Implementing Digital Thread for Legacy Defense Systems

Presenters Bio

- **Uriah Liggett – Principal Software Engineer – NLign Analytics Inc.**
  - **Nineteen years of industrial experience in the areas of software engineering and design**
  - **Extensive experience with problem analysis and software requirements gathering**
  - **A primary contributor to the design and implementation of the NLign Analytics platform**
  - **Has a particular focus on the design of software tools for data capture, analysis, and prognostics of aircraft structure data**
- **Martin Raming – Research Engineer – SwRI – A-10 ASIP USAF AFLCMC/WAA**
  - **Three years as lead A-10 ASIP NLign Support and Data Analytics/Management**
  - **Six years of aerospace fracture mechanics experience**

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About

- The Digital Thread (DT)
- Reasons for Adopting DT
- Before DT
- Challenges and Solutions Implementing DT
  - Part Serialization
  - 3D MBD and Finite Element Models
  - Aircraft Inconsistencies
  - Importing Historic Data
  - Data Quality
  - Reoccurring Inspections
  - Configuration Management
  - Modernizations
- Results After DT Implementation
- Analysis and Prognostics Enabled by DT
- Summary

The Digital Thread

- **A complete digital record of all significant events from design, manufacturing, service/sustainment, and removal of a product**

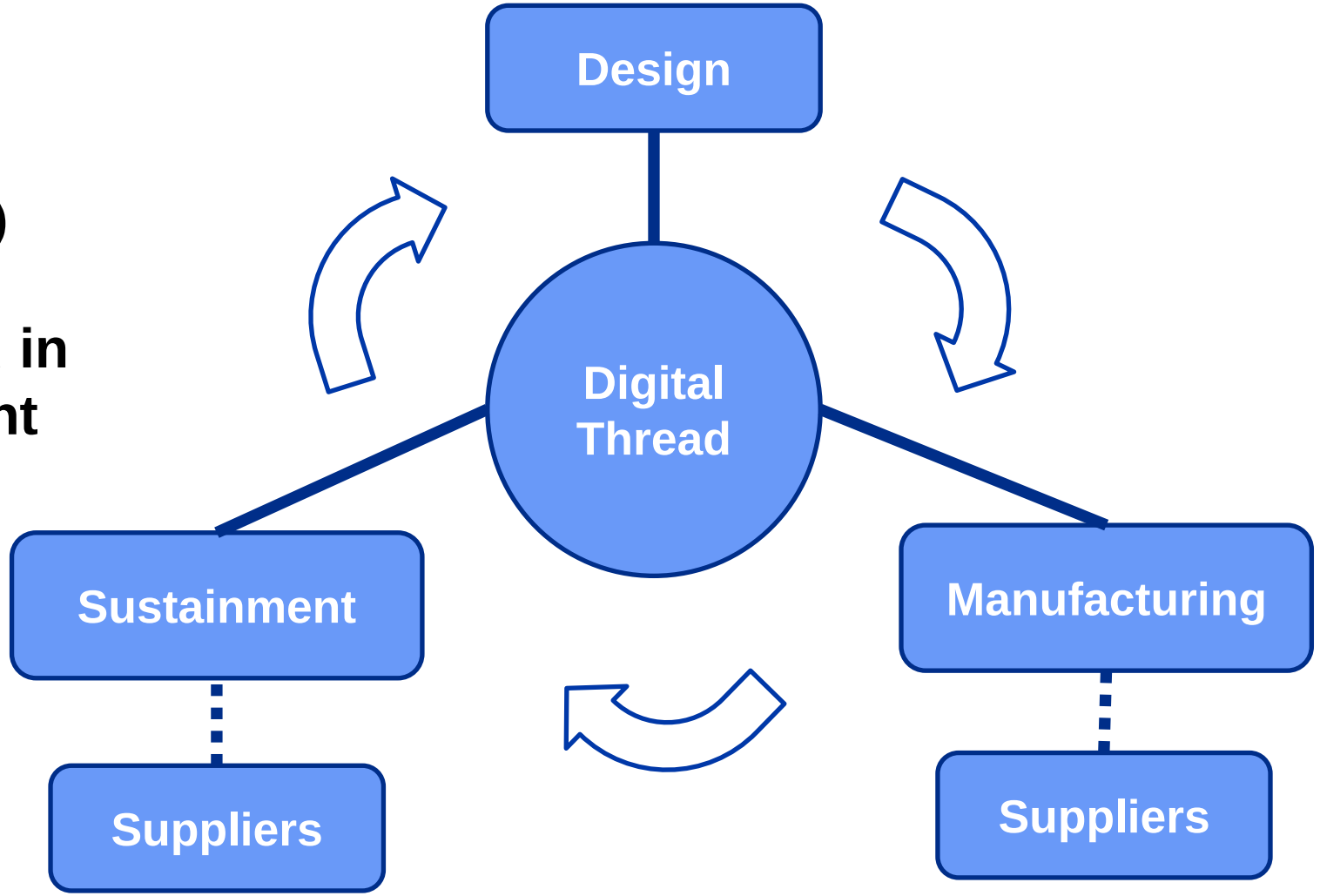
As-Designed State
- 3D CAD Assemblies
- Part Materials
- Design Requirements

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 Conditions
- Repairs and Modifications
- Part serialization

Digital Thread Lifecycle

- **Design**
- **Manufacturing**
  - **Primary assembly**
  - **Suppliers (component providers)**
- **Sustainment**
- **Information from digital thread in manufacturing and sustainment feed back into the design**

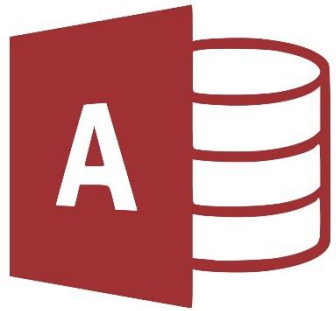


Reasons for Adopting Digital Thread

- **A-10 ASIP Organic Engineering Team**
  - **Engineering is performed in-house by USAF A-10 ASIP**
  - **Less Engagement by OEM**
- **Data Quality**
  - **More confidence in the data being collected**
  - **More accurate and complete data**
- **Data Fidelity**
  - **Collect more detailed and meaningful data with additional labor**
- **Data Communication and Availability**
  - **Improve turn-around time for engineering requests**
  - **All relevant information in a single location**

Data Organization Before Digital Thread

- **Data Management**
  - **Paper Log Books and Reports**
  - **Single user Access databases**
  - **Home Grown Applications**
  - **Excel Spreadsheets**
  - **Network Share Drives**
  - **Email History**
- **Issues**
  - **Simultaneous sharing and updating data**
  - **Limited access controls**
  - **Multiple sources of “truth”**
  - **Lost or deleted data**
  - **Searching for specific information**



