A-10 and the Path to the Digital Twin for Legacy Defense Systems

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ABSTRACT

Digital acquisition is trending across the United States Air Force (USAF) to optimize aircraft life cycle management. A desired output of digital acquisition is to provide accurate and efficient digital tools to reduce sustainment costs and increase aircraft availability through a digital twin. Legacy aircraft, like the A-10, face additional challenges to developing a digital twin compared to modern counterparts; however, legacy aircraft would benefit further and immediately from digital twin capabilities.

This research will investigate the route taken by the USAF's A-10 aircraft structural integrity program (ASIP) and system program office (SPO) to implement a complete digital thread solution for digital engineering to develop a digital twin for the fleet. Digital twins are comprised of three elements: design and characteristic data, real-time operational and maintenance data, and an information model. Additionally, for a digital twin to be successful, it is necessary to have an information modeling system capable of integrating these three elements through a digital thread.

1.0 INTRODUCTION

In January of 1973, the United States Airforce (USAF) selected the A-10 aircraft conceived by Fairchild Republic to meet the nation's future close-air support (CAS) needs. While the infancy of the USAF Aircraft Structural Integrity Program (ASIP) was more than a decade before the introduction of the A-10, the A-10 was designed at a time when fatigue life requirements were beginning to be considered with the first publication of MIL-STD-1530 in 1972 [1]. Through research between Fairchild and the USAF, the A-10 was given an expected service life of 6,000 flight hours.

In 1997 A-10 aircraft across the fleet were approaching or surpassing the safe service life of 6,000 hours, and a retirement plan was anticipated. However, without a replacement aircraft selected for production coinciding with shrinking budgets, the decision was made to sustain the A-10 beyond its original retirement age since it was speculated to be less costly than funding a replacement [2]. Sustainment efforts began with implementing a service life extension plan (SLEP). As inspections required by the SLEP discovered more and more critical cracks in the A-10 wings, maintenance costs significantly increased, raising budget concerns. Eventually, an enhanced wing replacement program was proposed and selected as a less costly alternative to keep the aircraft flying up to 16,000 hours. Ultimately, the wing replacement program was the catalyst to spark the beginnings of the A-10 digital transformation.

The anticipation of retirement for the A-10 in the early 1990s, compounded with Fairchild Republic's divestiture, resulted in a gap in documentation vital to ASIP. Additional discontinuity was caused by a decision made by the USAF to relocate the engineering authority of the A-10 from Sacramento Air Logistics Center to Ogden Air Logistics Center at Hill Air Force Base (HAFB). In 2002 a USAF investigation declared the A-10 ASIP was "broken." This potential disaster for the A-10 had a silver lining; the path towards recovery for A-10 ASIP resulted in a USAF organic engineering capability often only realized by the OEM [3] for a weapon system. The result was a solid engineering base that consisted of USAF and contractor engineering expertise with cost-effective consciousness that could effectively support A-10 ASIP and fulfill obligations required in MIL-STD-1530. This organic engineering ASIP team recognized the benefit of digital engineering solutions and pushed the need for a digital transition. Today, the A-10 is often viewed as leading the USAF into the digital future to sustain legacy aircraft.

1.1 Digital Thread Enabling the Digital Twin

While the digital thread is being deployed across the entire A-10 organization, forming a complex of intertangled networks, this investigation will focus on the digital engineering solutions deployed to fit the needs of the renewed A-10 ASIP of the structures department, a subset of the SPO's engineering branch. The digital twin in this work relates only to the structural health of the A-10 and does not include other pertinent aspects of the aircraft, such as mechanical systems, electric systems, and avionics.

The USAF's operation platform is compartmentalized, resulting in a separate digital twin for each system to be managed independently. Figure 1 shows where the A-10 structures group resides in the organizational hierarchy of the A-10. Also shown in Figure 1 are the different organizations involved in managing the A-10 fleet. There are three central departments: Depot, performing major repairs, intensive inspections, and overhauls; SPO, providing engineering support and managing upgrades; and the field, carrying-out aircraft missions and light maintenance. It is important to note that although the focus is on the digital twin implemented by A-10 ASIP, the field and depot play a vital role in providing inputs into the digital thread.

The digital thread implemented by ASIP is intended to act as more of a cycle than a process. This cycle is defined by Task V within MIL-STD-1530D [4] and starts with a requirement for ASIP to manage a force management database (FMD). The FMD intends to allow data-driven updates for ASIP tasks defined in the standard, like damage tolerance analyses (DTA) programs, technical orders, and non-destructive inspections (NDI). The cycle is continued as these updates are carried into the force structural maintenance plan (FSMP), the cornerstone of ASIP. In turn, the FSMP dictates daily maintenance operations where maintenance-related data originates, completing the cycle as data is fed into the FMD. In implementing the digital thread, A-10 ASIP has relied on software developed by NLign Analytics. The NLign software suite is currently used by all three significant departments mentioned above and has become a vital aspect of the digital thread for maintenance operations related to ASIP.

