td>AIR-6.7</td>
<td>Fleet, Training Commands, PMAs, FRCs, OPNAV, CNAF, and other DOD Services</td>
</tr>
<tr>
<td>Support Equipment</td>
<td>Encompasses all equipment required to perform system operation and maintenance. This includes associated multiple-end items, ground handling and maintenance equipment, tools, organizational, field, and depot support equipment, metrology and calibration equipment, test equipment, Automatic Test System (ATE) and related computer programs.</td>
<td>AIR-6.7</td>
<td>Fleet (Subs/Ship/Weapons), PMAs, FRCs</td>
</tr>
<tr>
<td>Packaging, Handling, Storage,</td>
<td>The resources, processes, procedures, design considerations, and methods to ensure that the system, equipment, and support items are properly packaged and preserved, handled, stored and transported.</td>
<td>AIR-6.7</td>
<td>Fleet, NAVSUP/NAVICP, DLA, NAVFAC, FRCs, PMAs</td>
</tr>
<tr>
<td>and Transportation (PHST)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilities</td>
<td>All permanent or semi-permanent real property assets required to support a system, including major modifications of existing structures. Used to minimize or eliminate the facilities required to operate and support a defense system.</td>
<td>AIR-6.7</td>
<td>Fleet, PMAs, NAVAIR Sites, NAVSEA, FRCs, CNAF, NAVFAC, CNIC</td>
</tr>
<tr>
<td>Computer Resource Support</td>
<td>Hardware and software are critical for operating most major weapon systems. Includes the facilities, hardware, software, documentation, and people needed to operate and support the software-intensive portion of weapon systems.</td>
<td>AIR-6.8</td>
<td>DoN CIO, AIR-7.2, CNAF N6, AIR-4.0, OPNAV N4, SPAWAR</td>
</tr>
<tr>
<td>Technical Data</td>
<td>Used to provide sufficient information to manufacture and support the system after deployment. The Technical Data Package (TDP) may include: engineering drawings/specifications, process descriptions, and other documents that define the physical dimensions, materials composition, performance characteristics, manufacture, assembly, and acceptance test procedures for producing and/or supporting the system.</td>
<td>AIR-6.8</td>
<td>AIR-4.0, CNAF N42, OPNAV N4, NAVAIR PEOs</td>
</tr>
<tr>
<td>Manpower &amp; Personnel</td>
<td>The &quot;spaces and faces&quot; support element of acquisition logistics, identification and programming for Civ &amp; Mil personnel, skills and grades required to operate and support the systems throughout its life cycle, peacetime and war.</td>
<td>AIR-6.8</td>
<td>SUPERS. N1, N88, NAVAIR PEOs, CNAF N1</td>
</tr>
</tbody>
</table>

Integrated Logistics Elements Leverage Model Based Data.
A Digital Repository Where **all** Systems Access Base Data Elements
Collaboration for Capability, Technology, and Skills

Industry
- Develop Strategic Manufacturing Partners
- Explore CRADAs for Technology Development and Insertion

Academia
- Establish Educational Partnership Agreements
- Integrate Industrial and Manufacturing Engineering Disciplines
- Leverage Senior Design Projects and Internships
- Specialized Training

Other DoD
- Partner with Regional DoD Depots
- Leverage DLA relationship
- Office of Naval Research
- SBIR programs
- OSD/NCMS/CTMA

Expand the Network/Improved Accessibility

CRADA with Nevada Composites for Rapid Composite Tooling

CRADA with Verisurf for Laser Scanning

2012 UCSD TIPS project for Model Based Instructions

Joint SDSU/UCSD/FRCSW Proposal for Composites Failure Prediction Research

OO-ALC Reverse Engineering, Nlign SBIR

ONR TIPS, RIF & S&T funds

FRCSW partner w/NCMS
- RARE Parts Team (AM)
- PLM for Sustainment
- E-drill
- Digital Pen
Create a Digital MRO!!
Include all Maintenance Levels

• Support a fully integrated Product Lifecycle Management (PLM) solution for COMFRC (and other DoD)
  – Industrial Equipment on COI and IT Hardware
  – Wireless Infrastructure Operational
  – Pilot Product Lifecycle Management (PLM) software

• Paperless Manufacturing - 3D Model Based Definition

• Pilot Model Based Instructions (MBIs)
  – UCSD Summer Intern Project
  – Evaluating Various Software Tools for Authoring & viewing with Adobe PDF

