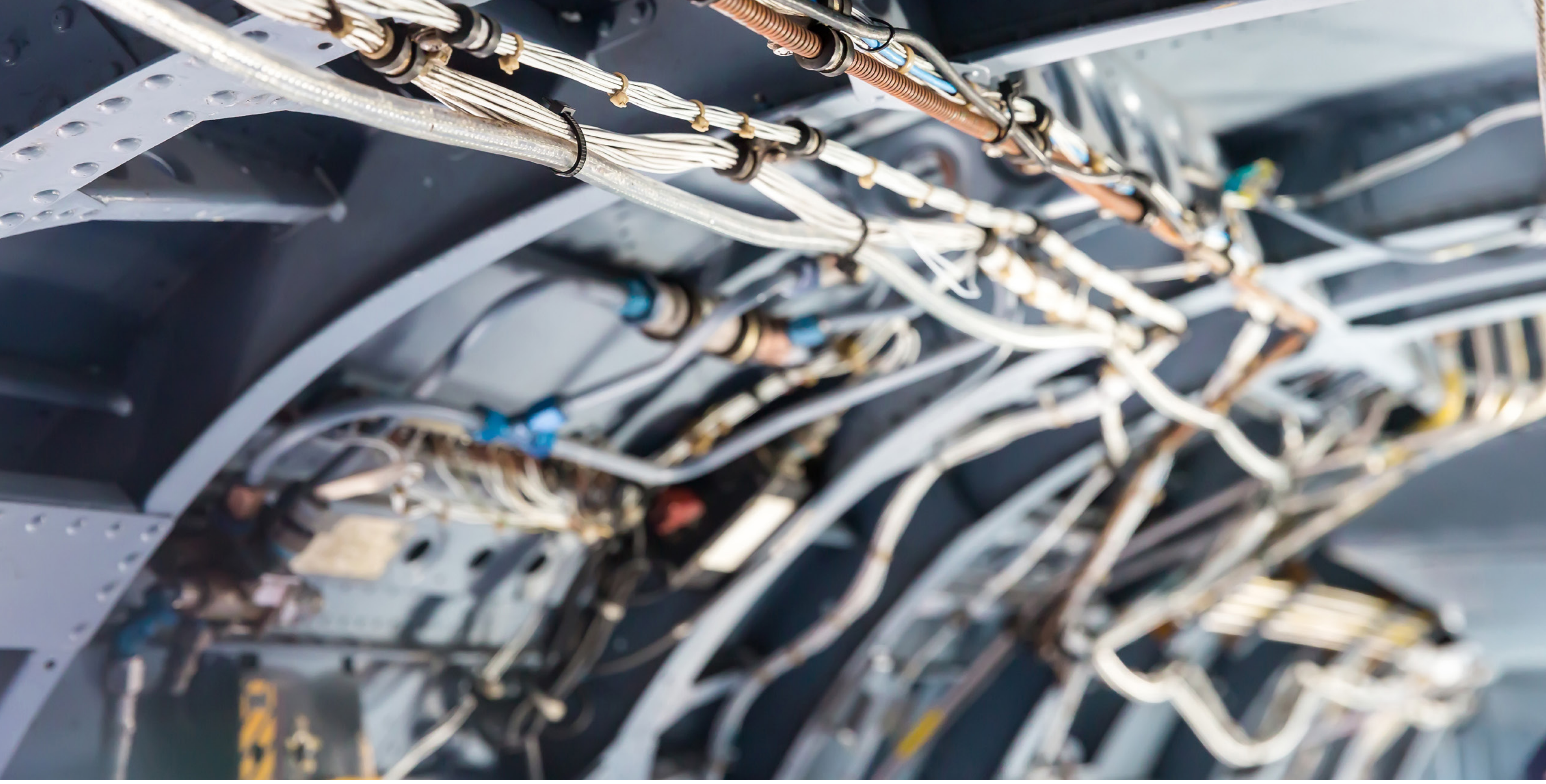

DIGITAL INDUSTRIES SOFTWARE

Wire harness design

The secret to developing successful aerospace and defense products

Executive summary
Grappling with constant change, budgetary constraints and increasingly stringent regulations, aerospace and defense product manufacturers are under tremendous pressure to do more with less, faster. As they seek to improve product performance and functionality by replacing legacy mechanical systems with electrification and software, they face numerous challenges related to quality, delivery and cost. Capital™ software addresses these challenges by simplifying the process of creating a digital twin to support data continuity and seamless data sharing throughout the design lifecycle. Using Capital, teams can optimize designs and production, and deliver modern aerospace and defense products to market rapidly and successfully.

