NLign Analytics "Structural Lifecycle Digital Environment" Enables Model-Driven Product Quality

CIMdata Commentary

Key takeaways:

- *The U.S. Department of Defense announced a new Digital Engineering Strategy in June 2018 that dictates 5 key pillars in transitioning the U.S. defense industry from document centric engineering processes to digital, model driven processes for the design, development, manufacturing and on-going use and sustainment of complex weapons systems. The DoD estimates that over $256B is spent annually in U.S. military system sustainment operations.*
- *NLign Analytics is providing mission-critical 3D digital model technologies to the DoD in support of this Digital Engineering directive to optimize product quality, minimize critical military asset downtime, and reduce total lifecycle costs.*
- *NLign Analytics customers are seeing up to 33% improvement in the structural integrity review process time as well as improvements in aircraft structural integrity data quality from 15% to 95% usable for decision making without relying solely on experience based knowledge and "best guess" assumptions.*
- *NLign Analytics creates a robust 3D "Structural Lifecycle Digital Environment" for each weapon system, tracing structural integrity data from manufacturing through quality inspection and sustainment. This is accomplished by capturing operational in-service data, analyzing and visually displaying all 3D non-conformances, structural damage, and failure areas. This 3D visual information enables engineers to identify potential repairs and rework for each individual asset as well as across a family or fleet of similar systems.*
- *NLign Analytics technology is available in an easy-to-implement engineering desktop environment as well as a mobile tablet environment for part quality data analysis and 3D model interactive viewing throughout the virtual enterprise. It is being used on the manufacturing floor and in aircraft repair depots as well as by aerospace and defense supply chain partners.*
- *NLign Analytics technology can also work in combination with many existing commercial tools from the major PLM, ERP, MRO, and MES solution providers and/or legacy in-house developed custom software tools for non-destructive inspection and structural quality assessment.*

Today's Market Drivers and the Need for Change

Over the past several decades, there has been significant growth in the use of enterprise software systems for supply chain management (SCM), quality management systems (QMS), product lifecycle management (PLM), manufacturing execution systems(MES), enterprise resource planning(ERP), and maintenance, repair and operations(MRO). However, despite these advances in digital information management technologies, the digital connection from the engineering design and manufacturing domains to in-service operations and the impact on the lifecycle quality assessment of "as built" versus "as operated" systems has been relatively minimal in many industries. It is still common to see inefficient manual and document based processes used to assess the in-service structural status of complex parts and systems used in mission critical applications for military aircraft, ships, missile systems, land vehicles, and energy production facilities. Where quality assessment software tools are in use, they are often used within organizational silos where the data is not captured in a form that provides useful

information to enable quick and effective decision-making. Additionally, there are a significant number of out of date legacy systems currently in use. These systems lack the state of the art analytics for real time operational data and cannot provide engineering, manufacturing, and operations personnel with the information they need to collaborate in order to make part design modifications and/or manufacturing rework decisions.[1]

Engineers also need accurate 3D visualization of the system in the "as built" and "as operating" states. This allows defects leading to operational failures to be readily identified, communicated visually for collaboration with quality engineering teams, and then quickly corrected via permanent design upgrades or even temporary in field modifications or fixes.

The U.S. DoD has recognized the urgent need for change from document-centric processes to a digital, model-driven approach due to systems sustainment cost issues and international competitive factors (i.e., warfighting superiority and operational flexibility). The DoD estimates that $256B was spent in FY2020 for military system sustainment operations with the U.S. Air Force accounting for approximately $65B of that total.[2] Despite these levels of spending on operations sustainment, of the approximately 5,400 aircraft in the Air Force fleet, the percentage that are able to fly at any given time has decreased steadily each year since fiscal year 2012, when 77.9 percent of aircraft were deemed flyable. By fiscal 2018, that airworthiness metric had plunged to 69.97 percent, according to statistics obtained by Air Force Times via the Freedom of Information Act.[3]

In the 2021 Department of Defense budget request document revised on May 13, 2020,[4] the DoD highlights the focus on weapons systems readiness. The studies examined the strengths and weaknesses of past and current Defense Readiness Reporting Systems to determine the shortfalls of the current readiness reporting framework and to identify the areas for improvement. They assessed and reviewed new analytical technologies that may help the Department more effectively and efficiently gather, analyze, and visualize readiness data.

