

An aerial view of an aircraft fuselage in a factory. The fuselage is light green and white, with yellow and red scaffolding around it. The Siemens logo is overlaid in the top left corner.

**SIEMENS**

*Ingenuity for life*

Siemens Digital Industries Software

# The digital thread: Reducing electrical systems program risk in the aerospace industry

## **Executive summary**

As we enter a new era in aerospace development, it's becoming abundantly clear how digital technologies such as the digital twin and digital thread are helping OEMs revolutionize how things are done across the entire product life cycle. This paper explores the many challenges aerospace OEMs and suppliers face today and how the model-based enterprise (MBE) lowers system program risk and delivers new avenues of innovation in electrical and electronic content platforms.

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# Introduction

Electronic and electrical design demands of the 21st century will no doubt present a tremendous challenge to aerospace OEMs. Profitability in all phases of platform development is a key concern. Along with staying profitable, there is need to constantly innovate. But with innovation comes risk. How do you limit risk to stay profitable?

Today, addressing exposure arising from electrification must be part of the mix. For example, while electronic and electrical content infuse long-term value into platforms, they bring new uncertainty to the task of platform integration. Historical platform integration approaches, dominated by processes optimized for the mechanical discipline, must be updated.

Further, aerospace design complexity is compounding dramatically year over year. Now more than ever, design requirements interact across multiple disciplines to impact the product hierarchy across the supply chain, demanding sophisticated implementations and increasing program risk.

Other issues and challenges exacerbating program risk include:

- Greater pressure on profit margins from new competitors
- The need to continuously increase production rates
- An increasing number of government/safety regulations
- New and tighter cost controls
- Greater emphasis on just-in-time, quality deliverables
- The need to re-purpose and re-use – across multiple platforms
- More supply chain collaboration and automation

In order to address these mounting demands – and stay competitive – OEMs are moving toward the digitalization of the design and integration of electrical and electronic systems. Digitalization means using digital technology to improve business operations, i.e. to improve the way work gets accomplished across the entire value chain.

Moving to an integrated, digitalized approach, seamlessly exploiting what is known about the product and its production process at any given time, allows manufacturers to achieve a much better balance between innovation and risk. With it, design project teams stand a much better chance of staying within budget and on time. Already, intelligent digital solutions have been successfully deployed in various program domains to design and implement aircraft electrical/electronic systems. This trend will only intensify as electrification takes hold of the future.

Because electronically enabled functions are being introduced into all aspects of the platform, semi-manual development methods of the past are no longer adequate and, in many situations, counterproductive. On a single commercial aircraft today, there are hundreds, if not thousands, of electronic devices/units, miles of electrical wiring, a multitude of configurations to implement and numerous safety and certification requirements to take into consideration. Manual and disjointed hand-off of requirements, work-in-process design data and final product descriptions are no longer an efficient business practice. Table 1 highlights the advantages digitalization can bring.

Digitalization enables	Which delivers
Automation	Fewer errors, less risk
Simulation	Better designs
Verification	Lower development costs
Optimization	Lower production costs
Re-use	Shorter cycle times
Re-purposing	More innovation
Sharing and reporting	Improved brand value

Table 1: Moving from drawings to digitalization.

*“Our partnership with the Siemens-Mentor team will combine best-in-class electrical design tools with Boeing’s vast experience and knowledge in our 2CES transformation of electrical design.”*

Boeing

# Platforms are becoming more electrical

Two major trends shape the aerospace industry today. First, increasing mission demands are escalating platform performance requirements. Whether it's further extending the range of twin engine commercial aircraft or enhancing fighter effectiveness using a swarm of remotely controlled drones, OEMs demand more mission capability.

The second trend is electrification. More than ever, platform developers implement the functionality required to deliver new mission capabilities using electrical solutions. These include electrically enabled capabilities, such as autoland and in-flight entertainment (IFE). Furthermore, electrical approaches are increasingly replacing mechanical, pneumatic and hydraulic implementations of existing functionality. For example, fly-by-wire systems, electronic flight instrument systems (EFIS) and combined vision systems (CVS) have become commonplace. In fact, electrical is expected to become the dominant discipline in the future. Why? The benefits range from increased reliability, through increased payload (i.e. reduced function weight), to lower energy demand.