A digital thread is essential to implement a digital twin, and there are nuances between the two. While still in work, the A-10 has managed to create a massive digital platform from historical records and drawings, providing design and as-built characteristic data, the first element needed for a digital twin. A-10's ASIP transitioned inspection-related data rooted in "pen and paper" to a fully digital data capture process at the depot in 2018. This digital database, combined with individual aircraft tracking (IAT), comprises the operational and as-maintained database, the second element of the digital twin. The third element of the digital twin of the A-10 is complicated and consists of many systems; some of these remain in development phases.

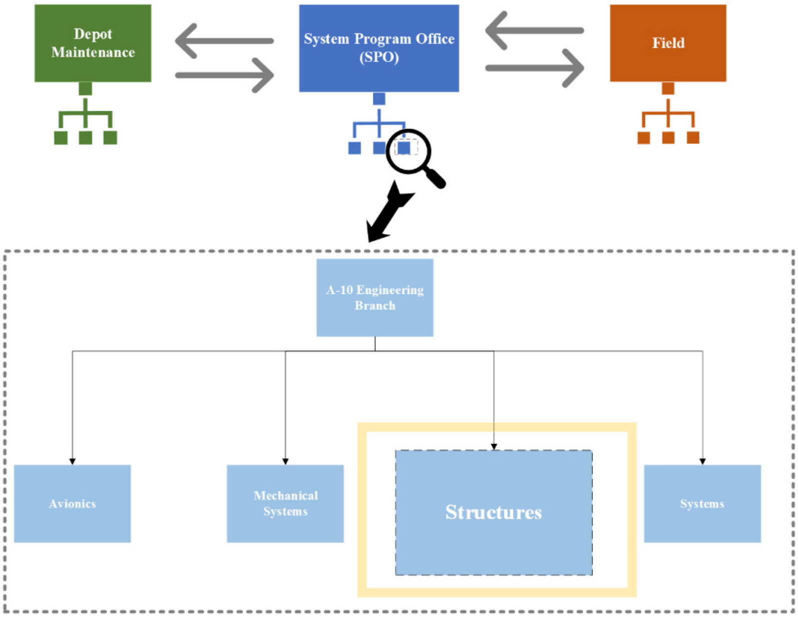


Figure 1: Simplified representation of sustainment organizations, drilling down to the structures group.

A primary goal of the digital twin is to allow engineering to proactively flag risk and prioritize inductions and maintenance tasks resulting in reduced sustainment costs and increased aircraft availability. Implementing a holistic predictive maintenance plan enabled by a digital twin minimizes operational irregularity costs, as described by R. Meissner et al. [5]. Figure 2 shows the potential cost avoidance by implementing a holistic predictive maintenance plan compared to a fixed interval maintenance plan. The benefits of a digital twin are significant and numerous; however, implementing a digital twin is an enormous undertaking. While implementing its digital thread to achieve a digital twin, A-10 ASIP experienced substantial setbacks and unforeseen cost expenditures and learned many lessons.

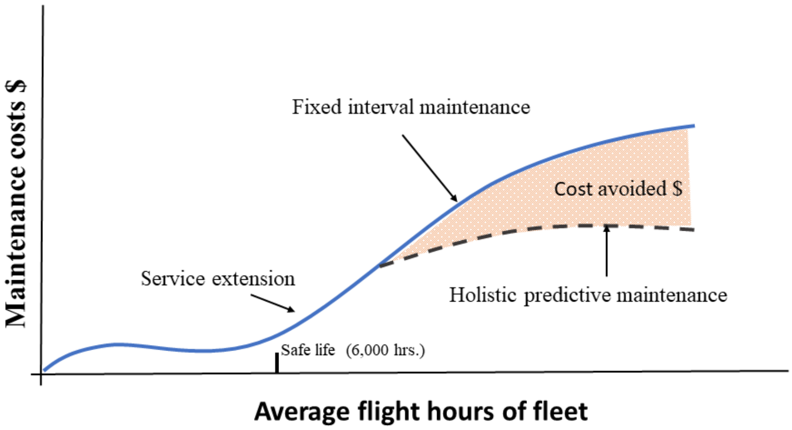


Figure 2: Potential maintenance costs for a fixed interval and holistic predictive plans versus average flight hours of fleet.

