Siemens Digital Industries Software

Six ways Capital reduces program risk during A&D platform development and integration

Executive summary

Electronic and electrical (E/E) design demands of the 21st century present a tremendous challenge to the Aerospace & Defense (A&D) industry. Profitability in all phases of E/E platform development and integration is a key concern. Along with staying profitable and addressing complexity, there is need to constantly innovate. This paper introduces six ways in which Capital improves the E/E platform and development process to reduce risk, foster new innovation and reach program goals.

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Contents

Introduction

The ongoing demand for increased performance, coupled with the trend toward implementing more capabilities using electrical systems, has made the development of Aerospace & Defense (A&D) platforms a high-risk endeavor. The industry faces competitive margin pressures at the platform level and throughout the supply chain. Now more than ever, design requirements interact across multiple disciplines to impact the product hierarchy across the supply chain, demanding sophisticated and digitalized implementations.

This paper describes how the Siemens Capital E/E Systems development environment, employing a complete digital twin of the platform electrical system reduces program risk. It covers six ways in which teams can effectively manage risk throughout the platform's lifecycle from definition, through design, into production and throughout the operating life for sustainment. Some of these techniques highlight the roles of automation and data reuse and how these approaches contribute to reducing risk during sophisticated, highly complex electrical platform development.

The core capabilities

A few of the core capabilities found in Capital's architecture include generative synthesis, configuration control, change management and built-in integration with multiple mechanical CAD environments. Another key capability is management of data and related IP access constraints associated with distributed work teams whether local or global. For a complete description of the Capital development environment, please visit the [Capital website].

During this time of uncertainty and scattered work locations, Capital users are able to share information across borders and across continents. Within organizations, Capital helps to break down silos which traditionally impeded progress between interdisciplinary teams.

The core capability ensures that all information that describes an electrical system is digital and resides in one accessible database as the "single source of truth." The result of having this information in a complete and highly integrated environment means that data can be fully shared and processes can be optimized, delivering significant productivity gains and allowing teams to successfully meet program milestones.

With a basic understanding of Capital, this paper describes six ways in which Capital's model-based approach addresses the challenges and complexities found in the A&D industry today.

#1 Optimize the electrical system's architecture before starting the design

A number of years ago industry visionaries talked about what it would be like if teams could try different architectures and assess their feasibility before developing the actual system. Today Capital makes this process possible by bringing in information from model-based systems engineering environments regardless of origin, whether implemented in SysML, Visio, Excel, or some other format. Capital consumes multi-domain system models normalizing their data to create electrical functional architecture models. These models drive electrical and electronic system development. They support trade studies to rapidly assess alternative logical, physical and network platform architectures.

This powerful capability allows platform architects to estimate system performance before electrical design implementation begins. By applying integrated analysis, they can derive performance metrics such as weight, cost, network latency, network traffic and CPU load to determine how one architecture compares to other architectures under consideration.

The newly discovered information is reviewed with systems engineering teams to progress towards establishing the architectural design. The ability to explore architectural alternatives early in the development process allows systems engineers to select a better starting point for the design teams and in this way, downstream correctness can be enacted for optimal results during the integration and manufacturing processes.

Armed with the chosen architecture, Capital extracts the information necessary to implement the electrical system. It intelligently parses this information to feed lifecycle development in four separate, but related, electrical disciplines: **electrical distribution** or EWIS, **electronics**, **communication networks**, and **software**. Each discipline uses this data across the complete development lifecycle from design through production and finally into operational maintenance.

Optimizing electrical system architecture lowers risk by fleshing out development dead-ends before multi-disciplinary design begins. Passing the salient architectural information to each discipline via a digital thread ensures each subsequent stage of electrical system development receives accurate information and stays in sync with the intentions of the system engineering team.

#2 Automatically apply hard won knowledge and experience

The best way to avoid errors, accelerate programs and increase productivity is to make use of hard won expertise. Sharing this information and applying it accurately is more difficult than it sounds. Often this kind of tribal knowledge resides in pockets throughout the organization and few know how to put this type of knowledge into operation. Happily, automated application of knowledge and experience is a core capability within Capital.