While the industry has made tremendous strides in introducing electronic and electrical systems into modern platforms, with obvious benefits to both the OEM and the end-user, it has driven platform power demand to new levels. Statistics reveal there's been a 10X increase in power consumption aboard modern aircraft over the past 50 years.

It wasn't too long ago that major aircraft OEMs were reluctant to install passenger USB ports on commercial aircraft because device recharging had a direct, detrimental effect on the aircraft's overall power availability. The introduction of increased power generation and integrated electrical solutions made it possible for passengers to plug-in and recharge their personal USB devices from the comfort of their own seat. This real-world example illustrates the ongoing electrical demands. Increased power consumption is a very real and growing concern.

Another implication of the increased use of electrical solutions is the increased size, weight and complexity of the electrical wiring interconnect system (EWIS) that connects them. Let's examine the case of a typical business jet to get a feel for an EWIS. A business jet can include over 120 independent electrical systems. Its EWIS could easily be composed of 350 harnesses, comprising as many as 30,000 wire segments. This could add up to over 50 miles of wire – and over 100,000 parts.

Increasing platform electrical content has resulted in EWIS weight growing faster than other aircraft elements, now accounting for up to three percent of total platform weight. With the increased use of digital communications, EWIS content has moved from simple point-to-point analog connections to more sophisticated digital buses to enable on-board network data communication. These can require expensive data cables, including high bandwidth fiber, driving EWIS cost and manufacturing complexity. Finally, EWIS complexity is compounded by a myriad of rules to minimize electrical interference, account for hazard zones and of course, ensure certification.

*“The Capital solution...will allow our design teams to explore and advance our products via integrated electrical systems architectures. This will bring clear benefits to those who buy and service our products, such as weight and lifecycle cost savings.”*

*Pilatus Aircraft Ltd*

# Increased complexity means greater potential for failure

Today, it's not uncommon for a single commercial aircraft to have hundreds of electronic control units, tens or even hundreds of miles of wire and unique configurations throughout all parts of the platform that need to meet numerous certification requirements. With the increase in electrical system content and complexity, a single iteration during design, verification, or compliance can place the entire program in jeopardy. Given the rise in electrification and complexity, moving to an intelligent digitalized solution now may help aerospace OEMs avoid possible calamities in the future. Already, aerospace manufacturers have suffered the consequences:

- A major U.S. aerospace manufacturer had to absorb \$1.26 billion in pretax accounting losses for wiring issues and damage to a test aircraft's fueling system, erasing any profit from the initial deliveries
- One major OEM saw its delivery schedule slip by six months and then experienced a second seven month delay after the company announced it had been struggling to install wiring into one of its more sophisticated aircraft
- In 2015, another major aircraft manufacturer had to write down more than \$4 billion in losses due to program cost overruns, development delays and slow sales – some of these setbacks were directly attributed to the aircraft's electrical and electronic systems



# The industry is ready for an historic disruption

The use of digital technologies will transform the aerospace industry in ways imagined today – and in ways not yet imagined tomorrow. Digitalization gives rise to an electrical model-based enterprise (MBE) which brings together multiple engineering domains to collaborate effectively up and down the supply chain. MBE allows for the creation of an interconnected and automated value chain, within and extending beyond, the platform OEM. Stakeholders within the OEM ecosystem employ a digital thread, exploiting digital data continuity, to reference a single model of the platform’s electrical system, its digital twin, across the platform’s lifecycle. The three tenets of a model-based enterprise are digitalization, automation and data re-use (figure 1).

## The value of an interconnected and automated value chain

A model-based approach brings designs, teams and business functions together, achieving the universal goal of innovation and a higher quality of product earlier in the program lifecycle. All parties involved, including first and

second tier suppliers, can easily and more accurately collaborate to build something unique and inspirational, rather than spend their time fearing and reacting to errors and the program slips that inevitably result.

