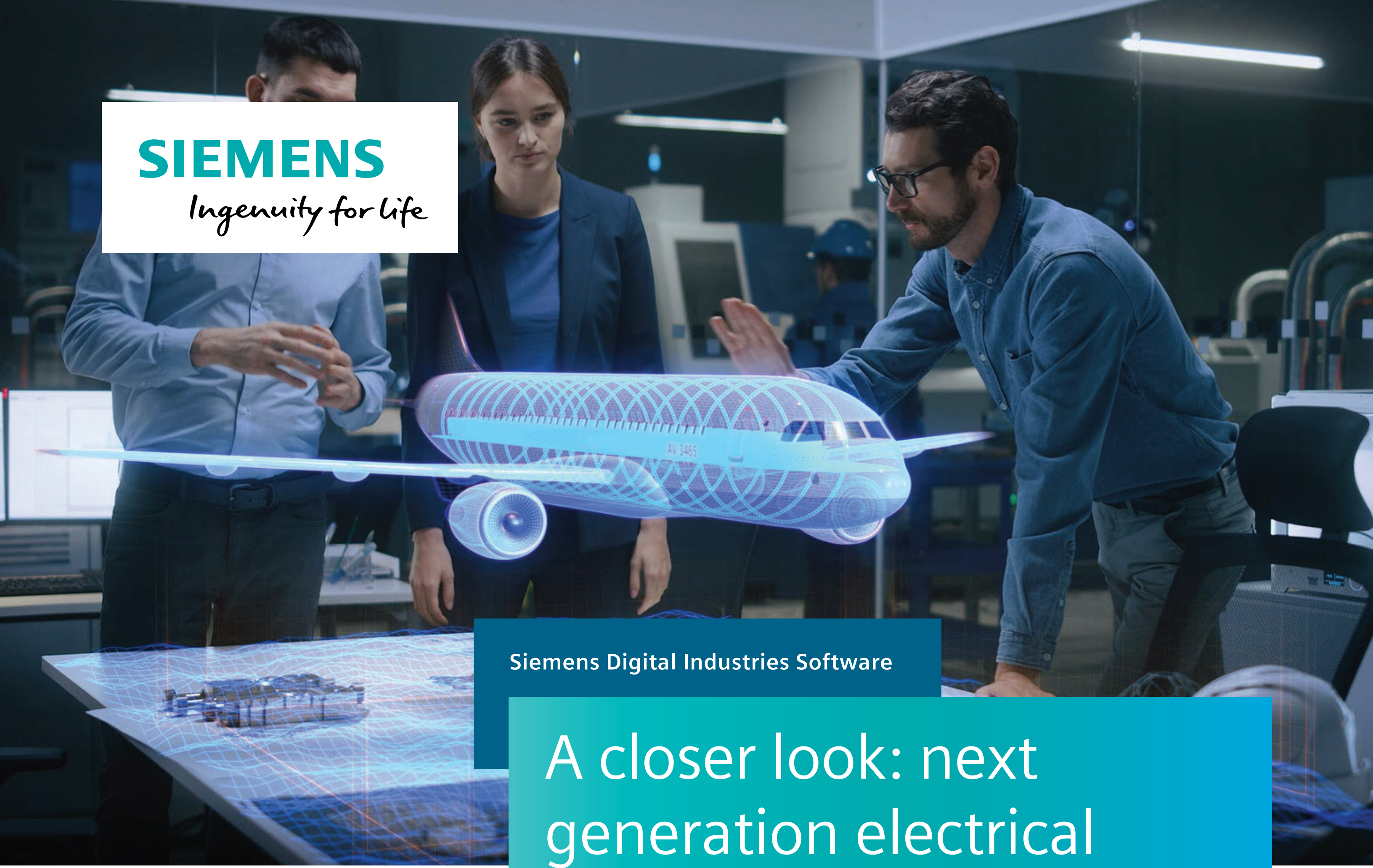

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Siemens Digital Industries Software

A closer look: next generation electrical system platform development

Aerospace and Defense

Executive summary

Recent innovations in commercial and defense aircraft have driven vast increases in the quantity and complexity of electrical systems within those platforms. Because of this the design and implementation of these systems are a significant factor in the overall program risk that has to be managed. This paper discusses approaches to improve the electrical platform development process to reduce risk and reach program goals.