Two major ways Capital enables this is through built-in design constraints and design rule checks.

Design constraints

Constraints guide design execution, providing real-time feedback to the development team as they conduct the design. This helps teams avoid the obvious errors that have been encountered before. By directly recording the learning of their most experienced design leaders, companies can make their best practices commonly available to the broad community of designers within their organization. In this way, institutionalized tribal knowledge becomes an organization's competitive advantage.

When combined with advanced design algorithms, these constraints enable generative synthesis of many aspects of the electrical system. They guide the automation used to transform inputs from upstream in the development process into a set of validated and deterministic outcomes. This removes much of the manual work from the development team, reducing error, accelerating solution space exploration and enabling designers to concentrate on innovation, rather than on design drudgery.

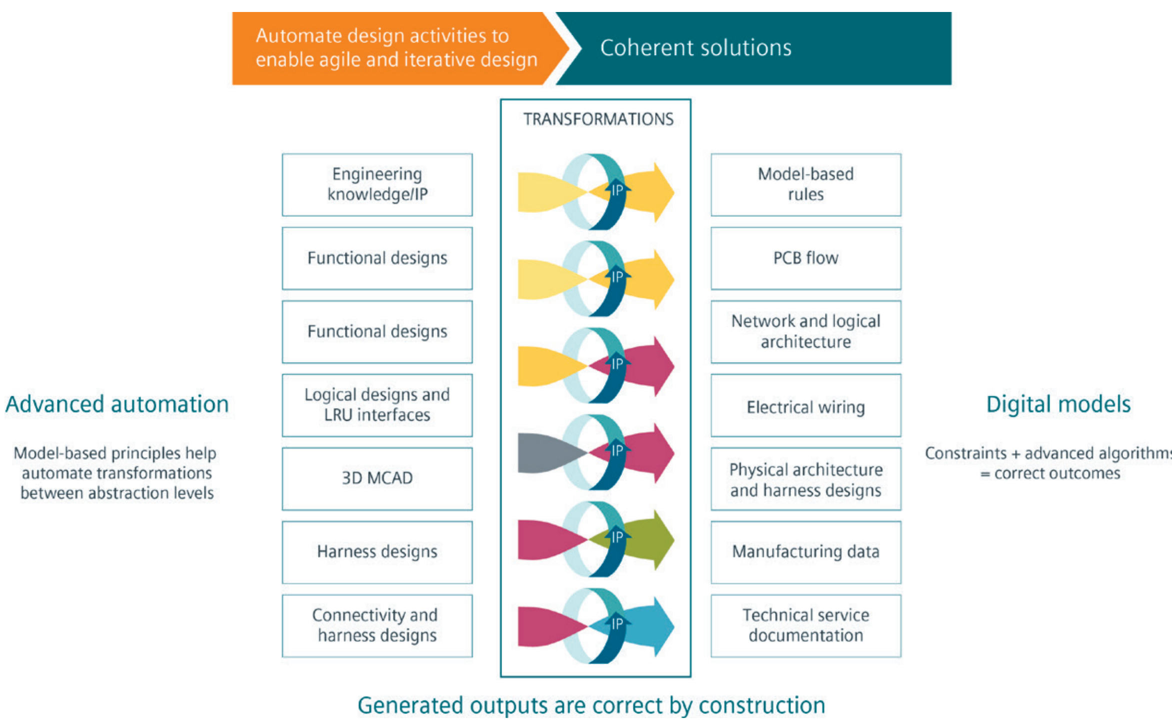

Figure 1. Examples of advanced automation: a set functional designs are passed into the generative synthesis transformation to create an interface control documentation to help drive LRU development. Users can take harness designs and convert them directly into manufacturing data to generate work instructions.

There are many situations within the process flow where teams can use the concept of generative synthesis to accelerate execution from one stage to the next while reducing errors associated with hand-offs or transitions to a new phase of development. Figure 1 describes a few of these transformations available in Capital. As a result of constraint-driven generative synthesis, designers achieve design closure with very few surprises.