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Introduction

The aerospace industry is undergoing a tremendous amount of change. Many aerospace programs are either over budget, late or both. The pressure to reduce program costs and accelerate schedules while meeting requirements is one of the biggest challenges. At the same time, aerospace programs are becoming increasingly complex and highly integrated. This increased complexity creates challenges in designing, manufacturing and certifying new products, and bringing them to market quickly.

Another key trend is an increase in electrification, which is driven by automation and the desire for greener solutions. As companies seek to improve their product performance, reduce weight and provide more functionality, they are in need of integrated solutions that rely on more software. Mechanical systems such as hydraulics are being replaced with electrical systems to improve reliability and maintainability.

All of this is occurring against a backdrop of increasingly stringent regulatory oversight. Major efforts over the last decade to delegate authority to original equipment manufacturers (OEMs) has been progressing, but not at the pace desired by the industry. Recent high-profile events have not only intensified public attention to product safety, they've prompted regulatory agencies to be directly involved in certification activities. One way to get ahead of regulatory requirements is to complete design validation earlier in the development process, which can be onerous and time-consuming. But there is hope.

Forward-thinking companies are moving towards digitalizing product design. Solid and robust harness design forms the foundation of reliable, high-quality and cost-effective product manufacturing to support on-time delivery. As a platform design moves from virtual to real product, the use of a configuration-controlled electrical digital twin brings critical advantages to the design of wire harnesses essential in modern aerospace and defense products.

This white paper explores how improving your harness design tools and processes enables your business to meet today's challenges and bring success to your programs. You'll learn:

- Three key challenges of wire harness design for aerospace products
- How the traditional process to harness design is insufficient for today's complex products
- How to create a digital twin that supports seamless data exchange throughout the product development lifecycle

Challenges

Designing wire harnesses for aerospace products is a highly complex endeavor that presents numerous challenges relating to quality, delivery and costs. Let's examine each of these areas in detail.

1) **Quality:** You need to establish a reference quality standard. The required product quality is not an option; it's an absolute requirement. Although engineers often focus on achieving the best-possible quality, that's different from the quality standard. They may be unable to deliver at the required level, or they may exceed it, however, neither is the desired outcome. Instead, the required level of quality as defined by the standard is the goal. For example, there may be a certain value for connection resistance, dimensional accuracy or other metrics that must be met. Having a clear understanding of the target quality standard is essential.

2) **Delivery:** Product delivery is the top priority for satisfying customer expectations and driving revenue. Numerous daily challenges – from material shortages to unplanned errors and rework – can put product delivery at risk. On-time delivery can be an advantage but, ultimately, you need to have control of the delivery schedule. The better you can forecast and execute on your delivery commitment, the more successful the product. Revenue is dependent upon product delivery, so it's tempting to focus on accelerating delivery as much as possible; however, focusing on reducing cycle time by boosting responsiveness is a more effective approach.

3) **Cost:** Any form of operation generates revenue, but on the top of that, there are costs that reduce your profits. The main components of costs are labor, materials and services, and to reduce costs, you must examine the elements of your processes to determine what you can eliminate. Activities that are considered to add value may, in fact, be driving up costs. While some cost drivers are out of your control, you can focus on reducing the costs you can control, such as labor, rework, and warranty costs, to increase your margin.

Let's take a closer look at the traditional approach to harness design, and a new approach that can better meet the challenges of quality, product delivery, and cost reduction.

A look at the traditional harness design process

Figure 1 illustrates the traditional harness design process, which typically involves creating a 2D wiring diagram of the design. This diagram is sent to the mechanical engineering team, which is responsible for designing a 3D routing of the installation. Along with the wiring diagram that illustrates the connections, mechanical engineers need to know a number of wire bundle parameters, as well as some of the design constraints. This information is usually calculated manually, using spreadsheets, then communicated to other stakeholders by email. Mechanical engineers enter the information into their models then complete the routing. This sets the geometry for the overall harness.