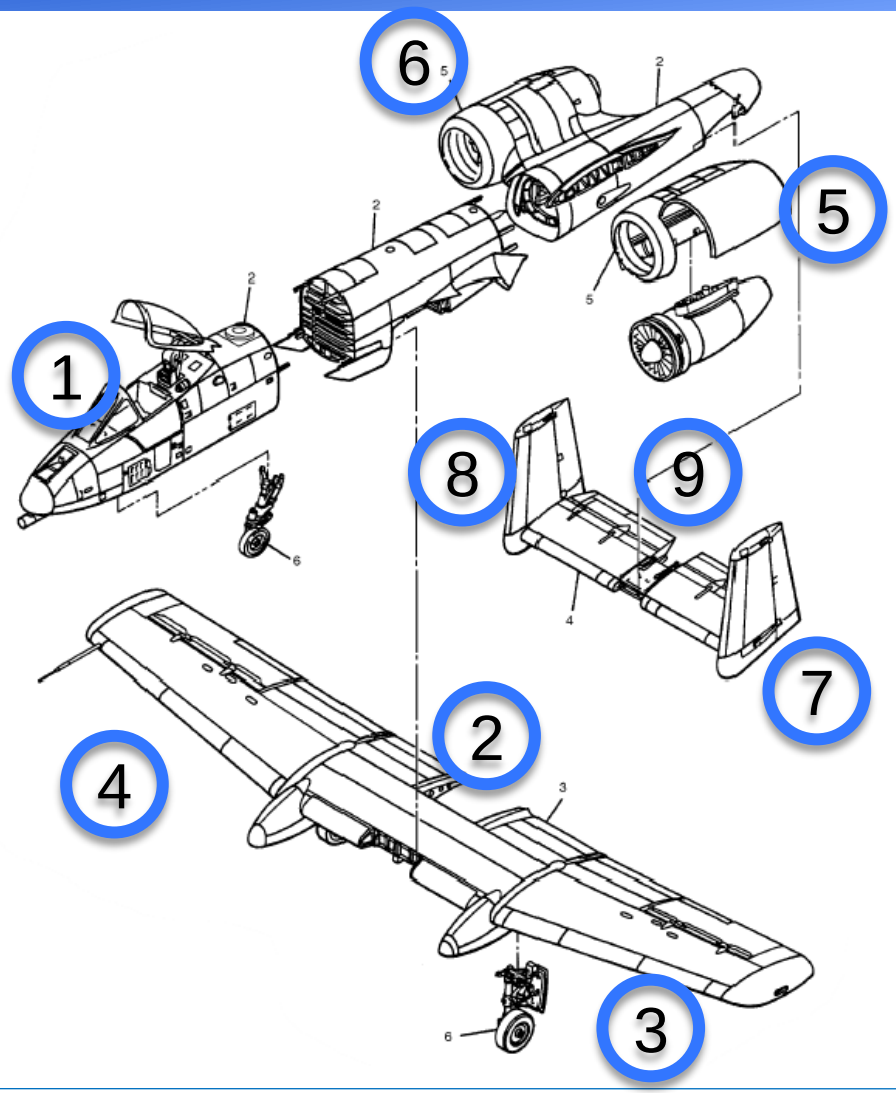
The Digital Thread – Challenges with Legacy Aircraft

- **A-10 State at Start of Digital Thread Implementation**
  - **As-Designed State**
    - **3D CAD Assemblies [unavailable]**
    - **Part Materials [variable over time]**
    - **Design Requirements [unavailable]**
  - **As-Built State**
    - **Tests and Inspections [unavailable]**
    - **Discrepant Conditions [unavailable]**
    - **Repairs and Modifications [unavailable]**
    - **Part serialization [paper only]**
  - **As-Maintained State**
    - **Usage Information [unreliable]**
    - **Component Installation History [inconsistent]**
    - **Tests and Inspections [paper only]**
    - **Discrepant Conditions [paper only]**
    - **Repairs and Modifications [incomplete]**
    - **Part serialization [unreliable]**

Legacy Aircraft Often Have Key Components of the Digital Thread Missing

Part Serialization

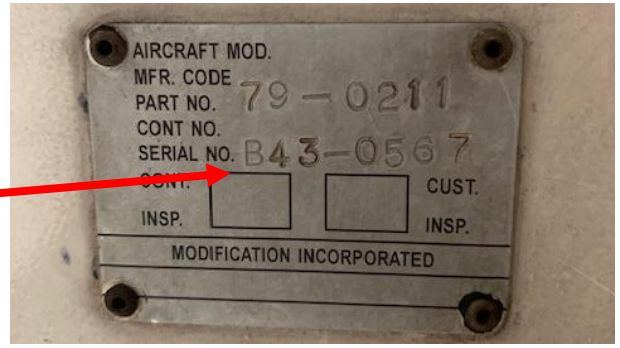
- **There are 9 Interchangeable Components**
  1. **Fuselage**
  2. **Center Wing Panel**
  3. **Left Outer Wing Panel**
  4. **Right Outer Wing Panel**
  5. **Left Nacelle**
  6. **Right Nacelle**
  7. **Left Vertical Tail**
  8. **Right Vertical Tail**
  9. **Horizontal Tail**
- **Can move from one aircraft to another**
- **Structurally significant**
- **Must be individually tracked**



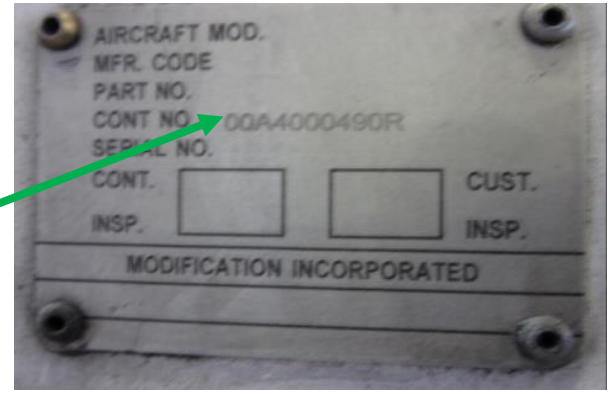
Part Serialization

- **On Part Serial Numbers**
  - **Serial numbers incorrectly substituted as parts were replaced**
    - **Nose cone of the nacelles and bird strikes**
  - **Usage data reported incorrectly due to worn/unreadable serial numbers**
  - **Serial numbers missing**

Incorrect Serialized Tracking Number



Correct AC Serialized Tracking Number



Part Serialization

- **On Part Serial Numbers**
  - **Serial renumbering was necessary**
    - **~300 Components renumbered**
  - **Serial numbers were relocated to reduce in-service wear**
  - **Serial number material was changed**
    - **A production, sprayed lacquer marking to riveted metal stamps**
  - **Addition of 2D barcodes in Data Matrix format**
  - **EWA wings incorporate metal stamps and multiple data matrix codes**