Design rule checks

But there's more. Automated design rule checks can be applied to verify that electrical system designs comply with not only requirements and regulations, but also heuristic rules of thumb that seasoned developers have uncovered from many program, test and integration cycles. Again, trial and error learning can be codified and automatically applied to the benefit of developers separated by many years from the teams that originally learned the lesson. And, in case users are concerned that these lessons may be too restricting, they don't have to be etched in stone: a built-in waiver process allows today's engineering teams to be alerted by a rule violation, consider the counsel being given by the departed development expert, and then accept or reject that counsel by waiving the violation.

Generative synthesis of a connected engineering flow for electrical systems

An example of a generative and connected engineering flow for the electrical system is depicted in figure 2. The image shows the steps associated with using information from system level functional models to drive the development of the platform's electrical distribution system, or the Electrical Wiring Interconnect System (EWIS).

Within this scenario, it's possible to rapidly generate and analyze the artifacts and abstractions needed at each stage of the EWIS lifecycle. Because of the data continuity provided by the digital thread, at each development stage, teams can extract the data and information necessary to optimize and automatically generate the artifacts and abstractions relevant to the following stage.

This begins with the system level functional models which are normalized to generate the electrical system's architecture. Next, the required logical system representation is extracted from the architecture. This enables the interactive or machine assisted generation of the electrical distribution system in the context of the aircraft platform topology.

After the resulting electrical system design has been analyzed for functional and regulatory compliance, the information necessary for harness design is extracted. Preparation for manufacturing uses the resulting harness designs to conduct manufacturing engineering, including generation of the manufacturing bill of process, a production cost estimate and the tooling and work instructions required for fabrication. Finally, the entirety of all relevant design data is extracted to produce a variety of publications. The generation of electronic service documentation directly connected to design data accelerates field service, maintenance, overhaul and retrofit.

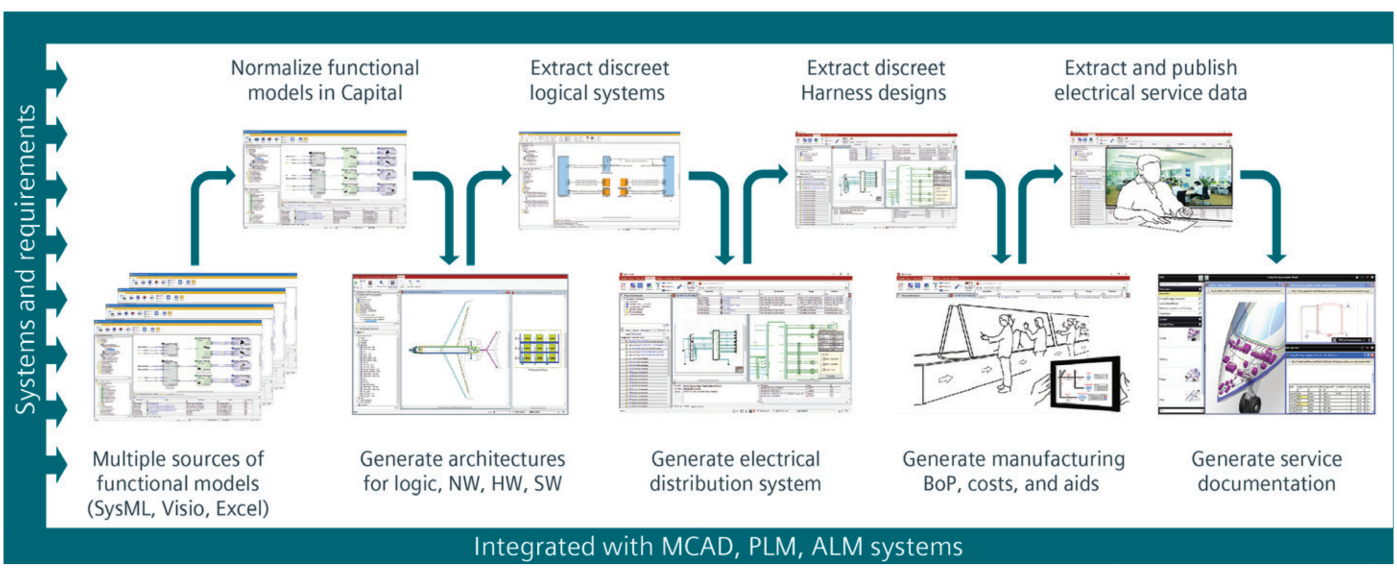

Figure 2. All processes are connected by a continuous digital thread assuring correct and real-time data transmission up and down the entire engineering flow.

