



DIGITAL TRANSFORMS PHYSICAL

Digital Logistics for In-Service Operations in Aerospace and Defense

**Digital Thread for Paperless Logistics
Connecting Engineering with Integrated
Logistics Support (ILS), Technical
Documentation and Service Operations**

WHITE PAPER





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PTC Digital Logistics for In-Service Operations

1. Disruption and Transformation of the Aftermarket Services in A&D

Digital technology can be applicable to many aspects of Logistics operations automating Logistics infrastructure, supply chains, shipping, distribution, warehousing, and many other disciplines of Logistics management. Manufacturing, Production and Service Logistics operations can be defined as interconnected subjects for broader Logistics processes and operations. This White Paper is focused on Engineering, Manufacturing and Service Logistics, which refers to all planning, coordination and service functions required to carry out manufacturing and assets in-service activities, including Integrated Logistics Support (ILS) business process.

In the A&D industry, on the verge of returning to normal and recovering from the COVID-19 pandemic crisis, OEM and MRO companies, in general, and their maintenance and in-service departments have experienced declines in spending of 40 percent or more⁽¹⁾. Therefore, they must adopt and implement disruptive changes and adjustments. Cost pressure, agility in demand management, balance of supply chain operations and access to a stable source of less expensive, yet certified, parts and new components, will be ever more important factors in A&D logistics and in-service operations. The ability to propagate engineering innovations and modern advances such as standardization, artificial intelligence and automation, downstream into maintenance operations - breaking silos between engineering, manufacturing, logistics and service - will become critical factor for success.

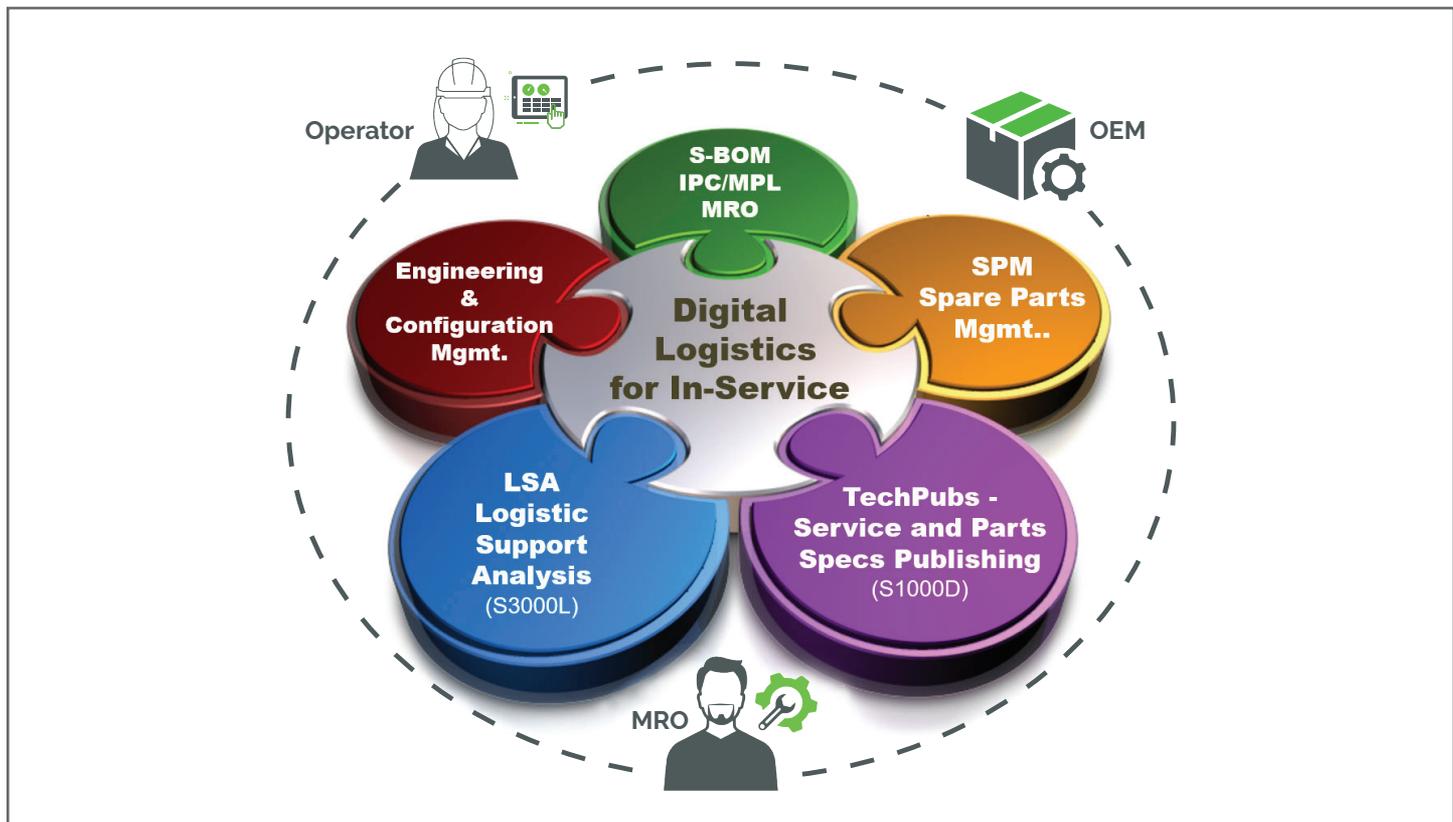
Complete process integration is essential from planning through to execution and fulfillment of part and service orders, based on the relevant, up to date maintenance documentation and service work instructions. This integration is necessary for complying with service-level agreements and keeping in-service operations efficient and, as a result, customer satisfaction as high as possible to remain competitive in the market.