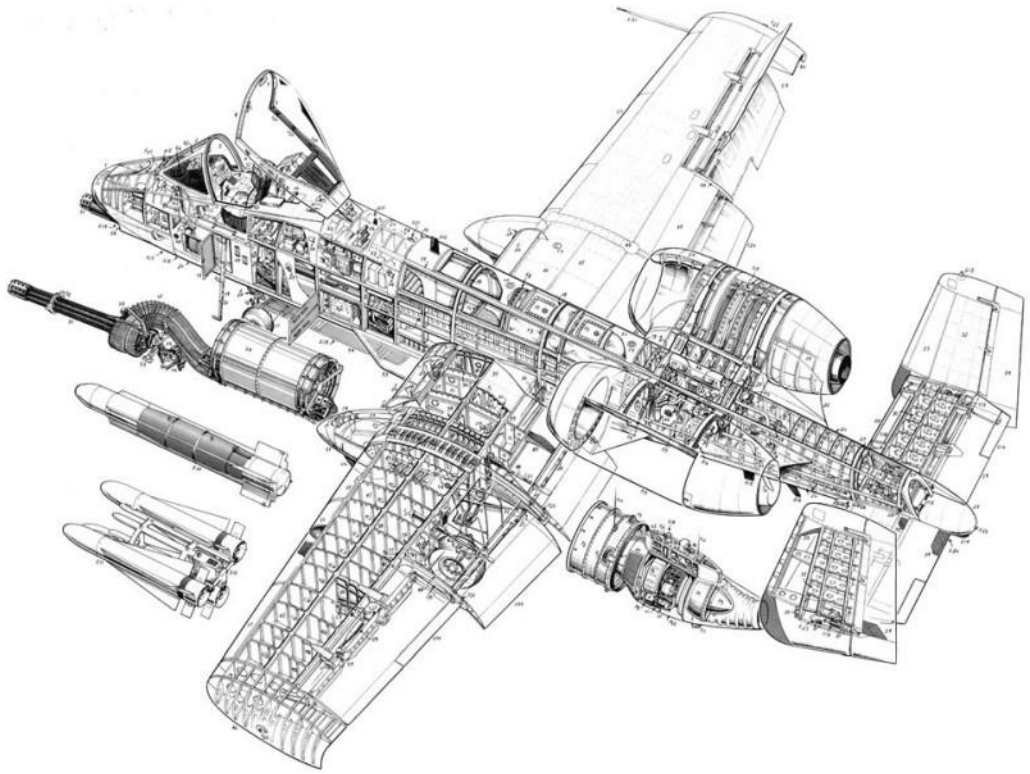
Serial Number: 12-34567
Part Number: L98-76543

3D Model Assemblies

- **Enhanced Wing Assembly (EWA)**
  - **Manufactured by Boeing**
  - **MBD delivered for entire center wing**
  - **Benefits of having MBD of wing convinced USAF to model the entire aircraft**

3D Model Assemblies

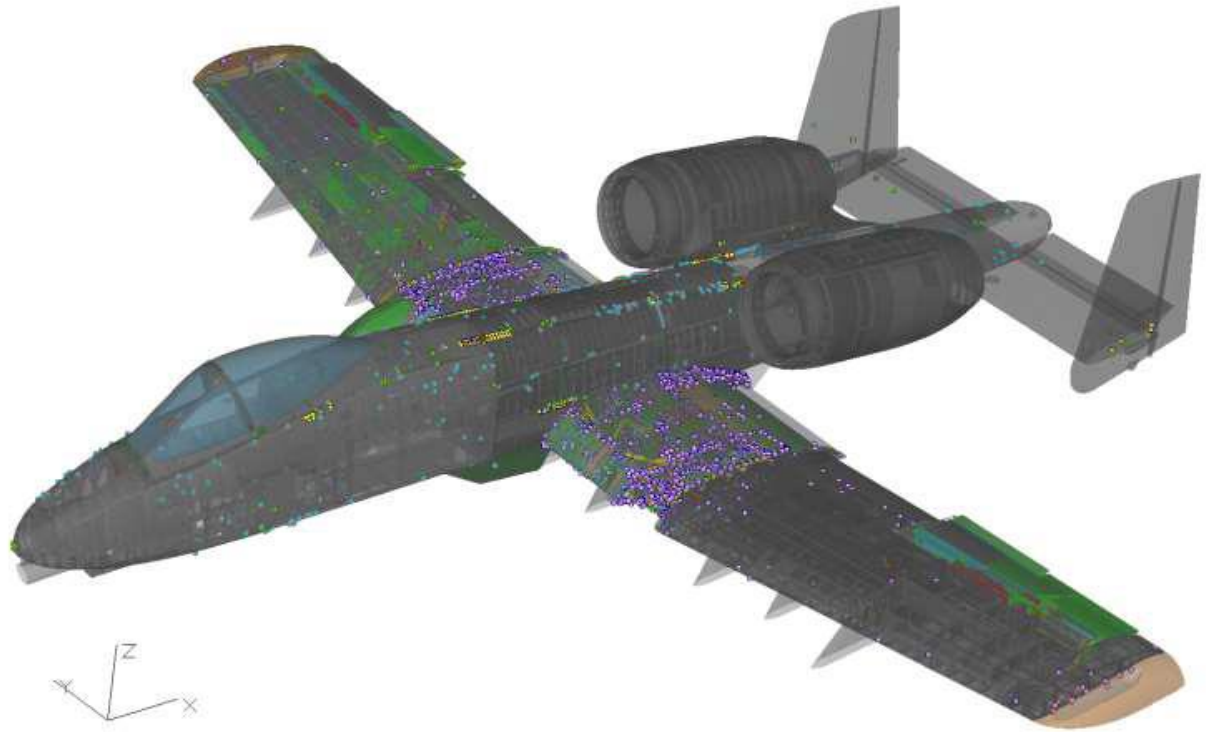
- **Lack of detailed 3D models**
- **Surface/contour model available early on**
- **FEM models of individual parts/areas**
- **FEM models are often flat (no 3D depth)**
- **2D paper drawings available**



www.aerospaceweb.org/aircraft/attack/a10/pics04.shtml

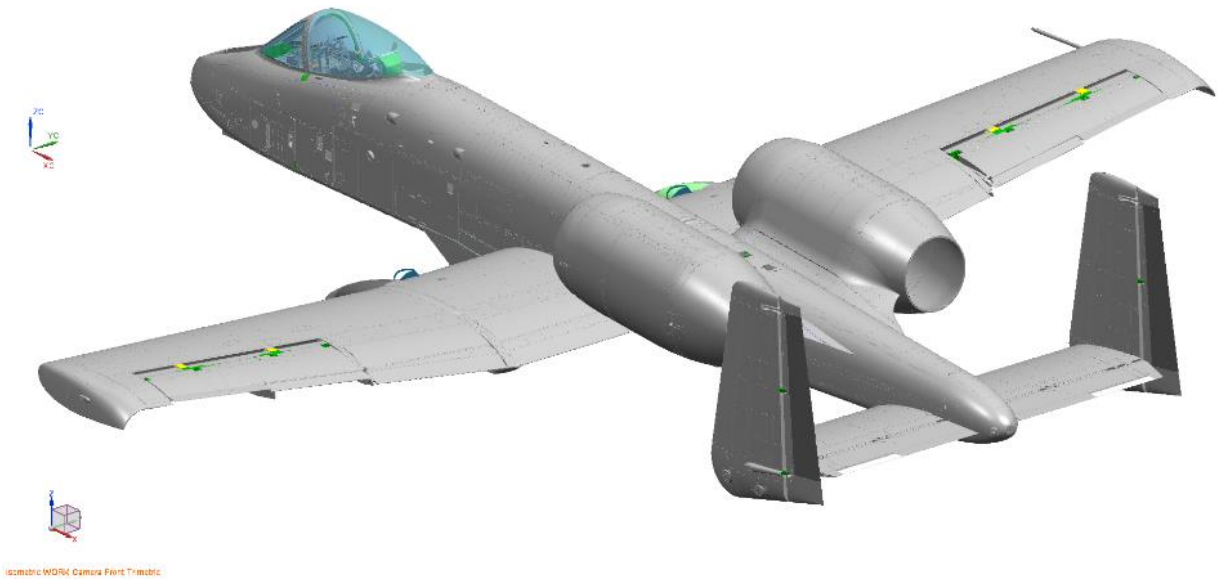
3D Model Assemblies

- **Create MBD models of entire Aircraft**
- **Initiated with EWA wings**
- **Created based on original 2D Drawings**
  - **Over 70,000 images scanned**
- **Over 25,000 parts!!**
- **One major section at a time**
- **Full assembly/part structure hierarchy**
- **3D format from STEP to JT**