The wire length and branch location information is sent to the harness engineer to create the harness layout and the design. The harness design is often completed in the form of stick line drawings, which define and illustrate the different lengths and branches of the harness. The fabrication team will use the stick line drawings to develop a formboard for laying down the wires, and may also need to reference the wire diagram to determine how to pin the connectors.

With so many manual steps and disconnected information transfer in between, mistakes are expected, resulting in required changes – routing and clamping changes, changes to the wire bundle length, chafing protection enhancements and more. These types of mistakes cannot be uncovered by bench testing the harness; therefore, most companies deal with changes at the time of installation.

The first build of the product reveals a lot. The effort requires the material review board (MRB) or liaison engineers at the final assembly floor to help investigate and resolve issues, and may include engineering inspection points. Issues are resolved and documented through a formal discrepancy resolution process, which can be cumbersome and time-consuming.

The bottom line is that while companies may be accustomed to handling design shortcomings, there's a major weakness in the traditional process: The manual and disconnected exchanges between multiple elements of harness design. A lot of energy, manual design checks and cross-functional design reviews go into minimizing mistakes, but the effectiveness is ultimately limited and highly dependent

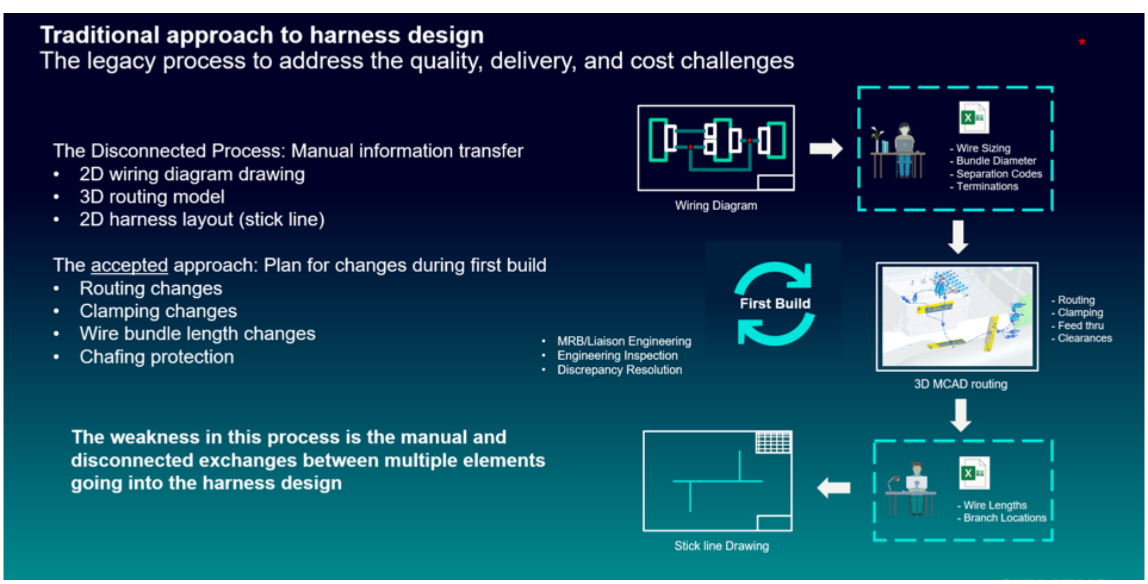

Figure 1. The traditional approach to harness design impacts quality, delivery and costs.

on the individual experience of team members. As complexity grows and the pace of change grows with it, it will be extremely difficult to sustain the business using this mostly manual approach.

Let's look at an example of how the traditional approach affects the design and manufacturing cycle, which demonstrates the impact of engineering effort at different stages of the development lifecycle. Figure 2 represents the typical development lifecycle, design manufacturing and installation, assuming 100 designs and 100 harnesses.

If the design is 99 percent accurate, that means there is one mistake per harness, or 100 mistakes. The data curve represents the engineering effort throughout the steps of the process ending at installation. Notice there are multiple weeks of design activity before the harness goes to fabrication, during which engineering support will be needed to address manufacturing issues. The majority of design mistakes will not be discovered until installation and testing, requiring a high level of engineering support and an urgency to find and correct mistakes quickly (see figure 2).