Circa 2012
Connect Reams of Digital Data

Etegent’s Nlign Software
- SBIR Project
- Composite Damage Mapping Software

Engineering Analysis
- Finite Element Analysis Models
- Strength and Fatigue
- SAMMT

Production Support
- Model Based Instructions (MBIs)
- Job Performance Aids/Training Performance Aids
- Digital Pen
- CASS Lab/ATE

AMSREL
- Laser Scan Data
- Portable CMM Data
- Digital Tooling Files
- 3MS data

Non Destructive Inspection
- Real-time X-RAY
- Computed Radiography files
- Backscatter X-Ray files
- Ultrasonic CSCAN & MAUS Data

Manufacturing
- CNC Tool Path Programs
- CMM First Article Programs
- 3D printer STL files
Digitize and Connect Terabytes of Information

Improving ASIP Analysis Using Structural Data Visualization Organization and Archival Techniques

Gary Steffes
AFRL/RXCA
(537) 265-4678
Gary.Steffes@wpafb.af.mil

Shane Perkins
NAVAIR - 12
(819) 546-429
Shane.Perkins@navair.daf.mil

Background – Engineering Analysis

★ Historical perspective
  ✫ Aging fleet drives increased inspection frequency and damage findings
  ✫ Increased repair demand necessitates a more robust evaluation tool for engineers
  ✫ Manual based methods are commonly being utilized to evaluate and analyze damaged components

★ Motivation from Engineering
  ✫ Streamlining of workload reduces non-value-added work hours and engineering turn-around-time (TAT)
  ✫ Robust archival of previous analyses drastically reduces redundant workload
  ✫ Engineering man hours are free to work other high priority tasks

Enable Connections of Industry and Government Data

Analytical Feature Development Foundation

- Air Force SBIR-II (2007) with Etagent Technologies
  - Executed SBIR-I plan
  - Aligned NDI data to a CAD-like model of structure
  - Facilitated communication between maintainers and engineers
    - Align digital images to various models
    - Expedite engineering evaluations and dispositions
    - Efforts culminated in development of software
      - NLign
    - Efforts continue to build a robust tool for maintenance of weapon systems

Software Overview

Collect-Organize-Archive-Analyze

Paper Forms
- Scanned Forms
- Smart Pens
- NDI Logs

Digital Images
- NDI C-scan Images
- Most standard digital cameras

Reference Data
- 2D & 3D CAD
- FEA models
- Design specific models
- Manufacturing specific models

Machine Data
- Machine Tool Log files
- Tool Path Data

Other Data
- Legacy databases
- Dimensional data
- Process data
- Laptops
- Tablets
- Manual data entry

Collect
- Automatically collect digital data
Capitalize on Nation-Wide Efforts

NAVAIR Integration Applications

★ Fleet Readiness Center – Southwest (North Island) – Shane Paredes

★ F-18 flight control structures
  - Mapping
  - Historical precedents
  - Management
  - Checking configuration

NAVAIR Data Collection Pieces

Reference Data
- Finite Element Model(s)
- Composite Ply Geometry
- Standard Repair Zones
- Local Engineering
- Specified Zones
- Weight Limited Areas
- Fastener Locations
- Substructure Geometry
- Any other 2D or 3D Representable Data

Evaluate
- Rapidly Evaluate Damage Condition
- Immediate historical knowledge
- Fast and Accurate assessment of damages

Archived Data
- Previous Damage Mappings
- Aircraft Specific Damages
- Component Specific Damages
- Previous Analyses & Designs
- Digital Images

Digital Images
- Damage extraction & mapping
Create Digital Pathways for Distance Repair

Or any repair!!!!!
Employ Connected Software Approaches

**Engineer Evaluation – NLign Alignment**

- Software algorithm performs 2D to 3D alignment
- User identifies point correlations

**Engineer Evaluation: Previous Analyses**

- All previously mapped damages are searchable for historical repair precedents
- Searchable by: Location, Damage Type, Serial Number, Aircraft Tail Number, Left/Right Hand, Repair Document ID, and/or any other user-defined criteria
- Redundant analysis work is minimized or eliminated by having access to a model-based representation of all previous damages and repairs
- Many repairs acceptable by previous analysis similarity

**Engineering Evaluation – Damage Mapping**

- Combined User / Software detection of damage indications projects damage locations from the 2D picture to the 3D model.

**Engineer Evaluation: Data Aggregation**

- Immediate visual representation on all relevant reference information required for analysis.
- Finite Element Model
- Composite Ply Boundaries
- Weight and Repair Limited Zones

- Minimal engineering time required to fully understand and evaluate damage indications. “Error-Adverse Process”
Leverage the Digital Pathway

Additional Uses: Configuration Evaluation

- Model based alignment allows for quick and visual representations of the effects of configuration changes.
- Software was used to evaluate potential short edge distance conditions caused by replacing an older longeron with a newer configuration.