2.0 STEPS TAKEN TO IMPLEMENT A DIGITAL TWIN

2.1 Enhanced Wing Assembly Pushing the Digital Transformation

The actual digital transition began for the A-10 ASIP when engineers began the groundwork to design a new enhanced wing assembly (EWA) for the aircraft in 2004. R. Heller et al. [5] provide a comprehensive set of all the requirements of the EWA. The digital transition began to meet the needs of multiple parties as the simultaneous production of various parts and hardware for the EWA started. The digital thread would allow for these parties to access and manage product definitions, engineering bill of materials, and configuration control simultaneously.

An effort was initiated by the SPO to fully define the legacy thick skin wing with computer-aided designed (CAD) 3D models using the original 2D hand drawings created by Fairchild Republic. These 3D models of the legacy wing would then be given to the contracting manufacturer to incorporate design changes with the idea that model-based definitions of the EWA and all associated parts would facilitate accelerated wing production. 3D solid models of the legacy wing were developed one section at a time.

As planned, Boeing utilized the 3D models of the thick legacy wing as a base and ultimately developed a new set of 3D models that comprise the design of the EWA. As part of the contract, the models developed by Boeing were included as a deliverable with the new wings, giving ownership of the “tech stack” [6] to the A-10 SPO.

The benefits of having complete model base definitions (MBD) for the wings were apparent and made a big difference for the A-10 ASIP, driving the need to develop models for the entire A-10. The benefits of MBD led the A-10 SPO to work with Northrup-Grumman to create MBD for every part of the A-10 aircraft. Northrup-Grumman eventually delivered 25,000 modeled A-10 parts. Like the legacy wing, these parts were developed using 2D hand drawings. As part of this effort and to make the 2D engineering drawings available to multiple parties, over 70,000 drawings were scanned and converted to PDFs.

2.2 Digital Environments for Product Life Management

As mentioned above, Teamcenter was initially chosen as A-10’s primary PLM software, making Teamcenter the “source of truth.” However, there are many challenges when implementing PLM software intended to house all required data for digital sustainment needs, especially for legacy aircraft. Most obstacles the A-10 Teamcenter PLM team faced and continues to see today are related to implementing customized data structures to capture data in a usable format. Adding to the challenge of implementing a PLM solution, the data structure is required to correctly capture inputs from legacy systems, outside contract support systems, and live internal data simultaneously. These custom data structures require a tremendous number of resources and time and require continuous maintenance since it is only possible for Siemens to maintain data structures that are out-of-the-box solutions. Ultimately, this has led to a timeline far exceeding the initial expectations for fully implementing the PLM software. Despite these setbacks, the A-10 SPO continues gaining traction with Teamcenter and has become vital to sustainment operations for all of the A-10.

While Teamcenter is intended to be the single “source of truth,” it was always known and anticipated that other PLM-related data systems would author data to be consumed by Teamcenter later. As mentioned before, the data architecture and the involved process of these digital environments are relatively complex and involve many organizations. For this paper, only the NLign Analytics Platform will be discussed further in detail.

NLign Analytics Platform is a software suite developed to analyze aircraft manufacturing and maintenance data in a 3D environment. NLign originates with a small business innovative research (SBIR) funding project led by Air Force Research Laboratory in 2007 [7]. The original intent of NLign software was to house NDI data. Through additional USAF programs, specifically SIBRs and rapid innovation funding (RIF), NLign received sprints of software enhancements to grow the software's capabilities. Today, NLign's product suite consists of three different products, all aimed at capturing, analyzing, and communicating as-maintained aircraft data in real-time to allow for rapid response from decision-makers. While NLign can be utilized by many other programs, much of its development was catered to fit the needs of ASIP applications.

The A-10's first use of NLign began with an individual, Hazen Sedgwick, in 2014 [8]. Mr. Sedgwick used NLign to house structural and damage tolerance analysis data initially. Shortly after this, in 2015, an effort was made to comb through the many locations where serialized data was stored and then combined and imported into NLign to be used as a centralized serial tracking database. In 2018, the software was expanded to replace paper logbooks to capture scheduled structural inspection (SSI) data at the depot at Hill AFB. The use of NLign's product suite has continued to expand with more than 20 data types collected and managed and is used at many maintenance touch points at the depot and field.

3.0 STATE OF THE DIGITAL TWIN FOR A-10

In an ideal situation, the digital thread is implemented in infancy during the concept design phase of an aircraft, and continuity remains for the entire product life cycle. An idealized concept of such a lifecycle is visualized in Figure 3. Figure 3 shows that the digital thread requires connections for data communication amongst every party involved in the product lifecycle. Also shown in Figure 3 is that the digital twin belongs to the owner instead of, for example, the manufacturer. There are several reasons the digital twin should belong to the owner. The main reason is that the digital twin best serves the owner but will also ensure the digital twin is conserved and maintained if the manufacturer or supplier becomes obsolete.