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Introduction

The Aerospace and Defense (A&D) industry faces competitive margin pressures at the platform level and throughout the supply chain. The industry is constantly looking for ways to control costs and improve collaboration. The ongoing demand for increased platform performance, coupled with the trend toward implementing more capabilities using electrical systems has made the development of these programs a high-risk endeavor. The goal is to reduce cost and minimize risk while introducing new levels of innovation and quality. OEMs and their suppliers must also take into consideration the increasingly stringent regulatory environment and the growing complexity behind certification requirements.

Up until now most platform systems have been primarily mechanical, but this is quickly changing due to the increased demand for electrification to deliver improved performance and operating cost reduction. This paper describes how a development environment employing a comprehensive digital twin of the platform electrical system reduces program risk. It discusses the importance of employing a mature and fully functional, multi-domain digital thread to enrich the digital twin throughout the platform's lifecycle from definition, through design, into production and throughout its operating life. It covers the role played by automation and reuse in reducing electrical system implementation risk.

A focus on platform electrification

Today modern aircraft platform differentiation is derived in a large part from innovations in electrical and electronics (E/E) systems. New capabilities integrated into a platform might range from the ability to deliver Wi-Fi connections on a commercial aircraft, to having a sophisticated system-of-systems, multi-mission platform in defense for coordinating objects on the ground, communicating with aircraft in the sky, or tracking satellites in space.

Traditional hydraulic or pneumatic capabilities are being implemented into platforms in a more electrical-hybrid manner. Electrification of functions not only saves weight but improves the reliability and safety of the aircraft.

In fact, the electrical content in aircraft has been growing rapidly over the past 20 years. Figure 1 shows the amount of power demand in modern commercial aircraft. Looking over the last 50 years, the power demand has grown by a factor of 10.

With the increasing amount of electrical functionality, a greater emphasis is placed on the electrical wiring interconnect system (EWIS). EWIS is growing in complexity as new and more innovative capabilities are added to the modern platform. A wide-body commercial aircraft can have over 500 kilometers in total cable length and more than 100,000 wires, which may include upwards of over 40,000 connectors.

As a result of more electrical complexity being introduced in both commercial and defense aircraft, the implementation and design of the EWIS is becoming increasingly difficult to achieve – adding risk to the profitability of not just the platform, but the entire organization. In some situations the increase in electrical systems content is at the point where if something goes wrong, it doesn't just place the program at risk, it puts the reputations of the people who are working on the program at risk as well.