Achieving the quality standard required for production and engineering is costly and challenging using the traditional approach. Harness bench testing only confirms consistency between the design and the harness, but it does not verify the design. As such, design errors cannot be detected at the production level through electrical testing. Although the bench test will detect manufacturing errors such as contacts exchanged, wrong connections or mis-pinned connectors, and workmanship errors such as poor crimping or unseated pins, it will not detect engineering errors. Incorrect component selection, sizing or wiring lengths, and incorrect or missing connectivity (for example, grounding) will go undetected. These errors will be found at the final assembly line. Errors missed during design and production are burdensome and time-consuming, and rework can be costly and disruptive to other installation activities, causing delays and putting delivery at risk. They may result in repeated removals and installations to gain access to the harness, the need to update documentation and secure approvals and reduced confidence that drives the need for multiple inspections. Late deliveries lead to financial penalties that eat away at margins and negatively impact your brand's reputation.

Finally, costs add up quickly due to intensive processes that involve multiple stakeholders, time-consuming design checks and inspections, unplanned and wasteful rework, and higher shipping fees to expedite delivery. The majority of true costs are not visible at first glance, but the impact on profitability is substantial.

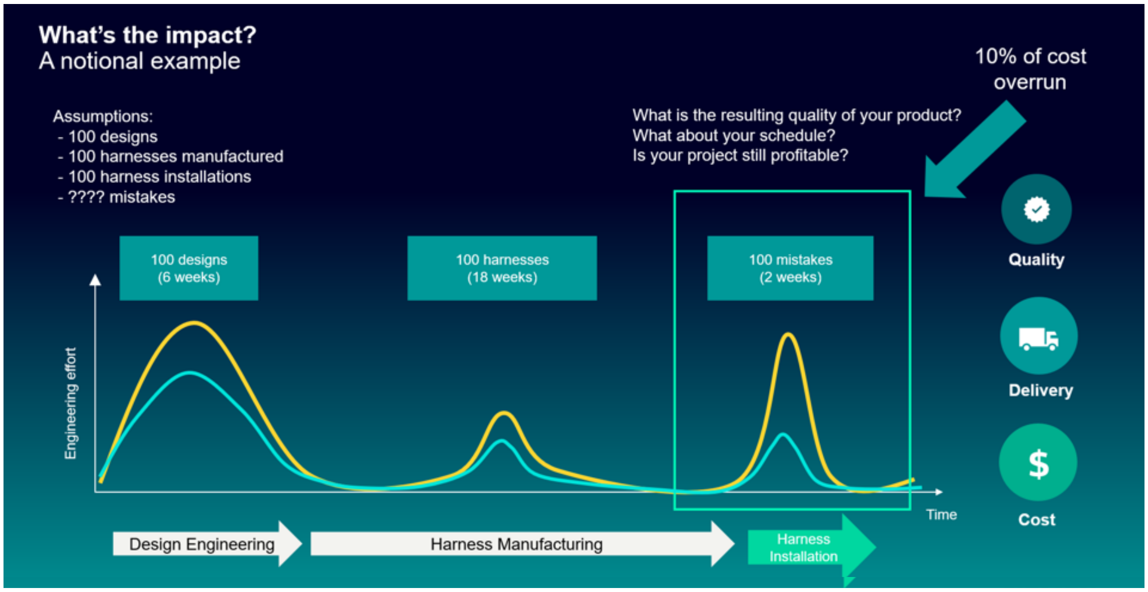

Figure 2. In the traditional harness design process, mistakes must be fixed during installation.

With better processes and tools we may be able to reduce the engineering effort. More importantly, if we can eliminate mistakes through the design lifecycle, we can significantly reduce rework, minimize scheduling risk and eliminate nonvalue added costs and waste (see figure 3).

