Digital Technology Innovations Converge to Transform MRO

By Tom Hennessey, VP of Marketing and Business Development at iBASEt

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MRO modernization is fueled by innovations in digital integration, 3D modeling and printing, IoT, UAVs, robotics, analytics, and AR.

Maintenance, repair, and overhaul (MRO) activities are critical to the lifecycle of highly engineered products. Safety, reliability, and regulatory compliance issues are obvious MRO mandates. The scale and scope of investment is also paramount—after all, airplanes can't be replaced like broken dishwashers. As demand escalates and resources shrink, MRO enterprises must become more advanced and efficient to stay competitive.

In aviation and similar industries, Smart Manufacturing is having a profound effect on MRO processes. Advanced analytics, IoT sensor data, cyber-physical systems, and integrated digital technology processes are modernizing MRO and boosting productivity and quality to unprecedented levels. The model-based enterprise (MBE) approach uses engineering 3D models in conjunction with digital manufacturing innovations to optimize inspection, spare parts management, and execution of repair work.

Digital Thread and Digital Twin

Two concepts comprise the core of the MBE vision and practice —digital thread and digital twin. These paradigms emerged from the military aircraft industry and their desire to improve the performance (and cost) of future programs by analyzing data captured digitally from end-to-end throughout a product's lifecycle, starting with design and extending through MRO.

The digital thread is a communication framework that enables connected data flow throughout the lifecycle and across traditionally segmented functions (design, engineering, production,

maintenance), ensuring an integrated, authoritative, up-to-the-minute view of the asset's data that can be accessed at any point along the way.

The digital twin is the digital model of a particular asset (product) that includes design specifications and engineering models describing its geometry, materials, components and behavior. More importantly, it includes the as-built and operational data unique to that specific physical asset (for aircraft, the "tail number"). The digital twin includes engineering changes made during production and deviations from original design, as well as inspection, operation, and MRO data.

In the context of aircraft maintenance complexity, it's easy to see how these comprehensive, harmonized digital records and models help minimize downtime, streamline regulatory compliance, and ensure excellence.
In addition to these (often still conceptual) models of digital integration, there are more tangible technologies that support work in the MRO shop. Following are brief descriptions of several innovative capabilities that are already driving real world progress toward the MBE ideal at leading MRO hangars:

3D Printing of Spare Parts

3D printing is already revolutionizing prototyping and production in many industries, including medical device manufacturing. In the MRO enterprise, 3D printing has the potential to transform spare parts inventory practices. Manufacturers of spare parts will store the digital data necessary to print parts and components in CAD software instead of storing physical parts on shelves, with obvious benefits to storage and distribution costs, inventory turnover, and time to repair (MTTR). 3D printing can also be an efficient solution to procuring hard-to-find or discontinued spare parts.

Automation with Robotics and UAVs

The rapidly expanding capabilities of autonomous equipment such as Unmanned Aerial Vehicles (UAVs) and robots are being leveraged in MRO shops. Automated inspection tasks are among the first applications. For example, UAVs capture images, compare them against the respective 3D models (digital twins) and quickly report any damage requiring further inspection

or repairs. Each inspection can be shortened by several hours, and work can be performed more accurately and safely (especially in hard to reach spaces).

Asset Sensor and Diagnostic Connectivity via the IoT

Technology advances now enable us to embed microcomputers in many devices and assets, which can then be connected to and exchange data with other systems and centralized data repositories (IoT). By analyzing exceptions and aggregate performance data against the asset's 3D model, engineers predict and diagnose issues as well as enhance future designs. By relying on sensor and usage statistics instead of a schedule of prescribed intervals, routine maintenance can become much more efficient and timely.

Advanced Guidance with Augmented Reality and Natural Language

Augmented reality (AR) is the ability to layer digital 3D images and virtual objects on top of the real-world images with the aid of smart glasses or hand-held tablet computers.

In MRO shops experimenting with the technology, AR recognizes the asset a user is examining, overlays the points where service is needed, and provides the necessary instructions and diagrams via integrated tablet interface. In combination with automated inspection methods (e.g., UAVs, sensor data) augmented inspection results could also be projected directly onto the asset's physical surface.

As natural language capabilities mature, voice driven interaction with smart glasses and tablets will enable hands-free interaction and even the ability to "chat" with the device in a more natural manner.

Advanced Analytical Capabilities

The ability to make more complete and nuanced use of the data collected by sensors in manufacturing equipment and products as well as by operational and business management systems will increasingly drive progress toward the MBE vision and realization of functional digital threads. More specifically, predictive and prescriptive analytics could radically improve how maintenance activities are planned. Today, most maintenance activities are planned based

on a combination of elapsed time and asset usage frequency, which leads to both excess and insufficient maintenance.

Through these examples of MRO innovation, the path to the fully model-based future of manufacturing is elucidated. As MRO spending and market pressures increase in the coming years, digital technologies will prove to be a key competitive differentiator in many industries. These innovations require experimentation, strategic implementation, and skill development. Don’t delay—digital transformation travels at jet speed.