#3 Collaborate across design disciplines

As platform electrical system content has increased getting all the systems, devices and components to fit within the airframe has become a significant challenge. Successful electro-mechanical integration requires a deep level of collaboration between the electrical and mechanical engineers.

Passing design information back and forth between the electrical and mechanical design environments is crucial to avoiding unpleasant surprises during test article fabrication. Organizations using Capital have enjoyed this ability, and the resulting reduction in design modifications and integration schedule slip for several years.

When applied during preliminary design, Capital allows for space reservation and integrated trade studies. Collaboration can be done effectively early in the process, so the electrical system designer and mechanical designer have a clear understanding of what space is allocated for the system (figure 3), what EWIS changes are requested, and what new volume can be approved.

Further, this cross collaboration allows for trial routing and identifies potential conflicts which the electrical engineer can communicate back to the mechanical designer. In this way, these two disciplines can collaborate and reduce the probability of having any of the physical conflicts show up later during integration.

During the main design phase, this type of collaboration continues to happen. Teams now have the ability to pass real-time information back and forth. Information sharing is continuous and connected up and down the value chain. With Capital's model-based approach, teams can simultaneously work together to design the electrical system in the mechanical context.

It must be noted that most teams do not work in this manner today. Typically, the electrical designer can do some work, package up the mechanical impact and send it over to the mechanical team. Likewise, the mechanical team can do its work, package up the electrical impact, and send it back over. This takes more time, but this is often how people work today – they're usually not simultaneously available. Capital has implemented a way of providing configuration controlled information sharing so that users can decouple the time at which they do the work.

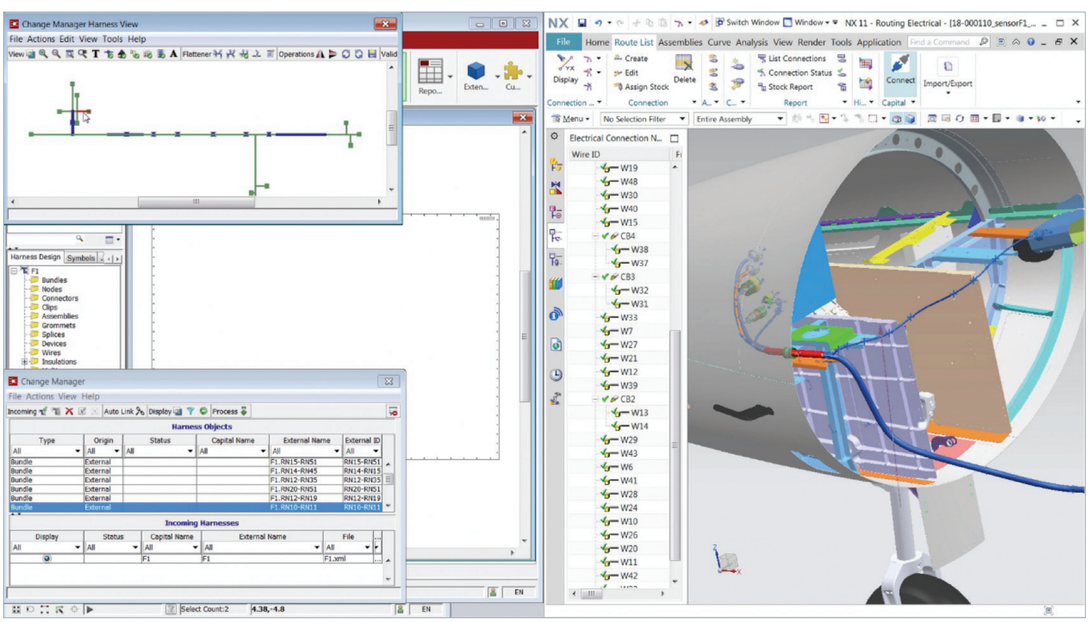

Figure 3. The integration between Capital and NX.

