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# Lenovo Validated Design for Smart Manufacturing with ThinkEdge Solutions

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Version 1.0

**Introducing manufacturing solutions for Industrial IoT with Edge architecture**

**Including real-time production monitoring and business Intelligence**

**Leveraging AI Quality Inspection on the Lenovo ThinkEdge SE30**

**Showcasing Digital Twin with Lenovo ThinkEdge SE450**

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# 1 Introduction

This document describes the reference architecture for the Manufacturing Solution (Project name Optimus) developed in partnership with the CERTI Institute (https://certi.org.br/en/) in Brazil. Lenovo and CERTI collaborated on the architectural vision and engineering effort to create this comprehensive reference architecture for manufacturing solutions utilizing Lenovo ThinkEdge devices. This paper aims to provide planning, design considerations, and best practices for implementing these solutions.

The architecture detailed in this document has been validated by both Lenovo and CERTI. The intended audience includes IT professionals, technical architects, sales engineers, and consultants. This document is intended to support the planning, design, and implementation of Industry 4.0 manufacturing solutions.

## Industry 4.0

Industry 4.0 is driving a transformation in manufacturing sites worldwide by integrating digital technologies that bridge the physical and digital worlds. Key technologies include:

- Autonomous robots and collaborative systems (cobotics)
- Industrial Internet of Things (IIoT)
- Big Data and cloud computing,
- Artificial intelligence (AI),
- Integration and simulation,
- Additive manufacturing and augmented/virtual reality (AR/VR).

These technologies offer numerous direct benefits, improving the performance and reducing wastes. These advancements enhance the quality, flexibility, and adaptability of production lines, ultimately resulting in higher overall gains.

### Industrial IoT

The term Industrial IoT (IIoT) originated from the Internet of things, which was initially defined by Ashton [1]. As with its predecessor, IIoT has various definitions in both industry and academia. However, all definitions converge on the idea that the primary focus of IIoT is the collection of data and actuation between physical and cyber systems. This interaction forms the basis of the cyber-physical system (CPS) concept, which is a fundamental element of Industry 4.0, as illustrated in Figure 1.

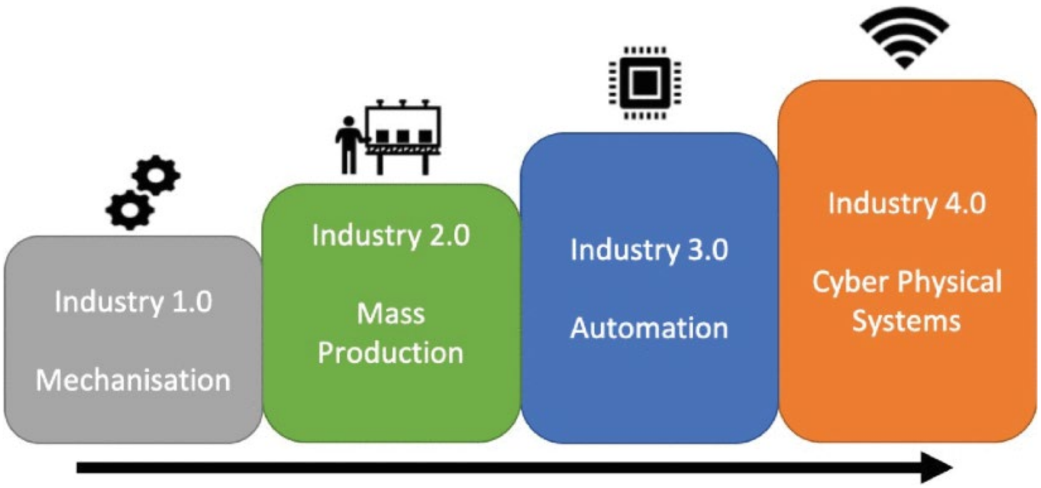


Figure 1 - IIoT and Cyber-physical System
Source: Fuller, A. et. al. 2020 [2]

### Digital Twin

One of the most advanced technologies in Industry 4.0 is Digital Twin. This technology integrates virtual and physical models, where real-time data is collected from the physical model and transmitted to the virtual model, while commands are sent from the virtual model to the physical one. This bi-directional feedback loop allows the virtual model to replicate and interact with the physical model dynamically.

The term “Digital Twin” was defined by Dr. Michael Grieves at the University of Michigan around 2001-2002, originally within the context of Product Lifecycle Management (PLM). Dr. Grieves introduced the concept as a virtual representation of what has been manufactured, proposing the idea of comparing the Digital Twin to its engineering design. This comparison helps to better understand discrepancies between what was designed and what was produced, thereby tightening the loop between design and execution [3].

As pointed by Fei Tao, et. al. [4] the digital twin was one of the most promising technologies for enabling the Industry 4.0 with a seamless integration between cyber and physical spaces. Creating a Digital Twin involves integrating flexible and modular manufacturing systems such as ERP (Enterprise Resource Planning), MES (Manufacturing Execution Systems), MOM (Manufacturing Operation Management), PLM (Product Lifecycle Management) among others.

In its advanced state, a Digital Twin can simulate the behaviour of a real physical model - such as a manufacturing plant - under various input and boundary conditions (environment, constraints, etc.), and act on it with artificial intelligence. This enables accurate prediction of the system's operation and allows for autonomous control of the physical model’s processes in the event of changes or disturbances in production. Additionally, it supports predictive maintenance by automatically scheduling maintenance activities when necessary.

## Edge Computing

Unlike the well-known cloud computing approach where the data storage and processing are centralized in a single location, Edge Computing (EC) brings data processing closer to the data source in decentralized nodes. This approach reduces latency and bandwidth requirements, making it an ideal application in smart cities, retail, manufacturing applications that require rapid decision-making closer to the sensors.

**Edge Computing offer several benefits:**

- **Improved control data manipulation:** By keeping data within on-premises infrastructure, organization can have better control over their data.
- **Distributed AI Processing:** Multiple nodes can process AI tasks, enhancing the efficiency and speed of the amount of data sent to the cloud.
- **Cost Reduction**: Edge Computing can reduce costs associated with cloud services by minimizing the amount of data sent to the cloud for processing.
- **Enhanced Privacy:** Data privacy is improved as sensitive information can be processed locally without being transmitted to the cloud.

These advantages make Edge Computing a robust solution for various applications that demand efficient, real-time data processing and decision-making. [5]

## Edge AI

The highly distributed infrastructure of Edge computing also facilitates bringing the AI processing to the Edge reducing the need to send all raw data to the cloud for model training. This set up supports data anonymization methods such as the Federated Learning proposed by Google® in 2016 [6] in which the Machine Learning (ML) models are trained on Edge nodes and sent to cloud for averaging with other models that can be resent to the decentralized nodes. This type of approach protects the data and enables compression of the digital information sent to the cloud. In this reference document we propose an alternative approach for Computer Vision with AI using on-premises solution for highly secure environment, without the need of a cloud by allowing edge clients to run inference applications while another Edge server is used for training and retraining the models.

## Lenovo® ThinkEdge®

The Lenovo ThinkEdge® devices used for the solutions presented in this document offers a range of benefits for the manufacturing applications These benefits include:

- **Rugged Design:** The ability to operate in tough environments, ensuring reliability and durability.
- **High connectivity and input availability**: Small form-factor servers with extensive connectivity options and input availability.
- **High processing capability:** Enhance security measures such as tamper-detection features.
- In addition, the Lenovo® ThinkEdge® servers enable AI model training, data aggregation, and edge note management. Key features include:
- **Baseboard Management Controller (BMC):** For efficient management of edge nodes.
- **Enhance Security:** Security features such as locking security bezels and brackets, allowing the server to be used closer to the edge without needing to be in a controlled server room.

These capabilities make Lenovo® ThinkEdge® devices and servers ideal for implementing advanced manufacturing solutions with robust processing, security, and connectivity in challenging environments.

# 2 Business problem and business value

This section outlines the business problem and the value generated by the Edge solutions for manufacturing. The solutions aim to enhance critical Key Performance Indicators (KPIs) in manufacturing. While these indicators are influenced by external factors such as economics and supply chain dynamics, they are also significantly impacted by internal production-related factors such as equipment availability, maintenance control, quality control, and the agility of process adjustments.

