Digital Twins and Threads in Action

This digital approach to preventive maintenance is transforming aviation — but how does it work?

By James Careless

"Digital twins" and "digital threads" are transforming aviation maintenance from a reactive stance to a preventive approach. But how are they making this change, and what substance is behind the buzzwords?

Making Sense of the Terms

First things first: What exactly are digital twins and digital threads, and how do they apply to aviation maintenance?

"A digital twin is a living, virtual replica of a physical asset, like an aircraft engine, mirroring its real-time behavior and history through connections to sensor data. It allows for simulation and prediction," said Paolo Colombo. He is the global industry development lead, aerospace and defense at Siemens Digital Industries Software. "A digital thread is the continuous, connected flow of data that links all information across an asset's lifecycle, from design to maintenance."

Siemens Digital Industries Software

In aviation maintenance, a digital twin provides the comprehensive view of an asset's health, while a digital thread is the essential conduit that feeds data into the

twin and disseminates its insights, ensuring seamless information exchange for proactive and efficient upkeep. "They are intrinsically linked, with the digital thread empowering the digital twin," Colombo said.

Digital Twinning in Action

Now that we have defined digital twins and digital threads, it is time to see how they are being applied in aviation maintenance.

Lufthansa Technik

Let's start with Lufthansa Technik, which uses AVIATAR's software products to help manage its aircraft maintenance program. "Digital twinning in Lufthansa

Paolo Colombo, Siemens Digital Industries Software

"Lufthansa Technik's Digital Tech Ops Ecosystem is used to know everything about the real-time condition of every aircraft and its components in the air and on ground, at any time and from anywhere, with managed data streams and centrally accessible up-to-date maintenance records," according to Lufthansa Technik's Frank Martens.

Frank Martens, Lufthansa Technik

Technik's Digital Tech Ops Ecosystem is used to know everything about the real-time condition of every aircraft and its components in the air and on ground, at any time and from anywhere, with managed data streams and centrally accessible up-to-date maintenance records," said Frank Martens, AVIATAR's senior director global sales and key account management. "The digital twin in this case is the aircraft as the physical counterpart, whereas digital threading means connecting these digital data with the broader IT landscape of an airline. We can use the data of the digital twin aircraft and combine it with other digital twins (e.g., MRO facilities, flight ops information and other aircraft) in order to create automated planning algorithms like AVIATAR's Line Maintenance Planning solution."

Dassault Systèmes

James Kornberg is the business consultant, aerospace and defense industry, at Dassault Systèmes. "The 'digital thread' is the digital continuity we are able to provide from design engineering to manufacturing, service engineering and maintenance activities," he told Aviation Maintenance. "It is now possible, with our solutions, to create maintenance instructions and spare parts catalogs that maintain a digital continuity from engineering data with the correct configuration of the aircraft in service."

According to Kornberg, Dassault Systèmes has advanced the digital twin model to create the "virtual twin" concept. "A virtual twin goes beyond a digital twin by not only mirroring physical objects but also simulating their behavior and evolution in real time," he explained. "This is a smart and dynamic replica of a product, a process, or a physical system in a virtual environment. The virtual twin is based on a holistic approach, meaning that it encompasses all the lifecycle phases from conception to disposal, on a unified platform, with digital continuity."

The Importance of Good Input

There is an old adage in the IT world: "Garbage in, garbage out." In plain language, the quality of any digital system's output can only be as good as the quality of the data used to create that output.

In the world of digital twins and threads, access to quality sensor and other input data is absolutely vital. Unfortunately, there's a wide range of aircraft in service today, many built decades ago when this kind of maintenance analysis was unheard of. For companies such as Siemens Digital Industries Software, this presents a problem.

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"We tackle this by designing solutions with open architectures and APIs to connect diverse systems," said Colombo. "We employ robust data harmonization tools from the Siemens Xcelerator portfolio to standardize information from various formats and units. For older aircraft, edge computing and data gateways collect and pre-process data locally before secure transmission. Semantic data models help interpret legacy data, and we often partner with experts for tailored integration strategies."

AVIATAR's ability to interconnect with maintenance and engineering systems, records management solutions and ERP systems, "allows our customers to create a single source of digital truth network-of-systems in an airlines operation, which are key to the digital transformation of the aviation industry," Martens said. "For example, Lufthansa Digital Tech Ops Ecosystem connects the AMOS maintenance system with AVIATAR's data analytics and flydocs' digital records and asset management solutions. Through seamless interfaces and secure data exchange, customers can integrate the Digital Tech Ops Ecosystem into their existing environment and extend its capabilities across the organization."

