University of Dayton Research Institute

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Whitepaper

Establishing and Ensuring Digital Twin Relevance for Sustainment, Modifications, and Upgrades

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Preface

UDRI appreciates the heavy lift ahead in the Air Force Digital Campaign, and is working with the Dayton community to bring additional support to help move the Air Force forward in its efforts. As part of a team consisting of the Dayton Development Coalition (DDC) and another contractor, UDRI was tasked with providing a series of whitepapers for initiatives linking digital twins to sustainment-related activities, including modifications and upgrades. With this tasking in mind, UDRI solicited inputs and insights from Air Force Lifecycle Management Center (AFLCMC) Digital Transformation Office (DTO), Rapid Sustainment Office (RO), and Support Equipment and Vehicles Program Office (WNZ) between 18 and 22 March 2022. The following series of initiatives is our first pass at translating those needs into a context consistent with the DDC tasking, and are offered to out AFLCMC customers for review and comment. We look forward to continuing discussions with AFLCMC and other Air Force organizations to advance these and other concepts contributing to the Air Force Digital Campaign.

Introduction

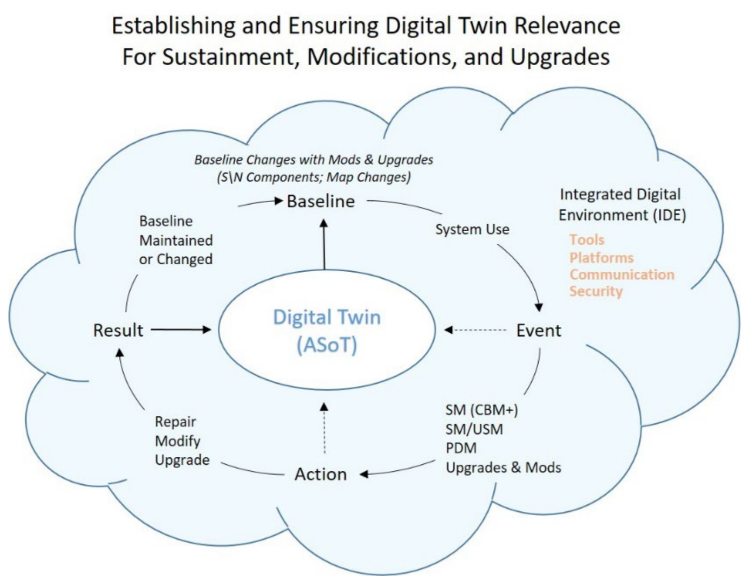
As the Department of Defense (DoD) and the Air Force (AF) embark on the journey of "digital transformation," vision and promise of realized potential abound in whitepapers, articles, and PowerPoint presentations. The key concepts like digital twin, authoritative source of truth, integrated digital environment, lifecycle management, tech stack, model-based systems engineering (MBSE), data architecture, and many more frame and dominate conversations about the future digital umbrella woven together with digital thread. Some forward-leaning AF systems program offices (SPOs) and sustainment organizations have already started to pursue digital transformation in the areas of digital twin, MBSE, and other key digital transformation aspects. These early efforts are good, bold, and necessary first steps. Beyond those first steps, however, lies the true untapped potential of digital transformation's impact in the realm of sustainment, modifications, and upgrades to AF weapons systems.

Problem Statement

Digital twins are at high risk of becoming static, obsolete, and of marginal relevance in the absence of processes, tools, data architectures, standards, and infrastructure to effectively and efficiently apply and maintain them throughout the subjects' sustainment lifecycle. While the creation of digital twins has become a focal point of AF digital transformation, many in the sustainment community are wondering how these digital twins will benefit their day-to-day operations, while others wonder how will the digital twins be kept current, or "relevant," through weapon systems lifecycle, especially to the "tail number" (individual aircraft) level of granularity. With the millions of aircraft maintenance (Mx) transactions performed on the AF fleet annually, how will digital twins help inform, shape, and guide those actions, and how will the outcome of those actions be fed back into their respective digital twins to maintain relevance?