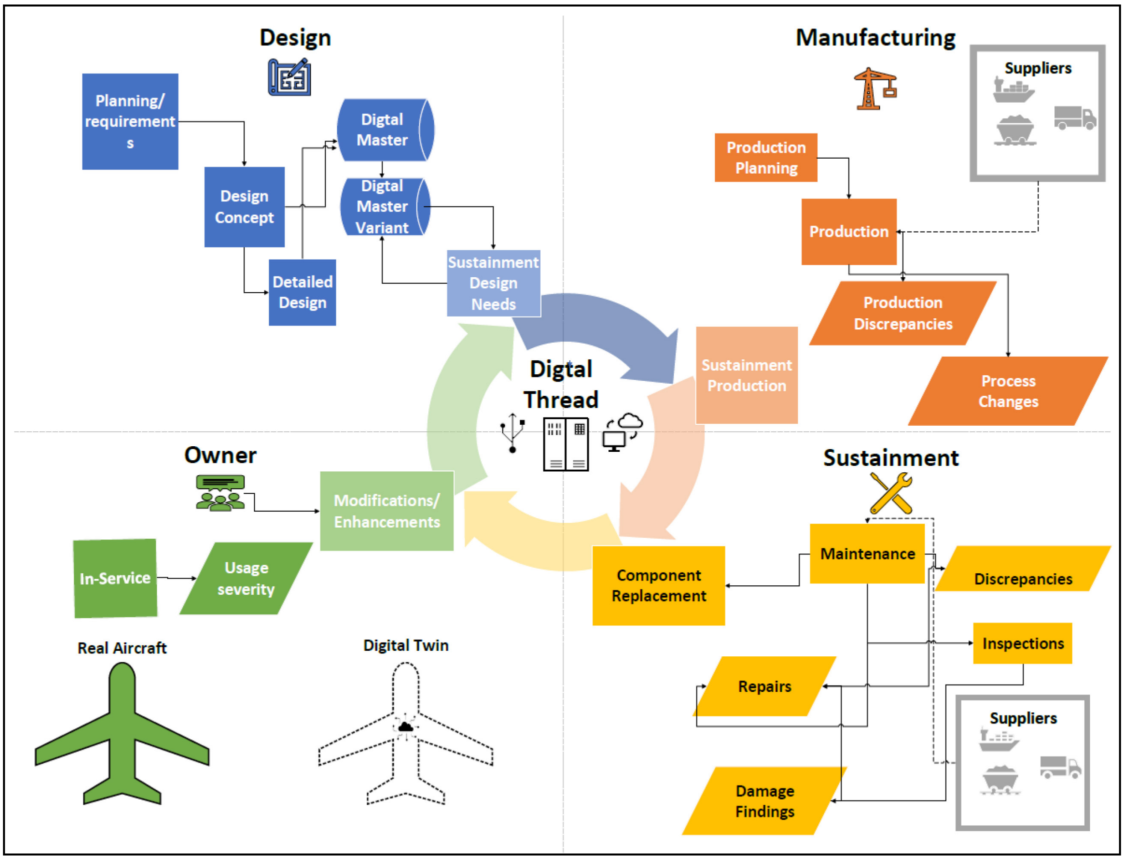


Figure 3: The digital tread and digital twin life cycle.

When a SLEP is instated, as the case for the A-10, this digital thread life cycle will continue, empowering holistic predictive maintenance actions. Continuing the digital thread for SLEP is more valuable than using the digital thread for as-designed service-life maintenance programs. However, for legacy aircraft like the A-10, this ideal situation is not possible since the aircraft was conceived, manufactured, and operated in an era before the rise of computers. Instead, it is necessary to assemble historical artifacts and piece together, as best as possible, a digital framework from non-digital sources.

3.1 Implementing the Digital Twin for A-10

The current state of a digital twin for A-10 would be better stated as a digital relative. The data necessary to provide a holistic interpretation of an aircraft or fleet is fragmented and resides in multiple systems. Interpreting historical records is another hurdle that must be navigated to progress toward a digital twin. The age of the aircraft and other factors have resulted in documentation gaps and poor data quality. Ultimately, the consequences of these deficiencies may be that a true digital equivalent may not be feasible for the A-10. Understanding the limitations, A-10 ASIP is still committed to pursuing a digital twin.

