Digital approach to airworthiness: A technical guide

Speed up aircraft certification through digital transformation

Executive summary

As a "system of systems" composed of software, hardware and electronics, aerospace and defense (A&D) products involve lengthy multidisciplinary development programs and interrelated verification activities to gain customer approval or regulatory certification. Customer demands and government regulations will continue to advance, so it is vital to have tools capable of evolving to support new verification processes and airworthiness standards. Failure is not an option for a commercial airliner, weapons platform or spacecraft, and delays are expensive and damaging to a company's reputation.

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| Introduction

The often-long path to certification is paved by verifying that regulatory requirements have been satisfied, a daunting task that has grown to the point of equaling or exceeding the time and cost of development. At the core of the certification process are the means of compliance, which determine the mechanisms used to substantiate and document the various compliance activities and to demonstrate how design requirements and safety criteria are met. This brings into question every specific activity within a verification program; including types of analyses, component and flight testing methods, test resources, instrumentation, change management, physical audits and conformity inspection, and validation procedures.

Verification teams must coordinate these activities across departments, engineering disciplines, program managers, physical locations and individual operators of test equipment. Several common questions, such as those illustrated in Figure 1, must be answered to determine if a single test is ready to proceed. These questions have become more challenging to answer as the demand for performance, quality, innovation and decarbonization grow. This complexity is a primary driver for increased risks and costs associated with verification programs and, ultimately, the final airworthiness certification.

Do I have all the correct requirements allocated to this test?

What's the status of our requirements verification program?

What requirements are traceable to which instrumentation? What's the go, no-go criteria for this test?

Are all analyses complete to ensure a safe and successful test?

Does the test article represent the production design including changes?

What past experience, test planning and reports can I use to accelerate this activity?

Figure 1.

Limitations of current processes for verification and airworthiness certification

As one of the final hurdles to clear before moving on to airworthiness certification, A&D verification activities usually end up with compressed schedules and accumulated risk from project and design changes. Verification managers are tasked with aligning data from the many verification tests, which involves engaging with multiple suppliers and dozens of employees who are often across numerous facilities. These disconnected sources of data create delays, waste and missed opportunities. While many companies have adopted a concurrent design approach, product definition often evolves during a program, making it difficult for verification to progress during development and slowing overall time to market. Collecting verification and compliance artifacts during a program's final push toward airworthiness certification generates extra stress at an already vulnerable time in a product's development.

Other typical pressures facing those managing the verification and certification efforts include:

- Keeping up new requirements that arise from use of evolving technologies and materials
- Coordinating and planning all preparation work for the verification and certification campaigns
- Finding opportunities to re-use verification methods and processes
- Reporting on project status across multiple concurrent verification activities
- Assessing the impact of requirements and design changes
- Responding to demands to shorten the schedule

The established procedures for verification were developed over several generations. However, many changes in the industry are driving new regulatory protocols, which will require a shift in companies' verification and certification processes. For example, electric-powered aircraft employ more composite materials and additive manufactured components, with different certification standards than previous propulsion systems and materials. With the change in certification requirements comes a change in the procedures and tools for verification testing and reporting. Adding to the overall complexity is the ever-increasing prevalence of software and electrical systems, causing businesses to devote more people, time and money to manage verification and certification activities.

Often, companies piecemeal a network of disconnected systems to manage each individual element. For example, a company may manage design data in a product lifecycle management (PLM) or product data management (PDM) solution. But, often those solutions do not integrate seamlessly into the company's multidisciplinary analysis and optimization (MDAO) tools or requirements management system. The massive amount of documentation necessary to verify these activities is often scattered across these data management systems. The time and effort needed to compile the documentation is detrimental to both the time and cost of verification and certification. Demonstrating compliance to achieve airworthiness certification will be a grueling activity without a shift in tools and processes.

A new way to manage verification and certification

Digitalization has become a mainstay of development and production processes but must also be a key component of verification and certification management processes. The ideal digital ecosystem is characterized by a closed-loop process guided by a digital thread woven through all elements exposed to verification and certification scrutiny. The digital thread allows the verification and certification deliverables to be integrated into the program plan, prioritizing compliance during each development phase. Further, these activities should be completed within a common development platform where the design, testing and analysis data, and requirements driving the design are also managed.

