Digital Transformation of the Aviation Enterprise

Submitted by GE Aviation Digital Solutions

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Most large military organizations around the globe are confronted with the challenge of keeping sophisticated systems working efficiently and effectively under financially constrained conditions. As global threats become more complex and more numerous, countries are facing the challenge of delivering significantly more capabilities without significant budget increases. The result is often lower readiness and availability of critical assets as investments in maintenance, training, and modernization are short-changed to generate near-term operational capability.

One way to get a handle around these pervasive challenges is through the better collection, analysis, and use of data from the assets, processes, and people that make up military organizations. Data can provide real-time visibility into the condition of critical equipment. It can be used to feed analytics that predict asset failures, project optimum spares levels, or reduce turn-around time within depots and MRO facilities. Data can help us understand what is happening, what is going to happen, and how we can change our behaviors to drive optimal outcomes around readiness, cost, and performance.

Data-Driven Transformation

There are some very significant obstacles, however, that today prevent
even the most digitally-sophisticated militaries from realizing the potential inherent in the data that they collect today and will collect in ever-greater quantities in the future. Some are obvious, such as cybersecurity concerns, while others, like IT system interoperability challenges and bureaucratic struggles, tend to be both less visible and more difficult to overcome. The key to getting started down the digital path is to understand the journey, build the business case for change, and establish proof points that build a constituency to undertake the hard work of getting systems and people to work together for the greater good.

In this paper we will discuss how Air Forces can start thinking through and planning their own digital transformations as well as provide examples of cutting-edge technologies already in use that can be leveraged in those efforts.

**Thinking about Digital Transformation**

At GE Aviation Digital Solutions we work with companies and organizations in the commercial aviation and military domains to help them solve their biggest challenges by unlocking the power of their data. Although GE Aviation's heritage is built on our engines, our digital solutions can meet customer demands at one or more of four levels:

- **Engine**: A combination of advanced data science and engineering expertise provides the ability to track operational life on engines, improve performance based on real-time data, and predict failures weeks or months before they happen. The result is longer engine life, lower cost of operations, and improved mission effectiveness.

- **Aircraft**: Many of the same tools that enable prediction and optimization of maintenance events at the engine level can be applied to the full aircraft, as well. GE can combine industrial data science, a thorough understanding of supply chains and MRO operations, and a platform that allows for partnering with other OEMs, to create a holistic airframe-level optimization solution.

- **Fleet**: While maintainers and operators are most interested in the health of individual aircraft, battlespace commanders and program managers are generally looking for information on the health of a unit or fleet. What problems are endemic to this airframe or operating environment? How many ready aircraft do I have available to fly right now? Can I help my pilots operate the
aircraft more fuel efficiently? Digital tools can help answer these questions based on the same single source of truth informing maintainers on the flight line.

- Enterprise: Digital transformation is ultimately about making aviation and military operators more efficient across their entire enterprise. That means tying disparate systems like design, engineering, manufacturing, operations, and sustainment together in a digital thread that enables rapid insights and cross-functional visibility.

Depending on the unique needs of the organization in question, it may make sense to start exploring the impact of digital transformation at different levels of the schema above. For organizations where engine data is the most readily available, or engine maintenance challenges are a significant driver or cost, downtime, or both, then starting at the engine level make eminent sense. For organizations with the principal goal of understanding health of equipment in a unit to make better operational decisions, aircraft and fleet-level efforts will bear the most fruit.

Our team at GE Aviation Digital Solutions is focused on helping our customers reassess asset utilization and performance, productivity and operational outcomes using best-in-class digital analytics-driven insights. Rather than simply launching into projects or rushing to sell products, however, we like to begin by really understanding those outcomes that matter most to each customer and the availability of data to impact them. We use a five step, services-driven approach to create a roadmap for each effort.

- **Step 1: Discovery**

  We conduct on-site interviews and a readiness assessment, all tied to your organization’s desired outcomes and to help you understand how digital can improve your business performance and capabilities.

- **Step 2: Workshop**

  Participate in a deep-dive workshop with GE experts to co-design your digital transformation blueprint, a structured approach to achieving your desired business outcomes through data and analytics.
Step 3: Proposal

Define how GE will partner with your team to take you through a digital transformation leveraging our proven products and services.