## Business problem

One of the fundamental premises for cyber-physical systems, according to the NSF National Science Foundation [7], is to ensure seamless integration with physical elements and computational algorithms. Achieving this integration on the factory shop floor has posed a significant challenge in the digital transformation of manufacturing due to the heterogeneous environment, which includes:

- Hardware
- Communication networks
- Communication protocols
- Operating Systems (OS)
- Application runtimes
- And other components

This diversity makes interoperability the primary challenge in successfully implementing edge computing [8]. Therefore, the question is how to harness the benefits of cloud computing at the Edge, enabling seamless Continuous Integration/Continuous Development (CI/CD) workflow and shared Storage, while also maintaining the low latency and data control of the edge solutions.

## Business value

According to Deloitte® research from 2019, the manufacturing sector leads in data creation, as illustrated in Figure 2. This positions the sector with the highest potential for data-driven AI solutions and digitalization.

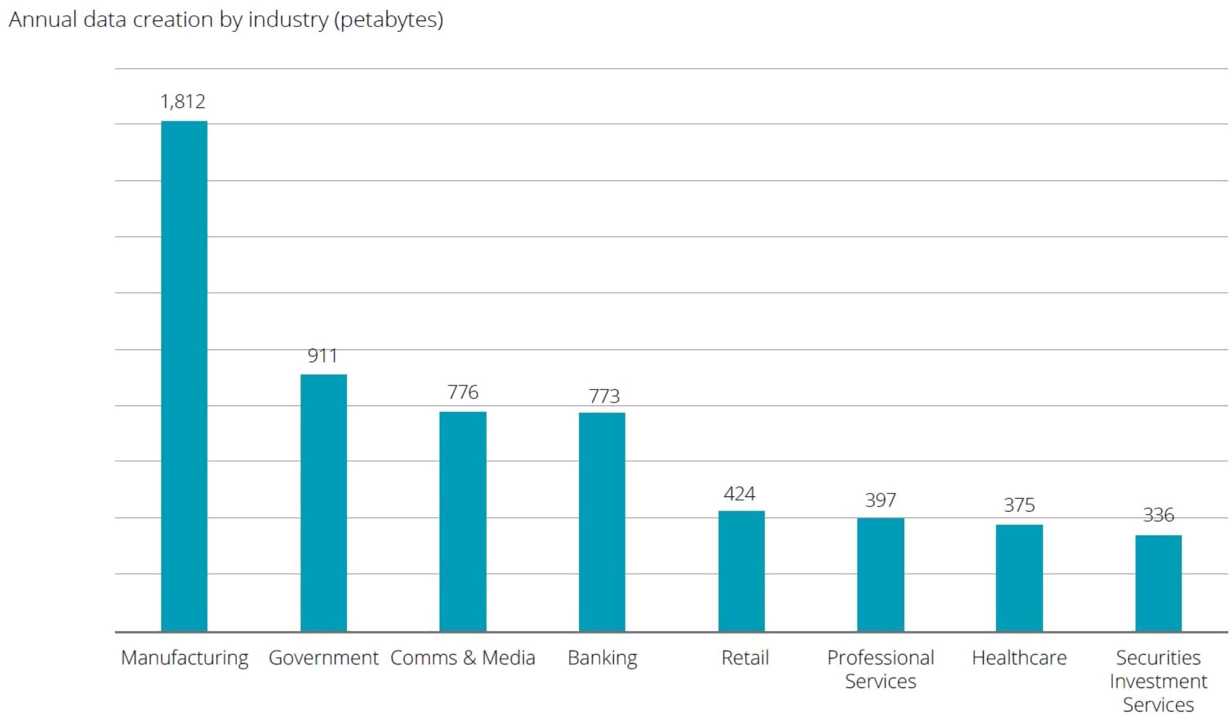


Figure 2 - Volume of annual data per Industry
Source: Deloitte® Survey on AI Adoption in Manufacturing, 2019.

The digitalization can lead to several benefits, including:

- Higher safety and sustainability
- Increased asset efficiency
- Improved product quality
- Reduced production costs

These benefits are highlighted in the Deloitte® 2024 manufacturing industry outlook [9], as illustrated in Figure 3.

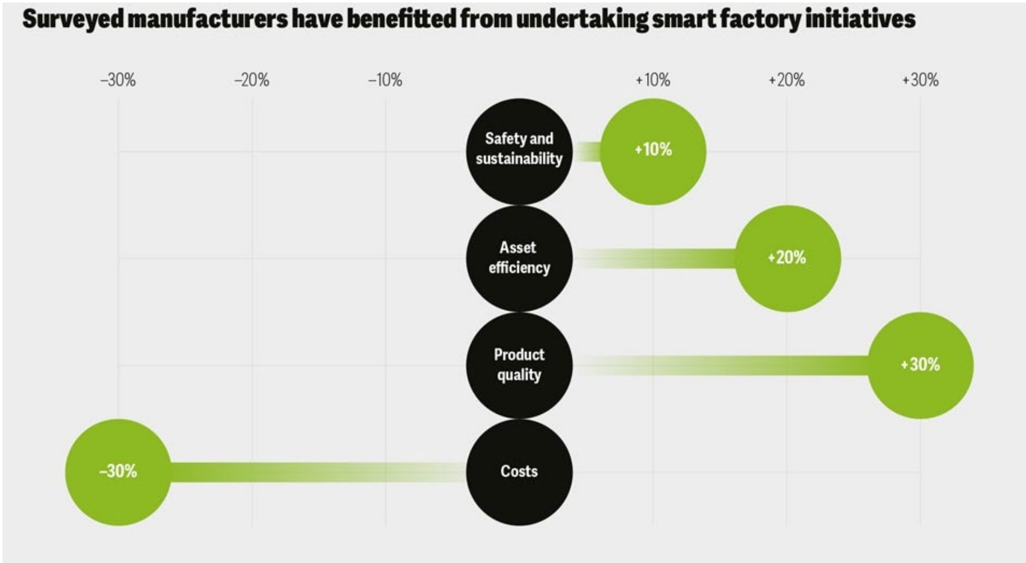


Figure 3 - Benefits of Smart Factory initiatives

Source: 2024 manufacturing Industry Outlook, Deloitte®, 2024

The utilization of automation combined with real-time digitalization in the manufacturing process also leads to significant improvements in Key Performance Indicators (KPIs) for manufacturing process and quality.

According to the 2020 Acatech study titled "Industrie 4.0 Maturity Index, Managing the Digital Transformation of Companies" [10], the steps for Industry 4.0 are illustrated in Figure 4The transition from Step 4 to Step 5 requires the addition of predictive capability, which significantly enhances business value by enabling the foresights of process failures before they occur. This predictive capability can be achieved through AI-powered applications running on the edge and/or cloud.

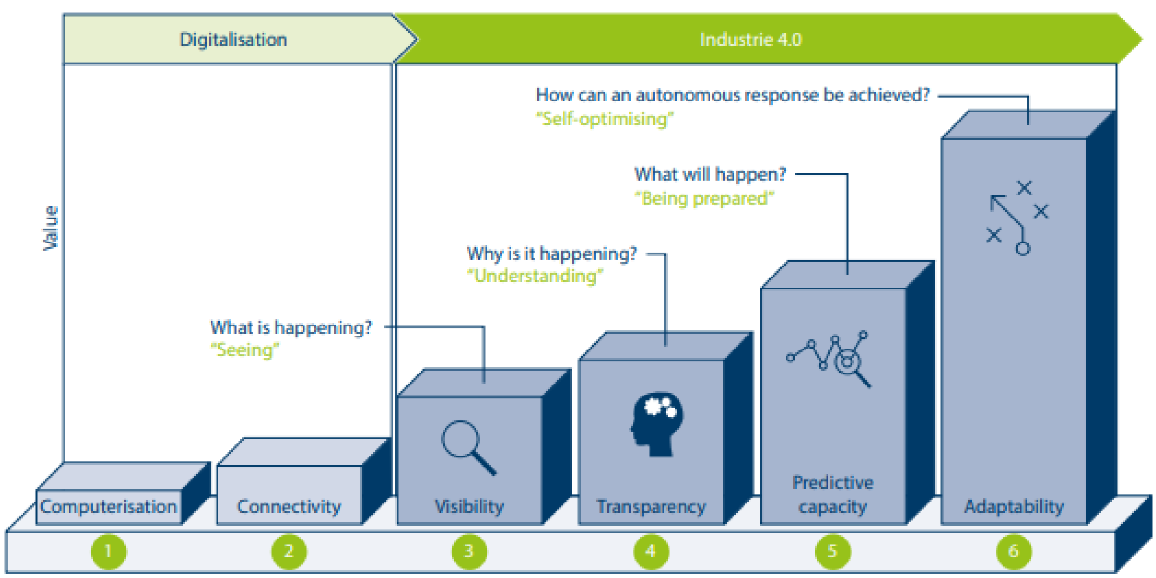


Figure 4 - Stages in the 4.0 Industry development path
Source: FIR e. V. at RWTH Aachen University [10]

