ptc

Digital Thread for Additive and Agile Manufacturing

Digital Thread beyond Design-for-Additive Manufacturing

Extending Additive Manufacturing with Lifecycle Management, Data Connectivity, Analytics, and IoT-based Production Management

WHITE PAPER

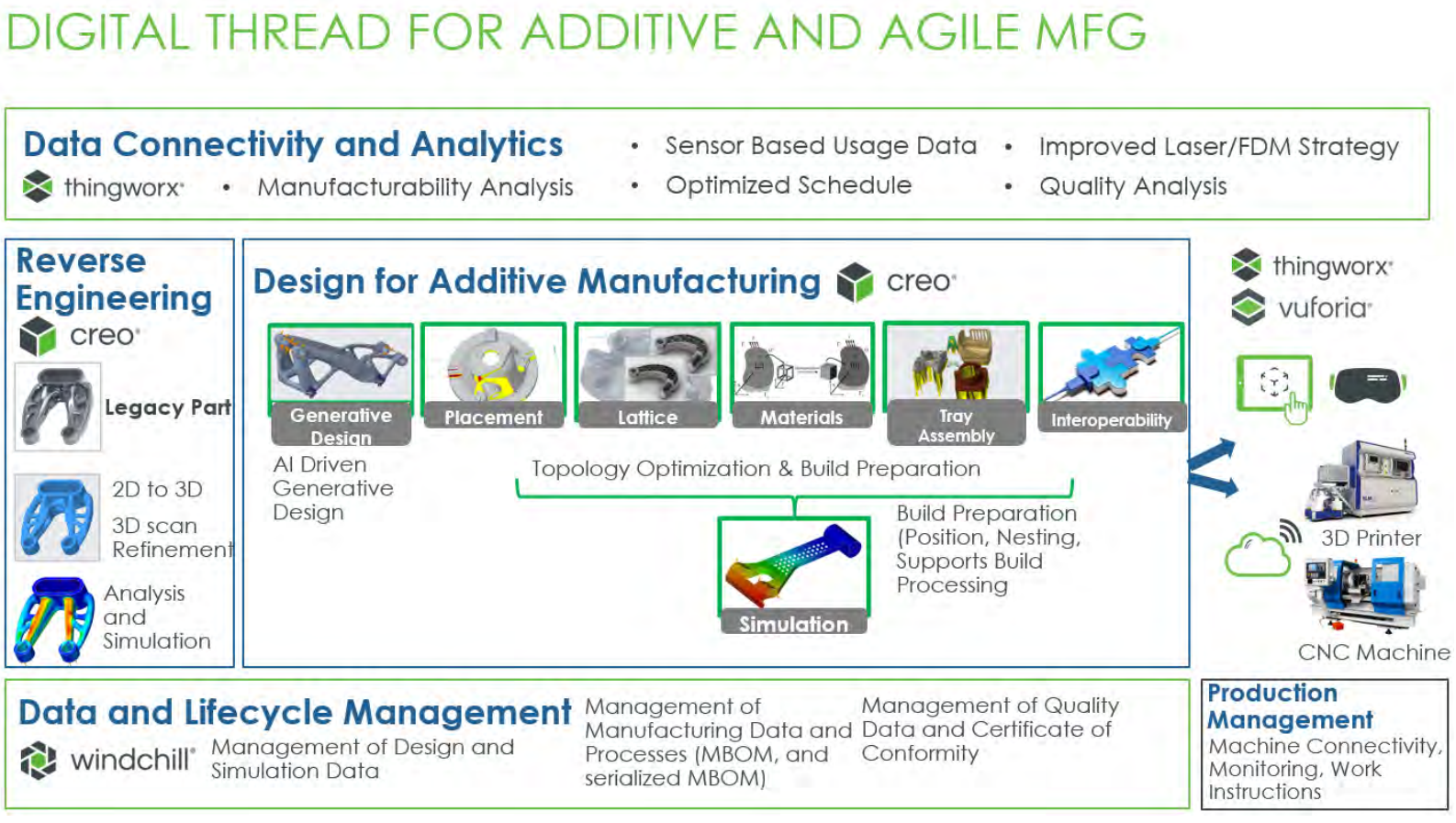
Digital Thread for Additive and Agile Manufacturing Executive Overview

PTC's Additive and Agile Manufacturing solution is based on multiple state-of-the-art technologies. The solution addresses and connects multiple disciplines: Materials Engineering, Design for Additive Manufacturing, Data and Lifecycle management, Production and 3D Printers management, into one solution. PTC 2D and 3D CAD tools with advanced generative design features help to design and re-engineer complex parts, manage, visualize and connect the data into 3D printers with advanced additive materials.

