Siemens Digital Industries Software

Maintaining profitability under pressure for wire harness manufacturers

Executive summary

The increasing electrical and electronic content of today's aircraft is shifting the responsibility for critical functions to the wiring harness and other electrical systems. This shift from mechanical to electronic enablement, coupled with more and more sophisticated electronic systems, has drastically increased the risk for harness manufacturers. In order to survive and grow in this challenging environment, harness manufacturers must significantly change their methods. A digital model-based flow unifies the previously fragmented domains of design and manufacturing and captures tribal knowledge held by experienced engineers through integrated design rules.

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Introduction

Aerospace harness manufacturing teams face more pressure today than ever before. Profitability is increasingly constrained by a variety of concurrent stresses. Platform electrification is driving unprecedented complexity in the electrical systems and wire harnesses in modern aircraft (figure 1). Simultaneously, harness manufacturers are facing greater demand for specific customer variants, more stringent regulatory certification requirements and increasing change activity.

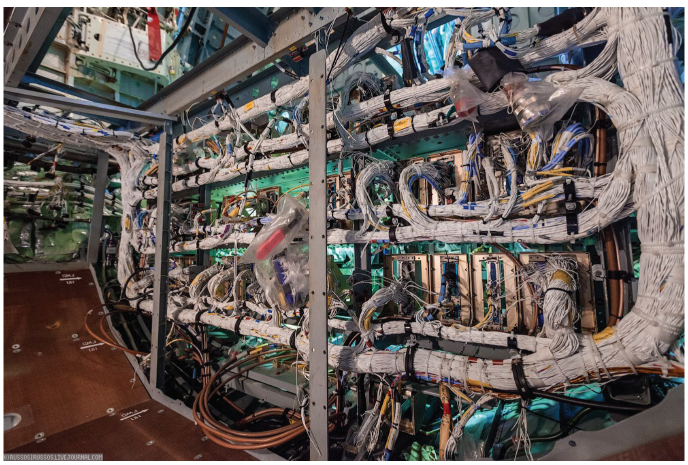

Figure 1. Electrical systems complexity is growing rapidly in modern aircraft and rate of increase is expected to continue.

As missions become more demanding, aircraft must be equipped with new and advanced capabilities. Most of these new capabilities are enabled by the electrical system within the aircraft. At the same time, aircraft manufacturers are pursuing hybrid electro-mechanical and electro-hydraulic systems to achieve higher reliability and lower aircraft weight.

The result is a vast increase in the number and scope of electrical systems on modern aircraft. This is made evident by the growth in the power demand of a modern aircraft. In the last 5 decades, power demands have increased more than tenfold. The aircraft electrical distribution system (Electrical Wiring Interconnect System or "EWIS") has also become far more complex. Today's aircraft commonly contain electrical systems with more than 500 km of cables, over 100,000 wires and more than 40,000 connectors. All told, these added electrical components now represent a significant portion of the total aircraft weight, which can add up to more than 7,000 kg of wire on larger aircraft.

Growing EWIS complexity has substantially increased the risk aircraft programs face, especially as they transition to production. Current processes were developed at a time when most aircraft functionality was implemented mechanically (including pneumatics and hydraulics). Now, as the EWIS grows and becomes more important to new capability implementation, companies face much higher risk. A problem discovered in first article integration or during the transition to production can require a major iteration in the development cycle, potentially costing billions of unexpected dollars. A problem of this scale not only puts the program cost and schedule at risk, but also the reputations of the program team, the reputations of the business unit and, in the worst case, the viability of the company.

At the same time, platform OEM's are required to implement more variants on the EWIS than ever before. Customers expect bespoke platform configurations at low cost and with extreme responsiveness from the harness supplier. Harness manufacturers not only must respond to these demands, but must seek to differentiate themselves through responsiveness to gain competitive advantage.

Regulatory flight certification is also becoming more and more stringent. New incidents lead to additional regulations that aircraft OEMs must meet. Meanwhile, special exemptions for the certification of new variants of existing aircraft have all but disappeared. And finally, both aircraft OEMs and harness suppliers must integrate changes as they arise from improvements to electrical system designs that reduce costs and improve manufacturability, reliability and performance.

