A-10 IMPLEMENTING PROGNOSTICS WITH THE DIGITAL THREAD

Martin Raming
Southwest Research Institute | A-10 ASIP USAF AFLCMC/WAA

Co-Authors: Hazen Sedgwick (USAF-Hill AFB), Luciano Smith (SwRI), and Paul Clark Ph.D. (SwRI)

ICAF
International Committee on Aeronautical Fatigue and Structural Integrity

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U.S. AIR FORCE

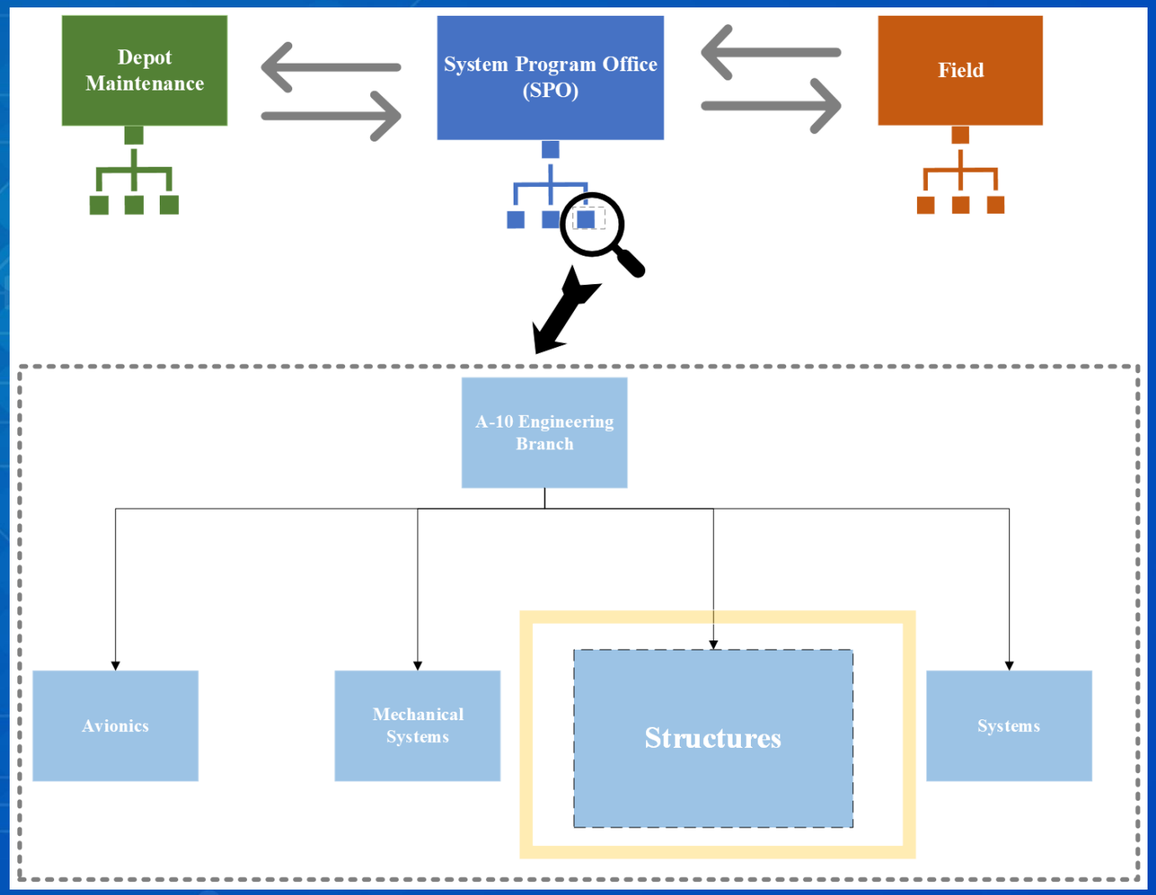
Background

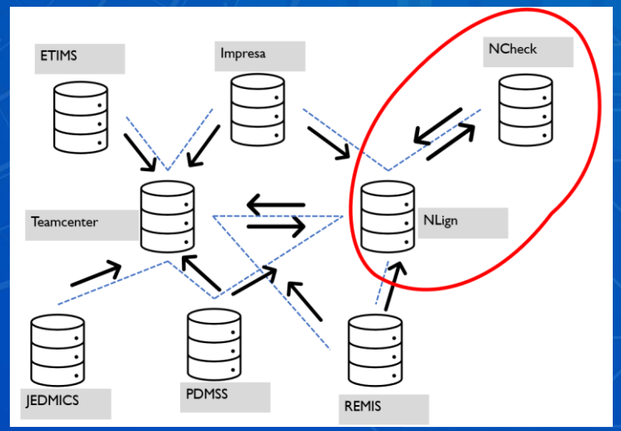
- 1973 A-10 Aircraft by Fairchild-Republic is selected to fulfill close-air support (CAS) by the United States Air force (USAF)
- 1997 A-10 fleet approaching safe service life of 6,000 hours[1]
- 2002 A USAF investigation declares A-10 ASIP "broken"
  - The path towards recovery for A-10 ASIP resulted in a cost-effective organic engineering expertise unique to the USAF [2]
- 2007 Digital transformation for the A-10 begins with the design of an enhanced wing assembly (EWA) as part of a wing replacement program

https://www.thedrive.com/content-b/message-editor%2F1603460087257-1.jpg?auto=webp&optimize=high&quality=70&width=1440

Breadth of A-10 SPO Digital Thread

- Three main departments: Depot, Field, and System Program Office (SPO)
- Multiple digital thread systems utilized
- Focus on A-10 ASIP digital thread