Proposed Solution/Scope

Establish a set of minimum viable prototype (MVP) applications of digital twin to (1) predictive Mx, leveraging Condition-Based Mx Plus (CBM+); (2) field-level unscheduled and scheduled Mx (USM/SM) activities resulting from routine flight operations and sortie generation; (3) scheduled programmed depot Mx (PDM) activities; and (4) planned upgrades and modifications.



Objectives

1. Define fundamental processes needed to keep digital twins current and viable authoritative sources of truth (ASoT) throughout object lifecycle as shaped by Mx, modifications, and upgrades.
2. Define and establish MVP data architecture(s) required to maintain digital twins.
3. Define and establish MVP integrated digital environment(s) (IDE), to include software tools and platform, to support the fundamental processes from Objective 1 and consistent with the data architecture(s) from Objective 2.
4. Apply and adapt MVPs and processes from Objectives 1-3 to any or all of the proposed solution scenarios (CBM+, USM/SM, PDM, and upgrades/modifications).
5. Draft roadmap(s) for scaling MVPs to platform/enterprise levels, as appropriate, to realize potential of digital twin application to sustainment, modification, and upgrade activities.

Technical Approach

For each of the 4 proposed MVP applications (CBM+, SM/USM, PDM, and Upgrades/Modifications), a two-phased approach will be undertaken to minimize risk and leverage learnings among the application cases. An MBSE approach will be taken throughout.

Phase I: Design, Test, Verify, Validate Concept & Model

Phase I will focus on establishing, modeling, verifying and validating the concepts for each approach. Some elements of the Phase I approach are expected to be shared among use cases, while other elements are anticipated to be unique among use cases. Critical processes affecting data flow, decision-making, maintenance actions, maintenance data collection, will be mapped in the context of closed-loop data flow from and back into the affected digital twin(s). Once the data flow process is established, a basic data architecture will be defined. With fundamental data flow and data architecture defined, an MVP of information systems architecture for the integrated digital environment (IDE) will be established to reference and update the digital twin(s) electronically with minimal human data entry or correction.

This IDE is envisioned to leverage and include existing Mx data collection (MDC) systems; digital twin models and supporting software tools and data structures; product lifecycle management (PLM) platforms (e.g. Teamcenter), electronic technical orders (TOs), product design and modeling software (e.g. Solidworks, Creo), MBSE software (e.g. Cameo), reporting software, and other relevant digital tools. MBSE models using the Systems Modeling Language (SysML) will be generated at the appropriate level for subject systems, subsystems, or components and for relevant processes. Upon completion of these tasks and resulting models, the project team will simulate process execution to verify the viability of the process and to identify any missing or deficient aspects of the models and to resolve them. Once models and processes are verified, the team will conduct another simulation and review with key stakeholders to validate expected performance characteristics and outcomes and resolve any resulting gaps. Upon stakeholder acceptance of the proposed solution and approach, the team will then finalize the scope and structure of hardware, software, and services required to implement the MVP for selected solution scenarios (CBM+, USM/SM, PDM, and upgrades/modifications). At this point, Phase II budgets and schedules will be updated and specific system platforms and end items will be identified for developing and demonstrating the MVPs in Phase II.

Phase II: Build MVP Ecosystem, Data Architecture, Process & Implement Learning Loop

Building on Phase I outcomes, Phase II will establish an MVP digital ecosystem, data architecture, and processes for leveraging and maintaining digital twins for sustainment, upgrade, and modification activities, and will include 15-18 months of hands-on use in any of four proposed application scenarios. The outcome of Phase II will include recommendations for interfacing digital twins with other essential and emerging maintenance digital data sources, systems, and processes; system and data architectures for successful integration of digital twins into sustainment-related environments; a summary of best practices observed and discovered; and a high-level roadmap for scaling application of digital twins throughout the AF sustainment enterprise.