#4 Generate compliance evidence as the electrical system evolves

Of the many challenges facing the A&D industry today, perhaps foremost is addressing the impact of electrical complexity on compliance. It's vitally important for OEMs to be able to meet all of the regulatory requirements and to show evidence of this to regulatory authorities.

One way manufacturers generate evidence of regulatory compliance today is through analysis. The electrical system is modeled, its operation is simulated and finally appropriate data reduction and analysis is applied to determine if the system is in compliance. If it is, a report is generated for submission and audit by the regulatory authority. If it isn't, a design iteration is undertaken.

While effective, today's implementations are often far from optimal. Most of the analysis tools are disconnected from the design environment. This means it can take weeks to re-enter the design data, resolve any errors and complete the analysis. In the meantime, it's quite possible the designer has moved on to a new electrical system implementation. The particular designer continues working, assuming that the design is compliant.

Weeks later, analysis results indicate that changes are needed. Now there are gaps between the analyzed data and the current design that need to be reconciled before further work is completed. This can be further

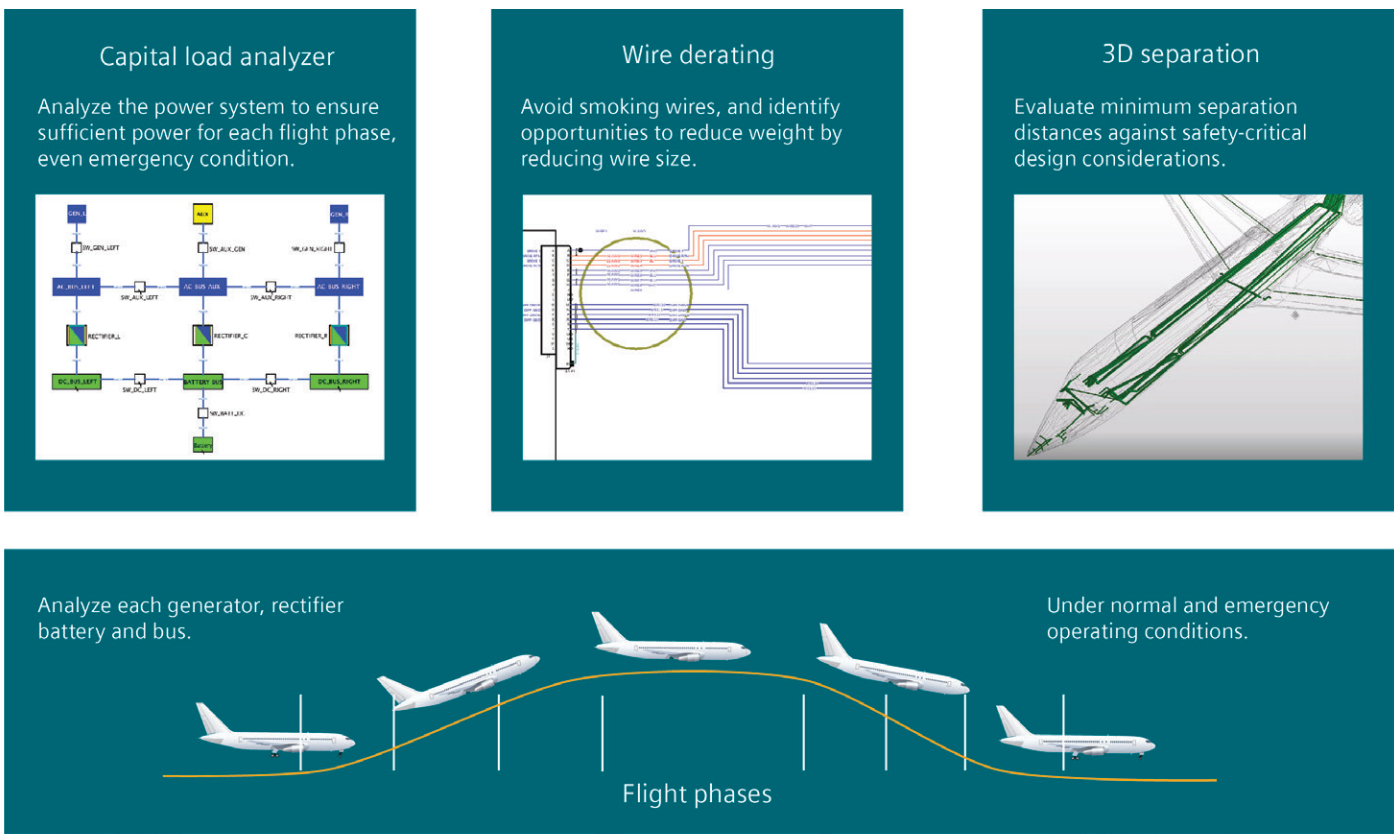

Figure 4. The Capital compliance solution ensures safe electrical design in all flight operations.

complicated if work-in-process configuration control didn't account for the changes since the design was submitted for analysis.

To make matters worse, it can take additional weeks to generate the report for audit because the information that finally comes out of the design team and the analysis team has to be put into a format that the regulatory authority can consume properly. Setting this up takes significant time. Finally, after many weeks, an authoritative review and determination of compliance can be made. Often this review results in questions which precipitate the need for yet another design/analysis cycle.