Together, these four factors have increased stress on harness manufacturers as never before, whether they are vertically integrated within an OEM or an external supplier. Manufacturers need to respond to change from both the OEMs and their own harness product and process engineering teams. And they must do this urgently, as electrical system changes are frequently communicated at the last minute with little time to spare if a production program is to meet its schedule. All this results in a new harness manufacturing reality: new harness variants are required more frequently and produced in smaller quantities. What does this mean for the ability of a program to achieve profitability?

Impacts of current trends to production ramp and profitability

It is essential for harness manufacturers to achieve a predictable ramp of production efficiency to the start of full-rate production (SoP). Recovering from a missed SoP milestone can consume the expected profit from the entire production run thereafter. Consider the example below (figure 2). The planned production ramp is shown in green, with 80 percent production efficiency being achieved after 14 weeks.

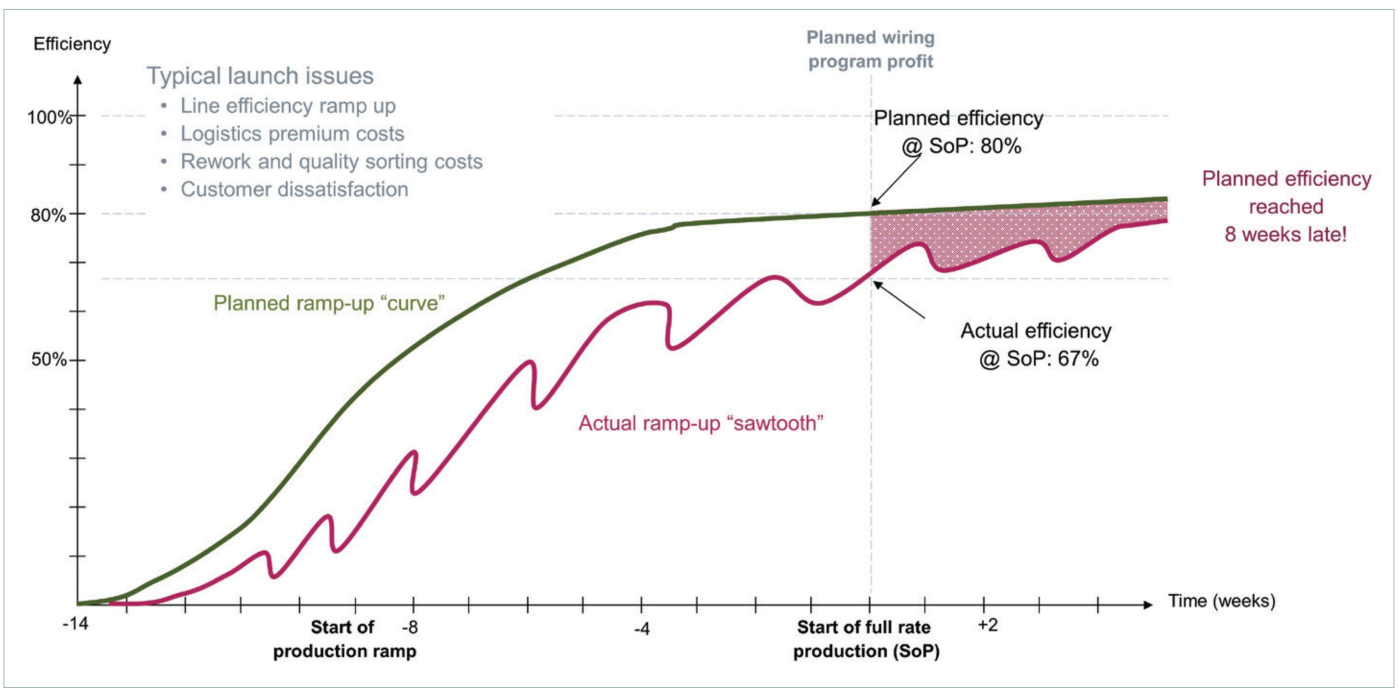

Figure 2. Plans for a smooth production ramp-up are often foiled by issues such as design change, missing material, data errors and more. The result is a 'sawtooth' shaped ramp-up that misses planned SoP.

In reality, there are a host of factors that disturb the realization of planned production ramps. Changes in harness design or the demands from the customer, missing material, data transfer errors and quality problems can all disrupt the build-up of production efficiency. This results in the actual production ramp (shown in red above) adopting a 'sawtooth' shape. In our example, we estimate the effects of some mistakes made in the creation of tooling, work instructions and other production support materials. The lost time resolving these issues means that at the planned time of SoP, production is only operating at **67 percent** efficiency.