Solution Description

PTC Additive and Agile Manufacturing solution enables Digital Thread for Additive Manufacturing, which connects and encompasses multiple phases, such as:

- **Parts Request & Requirements –** Digital Twin models creation, with scanning, reverse engineering, AI-driven generative design and analysis
- **Parts Design –** advanced material engineering libraries, 2D designs into 3D models conversion, Solids and Lattice Structures analysis, visualization and simulation
- **Parts Build Preparation and Processing,** with light-weighting and topology optimization, build preparation, plan and processing, simulation and manufacturability analysis
- **Parts 3D Print and Production –** Optimized Fabrication Management, with MES connectivity, routing transfer, operator and work instructions (also via AR), print authorization and scheduling
- **Parts 3D Print Post-Processing** – Per-Part post-processing and finishing, with process monitoring, materials and parts tracking, materials supply automation, for an individual or multiple 3D printers'
- **Parts Validation and Verification –** Digital Twin Quality Analysis, with inspection, build data analysis, materials compliance, quality control against legacy, re-engineered parts and process performance analytics



Value Proposition

PTC Additive and Agile Manufacturing solution is a multidisciplinary Digital Thread Solution offering, based on an open framework of connected and interoperable, industrialized software products.

PTC ThingWorx IIoT Platform is a key component of the solution, enabling Digital Thread connectivity, openness and data integration with other legacy and commercial software systems and applications. The solution provides a set of configuration tools and APIs and can be implemented based on an organization's Additive Manufacturing best practices, various 3D printers and on-demand requirements.

The solution framework supports gradual and scalable deployment and integration, in which each phase (described above) can be deployed according to an organization's priorities. For instance, first CAD, Generative Design and Design Simulation for obsolete legacy parts re-engineering, advanced materials engineering and 3D models generation; and then after, 3D printing production planning, work instructions (also via Augmented Reality) and control.

PTC'S ADDITIVE MANUFACTURING SOLUTION

Overall Expected Savings

$45M Each Year Per Facility

Challenges	Use Cases	Operational Impact	Expected Value
Supply Chain Interruptions	Reverse Engineering Part that are FAA Certified	**10%** Quality Improvement	**$15M** Saved with Less Scrap & Rework
Strength to Weight Ratio Too Low	Additive Manufacturing	**12%** Reduction in Engineering Costs and Lead Time	**$10M** Gain with Improved Time to Market
Loss of Revenue From Rework and Waste	Manufacturing Mission Ready Spare Parts	**15%** Reduction in Production, Fabrication and Material Costs	**$10M** Reduction in Production, Fabrication and Material Costs
Long Lead Times	Airframe assembly and design optimization	**18%** Decrease in Service Costs	**$10M** Less in Logistics and Service Cost