## Realizing the electrical MBE

An aircraft platform consists of multi-domain systems that are carefully integrated to perform the intended functions of its design. Tools with the capability to deliver advanced automation across a flow extending from electrical/electronic architecture definition, through detailed electrical design and wire harness manufacturing, to documentation and diagnostics are essential. These tools need to smoothly integrate with other design disciplines, such as mechanical computer-aided design tools, systems engineering tools and manufacturing/ shop floor systems. They must also be capable of addressing the challenges of engineering change orders, with the goal of reducing the volume of change orders with higher first-time quality achieved via the digital twin.

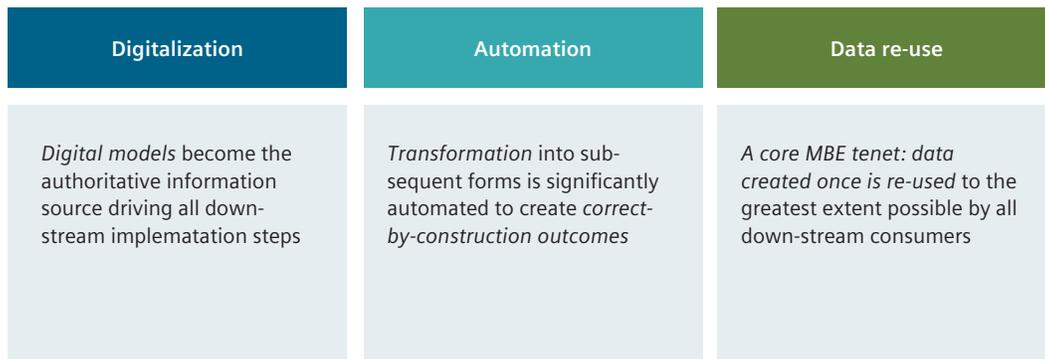


Figure 1: Through a model-based approach, OEMs strengthen their value chain to achieve better on-time delivery, higher quality parts, fewer errors and minimal cost overruns.

# The emergence of the digital twin and the digital thread

Siemens has been at the forefront of digital twin technology for many years and has seen widespread adoption across numerous industries including aerospace. 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. Digital twins are used throughout the product lifecycle to simulate, predict and optimize the product and/or production system before committing to a major investment.

By incorporating multi-physics simulation, data analytics and machine learning capabilities, digital twins are able to demonstrate the impact of design changes, production options, usage scenarios, environmental conditions and other endless variables – reducing the need for physical prototypes, compressing development time and improving quality of the final product or process.

The potential applications for a digital twin depend on what stage of the product lifecycle it models. Generally speaking, there are three types of digital twin – product, production and performance (figure 2).

The combination and integration of the three digital twins as they evolve together is accomplished by the digital thread. The term “thread” is used because it is woven into and brings together data, from all stages of the design, production and operating lifecycles. The digital thread is made possible by employing a software architecture that natively incorporates digital data continuity across the many representations of the product, its production processes and its operating environment.