# 3 Goals & Requirements

The solutions presented in this document were designed and validated in a relevant test environment inside Lenovo® Automation Lab in Brazil, utilizing open-source solutions and in-house software development. These solutions were applied to desktop assembling process, focusing on four pillars: automation with AI, IIoT for data collection, digital twin, and automated quality inspection with computer vision, according to Figure 5.

To achieve the validation goals, three robot cells were constructed for automatic memory insertion, CPU insertion and motherboard screwing. All data collected on by the edge clients was transmitted to a ThinkEdge® Server running the in-house Digital Twin Platform. This platform enabled real-time data visualization, predictive maintenance with AI, and production control dashboards. After assembly, the manufactured computers passed through an inspection system using AI computer vision solutions to ensure process quality, also running on ThinkEdge® devices.

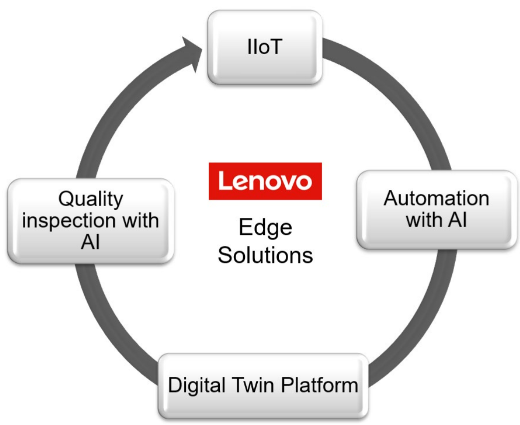


Figure 5 - Goals of the manufacturing solutions

## Functional requirements

For the automation solutions, the robot cells were built as shown on Figure 6. The overall equipment is listed on Table 1.

**Automation specific requirements**:

- Strict response time requirements:
  - Cycle time of each assembling cell cannot be reduced by the monitoring process
  - Aligned with the manufacturing target KPIs, necessitating low-latency data collection and processing at the Edge.
- Robots Indexing:
  - Utilizing computer vision processed at the edge for precise indexing of robots without the need of specific fixture mechanisms for each different assembled product.
- Security Monitoring:

- Continuous monitoring of the robot cell safety at the Edge with quick response time.
  - Robot operation is switched-off when doors are opened.
- HMI (Human Machine Interface)
  - Touchscreen monitors for easier configuration of Node-red Instance running on SE30.
  - Safety buttons and lightning for operators


Figure 6 - Automated Robot cells inside Lenovo® Brazil Manufacturing

Table 1 - List of equipment in each robot cell

| **Equipment used for Validation** | **Application** |
|---|---|
| ThinkEdge SE30 | Edge processing |
| Epson C8 robot + controller RC700 | Automation |
| Epson CV2 | Computer Vision |
| Epson PC Vision Software | Computer Vision |
| Epson RC 7.0+ Software | Robot Control |
| Epson 5MP Industrial IP Camera | Robot arm computer vision |
| Basler 20MP industrial IP Camera | Robot cell computer vision |

The Lenovo® ThinkEdge® SE30 shown on Figure 7 was configured according to Table 2.

| | |
|---|---|
| 1. Power connector | 8. Power button |
| 2. HDMI (for Celeron, i3) / DisplayPort (for i5) | 9. Serial |
| 3. USB 3.2 Gen 2 | 10. Serial |
| 4. Thunderbolt 4 | 11. USB-C 3.2 Gen 2 |
| 5. Ethernet (RJ-45) | 12. USB 3.2 Gen 2 |
| 6. Ethernet (RJ-45) | 13. USB 3.2 Gen 2 |
| 7. Kensington Security Slot | 14. Headphone / microphone combo jack (3.5mm) |

Figure 7 - Lenovo® ThinkEdge® SE30

Table 2 - Lenovo ThinkEdge SE30 configuration

| **Item** | **Description** |
|---|---|
| CPU | Intel® Core™ i5 vPro 11th Gen S2(C/L) |
| SSD | 256GB SSD M.2 2230 PCIe® 3.0 NVMe® |
| RAM memory | 16GB DDR4-3200 soldered memory |
| Operational System | W10 IoT 2021 LTSC Value DPK WW |
| Ethernet | Gigabit Ethernet (Realtek® RTL8111KI) and 2.5 Gigabit Ethernet (Intel® I225) |
| Graphics | Integrated Intel® Iris® Xe Graphics |
| WLAN + Bluetooth | Intel® 9260, Wi-Fi® 5, 802.11ac 2x2 + BT5.1, vPro® |
| Power Adapter | 65W 89% Adapter |
| Dimension | 179 x 88 x 51.5 mm (7.05 x 3.46 x 2.03 inches) |

**IIoT / Digital Twin specific requirements:**

- Real-time data collection from robots transmitted to the platform using the MQTT (Message Queuing Telemetry Transport) protocol.

- Data collection, processing, and storage implemented exclusively with on-premises solutions.
- Real-time representation of the physical process through 3D visualization.
- Datalake repository enabling AI applications, such as predictive maintenance.

Data aggregation and processing for the Digital Twin platform were implemented on the ThinkEdge® SE450, configured as Table 3 and depicted in Figure 8

Figure 8 - ThinkEdge® SE450

Table 3 - ThinkEdge® SE450 configuration

| **ThinkEdge SE450 (7D8TCT01WW)** | **Qty** |
|---|---|
| Intel® Xeon® Silver 4314 @2.40GHz 16C/32T | 1 |
| ThinkSystem® 32GB TruDDR4 3200 MHz (2Rx4 1.2V) RDIMM | 4 |
| SSD M.2 5300 960GB SATA NHS SSD | 2 |
| SSD SATA 480GB | 2 |
| GPU, Nvidia®, Ampere A2, PCIe, 16GB, 40W, half length, passive cooling, graphic GPU | 1 |
| Chassis 2U 300mm | 1 |

**Quality inspection requirements:**

The AI developed includes inspections and detection capabilities:

- Label inspection – Verify that correct label is placed according to the Product Structure
- Keyboard inspection
- Screw detection – Check that all screws are placed correct and in the right place.

For this task the list of equipment used is according to Table 4

Table 4 - Equipment for quality inspection

| Equipment used for Validation | Application |
|---|---|
| Lenovo® ThinkEdge® SE30 | model inference |
| Lenovo® ThinkEdge® SE450 | Model training |
| Camera | Image acquisition |
| PyTorch | Model training |
| LabVIEW® Application | Front-end |

## Non-functional requirements

In addition to the functional requirements, several non-functional requirements were considered to ensure the performance, usability, security, privacy, maintainability, and manageability of the solutions. These include:

Table 5 - Non-Functional requirements

| Requirement | Description |
|---|---|
| Scalability | The automation / IIoT solution with digital twin must enable users to add new equipment to the platform for monitoring with ease. This includes the deployment of new Edge clients for data collection.<br>For the Quality inspection, all models retrained with images captured by one node must be replicated across all Edge clients. This ensures that new nodes can be easily integrated to the system, maintaining consistency and accuracy in inspections. |
| Physical footprint | The selected Edge solutions must have a small footprint to fit seamlessly within the robot cells and the quality inspection workbench. |
| Ease of installation | Reduced complexity for Edge / automation deployment. The use of Docker and Portainer simplifies the installation of the Edge nodes. This setup allows for easy management through a virtual machine (VM) running on the server. |
| Ease of management/operations | Portainer reduces complexity of managing Docker containers, allowing for efficient oversight and operations.<br>The system supports self-updating of application and AI models through the network, ensuring the latest versions are always in use. |
| Security | Edge devices are equipped with tamper detection and locking mechanisms to prevent unauthorized access and intrusion. On-premise |

| | |
|---|---|
| | solution with all Edge clients isolated from the external network. MQTT broker secured on the Edge server<br>LDAP password authentication with Keycloak, Network Access Control (NAC) with zero-trust policy, HTTPS certificate. |
| High performance | The response time of the automation and AI inspection must be minimized to meet the stringent requirements of each assembly and inspection operation. |

# 4 Design Overview

This section provides an in-depth description of how the solutions were designed for meeting the listed requirements. It also offers a reference design for similar solutions for manufacturing, utilizing on-premises setups and open-source software.

