DIGITAL INDUSTRIES SOFTWARE

Optimizing aircraft communication network design

Enhancing the quality and reliability of aircraft while reducing costly program iterations

Executive summary
Communication networks are a critical aspect of modern aircraft. Ever-more sophisticated avionics and electrification increases complexity, which in turn boosts demands on network communication design to a level that breaks traditional document-based processes and tools, even when managed digitally. Innovating product features is not enough; there is also a pressing need to innovate processes and tooling to catch up with the accelerating pace of digital transformation. Today's leading organizations have to be able to redefine themselves at a faster and faster pace.

However, most companies are still trying to use yesterday's tools and processes to develop tomorrow's highly complex products. It's becoming increasingly clear the aerospace industry is ripe for disruption, particularly in the area of inner-cabinet communication design.

Olga Secerov
Siemens Digital Industries Software

Introduction

In this white paper we explore the challenges of aircraft network design, why moving away from old processes is crucial and discover how Capital™ Network Designer for Aerospace software, which is part of the Siemens Xcelerator business platform of software, hardware and services, delivers results. Capital Network Designer for Aerospace is a model-based, multi-protocol communication network design solution that reduces costs, enhances quality and avoids costly program iterations.

"We won't experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress at today's rate."

– Ray Kurzweil, Futurist

Aerospace and defense industry trends

Primed for disruption

Several trends have emerged in the aerospace industry that require network designers to balance innovation and risk.

- **Pressure to reduce program costs:** Producing within the constraints of budgets and schedules while meeting program requirements is a constant challenge for original equipment manufacturers (OEMs) and suppliers
- **Increased electrification:** The rise of automation and autonomous vehicles is driving electrification and the need for software as the industry works to reduce carbon emissions. OEMs are replacing mechanical systems such as hydraulics with electrical systems to improve the reliability and maintainability of their products
- **Globalization:** OEMs are grappling with global competitors and supply chains and a global workforce as people continue to work remotely, increasing the imperative for effective collaboration
- **Increasing complexity and integration:** Today's aerospace programs are highly integrated, and as companies work to improve product performance and reduce weight, they seek integrated solutions and rely more on software

Globalization and electrification drive complexity, which in turn increases pressure on program costs and schedules. These trends have escalated program risk and the aerospace industry has been struggling with ever-increasing program costs and schedules – and embarrassing overruns – for decades.

According to Accenture's Aerospace and Defense vision for 2021, digital transformation in this space is moving far more quickly compared to other industries.

As the pace of innovation continues to accelerate, companies are digitally transforming to improve their productivity. As such, there's a pressing need to improve processes and tooling and this is creating a variety of challenges for the industry and network designers.

> "Ninety-seven percent of aerospace and defense executives say their company is innovating with an urgency and call to action this year."
>
> – Accenture, Aerospace and Defense Tech Vision, 2021

Challenges of network design

In the past, companies could rely on processes that were based on documents as deliverables, which were tedious but simple to manage. But design complexity is increasing. In today's aerospace products, each function breaks down into multiple systems influencing tens or even hundreds of thousands of interactions, which must be identified and managed. Such complexity cannot be handled with spreadsheets and document-based processes, even if such documents are managed digitally. If you consider these systems are handled by different suppliers, it is even more complex and challenging.

Today many systems, functional models and legacy wiring and networks from different platforms must be combined and integrated into a single architecture. Components and functions may need to move, and the implication of these actions must be measured and assessed to ensure they are technically and financially viable. Meanwhile, products encompass more content and components, which means the need for new network capabilities is growing. As the number of signals increases and new systems and functionality are added, these signals must be shared on the network without significant changes to the network's size.