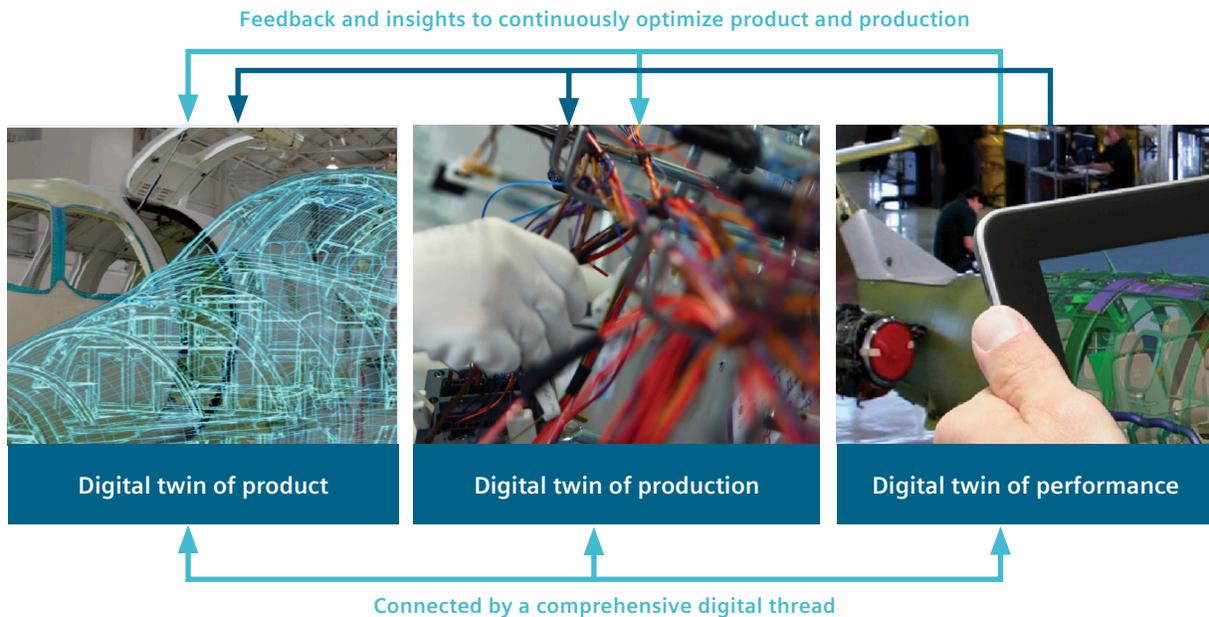


Figure 2: Digital twin of product, production and performance is connected by the digital thread, the “life line” that brings data together from the design, production and operating lifecycles.

# The digital twin of product, production and performance

A digital twin of product, production and performance provides a core model of the product lifecycle, allowing aerospace teams (and future engineers) to create, iterate, replicate and improve valuable programs. The results are data coherency and stability, integration and advanced automation. This significantly de-risks and streamlines platform electrical system design and integration processes. The digital twin model also offers clear benefits to those who buy and service aerospace products, including lifecycle cost analysis and savings, faster maintenance turnaround times and greater platform operational availability.

It's also about feedback up and down and throughout the entire value chain. The digital thread reaches back to the early stages of product design and spreads rich data forward into platform production, maintenance and operation. In essence, designers, fabricators, assemblers, suppliers, maintainers and operators create a full, closed-loop decision environment for continuous optimization

throughout all aspects of the value chain during the years of platform development and the decades of platform operation.

For the aerospace industry, the digital twin, digital thread and model-based enterprise deliver the following advantages:

- Reduced risk of cost and schedule overruns
- Improvements in productivity
- Improved technical performance
- Automation of electronic and electrical systems
- Increase first-time quality and design efficiency

The digital twin for aerospace allows program leaders to keep commitments to their customers, helps all users keep promises of quality and enables engineering teams to explore and advance highly innovative products.

*“Constraints defined early...  
maintained throughout the flow  
to ensure that the as-built wire  
routing meets EWIS mandates.”*

*Bombardier Aerospace*

# Capital: The electrical digital twin and digital thread

Siemens has been working diligently for nearly two decades to enable the model based enterprise for the electrical discipline. The result is Capital®, a software environment architected upon the principle of digital data continuity and built to capture and enrich the multiple digital twins of the platform electrical system: product, production and operation.

The primary reason to adopt the Capital tool suite is that it reduces the risk program teams face as they design and integrate platform-level electrical systems. Using Capital, teams reduce risk throughout all stages of the product lifecycle and are allowed greater flexibility to innovate.