Capital addresses this challenge by granting compliance analysis tools direct access to its configuration controlled digital twin of the electrical system. Capital itself already supports three different aspects of electrical compliance: load analysis, wire derating and 3D separation (figure 4). This means that compliance simulation and analysis can take place contemporaneously with design changes. A designer can know whether a current electrical system design complies in minutes, not days or weeks. In fact, for compliance aspects that are easily described, users develop rule based checks that provide feedback on potential compliance violations in real-time, as the design is modified.

Capital also streamlines compliance report generation. Working with regulatory authorities, users define report templates that express all essential compliance data in a format they find most helpful. Capital then automatically populates analysis results into these templates. Both design teams, and their regulatory counterparts, can now have a complete report in minutes after the analysis has been finished. More importantly, these reports are associated with a specific design configuration, leaving an audit trail that can be referred to as the platform evolves.

This is a potent capability in that it provides design teams increased flexibility to innovate while meeting regulatory requirements, and facilitates the institutional memory required to support, and survive, a rigorous compliance audit.

#5 Link manufacturing engineering directly to harness design

Whether an OEM or an independent supplier, aerospace harness manufacturing teams are under more stress than ever. They find their business suffering from profitability constraints on all sides; from increased harness complexity driven by more electric platforms, to the need to rapidly transition design changes into production, to serving demanding customers who expect ever lower cost assemblies delivered just-in-time, while they threaten to further vertically integrate into harness manufacture.

Meanwhile, platform designers are changing their electrical systems, and consequently, harnesses more frequently need to respond to the changing demands of their customers. They expect their harness suppliers to keep up, transitioning these changes into production quickly and with a minimum of cost and schedule impact. All this results in a new harness manufacturing reality: more harness variants, produced in more frequent, shorter duration production runs and in smaller quantities.

With the combined need for more and shorter duration production runs with increased EWIS, individual harness complexity is increased, which results is an extremely challenging environment to achieve profitability.