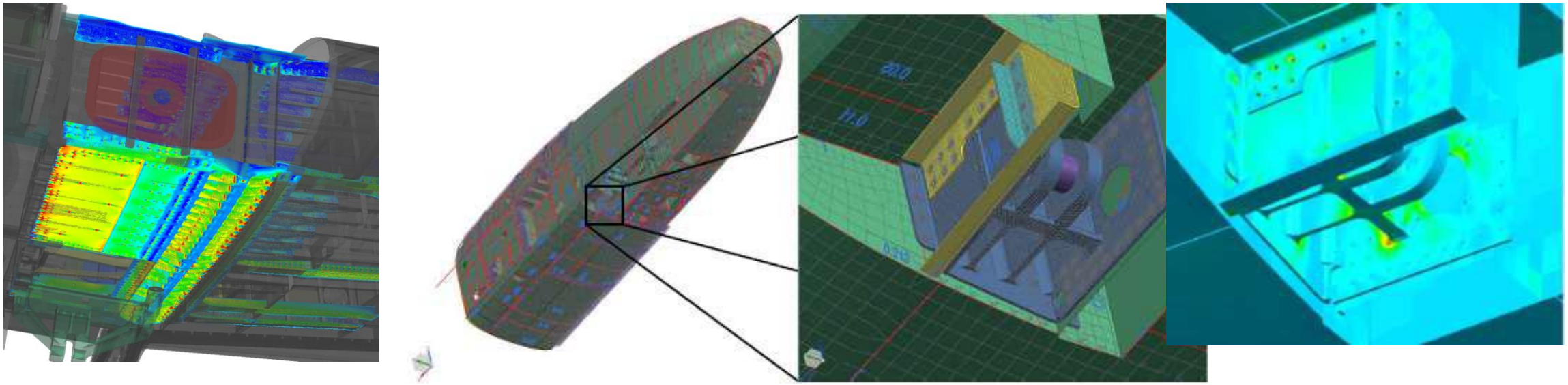
3D Model Assemblies Challenges

- **Deficiencies range from simple typos to dimensional issues**
- **Engineering change orders (EOs) were NOT incorporated into 2D drawings**
- **Potential number of unique configurations very large**
- **Independent validation and verification necessary**
- **~ 20% of delivered models incorrect**



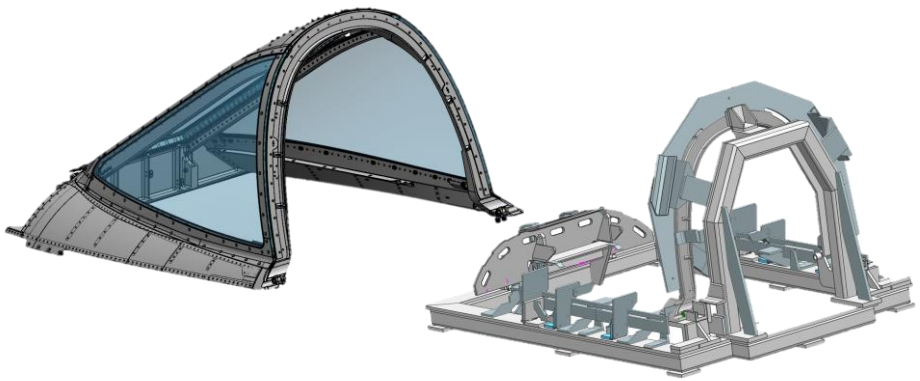
FEM Model Fusion

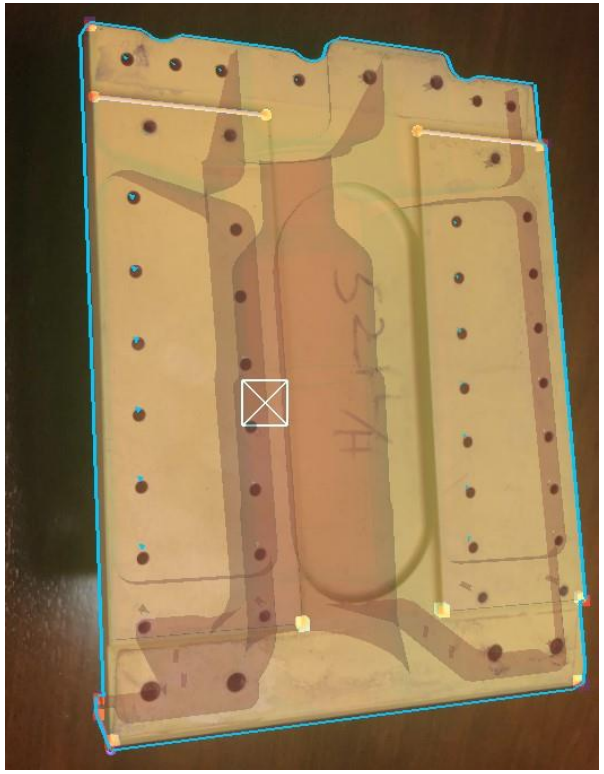
- **Integrate FEM models into the same coordinate system as the aircraft**
- **Data overlays onto FEM models**

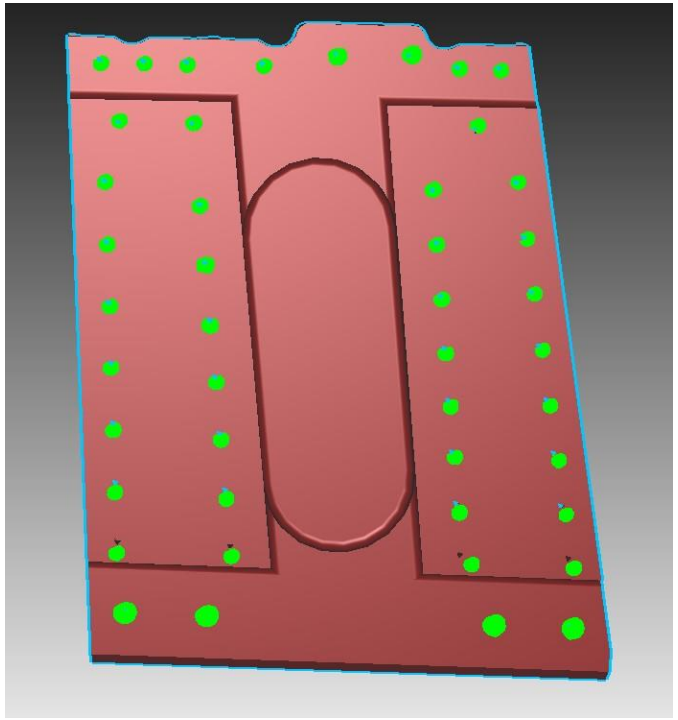


Aircraft Challenges

- **Inconsistent hole locations**
- **Extra holes**
- **Missing holes**
- **Part Interchangeability**
- **Lost OEM manufacturing equipment (e.g. Casting Mold, Masters, fixtures Etc.)**