ASIP Digital Thread Requirements

5.5.12
Force Management Database

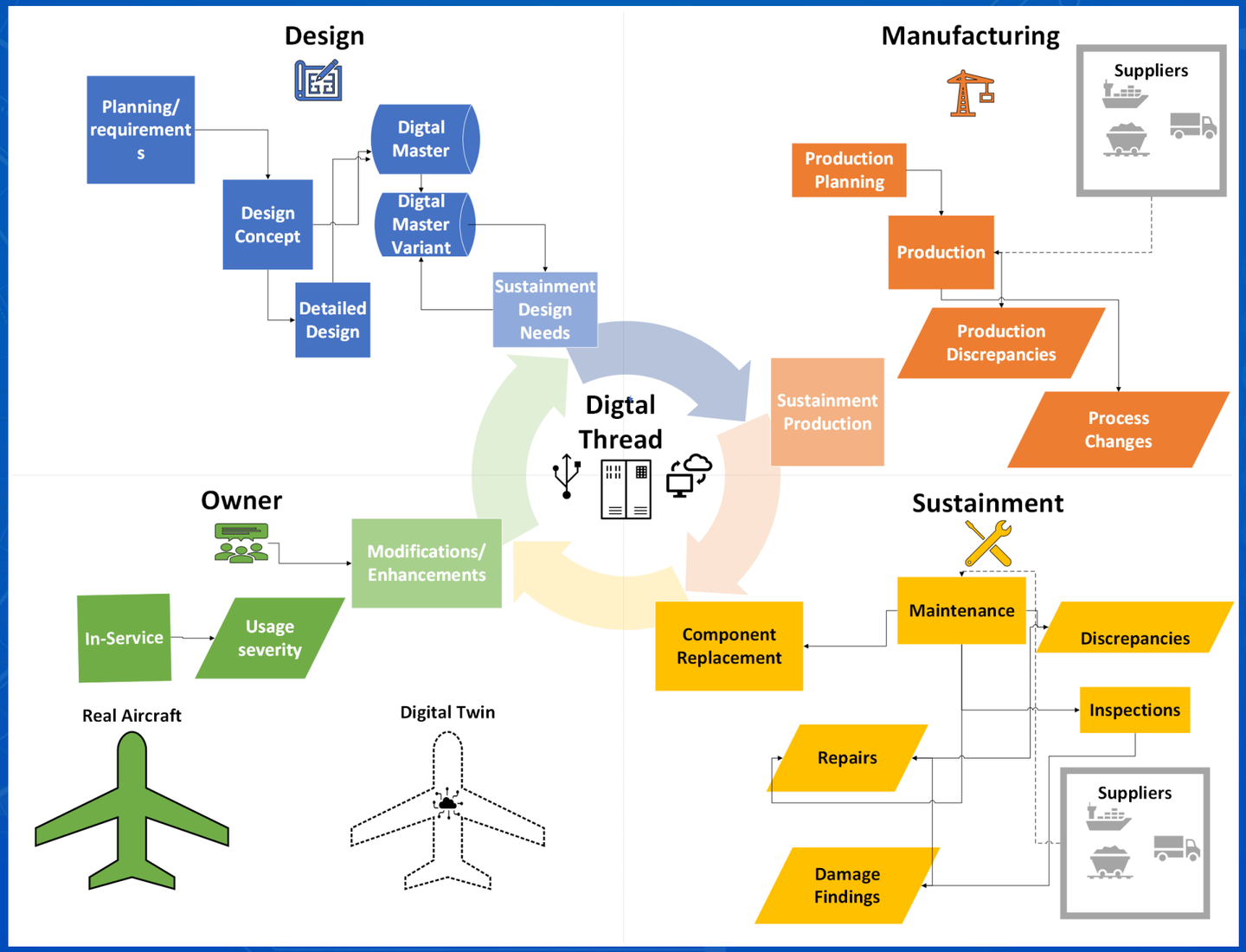
MIL-STD-1530D
Task V [3]

- 5.5.1 L/ESS
- 5.5.2 IAT Execution
- 5.5.11 Repairs
- 5.5.8 ACI
- 5.5.15 Others as Required

- 5.5.3 DADTA Updates
- 5.5.7 CPCP & Corrosion Updates
- 5.5.4 L/ESS & IAT Updates
- 5.5.10 T.O. Updates
- 5.5.5 NDI Updates
- 5.5.13 Structural Certification Updates
- 5.5.6 Structural Risk Analysis Updates
- 5.5.14 Economic Service Life Analysis Updates

5.5.9
FSMP updates

The Digital Thread Lifecycle



Data Collection Before Digital Transformation

- Paper Logbooks
  - Handwritten
  - Signatures and stamps
  - Stored in cabinets
  - Delivered periodically

Data Collection Before Digital Transformation

1. Mechanic prepares the aircraft or component for inspection
2. NDI notified, and an inspection performed.
3. Findings documented in the logbook
4. Mechanics perform corrective maintenance actions by oversizing the hole by a nominal size
5. NDI reinspects repaired holes.
6. Steps 4 and 5 would be repeated until NDI cleared the hole or maximum oversize diameter reached

Process

Example of fuselage inspection #2 with fabricated data

1	2	3	4	5	6	7	8	9
	NDI: Record				MX: Record			
Hole #	Upper Longeron Plate	Upper Longeron J-Extrusion	FS 468.50 Frame	-63 Strap	Hole Diameters (+/- 0.001 in.)		AFMC Form 202 #	Comments
	Holes 1 and 2 (0.183 in.) Hole 3, 4, 5 (0.250 in.)	Hole 3, 4, 5 (0.250 in.)	Holes 1 and 2 (0.460 in.)	Hole 5 (0.190 in.)	Initial	Repair (Pre-Coldwork)		
RH 1			All Clear		0.460 N/A N/A N/A N/A			
RH 2					N/A N/A N/A			
RH 3	70% 50% Clear				0.25 N/A N/A N/A N/A	0.266 0.278		
RH 4					N/A N/A N/A N/A			
RH 5					N/A N/A N/A N/A			