Success in the aftermarket maintenance operations requires that A&D companies recognize the service as the product. As such, service offer differentiation, right logistic planning and efficient delivery of services will determine efficiency and profitability. The greatest differentiator is the quality of logistics and in-service operations with seamless interoperability to product design and engineering.

Airlines and equipment operators have choices when it comes to contracting maintenance and repair services and purchasing spare parts. There are many OEMs, MROs, maintenance repair companies and aftermarket parts vendors that are competing for this business. It is critical that A&D manufacturers and OEMs will provide required and standardized logistic and in-service support and must offer best-in-class interaction with their customers and maintenance organizations.

According to McKinsey report⁽¹⁾: Digital is the next horizon for global aerospace and defense, emerging from the COVID-19 pandemic downturn. It is the key for a more resilient, efficient, and innovative A&D company.

PTC Digital Logistics for In-Service Operations is a transformative solution offering that links design to sustainability through Digital Thread for paperless logistics, while supporting **S-Series Standards** for Integrated Logistics Support (ILS).



2. In the Past: Trading Efficiency for In-service Time

A&D maintenance and service companies streamline their operations to support serviceable equipment and fleets during their life. Service Lifecycle Management (SLM) for serviceable equipment is the key discipline that combines tools, infrastructure, standards, human skills, spare parts, cost, and other functional areas. However, maintenance and servicing organizations are struggling to identify and keep up to date maintenance documentation, which creates risk of missing or poor service information. Inadequate access to information for service planners and technicians can cause longer repair times and equipment downtime. Improper spare parts can be ordered for service; service issues can be unresolved; quality, compliance, and service level agreement (SLA) authorizations cannot be achieved.

SLM procedures can be complex and require a proper integration of information coming from many different OEMs and equipment manufacturers, for all existing serviceable equipment configurations. Furthermore, MRO and servicing organizations can manufacture and retrofit their own parts and create correspondent technical documentations, which must be managed in context of other SLM processes.

1 [Digital is the next horizon for global aerospace and defense - May 2021](#)

A&D manufacturers and OEMs are required to provide the right documentation, specifications, and service manuals for equipment they manufacture. However, multitude of product configurations, rapid changes in designs and processes make the logistic, in-service, and technical manuals creation inefficient, time and resources consuming. Siloed approach and separate systems of record between engineering, manufacturing, service, and technical documentation functions create lack of consistency and cause information packages duplication.

Manufacturer's adoption and enablement of the new value-added technologies, such as animated media, videos, 3D illustrations, interactive instructions, etc., require real time access to clean and contextualized maintenance and logistic data (drawings, specs, serial numbers, logistics data, tools, etc.)

All the above-mentioned aspects require collaboration, consolidation and integration of functions and systems of record into cross-functional Digital Thread connecting Engineering with Integrated Logistics Support (ILS), Technical Documentation and Service Operations.

For A&D OEMs, MROs and other maintenance and servicing companies Digital Thread for Logistics and In-Service Operations will address the challenge of outdated service information and operational complexity, by aggregating multiple sources of content into a single delivery platform - the single source of engineering, logistic, service and parts information. The solution compliance with the S-Series ILS standards will enable seamless transmission of technical data (logistics, provisioning, technical publications/IETMs, scheduled maintenance and maintenance data feedback) across multiple enterprise functions.



3. Digital Thread for Paperless Logistics and In-Service Operations

Digital Thread means bi-directional data, operations, and tasks continuity, up and down stream, of where the product or part is in its lifecycle. This connects the product data from engineering design and product lifecycle management to manufacturing work instructions, supply chain management, logistic information, service instructions and on to service execution procedures and maintenance events. Digital Thread is a cross-functional process that keeps data consistency and relevancy and enables execute data and processes as it is currently known in the system.

PTC is offering an end-to-end Digital Thread solution for paperless logistics and in-service operations with the capability to manage a multi-dimension BOM (Requirements, Engineering BOM, Manufacturing BOM, Service BOM, Logistic Support Analysis - LSA BOM, Illustrated Part Catalog - IPC BOM) and the associated Engineering MBD, Manufacturing Process Plans, Technical Publications, Service Manuals, and maintenance tasks. The Digital Thread enables cross-functional change orchestration, from the design to the visualization, thru LSA, that means that a change can be propagated across domains that did not communicate before. This advantage allows the use of PTC solution everywhere with a maximum gain.

For example, in the typical process, the Engineering Bill of Materials (EBOM) can be transformed to a Service Bill of Materials (SBOM). This SBOM is then used in the creation of Parts Lists for Illustrated Parts Catalogs. The 3D geometry from the EBOM is used to create appropriate 3D Illustrations for the Illustrated Parts Catalog (IPC) or is transformed to 2D Illustrations for a PDF version of the Parts Catalog. For organizations that have a Manufacturing Bill of Materials (MBOM), that can also be used as the input to the SBOM.