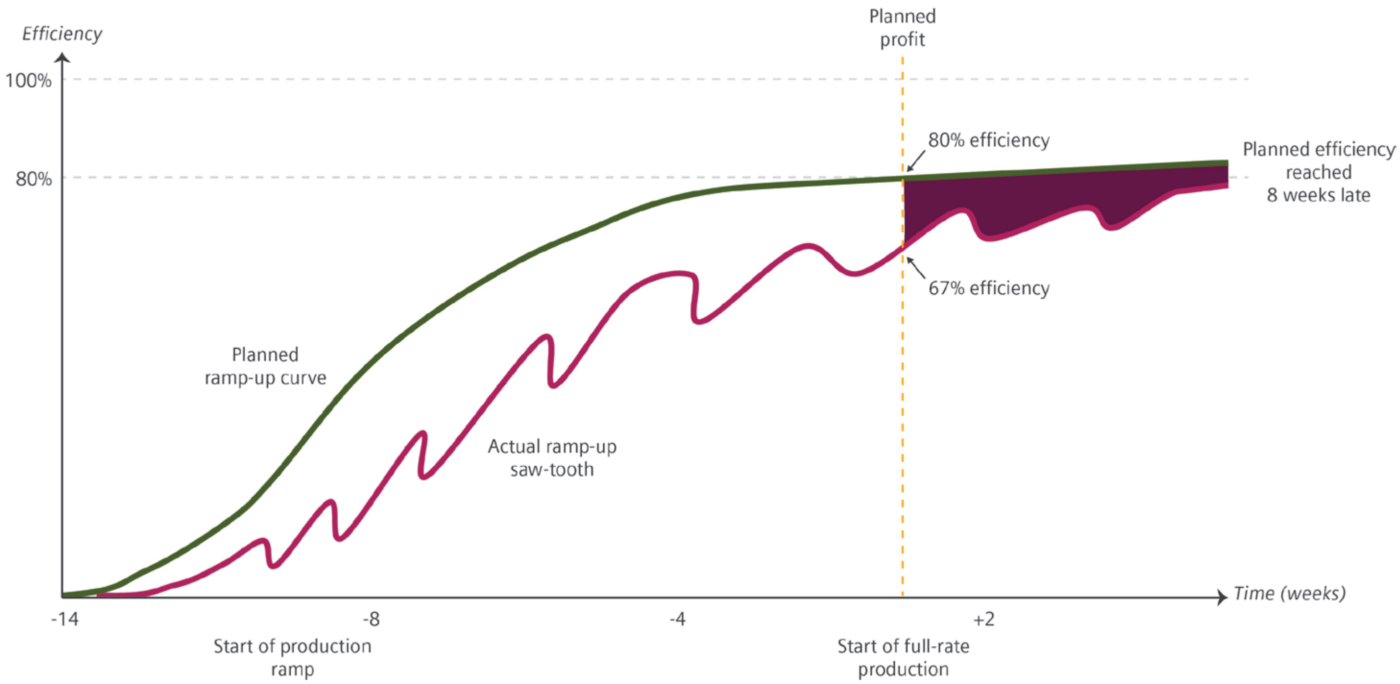

Figure 5. Traditional "planned" production ramp versus typical "actual" ramp.

Typically, a harness manufacturer will develop a detailed plan to ramp production of a new harness (figure 5). Harness manufacturers will carefully execute this plan, targeting 80 percent production efficiency by the time they reach the start of full rate production, or SoP. Hitting this efficiency target is important since production run profitability depends on it. However, because the harness is complex and organizations rely on multiple, distinct environments to prepare for production, mistakes are often made in creating the tooling, work instructions, or other production support artifacts. The result? Actual production ramp-up starts and stops to resolve these issues. At the time full production begins, an organization may only be at 67 percent operating efficiency.

This doesn't sound so bad, but the problem is by the time it takes to reach the 80 percent target, teams lose money on every harness. By the time teams recover, they have often lost enough money to consume the entire predicted profit for the run!

Capital addresses this challenge by connecting harness product and process engineering to the electrical system's digital twin. The tools and processes that comprise this domain represent an advanced solution unto themselves. Direct access to the electrical system digital twin enables an automated harness manufacturing engineering flow that requires NO manual data reentry. Consequently, generating important manufacturing aids, tooling and even cost estimates can be done quickly and accurately, the first time. The flow ranges from harness design to work instruction generation. It encompasses product engineering, including product cost optimization, form board design, assembly and sub-assembly design, manufacturing process design, optimization and documentation.

This capability allows harness manufacturers to meet expectations for responsiveness, quality, delivery time and profitability. In fact, many harness manufacturers using Capital now welcome change requests from their customers, seeing it as a source of competitive differentiation, rather than an onerous burden.

#6 Accelerate routine maintenance and maximize operational availability

In-service operation is the longest duration phase of a platform's lifecycle, and the most costly. Often, teams forget this because of the considerable challenges associated with designing, certifying and producing a new aircraft. However, the fact is that sustainment costs drive a team's ability to field and operate the fleet desired. For example, according to Dr. Will Roper, Assistant Secretary of the US Air Force for Acquisition, Technology and Logistics, 70 percent of the US Air Force acquisition budget goes toward sustainment. This needs to be lower to afford increased capability in the future.