## IIoT/ Digital Twin Architecture

The designed solution architecture for the data collection and Digital Twin Platform is structured as shown in Figure 9. This architecture provides an OT/IT (Operational Technology / Information Technology) convergence where data collected by the Lenovo® ThinkEdge® SE30s is processed and standardized via MQTT. The data is then sent to the ThinkEdge® Server SE450 for the digital twin visualization, historical data management, and integration with other manufacturing applications.

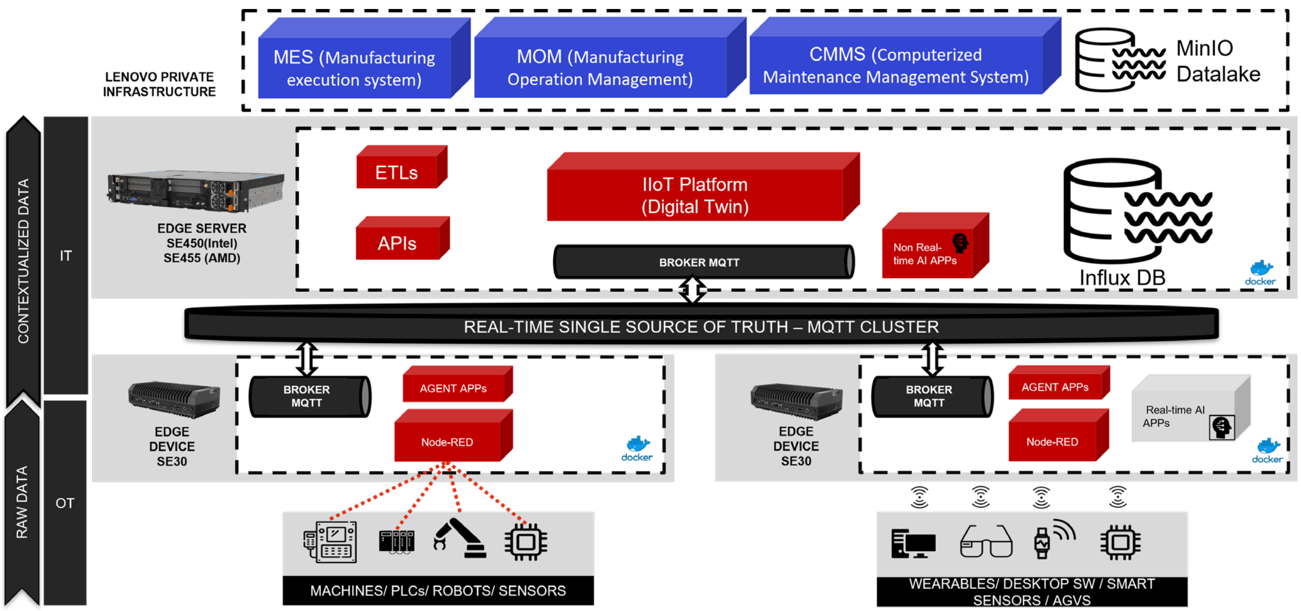


Figure 9 - Project Architecture

The specific modules used were the following:

- **Node-RED:** A low-code tool for connecting hardware devices and APIs, facilitating data collection and transformation. Ideal for bridging operational technology (OT) and information technology (IT).
- **MQTT Cluster:** Centralizes and democratizes the real-time values of all data points, avoiding point-to-point integration and enabling real-time data exchange. Acts as a single source of truth for the current state of the shop floor. The developed solution used EMQX open-source solution for validation.
- **InfluxDB:** An open-source time-series data platform for storing historical values of all data points, supporting big data analytics.
- **IIoT Platform:** Focuses on device and asset management, including maintenance control, real-time data analysis, and control.

- **MinIO Datalake**: Perfect for centralizing and democratizing data for AI and business intelligence applications.

## IIoT/Digital Twin Dataflow

As illustrated in Figure 10, the dataflow of this application involves each SE30 in the robot cells are being used for data collection and edge processing of signals coming from the Epson® RC700 robot controller. All data is aggregated on the SE450 for data storage and digital Twin commands. This setup also enables further AI applications with historical data, such as predictive maintenance, as a key step towards advancing Industry 4.0.

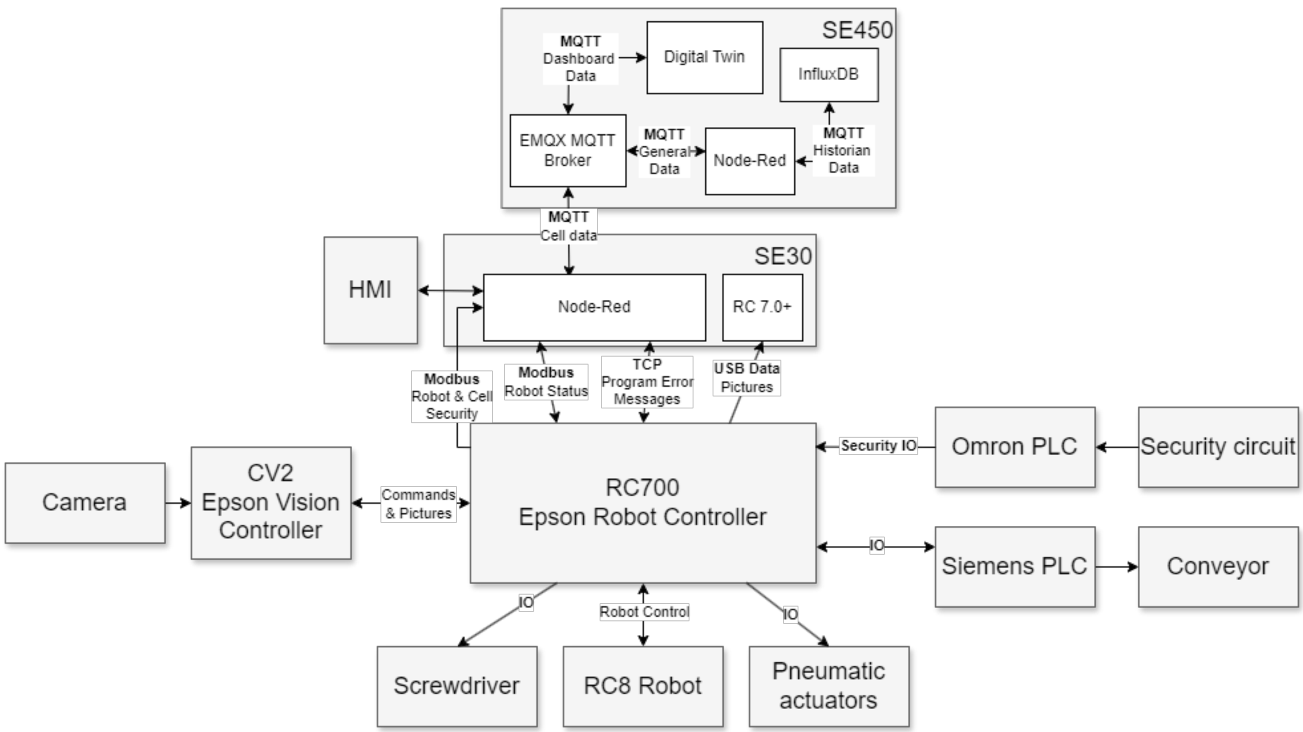


Figure 10 - IIoT dataflow

# AI quality inspection

The AI-powered quality inspection is trained for each computer model assembled, enabling it to detect assembly process failures. The SE450 is used for training the model with PyTorch. All the SE30's clients are running the inference process using a Lenovo's custom application developed with PyTorch featuring a LabVIEW® front-end. The system architecture is configured as shown in Figure 11.