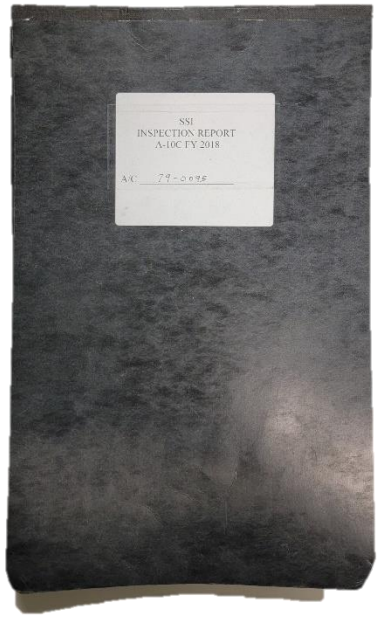






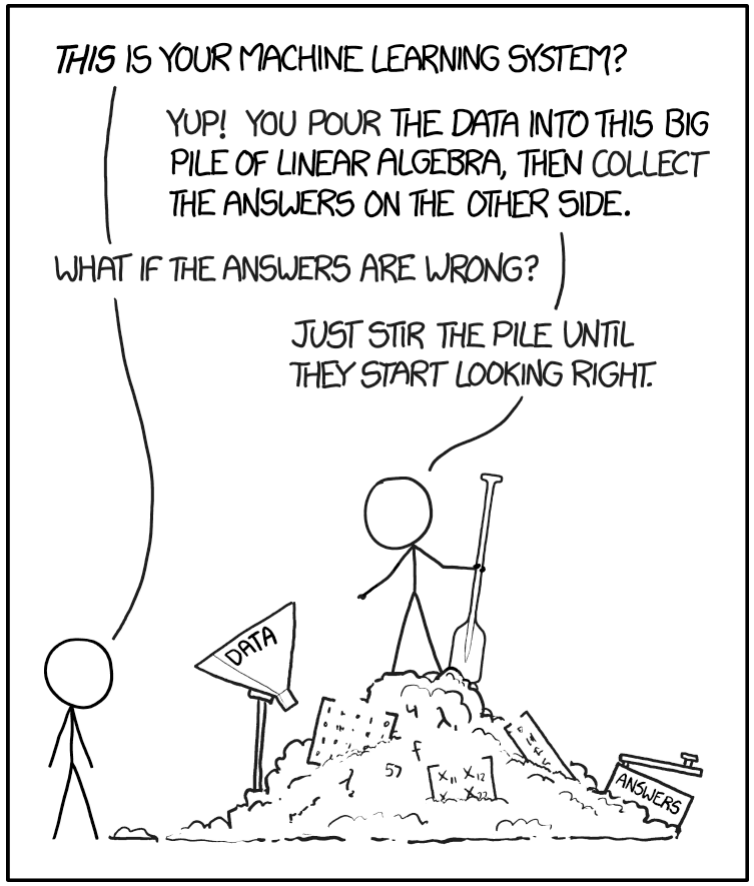
Importing Historical Data

- **Still largely a manual process**
- **Bulk import tools to speed up the process**
- **Data cleanup must occur**
- **Document data confidence and quality**
- **Note assumptions**



Data Challenges

- **Missing locations**
- **Variation in data collection techniques**
  - **NDI techs rotation monthly between shops**
  - **Mechanics recording dimensional data**
- **Incorrect serial numbers selected**
- **Incorrect inspection selected**
- **Damage type not recorded**
- **Measurements not recorded**
- **Work orders in place of inspection sheets**



https://xkcd.com/1838/

Types of Data

Maintenance/Inspection

- SSI Data Input
- Blend Measurement
- Maintenance Discrepancy
- Phase – Findings
- Paint Score & Thickness
- TCTO/ACI Inspections
- Hog Back (Precision Optics Measurement)
- ATTACK Sheet

Engineering

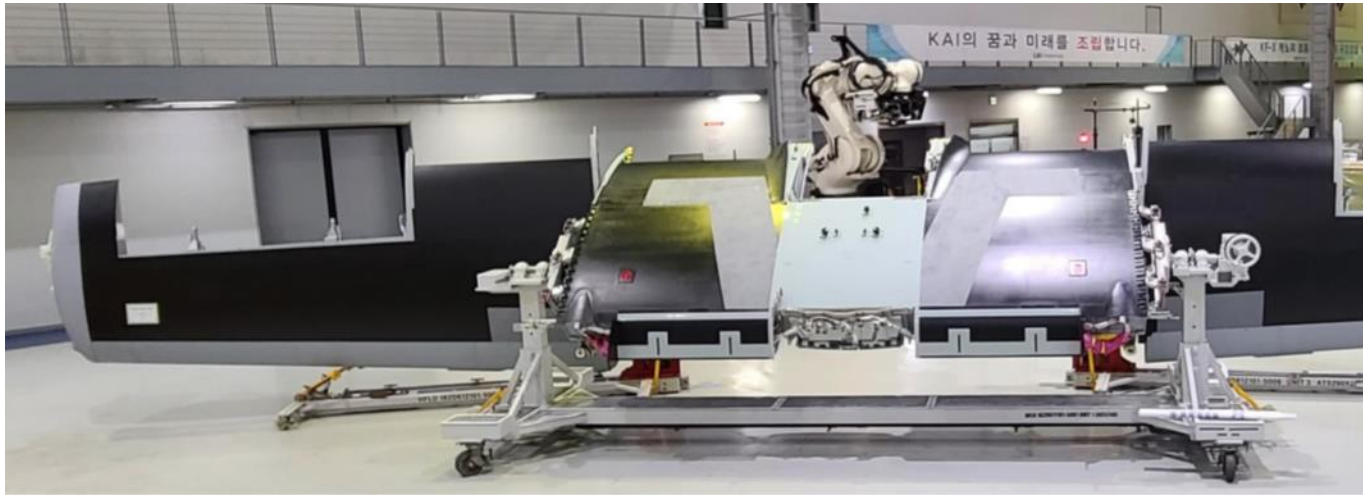
- Liasson Engineering Review (LENR)
- Engineering Support Analysis
- Test and Teardown
- Strain Gauge Data
- Patch Tracking
- Non-A-10 Support Analysis
- Non Conformance (EWA-Production)
- Non Conformance (202) – Historicals
- Non Conformance (107) – Historicals
- A-10 DTA CP Inputs