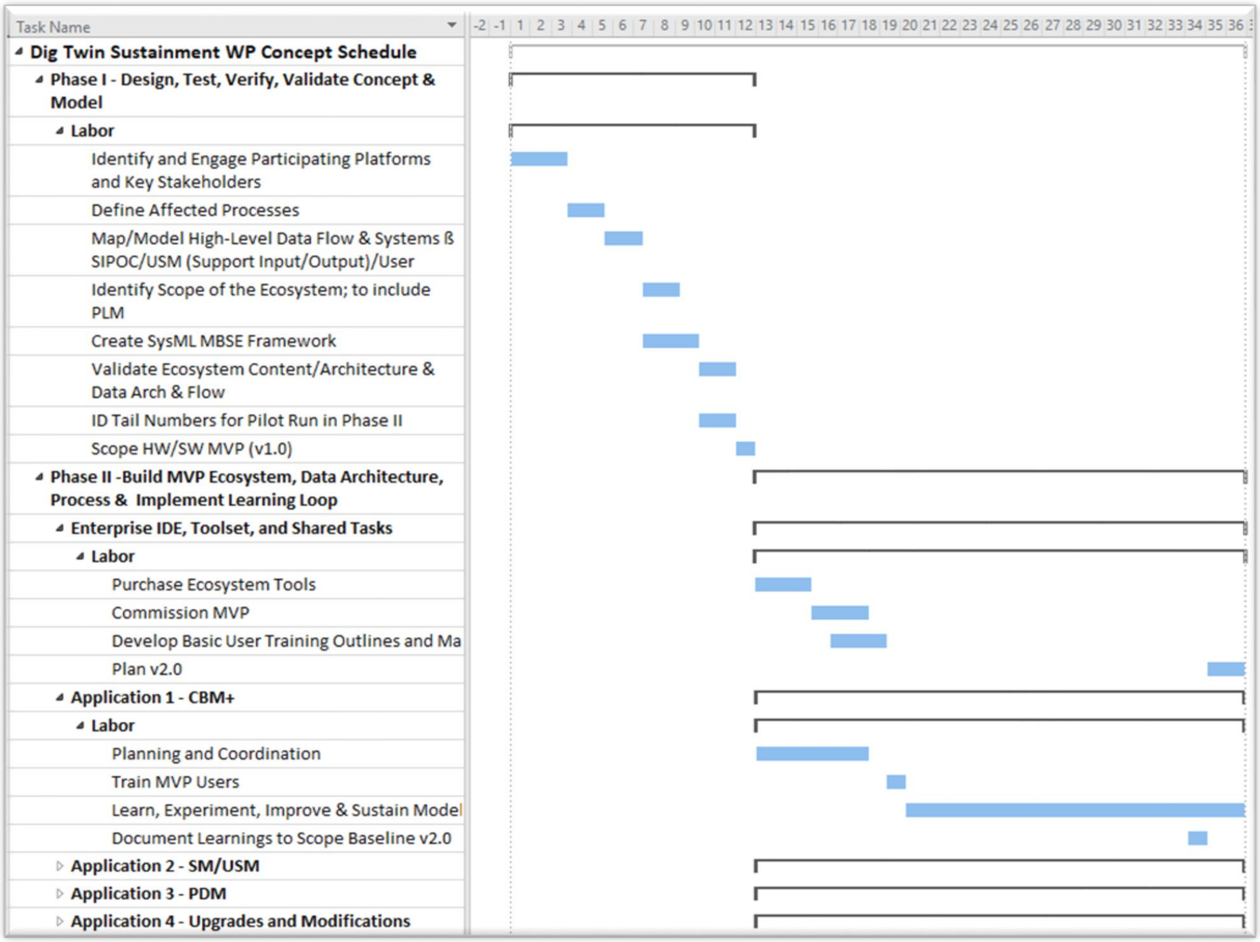
Phase II will commence with procurement of IDE ecosystem tools and services as defined by Phase I. The project team will install, integrate, and commission the IDE and tool sets and prepare basic training outlines and materials and train application team member for application project start-up.