As stated in this document, "In order to successfully measure the readiness of warfighting force elements, the Defense Department must:

- Improve the data quality, accessibility, and flexibility of our readiness reporting system by accessing, linking and leveraging many authoritative data sources (ADS) across the DoD.
- Increase diagnostic capabilities by providing more specific and adaptable data pertaining to factors that contribute to readiness at its current or predicted levels.
- Develop consistent, intuitive methods to identify root causes of readiness degradation.
- Visualize common readiness trends across the Total Force, and develop predictive models to forecast the impacts on future readiness that result from current decisions, based on leading indicators."

To specifically address these major challenges stated above, groups within the U.S. Air Force and U.S. Navy as well as major A&D prime contractors to DoD, have been adopting NLign Analytics technology and incorporating a 3D model-driven product quality approach into their

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[1] Research for this commentary was partially supported by NLign Analytics.

[2] Office of the Under Secretary of Defense (Comptroller) / Chief Financial Officer. Operation and Maintenance Overview Fiscal Year 2020 Budget Estimates. March 2019.

[3] Losey, Stephen. *Aircraft mission-capable rates hit new low in Air Force, despite efforts to improve.* AirForceTimes. July 2019. https://www.airforcetimes.com/news/your-air-force/2019/07/26/aircraft-mission-capable-rates-hit-new-low-in-air-force-despite-efforts-to-improve/

[4] Office of the Under Secretary of Defense (Comptroller) / Chief Financial Officer. United States Department of Defense. Fiscal Year 2021 Budget Request. February 2020. Revised May 13, 2020.

long established but typically much more document-based Materiel Review Board (MRB) processes and associated manual best practices for Structural Lifecycle Management (SLM). An example of where the model-driven product quality approach using NLign technology has already been successfully employed is in the Air Force Aircraft Structural Integrity Program (ASIP) as applied to the A-10 close air support aircraft upgrade (see Figure 1).

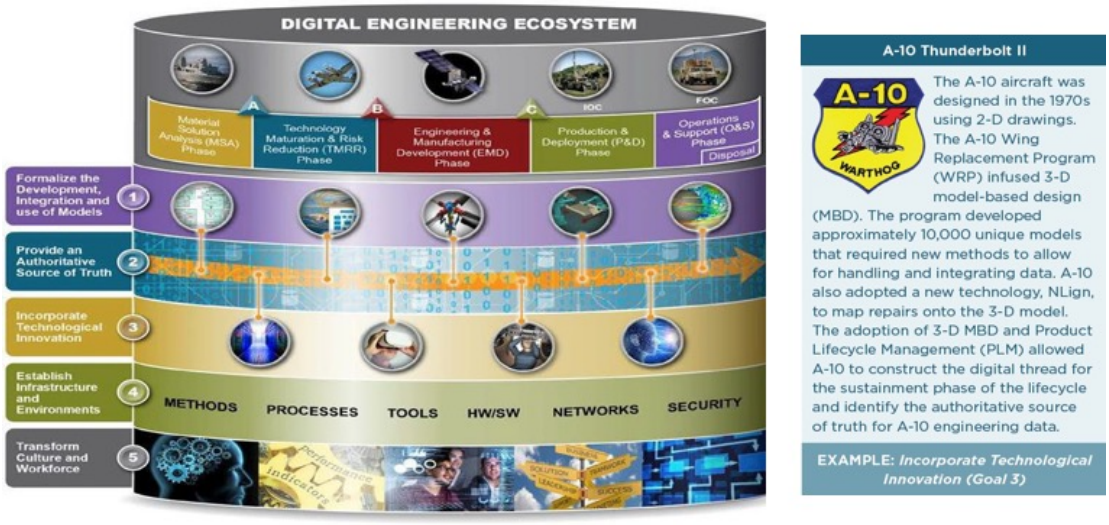

Figure 1—NLign Analytics Enabled the DoD Digital Engineering Strategy in the A-10 Program
(Courtesy of NLign Analytics and U.S. DoD)

Similar asset readiness and predictive maintenance challenges and associated cost saving opportunities also exist in the commercial airline and commercial air freight industries. According to Oliver Wyman, "Total MRO spend is expected to rise to $116 billion by 2029, up from $81.9 billion in 2019. Aside from the growth in the commercial fleet, the increase will be driven by more expensive maintenance visits and technology enhancements. The annual average growth rate for the MRO market will be 3.5 percent over the decade. More of this growth will take place between 2024 and 2029, when MRO spend will grow $19 billion versus $15 billion between 2019 and the start of 2024."[5]

The NLign Analytics Technology: A Driver of Business Value

NLign Analytics has been in the business of creating engineering software solutions to identify and predict the structural integrity of large scale systems for almost 15 years. The NLign Analytics technology was initially developed in conjunction with applied research projects in the U.S. Air Force and has since evolved into an integrated suite of commercial software applications that includes six U.S. technology patents.