Original Configuration
Configuration Change Evaluation

Potential Short Edge Distance Locations

Maintenance/repair data accessible, storable, current and available to anyone, anywhere

Connected using S1000D constructs, employing graphics, linkages, navigation, fly-over and more!!!

Additional Uses: Inspection / Repair Evaluation

- Cracks are found during inspection and a known repair exists in the area.
- How to evaluate if crack indications are within repair area criteria?

Photograph Damage
Align to Model
Evaluate Indication

Crack Marking
Damage Extraction
Standard Repair Cutoff Area
Crack Mapping
FRCSW a Key Player in DT Development
“TO BE” State:

• Maintenance based on early identification of damage & damage precursors

• Individual aircraft history available to operators, maintainers, & engineers

• Preventative maintenance & repairs/retrofits are personalized by Tail Number

• Majority of effort is in predicting, preventing, & managing damage state throughout life

Future Lifecycle Management will be Predictive, Integrated, Individualized, Preventative and Accessible to all
Enterprise Digital Thread Plan

Digital Thread Infrastructure
- Connectivity + Workforce + Digital Tools + Data

Manufacturing Pilots
- NAVAIR Enterprise Development
  - Data Management
  - Gateway for Fleet Data Access
  - Life Cycle Management Workforce
  - Data Standards
  - Process Development

Process/IT Tools Pilots
- NAVAIR Enterprise Deployment
  - NAE
  - Legacy Systems
  - Business Model
  - Policy and Process

Connectivity + Workforce + Digital Tools + Data

FY15  FY16  FY18+
• Successful Demonstration of Product Lifecycle Management (PLM) Software to support 3MS in a Model Based Environment
  – NCMS/CTMA project proved ability to seamlessly transfer large 3D digital files between engineering and manufacturing across the FRC enterprise

• Key Player on NAVAIR’s Additive Manufacturing IPT
  – Top level goal to produce flight critical metallic part at an FRC in 3 years and install in aircraft.
  – Targeted Use Case: Traditional Repair Fittings
    • Since 2008, FRCSW has produced over 1200 machined repair parts comprised of 98 different part numbers.
Current location Bldg 250

Proposed layout for new location in Bldg 472. Collocated advanced manufacturing with CNC, CMMs and various AM equipment and staff

Will leverage and enhance activity within the Digital Thread
Overall Benefits

- Increased accuracy in damage evaluation and analysis
- Improved aircraft health monitoring and damage trend recognition
- Fewer Engineering man-hours per repair disposition
- Reduced repair queue time and turn-around-time (TAT)
- Less duplicate work effort by use of a more robust archive capability
- Engineers are freed up to work other priority tasks!
- Reduction in shop and fleet effort required to report damages
- Reduced Aircraft-on-Ground (AOG) time
- Improved Engineering support efficiency to maintenance overhaul lines
- All the above lead to annual cost savings

“Digital Thread” = Connects all aspects of Engineering, Logistics, Material and Production. The Product Life Cycle Link

“To Be” State: CONNECTIONS

- AIRWORKS
- ERP
- SharePoint
- System Engineering Tools
- PMT
- PMA
- Flight Clearance

Digital Thread Enterprise (DTE) Services
Systems Integration Development Lab:
Skilled SME’s = CAD/CAM/CAE, PLM, LCM, Integrators

Interfaces to Legacy ALE Systems

Interfaces to OEM’s

JDRS
NAVICP
DLA
OEM’s

Other Requirements Interfaces
What Can We Achieve?

Accessible, Current and Deliverable Data to Anyone, Anywhere
• Our vision is that a conduit exists for digital data, regardless of source that has a vehicle upon which to be accessed and available for anyone, anytime for any purpose

• The S100D standard can be critical element that connects data within the Digital Thread

• Be it an engineer’ product design, a logisticians outfitting of an IETM, a production controller ordering a part, or an artisan installing or repairing a system, they all have access to current data that is linked, standardized and controlled

• Using the digital thread conduit, production personnel can perform tasks by directly accessing Engineering/logistics data and related systems

• With the digital thread manufacturing can directly access and fabricate parts that are fully solid model based employing “live” configuration management control. SPEED, SPEED, SPEED

The DT, One Stop, Multi-Purpose, Multi Outcomes
On behalf of our 4,000 employees

Thank You!