For service content, the associativity of design data and service content that the digital thread provides, allows for impact analysis and change management. If the product design changes, the engineer can query for what in the service content must also change. The change can be communicated to the content writers who are responsible for the affected content. If 3D geometry is leveraged in the illustration process, illustrations can be refreshed or updated with the latest geometry without the need to start from scratch. Also, if a customer provides feedback on the service content, the information can be relayed back to the designers.

Additional capability of Augmented, Virtual and Mixed Reality (AR/VR/MR) can leverage the same 3D geometry and related illustration efforts to efficiently generate interactive technical publications and service work instructions. In addition, IIoT capabilities can enhance the solution for prognostic and condition-based maintenance (CBM+).

PTC end-to-end Digital Thread capabilities enable:

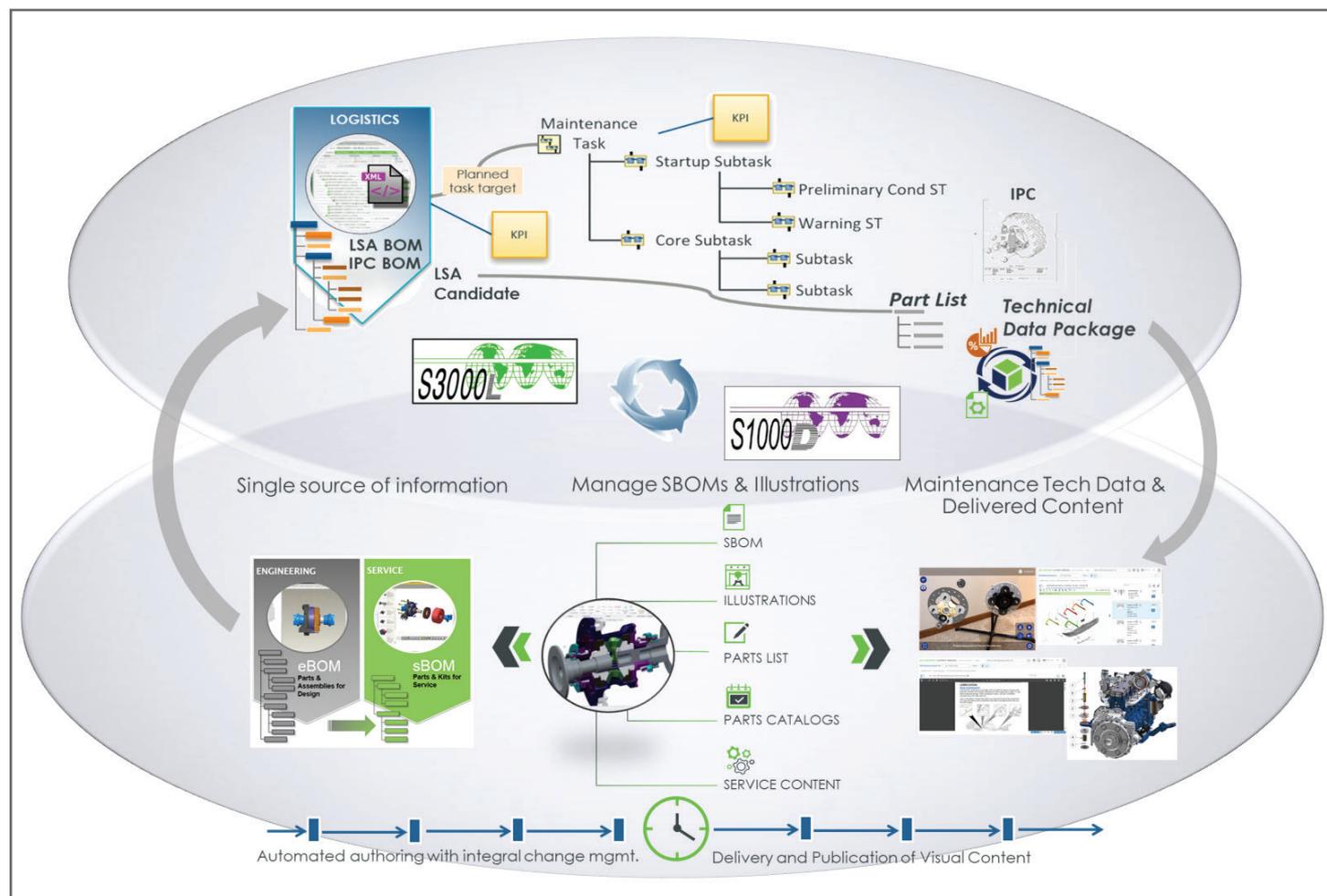
- integration of project and logistics systems that help to ensure timely, consistent information on maintenance performance. This enables proactive management and helps assure delivery against service-level agreements (SLAs) and meet PBL (Performance-based Logistics) KPIs
- management and execution of the end-to-end in-service process for designers, engineers, logisticians, publication managers and field service technicians. This keeps the service optimal and cost efficient
- safe, compliant, and efficient delivery of service documentation, technical manuals, and timely services thru the complete integration across maintenance engineering, planning, execution, and support functions.
- real-time, dynamic decision-making analysis and insights for service operations managers, regarding either individual asset or/and fleets specific service – the data, which is the critical input for Condition-based Maintenance (CBM+)