Any, some, or all of 4 proposed application (CBM+, SM/USM, PDM, and Upgrades/Modifications) projects may be undertaken, dependent upon available funding. Further description of the application projects are provided in Appendices A-D.

Selected application projects will apply and adapt the constructs developed in Phase I to experiment, understand, improve, and enhance digital twin relevance and sustainability in their respected use cases. A mindset of "fail fast, learn faster" will be promoted to encourage innovation and risk taking in movement of data and information, but will in no way be allowed to jeopardize safety of flight or ground operations. Application will be focused to a single or small number of end items to minimize complexity and maximize fundamental understating of interactions and outcomes. Stakeholders for the affected organizations will be involved in planning, execution, information sharing, and evolution of digital twins relevant to their roles and mission needs. Experimentation and application may be scaled to additional end items as results, success, and opportunity permit. Lessons learned will be captured, analyzed, and applied to recommendations for the subsequent versions of the IDE, digital twins, relevant processes, and creation of a roadmap for scaling to platform/AF enterprise-level(s).

Schedule

Proposed scope of effort spans a 36-month period of performance, divided into 2 serial phases. Phase I is estimated at 12 months, and Phase II is estimated at 24 months. The Gantt chart below illustrates relative timing of tasks within Phase I; Phase II Enterprise IDE, Toolset, and Shared Tasks; and representative sequencing of Application-centric tasks.



Conclusion

The promise and potential of a "Digital AF" are undisputable – the path to realizing that potential is long and complex. The initiatives proposed in this whitepaper provide a manageable and practical approach to rapidly establish and scale working digital ecosystem prototypes and data architectures to support sustainment activities leveraging digital twins – and for maintaining fidelity and relevance of digital twins as their physical siblings undergo sustainment-related changes throughout their lifecycles.

Appendix A – Digital Twins and Predictive Maintenance Using CBM+

Problem Statement

Digital twins and Condition-Based Maintenance Plus (CBM+) are digital tools being developed and employed to improve the readiness and lifecycle management of Air Force (AF) weapons systems (WS). While each of the standalone tools benefits the warfighter and sustainer, integration of the systems and their data could provide a synergistic effect far greater than the sum of the individual pieces. Furthermore, for each to realize its full potential, they need to be synchronized to maintain a real-time or near-real-time authoritative source of truth (ASoT) by which the physical twins can be effectively and optimally managed.

Proposed Solution and Scope of Effort

UDRI proposes establishment of a minimum viable prototype (MVP) to integrate and exercise digital twin with predictive maintenance (Mx) using CBM+ consistent with tenets of the AF Digital Campaign to establish a data architecture, integrated digital environment (IDE) and tools, and processes to synchronize and synergize a digital twin/CBM+ digital thread which can be rapidly scaled across the AF enterprise.

Objectives/Benefits

Objective	Benefit
1. Define processes needed to synchronize and synergize digital twin and CBM+	Definition of system boundaries for digital twin/CBM+ digital thread
2. Define and establish data architecture required to synchronize digital twin and CBM+	Exchange of essential and relevant data to synchronize digital twin and CBM+ to ensure ASoT is maintained and not corrupted by digital twin/CBM+ digital thread
3. Define and establish IDE, to include software tools and platform	Working digital environment and tools consistent with AF Digital Campaign objectives to facilitate maintenance of ASoT and access of relevant data
4. Apply and adapt MVPs to digital twin and CBM+	Practical understanding of actual and potential benefit and limitations of digital twin / CBM+ digital thread
5. Draft roadmap(s) for scaling digital twin/CBM+ MVP to platform/enterprise levels	Experientially-based plan to rapidly scale digital twin/CBM+ digital thread

Stakeholders/Potential Stakeholders

This application project has several AF and industry stakeholders and potential stakeholders which will be vetted/engaged during Phase I of the project, with a focused subset remaining engaged for the development of the MVP to be established in Phase II. An initial list of potential stakeholders is provided below.