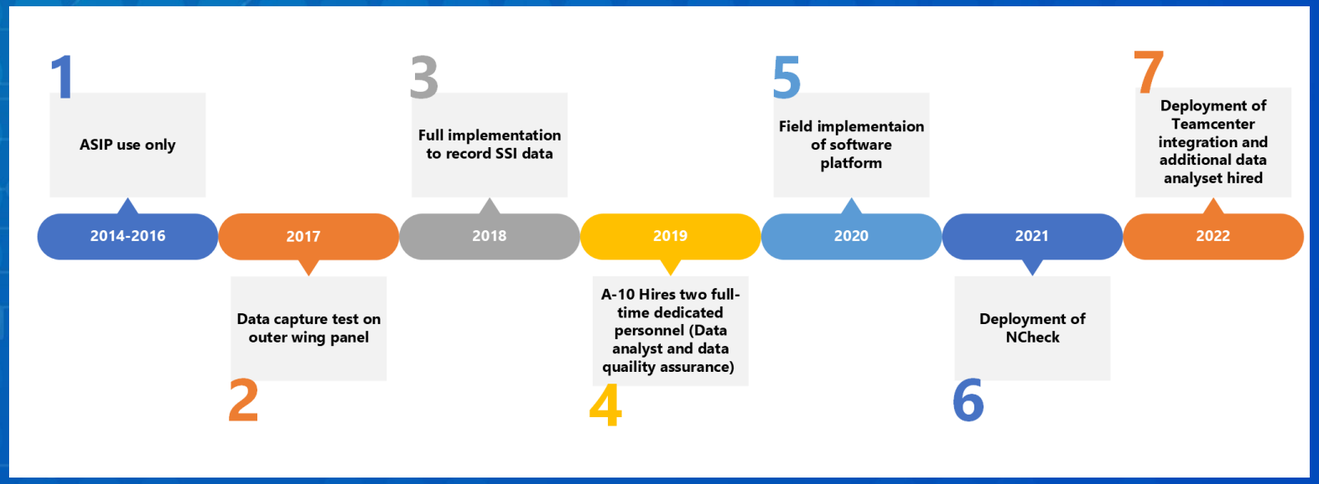
F07-003S03-C06

REV 2(3)

Requirements

Digital Environments

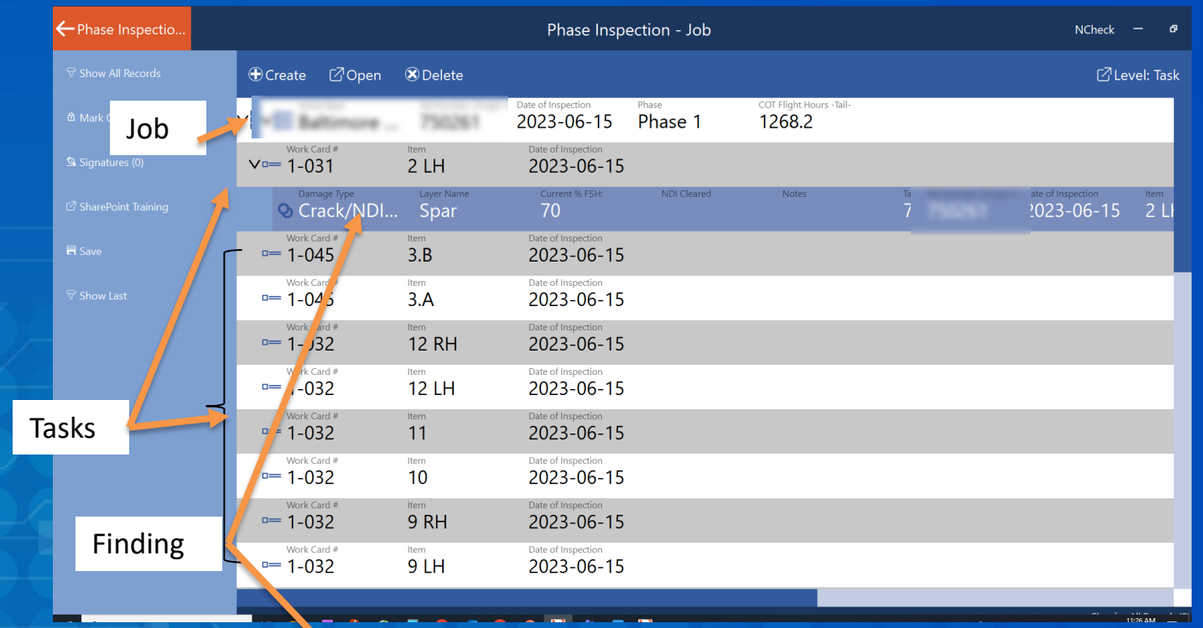
- NLign Analytics Platform
  - Small Business Innovation(SBIR) Funding
  - NDI data in the beginning
  - Sprints of software enhancements (USAF funded)

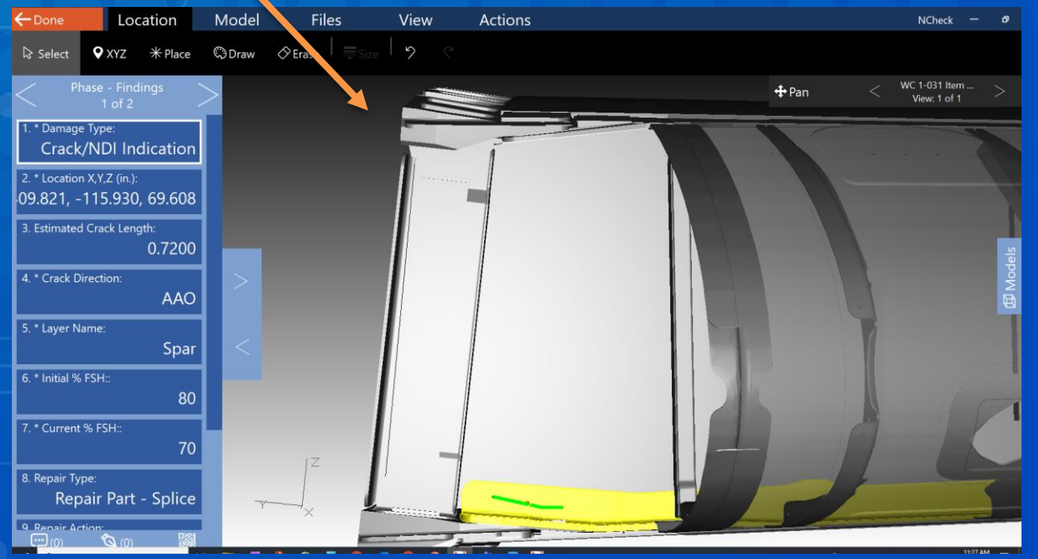


Timeline of NLign implementation [6]