4. Solution Offering Description

PTC Digital Logistics for In-Service Operations solution is an enterprise solution offering that leverages engineering and manufacturing product information to improve the process for defining, managing, updating, and delivering configuration-specific service and parts information throughout a component or system's lifecycle. The solution accelerates the

processes for creation, management, and delivery of regulatory compliant (S-SERIES, MIL-STD, DITA) information used in the successful operation and maintenance of A&D products, throughout their service lifecycle. In addition, it increases part ordering accuracy and utilization throughout the service network (field service, contact center, end user, parts depot, publications manager, engineering) by automatically identifying valid service part options based on specific product configurations and service events. The addition of the **GPSL S1000D** module ensures compliance with specifications set by industry regulatory standards.

This open, unified, and connected solution enables common reference and flow between Service and Engineering data, with direct access to the 3D models in the up-to-date configurations.



PTC Digital Logistics for In-Service Operations solution is based on the following functional capabilities:

- PLM capability for Bill of Materials (BOMs) transitions (EBOM or MBOM to SBOM) and Configuration Management. (5.1.)
- Service Parts Information and Instructions (SPII) for Parts, serialization, classification and catalogs, 3D illustration (Part Lists, IPC BOM), etc. This capability enables Service Parts lifecycle management. (5.2)
- Integrated Logistics Support Analysis (LSA), based on S3000L international specifications for the A&D industry. LSA capability provides rules for the usage for the Product breakdown for logistics purposes – LSA BOM and methodology for various maintenance analysis, and maintenance data integration. (5.3)
- Technical Publications (Tech Pubs) authoring and management capability for creation of reusable IETMs – Interactive Electronic Technical Manuals, XML-based content components and complete content management functionality. (5.4)
- Transitioning, authoring, and delivering S1000D technical publication content, based on up-to-date engineering and logistics data. (5.5.)
- Publishing capability to automatically publish up-to-date content across multiple audiences and formats, including Augmented and Virtual Reality (AR/VR)

The solution offering can be extended with service parts inventory optimization and availability capability, connecting the Digital Thread for Logistic and In-Service operations with PTC Servigistics Service Parts Management solution for inventory planning, forecasting, analytics, and optimization, across Supply Chains. It can also be extended with Windchill Risk and Reliability (WRR) offering comprehensive analysis tools to support the LSA record.

PTC technology is certified for [Codex of Openness](#), which enables PTC Digital Logistics for In-Service Operations solution integrate and interoperate with existing maintenance management tools, systems and databases, such as MRO systems, MIS, CMMS, EAM, QMS, and others. Implementing end-to-end Digital Thread across disciplines and multiple IT systems is a very critical step for A&D companies' digital transformation.

5. Tools, Solutions and Data Processes

The solution offering is based on a modular framework comprised of several tools and technology capabilities integrated into one solution – PTC Digital Logistics for In-Service Operations.

The solution framework is based on a modular architecture, which enables integration, seamless data exchange and interoperability between several Commercial Off the Shelf (COTS) software tools. The modular nature of the solution offering is purposely created to address industry requirement for flexible deployment and gradual adoption of digital transformation in the A&D Aftermarket Services industry.

A&D companies, OEMs, MROs, and maintenance repair companies can adopt and deploy digital in-service operations, integrated logistics support and paperless maintenance capabilities gradually, step-by-step, on top of their existing processes and systems, transforming them into operational Digital Thread.

The modular deployment of the tools and capabilities in the solution framework depends on organization's maintenance and service data processes and prioritized use cases, such as:

- requirement for integrated closed-loop change management process across engineering, logistics, service and IETMs creation functions
- need to address logistics support analysis for service quality and its impact on field service
- improve accuracy of service technical manuals through integration of parts catalogs, publications management and implementation of S1000D rules.
- digital transformation requirements around augmented reality adoption for training or service
- transformational opportunities to leverage existing IT systems and CBM+ ready infrastructure