Potential Stakeholder	Aspect/Initiatives
AF Offices	
Digital Transformation Office (DTO)	AF Digital Campaign, Digital Twin
Rapid Sustainment Office (RSO)	CBM+, Digital Engineering for Sustainment
AF Platforms	
B-1	Digital Twin, CBM+
F-16	Digital Twin
A-10	Digital Twin
C-5	CBM+
C-17	CBM+
HH-60	CBM+
CV-22	CBM+

Technical Approach

Phase I: Phase I of this initiative will follow the technical approach outlined in the umbrella whitepaper, with a focus on exploring and understanding the potential of integrating CBM+ and digital twin(s) in an integrated data environment (IDE) and the processes required to support; establishing appropriate interface control definitions and supporting data structures; and definition of the IDE elements and system architecture. Key sustainment stakeholders in CBM+ and digital twin communities will be included and engaged to design, verify, and validate a plan to implement, test, and develop an MVP of the system and processes in Phase II.

Phase II: Phase II will also follow the technical approach outlined in the umbrella whitepaper, with a focus on establishing the IDE processes and procedures, then exercising, reviewing, and iterating them over a 15-18 month period of application and experimentation. At the conclusion of Phase II, if deemed viable by stakeholders, a high-level roadmap to scale the integration of CBM+ and digital twin will be delivered.

Conclusion

Integration of CBM+ and digital twin suggests great potential benefit for the AF. This initiative provides a timely, affordable, and forward-leaning vehicle to rapidly innovate, experiment, and scale this digital opportunity with minimal risk and significant potential pay-off.

Appendix B – Digital Twins and Field-Level Maintenance

Problem Statement

Digital twins, translated to the individual aircraft level of detail, are a desirable and visionary outcome of the Air Force's (AF) digital transformation. The potential of being able to model each individual aircraft in the AF fleet and keep those models current and relevant on a day-by-day basis as they sortie, recover, and regenerate offers maintainers, logisticians, and engineers a unique opportunity to query, understand, and predict the condition and health of any given aircraft at any given time – using a single authoritative source of truth (ASoT). The challenge of maintaining such digital twin ASoTs with reasonable fidelity is having processes, tools, and infrastructure for capturing, standardizing, and applying field-level maintenance (Mx) data to the digital twin ASoT in a timely and meaningful way.

Proposed Solution and Scope of Effort

UDRI proposes establishment of a minimum viable prototype (MVP) to integrate and exercise digital twin(s) with current and emerging field-level Mx data collection systems (MDC) consistent with tenets of the AF Digital Campaign. The primary focus will be to establish a data architecture, integrated digital environment (IDE) and tools, and processes to create a baseline for a digital twin/MDC system digital thread which can be rapidly scaled across the AF enterprise. Furthermore, digital twin models also have potential for providing maintainers model-based views of the aircraft with which the maintainers and engineers can interact and query to gain additional insight into formulating repair strategies and approaches complementary to traditional technical order procedures and illustrations. This aspect will also be explored and recommendations for application and scaling will be offered.

Objectives/Benefits

Objective	Benefit
1. Define processes needed to synchronize and synergize digital twin and MDC	Definition of system boundaries for digital twin/MDC digital thread
2. Define and establish data architecture required to synchronize digital twin and MDC	Exchange of essential and relevant data to synchronize digital twin and MDC to ensure ASoT is maintained and not corrupted by digital twin/MDC digital thread
3. Define and establish IDE, to include software tools and platform	Working digital environment and tools consistent with AF Digital Campaign objectives to facilitate maintenance of ASoT and access of relevant data
4. Apply and adapt MVPs to digital twin, MDCs, and fundamental field-level maintenance processes	Practical understanding of actual and potential benefit and limitations of digital twin/MDC digital thread
5. Draft roadmap(s) for scaling digital twin/MDC MVP to platform/enterprise levels	Experientially-based plan to rapidly scale digital twin/MDC digital thread

Stakeholders/Potential Stakeholders

This application project has several AF and industry stakeholders and potential stakeholders which will be vetted/engaged during Phase I of the project, with a focused subset remaining engaged for the development of the MVP to be established in Phase II. An initial list of potential stakeholders is provided below.