So, what is special about NLign that is not found in other quality software tools or enterprise software applications such as PLM, QMS, ERP, MRO, and MES systems? The key foundational elements of the NLign Structural Lifecycle Digital Environment are:

- Ability to acquire and create the baseline "Structural Integrity Digital Twin."
  - Easily acquire and process physical inspection data from a wide variety of non-destructive inspection (NDI) and measurement sources including photos and 2D drawings and tie it to a 3D location on a digital model.

[5] Wyman, Oliver. Global Fleet & MRO Market Forecast 2019–2029 Commentary. https://www.oliverwyman.com/our-expertise/insights/2019/jan/global-fleet-mro-market-forecast-commentary-2019-2029.html

  - A mobile device/tablet environment that enables manufacturing and in-service operations to enter structured data in the context of the visual 3D part.
  - Align the 3D part physical inspection data and map structural failure data on to a 3D geometric digital representation of the part aligned with part/BOM numbers and assigned criticality codes (or create a 3D model if none exists).
  - Ability to tie structural integrity disposition analysis to specific 3D defect locations in the physical part.
  - Ability to spatially search across a fleet of aircraft to identify recurring "hot spots," historical analysis and repairs, and identify historic repairs on a particular aircraft that could impact future repair analysis.
- Understand the "As Built" and/or "As Maintained" state of the current structure and enable decision making to improve manufacturing quality and/or define field fixes.
  - The NLign suite of data analytics and 3D model interrogation capabilities enable mapping of failure areas and/or material quality discrepancies in a part onto the 3D digital model. It can also compare those key structural integrity failure areas to results from a 3D structural FEA analysis. Potential design modifications/fixes can also be visually compared to the "As Is" and "To Be" states of the structure.
  - Structural integrity criticality analysis can be performed based on defect type codes and analyses are configurable to customer requirements. Pre-defined analysis inputs ensure that quality analysis data and assumptions are complete and valid based on type of analysis performed. Quality analyses can also be performed across a fleet of vehicles in different service environments or a family of manufactured parts prior to assembly and in service deployment.
  - Prognostics charts aid in maintenance scheduling and budgeting decisions.