Digital Data Capture

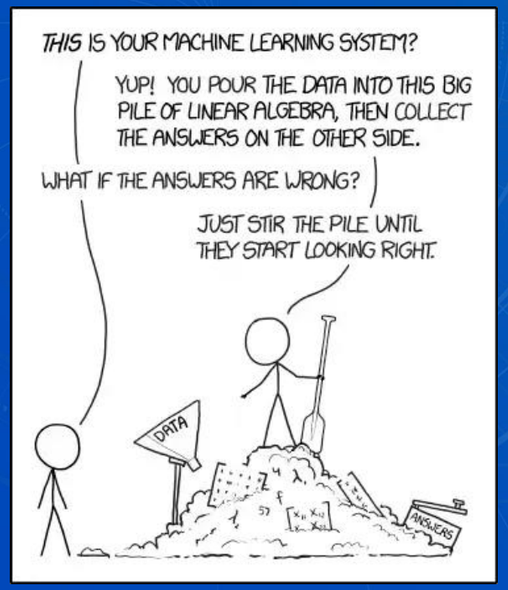
- NLign as data capture software replaces logbooks in 2018
- NCheck developed with SIBR funding
- Full transition to NCheck as data capture software at the shop floor



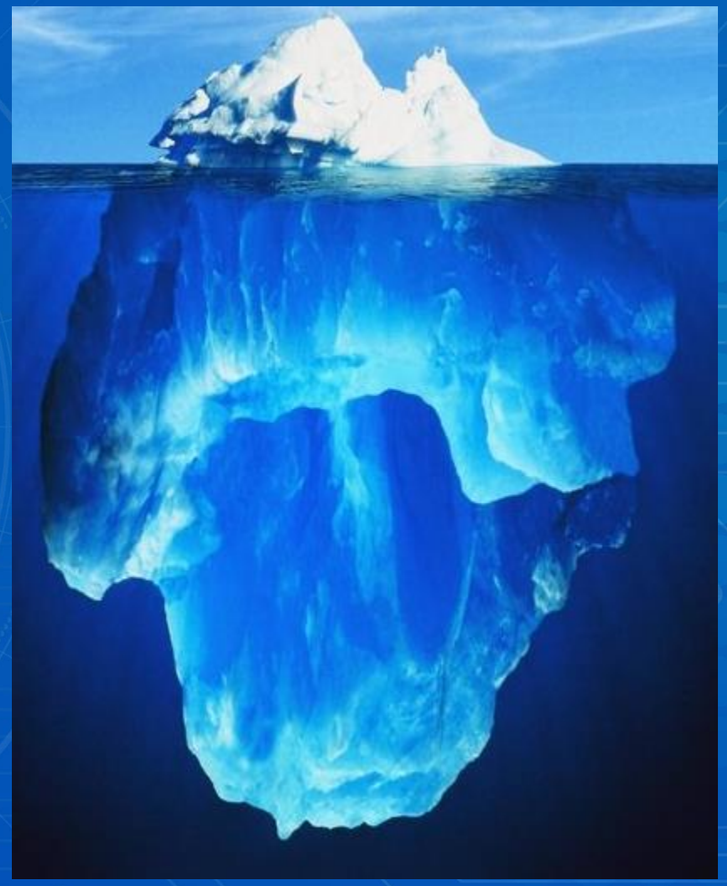


Data Requirements for Prognostics

- High Quality
- Decisive



https://xkcd.com/1838/



https://www.tokresource.org/tip-of-the-iceberg

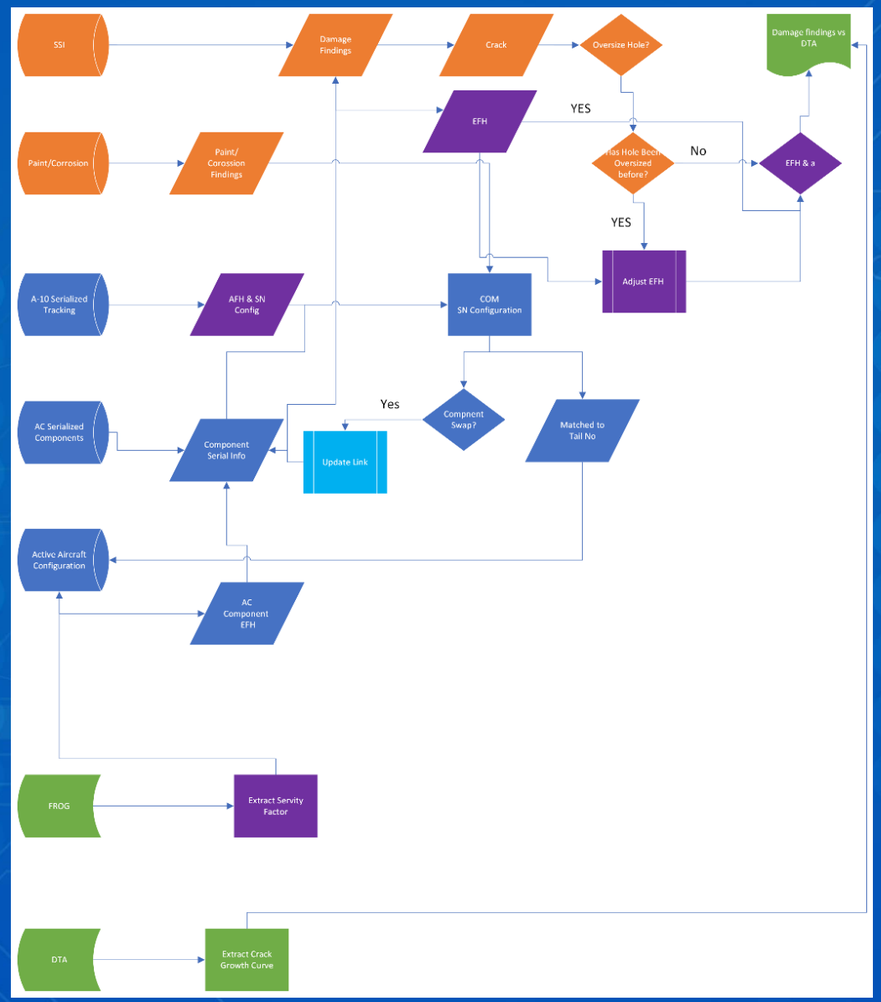
What it takes to meet requirements

- Data architects
  - 2 full time at A-10
- Data quality analyst
  - 1 full time at A-10
- We are all data wranglers and it takes up a lot of time
- Accountability from the shop