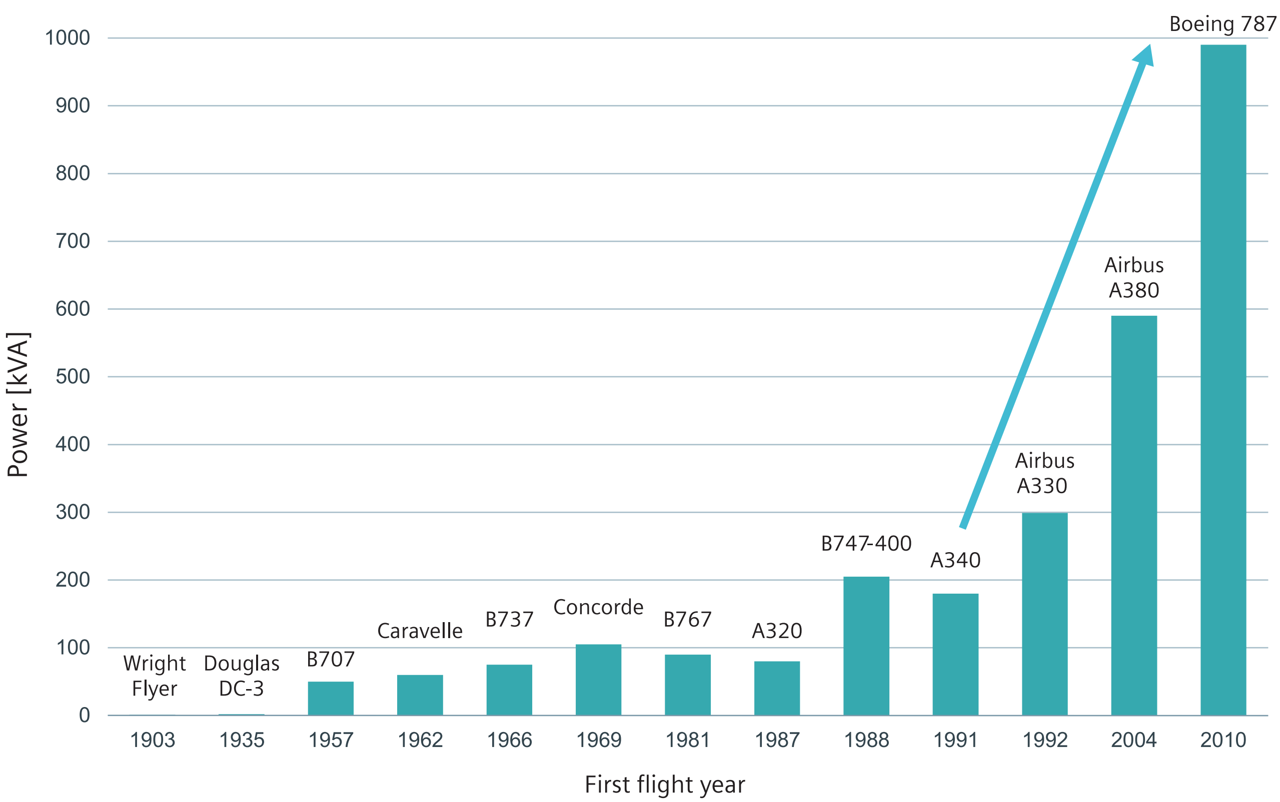

Figure 1: Electrical content in aircraft has grown by a factor of ten in the past 50 years.

The need to hit program milestones

For the A&D industry, delivering aircraft to customers on time and within budget is a task that's becoming increasingly difficult with growing complexity. The demand for more electrical functionality only exacerbates the situation. To stay competitive, OEMs must retire risk earlier in the program to avoid unforeseen problems during key milestones. Uncovering a problem at a key milestone leaves an aircraft manufacturer with few options. These are often extremely difficult and expensive to implement late in the process.

During program execution, the cost and impact of a problem greatly increases the longer it goes undetected. Design problems not identified within the design process can slip past traditional preliminary or critical design reviews (PDR and CDR) and manifest themselves at later milestones. Late changes not only drive design changes, but also have costly rework and schedule impact that puts at risk milestones such as integration complete, production readiness review (PRR), validation and flight testing, type certification (TC) for commercial or customer acceptance for defense, and entry into service (EIS).

To avoid surprises late in the development cycle, OEMs require an approach that not only anticipates problems before integration, but delivers insights and key understandings throughout the entire product lifecycle process. To stay on schedule and avoid late-stage surprises OEMs must be able to accelerate the uncovering of potential certification and regulatory compliance issues earlier in the program development cycle.

How Capital helps to derisk key milestones:

Integration complete
Capital checks to make sure everything is connected as expected. Design Rule Checks (DRC) ensure logical electrical connectivity is correct and the downstream physical piece parts have been defined and are coherent with the logical schematic. Furthermore, Capital enables advanced ECAD/MCAD collaboration to ensure wire harnesses are the correct length given the 3D platform routing.

Production readiness review (PRR)
This milestone indicates a key hand-off from engineering to production/manufacturing. Capital delivers critical elements of this milestone by enabling complete physical harness design using data defined in the logical schematic. This can be used to automatically generate work instructions based on the production floor layout and equipment, designing formboards based on customizable placement rules and providing a structured bill of materials (SBOM).