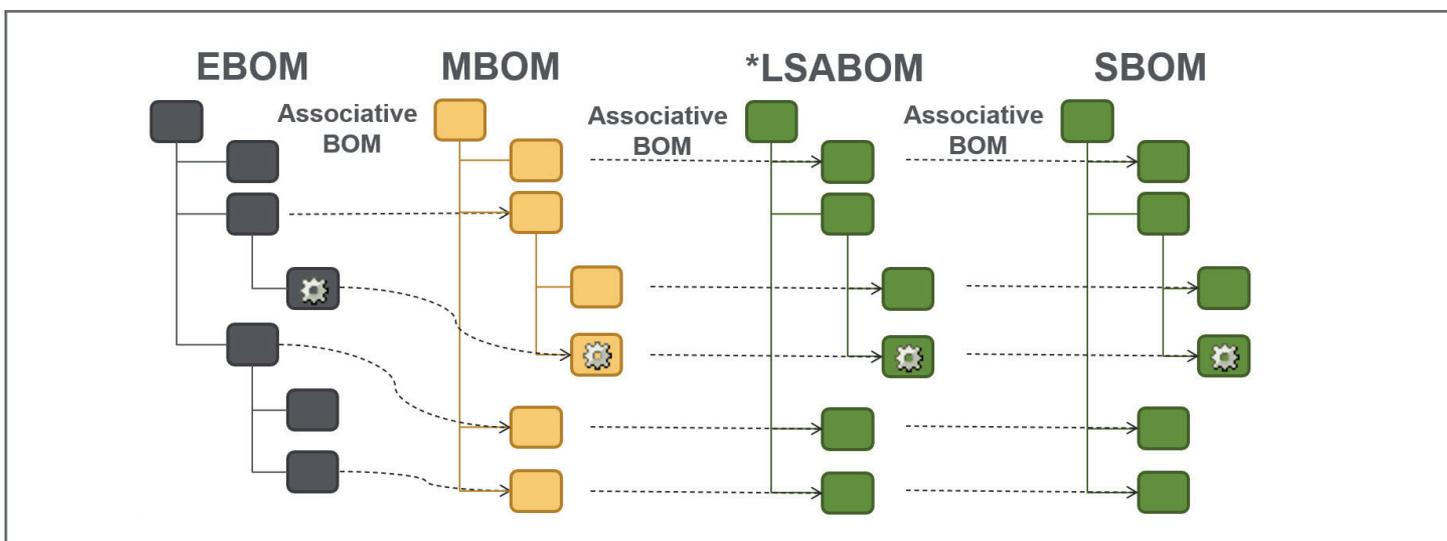
PTC Digital Logistics for In-Service Operations solution architecture enables Digital Thread of data workflows and processes that can address multiple use cases, depending on the prioritized and deployed toolset of technologies.

Following are the Tools and Solutions that constitute PTC Digital Logistics for In-Service Operations solution offering framework:

5.1. PLM capability for Bill of Materials (BOMs) transitions – PTC Windchill PLM

PTC Windchill enables complete integration of CAD and PLM data into a single source of truth through a multi-dimensional BOM. It brings standard processes around managing the BOM throughout the entire lifecycle from early concept, through all iterations, design cycles and stages until it is fully released, and further, into manufacturing BOM and service BOM. This ensures that BOM information is complete, accurate and consistent, across BOM transformation process. PTC Windchill includes the ability to manage and navigate a full product structure that includes all associated items and parts that define a product – MCAD, ECAD, Software, drawing, etc., along with production planning, manufacturing, and service information. This means the ability to view a full Digital Product Definition. Additionally, PTC Windchill includes reports on product history, save-as information, part numbers, red-line markups, changes, verifications, preferred suppliers, work instructions, and other information that is traceable thus making engineering, manufacturing, and service decisions easier.

Windchill multi-BOM transformation capability creates associative relationships between parts and items in different BOMs (EBOM, MBOM, LSA BOM, IPC BOM, SBOM, etc.), where each item on the BOM can be directly linked to correspondent items in other BOMs, and all other information, such as 2D and 3D illustrated parts catalogs, service documentation, tools, assembly work instructions, and more. Windchill multi-BOM associativity relationships and links can be illustrated in the following image:



5.2. Service Parts Information and Service Parts Lifecycle Management – PTC Windchill SPII module

PTC Windchill Service Parts Information and Instructions (SPII) module enables management of context-specific service information, organizing and optimizing it for accuracy, applicability, and rich, graphics-driven delivery. This capability facilitates information reuse, streamline change management, and enable delivery of configuration-based technical publications.

PTC SPII enables manufacturers and service organizations to manage information based on how the product is configured and serviced in the field. Bill of Materials (BOMs) transformed into service-oriented breakdown structures of products and parts, used to organize all the content required to operate and service those products and parts throughout their lifecycle. The definition of product hierarchy captures the product classification to allow easy navigation of service information. While applicability rules define which pieces of content are applicable for specific situations for a given product configuration and usage conditions.

Publication structures can also be generated based on associative SBOM to deliver the information in traditional publications-based manner.

Service-oriented information structures provide breakdown into serviceable systems, sub-systems, parts, service instructions procedures and content information, such as: illustrations, publications, multimedia, videos, graphics, etc. Well-defined associative SBOM Information Structures will enable content applicability based on product options, operating conditions, serial numbers, date effectivity, etc. The SBOM Information Structures will enable initial and incremental publishing and delivery of Illustrated Part Catalogs (IPC BOMs) and rich service information specific to product configuration.



5.3. Integrated Logistics Support Analysis (LSA) – PTC Windchill LSA VRD

PTC Windchill LSA Value-ready Delivery module (VRD) provides Logistics Support Analysis (LSA) capability, which is one of the most important processes to realize the requirements of Integrated Logistic Support (ILS). PTC's LSA VRD is based on the [S3000L Specification](#)

Part of the [S-Series Standards](#), the S3000L Specification defines requirements for Integrated Product Support, configuration management, the analysis activities and the data model for information exchange governing the performance of LSA during the life cycle of any (complex) technical system.