PTC Additive and Agile Manufacturing Solution Offering Capabilities

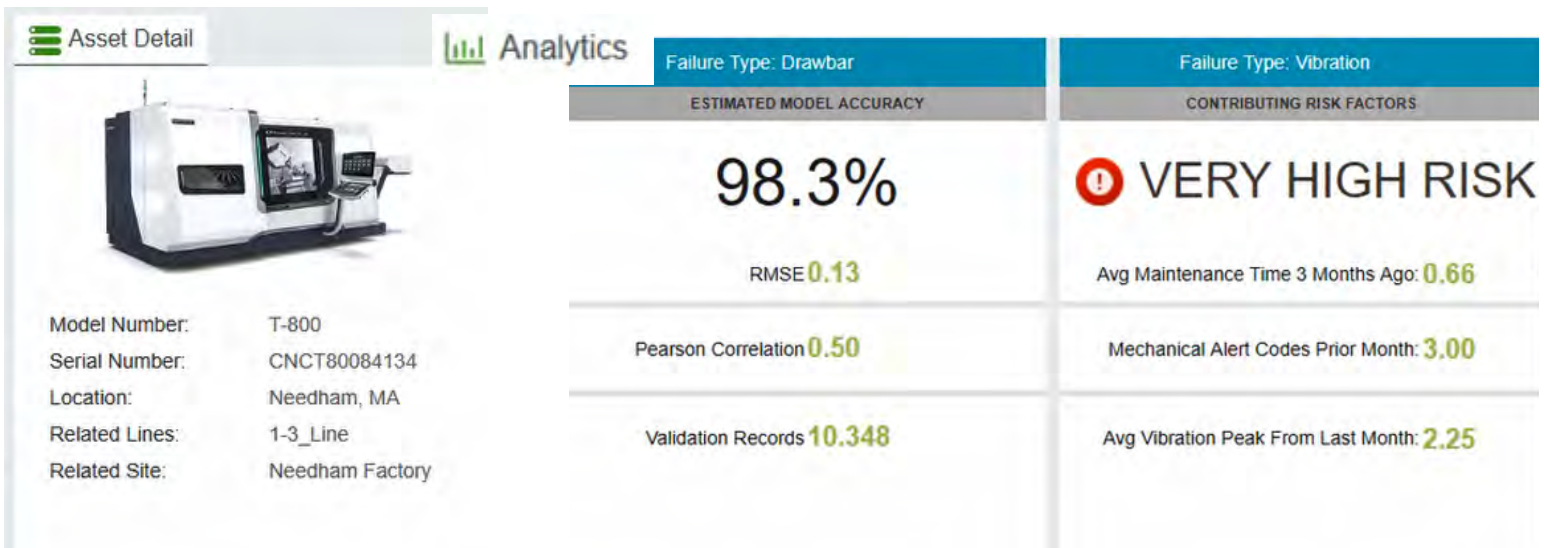
1. Industrial IoT Platform – ThingWorx for 3D Printers Production Management.

ThingWorx can be optimized for scheduling and data monitoring for team leaders and improves communication of scheduling updates for all operators. PTC has implemented a centralized and time-saving solutions for other major defense manufacturers. The platform can integrate with existing environments and interfaces with SAP, MRO or MES systems where production orders are generated and via this integration, flowed to the required machines for processing. The solution will replace siloed systems which are managed separately by the team leaders and represents a single source of real-time information, resulting in a more smooth-running operation. Dynamic scheduling capabilities can be created utilizing configurable business logic that provides the operator choices of machines based on job requirements, availability and cost.

2. ThingWorx Industrial IoT Data Analytics

ThingWorx provides end-to-end capabilities to connect devices, build IIoT solutions, extract actionable insights from data, manage the IIoT ecosystem, and create compelling end-user experiences. ThingWorx Analytics is not a separate product but a set of analytics capabilities in the ThingWorx platform that support the needs of IIoT application and solution developers so that they can unlock the value from their data. ThingWorx Analytics uses sophisticated artificial intelligence and machine learning technology to tackle the specific challenges presented by industrial IoT data. Through automation, ThingWorx Analytics delivers reliable, actionable insights in real-time to applications and AR experiences built on the ThingWorx platform.

ThingWorx Analytics is designed to simplify and automate the complex analytical process for IIoT solution developers that may not have expertise in data modeling, complex mathematics, statistical analysis, artificial intelligence, or machine learning.



Features Include:

- **Predictive Modeling –** Incorporate supervised machine learning into IIoT solutions.
- **Explanatory Analytics –** Better understand IIoT data. Through a variety of advanced algorithms, these procedures let users discover useful patterns and correlations within data.
- **Real-Time Monitoring –** Monitors data streams using a variety of statistical and machine learning techniques to learn "normal" conditions and identify unexpected changes in.
- **Predictive Scoring –** Predict future outcomes. ThingWorx Analytics functionality includes the ability to make predictions based on data.
- **Prescriptive Scoring –** Improve future performance and results. Automatically execute simulations to generate recommendations to optimize the performance of the product or process.
- **Digital Simulation –** Simulate behavior of physical products in the digital world. Simulation models bring deep product specific knowledge and subject matter expertise.

    - All data that can be obtained from the machine is available for use for dashboarding, analytics etc. Examples include system up time, configuration, consumption, predictive maintenance information, quality etc.