Of course, if the data from legacy aircraft is not available or not accessible, it is not possible to connect it to AVIATAR, the Ecosystem or any other digital tool. In these circumstances, "it is up to the operator to decide how to proceed, but we have always found solutions for customer challenges," said Martens. "Some AVIATAR solutions like the digital Technical Logbook do not need data from the aircraft. Instead, they use data coming from pilots, flight ops systems, or the tech ops team of an airline ideally via AMOS — while the 'paperwork' is stored digitally in flydocs' Digital Records Management."

James Kornberg, Dassault Systemes

As for Dassault Systèmes? "Depending on the IT system, some migrations are possible," said Kornberg. "We are leveraging AI to convert data from legacy aircraft to feed the virtual twin, to enhance the operation of legacy aircraft."

The Impact on Daily Workflows

So far, we have delved into the big picture view of digital twins and threads. So how does this theory play out on the MRO shop floor?

"Consider aircraft landing gear," replied Colombo. "For a maintenance technician, the digital twin transforms their work from reactive to proactive. Instead of relying solely on manuals, they receive real-time alerts from the digital twin about potential issues, like an unusual hydraulic pressure.

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Using augmented reality on a tablet, they can overlay the twin's data onto the physical component, instantly accessing full historical data, repair instructions, and even precise tool requirements. This drastically reduces troubleshooting time and No Fault Found removals."

For a fleet engineer in their office, a digital twin can provide a real-time, holistic view of every landing gear across the entire fleet. They can use this overview to predict precisely component lifespans based on actual operational data, enabling highly optimized, condition-based maintenance planning. "This capability also allows for deep root cause analysis across the fleet and provides invaluable feedback for design improvements, moving beyond aggregated reports to granular, predictive insights. Through the full digital backbone Siemens provides, AI can tell operators if spare parts are available or order them, identify who is certified for this repair and much more, all to minimize the downtime of the aircraft," said Colombo.

On a more general scale, "The daily workflow of a maintenance technician on the ground is changing dramatically in a fully digitalized airline," Martens said. "While technicians used paper-based systems in the past, they are now using tablets or smartphones to get and sign off on work orders."

In Dassault Systèmes' case, their virtual twin console helps fleet engineers to update maintenance assets and technical documentation painlessly. "When a design change or a service bulletin has to be implemented, the fleet engineer has to analyze all the possible in-service configurations to implement a change," explained Kornberg. "This is a cumbersome task that consumes a lot of time. The virtual twin solves this problem by displaying all the possible configurations. The fleet engineer can then make their choice and implement the change only once."

Digital twins can provide a real-time, holistic view of components across a fleet. This overview can be used to precisely predict component lifespans based on actual operational data, enabling optimized, condition-based maintenance planning says Siemens' Paolo Colombo.

ROI: Are Digital Twins and Threads Worth the Cost?

It takes a lot of time and money to implement a digital twin system, and ROI (return on Investment) is a big priority for the aviation industry. So, is this technology worth the expense?

According to Paolo Colombo, the answer is yes. "The ROI is very concrete and measurable," he told Aviation Maintenance. "Industry studies and airline programs report double-digit reductions in AOG (Aircraft on Ground) time, often 15 to 30 percent; improvements of 10 to 20 percent in spare-parts inventory efficiency; and material reductions in No Fault Found removals, depending on fleet maturity, data quality, and operational scope."

What makes this ROI tangible is where the value shows up operationally. "AOG improvements are driven by earlier fault isolation and better decision-making before an aircraft ever reaches the gate, which shortens troubleshooting cycles and avoids cascading delays," said Colombo. "Inventory gains come from higher confidence in parts conditions and demand signals, allowing operators to position the right parts at the right stations instead of buffering uncertainty with excess stock. Reductions in No Fault Found removals stem from improved diagnostic precision — maintenance actions are more targeted, so components are removed because they are likely to be faulty, not simply because there is a suspected issue."

Most importantly, these benefits are spread across the entire maintenance ecosystem. Fewer AOG events reduce downstream disruptions to crew, schedules, and customer recovery costs. More accurate parts usage improves relationships with MROs and suppliers by stabilizing repair flows.