The harness manufacturer now must continue to ramp production efficiency to meet their initial target. During this time, they will lose money on every harness produced due to unplanned costs. These manifest in a few ways:

- Sub-optimal line efficiency: Each harness takes more man hours to produce and generates more scrap.
- Logistics premium costs: Costly expedited shipping options are used to make up for production delays.
- Rework and quality sorting: Subpar quality or late design changes may require as-produced harnesses to be reworked before delivery to the customer.
- Customer returns: Low quality or mis-built harnesses returned by the customer for rework or replacement.

The result is a continual erosion of the manufacturer's profit margin, potentially consuming the entire program budget and expected profit.

Why does this occur? Predictable and profitable harness manufacturing is extremely difficult, and getting harder. In addition, today's approaches to harness engineering, manufacturing and compliance certification remain onerous, slow and expensive.

The challenges of current methods

Engineering and manufacturing methods common across the industry have been in use for decades, and are showing their limitations in a new era. Current methods were developed for relatively simple electrical systems and, as a result, wire harness manufacturing continues to be an extremely labor-intensive process (figure 3). Today, approximately 85% of all wire harness manufacturing operations are carried out manually.

Even more troublesome is the fragmentation between the harness design and manufacturing systems. Design and manufacturing engineers often transfer data manually between their respective domains, recreating and reentering data into each of their systems.

This is slow, error-prone, and an inefficient use of engineers' time and attention. As manufacturing engineers make changes to improve the manufacturability of the harness, these changes often are lost in the transition of data between teams. Even in state-of-the-art facilities, the high-level process from design engineering through product engineering, manufacturing engineering, and generation of the manufacturing documentation is completed with general office applications and 2D CAD drawings. The information is passed along to the next person in the chain, who manually recreates the information in another format or style.

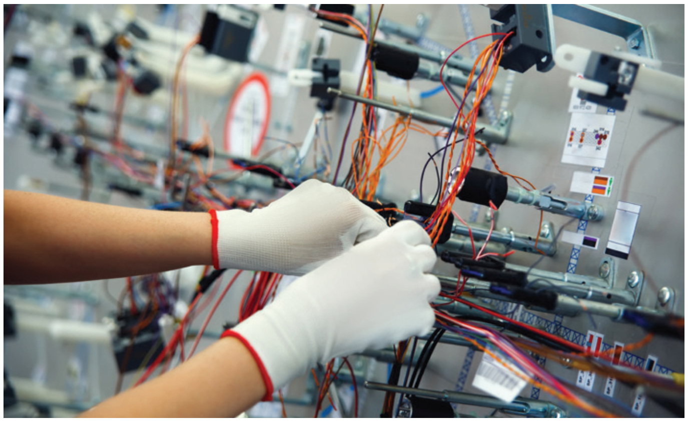

Figure 3. Wire harness manufacturing is still a labor intensive process relying on manual assembly.

Unfortunately, upstream project delays can reduce the time available for the manufacturing engineers to generate work instructions. If the instructions arrive late or with inadequate detail, then the assemblers on the shop floor must seek out additional guidance. Furthermore, inadequate instructions can degrade the quality of the finished harnesses, causing them to fail post-production testing. Suddenly, key program delivery milestones are missed, and unexpected late freight costs are incurred to make up for lost time and yield.

This is no longer contemporary nor acceptable. New product introduction cycles can take months, and design changes up to a few weeks to be fully implemented. Manual data sharing and reentry causes mistakes that cost money, need time to fix and, even worse, can jeopardize a good customer relationship.

The accelerating pace of program milestones means that manufacturing engineers have little time to optimize the manufacturing process, leading to a sub-optimal process from the beginning. Under current methods, creating work instructions is a difficult, time-consuming, and challenging job that requires skill and expertise to complete accurately, and on time. Work instructions that are late or low-quality can lead to inadequate and unsatisfactory workstations, further leading to assembler errors.

Another significant challenge is loss of institutional know how. This "tribal knowledge" is information about processes, methodologies, and more that is stored only in employees' memories. Tribal knowledge is unwritten, but is often critical to successfully implementing a process, creating a product, or maintaining quality levels. Employees that change roles or leave the company will take this information with them, undermining the process or product they once oversaw.