Growth of software complexity in aerospace systems

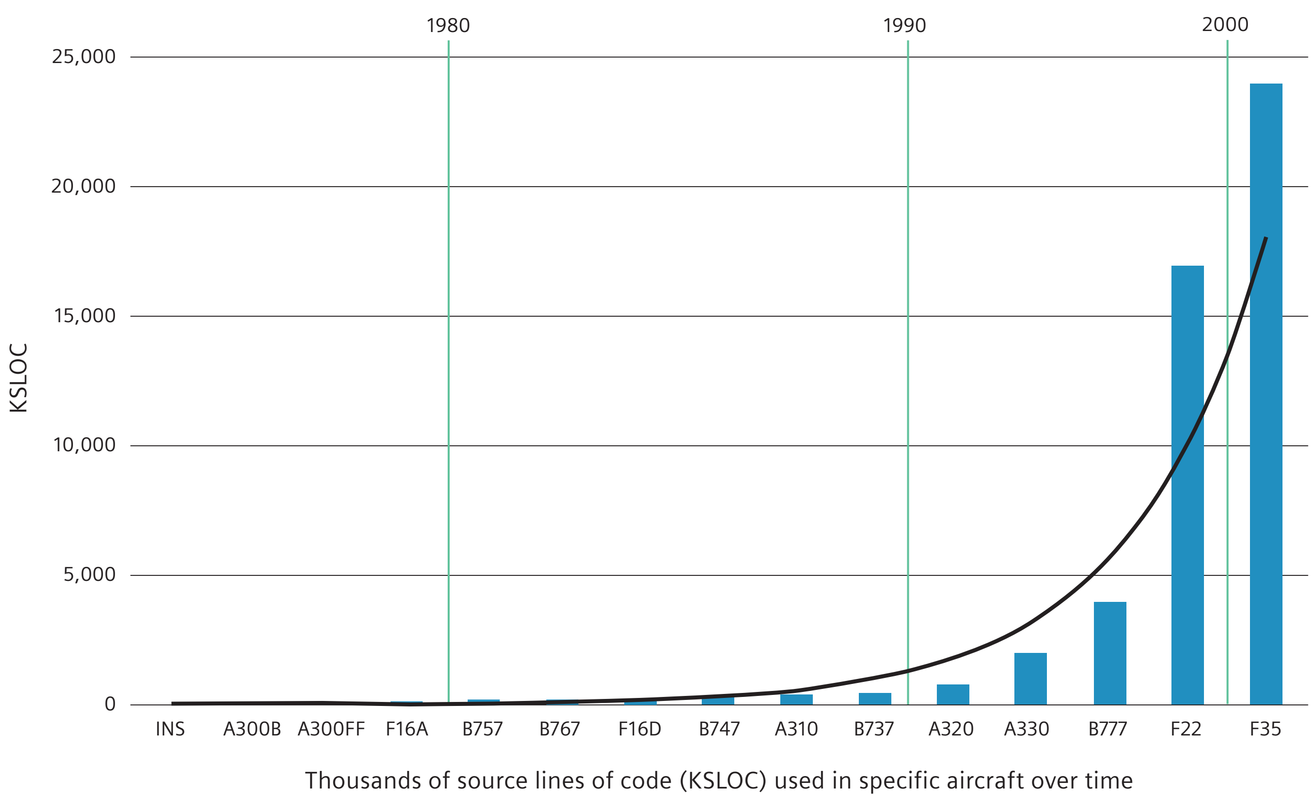

Figure 1. The number of lines of code in modern aircraft have increased exponentially.

Electrical is moving to software, expanding network content and software complexity. This is mainly due to the growing number of functions resulting from electrification, automation and other sophisticated features. That trend has been in place for at least five decades and applies to both commercial and military aircraft (see figure 1). The trend toward electrification places demands on the network and network performance.

Traditional processes focus on development rather than defining the process. However, increased complexity results in more bugs late in the process, which can cause delays and impact quality. With existing systems, engineering tools and processes, most errors are detected during the integration and test phases. The cost to fix these errors at later stages of development can be 16 to 100 times the cost of correcting them during the design phase when they are first introduced. Development costs are rising exponentially so affordability is becoming a significant issue for new aircraft, making some projects financially unfeasible.

Figure 2. Late-stage rotorcraft modifications affected network design, delaying the production line and driving up costs significantly.

Making the case for network analysis

A new approach must be adopted to reframe and remodel the fundamentals of systems and network engineering. Integration and validation must happen earlier, which, requires network analysis. Having a well-defined system during the design phase can help to simplify vertical integration and reduce the workload on the implementation team. Early validation ensures less manual work is invested in testing without affecting quality.

Let’s take a real-world example (see figure 2).