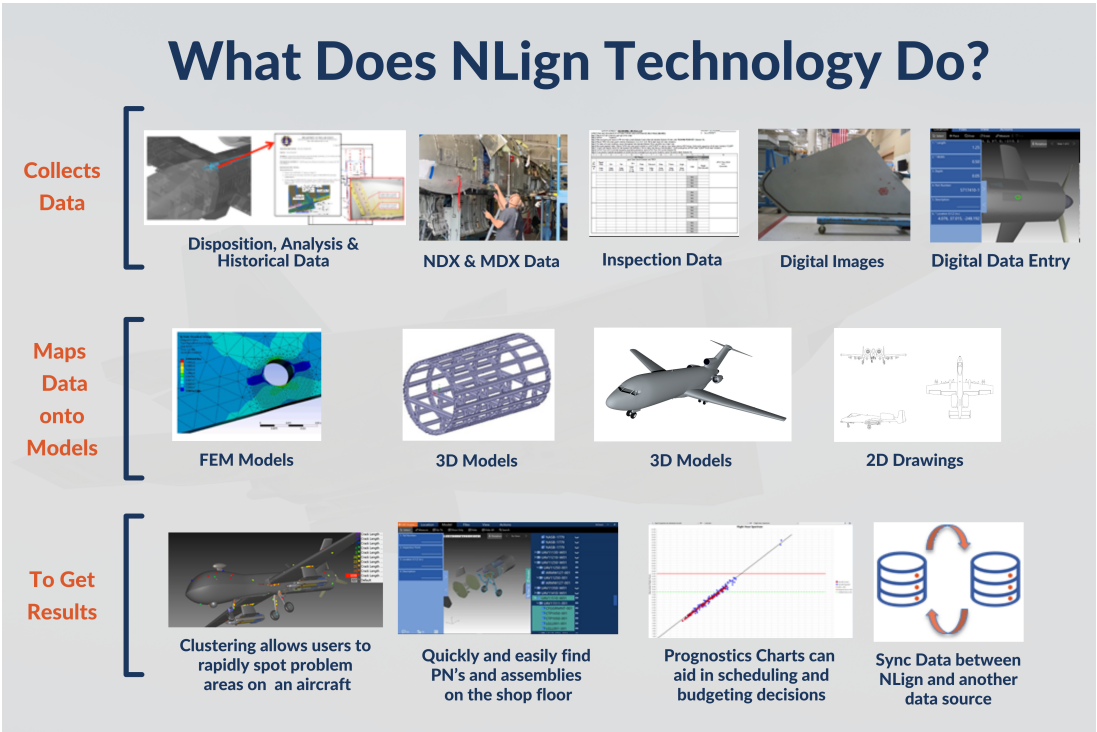

Figure 2—NLign Environment for Model-Driven Product Quality Analysis
(Courtesy of NLign Analytics)

- By Leveraging the patented spatial database capability, design engineers, manufacturing and quality engineers, and operations personnel can collaboratively share, update and manage the "Structural Integrity Digital Twin" across the virtual extended enterprise and throughout the product operations lifecycle, including supply chain partners. This empowers the engineers to:
  - Equip Lifecycle traceability—Track and report out structural integrity metrics over time-for a single system or across a grouping of assets (fleet characteristics).
  - Enable "Digital Thread for Structural Quality"—Provide an "Authoritative Source of Truth" for structural quality and integrity across the enterprise.
  - Allow Data Openness—Enable connections and integrations with enterprise systems such as PLM, QMS, ERP, MRO, MES, and in-house quality software applications.

NLign Analytics Technology Adoption: Key Customer Success

Current major customers of the NLign Analytics software technology and services include:

- Northrop Grumman—T-38 trainer aircraft and F-35 fighter aircraft.
- Boeing—787 Dreamliner, F-15, B-1B, and F/A-18 programs.
- U.S. Air Force—AFRL, ICBM, AFLC- A-10, T-38, F-15, B-1B, C5, C130, and Global Hawk.
- U.S. Navy—Naval Air Systems Command MQ4, F/A-18, P-8, and V22.
- Other U.S. and Foreign Government OEMs and suppliers.

Several major customers and aircraft programs have been using NLign Technology long enough to be able to measure and publicly disclose real world business impact metrics in moving from manual, document-based processes such as the A&D MRB process into a model-driven process leveraging the NLign Structural Lifecycle Digital Environment:

- Air Force A-10/ASIP program key results:
  - Helped double the service life of the workhorse A-10 close air support aircraft between maintenance cycles.
  - Dramatic increase in the quality of data. The quality of inspection records went from 17% good in 2017 to a current 95% in 2019.
  - 800% increase in data communication from time of induction to receipt of inspection data by engineering.
- Northrop Grumman F-35 fighter program:
  - Real-time data communication with engineering, mitigating errors in data and ultimately receiving 100% quality data for downstream usage.
  - Estimates use of NLign saved 33% of MRB process labor hours.
  - USAF estimated cost savings of $1B over life of F-35 production.
- Current NLign Analytics technology and solution partners include:
  - ANSYS
  - Siemens Digital Industries Software
  - PTC

Conclusion

CIMdata believes that the availability of next generation model-based quality analysis technologies such as the NLign Structural Lifecycle Digital Environment fills a major gap in the intersection of the current suite of commercial software tools and product innovation platforms provided by the major enterprise software solution providers such as Altair, ANSYS, Dassault Systèmes, Hexagon, Infor, PTC, Oracle, SAP and Siemens Digital Industries Software.

As such, we expect that when NLign is used in combination with PLM, QMS, ERP, MRO, and MES systems, this integration can be a major step forward for industry in achieving one key aspect of the digital thread for structural integrity and system quality across the entire product lifecycle. The use of 3D virtual reality/augmented reality (VR/AR) environments combined with advanced data analytics and AI/ML (machine learning) technologies to create and continuously enhance digital twins will accrue significant business benefits to end users of weapons systems such as the U.S. Department of Defense deploys and maintains as well as to the companies that design and manufacture such complex weapons systems. More importantly, these digital technologies are now beginning to mature to the level where adoption should not be limited only to high value assets such as those found in the aerospace and defense industry.

From CIMdata's perspective, NLign is currently providing a high impact set of 3D model-based product quality and reliability applications that can have significant business impact and ROI across a wide range of industries and product lifecycle applications. We look forward to monitoring their business success, future technology enhancements, and the more widespread adoption of this valuable technology across a range of industries over the next several years. For more information about NLign Analytics and its solutions please see https://nlign.com/.

About CIMdata

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