For example, Capital:

- Communicates changes back and forth across the value chain so that systems engineers, design engineers and manufacturing teams aren't blindsided by improvements proposed by one of these teams
- Interrogates the electrical system digital twin to report violations to critical compliance rules, such as signal separation, as they occur
- Controls access to critical intellectual property to protect program teams from unauthorized disclosure of information
- Communicates complete MBOMs to manufacturing teams to reduce excess parts inventory kept on hand 'just-in-case we missed something' needed to make the EWIS delivery schedule

With Capital, electrical program teams shift from reacting to risks as they arise to proactively practicing "Program Execution Excellence."

Further, design project teams using Capital:

- Enrich the digital twin of their electrical system throughout the platform's lifecycle
- Minimize the need for costly engineering change orders (ECOs)
- Achieve functional and compliant first articles with fewer design/integration/production iterations
- Re-use the information comprising the electrical systems digital twin as they take on the challenge of each lifecycle stage – from definition, through design, into production and throughout its operating life for sustainment
- Accrue productivity advantages across the various program phases
- Reduce the risk faced by electrical programs, enabling them to creatively innovate
- Capital delivers advanced automation across a multi-domain flow extending from E/E architecture definition, through detailed electrical design and wire harness manufacturing, to documentation and diagnostics (figure 3)
- Capital's features include functional verification, manufacturing work instruction generation and configuration management and design change management

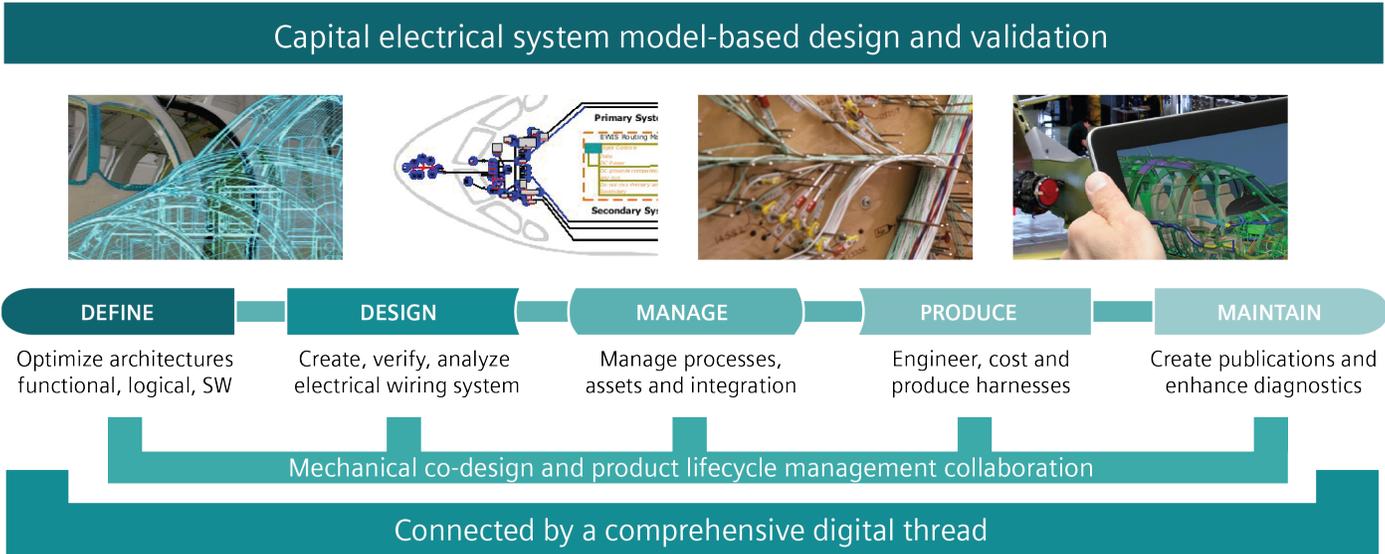


Figure 3: The Capital tool suite is an end-to-end digitalization solution that spans the electrical system product lifecycle. Its digital thread integrates E/E tools across the platform lifecycle domains, supporting key project milestones and lifecycle phase transitions.