In creating the rotorcraft platform, it was necessary for a leading aircraft design firm to integrate a new defensive subsystem to the existing rotorcraft platform. Network signals were distributed to an existing network, but unfortunately no robust network validation was conducted because the engineering team assumed a modification would not impact the entire integration. However, there were multiple failures during functional test procedures, and the team discovered the existing network bandwidth was insufficient to handle the additional load. As a result, an entirely new network had to be added, including a network switch. Some modifications to aircraft in the assembly line and harnesses were also required.

There were serious consequences. The engineering, manufacturing and publications rework costs totaled approximately $1.5 million. What’s more, because the production line was halted, $180 million worth of revenue was put at risk.

Challenges

The following are some tooling and process-related trends and challenges stemming from increasing integration and complexity:

- **Digital continuity** is essential for effective collaboration across domains – a challenging if not impossible task with the current lack of standardization for efficient data exchange
- **Early verification** is also crucial to guarantee that designs will work as intended. Using homegrown tools and processes, teams detect most errors during the integration and test phases, significantly increasing the costs of already expensive programs. It has never been more important to check data consistency and protocol violations at design time, and understand behaviors such as worst-case time to end timing
- **Data coherence** is essential to enable everyone to work with a common data set instead of isolated document-based flows
- To meet the pace of innovation, **cycle times must be reduced** because innovative features must be added faster and in an agile way to products

Key challenges

- Burgeoning network content and complexity
- Reaching the limits of affordability
- Sustaining growth with current tools and processes

However, there are network design bottlenecks that must be overcome:

- A lack of timing analysis capabilities inhibit our ability to right-size the network or fully use available bandwidth
- Lack of specialist network design tools and design automation can impede productivity and impair quality
- A heavy dependence on physical testing means validation happens late in the design lifecycle, increasing the risk of delays

To resolve these issues, integration must happen virtually and earlier in the design lifecycle. The need for advanced network design tools has never been more important to master the increasing complexity, reduce the design cycle time and improve quality at lower cost.

Building better networks

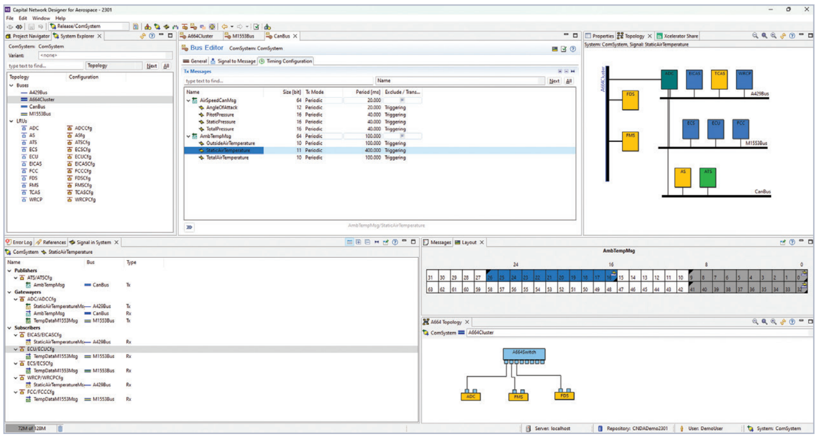

Figure 3. Capital Network Designer for Aerospace is a model-based collaborative multi-protocol network communication design platform.

Siemens Digital Industries Software's network design and verification environment, Capital Network Designer for Aerospace, provides early validation to achieve efficient and collaborative multi-protocol communications design.

The platform offers multiple features and capabilities that help network designers overcome the challenges of aerospace network design:

- **Correct by design:** Promotes deliverability with early verification
- **Multi-protocol:** Removes the labor-intensive coordination
- **Generative design:** Reduces the design cycles and expert needs
- **Team collaboration:** Supports increasing complexity of network design
- **Digital continuity:** Enables access to the same data downstream

Using Capital Network Designer optimizes communication for the entire distributed communication system and maximizes the usage of each communication bus. Generating automated messages and built-in checks, metrics and timing analyzers enable messages to be delivered with no more than the required latency. Validation happens early in the design process to minimize the need for expensive changes late in the design lifecycle.