3. Openness, Connectedness, Configurability and Ease of Deployment

It is important to note that ThingWorx is an open and flexible application development platform that enables users/developers to rapidly build and configure their own applications with little to no code or software development experience. As ThingWorx is an application development platform, its true power is unleashed through users developing (configuring) applications for their own unique use cases.

ThingWorx Kepware Server, powered by Kepware, is a single solution for collecting, aggregating, and providing secure access to industrial operations data that serves as the communications bridge between diverse hardware and software applications. Its platform design allows users to connect, manage, monitor, and control diverse automation devices and software applications—from plant control systems to enterprise information systems.

ThingWorx Kepware Server leverages OPC and IT-centric communication protocols to provide secure data access to industrial assets, including 3D Printers. Its library of 150+ device drivers, client drivers, and advanced plug-ins enables access to thousands of devices and other data sources, providing visibility across the enterprise for improved decision-making from the shop floor to the top floor.

The entire set of functionalities of the ThingWorx platform is exposed through a series of secure REST APIs to allow other systems to easily connect and interface with the platform through standard web transactions. ThingWorx provides full support for REST/SOAP calls into ThingWorx as well as REST/SOAP calls out of ThingWorx to other systems. ThingWorx provides nearly 100 API services with hundreds of API operations in aggregate. These services enable metadata manipulation of the runtime components and provide deep application integration capabilities.

4. Integration and Interoperability of Digital Twins, MES and ERP Systems

ThingWorx allows users to incorporate and aggregate data from anywhere: Sensored products and systems, PLCs, IoT gateways, existing product clouds, and business systems such as CRM, ERP, and PLM, among others.

ThingWorx Flow is an integration platform that enables users to automate tasks by connecting to on-premise systems, cloud systems, and devices with a visual workflow canvas.

In ThingWorx Flow, a workflow can be configured to be executed by external system events, via triggers, or by an external invocation via a webhook URL.

The steps in a workflow are actions that invoke RESTful services on third-party systems. Each action is configured with a connection for authenticating and with the input data to be passed to the third-party system. The output data from these actions can then be used in subsequent actions in the workflow.

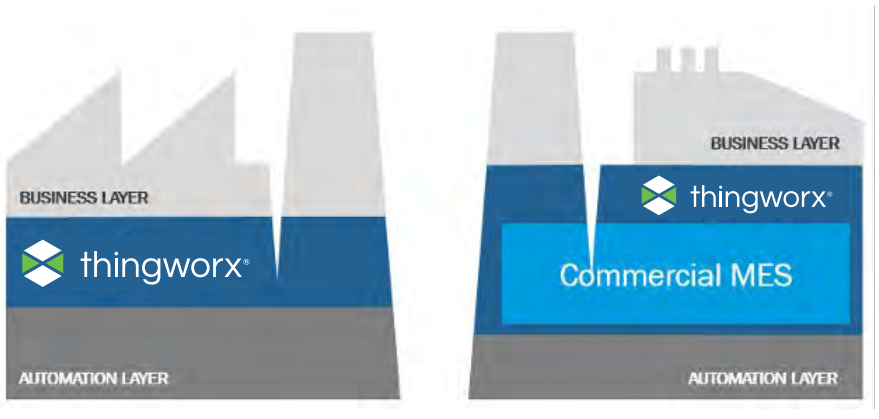
ThingWorx Flow offers various advantages such as:

- **Reducing time, effort, and skill to connect systems and devices**
- **Easy creation and modification of visual flows without programming**

ThingWorx can be used to rapidly create MES solutions aligned with unique requirements. In addition, ThingWorx can be used to supplement a variety of commercial MES.

Commercial off-the-shelf MES has merit and applicability. Additive manufacturing business processes could be similar across various 3D Printers and manufacturing modes, however, such printing processes need to be modeled for particular fabrication procedure. MES extensions are needed to model work processes that often span multiple software systems, enforce unique organization specific business rules, align the commercial MES with a manufacturing mode it might not be suited for (discrete, batch, continuous), or align the commercial MES with a manufacturing strategy that it might not be suited for (engineer to order, make to order, make to stock).

ThingWorx can be applied to supplement the commercial MES by rapidly creating interfaces to business systems and factory assets, creating rich interactive composite user interfaces spanning multiple systems, and creating applications to fill functional whitespaces.