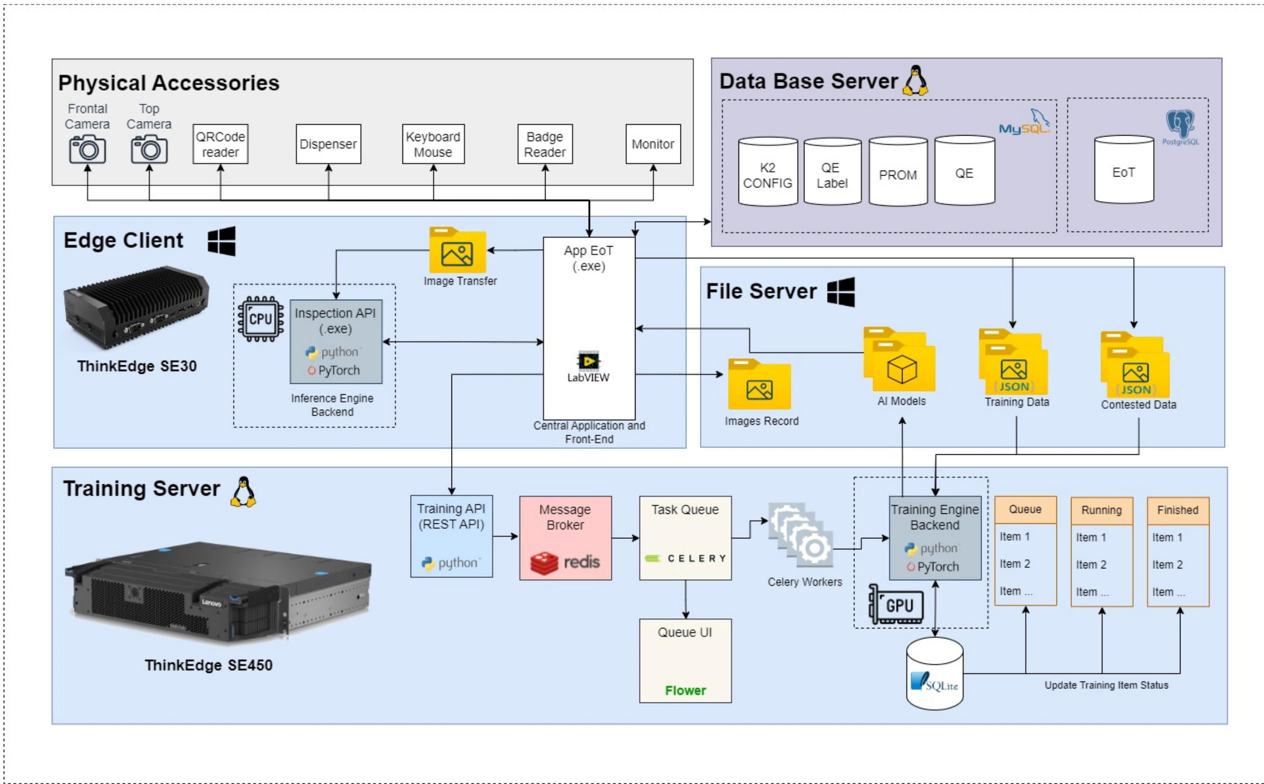


Figure 11 - Quality Inspection Architecture

## Quality Inspection Dataflow

Images are taken and processed directly on the Edge for each manufacturing line. The results are displayed on a monitor, used as HMI for each line. In the event of a false-negative result, the operator can tag the image correctly and send it for retraining on the SE450 server. Once trained, the updated model is replicated to the others SE30 clients, ensuring they use the new model. This data flow is depicted in Figure 12.

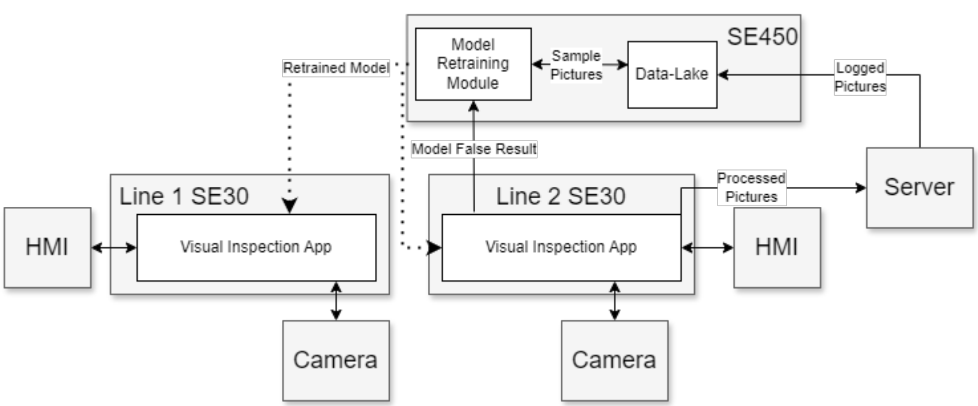


Figure 12 - Quality Inspection with AI dataflow

# 5 Deployment Infrastructure

The infrastructure view of the Server/Client applications and management solution implement is shown in Figure 13. The OT solutions are deployed on the ThinkEdge® SE30 devices using docker containerized images and monitored from the ThinkEdge® SE450 using Portainer with the management Virtual Machine (VM). All VMs installed in the SE450, as detailed in the picture, are virtualized, and monitored with Proxmox hypervisor. The setup includes:

- **Management VM:** Manages the Edge Clients' containerized images though Docker/Portainer
- **IIoT VM**: Collects IoT Data from the Edge Nodes and aggregates the information for Digital Twin visualization.
- **Datalake VM:** Aggregate Data for object storage with MinIO.
- **AI Training VM**: Trains new models or retrains existing models for the AI quality inspection solutions.

On the OT side, the ThinkEdge® SE30 run Node-Red for IoT Data Collection or the proprietary AI solution for the quality inspection.