Successful digital verification and certification management programs start with providing a common location for digital product data accessible by all users, as well as:

- Providing a single collaborative platform for design, analysis and test organizations to work in unison, have a single source of truth, and have visibility not only into driving requirements but also to changes in those requirements

- Moving from a document-centric approach to a data-centric one, allowing for granular changes to plans, test definitions, procedures and other documentation while supporting real-time reviews and configuration control

- Synchronizing design models, analyses and test articles to facilitate the production design, as well as all the modifications made to the test article, so it will remain valid for proving requirements

- Connecting relevant stakeholders worldwide to verification and airworthiness certification data via secure cloud-based services
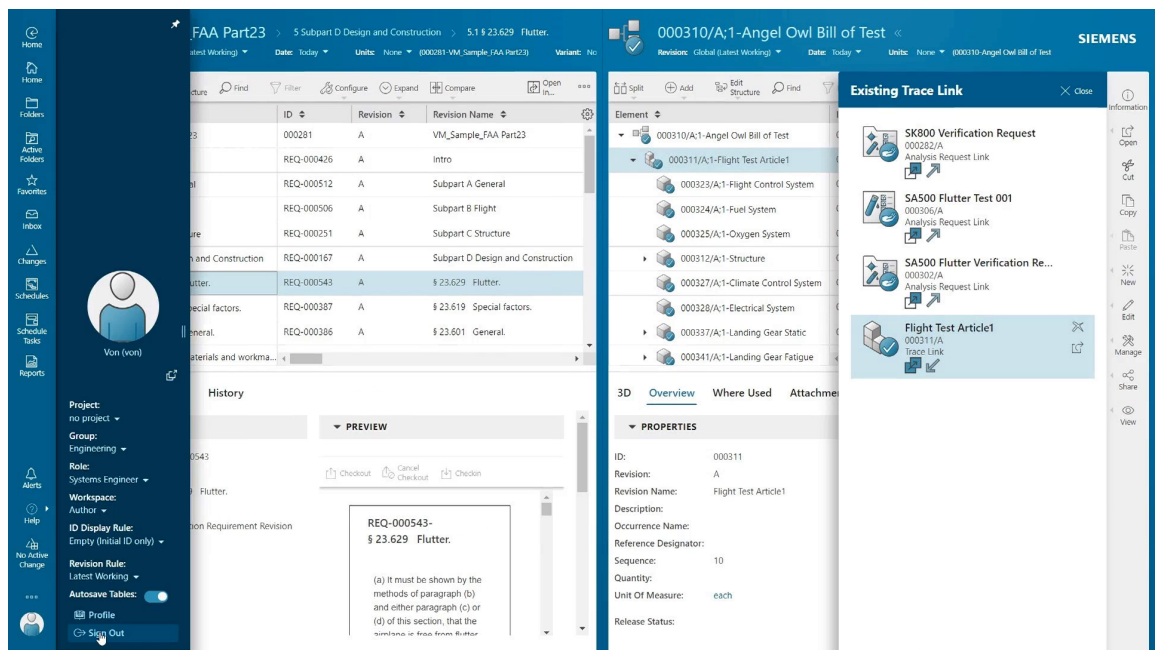

Figure 2. Defining the planned configuration of all test articles needed for testing.

Automated traceability enabled by the digital thread, which links verification and certification artifacts across all data sources, closes the loop from the method of compliance requirements to a tested and verified product. This powerful ability allows verification and certification groups to:

• Identify the impact of proposed changes to requirements, design and test elements and examine relationships between verification and certification elements to understand dependencies, thus minimizing schedule and cost overruns

• Confirm testing was performed and documented correctly by tracing physical test articles to the procedures, instrumentation, calibration data and other relevant records

Workflows ensure the right people are engaged at the right time based on their responsibilities while capturing a complete record of related information. Incorporating workflow-initiated verification and certification tasks into each development activity streamlines work and associates certification dependencies with program activities. Proactively addressing these dependencies during development mitigates delays in verification and certification efforts.

Configurable workflows based on standards, approved processes and best practices enable teams to:

• Demonstrate disciplined processes are adhered to and that there is accountability throughout the lifecycle

• Document who performed verification activities and when they were performed

• Integrate analysis-to-analysis handoffs (an often-overlooked failure point) to manage the process of using outputs from one analysis as inputs in subsequent analyses

• Standardize practices that support more accurate planning and estimating and facilitate intelligent re-use of test procedures and plans

Essential to successful verification and certification management programs are robust reporting and planning capabilities. With these tools, the rate of achieving schedule and cost goals is improved through:

• Complete visibility of all verification and certification activities and deliverables with live status in dashboard reporting

• Tying the status of verification-related tests and analyses back to the requirements and work breakdown structure (WBS) elements (for example, scheduled events and planned resources)

• Analyses to support planning, as well as assessing safety and the likelihood of success, which can then be reported upon, providing traceable rationale and documentation

• Analytics and dashboards that provide both ad hoc traceability and support for compliance and certification reporting

Success with a model-based systems engineering approach

While equally vital to the success of any A&D program, verification and airworthiness certification are two distinct processes. Still, both processes involve compiling, tracking and tracing massive amounts of data and organizing it to demonstrate the safety, reliability and performance of an A&D product. Each of the two processes can take years and require diverse virtual and physical methods. Ideally, these processes need to run concurrently with design changes and releases to manage the context of verifications and results effectively. Because of the parallels between the two processes, optimizing their management is also very similar.