Type certification (TC)
Capital enables customers to demonstrate compliance to applicable regulations. For example, EWIS signal separation can be codified into rules and design constraints from the very beginning of the design process to ensure compliance is achieved. Capital's electrical load analysis, wire de-rating, voltage drop, failure mode and effects analysis (FMEA) and sneak circuit analysis are additional analyses that support electrical regulations and can be used to confirm the intended function is correct.

Entry into service (EIS)
De-risking the milestones also de-risks this key program milestone. EIS enables the airline manufacturer to begin making revenue and add profitability to its bottom line, a key objective supported by Capital.

Digitalization changes everything

In order to address the mounting demands in certification, emerging new safety requirements and the rise in overall complexity, the A&D industry is moving towards a new engineering strategy. Digitalization, by means of adopting a model-based approach and digital technologies, not only allows OEMs to develop, integrate and access models up and down the value chain, but presents users within an organization an integrated, coherent and connected source of data. Digitalization establishes a common infrastructure among different domains and environments so all data can be shared and processes can be optimized.

Siemens has been at the forefront of the digital transformation for many years. The Siemens comprehensive digital twin has seen widespread adoption across numerous industries including A&D.

The digital twin defined
A digital twin is a virtual representation of a physical product or business process, which is used to understand and predict outcomes of the physical counterpart. Performance characteristics can be tested on the digital twin before the actual implementation begins. A comprehensive digital twin can be used throughout the product lifecycle to design, simulate, predict and optimize the product and/or production system before committing to a major investment. The digital twin can play a critical role in building toward milestone acceptance. By incorporating multi-physics simulation, data analytics and machine learning capabilities, the digital twin can demonstrate the impact of design changes, requirements, production options, usage scenarios, environmental conditions and other variables.