Potential Stakeholder	Aspect/Initiatives
AF Offices	
Digital Transformation Office (DTO)	AF Digital Campaign, Digital Twin
Rapid Sustainment Office (RSO)	Project Lighthouse, Digital Engineering for Sustainment
AF Platforms	
B-1	Digital Twin
A-10	Digital Twin
F-16	Digital Twin
F-15	
C-5	
F-22	
RQ-4B	

Technical Approach

Phase I: Phase I of this initiative will follow the technical approach outlined in the umbrella whitepaper, with a focus on exploring and understanding the potential of integrating MDC and digital twin(s) in an integrated data environment (IDE) and the processes required to support; establishing appropriate interface control definitions and supporting data structures; and definition of the IDE elements and system architecture. Learnings and insights from the RSO Lighthouse project, which explored and modeled aircraft generation process and data flows, will be reviewed, assessed, and leveraged where applicable. Prior project(s), which demonstrated mapping of Mx actions on specific airframes to 3D models, and associated tools will be reviewed and considered for a place in the solution design. Key sustainment stakeholders in MDC and digital twin communities will be included and engaged to design, verify, and validate a plan to implement, test, and develop an MVP of the system and processes in Phase II.

Phase II: Phase II will also follow the technical approach outlined in the umbrella whitepaper, with a focus on establishing the IDE, processes, and procedures, and exercising, reviewing, and iterating them over a 15-18 month period of application and experimentation. At the conclusion of Phase II, if deemed viable by stakeholders, a high-level roadmap to scale the integration of MDC and digital twin will be delivered.

Conclusion

Integration of MDC and digital twin suggests great potential benefit for the AF. This initiative provides a timely, affordable, and forward-leaning vehicle to rapidly innovate, experiment, and scale this digital opportunity with minimal risk and significant potential pay-off.

Appendix C - Digital Twins and Programmed Depot Maintenance (PDM)

Problem Statement

Digital twins, translated to the individual aircraft level of detail, are a desirable and visionary outcome of the Air Force's (AF) digital transformation. The potential of being able to model each individual aircraft in the AF fleet and keep those models current and relevant throughout programmed depot maintenance (PDM) and major overhaul activities offers maintainers, logisticians, and engineers a unique opportunity to query, understand, and predict the condition and health of any given aircraft at any given time – using a single authoritative source of truth (ASoT). The challenge of maintaining such digital twin ASoTs with reasonable fidelity is having processes, tools, and infrastructure for capturing, standardizing, and applying PDM data to the digital twin ASoT in a timely and meaningful way.

Proposed Solution and Scope of Effort

UDRI proposes establishment of a minimum viable prototype (MVP) to integrate and exercise digital twin(s) with current and emerging PDM maintenance data collection systems (MDC) consistent with tenets of the AF Digital Campaign. The primary focus will be to establish a data architecture, integrated digital environment (IDE) and tools, and processes to create a baseline of a digital twin/PDM MDC system digital thread which can be rapidly scaled across the AF enterprise. Furthermore, digital twin models also have potential for providing maintainers model-based views of the aircraft with which the maintainers and engineers can interact and query to gain additional insight into formulating repair strategies and approaches complementary to traditional technical order procedures and illustrations. This aspect will also be explored and recommendations for application and scaling will be offered.