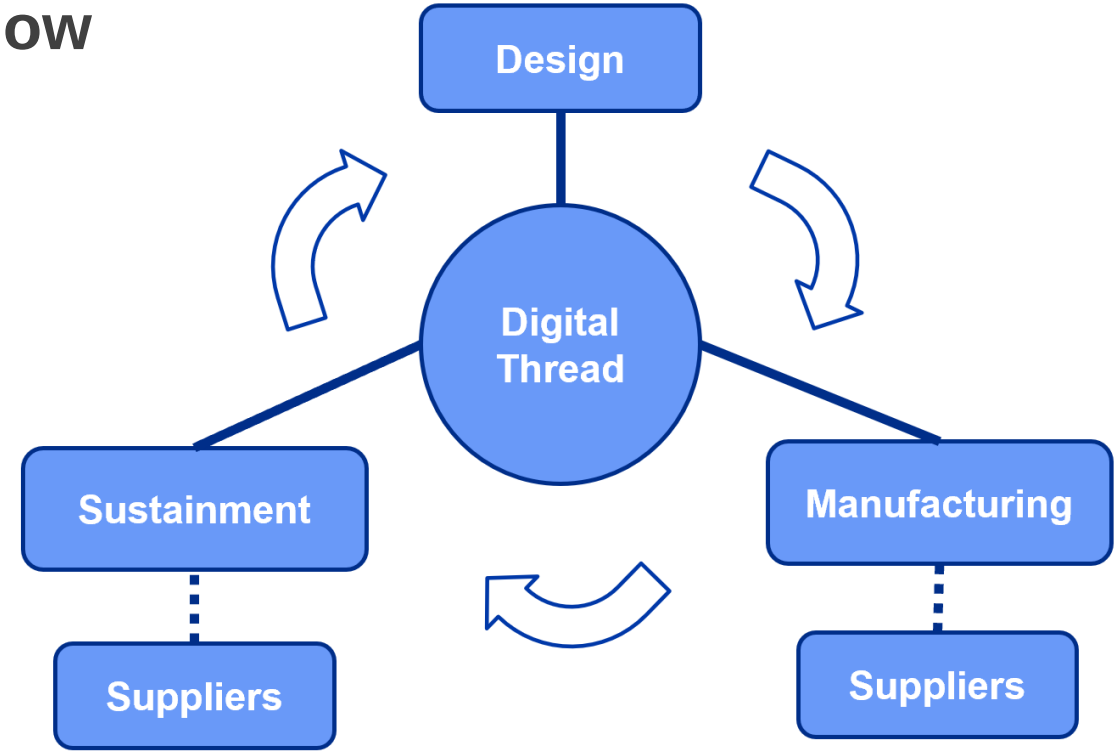
Serial Tracking

- AC Serialized Components
- A-10 Serialized Tracking
- Aircraft Current Configuration
- AMARG Wing Condition

Types of Data

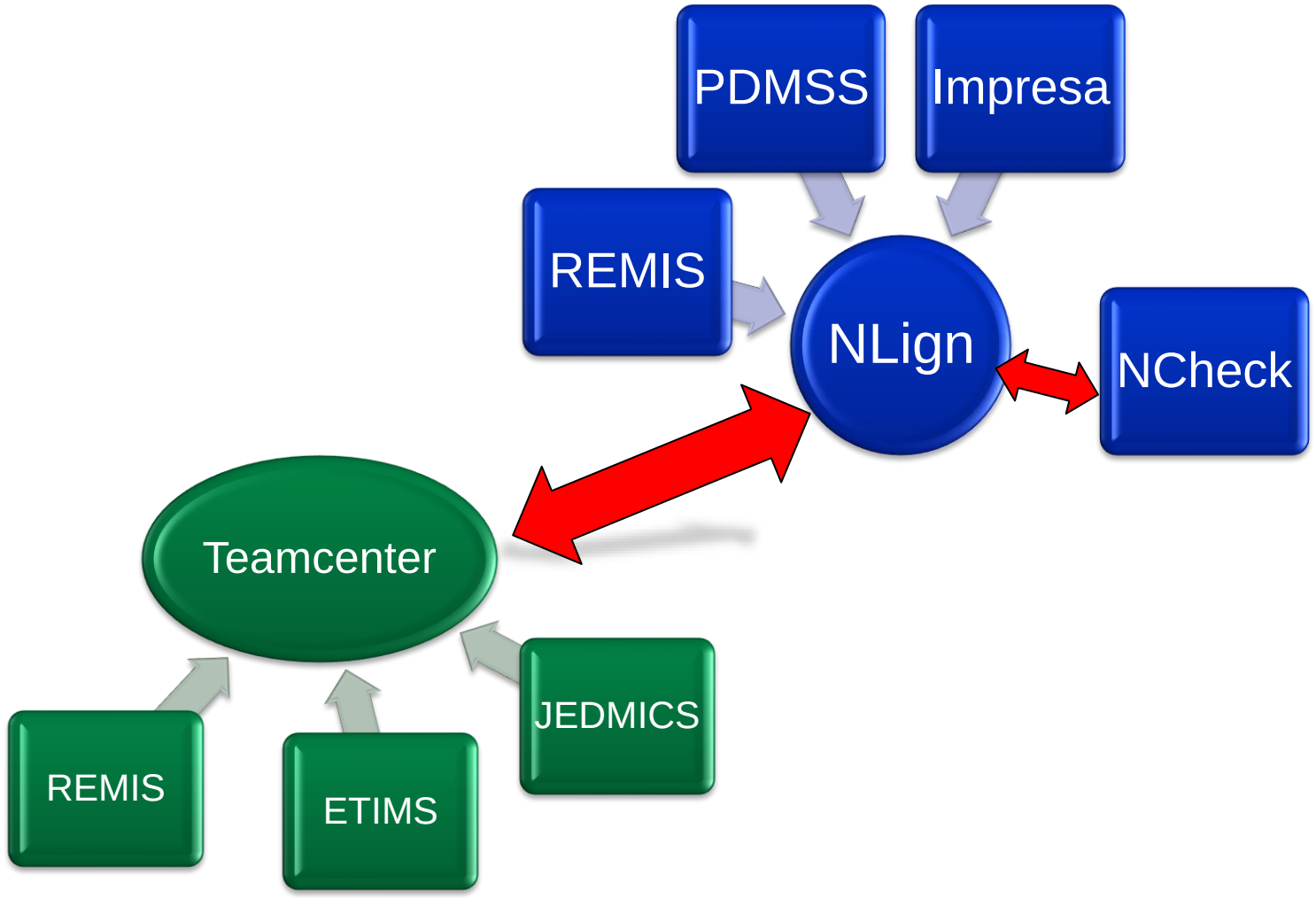
- **Non Conformance (EWA-Production)**
- **Completing the digital thread lifecycle**
- **Second round of manufacturing occurring now**





Data Sources

- **Maintenance**
  - **NLign**
  - **NCheck**
  - **Teamcenter**
  - **REMIS**
  - **JEDMICS**
  - **ETIMS**
- **Manufacturing**
  - **OEM Supplied**



Reoccurring Inspections

- **Scheduled Structural Inspections (SSI)**
  - **Fuselage: 20 Inspections**
  - **CWP: 96 Inspections**
  - **OWP: 14 Inspections**
  - **Nacelles: 3 Inspections**
  - **Vertical: 1 Inspections**
  - **Horizontal: 2 Inspections**
- **Results Entered onto Paper Logbook**
- **Engineering Access Within 3 Months AFTER the Aircraft Leaves Depot**
- **No ability for engineering to address data issues while the asset is open and accessible**
- **Engineer Tech required to manually input data into database**
- **Without these continual checks and continued communication done by A-10 SPO engineering, quality is likely to drop. SSI data is only beginning to be seen as an item with as much significance as wing production**