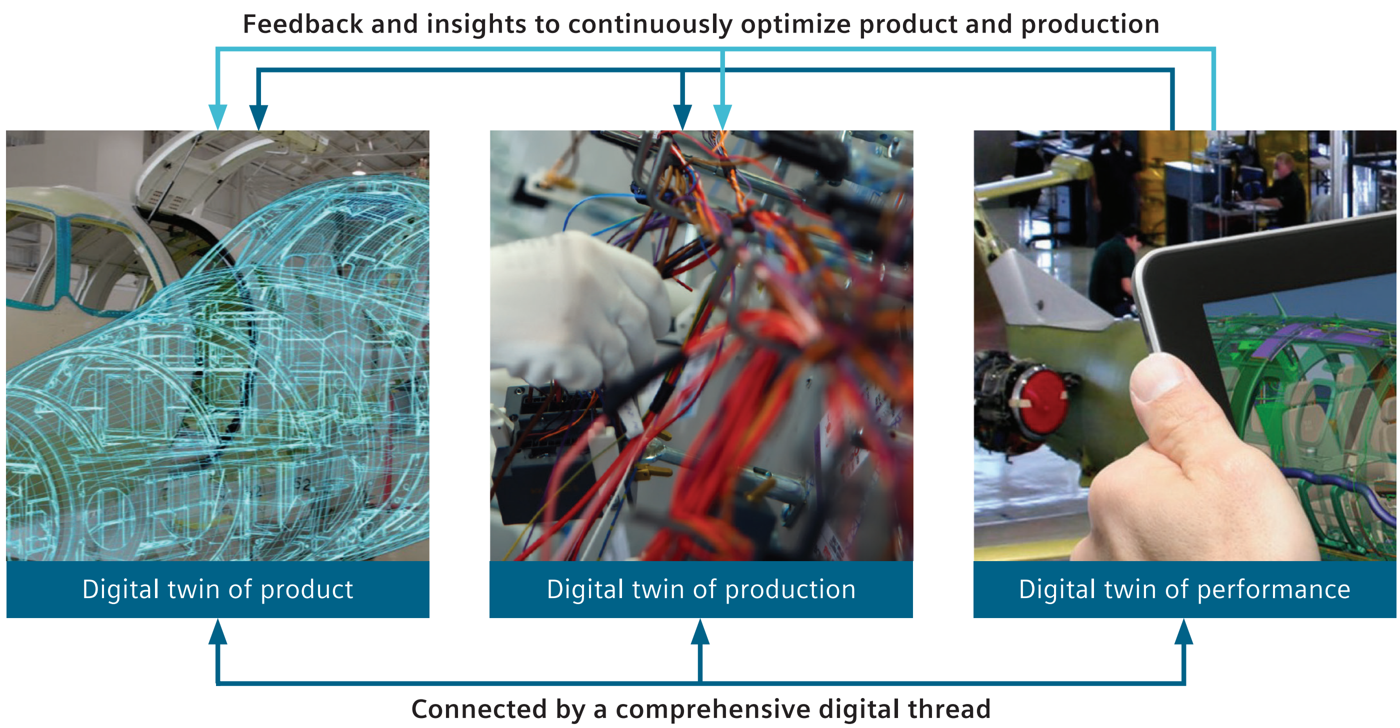

Figure 2: Product, production and performance domains of the digital twin are connected by the digital thread, providing users with an automated exchange of data continuity across the product lifecycle.

The potential applications for a digital twin depend on what stage of the product lifecycle it models. Generally speaking, the Siemens comprehensive digital twin covers the domains of product, production and performance during the product's operational life (figure 2). The combination and integration of the three domains as they evolve is accomplished by the connective digital thread. The term "thread" is used because it is woven into and brings together data from all stages of the product's design, production and operational life. The digital thread is made possible by employing a software architecture that natively incorporates digital data continuity across connected domains and processes. Because it is a closed loop environment, users can extract information for continuous optimization. Design engineering and manufacturing teams can collaborate in real time.

Aerospace and defense customers are increasingly realizing the value behind the digital enterprise. Organizations are taking note and encouraging the move, not just among commercial aerospace platform providers, but also among partners and suppliers in the Defense industry. Kristin Baldwin, the Acting Deputy Assistant Secretary of Defense for Systems Engineering, released a digital engineering strategy document that calls for the complete DoD supply chain to begin moving towards a model-based digital twin and digital thread approach. Ms. Baldwin is essentially calling for the U.S. Defense industry to implement the capabilities digitalization provides to enable a historic digital transformation.

"We are shifting toward a dynamic digital engineering ecosystem. This digital engineering transformation is necessary to meet new threats, maintain overmatch and leverage technology advancements."

Kristin Baldwin
Acting Deputy Assistant Secretary of Defense for Systems Engineering

The model-based approach to electrical systems development

The Siemens Capital E/E Systems development solution is a model-based approach integrated across the product lifecycle of electrical system design, manufacture and into service. Capital is part of Siemens Xcelerator portfolio, which provides a comprehensive, integrated portfolio of software, services and an application development platform. The portfolio accelerates digital transformation and facilitates both the comprehensive digital twin and digital thread.

Capital and the comprehensive digital twin

Capital can deliver a full E/E systems flow, as shown in figure 3. The first stage of development is identifying the platform requirements and carrying out multi-domain systems modeling covering all domains, including mechanical, electrical, electronics, thermal, software, etc. From that multi-domain systems model the E/E system aspects can be extracted. This enables the development of a functional definition of the E/E system and to define the system architecture to allocate functions correctly. From this a Bill-Of-Functions can be extracted, which can be passed from Capital to associated electronic design tools such as Xpedition for multi-board PCB design.

As well as driving electronics design, Capital provides a flow that covers the electrical system design, harness manufacturing engineering and in-service publication creation. This is where the electrical distribution system is designed (both logically and physically), verified by correct-by-construction methods (this refers to active design-rule checks which run in the background when designing electrical systems, catching errors at the design stage) and prepared for manufacture. The manufacturing of electrical harnesses is extremely complex and Capital provides solutions to optimize that process, so significant efficiency and operational gains can be realized. Following the entry of products into service customers then need to be able to efficiently service, diagnose and repair electrical systems, and Capital provides solutions to make that process far more efficient than is typically possible without advanced tools.