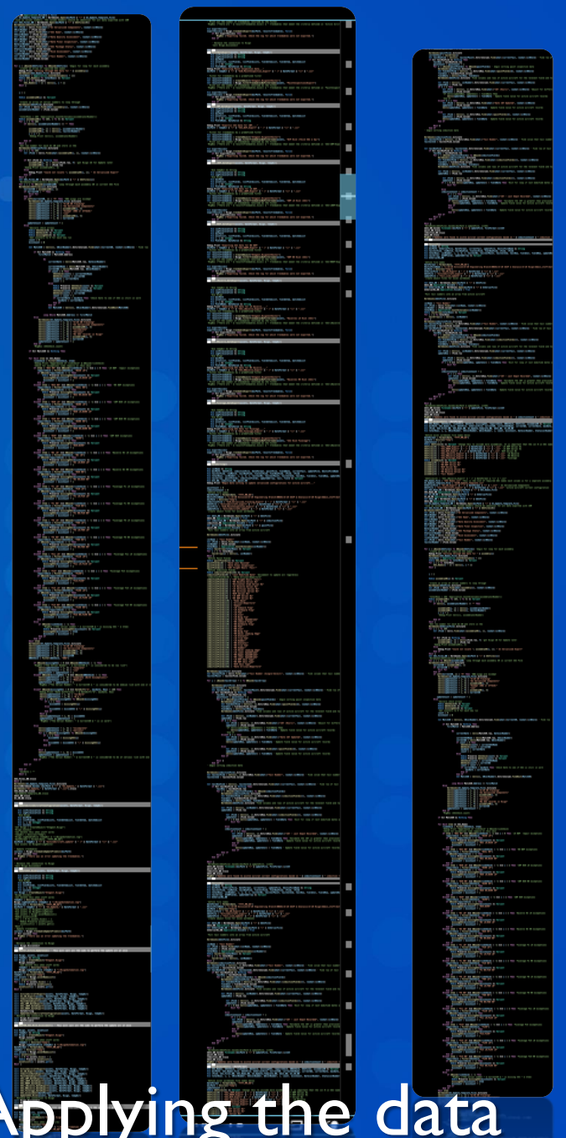
Prognostic Data Model

Data alone is insufficient to convey technical statements [6]