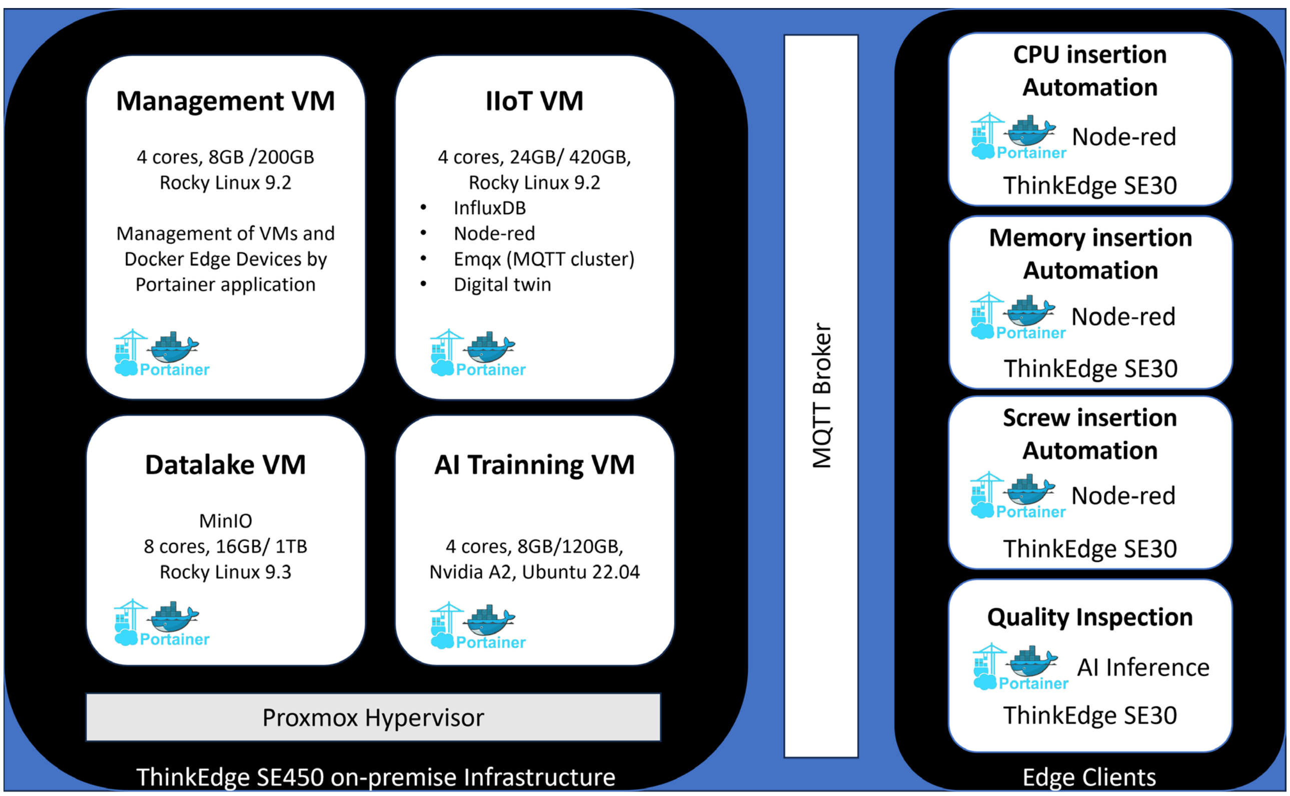

Figure 13 - Server and client infrastructure

# 6 Deployment considerations

The specific configurations required for the server, compute nodes and infrastructure are described below:

## Systems management

The deployment of containers on client machines is managed via a dedicated VM using Docker and Portainer, ensuring streamlined configuration and oversight. All images and containers are securely stored in a GitLab repository for backup and version control. In the second phase, we will implement clustering for the SE450, which will enhance disaster recovery capabilities and simplify management.

## Server / Compute Nodes

The SE450, equipped with a hypervisor solution will host the VMs configured as outlined in the previous chapter. Physical connections between the SE30 devices and the OT equipment can be established via ethernet cable or RS232/RS485 connection, with BIOS configured to support these interfaces. Additionally, to ensure accurate quality inspection, it’s crucial to properly position the camera and optimize lighting conditions.

## Networking

All devices are connected through CAT-6 LAN cable, forming a tree-topology network, with the SE450 serving as the central hub to aggregate the data from all Edge Nodes. The SE450 also interfaces with other manufacturing servers, enabling seamless integration with applications such as the Manufacturing Execution System (MES)

## Storage integration

Given the stringent on-premises requirements of the developed solutions, local storage is shared by the applications and installed directly on the SE450.

## Performance considerations

Performance and sizing consideration include latency requirements for data collection. In validated scenarios, a cabled LAN was selected to better stability and safety. However, the SE30 and SE450 also support WLAN or WWAN, offering high-speed and low-latency performance without the need for cabling. For each specific use case, the storage sizing needs to be determined based on the number of nodes, file sizes, and retention policy.

For the quality inspection with AI, the following considerations are important:

- **Training Request**: The number of simultaneous nodes sending training requests to the SE450 must be factored in.
- **AI inference**: The SE30 was selected for inference due to its alignments with the project’s requirements.

- **Model training:** An Nvidia® A2 GPU was selected for initial validation. For scenarios requiring faster response times, more powerful GPUs, such as Nvidia® L4 or larger GPUs with the 360mm chassis version of the SE450 should be considered.

# 7 Solution Validation

For the validation of the Digital Twin solution, the 3D model of the Lab was built within the in-house developed platform. Data collected through MQTT from the SE30 devices connected to the robots was sent to the platform in real-time, enabling easy visualization of the robots' status. Additionally, the other flow of commands from the digital platform to the robots was validated. This validation is illustrated in Figure 14. The high computing power of the SE30 resulted in low latency for data collection and processing.

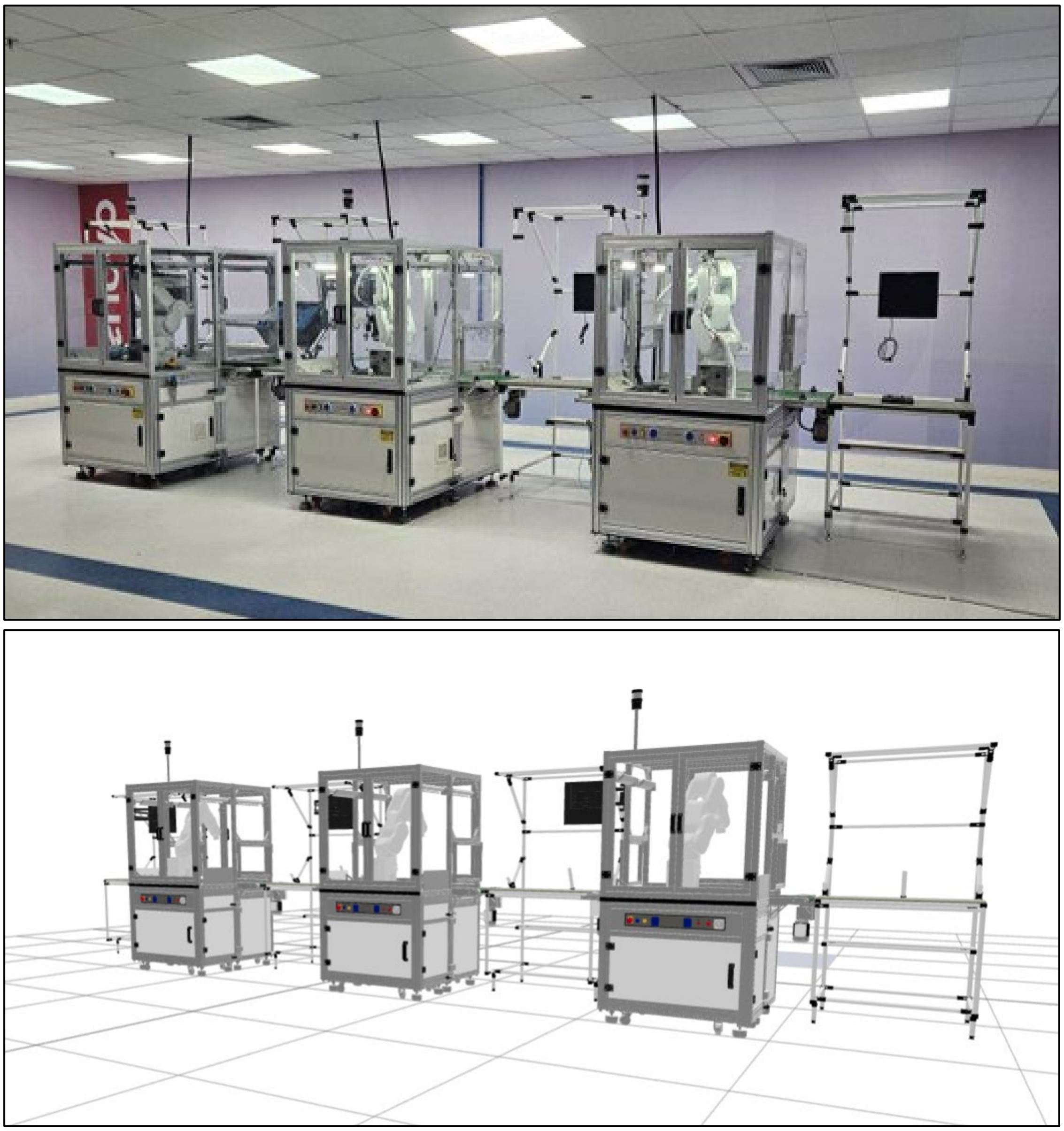

Figure 14 - Digital Twin view (a)Physical view (b)Cyber view

# Quality inspection system validation

The quality inspection system was validated based on the application's response time and the accuracy of the AI inspection. The response time of the application was tested with different hardware configurations. The result achieved with the SE30 (Intel® Core i5™, 16GBRAM) demonstrated that the inspections for labels, screw & keyboard using images captured from three different faces of the product (lid open "A3", back cover "C" and lid closed "A1") could be performed in 6,2 seconds. This duration includes the images acquisition, application requisition, and AI inference, meeting the requirements for the quality inspection response time. Results are displayed in Figure 15