ThingWorx can also be used to create a unique MES perfectly aligned with specific functional requirements. This approach is valid when a costly, time consuming, and full breadth MES implementation is not practical due to cost constraints, time constraints, far-reaching ERP, far reaching automation layer, lack of automation, manual processes, and or required agility. In this case, ThingWorx can be used to create an inexpensive "Light" MES. ThingWorx can also be used to extend a manufacturing-oriented ERP system to the factory floor by providing role-based, easy-to-use operator user interfaces and supplemental data collection. For example, ThingWorx could be used to create a web front end for production and consumption reporting to ERP.

The ThingWorx Operator Advisor allows organizations to transform their performance by giving operators on the shop floor direct access to all the data from various systems within a single screen. Users can access order specific, up-to-date accurate information, and improve product quality and user productivity by guiding and monitoring the execution of the work. There are 5 major components to the ThingWorx Operator Advisor. Every component has an underlying ISA-95 based data model to allow data from any system to be sourced and immediately contextualized in the platform, as well as contained UI components that can be used as standalone screens or embedded within other mashups.

- **Work Orders sourced from an ERP systems.**
- **Work Instructions sourced agnostically.**
- **Execution Control:** allow operators to broadcast exactly what they're doing when and understand where each work order is in the process.
- **Machine Connection:** allow operators to understand exactly what is going on with the machines they are working on, reusing data sourced from asset advisor.
- **Operator Data Collection:** collect reason codes, quality data, alarms and notifications directly from the Operator.

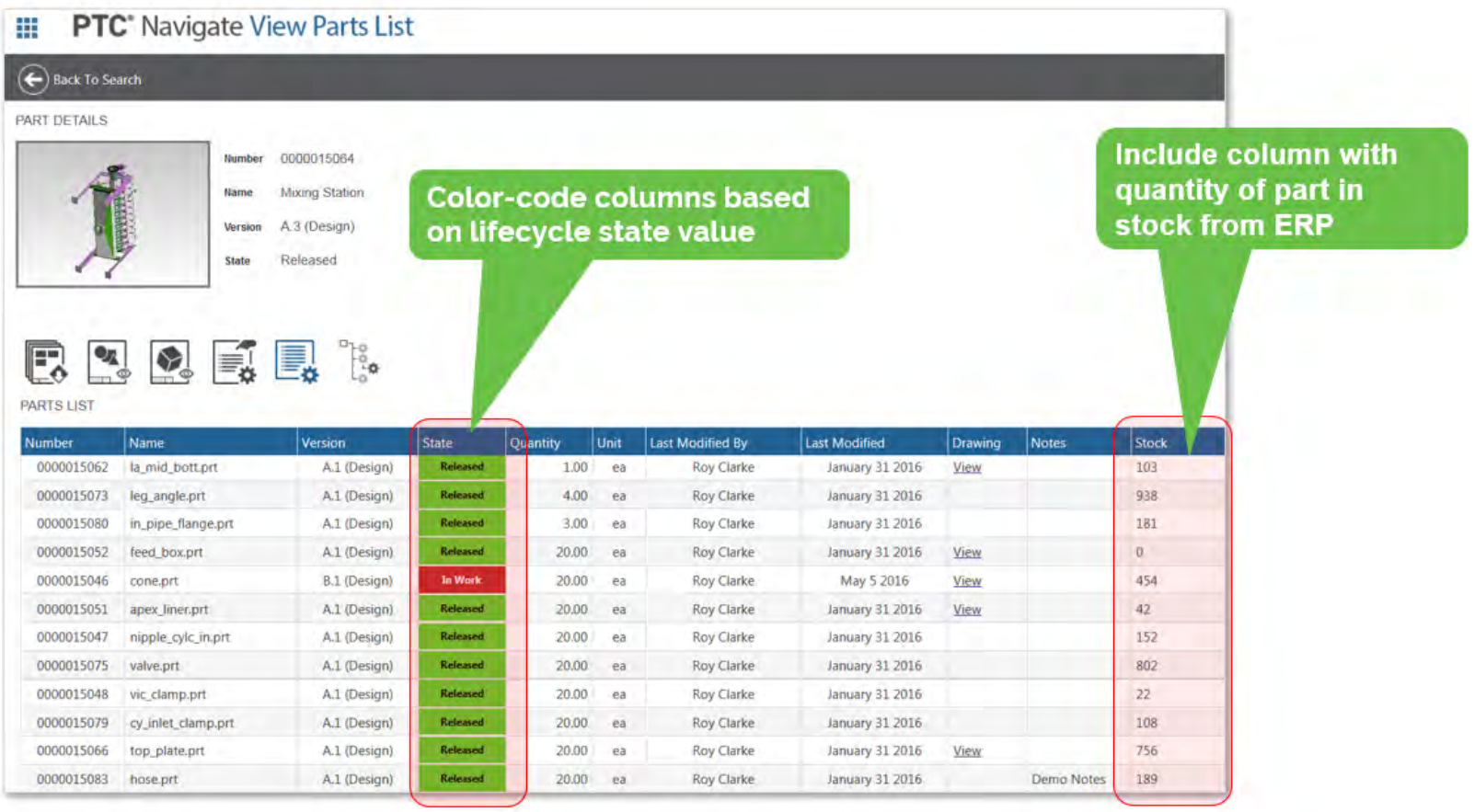
5. Parts Digital Twin Lifecycle, Data Continuity and Materials Inventory Management