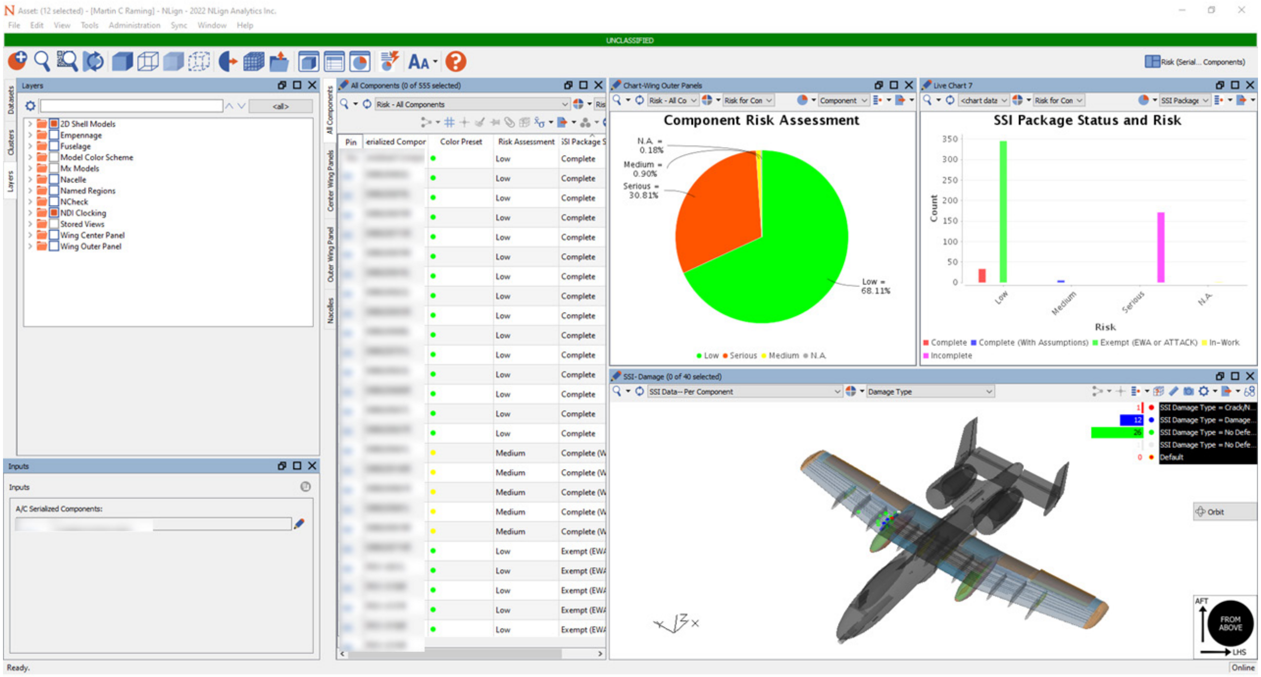
Historically, building a holistic prognosis that can be used for addressing engineering-related activities is manually intensive and time-consuming. Typically, the necessary data must be quarried from multiple sources and copied to the user's computer in numerous formats. The data is then distilled manually, or in some cases, a pre-written Microsoft computer object model (COM), like an Excel macro, is used to extract data. With the necessary data, a data model is then applied to achieve the desired output. The actual "data model" is usually statistics, basic math calculations, and historical context, all performed at the discretion of the individual tasked to provide the prognosis. The final output is typically a report that can be used to communicate the findings and recommendations and document the engineering rigor performed. Generating a report is the last step, and a meaningful digital equivalent of the document is not pursued.

3.1.1 Current State of A-10's Digital Twin

A true digital twin would eliminate almost all of the manual effort described above to provide the desired output and likely provide a more accurate synopsis, including other benefits. Although A-10 ASIP has yet to implement a digital twin fully, the program has used digital engineering processes, software, and standard practices to evolve toward a digital twin. Today, A-10 ASIP engineers utilize NLign and Teamcenter digital platforms to derive outputs necessary for a holistic prognostic interpretation of the A-10. A soft integration between the two systems has been implemented to extract data critical to the data model. The data model is similar to the historical process, consisting of statistics, mathematical manipulation, and historical context and relationships. However, it differs because it is done automatically using approved algorithms prescribed by the desired outputs. The data model output is commonly presented in two formats, a dashboard or a generated report in PDF, spreadsheet, or presentation. An example of a dashboard available in NLign can be seen in Figure 4.

Currently, the software platforms used do not have scriptable data models that are robust enough to meet the requirements of the A-10 ASIP. Therefore, the algorithms are written internally and rely on several computer languages. Most data manipulation and statistics is currently done using Microsoft VBA, but a transition to Python with the Pandas library is in-work. MATLAB is also used, but typically to merge data and back up digital records to a shared drive.