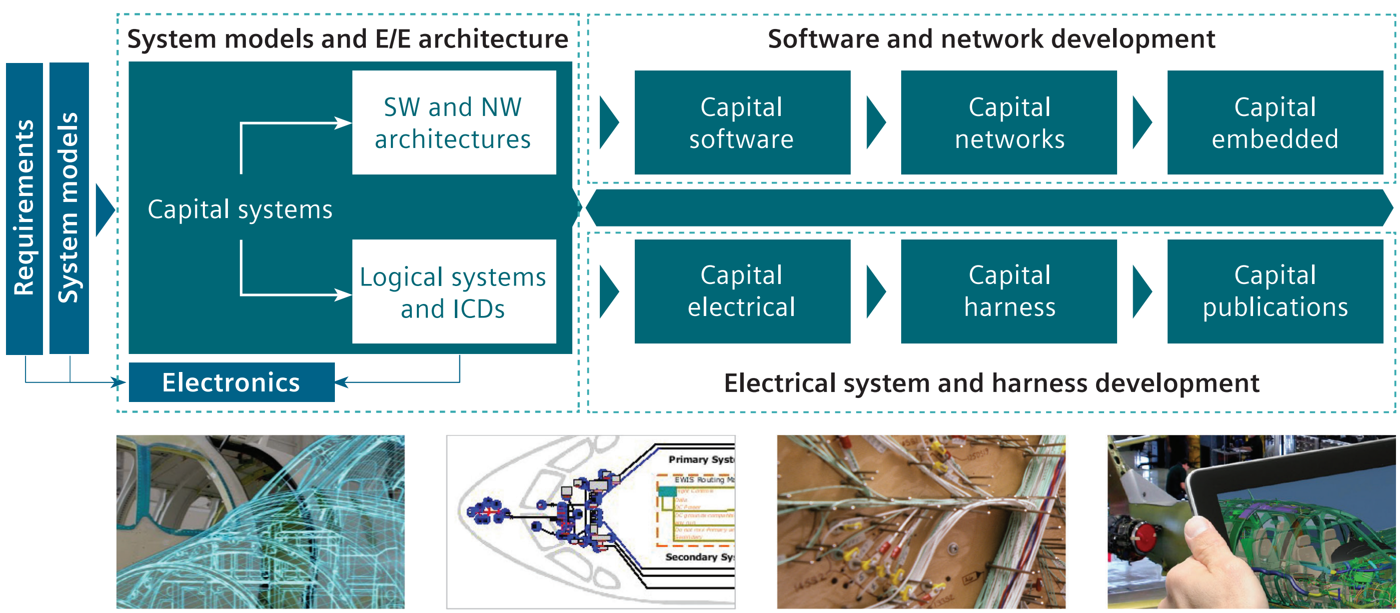

Figure 3: For the past 20 years and over 1,800 man years of development work, Siemens Capital has continuously advanced to respond to customer engineering challenges and A&D use cases.

Capital is data-centric and built upon a data and process backbone to enable extremely high levels of automation, data coherency and integration with adjacent domains such as mechanical design. This E/E data management system enables the traceability, change and configuration management that the aerospace and defense industries demand.

More recently an embedded software development flow has been added. The first step after the E/E systems definition stage is to develop an embedded software component and architecture design, where software functionality is partitioned into subsystems. This can then be fed into network tools to design, analyze and verify the communication networks before again flowing through to the embedded software implementation stage (which is primarily focussed on automotive and adjacent industries).

The E/E systems are part of a wider program lifecycle within organizations and deep integrations are provided into PLM systems, such as Teamcenter, and other necessary domains throughout the product development process. With the exploding complexity of E/E systems, development happens in the context of Model Based Systems Engineering (MBSE). To deliver this the E/E systems integrate into other domains to deliver a truly integrated system development environment, including MCAD, PLM and ALM systems.

Capital core tenets

Capital can provide a significant level of value because of the core tenets upon which the portfolio has been developed. The first of these is **data coherency**. This ensures data is consistent as it flows up and down the different abstractions in the electrical systems development lifecycle. It enables traceability, robust change management and configuration control. Data coherency means all necessary information is passed to team members during the critical stages of the development process.