Loss of tribal knowledge presents a very real risk for many companies, harness manufacturers included. Ten thousand baby boomers retire every day in the US. In Canada, from 2011 to 2016, there was a 20% increase in the number of Canadians who reached retiring age or older. And in the UK, it's predicted that about one in every four people will be age 65 or older by 2039. The workforce is shrinking, and this will have significant repercussions if not addressed.

Let's look at how this relates to the manufacturing engineering flow. Figure 4 shows a typical, high-level manufacturing engineering flow in the wire harness industry. First, design engineering releases initial designs or engineering changes for costing and providing quotes to the customer. Next, the main formboard is designed, followed by production modules and subassemblies, which sometimes require their own assembly board. Engineers will design a bill of process (BOP) for the entire harness, allocating wires, splices, twisted

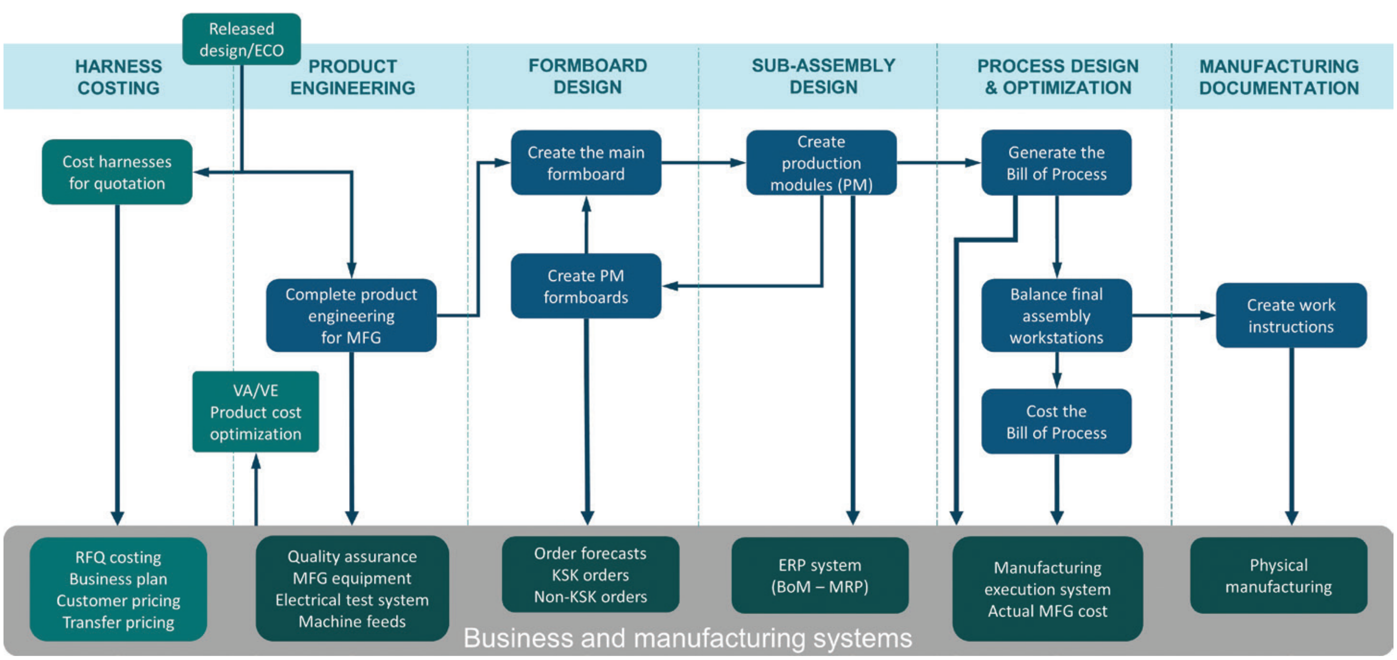

Figure 4. The high level manufacturing engineering flow in the wire harness industry.

wires, and all remaining material to its designated equipment or work station. The BOP is then released into the enterprise resource planning (ERP) system. This is followed by balancing and optimization of the final assembly carousel and then creation of the work instructions.

Today, errors from data reentry can occur at any of these stages, each of which requires great skill and experience. Adjustments and corrections made downstream in the flow must be fed upstream manually in order to achieve data coherency. The conventional wire harness manufacturing methodology is vulnerable to errors from fragmented processes, and the loss of tribal knowledge as engineers retire or leave their jobs. Other key issues include inconsistent or inaccurate costings, sub-optimal formboard design or manufacturing process design, and misplacing key information on the shop floor. These can lead directly to inefficiency during production. Manufacturing and overall costs can then overshoot the quotation made to the customer, and production quality can suffer.