Configuration Management

- **9 Individually Tracked Serialized Components**
  - **Fuselage**
  - **Center Wing Panels (CWP)**
  - **Left/Right Outer Wing Panels (OWP)**
  - **Left/Right Nacelles**
  - **Left/Right Vertical Tails**
  - **Horizontal Tail**
- **Tracked Separately**
  - **Actual Flight Hours**
  - **Effective Flight Hours**
  - **Corrosion Days**
  - **Status**
  - **Installed Aircraft**
  - **Geographic Location**
  - **Etc**
- **Track Configuration Changes in Field and Depot**

Steps Taken to Achieve Digital Thread

- **Utilized Digital Thread specific software as the repository system (NLign)**
- **Created Full MBD 3D Assemblies of Entire Aircraft**
- **Imported FEM models and MBD models into the DT system**
- **Integrated the DT repository with the PLM system**
- **Organized and imported all available historic data**
- **Established processes for keeping the DT up to date**
  - **All new data is placed into the DT system (NLign)**
  - **All new data is placed directly on the 3D model assemblies for accurate locations and part numbers**
  - **Utilized software for capturing all new data digitally and accurately from the start (NCheck)**

Results After Digital Thread Implementation

- **Data usability improvements, fewer assumptions**
  - **~ 100% accuracy**
- **Data accessibility improvements**
  - **~800% Faster**
  - **XYZ coordinates**
- **Engineering Response time reduced from weeks to days**
- **Continuing improvements as database grows through appended engineering response**
- **Visualize engineering substantiation and documentation in 3D space**
- **Issues addressed while asset is open and accessible**
- **Inspection improvements and additions**
- **Moving Closer to High Level Goals**
  - **Reducing sustainment costs**
  - **Improving aircraft availability**
  - **Extending aircraft life**

Results After Digital Thread Implementation

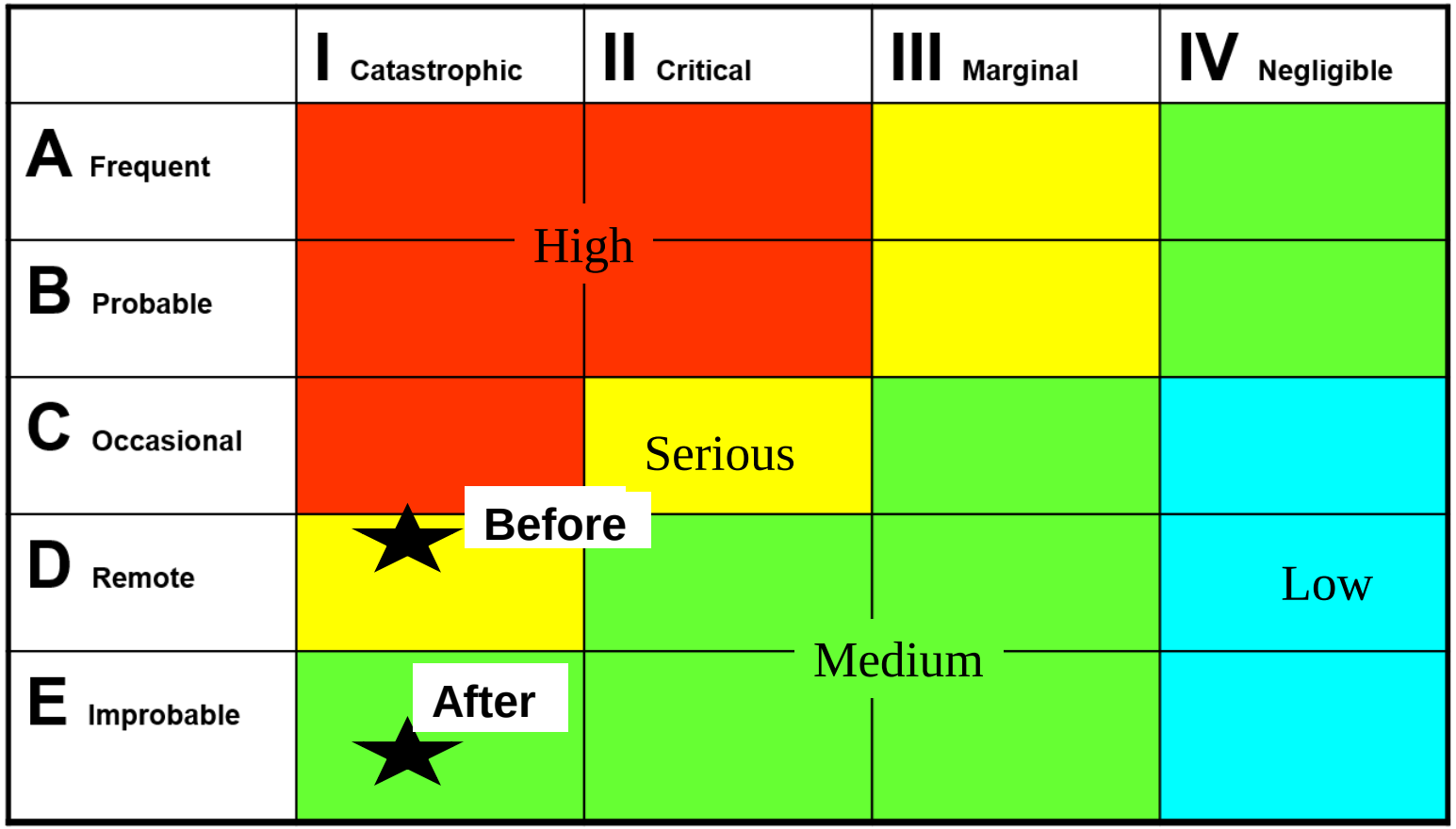
Global Product Data Interoperability Summit | **2022**

Chart Clarifications

- Only associating the quality of fatigue indication data to depot cost (Main purpose for depot induction)
- Based on calendar year not fiscal year
- Year 2019 is from Jan-June
- Based on an average depot cost (weighted based on induction purpose)