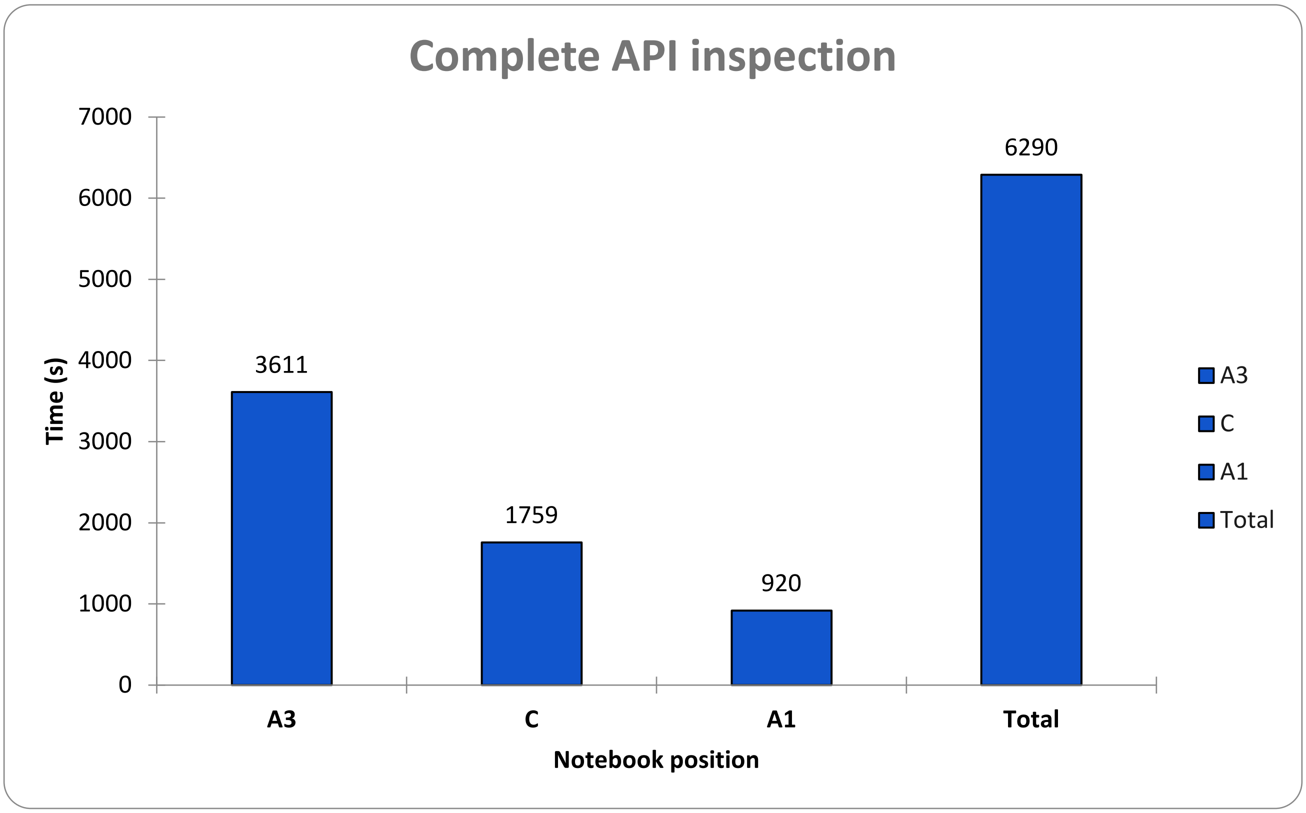


Figure 15 - Inspection time response.

## Accuracy of the Quality Inspection System

The Label inspection task was considered the most critical for system accuracy due to the similarity of labels and the variability in images caused by lightning conditions. For validation, the solution was trained using 45.903 images and test with 6.534 images, including labels from Intel®, and other hardware and technology vendors. The AI achieved a mean accuracy of 98.77% for most labels, with 100% accuracy for most Intel® and AMD® labels. The lowest accuracy was observed with Windows® holographic labels due to the angular lightning variance.

The results for the label inspection are displayed in Figure 16 showing two labels properly detected with 100% accuracy.

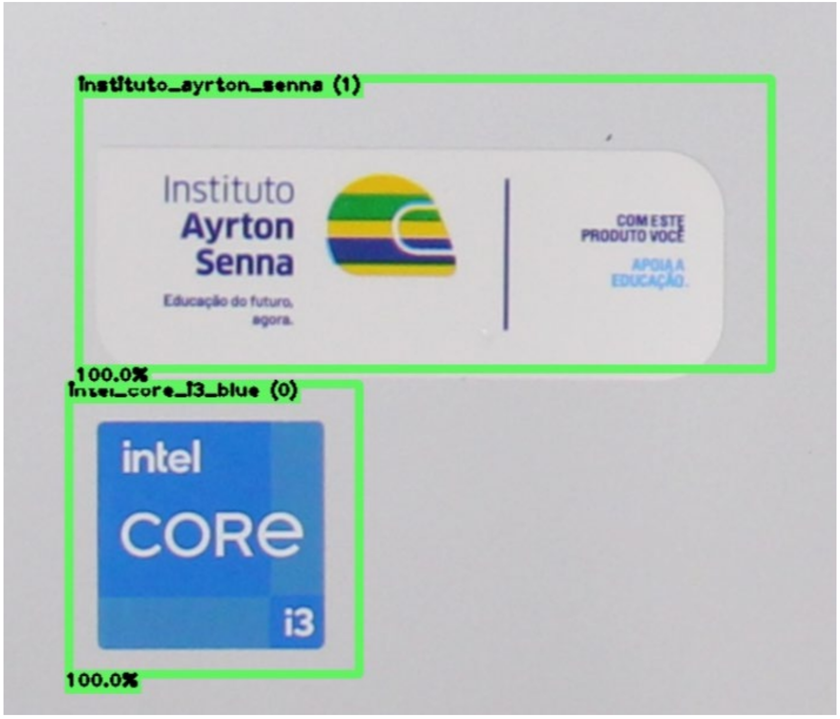


Figure 16 - Label Inspection validation

The results for keyboard inspection are shown in Figure 17 and the screw detection is displayed in Figure 18.

Figure 17 - Keyboard inspection

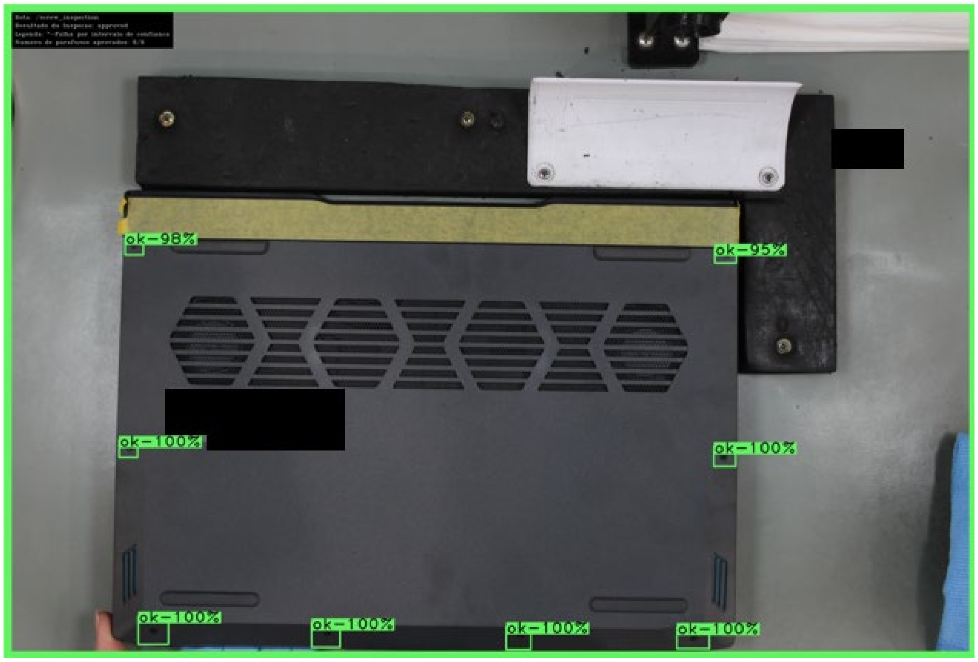


Figure 18 - Screw detection

# 8 Appendix: Bill of materials

This appendix contains the bill of materials (BOMs) for different configurations of hardware for Smart Manufacturing deployments. There are sections for user servers, management servers, storage, and networking.