The generated reports are a combination of the desired outputs to provide results in a format intended to be ingested by humans in a non-digital manner. These reports have roots far outdating the digital era and will likely never be replaced entirely with a truly digital format. While a digital copy of the document is an easy option to make available in the digital thread, a digital copy cannot provide the data in the necessary format to be utilized by data models to continue the digital thread lifecycle. Instead, discretized metadata with context and applied relationships is needed to provide a technical depiction of the document and to append these results to the digital thread correctly.



Layers

- ☒ 2D Shell Models
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- ☐ Fuselage
- ☐ Model Color Scheme
- ☐ Mx Models
- ☐ Nacelle
- ☐ Named Regions
- ☐ NCheck
- ☒ NDI Clocking
- ☐ Stored Views
- ☐ Wing Center Panel
- ☐ Wing Outer Panel

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Figure 4: An example of dashboard implemented in NLign to assess aircraft component risk based on inspection data.

A-10 has two solutions to ensure that reports are captured into the digital thread in a way that meets the requirements of the digital twin. The first method uses report generation tools to formulate a report based on inputted data. For example, a liaison engineering report (LENR) is initiated by creating a digital record in NLign, consisting of fields of pertinent metadata that the engineer fills out. The report generation wizard can then reference the digital record to output the report. The report generation wizard utilizes a Microsoft Word template with prefilled syntax, similar to XML, to correctly map and populate the document with the metadata from the digital record. The second tool A-10 ASIP uses depends on COM automation and embedded macros in a report template made available for use. When the report is complete, the user can initiate the COM to create an equivalent with a press of a button. The COM will create a new digital record, map the metadata according to the algorithm and attach a digital copy of the document. This second option has advantages: if a report is modified or revised, the changes can easily be reflected in the digital record by rerunning the COM.

3.1.2 Data Capture for A-10's Digital Twin

The A-10 transitioned from paper logbooks and began capturing maintenance data in 2018 using the NLign application. NLign allows maintenance data critical to ASIP to be accessed by engineers immediately through its connection to the digital thread. NThread, provided as part of NLign's Analytics platform, includes the framework to easily implement NLign Analytics' software into A-10s digital thread hosted by Hill Enterprise Data Center (HEDC) at Hill AFB.

In 2020 NLign Analytics offered an additional product called NCheck. NCheck was designed to be a sister application to NLign as a more user-friendly data entry platform, leaving NLign as the designated analysis software to be used by engineering. A-10 has fully transitioned to using NCheck for data entry and has seen improvements, specifically reduced training needs and increased participation by maintainers. NCheck also offers a simplified data structure allowing ASIP to actively provide partially filled records, referred to as "Jobs," based on anticipated induction and maintenance needs. Also, within this data structure, a child of the

NCheck Job can be predefined to request data from a specific inspection task and is appropriately named "Tasks." In NCheck, a Job is a typical inspection package, and a Task is a particular inspection location. Jobs and Tasks drastically simplify data entry and are critical to using Smart Tools. While these improvements are crucial, the NCheck transition required time and resources with thoughtful planning and significant data restructuring.

The digital framework made it possible to request additional important information that was not possible with paper logbooks, such as repair types and metadata associated with technical support requests. NLign and NCheck also make sharing pictures and videos easy in real time, eliminating the timely and prohibited process of using individuals' smartphones and email. With a successful implementation of depot-level inspection data capture and vast improvement of data quality, it was decided to expand the digital thread and utilize NCheck to capture additional maintenance processes and touchpoints.

Today, A-10 ASIP uses NCheck to expand the FMD by capturing maintenance data from TCTO inspection, ACI, Hog Back fuselage structural repair, field phase inspection, field paint/corrosion inspections, blend measurements, and general maintenance discrepancies. With the expanded use of NLign and NCheck into additional touchpoints throughout the A-10, a growing need materialized for integrations or syncing capabilities with other digital thread platforms. Through enhancement requests from A-10 ASIP, NLign Analytics has developed several soft integrations to provide data syncing and automated record creation. A-10 utilizes a soft integration with three USAF systems: Teamcenter, Impresa, and PDMSS. The soft integration between Teamcenter is currently only used to sync Engineering Technical Assistance Requests (ETAR) metadata and A-10-part specifications. However, it is undoubtedly the more critical of the three and has the potential for significant positive impacts as it is fully utilized. The soft integration with Impresa and PDMSS has allowed ASIP to automate the creation of Jobs and Tasks in NCheck and partially populate fields saving time for maintenance and ensuring the correct inspection packages are assigned.

The NLign software platform has also become the data repository for many engineering-related activities. Engineering repair dispositions and support analysis are the primary sources of engineering-related data that are continually growing. Test and teardown data, strain-gauge data from full-scale fatigue tests, EWA production non-conformance data, patch tracking data, and historical ETARs are additional data types used in the software's analysis tools.