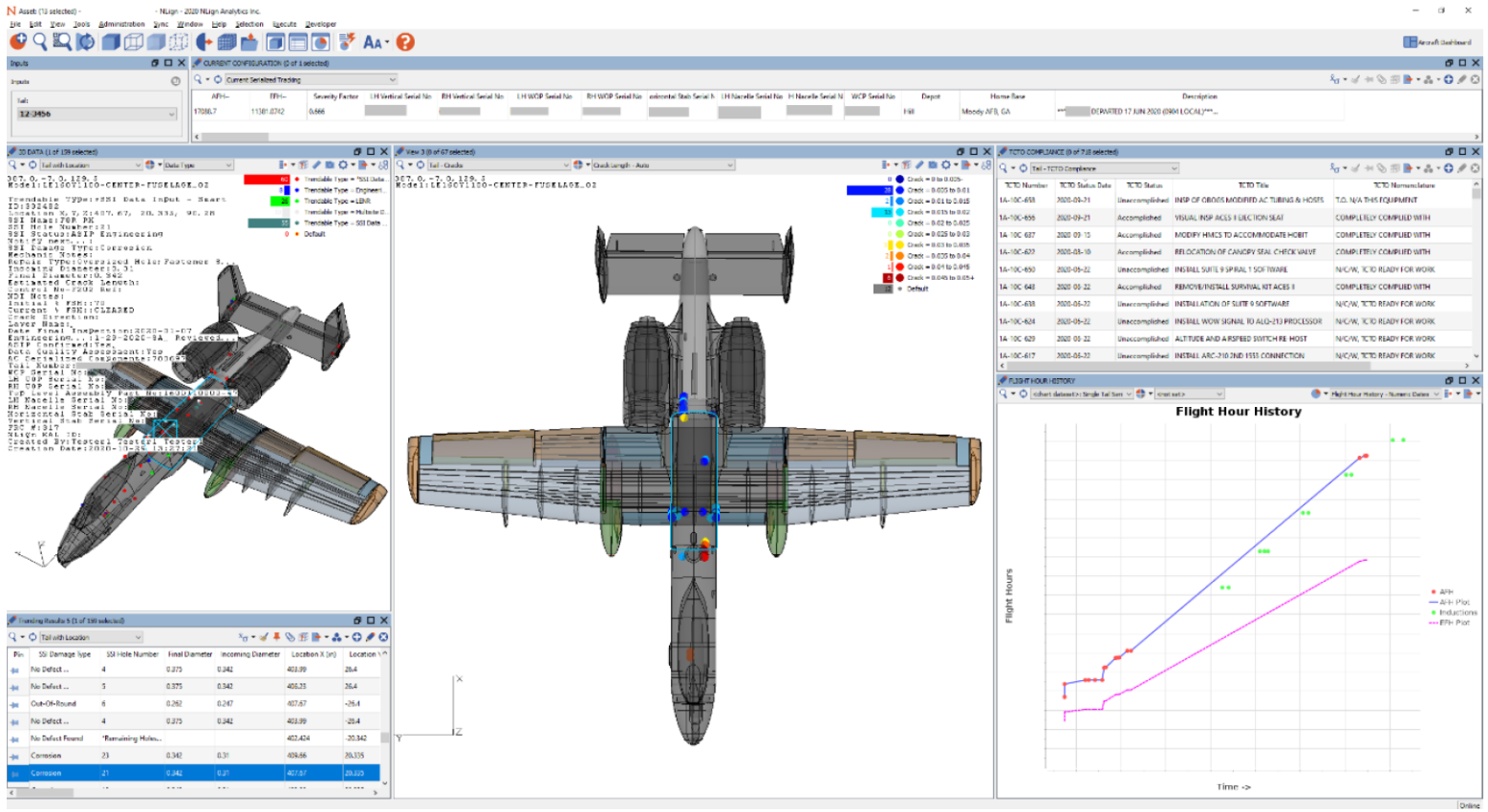
Results After Digital Thread Implementation

A-10 Hazard Risk Index
(Tailored from MIL-STD-882E)



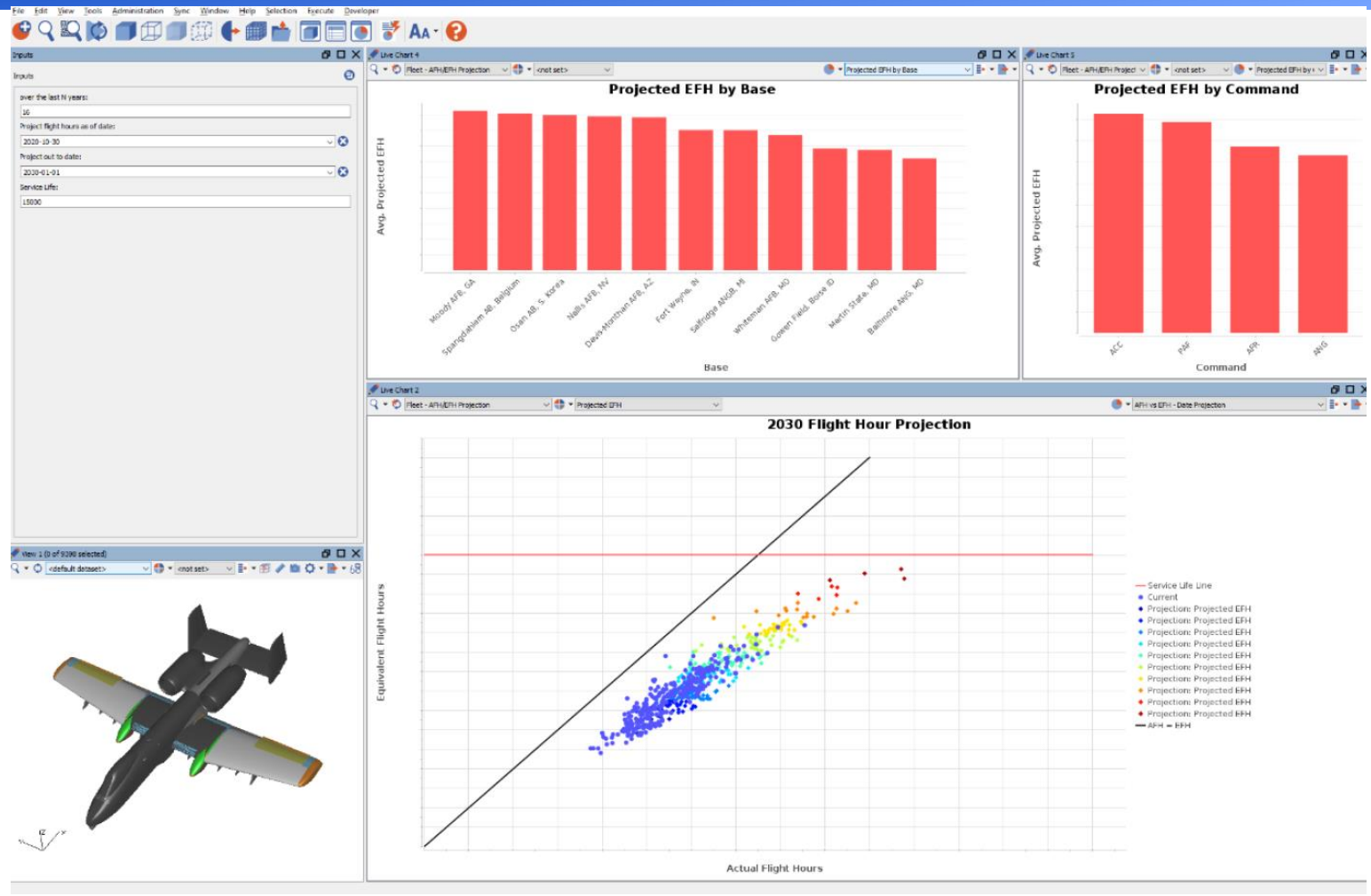
Analysis Enabled by Digital Thread

- **Real-time Aircraft and Component Analysis**
  - **Accurate**
  - **Real-time**
  - **Current State**
  - **Historic State and Events**
  - **Current Configuration (BOM)**



Prognostics Enabled by Digital Thread

- **Flight Hour Projections**
  - **Project AFH and EFH based upon average fleet usage**
  - **Individual aircraft usage**
  - **Adjust the number of years used**
  - **Ability to construct more options**



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Questions

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