Logistics Support Analysis (LSA) plays a critical role in the design of a product because it helps identify potential failures early on during product development when the costs associated with remedial action are minimal, compared to the costs when the product is already in service. The output of such a process is an LSA BOM with serviceable parts and associated analysis, including tasks to be performed for all service and support. However, without linking from these tasks to the actual procedures (defining how to perform the work) or the parts in the LSA BOM to the part catalog, the companies don't have a single change control process, or they may find that they are missing critical procedures or part data. Without this linkage, the result can be unreliable documentation, inconsistent IPD parts information and costly non-compliance situations.

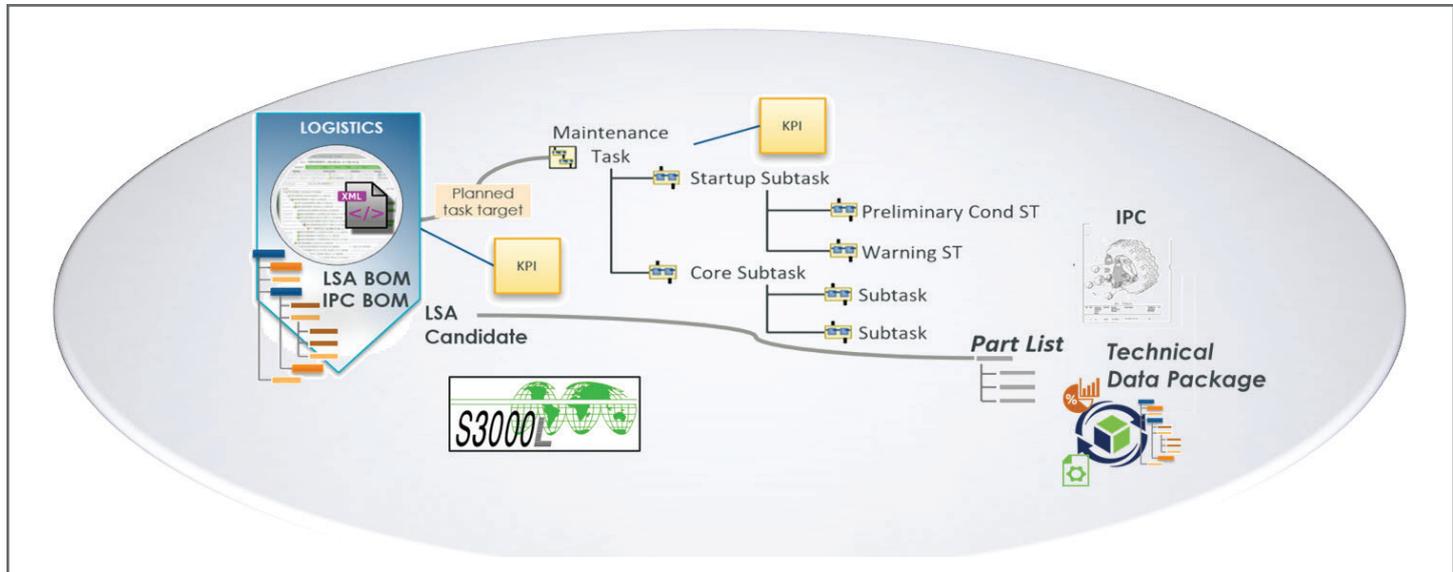
PTC Windchill LSA enables dynamic creation of Product breakdown structures (LSA BOM) for logistic purposes with associativity to engineering source data (EBOM) and subsequent selection of LSA Candidate Items. Associative relationship to Manufacturing BOM (MBOM) can be created, in addition to the EBOM association, in case customer process requires such connection. Product design (EBOM) or Serialized MBOM configurations can be taken into consideration and used for dynamic creation of the LSA BOM breakdown structure.

Service LSA breakdown structure should include Part logistic information, like zonal location, assembly sequence, tools, storage and packaging procedures, environmental data, etc., which will help reusing existing service Parts. Additionally, logistic information on the Part point of use should be managed in the LSA BOM breakdown structure, too.

LSA Candidate Items should be identified in the LSA BOM structure to perform logistics and parts quality analysis. For each LSA Candidate Item and the correspondent Products, LSA Tasks and KPI analysis can be created for Reliability, Availability, Maintainability and Testability (RAMT) subjects, Operational, Material, Cost, Level of Repair (LORA) and other KPI analysis. Additionally, thanks to the associativity between the LSA BOM and the EBOM, design change impact to service performance analysis and cost-efficient support reports can be generated.

PTC Windchill LSA module will manage Candidate Item Lists (CILs), generate reports, export logistic information, create illustrated Part Lists and provide input for Service Parts Information and Technical Publications capabilities for downstream process of IETMs creation. The module supports export of logistics and service tasks structure in several formats and templates, which is compliant with S3000L dataset format, MIL-STD-1388-2B format and other formats, including direct generation of S1000D data modules.

PTC Windchill LSA module enables service data digital continuity, synchronization, traceability, and analysis. By establishing central repository of Service and Engineering data, it creates unique service representation of an engineering Part and facilitates integrated change management, across the disciplines. Engineering, Logistics, Service and Technical Illustration teams will work on the same 3D model.