Let's revisit the rotorcraft example to see how using Capital Network Designer can mitigate the challenges associated with aircraft network design.

Using Capital Network Designer makes it possible to integrate new signals into an existing network with ease and extend the multi-bus communication system virtually. Additionally, it includes complex built-in design rule checks, making it possible to achieve system-level consistency early in the design phase – prior to physical testing.

Capital Network Designer offers a timing analysis feature implemented based on complex mathematical rules to provide signal deliverability, and it performs bus load analysis to prevent overload. Based on the results, if necessary it is possible to further optimize the communication system.

Together these features enable correct-by-design networks prior to functional testing, saving time, reducing costs and preventing expensive program iterations.

Capital and Siemens Xcelerator

Capital is a product with significant history in electric/electronics (E/E) systems development. The platform has evolved over the last five years to offer added capabilities to meet the needs of the aerospace industry.

Siemens approaches vehicle electrification systems by integrating requirements and systems models into a comprehensive E/E architecture that drives the development of software architecture, network communication, architecture, integration, verification and visualization of embedded software systems. It does this by delivering proper electrical distribution guides design, manufacturing and service publications. This entire flow makes it possible for vehicle-level features to be implemented in a collaborative manner.

To help teams tackle the increasing complexity of developing systems, model-based systems engineering (MBSE) provides the context. Siemens focuses on three key elements of this comprehensive solution driven by a common E/E architecture: network communications, software development and electrical distribution.

Network design tools are in the upper arm of the flow, and because software architecture and implementation are out of the scope of aerospace network design for now due to lack of standardization, Capital Network Designer for Aerospace is used to retrieve data directly from the E/E systems architecture. Through the digital track, the system consumes the desired network topology derived from the E/E architecture and the correlative signal matrix, including timing requirements.

In addition to the built-in system import from Capital systems with its upstream/downstream REST API, Capital Network Designer can be used to break up domain silos, making it possible to import system designs and legacy data as input for network design, as well as feed downstream with preferred file formats for LRU and test equipment configuration (see figure 4).

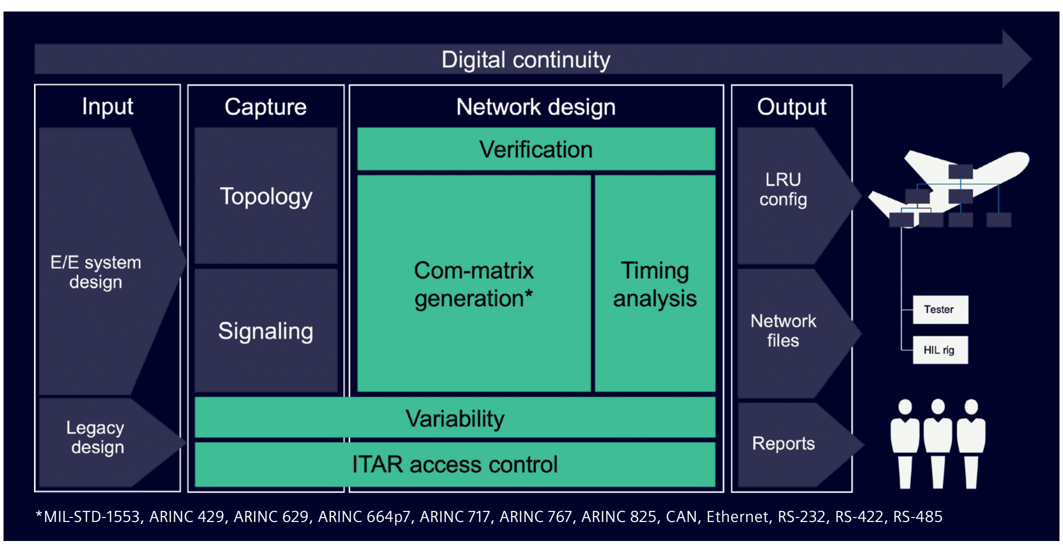

Figure 4. Using Capital Network Designer enables rapid design of validated and correct networks for the aerospace industry.

Early verification with software consistency checks is supported in all the design phases, helping network engineers create a valid network communication design.