Step 4: Execution

We begin to unlock the value of your assets, leveraging your data for human insights at machine scale. Improve processes across your enterprise for better decision-making, revenue loss prevention and increased asset utilization.

Step 5: Extension

Build upon your existing digital investment, adding expertise in predictive analytics, asset health, intelligent asset strategies, airline network operations and operations excellent to your existing software solutions.

In our experience working with dozens of airlines and militaries globally, following this process leads to better and more demonstrable results that create a self-sustaining momentum behind digital transformation. Our advice is to beware of vendors with one product that they claim solves every problem.

That said, there are some common needs that crop up again and again across military and civil aviation and, rather than starting with a blank sheet of paper, GE Aviation Digital Solutions has matured technologies that can be pulled into our customers' transformation roadmaps to accelerate their journey.

**Capability 1: An Industrial Internet Platform**

It is easy to underestimate the challenges in making an important ‘data driven’ transition in technology and business model. That requires new capabilities in software development and analytics. It will motivate the adoption—and nurturing—of new partnerships, operational models, and opportunities.

Ultimately however, most transitions fail because they underestimate the complexity, pervasiveness, and organizational impact of the challenge as well as the technology needed to underpin that shift.
• Industrial data is growing twice as fast as any other sector. Yet today, less than 3% of that data is tagged and used in a meaningful fashion\(^1\)
• Data sets can be fragmented and siloed such that they can’t be used elsewhere in the organization
• Operational technology (OT) and information technology (IT) systems often operate separately, leading to duplication as the roles these functions play in organizations converge
• Edge devices are not always connected, maybe air-gapped due to privacy/regulatory/security implications, or may need to continue operating when the connection is temporarily unavailable
• Applications may need to adapt to local conditions at the edge in real-time and so won’t be able to wait for the data to get to the cloud, be analyzed, and be able to send back insights
• Diverse practices lead to performance variability as many of the best practices are used in some but not all parts of an organization
• And, even though there are islands of excellence that meet various key performance indicators (KPIs), opportunities may be missed if those KPIs are

Tapping into the power of an Industrial Internet platform can help companies get the answers to the questions above that they need. The platform should:
• Be machine-centric
• Support heterogeneous data acquisition, storage, management, integration, and access
• Provide advanced predictive analytics
• Guide personnel with intuitive user experiences on their device of choice
• Be delivered securely in the cloud and at the edge

That’s why GE built Predix – the Industrial Internet platform. By packaging its own capabilities and transformation experience, GE created Predix to guide industrial companies through this complex technology and business transition, putting them in charge of their IIoT journey. By using this comprehensive platform, businesses can create innovative apps on Predix that turn real-time operational data into actionable insights. Predix equips them with everything they need to rapidly build, securely deploy, and effectively operate industrial apps.

**Capability 2: The Digital Twin**

A digital twin is a digital representation of a physical asset. The “twin” assumes control over the operation of the asset and helps drive new insights based on observation of the twin asset.

For instance, if full flight data is available for an engine, a digital twin can determine whether a part will break far ahead of time, enabling condition-based maintenance with unscheduled downtime.

Just as your personal profile on Amazon differs from your profile on your company’s HR system, a physical asset can have multiple twins that function for different business outcomes. Information from the digital twins is rolled up to the engine level to determine the overall maintenance and workscope schedule, engine optimization and health, among other information.

In one instance, GE used Digital Twins to address a challenge with a component on our GE90 engine that was limiting the time on wing (TOW) of a Middle East region fleet. Analytics allowed us to effectively segment the fleet and isolate the issues unique to the region. Using an analytic, we produced an exact transfer function between part life and engine operation. Using data science techniques, we built these transfer functions, coupling engine operational data with environmental data, air quality and city pair information.

This process allows us to expand our ability to build complex, multi-
variable predictive models to accurately segment beyond the capability of ordinary physics-based models. Implementation of the analytic, coupled with climb de-rate and optimized water wash processes, achieved a reduction in the distress of this specific component.

In a different instance, GE used another type of Digital Twin, called a cumulative damage or cumulative distress model (CDM), to effectively guide the workscope content on an engine at a component and ESN level. In this cumulative distress model the distress variation is driven by the variation in the operation (i.e. how it is flown and where it is flown). This type of analysis is only possible when the data is available. The state of distress at removal determines the level of repair or replacement required. Predictive analytics allow us to have the parts ready and to specify the necessary workscope.