Objectives/Benefits

Objective	Benefit
1. Define processes needed to synchronize and synergize digital twin and PDM MDC	Definition of system boundaries for digital twin/PDM MDC digital thread
2. Define and establish data architecture required to synchronize digital twin and PDM MDC	Exchange of essential and relevant data to synchronize digital twin and MDC to ensure ASoT is maintained and not corrupted by digital twin/PDM MDC digital thread
3. Define and establish IDE, to include software tools and platform	Working digital environment and tools consistent with AF Digital Campaign objectives to facilitate maintenance of ASoT and access of relevant data
4. Apply and adapt MVPs to digital twin, PDM MDCs, and fundamental depot-level maintenance processes	Practical understanding of actual and potential benefit and limitations of digital twin/PDM MDC digital thread
5. Draft roadmap(s) for scaling digital twin/PDM MDC MVP to platform/enterprise levels	Experientially-based plan to rapidly scale digital twin/PDM MDC digital thread

Stakeholders/Potential Stakeholders

This application project has several AF and industry stakeholders and potential stakeholders which will be vetted/engaged during Phase I of the project, with a focused subset remaining engaged for the development of the MVP to be established in Phase II. An initial list of potential stakeholders is provided below.

Potential Stakeholder	Aspect/Initiatives
AF Offices	
Digital Transformation Office (DTO)	AF Digital Campaign, Digital Twin
Rapid Sustainment Office (RSO)	Digital Engineering for Sustainment
Air Force Sustainment Center (AFSC)	Project Athena
AF Platforms	
B-1	Digital Twin
A-10	Digital Twin
F-16	Digital Twin
F-15	
C-5	
F-22	
RQ-4B	

Technical Approach

Phase I: Phase I of this initiative will follow the technical approach outlined in the umbrella whitepaper, with a focus on exploring and understanding the potential of integrating PDM MDC and digital twin(s) in an integrated data environment (IDE) and the processes required to support; establishing appropriate interface control definitions and supporting data structures; and definition of the IDE elements and system architecture. AFSC's Athena Project will be reviewed and applicable elements will be integrated/interfaced with this effort. Prior project(s), which demonstrated mapping of Mx actions on specific airframes to 3D models, and associated tools will be reviewed and considered for a place in the solution design. Key sustainment stakeholders in MDC and digital twin communities will be included and engaged to design, verify, and validate a plan to implement, test, and develop an MVP of the system and processes in Phase II.

Phase II: Phase II will also follow the technical approach outlined in the umbrella whitepaper, with a focus on establishing the IDE, processes, and procedures, and exercising, reviewing, and iterating them over a 15-18 month period of application and experimentation. At the conclusion of Phase II, if deemed viable by stakeholders, a high-level roadmap to scale the integration of MDC and digital twin will be delivered.

Conclusion

Integration of PDM MDC and digital twin suggests great potential benefit for the AF. This initiative provides a timely, affordable, and forward-leaning vehicle to rapidly innovate, experiment, and scale this digital opportunity with minimal risk and significant potential pay-off.

Appendix D - Digital Twins and Upgrades/Modifications

Problem Statement

Arguably one of the most holistic applications of digital twin involves using digital twins as baseline authoritative sources of truth (ASoT) in the design, verification, validation, implementation, and documentation of system modifications and upgrades. In this application, a true lifecycle "digital thread" for the affected modification or upgrade can be spun and maintained utilizing the digital twin model. Currently, the Air Force (AF) has no established processes, procedures, tools, data architecture, or integrated digital environment (IDE) to consistently apply and scale this application of digital twin across original equipment manufacturers (OEMs), Air Force Research Laboratory (AFRL), Air Force Lifecycle Management Center (AFLCMC), the Air Force Sustainment Center (AFSC), and other key stakeholders and contributors.