Before the digital transformation, ASIP engineers were forced to chase through multiple resources to find relevant serialized information, often finding gaps in the data. While Teamcenter's service life module (SLM) will soon be posed as the official repository for serialized information, NLign was chosen to house the information for ASIP needs until SLM is in production. In addition to the nine significant structural components of the A-10, more than 30 serialized components, for example flight controls, are tracked with the digital thread in NLign. A dataset has also been established to filter through the serialized information and provide a snapshot of the current configuration for each aircraft.

3.1.3 Road Map to an A-10 Fatigue and Structural Integrity Digital Twin

For now, multiple data systems are implemented to sustain the A-10, and the responsibility falls on the respective engineering groups to implement digital engineering tools. For A-10 ASIP, the goal is a fatigue and structural integrity digital equivalent or digital twin. This digital twin will not be realized at once but instead in phases starting from a "digital relative" and transitioning to a 'digital brother" before finally becoming a digital twin, as proposed by E. Gomez-Escalonilla et al. [6].

The next phase for A-10 ASIP's digital twin will center around developing a data model to validate DTA fatigue predictions with inspection results with crack indications. The validation would be exclusive to bolt/drain holes with crack findings that can be matched to critical points utilized in the DTA. At first glance, this objective seems straightforward, but as a plan was formulated to develop a data model, it became clear that this would be a significant undertaking. One of the major challenges would be ensuring that flight hours associated with crack findings are equivalent to the hours of DTA results. Several factors need to be considered to assign equivalent flight hours to a given location with damage findings. The most significant challenge comes from the fact that the actual flight hours of an aircraft/component are not necessarily equivalent since the clock for a specific hole gets reset to zero whenever over-sizing procedures remove a crack. Therefore, it is required that every hole used in the data model be considered unique and independent of the aircraft/component and neighboring holes. The scope of this task is enormous, as there are over 120 SSI locations, and most SSIs contain many holes, several with over hundreds of holes.

Further digital twin development beyond the next phase will build on the work described above. Once a data model is successfully implemented to compare fatigue predictions to inspection crack findings, a second phase will begin to move from validating fatigue predictions to predicting crack growth based on validated fatigue prediction. This data model will be implemented by comparing equivalent flight hours and interpolating these hours into the future based on current operating trends. These projected equivalent hours, fatigue predictions, and statistical biases derived from validation will allow the data model to proactively predict the potential failure time of specific locations for any given aircraft.

There is the potential for many more phases, and there will undoubtedly be projects deployed in parallel to expand the capabilities of A-10's digital twin. For example, several projects are to better facilitate data interoperability amongst the multiple digital thread systems utilized by A-10. One of these projects is a collaborative effort to distribute A-10-part models from Teamcenter to NLign automatically. This project would allow for high-fidelity model assemblies that match the current configurations of active aircraft to be available in both systems.

4.0 DISCUSSION AND RESULTS

In pursuing a digital twin, A-10 ASIP has developed digital prognostic tools that allow engineers to make predictions based on a holistic interpretation of data, permitting for directed and proactive maintenance actions. A pointed and proactive maintenance approach leads to millions in cost avoidance compared to the historical timed interval maintenance.

Additionally, the digital platforms that initiate a digital twin have greatly improved efficiencies compared to historical processes. One example of this can be noticed with liaison engineers providing technical assistance. Liaison engineers typically start a response to an ETAR by performing research on similar ETARs; if an analogous historic ETAR is found when compared to the current ETAR being worked, the engineer can append the historical disposition to the present disposition, quickly finishing the response. Before implementing the digital twin, liaison engineers would have to sort through multiple systems, which were often uncontrolled, typically resulting in hours of research and very little relevant information found. Through the digital thread, liaison engineers can usually find similar ETARs to append in minutes and have confidence in the data as it is controlled. Additionally, the engineering rigor for current and future ETARs is fully captured in the digital thread, expanding the database to allow more appended responses.

4.1 Lessons Learned from Initiating a Digital Twin

While the benefits of implementing a digital twin for legacy aircraft are numerous, specific costs and challenges may often get overlooked in the excitement of current digital engineering conversations. Correct implementation of digital twin software requires more resources and time than the original assessment. Additionally, there are often obstacles that take time to anticipate beforehand. A-10 ASIP currently has two full-time data analysts and one full-time engineering technician to implement a single digital twin system. The need for this support staff often surprises other programs looking to make a digital transformation. In reality, there is a need for even more personnel to ensure the vision of the digital twin can be fully implemented, and this need will only grow as more data is collected.