Finally, GE uses Digital Twins for early detection of anomalous mechanical events and offers remote monitoring and diagnostics as a service for customers around the globe. This early warning capability allows aircraft operators to swap aircraft or perform required maintenance before a piece of equipment fails, allowing them to achieve their mission at higher reliability and lower cost.

In one example, GE detected increased exhaust gas temperature of a jet engine. The increases in exhaust gas temperature were accompanied by an increase in fuel flow and a drop in compressor speed. The changes in all 3 parameters were seen in both takeoff and cruise operation. GE generated a high priority notification to the customer monitoring center and the customer ordered the plane taken out of service and re-routed to a maintenance station. A borescope was performed on the engine. The borescope found that a portion of a high pressure turbine (HPT) blade was missing.

If the customer had not received notification from GE, the engine would have remained in operation and additional damage to the engine would have resulted. In addition, if the issue had continued to progress, it would have resulted in an in-flight shut down of the engine, which would have resulted in an increased safety risk and increased operational and maintenance costs.

**Capability 3: Industrial Applications**
The true potential of digital transformation for military organizations will be reached when digital twins running on a dedicated industrial
internet platform are married to powerful applications that enable better decisionmaking at the human level. Whether these applications are brand-new, cloud-native, and custom-built or are refactored commercial legacy applications moving from a data center to a secure cloud, the value is in the outcome they deliver for the warfighter. We highlight two applications, Asset Performance Management (APM) and Digital Maintenance, Repair, and Overhaul (Digital MRO) below.

**Asset Performance Management (APM)**

APM provides the ability to manage the lifecycle of an asset, including optimizing maintenance activities. The components of APM are described in the figure below.

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**Readiness**

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![Readiness - Failure Curve Diagram](image-url)
As shown in the diagram, equipment failure typically starts slowly and then reaches an inflection point following rapidly by failure. The goal of asset performance management is to catch and eliminate failures as far up the curve as possible. Doing so enables increasing advanced notice of equipment failure, culminating in a prescriptive approach that enables an asset maintenance strategy based on definitive risk assessment techniques.

The objective, of course, is to operate at a point where readiness is highest and maintenance costs are lowest, the upper left of the curve. APM provides modular capability to move from Break/Fix to Reactive to Proactive, and finally to Prescriptive asset maintenance management.

Digital Maintenance, Repair and Overhaul (Digital MRO)

MRO or Depot activities are critical to managing asset lifecycles. GE Digital MRO offers an integrated suite of four products that together help manage your asset operations, removals, inductions, material and capacity planning and availability, engine workscoping, test cell operations and financial impact. These four modules are described below, along with the documented impact from implementing the technology in GE’s own MRO shops.

1. Slot Tracker visually coordinates the flow of information and assets into the shop, minimizing wait time for new slots and unfilled (wasted) slots. Using Slot Tracker enabled GE to quickly achieve a 34% improvement in missed slots, from 246 to 163.

2. Enterprise Workscoping dynamically creates a standardized workscope and contains the amount of work escalations. The tool provided GE with a 5% reduction in overhaul costs and a 7-day reduction in power plant burden to workscope a single engine, from 8 to approximately 1.

3. Operations Advisor provides a full network view of work in progress, and a thorough comprehension of any constraints.

4. Test Cell Scheduler ensures visual coordination of asset flow and troubleshooting until the asset is out of the shop, resulting in maximum use of output test facilities.

Conclusion: The Opportunity Ahead

As the Royal Singapore Air Force and other military organizations take steps towards embracing digital transformation, they will face an
overabundance of choice in tools, a paucity of clear roadmaps to success, and a host of challenges moving from siloed systems to seamless connectivity. It is important that the right stakeholders inside the RSAF share a vision for where they want to start the journey, whether at the engine, aircraft, fleet or enterprise levels.

Gaining that level of clarity often requires working closely with digital experts who can properly define the right outcomes, obstacles, and opportunities along the path. With a plan in hand, the next step is building solutions that can deliver results. In GE's experience as a leading digital industrial company, we have found that the powerful combination of an industrial internet platform, digital twin technology, and proven applications is the best path to deliver results that matter.