Capital takes on this challenge directly by increasing the efficiency of aircraft maintenance, which in turn, reduces repair and maintenance turnaround time. This increases aircraft operational availability, and the effective size of our fleet.

Capital does this by deriving accurate maintenance documentation directly from the digital twin of the aircraft's electrical system. It has knowledge of, not only the generic electrical system designs for an aircraft model or variant, but also of the specific version of the electrical system effective for a specific produced and certified tail number. This means that maintenance personnel can know exactly how the as-built aircraft was configured. And, if proper care was taken throughout its life, this knowledge can be extended to include its modification history, providing as-modified updates to the maintenance documentation.

Furthermore, this documentation can be delivered in a variety of formats. While many are familiar with tried and true paper repair manuals, electronic repair manuals, known as Interactive Electronic Technical Manuals or IETMs, are increasingly popular. Capital supports these today, making tail specific electrical system maintenance information available on an iPad, laptop or even through augmented reality systems. Information is presented in a user-friendly format, enabling quick tracing of connectivity through a system as well as rapid navigation to assembly and part information. Cross-disciplinary information is as important in this lifecycle stage as during design. So, Capital presents the electrical system maintenance information in the aircraft's mechanical context, when this data is available. Military and aerospace companies are already applying this type of information to their aircraft programs.

Conclusion

Companies and organizations adopting digital twin and digital thread technologies are finding they can use digitalization as a competitive advantage. Digitalization is a proven business process well-suited for the 21st century. Figure 6 shows that companies who move to a digital enterprise become the top five percent performers in their sector or industry.

Already aerospace companies are making the transition to a more digitalized work environment. These forward thinking and acting companies 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 7).

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, Boeing used model-based techniques. In fact, the Boeing T-7A Advanced Pilot Training System 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]

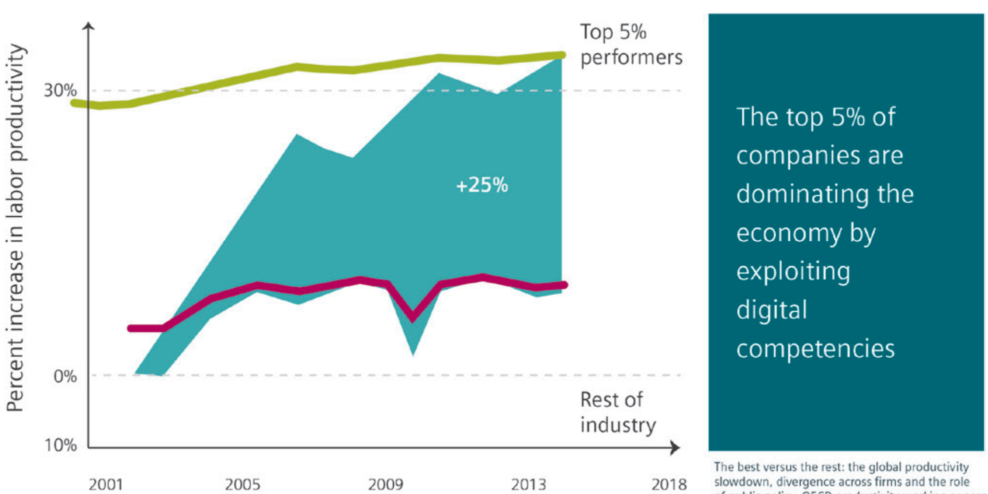

Figure 6. The A&D industry is still early to digitalization of operations and there is still a lot of territory in which to grow and become more profitable.

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 and defense companies confidence as they move through the electrical product lifecycle to successful product launch into service and beyond.

For details on how Capital is used across the Boeing enterprise, please read the press release.

For more information on how Capital is benefiting the A&D industry, please visit the Capital Aerospace & Defense website.

Reduce platform weight to increase payload capacity

Optimized by integrating electrical and MCAD design, orchestraded 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 7. Capital customers who are adapting to the digital enterprise.

Reference

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

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