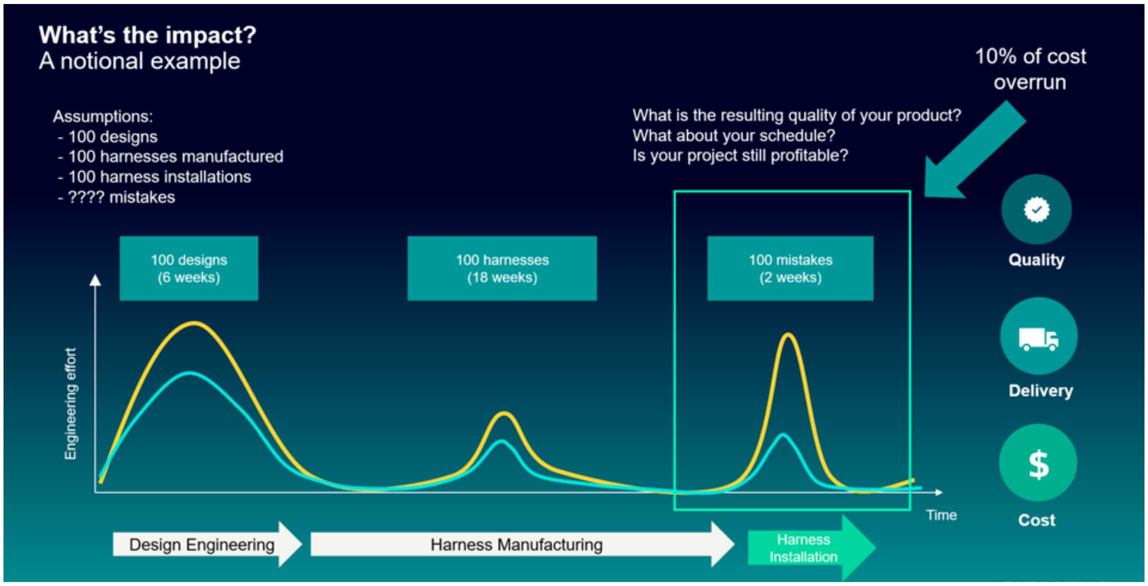

Figure 3. Engineering effort is substantially reduced if mistakes are caught early in the design lifecycle.

A shift toward digitalization

Forward-looking organizations are shifting from the traditional approach to harness design to digitization. A digital twin of the entire aircraft for multiple design disciplines can be connected so information can be accessed directly or transferred digitally to create a common digital thread, supporting the flow of information up and down the design and manufacturing chain. By creating a virtual copy of the design, the harness can be validated electronically against design rules, eliminating the need to manually transfer and transcribe information between the design disciplines (see figure 4).

Using a digital twin enables the integration of disciplines, teams and domains for seamless data sharing, reducing delays during handover. It enables early and frequent analysis to reduce risk by validating systems prior to and during implementation. Teams can optimize designs, production and product utilization using simulations while ensuring requirements traceability.

When wire harness design is included in electrical system design, simulations and analysis can be performed without the use of complex mathematical models, product prototyping or mental gymnastics. Rather than being reactive and scrambling to fix errors, teams can be proactive and detect potential problems early. As a result, quality is improved, delivery is accelerated and costs are reduced.

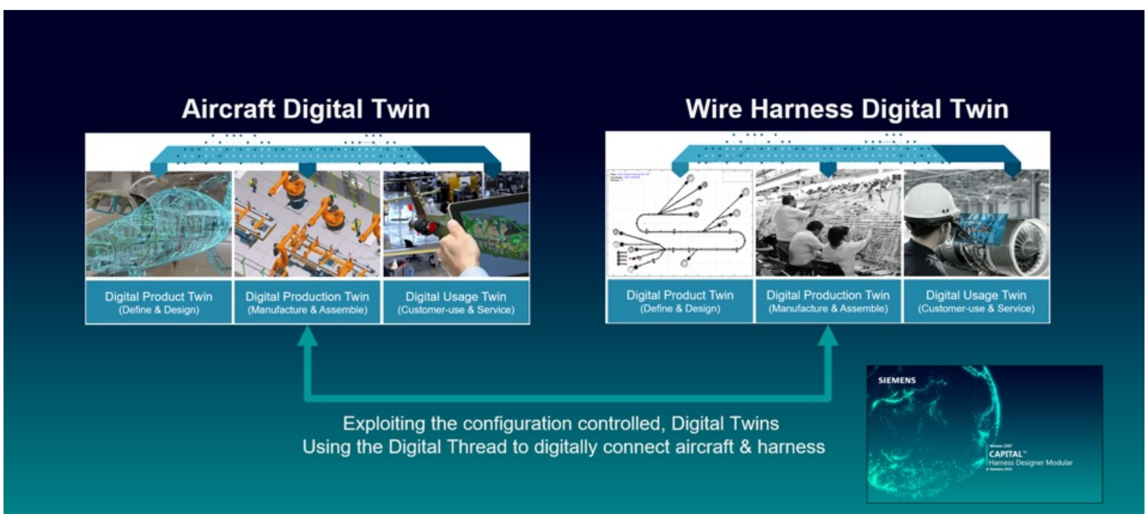

Figure 4. A digital twin enables data continuity throughout the design lifecycle.