- Structure
- Context
- Relationships

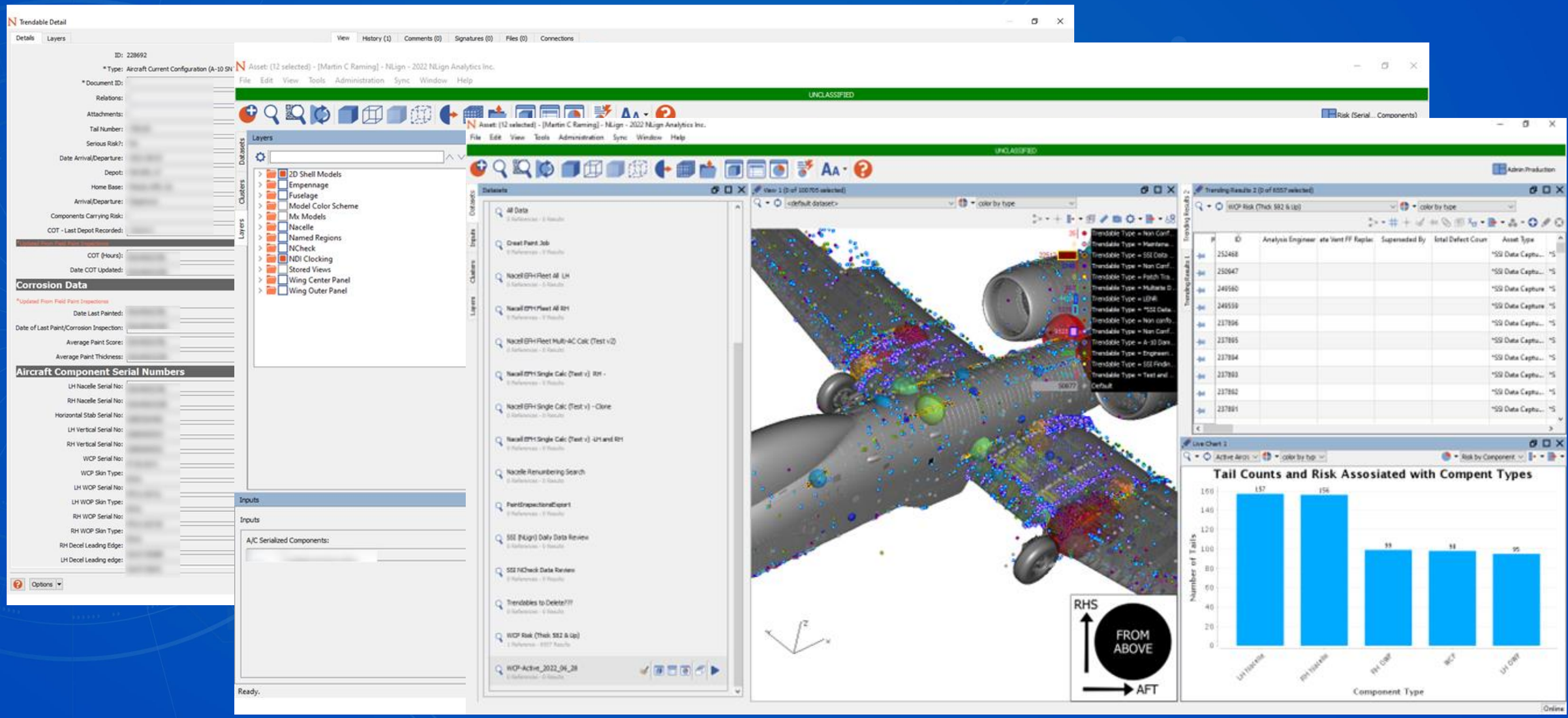


- Data Model

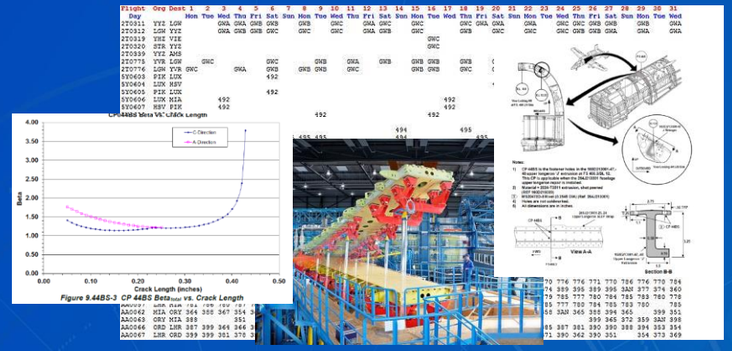


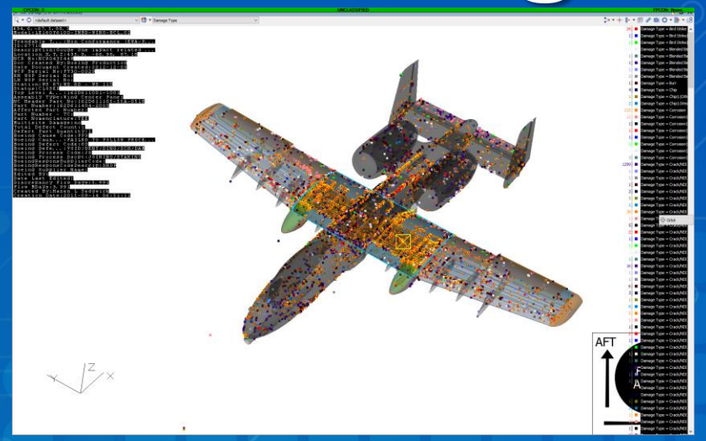
- Applying the data model with COMs

NLign User Interface and Dashboards



Risk Based Inductions and Prognostics





https://www.dvidshub.net/news/432685/re-winging-10-makeover

PRoF

- Individual aircraft tracking (IAT) and usage severities
- Fatigue characteristics of specific material
- Unique geometries that are considered the most critical
- DTA
- Fatigue test data

+

Holistic Prognostics

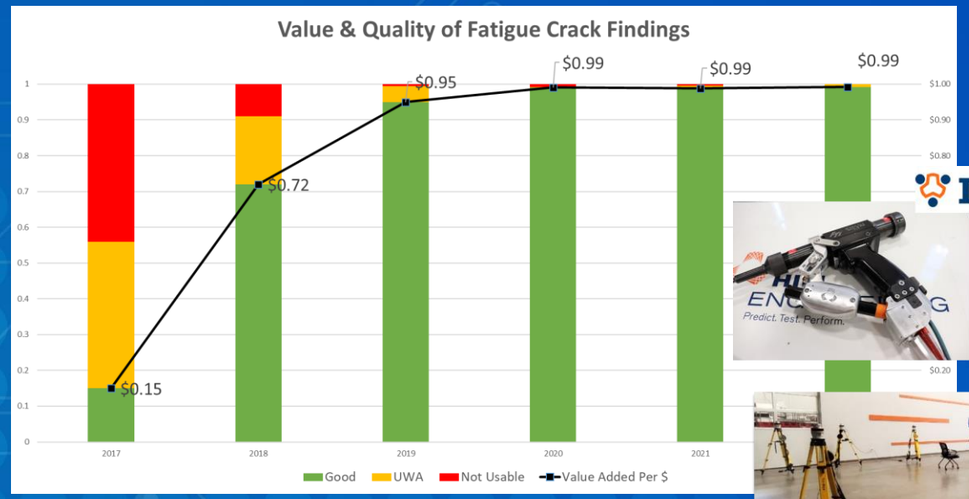
- High Level overview to component specific
- Live inspection findings
- Repairs
- Maintenance discrepancies
- ETAR, TCTOs, ACI