Maintain profitability through digitalization

The most sophisticated members of the manufacturing community recognize the need to change. Using a technique termed digitalization, they are applying digital technology to transform their business processes. These leaders are already adopting model-based development techniques, from concept development, through design, and into manufacturing, to reduce cost and schedule risk, accelerate production ramp, and improve productivity.

A model-based flow unifies the previously fragmented domains of design and manufacturing by automating data exchange and providing engineers with access to cross-domain decisions. Tribal knowledge, previously held by experienced engineers, is captured through integrated design rules that support automation, guiding all engineers in consistently and automatically checking designs for errors.

There are three key aspects to digitalization and the model-based enterprise in the wire harness industry (figure 5). First are digital models of the wire harness product and the manufacturing process. The digital models of the harness and production process together constitute the digital twin. Automation is the second pillar. Modern harness design and manufacturing solutions can consume design rules created by veteran engineers and use them to automate the transformation of the digital harness and process models into bills-of-process, work instructions, and other output formats. This simultaneously embeds tribal knowledge into the company's production flow, safeguarding it from employee turnover. The third pillar is data reuse. Instead of recreating or reentering data, in a model-based engineering flow, data is created once and reused to the greatest extent possible by all upstream and downstream consumers.

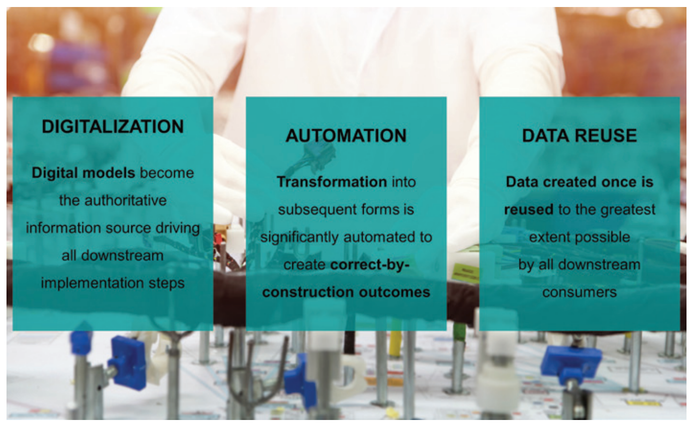

Figure 5. The three key tenets of a model-based enterprise: digitalization, automation, and data reuse.

In a digital world, companies create a digital thread in which all of the functions, from architectural and functional design through to physical design, manufacturing engineering and after-sales service, can all use the same data. At every stage of the harness lifecycle, each stakeholder can use the same data models and have access to decisions that are made in other domains. Using a digital thread, design cycles are faster and issues can be caught and resolved earlier in the process when they are much less expensive. By also reducing design rework, data reuse minimizes costs and enables superior manufacturing efficiency.

Bringing Harness Manufacturing into the Digital Age

Harness manufacturers are concerned with designing sub-assemblies, engineering formboards, line balancing, and generating the bill of process and workbooks. Manufacturers also operate within the context of a larger ecosystem. They typically must interact with an ERP system, manufacturing execution systems (MES), as well as systems on the shop floor that need to be connected, such as wire preparation and automatic test equipment.

Digitalization can streamline the passing of data from each of these systems and processes to each of the others. Automation further improves the effectiveness of harness manufacturing enterprises. Engineers specify design rules to guide the automation, embedding tribal knowledge into the process. Then, the automation leverages the product and process digital models to complete a variety of tasks including generating process designs, calculating costs, and producing documentation for assemblers on the shop floor. The digital twin provides the model, and the automation generates the information needed downstream.

For example, over time a harness manufacturer will have identified an optimal procedure for designing connector sub-assemblies. Senior engineers can input the steps of this procedure as standard, reusable rules and constraints for automation. As a first step, these rules may dictate that modules should be created for various groups of spliced connectivity, turning them into sub-assemblies. The next step may be to create modules for connectors with wires that all belong to the same variants, followed by creating modules for connectors with the lowest number of remaining wires. Finally, if a module contains all of the wires in the relevant bundles, then include insulations and fixings on those bundles. With a digital twin of the harness, advanced harness engineering software, such as Capital, can automatically apply these rules to complete this task in seconds or minutes, depending on the size of the harness.