How to create a digital twin

Creating a digital twin is much easier than you might expect. Simply combine the aircraft harness topology and wiring connections, and create a comprehensive model, which enables a digital process (see figure 5). The result is a virtual harness model that contains not only the geometry, but all the wiring data, creating a solid foundation for further processing according to the unique requirements of your customer or business model.

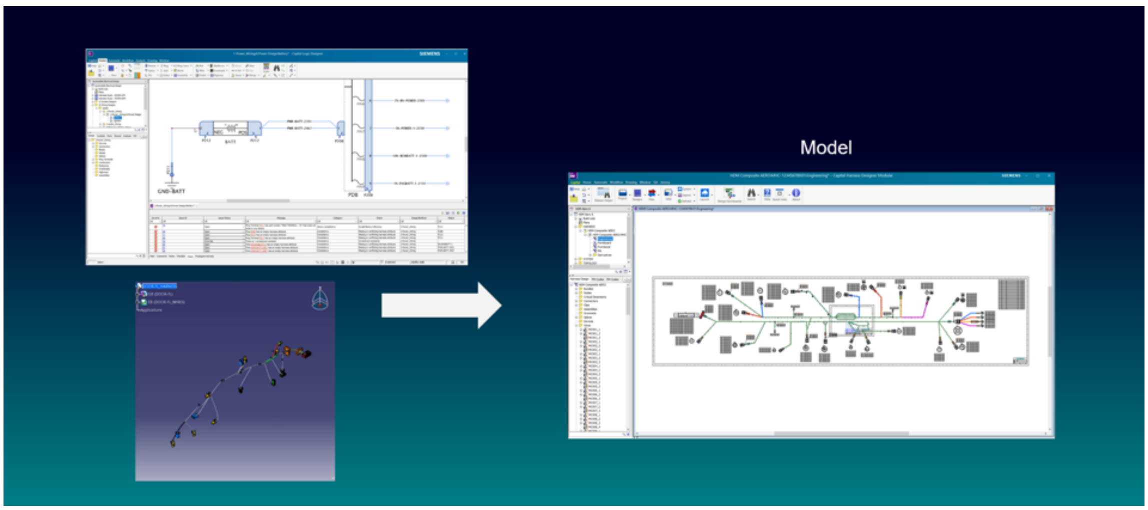

Figure 5. Combine the aircraft harness topology and wiring connections to enable a digital process.

The value delivered by creating a digital twin can be illustrated with a pyramid diagram (see figure 6).

At the bottom is the model – the foundation for model-based electronics engineering (MBEE).

The model, as the digital twin, can contain more information than normally captured in a traditional 2D drawing.

Figure 6. Using a digital twin delivers value with simplified validation, traceability and correct-by-construction design.