"Over time, the organization shifts from reactive maintenance to a more predictive, evidence-based model, where each avoided disruption reinforces the business case," Cervellera said. "The result is not a theoretical ROI, but one that is visible in daily operations, maintenance planning meetings, and network performance outcomes."

Frank Martens has a different take on this question. From his perspective, the ROI from digital twins can only be calculated by each airline and depends on the processes implemented to react to digital information and how this information is used. "It also depends on aircraft and engine types and other data connected," he said. "And it is also up to the airline to select the digital solutions they want to use."

Barriers to Widespread Adoption

Clearly, digital twins and digital threads offer real value to MROs and their customers. However, widespread adoption

of this technology has yet to take place. But why?

"Widespread adoption faces a combination of factors," said Colombo. "Data standardization and integration complexity are major hurdles, as organizations grapple with silos and inconsistent data formats, demanding significant data engineering effort. The initial investment cost for software, sensors, and infrastructure must be budgeted, requiring strong business cases. Organizational change management and potential workforce resistance are also critical, as implementing digital twins fundamentally shifts work processes. There's also a skills gap in areas like data science and IoT, and significant cybersecurity concerns with connecting OT and IT systems. Finally, a lack of clear strategic vision can hinder successful implementation."

The "newness" of digital twins is also an obstacle. For many airlines and their MROs, "This is a new land," Kornberg said. "Since we are in a phase where companies do not want to take many risks, we need to demonstrate the value of technology innovation, and the costs of relying only on legacy IT systems. That said, we are seeing a growing adoption of virtual twin technology across industries. Powered by AI, virtual twin experiences can revolutionize product development, lifecycle management, and supply chains and their operation. Relying on IT legacy systems to bring products and new innovations to market simply cannot be the foundation of a growing business in the age of AI."

"The digital transformation of an airline is a very complex endeavor that can take many years to be completed, but it's worth it for many reasons," added Martens. "Besides efficiency gains it also increases the reliability of an aircraft fleet. This being said, in the process of digital transformation some airlines may face issues with data. Sometimes it's the quality, the format or the accessibility. Legacy IT systems that do not provide industry standard interfaces could also be an obstacle, but many airlines have proven that digital transformation is not only manageable but delivers great results."

The Impact of AI

There is no doubt that AI is transforming every industry it touches. The experts we interviewed expect it to have the same significant impact on digital twins.

"AI and predictive modeling will dramatically evolve digital twins, leading to even more sophisticated capabilities," Colombo predicted. "We'll see enhanced predictive accuracy, moving beyond simple failure prediction to understand how and when components will fail, enabling ultra-precise, condition-based maintenance. Assets will become more self-optimizing, with digital twins suggesting real-time adjustments for efficiency or extended life. Autonomous data collection and initial analysis by drones and robots, guided by AI, will highlight anomalies for human review. These 'cognitive' digital twins will reason through issues and recommend optimal actions. However, the human element will remain absolutely central. AI will serve as a powerful assistant, augmenting the capabilities of technicians and engineers, providing deeper insights and faster information. Their role will evolve from reactive problem-solvers to proactive strategists, leveraging these advanced tools for unprecedented efficiency, safety, and performance."

"AI will assist technicians and engineers for improved quality and efficiency and will not replace them," agreed Kornberg. "We believe that technologies like virtual companions will help humans in their daily work, enabling humans and AI to collaborate safely, intelligently, and at scale on the most complex industrial challenges. While AI companions will empower professionals with new expertise, humans will still make decisions especially in the highly regulated aerospace industry where safety is the number one priority."

Frank Martens believes that nothing is changing the MRO industry and driving the development of new solutions more than digitalization. "It is the only game changer of this decade," he said. "With 50 times more data being generated by new aircraft types and approximately 50% of airline operating costs consisting directly or indirectly of MRO services, further cost reductions can only be accomplished through MRO and operational optimization through technology."

But don't count the humans out quite yet. "Especially in technical operations, the aviation industry will always depend on highly trained and dedicated professionals — no matter how advanced digitalization becomes," Martens concluded. "While new technologies, data-driven tools, and automation continue to enhance efficiency and precision, they can never replace the deep expertise, critical judgment, and hands-on skill of our people. At Lufthansa Technik, our employees remain our greatest asset: their knowledge, experience, and commitment are what keep aircraft flying and our industry moving forward." AVM