Capital serves all the electrical development phases of a program including:

- Define: Optimizes electrical/electronic architectures against targets such as cost and weight
- Design: Maximizes electrical system and wire harness development efficiency and data quality. Provides a comprehensive environment spanning signal connectivity capture, system based and platform level wiring design and harness design and engineering
- Produce: Improves the efficiency of harness design and formboard design. Optimizes harness assembly and helps minimize harness cost. Automatically generates work instructions that reflect the harness design
- Maintain: Reduces the cost and improves the accuracy and timeliness of service publications by creating formatted documentation directly from source design data. Provides real-time, adaptive access to platform service information, interactively guiding the service technician to more rapidly complete the repair or maintenance

Rich data modeling and data management are central to Capital, complementing the model-based enterprise strategy. Architected for enterprise deployments, Capital is built to integrate with adjacent disciplines such as requirements capture, mechanical CAD, manufacturing execution and product lifecycle management. IT scalability, security features and modern computing environments are supported. Capital can be deployed into an Oracle RDBMS environment or implemented using its own embedded database.

**90 percent ECO reduction:**  
*“Improvement attributed to Capital’s detailed component modeling, extensive design rule checking (DRC) and database stability.”*

L3 Link

# De-risking key integration milestones: How Capital is helping today

The Capital suite of tools is known for optimizing and streamlining workflows across all domains in aerospace design and manufacturing. A few of the key program milestones Capital helps to de-risk include:

## 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 support the logical schematic. Furthermore, Capital enables advanced ECAD/MCAD collaboration to ensure wire harnesses are the correct length given the platform routing.

## Production readiness review (PRR)

This milestone indicates a key hand-off from engineering to production/manufacturing. Capital brings together critical elements of this milestone by performing complete physical harness design using data defined in the logical schematic, automatically generating 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) to the business.

## 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 can be met. 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 intended function.

## 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.

# Conclusion

As we enter a new era in aerospace development, it is quite clear digital technologies are revolutionizing major industries across the globe. Aerospace electrical systems are no exception. Digitalization will require a new way to look at familiar challenges along with incorporating new methods to deal with a growing list of complexities – in order to lower risk throughout the entire product lifecycle.

The Capital tool suite from Siemens offers aerospace electrical system developers a significant step forward. By grounding the electrical discipline in a more integrated and virtual environment, aerospace manufacturers increase engineering team and vendor engagement, improve response times, introduce new technology and innovation, reduce cost of documentation and improve affordability up and down the supply chain through repurpose and re-use. Most important, engineering teams reduce the probability of being surprised by, i.e. the risk

of, an unexpected issue during platform integration that could force a costly iteration, which in turn, could impact budget, schedule and perhaps individual careers.

The E/E tools from Capital provide the only mature, end-to-end digital thread for electrical system design and integration. The tool suite is at the forefront of Program Execution Excellence. It is the only electrical environment that spans the full electrical system value chain – from electrical system definition, through design, into manufacture and finally, to support and maintenance.

To read more about how Boeing is using Capital across its enterprise, see this [press release from Siemens](#). For more information on how Capital is benefiting the aerospace and defense industries, please visit this web page.

If you'd like specific information on the comprehensive suite of Capital tools, visit [here](#).

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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. Our solutions help 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 [www.sw.siemens.com](http://www.sw.siemens.com) or follow us on [LinkedIn](#), [Twitter](#), [Facebook](#) and [Instagram](#). Siemens Digital Industries Software – Where today meets tomorrow.

## About the author

Anthony Nicoli leads the aerospace business for Siemens' Integrated Electrical Systems (IES) business segment. He is charged with expanding IESD's contribution to this market. Prior to this role, Tony led the Mentor Graphics technical sales team serving The Boeing Company. He joined Mentor in 1999, growing to lead the marketing organization for Mentor Graphics' integrated circuit physical verification product line, Calibre, before joining Mentor's sales team. He 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. Tony holds Bachelors and Masters Degrees in Electrical Engineering from the Massachusetts Institute of Technology and a Masters in Business Administration from Northeastern University.

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