In recent years, A&D firms have gravitated toward a model-based systems engineering (MBSE) approach to develop the "system of systems" products typical to the industry. An MBSE approach orchestrates the entire technical program by tracing final verification and certification results back through design, analysis and test, to the original requirements. With that shift comes the opportunity for significant improvement in how verification and certification processes are managed. Specifically, the underlying reasons for the disconnects that prevent closed-loop processes can now be overcome or avoided entirely by implementing Siemens' Verification Management digital thread. The thread
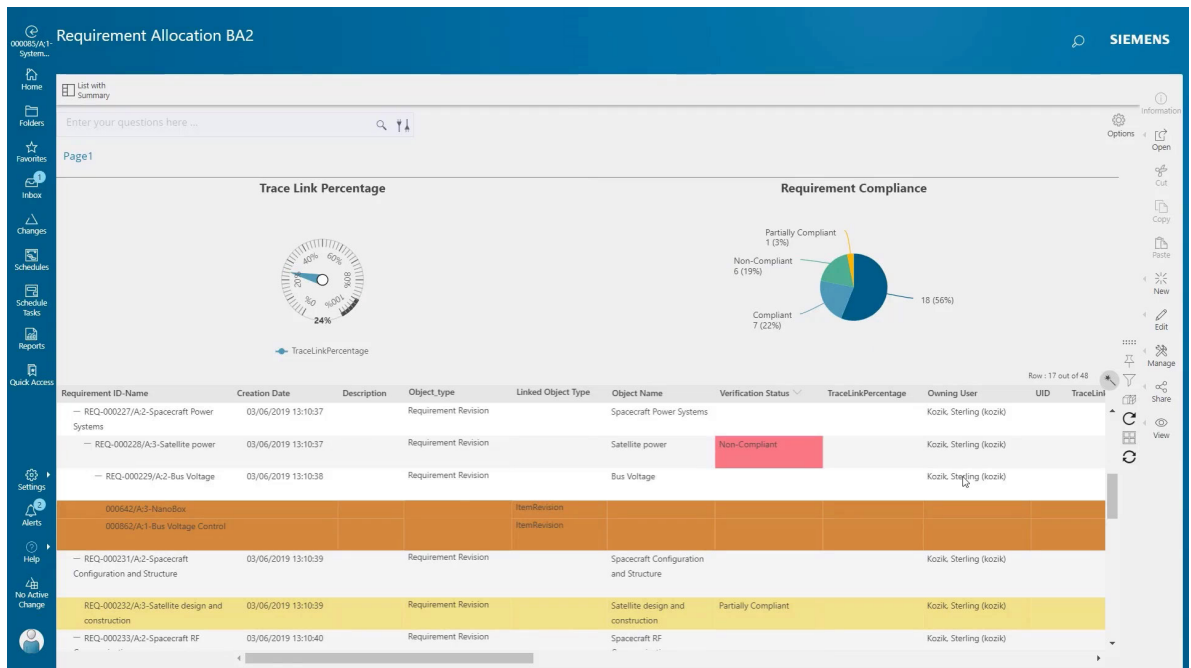

Figure 3. A compliance report is generated to indicate that the design meets the requirements.

facilitates a digital twin of verification and certification programs. It is incorporated into the overall development plan, providing the comprehensive traceability needed to support digital certification and verification throughout the entire program by fully integrating:

- Requirements management
- System analysis and test
- Schedule management
- Configuration management
- WBS/tasks planning and execution
- BOM management (including, but not limited to engineering and manufacturing views)
- Change and workflow management
- CAD model management
- As-built definition (complete serial-number-specific accounting of all manufacturing deviations)
- Test article definition and history

Though physical testing remains key in verification and certification programs, there is an increased reliance on digital methods for proving requirements. That means companies must link data originating from numerous virtual and physical testing platforms to the most up-to-date designs and requirements. Manually correlating these items will stall verification and certification efforts and will bring a program to a screeching halt in the case of an audit. However, the Verification Management digital thread fosters automated test correlation and linkages. It makes it easy to search for and locate the data needed to respond to internal and external audits. Demonstrating this control and traceability over verification and certification processes helps create a cooperative and trusting relationship with customers and regulatory authorities.