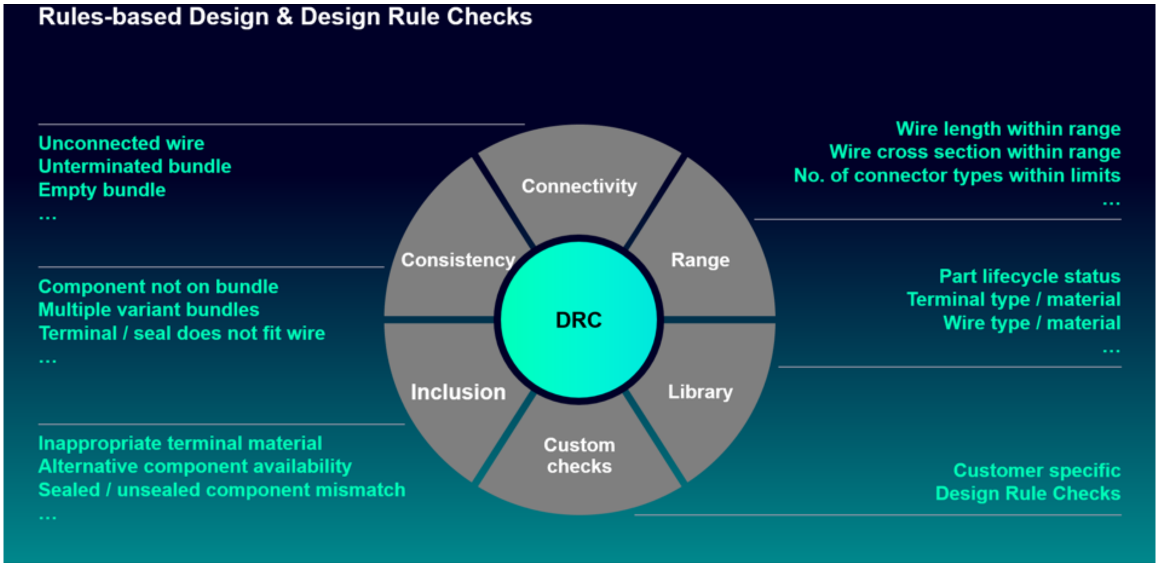

Figure 7. Using a digital twin, teams can automate design rule checks to support high quality and on-time delivery while lowering costs.

The second layer is validation, which consists of automated design checks, eliminating human-led iterations at this level. These design rule checks help to ensure connectivity, range, consistency and other elements of a high-quality harness design (see figure 7).

The system can verify the design based on standard or customized tools. For example, rules-base design and design rule checks can be used to ensure connectivity by enabling you to check if all your wires have terminations at both ends and are connected, and if there are any empty harnesses. They can also help verify range, which defines the limits within which a parameter must be contained, for example, minimum or maximum cable length, the cross-sectional range of cable, or electrical connection parameters such as temperature range or environmental resistance. The system checks whether the length and diameters comply with the requirements. It also automatically verifies that the parts you are using are in accordance with the specifications in the library, and they are up to date. Library rule check assures that the materials you're using are allowed to be used and approved for production.

Using the digital twin enables you to check component consistency and compatibility, as well. For instance, do the contacts match the connectors? Are the receiving plugs used appropriate? Have used the right substitute when needed, and have you obtained the right material compatibility? These are just examples; each company has its own rules specific to a particular project or type of the harness.

Finally, at the top of the pyramid is generative design – the use of automation design rules and processes to enable automatic generation of designs, which are correct by construction. By developing solutions that meet criteria specified upfront, generative design enables the team to offload many of the laborious tasks associated with design evolution, assessment and evaluation. However, it is important to highlight this builds from the bottom-up, and your company will realize additional value as you build out each layer of the pyramid.

Let's take a look at the benefits of this approach using Capital, which is part of the Xcelerator portfolio, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, for system development. Capital is a comprehensive electrical/electronic (E/E) systems development solution for complex platforms in industries as diverse as automotive, aerospace, and adjacent industries. The powerful design automation capabilities in Capital coupled with its model-based wiring harness engineering flow achieves all that and more. This helps harness manufacturers cut costs, improve product quality and boost efficiency.

Capital Harness Designer enables the digital exchange of design data, eliminating errors, rework and delivery delays. Since the design process is digitally connected across disciplines, teams benefit from model-based writing design and the ability to sync design details from the wiring diagram to the mechanical engineering team. The 3D routing information can be digitally passed to the harness design as well, eliminating error-prone manual calculations, and data interpretation and transcription.

As the model contains more information than traditional design formats, the harness design information is highly enriched from the beginning, including not only lengths and branch positions, but pin-to-pin connectivity, cavity materials, sizing and even bend radius requirements for the bundle. The result is digital synchronization of the design elements, eliminating mistakes and rework, both during the design process and, more importantly, during final manufacturing. Importantly, accuracy is improved, which has a direct impact on the reputation of engineering teams responsible for the designs.

The new, digitalized workflow begins with design engineering

Taking the advantage of rules-based engineering, including automated parts selection, styling, calculation and design rule checks, we can begin to create the model – the foundation of the value pyramid depicted in figure 2 above. Capital Harness Designer Modular allows you to create and enrich a virtual product and synchronize the 3D model of the harness with the connection list, creating the digital twin. These activities are executed automatically and verified by design logic.