Proposed Solution and Scope of Effort

UDRI proposes establishment of a minimum viable prototype (MVP) to integrate and exercise digital twin(s) to support design, testing, implementation, and documentation of modifications and upgrades consistent with tenets of the AF Digital Campaign. The primary focus will be to establish a data architecture, integrated digital environment (IDE) and tools, and processes to create a baseline of a digital twin/PDM MDC system digital thread which can be rapidly scaled across the AF enterprise. Furthermore, digital twin models in this application can also provide relevant interface definitions to enable downstream model-based systems engineering analysis and upgrade/modification design of affected ground support equipment such as generators, air conditioning units, hydraulic carts, and system test equipment. Such interfaces and system interactions will also be taken into consideration.

Objectives/Benefits

Objective	Benefit
1. Define processes needed to synchronize and synergize digital twin and system upgrades and modifications	Definition of system boundaries for digital twin and system upgrades and modifications digital thread
2. Define and establish data architecture required to synchronize digital twin and system upgrades and modifications	Exchange of essential and relevant data to synchronize digital twin and MDC to ensure ASoT is maintained and not corrupted by digital twin and system upgrades and modifications digital thread
3. Define and establish IDE, to include software tools and platform	Working digital environment and tools consistent with AF Digital Campaign objectives to facilitate maintenance of ASoT and access of relevant data
4. Apply and adapt MVPs to digital twin and system upgrades and modifications processes	Practical understanding of actual and potential benefit and limitations of digital twin and system upgrades and modifications digital thread
5. Draft roadmap(s) for scaling digital twin and system upgrades and modifications MVP to platform/enterprise levels	Experientially-based plan to rapidly scale digital twin and system upgrades and modifications digital thread

Stakeholders/Potential Stakeholders

This application project has several AF and industry stakeholders and potential stakeholders which will be vetted/engaged during Phase I of the project, with a focused subset remaining engaged for the development of the MVP to be established in Phase II. An initial list of potential stakeholders is provided below.

Potential Stakeholder	Aspect/Initiatives
AF Offices	
Digital Transformation Office (DTO)	AF Digital Campaign, Digital Twin
Rapid Sustainment Office (RSO)	Digital Engineering for Sustainment
Air Force Sustainment Center (AFSC)	Upgrades and Modifications, Project Athena
Air Force Research Laboratory (AFRL)	Prototype Upgrades and Modifications
Support Equipment and Vehicles Program Office	
AF Platforms	
B-1	Digital Twin, Upgrades and Modifications
A-10	Digital Twin, Upgrades and Modifications
F-16	Digital Twin, Upgrades and Modifications
Others TBD	Upgrades and Modifications

Technical Approach

Phase I: Phase I of this initiative will follow the technical approach outlined in the umbrella whitepaper, with a focus on establishing digital twin(s) as baseline ASoT for upgrade and modification design, testing, implementation, and documentation in an integrated data environment (IDE) and the processes required to support; establishing appropriate interface control definitions and supporting data structures; and definition of the IDE elements and system architecture.

Upgrades originating in AFRL and industry will be given consideration in this MVP, as threads for both need to eventually be established, and with the understanding that this project's funding may be sufficient to pursue only one. Key sustainment stakeholders in upgrades/modifications and digital twin communities will be included and engaged to design, verify, and validate a plan to implement, test, and develop an MVP of the system and processes in Phase II.

Phase II: Phase II will also follow the technical approach outlined in the umbrella whitepaper, with a focus on establishing the IDE, processes, and procedures, and exercising, reviewing, and iterating them over a 15-18 month period of application and experimentation. While it is understood that many upgrade and modification design cycles exceed the 15-18 month period of performance (PoP), this effort will endeavor application as far into the upgrade and modification cycle as funding and PoP permits. At the conclusion of Phase II, if deemed viable by stakeholders, a high-level roadmap to scale the integration of MDC and digital twin will be delivered.

Conclusion

Integration of upgrade and modification design, test, implementation and documentation with digital twin suggests great potential benefit for the AF. This initiative provides a timely, affordable, and forward-leaning vehicle to rapidly innovate, experiment, and scale this digital opportunity with minimal risk and significant potential pay-off.