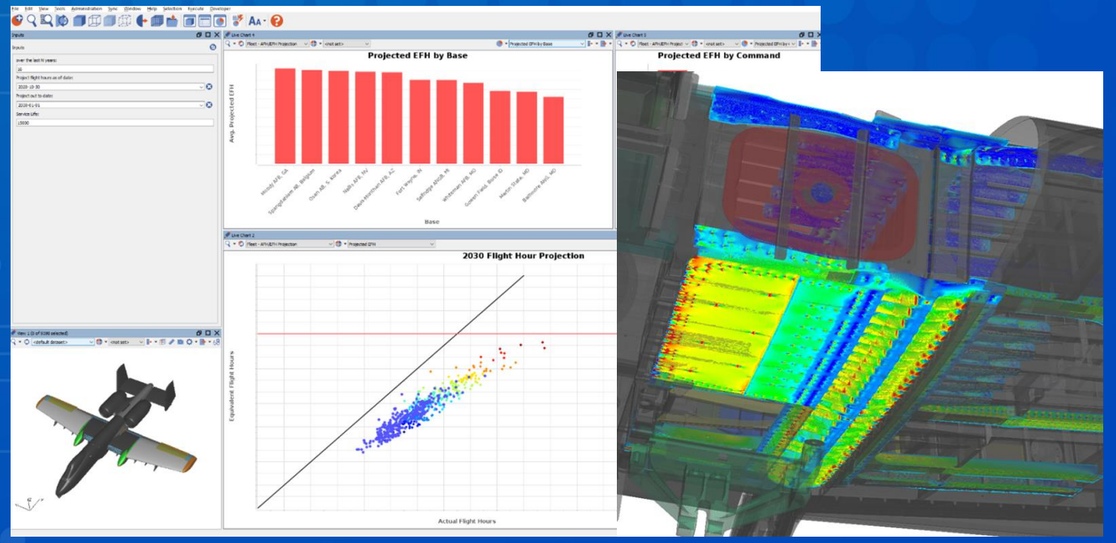
=

Predictive depot induction priorities

Results

- Risk based induction prioritization
  - ~35% increase in hours on average between inductions
  - Depot burden reduce and cost avoidance of millions
- Instant risk assessment of components, aircraft, and fleet
- Data usability improvements, fewer assumptions
  - ~ 100% captured data
- Data accessibility improvements
  - ~800% Faster
  - XYZ coordinates
  - Continued interaction with maintenance group
- Engineering response time reduced from weeks to days
- Implementation of Smart Tools
- Issues addressed while asset is open and accessible
- 10s of millions $$ in cost avoidance





Digital Thread and the Lessons Learned

- **It is not trivial !**
- Data wrangling consumes a significant amount of human resources
- A.I. tools are needed to fully implement digital engineering solutions
- Merging data to be meaningful requires significant effort
- Culture change at the shop requires effort from all parties
- Hardware limitations for maintainers is significant
- IT support is mandatory but often lacking
- It is critical to consider goals before data collection begins

Thank you!

U.S. AIR FORCE

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[1]
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[6]
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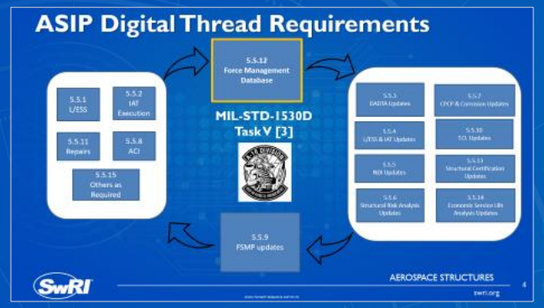
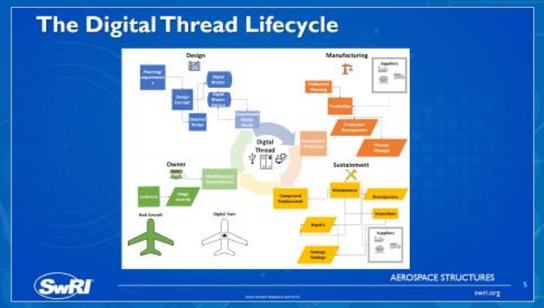
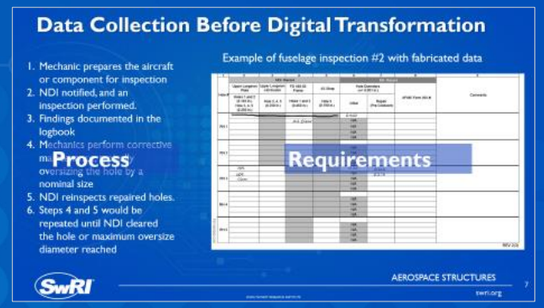
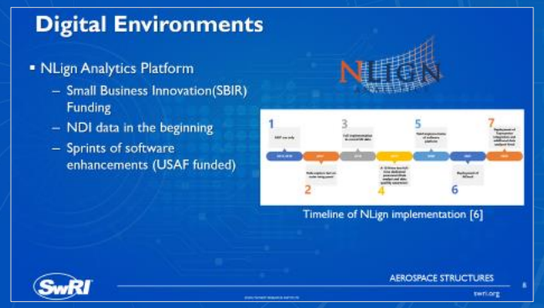
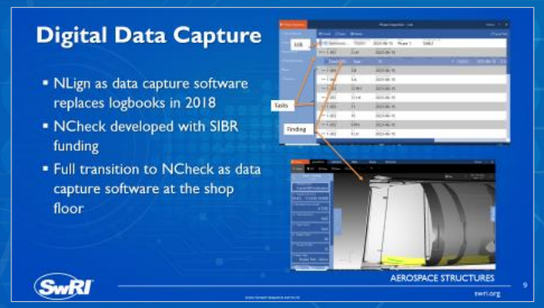
Summary