Siemens' strategy and unique capabilities

The Verification Management digital thread makes certification an integral part of the overall product development process by building traceability of regulatory requirements, means of compliance, test/analysis/ simulation execution and results into the day-to-day tasks of development teams. One standardized platform managing and linking configuration of analysis and test articles from requirements to verification reduces the need to import, export and recreate complex data. The digital twin brings visibility to the impact of changes to designs and requirements across engineering disciplines, bolstering the ability to collaborate within a diverse supply chain. Furthermore, the Verification Management digital thread facilitates a collaborative environment between A&D firms and regulatory bodies, where authorities can view and approve certification plans, share compliance reporting and communicate with the company. As a result of implementing the Verification Management digital thread, A&D firms can expect to see:

- Accelerated process for receiving type, production and airworthiness certificates
- Reduced risks to program schedule, budget and deliverables
- Improved program performance with a single verification management system
- Increased traceability of requirement linkages through design, analysis and test
- Reduced verification and certification costs from improved planning and execution
- Better estimates for verification on new programs
- Proactive management of requirements compliance with real-time reporting
- Accelerated program audits with accurate, up-to-date documented deliverables and activities
- Reduced cost of any necessary minor or major changes throughout the extended life of A&D products
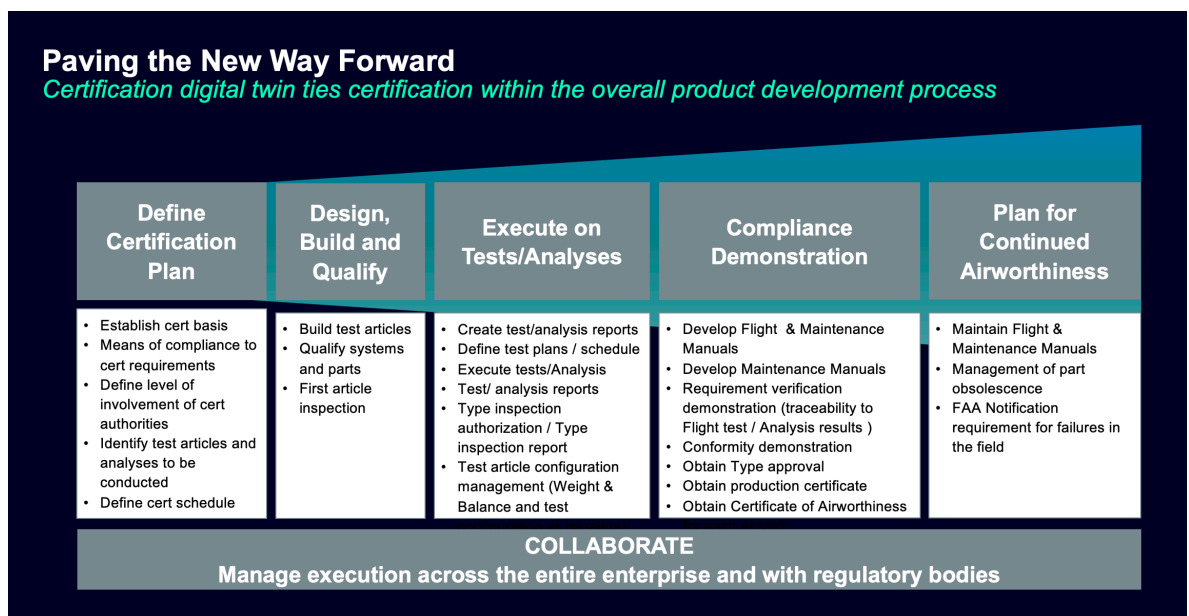- Better overall ability to meet product support and continued airworthiness requirements

Figure 4. Capabilities provided by Verification Management.

| Conclusion

The Verification Management solution helps A&D companies execute programs on schedule and budget by providing closed-loop requirement traceability into all activities of the design and verification process, which confirms requirement compliance and simplifies both internal and external program audits. By securely connecting stakeholders worldwide through cloud-based services to the Verification Management tools, processes and data, programs can progress with the visibility and clarity needed to be assured that verification and certification goals are met. Incorporating

verification and certification activities into day-to-day tasks prevents verification from being a late-in-the-game process, allowing companies to move toward certification much faster, at lower overall cost and with maximum quality.

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