Com-matrix generation or tracking of signals into messages based on complex rules is one of the biggest network design challenges the platform addresses. In this phase, complex protocols and specific rules must be applied that are different for all the communication protocols.

Timing analysis enables messages to be delivered with no more than the required latency by being able to calculate busload and signals worst-case delay values for distributed networks, helping to prevent data loss and optimize designs.

The platform supports definitions of variants of the same communication system and different system variants can share a common supersystem, reducing costs and saving time. Additionally, access control support for signals, messages and attributes restricts visibility and fulfills information technology (IT) regulations.

Capital is part of Siemens Xcelerator, the comprehensive digital twin and the MBSE solution for design, development and production (see figure 5).

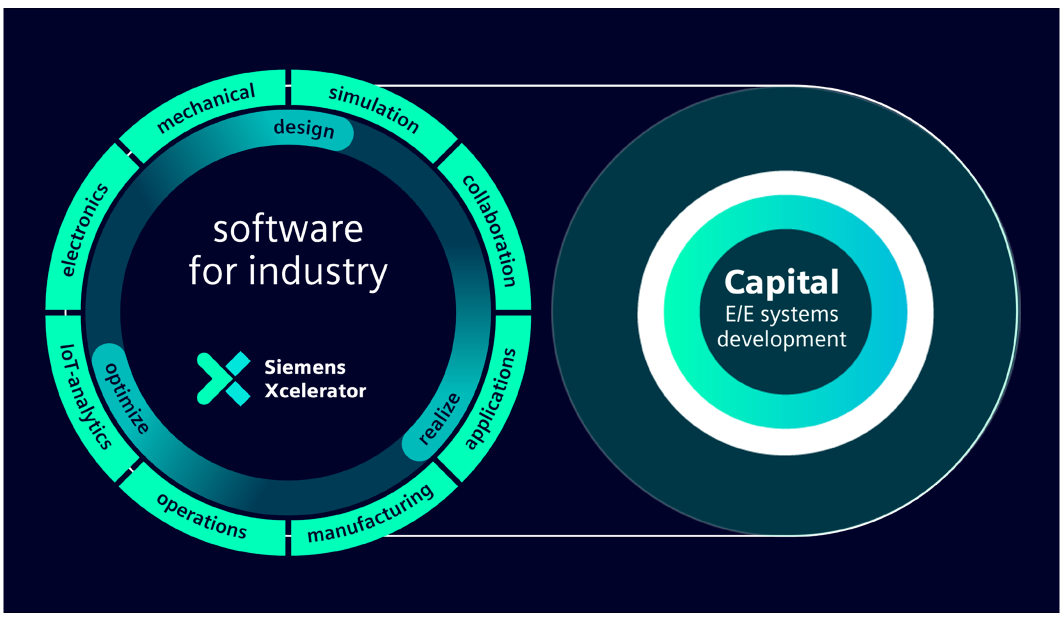

Figure 5. Siemens Xcelerator encompasses software solutions that support an array of engineering disciplines such as mechanical electronics, software design tools, simulation environments, manufacturing operations, planning and management solutions.

Conclusion

Capital Network Designer for Aerospace delivers the keys to success with model-based systems engineering to enable the design of right-size networks, while enhancing the quality and reliability of aircraft and helping to avoid costly program iterations.

Key benefits of Capital Network Designer for Aerospace:

- Breaks up domain silos to provide digital continuity
- Strengthens internal collaboration to increase efficiency
- Delivers data that is always up to date and available
- Moves away from isolated bus designs in Excel spreadsheets
- Provides visibility and reduces development cycles to meet tight schedules
- Decreases the need for network design experts
- Provides early verification to reduce cost

Siemens Digital Industries Software

Americas: 1 800 498 5351

EMEA: 00 800 70002222

Asia-Pacific: 001 800 03061910

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Siemens Digital Industries Software helps organizations of all sizes digitally transform using software, hardware and services from the Siemens Xcelerator business platform. Siemens' software and the comprehensive digital twin enable companies to optimize their design, engineering and manufacturing processes to turn today's ideas into the sustainable products of the future. From chips to entire systems, from product to process, across all industries, Siemens Digital Industries Software is where today meets tomorrow.

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