Cultural change on the shop floor is the most significant obstacle A-10 has faced and continues to face while implementing a digital twin. Despite ASIP's request and provided training as well as requirements being included in TOs, data was missing from the shop floor. When confronting the issue, shop personnel gave many reasons, but the most common response is, "The way we have always done it works fine." In addition to setting requirements, presence from leadership requesting action is also needed to achieve data entry compliance. Demanding leadership intervention is often met with resistance, requiring a series of meetings to convey the benefits of the digital twin before any action is taken. Also, technological proficiency is not a standard skill set among maintainers and technicians. Therefore, adaptation of digital twin software at the shop requires additional support beyond typical institution IT support as the software is specialized.

Implementing the digital twin in the field presented unanticipated obstacles not always present at the depot. Access to adequate hardware was a consistent issue encountered during the field deployment of NCheck. Except for a single field unit, the A-10 SPO needed to provide hardened tablets for the field units to capture data with NCheck. The hardware procurement and exchange processes are also complicated and time intensive due to USAF policies. The provided hardware must also be imaged and inventoried by the local unit's equipment custodian instead of the depot, or the hardware cannot be managed locally. Network access issues are also a consistent problem in the field, which has led the developers of NCheck to create an off-network solution. When offline, NCheck will cache data as it is entered to sync it later once a network connection is re-established.

The adage "garbage in, garbage out" certainly applies to collecting data. Still, it is also possible to have meaningful and valid data as input but fail to provide the desired output. As is the case with the more than 6,300 corrosion images taken by A-10 field units over the past two years. The photos are taken and attached to data records in NCheck as part of a TO requirement; however, it is impossible to automate corrosion detection on these images with the current software. Additionally, such a large volume of images would be too time intensive to do manually. Therefore, A-10 is researching image processing software options to automate corrosion detection and limit variability within photos taken to enhance the current prognostic tools and proactively prevent corrosion within the fleet.

In some cases, data was not being entered in the field because of a lack of IT support; the units could not get updated software, allowing them to bypass the data entry requirements. Lastly, the frequent change in personnel inherent to active-duty military makes it challenging to ensure knowledge is passed down. The release of NCheck has eased issues related to the lack of knowledge transfer as the application is designed to be user-friendly and semi-intuitive for users.

5.0 CONCLUSION

Digital engineering and digital platforms have received celebrity-like status amongst ASIP communities in the USAF and beyond, primarily due to the expectations of enormous gains using these powerful digital tools. However, the reality of implementing a complete digital twin solution is drastically more challenging than the duplicity that generated this hype [7]. The A-10 and other programs actively pursuing a digital twin solution are overcoming the disillusion and adjusting their focus and expectations to what is possible and reasonable [8].

Implementation of a digital twin for a legacy aircraft is not a trivial feat; however, the benefits of a digital twin dwarf the costs of implementation. As a result of initiating a digital twin, A-10 ASIP has a library of fleet data that can be used to accurately guide ASIP engineering activities like fleet/aircraft risk and prognostics, validation of damage tolerance analyses, corrosion prevention and prediction, analytical condition inspection (ACI) selection, and engineering liaison support. The future of aircraft sustainment will heavily rely on digital engineering solutions; therefore, it is vital for all parties involved to be included in the path toward a digital future cohesively instead of internal grandiloquence.

6.0 REFERENCES

[1] M.-S.-1. (USAF), “Military Standard, Aircraft Structural Integrity Program, Airplane Requirements,” USAF, 1972.

[2] S. R. Jones and G. A. Zsidisin, “Performance Implications of Product Life Cycle Extension: The Case of the A-10 Aircraft,” Journal of Business Logistics, vol. 29, no. 2, pp. 189-214, 2008.

[3] M. L. Thomsen Ph.D., P. N. Clark Ph.D. and R. E. Heller, “Development of Cost Effective Organic Engineering Expertise Balancing Weapon System Support Between Government and Engineering Support Contractors,” in United States ASIP Conference, San Antonio, TX, 2011.

[4] USAF, MIL-STD-1530D DoD Standard Aircraft Structural Integrity Program, 2016.

[5] R. Meissner, A. Rahn and K. Wicke, “Developing prescriptive maintenance strategies in aviation industry based on a discrete-event simulation framework for post-prognostics decision making,” Reliability Engineering and System Safety, vol. 214, 2021.

[6] J. Gomez-Escalonilla, F. Sanchez, O. Valencia and M. J. Rebollo, “A holistic digital twin for service life extension programs,” in International Committee on Aeronautical Fatigue and Structural Integrity (ICAF), Delft, 2023.

[7] E. Lindgren, “Unites States Topical National Review,” in International Committee of Aeronautical Fatigue and Structural Integrity, Delft, 2023.

[8] H. Sedgwick, Interviewee, On the Origins of A-10 ASIPs use of NLign and Prognostic Goals. [Interview]. 18 April 2023.