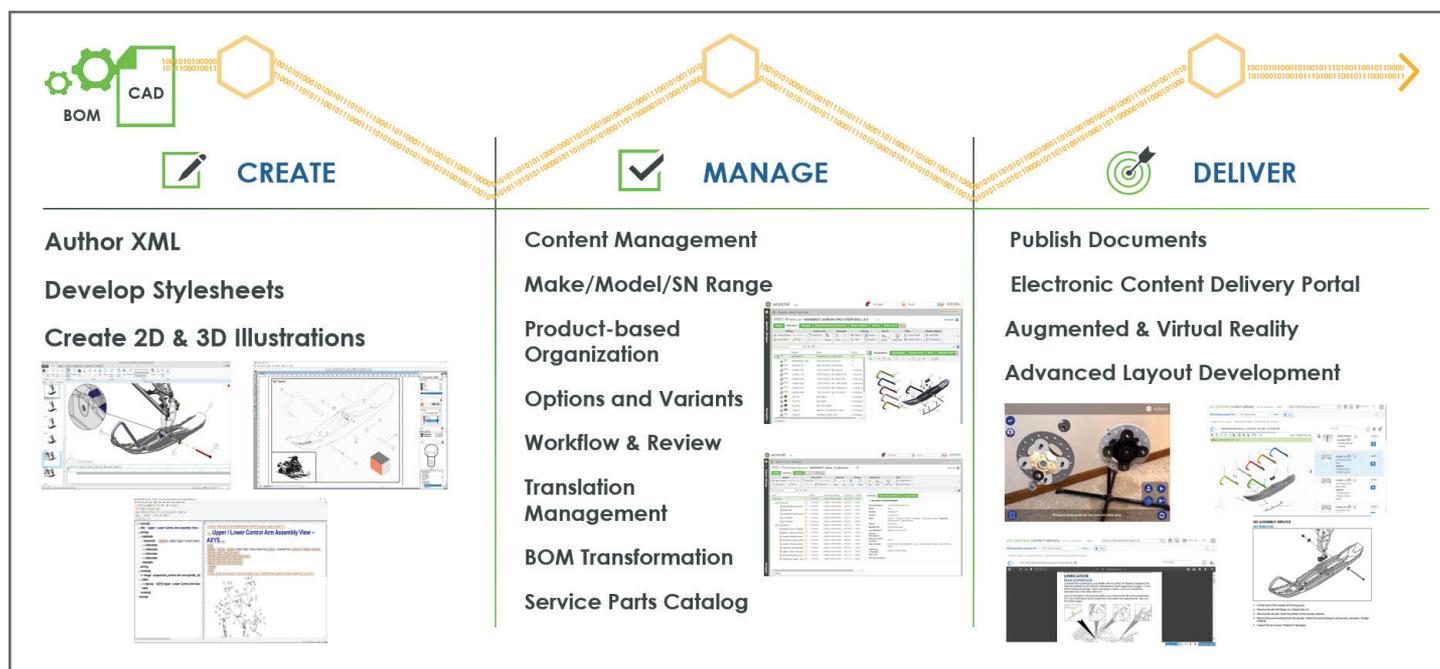
5.4. Tech Pubs authoring, management, and publishing – PTC Arbortext

PTC Arbortext set of tools is the end-to-end, dynamic publishing solution which streamlines how organizations create, manage, and deliver technical publications. This is industry's most adopted XML authoring, styling, and publishing software, that helps companies create contextual, up-to-date, product-centric interactive electronic technical content.

Integration of PTC Arbortext with PTC Windchill creates fully capable Content Management System for equipment service information, that manages contextual technical information and illustrations in alignment with the original product definition – to ensure information accuracy, timeliness, and consistency. The solution enables technical information digital continuity through creation, management, and delivery stages, while maintaining associative relationship to the engineering, logistics and service data. The reusable XML based content components maintained in a database with the ability to automatically publish up-to-date technical illustrations and service manuals across multiple audiences and formats.

PTC Arbortext tools support industry standards like DITA and S1000D, allow authors to incorporate interactive, CAD-driven 2D/3D technical illustrations and create high-quality, media-neutral product and service content.

The solution associates information from Engineering through Tech Pubs to the end user, ensuring its trustworthiness and precise filtration for the service task at hand. It enables the best-available service information to drive parts revenue, productivity, and loyalty.



5.5. S1000D technical publications – GPSL S1000D Solution and GPSL ViewPoint

GPSL S1000D module, extends PTC Windchill PLM platform and SPII module to ensure compliance of the published IETMs (IETPs) with S1000D international standard specification for technical publications. The **S-Series S1000D standard** is widely adopted in Defense, Civil Aviation, Construction and Shipbuilding industries.

GPSL S1000D for PTC Windchill leverages SPII and LSA VRD to link PLM engineering data to the service data, enabling publication managers and illustrators to create high-quality, S1000D-compliant service and spare parts information from Windchill. The solution provides preconfigured libraries containing all S1000D defined codes and technical attributes, stylesheet files for authoring and publishing S1000D content, connecting it with Illustrated Parts Data from Windchill managed parts lists.