The second tenet is **open integration** which recognizes many systems, not all provided by Siemens, are involved when developing a platform. Capital offers a rich API and many out-of-the-box bridges to allow users to integrate with necessary adjacent discipline's software systems, such as mechanical CAD environments. With integration into MCAD environments, users trade information with legacy systems to gain the capability of bringing in more component data.

The final tenet built into Capital is **advanced automation**. This allows users to take routine manual functions and automate them to increase team productivity. It allows an organization to capture and operationally share best practices arising from the learning and expertise of its team members. These practices can then be applied throughout the company. This codified information enables the transition of information to employees supporting ongoing quality goals and reduces the risk normally associated with staff changes.

Conclusion

Many aerospace companies are making the transition to a more digitalized work environment and have experienced notable successes along the way. Companies such as Pilatus, KAI, Bell and Boeing have shared publicly how their adoption of Capital to design and manufacture their electrical systems has added significant value to their product development processes (figure 4).

In fact, one Capital customer, Boeing has applied model-based systems engineering extensively to their advanced platforms, including the T-7A. Working with their partner, SAAB, they used model-based techniques. The Boeing T-7A Advanced Pilot Training System has received Aviation Week Network's Game Changer Award. The program was recognized for its innovative use of model-based engineering, allowing the program to move from firm concept to flying two production-relevant jets within 36 months.[1]

Risk reduction in many respects is about increasing confidence and constraining outcomes. If OEMs are able to do this more effectively they are more able to take on other kinds of risk to increase innovation. By transitioning to a more digitalized work environment OEMs can become more streamlined in their operations, through the ability to automate and optimize their processes with a proven digital twin and digital thread.

It's vitally important to reduce program risk to hit milestones and avoid significantly negative business impacts. Advanced solutions such as Capital can help organizations achieve this and give aerospace OEMs confidence as they move through the electrical product lifecycle to successful product launch into service and beyond.

Reduce platform weight to increase payload capacity

Optimized by integrating electrical and MCAD design, orchestrated by integration with Teamcenter.

"Keeping our products ahead of the market requires the creation of intimate connections between avionics and other aspects of the aircraft, such as mechanical systems."

Pilatus

Increase efficiency with an improved electrical process

Modern helicopters have complex wiring interconnections 20% reduction in wiring system design time compared with previous norms.

"Capital gives a substantial productivity boost... tools are easy to use, with superior automation, and ensure high level of data correctness."

KAI

Transform business process with better design systems

Architected the electrical system using generative design.

Merged systems definition with packaging requirements, reducing downstream design cycles.

Bell Helicopter were able to significantly streamline their wiring design processes on the Bell 525 Relentless program.

Bell

Enterprise commitment to the digital thread

Organizational transformation via automation and digitalization.

Meet the challenges of next gen electrical design and manufacturing.

"Our partnership with the Siemens team will combine best-in-class electrical design tools with Boeing's vast experience and knowledge in our 2CES transformation of electrical design."

Boeing

Figure 4: Capital customers who are adapting to the digital enterprise.

1. Boeing Press Release ST. LOUIS, Oct. 24, 2019

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About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. The Xcelerator portfolio helps companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

About the authors

Anthony Nicoli is the aerospace and defense director for the Integrated Electrical Systems (IES) segment of Siemens Digital Industries Software. He has spent nearly twenty years in the defense industry, developing electro-optic and electro-acoustic systems and businesses, working primarily in the tactical missile countermeasure and underwater imaging domains. Nicoli holds Bachelors and Masters Degrees in Electrical Engineering from the Massachusetts Institute of Technology and a Masters in Business Administration from Northeastern University.

Steve Caravella is solutions architect for the Integrated Electrical Systems (IES) segment of Siemens Digital Industries Software. He has over 28 years' experience in the aerospace industry ranging from new aircraft development to in-service modification for civil and government customers. His experience includes leading and executing projects and programs in technical and program management roles, defining and implementing new business processes/tools, and developing and mentoring engineering teams. He possess a broad experience base, with technical strengths in Airworthiness and engineering design (Structures, Systems Engineering) combined with a strong customer and end-user focus. Caravella holds a Bachelor of Science in Engineering Mechanics from University of Wisconsin-Madison.

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