In another example, design rules can automate formboard fixture selection, placement, and other factors (figure 6). Senior engineers with years of experience selecting and placing these fixtures can describe guidelines for the best fixture type, placement, and quantity given the junction, connector, and bundle size and length. The software can use these rules to automate the placement of fixtures, drill points, and jigs, greatly accelerating formboard design speed and accuracy.

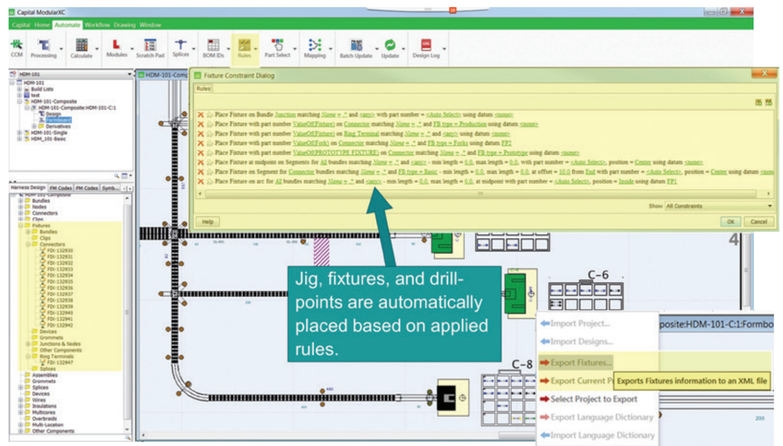

Figure 6. Design rules can help automate the placement and selection of formboard fixtures.

With a digital model of the harness and production process, engineers can automatically generate work instructions. Engineers can incorporate workbook templates, libraries, and style sets to ensure the instructions are accurate and comply with company industrialization and quality standards. It starts with the digital model of the harness. Although it looks like a simple drawing of the harness layout, engineers have enriched this design with specific component, material, and other data, making it a digital model of the physical harness. The digital harness model is the foundation of a model-based approach for harness engineering.

From this model, the harness engineering software can generate extremely rich work instructions that include data charts for wire cutting, and such data can be fed directly into wire cutting machinery. The generated work instructions include diagrams for twisted wires, jacketed multi-cores, spliced daisy chains, as well as detailed instructions for pre-populating connectors with wires or cavity plugs. Engineers can also generate various formboard diagrams showing shop-floor operators how to lay-up sub-assemblies onto the board. Using a digital thread to make this a continuous process, fed from the same data from start to finish, can greatly improve the efficiency and accuracy of the final assembly process.

Harness manufacturing of tomorrow

Digitalization and the digital thread will enable harness manufacturers to adapt to the challenges of tomorrow more effectively, maintaining profitability despite increased pressures. A traditional shop floor begins with preparing materials for assembly through wire cutting, wire preparation, splicing, and connector pre-load. Then the harness is assembled on the formboards, and technicians perform post-assembly tasks. Advanced solutions already can automate the design and optimization of the bill of process, production of the necessary workbooks, and the production of the formboards.

Moving forward these solutions will integrate with a network of other systems. ERP systems will help manage the material stores for harness manufacturing, while a manufacturing execution system (MES) can supply workbooks around the shop floor, gather and supply real-time data from the shop floor, and generate feedback based on that data to help improve the processes and designs. With an entirely digitalized process, from model-based planning and simulation to integrated manufacturing systems, harness manufacturers can realize significant improvements in efficiency and productivity. A model-based engineering approach with a continuous digital thread can help harness manufacturers reduce design errors by 50%, quote-to-production cycle time by 30%, and formboard design time by up to 85%.

As a result, we can achieve a more effective production ramp and ensure the realization of efficiency at SoP. Compared to the earlier example, the use of the digital twin and digital thread have ensured correct-by-construction design and enabled manufacturing process modeling (figure 7). This allows for a faster and more predictable ramp up with fewer disruptions as compared to traditional methods.