ThingWorx provides product data access though its integrations with Windchill PLM System. Parts can be identified when selecting the part from a tree or on the 3D CAD directly.

Through the integration of ThingWorx with Windchill, part creation and versioning are managed so that operators are always presented with up-to-date parts and work instructions. Through Creo Parametric, applicable parameters can be incorporated into the .pak file and managed on the part structure. This information can then be exposed to the operator when prompted to print the order. Unique identifiers are generated by job orders throughout the production process and can be managed in the ThingWorx Platform.

When enabled, the Classification and Reuse option creates a repository for part and supplier data that can be searched based on classifications and parameters. This allows customers to consolidate suppliers, standardize parts, manage multiple part number schemes and promote the reuse of design and component knowledge across the manufacturing organization.

Source materials, such as metals, plastics, etc., can be managed in Windchill as a part. If it is managed in a separate Parts Store, then as long as there exists a Database and/or APIs to perform GET, POST, and PUT functions, then the Source Material attributes (such as pricing, availability, etc.) can be integrated and managed in ThingWorx. Once managed in the ThingWorx platform, subscriptions to those attributes can trigger alerts or notifications via standard communication protocols (e.g., text messages, emails, etc.).



6. Solution Architecture, Security and Deployment

The ThingWorx Platform can be deployed in a variety of ways: In the cloud, on-premise, or with a hybrid approach. The ThingWorx Platform's integration with leading cloud vendors, such as AWS IoT, Azure IoT Hub, and GE Predix, enables organizations to seamlessly have the best of both worlds––the cloud service of choice and all the rapid development capabilities that the ThingWorx Platform provides

Due to the open and extensible nature of the platform, ThingWorx relies on a shared responsibility model for security. ThingWorx enables users to create applications flexibly with respect to the security features of applications. ThingWorx helps customers to build secure IoT solutions by supporting:

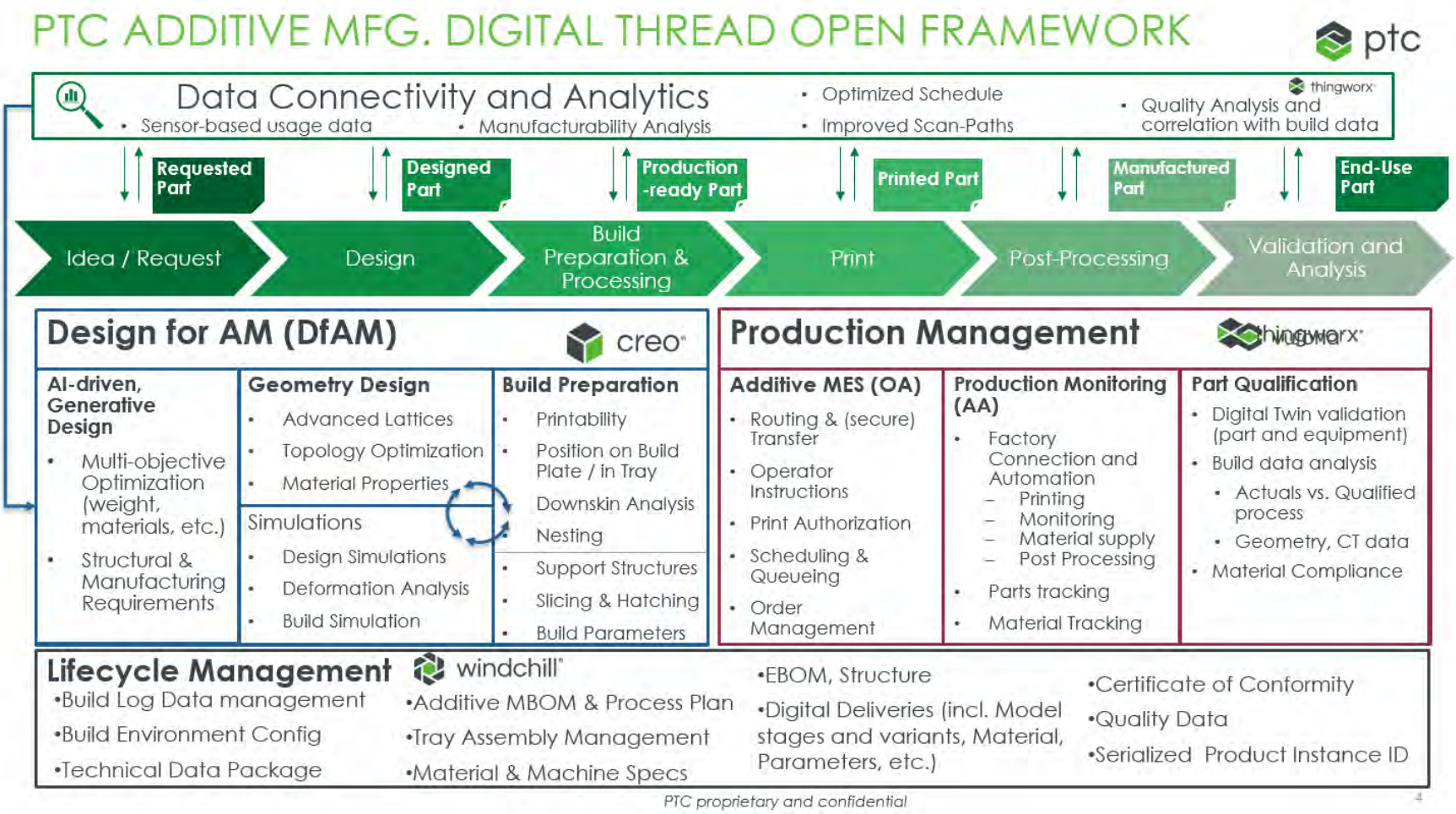
- **Extremely flexible permissions and visibility capabilities including Access Control Lists**
- **Design and runtime permissions down to the Property level**
- **Visibility based on organizational structure**
- **Robust user and group management**
- **Ability to remotely update edge devices for security**
- **Integration with Active Directory and Single Sign-on (via Ping Federate)**
- **TLS encryption**
- **Full audit trail of all actions in the development environment**

Windchill delivers superior capabilities for secure collaboration meeting ITAR and export control requirements. Specifically, these include:

- **Security Labels -** a classification scheme for business objects which tags content according to ITAR, export-controlled, and proprietary data management policies
- **The ability to associate export authorization agreements to business objects labeled using the new security schema**
- **The ability to define expiration periods for the authorized technology transfers**
- **Additional access control mechanisms and schemes**

PTC solution offering is based on several industrialized software tools, which can be deployed On-Premise or on Secure Cloud infrastructure:

- **ThingWorx IIoT, Kepware –** Digital Work Instructions, scheduling, job management, 3D Printers connectivity hub – for data connectivity, visualization and analytics, including Machine Learning, which applicable across all phases in the Digital Thread
- **Creo Parametric, Creo AMX and Creo Simulation Live –** Particularly, for Parts Request and Design phases, with AI-based Generative Design
- **Windchill PLM –** For data management, materials, suppliers, compliance and all aspects of Additive Lifecycle, which applicable across all phases in the Digital Thread
- **Vuforia AR –** For Augmented Reality capabilities during Production, Post-Processing and Verification phases



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