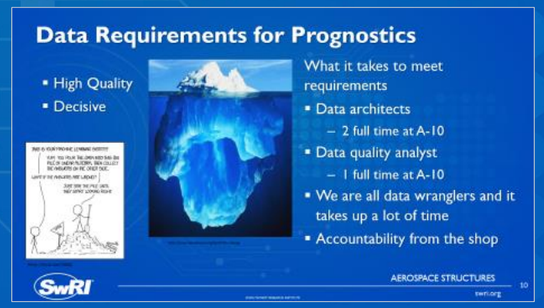


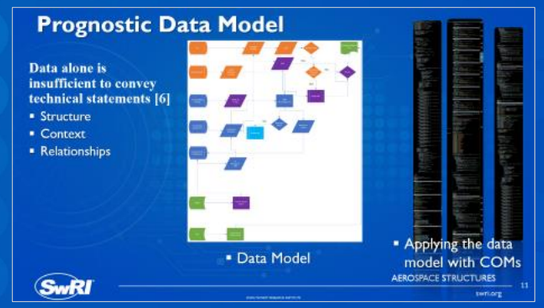


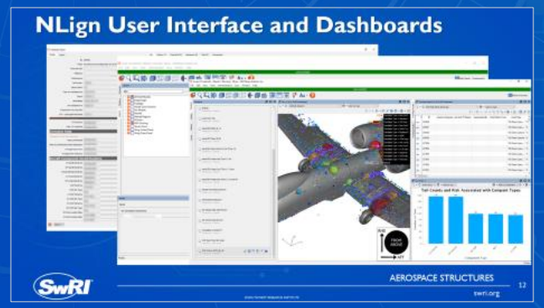


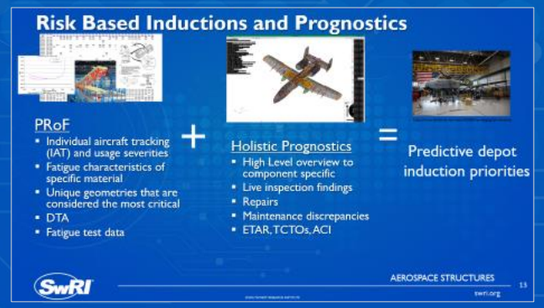


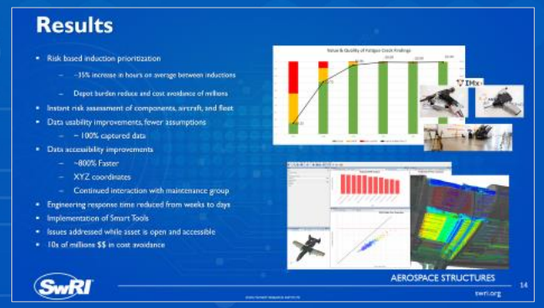












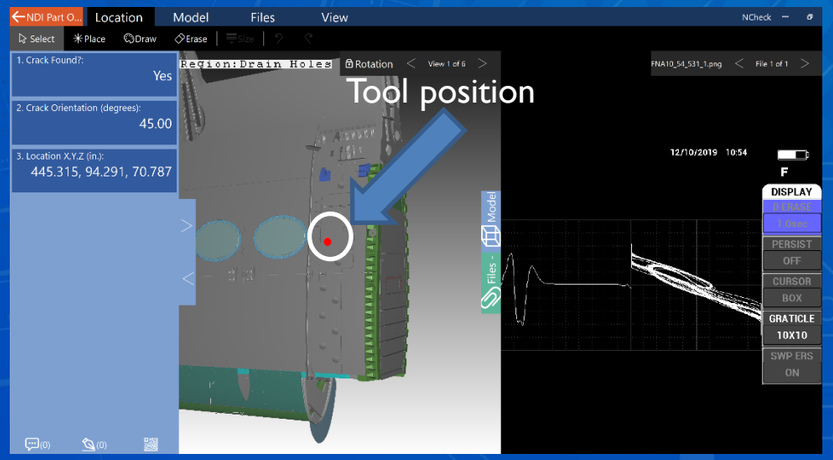
Smart Maintenance Tools

- Spatial Position Tracking
  - 4-6 infrared transmitters
  - Requires line-of-sight & provides up to 6 DOF spatial positional accuracy down to 0.01 inch
- Automatic data population with validation checks
- Expanded Digital thread with full data repository
  - NDI - full wave form for Automated Defect Analysis
  - Cx Puller - key data and process parameters for "full credit"
  - Screenshots, videos, measurements, and report files
- NCheck as user interface and digital thread repository
- A-10 Val/Ver tentatively scheduled for summer of 2023

Cx puller

NDI EC probe

Spatial position system



NCheck user interface

FATIGUE TECHNOLOGY

HILL ENGINEERING
Predict. Test. Perform.

AEROSPACE STRUCTURES

The Digital Thread – Legacy Aircraft

- Aircraft State at Start of Digital Thread Implementation
  - As-Designed State
    - 3D CAD assemblies
    - Part materials
    - Design requirements
  - As-Built State
    - Tests and inspections
    - Discrepant conditions
    - Repairs and modifications
    - Part serialization
  - As-Maintained State
    - Usage information
    - Component installation history
    - Tests and inspections
    - Discrepant condition
    - Repairs and modifications
    - Part serialization

Legacy Aircraft Often Have Key Components of the Digital Thread …

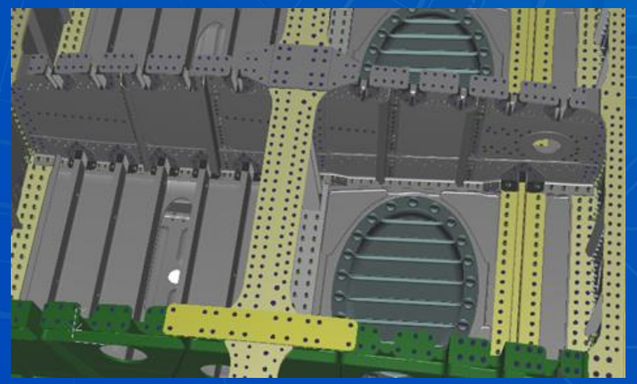
- Unavailable
- Variable over time
- Paper only
- Inconsistent
- Incomplete
- Unreliable

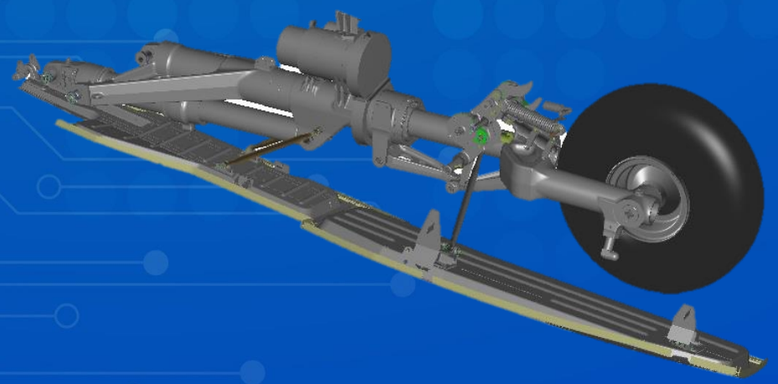
https://www.cnn.com/travel/article/20-iconic-aircraft-vintage/index.html

Digital Transition at the Beginning

- EWA Wing Replacement Program (the catalysis)
  - Model based definition
  - Configuration control
  - Engineering bill of materials (EBOM)

[4]





Data Collection Before Digital Transformation

- Engineering Access 7-9 Months AFTER the aircraft leaves depot
- No guarantee an inspection was performed
- No ability for engineering to address data issues while the asset is open and accessible
- Engineer Tech required to manually input data into database
- Limited data type request