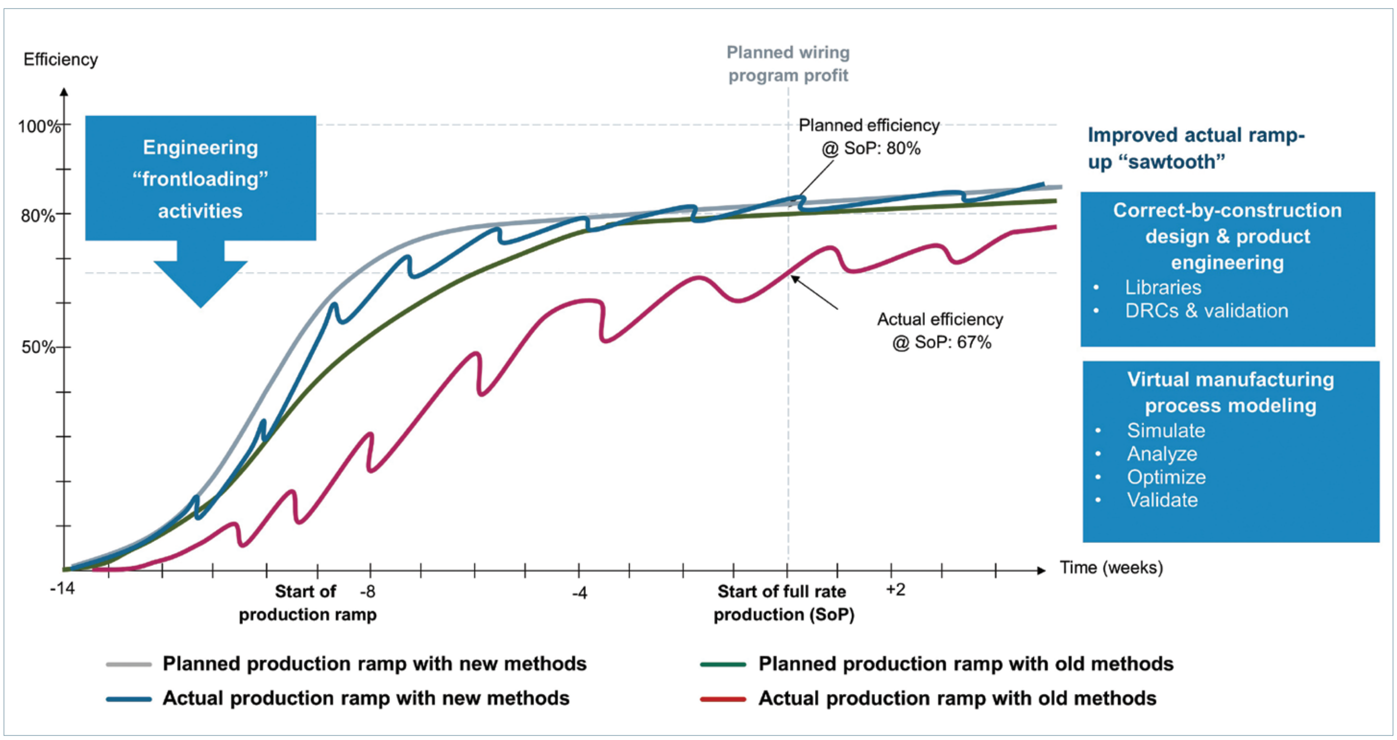

Figure 7. Production ramp improvement realized by leveraging the digital twin and digital thread.

Thriving in a Changing Industry

The fabric of the harness manufacturing industry is changing as new technologies and pressures accelerate the already growing EWIS complexity and sophistication across the aerospace industry. The increasing electrical and electronic content of today's aircraft is shifting the responsibility for critical functions to the wiring harness and other electrical systems. This shift from mechanical to electronic enablement, coupled with more and more sophisticated electronic systems, has drastically increased the risk for harness manufacturers. Meanwhile suppliers are under more pressure to deliver low-cost harnesses with rapid response times.

The threat of losing valuable on-the-job experience and knowledge from an aging workforce also looms large for harness manufacturers. As engineers reach retirement, or find new roles, they take important but unwritten information about company processes and design practices. It is vital that harness manufacturers capture this information digitally to inform and guide the incoming workforce and to automate complex processes.

In order to survive and grow in this challenging environment, harness manufacturers must significantly change their methods. Digitalization is a key adaptation for harness makers, offering the tools needed to survive in an extremely dynamic industry. A digital model-based flow unifies the previously fragmented domains of design and manufacturing and captures tribal knowledge held by experienced engineers through integrated design rules. To meet the demands of an evolving industry, it is time for wire harness makers to become digital enterprises.

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