Continuing to use Capital Harness Designer Modular, you can then decompose the harness into subservices by functional or production models, or their derivatives. By adding on Capital Formboard Designer, you can create a formboard that’s ready for manufacturing and configured in the most optimal way, taking into consideration ergonomic zones that are the most comfortable for the operators. What’s more, you can automatically manage two similar harnesses, creating one comprehensive formboard.

The structured bill-of-process (BOP) presents a virtual twin of the production process. Using Capital Harness Process Designer, you can create your own set of manufacturing tasks required to do the assembly, and the system will guide you through all steps to prepare the best manufacturing scenario. Once you have your harness prepared and have completed the calculations based on the production sequence you created, you can perform the costing of your product using Capital Harness Costing. You can then make comparisons in order to assess the cost impact of the modification or configuration you're carrying out on your harness.

The final stage of the process is the preparation and execution of production. Here, you will perform line balancing with the line balancing tool, saving time and iterations. The system takes into account workstations, material and flow, and will optimize your production line, providing the most efficient configuration. Once the design is created and corrected, the manufacturing process is established and optimized, and you can create your own personalized work instructions using Capital Workbooks. The Workbooks will reflect all of the manufacturing steps and necessary components and materials for every manufacturing stage, including the tools required to perform the process according to the quality standard.

After you create the model, generate the bill-of-process, and establish time and material cost calculations, your production line is optimized and you have all the necessary instructions necessary to manufacture the harness. In short, you have moved to the "what" – the harness product engineering model – to the "how" – a digitized production process that's optimized and ready for production.

Benefits of using Capital for wire harness design

1) **Automate and manage:** Build a solid foundation and take advantage of all the opportunities that come from a seamless data flow.

2) **Reduce program risk:** Reach the planned level of quality, timeliness and profitability.

3) **Avoid iterations:** No more costly tryouts, reworks or delays – achieve first-time-right manufacturing.

Capital in action

Capital delivers quantitative business and operational impacts to customers delivering the following aerospace solutions:

- **Flight Simulators:** 90 percent manufacturing design change reduction
- **Business jets:** 85 percent formboard design time reduction
- **Satellites:** 3-month schedule reduction
- **Space capsule:** First time right harnesses achieved
- **Helicopters:** Zero scrapped wire harnesses (first time ever)

Creating the foundation for next-generation aerospace products

The aerospace industry demands more than just increased electrification. In addition, aircraft versions, increased regulatory product and process requirements and global competition are forcing the use of holistic systems that provide data transparency and configurability assured by seamless data flow (digital continuity). Solid and robust harness design forms the foundation for reliable, cost-effective and successful aircraft manufacturing that meets all of these requirements, and as the platform develops from the virtual to a physical product, using a digital twin delivers numerous critical advantages that are essential for building modern aerospace and defense products.

By enabling design teams to create and leverage a digital twin throughout wire harness design and manufacturing, Capital delivers:

- Higher quality due to rejection of error-prone manual methods
- Data correctness when not exposed to manual iterations
- Urgent updates with faster connected processes
- Enhanced management of growing complexity

Learn more about Siemens solutions for Aerospace and Defense at https://www.plm.automation.siemens.com/global/en/industries/aerospace-defense/.

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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. Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, helps companies of all sizes create and leverage a comprehensive digital twin that provides 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.

Steve Caravella

Steve Caravella is solutions architect and market development manager in the aerospace industry 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 degree in Engineering Mechanics from University of Wisconsin-Madison.

Bartosz Czarnecki

Bartosz Czarnecki is Product Manager and Leader of Harness Manufacturing, one of the eight Domains within Siemens Digital Industries Software Integrated Electrical Systems (IES).

His entire 17-year professional life has been dedicated to electrical harnesses. Since the very beginning of his career, he has been employed in the aerospace industry, where he held various positions, starting with electrical operator, then process engineer to production engineering manager. All this in the area of electrical harnesses. In addition to the aerospace industry, part of his career has been dedicated to the space industry. During the adventure with space, he focused not only on production engineering, manufacturing, and testing of electrical harnesses, but also, due to the specificity of the area, worked on their design.

He is an engineer with Master's degree from Technical University of Radom (Poland), where he graduated in Electrotechnics.