Linking the service information in this way means that any changes made upstream by engineering or LSA processes, are recognized right away in all the impacted service content and correspondent IETPs. This linkage reduces the time and cost of creating S1000D service information as well as ensuring that end users have easy access to real-time, integrated, and accurate technical and maintenance information across the entire Service Network.

GPSL ViewPoint is a new generation of IETP Viewer for S1000D and US MIL-STD information. Its enables S1000D service content viewing and management capability for service technicians, online or offline, along the Digital Thread for Logistics and In-Service Operations.

6. Digital Logistics for In-Service Operations Value Map

The objective of A&D companies for maintenance operations is that prior to an Asset or Equipment entry into service all resources required to support the Equipment must be defined. Requirements for visibility, monitoring and cost-effectiveness of the actual usage of

support resources become critical. In case of technical or logistics insufficiencies based on in-service data, potential modifications of the maintenance operations must be identified and implemented.

The positive effects of the implementation of PTC Digital Logistics for In-Service Operations solution offering include, but are not limited to:

- Enhancing Equipment availability and uptime
- Harmonizing and improving required resources for effective maintenance and in-service operations
- Improving in-service operations with rapid incorporation of modifications
- Reducing the logistic footprint and logistic support cost

Easy access to real-time, integrated, and accurate technical and maintenance information across the service network

- Contextual, interactive information delivery
- Service Information is based on the product structure, rather than a set of documents.
- Automated change processes to keep service information aligned with engineering changes.
- As-supported, tail number-specific, or equipment-specific information management
- Configuration, tail number-specific, effectivity or model-based information filtering and management.
- Author and manage industry compliant maintenance information (S1000D, Mil-STD, DITA)

Graphically enabled, product, task, and language-specific service information

- Creation of interactive 3D and 2D illustrations and schematics
- Deliver information relevant to the user's role, location and task

Create associative Service BOM-driven spare parts strategy.

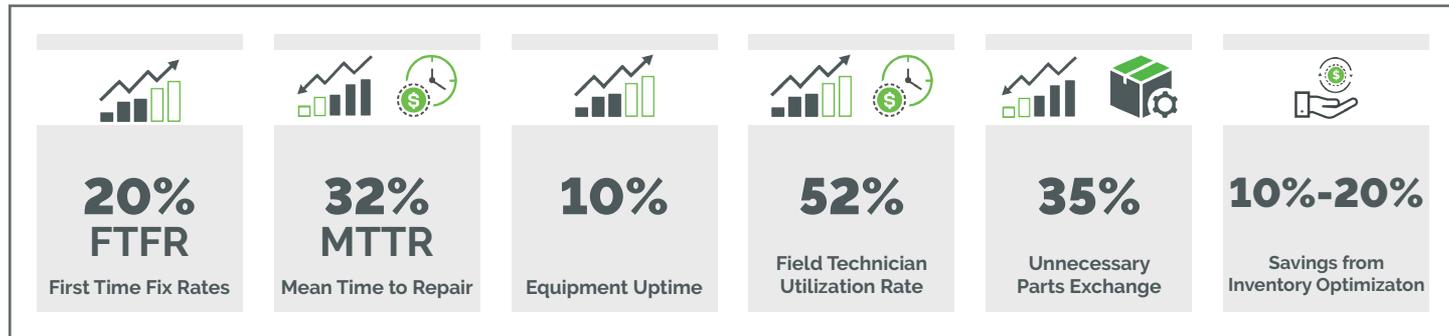
- Generate associative service bill-of-material (BOM) from existing product information.
- Leverage applicability and geometry information to manage a comprehensive service BOM.
- Creation of interactive 3D and 2D parts illustrations
- Restructure source engineering or manufacturing BOM into Service BOMs, define part relationships and establish traceability for integration change management.

Manage configuration-specific service and parts content and automate change processes.

- Organize and manage parts catalog information around the product structure.
- Automated change processes to keep service information aligned with engineering changes.
- GPSL S1000D module ensures compliance with specifications set by industry regulatory standards.

Deliver dynamic service parts catalogs and 3D interactive parts lists.

- Visualize rich, interactive and 3D illustrations for service parts.
- Enable single online system for accessing all parts catalogs.



Resources:

- PTC Federal, Aerospace and Defense:
<https://www.ptc.com/en/industries/aerospace-and-defense>
- PTC Service Optimization Solutions:
<https://www.ptc.com/en/solutions/service-optimization>
- PTC Arbortext: <https://www.ptc.com/en/products/arbortext>
- PTC Powerful Digital Threads Deliver Peak Service Outcomes Blog:
<https://www.ptc.com/en/blogs/service/digital-threads-deliver-peak-service-outcomes>
- PTC Powerful Digital Threads Deliver Peak Service Outcomes Webcast:
<https://www.youtube.com/watch?v=eoYlT0zbqZE&t=22s>
- PTC Explicit and Implicit Linking of Service Content to Product Design Whitepaper:
<https://www.ptc.com/en/resources/service-lifecycle-management/white-paper/arbortext-implicit-explicit>
- GPSL S1000D: <https://gpsl.co/industry/aerospace-and-defence>
- Unlocking the Potential of Industrie 4.0: <https://www.youtube.com/watch?v=nHfY56lHZjU>
- Use of AR in Aviation Maintenance https://youtu.be/xUVP00_T5Bk



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