The BOM lists in this appendix are not meant to be exhaustive and should always be verified using the appropriate configuration tools. Any discussion of pricing, support, and maintenance options are beyond the scope of this document.

Within a specific BOM section, optional items are numbered with alternatives shown as lower-case letters. For example, a Fibre Channel adapter for a compute server is only needed for shared storage connected through a SAN.

## BOM for compute servers

For the SE30, the following options apply to the bill of materials:

Table 6 - SE30 BOM

| Part Number | Material Description | Qty |
|---|---|---|
| 11NB001BBP | Desktop TE SE30 I51145V 16G 256G W10IOT | |
| SBB1K34463 | UL Warning C/L LBL BK | 1 |
| SBB1K34467 | UL Warning P/L LBL M_BR2032 | 1 |
| SBB1N66732 | UL4200A Flyer Non-CRU BR2032 | 1 |
| SBB1A24125 | Back Cover w/o Heatpipe DP | 1 |
| SBB0G92499 | Line Cord C5 Brazil | 1 |
| SBB1A18981 | SG ENG/BRL/ARA/FRA/SPA | 1 |
| SBB1A24085 | 65W 89% Adapter BK -20~60C | 1 |
| SBB0F52821 | MEXICO NOM MARK CARTON LABEL | 1 |
| SBB0L54571 | USB TRDTNL KB BK BRL | 1 |
| SBB0T14030 | High temp Warning LBL | 1 |
| SBB1K29603 | Italy Env label | 1 |
| SBB1K39001 | PUB BRL | 1 |
| SBB0X40698 | W10 IOT LTSC21-BRL | 1 |
| SBB1B50567 | 9260NGW LBL OEM ZAF | 1 |
| SBB0L52928 | USB Calliope Mouse BK | 1 |
| SBB1A23859 | 0.81L TGL-U Fanless | 1 |
| SBB0T14540 | Ukraine Carton Label | 1 |
| SBB1B55142 | MFG printing LBL OEM | 1 |
| SBB0K62289 | China CCC mark carton LBL MTY | 1 |
| SBB1B49551 | EQM mark label(P/L) | 1 |
| SBB0T14664 | MI system LBL 65W Adapter WT | 1 |
| SBB0T14627 | Carton label for Nano | 1 |
| SBB1A23971 | USB-C to HDMI 0~50C | 1 |

| | | |
|---|---|---|
| SBB0T20235 | A 65W adapter India BIS LBL | 1 |
| SBB1A24467 | Russia CU Cert lbl Tiny | 1 |
| SBB1A23887 | 256GB SSD M.2 2230 NVMe TLC | 1 |
| SBB0G92313 | CEL Category D | 1 |
| SBB1B51699 | Core i5 vPro 11th Gen S2(C/L) | 1 |
| SBB1A24134 | 5B20U54711 MB FRU IOT DPK | 1 |
| SBB1B54862 | MI for Industrial Computer(C/L) | 1 |
| SBB1B50566 | 9260NGW Printing LBL OEM | 1 |
| SBB0M47608 | Win10 IoT Enterprise Flag | 1 |
| SBB1B50370 | 9260NGW LBL UAE | 1 |
| SBB1A23853 | TGL-U I5-1145GRE vPro+16G DP | 1 |
| SBB1A24078 | Intel 9260 2X2AC+BT vPro WW | 1 |
| SBB0T18348 | India BIS Label | 1 |
| SBB0T16881 | Carton label Nano OEM | 1 |
| SBB1H10111 | France_TRIMAN label(P/L) | 1 |
| SBB1B50680 | 9260NGW LBL BRL | 1 |
| SBB0T14628 | Systerm LBL BK for Nano | 1 |
| SBB1K32866 | Dummy Israel Importer Label | 1 |
| SBB1A23874 | 15W Cooler Kit | 1 |
| SBB1A22774 | Enable tpm key | 1 |
| SBB0T14539 | Taiwan New Label | 1 |
| SBB0F52822 | European CE Mark For Carton Label | 1 |
| SBB1B50425 | 9260NGW Carton LBL OEM | 1 |
| SBB0T14751 | China CCC Mark Carton Label | 1 |
| SBB1F35175 | W10 IoT 2021 LTSC Value DPK WW | 1 |
| SBB0J03224 | CEL EG1 Label | 1 |
| SBB1B49841 | PKG w/ TRDTNL KYB FNL WW | 1 |

SE450 Bill of Materials Options:

Table 7 - SE450 BOM

| Material | Material Description | Qty |
|---|---|---|
| 0000000-FN496 | LABEL Label GBM | 2 |
| 0000000-NC817 | PACKAGING Label BOM | 1 |
| 0000000-WG047 | PACKAGING Dist label GBM | 1 |
| 0000000-Y7997 | PACKAGING 1200x600mm Pallet | 1 |
| 0000000-Y8535 | PACKAGING 1200x600 Pallet BOM | 1 |
| 0000000-YD664 | L1 MI USB slave | 1 |
| SG27B23467 | GPU, Nvidia®, Ampere A2, PCIe, 16GB, 40W, half length, passive cooling, graphic GPU | 1 |

| | | |
|---|---|---|
| SBB7A18-236 | L1 SP ICX Intel® 4314 16C/2.4G/135W | 1 |
| SBB7A18-398 | L1 SM 32GB 3200MHz 2RX4 1.2V RDIMM | 4 |
| 0000001-DC058 | TAPE PKG Hand Tape | 0,01 |
| 0000001-DC058 | TAPE PKG Hand Tape | 0.008333 |
| 0000001-R3797 | PACKAGING 5*51*51*521mm-90EdgePrct | 4 |
| 0000006-P6550 | PACKAGING tamper label | 1 |
| 0000013-J2919 | PACKAGING C.P | 0 |
| 0000020-P0566 | PACKAGING IRON BUCKLE | 0 |
| 0000024-L0548 | L1 MI DUMMY 000xxxx | 2 |
| 0000026-K6042 | SCREW M3x3 PHILLIPS | 8 |
| 0000027-F4212 | SCREW M 3.5 STEEL | 3 |
| 0000027-F4212 | SCREW M 3.5 STEEL | 4 |
| 0000037-L7558 | PACKAGING sanstrap | 3 |
| 0000039-M5508 | LINECORD JCord - 2M | 2 |
| 0000041-H8524 | PACKAGING IBM LOGO | 0.166667 |
| 0000041-Y5557 | PACKAGING IRON BUCKLE | 0.166667 |
| 0000043-X3129 | PACKAGING CTN Label 4x6 | 0 |
| 0000043-X3177 | PACKAGING 5*50*50*826mm-90EdgePrct | 0 |
| 0000043-X3229 | PACKAGING corner protect | 0 |
| 0000044-E1939 | PACKAGING stretch wrap | 0.166667 |
| 0000044-E1942 | LABEL Carton label | 2 |
| 0000046-C7465 | L1 PWRC 2.0M, 13A/125V | 2 |
| 0000046-D2194 | PACKAGING Corner Protect | 4 |
| 0000068-Y7397 | L1 MI SELECT STORAGE | 1 |
| 0000081-Y7879 | LABEL Mfg Proc Lbl | 1 |
| 0000095-Y4095 | L1 MI_P CONF ID 01 | 1 |
| 0000095-Y4137 | L1 MI_P CONTRLR 01 | 1 |
| 0000095-Y4825 | GBM Memory Labels | 2 |
| 0000095-Y4828 | LABEL MemoryLabeling | 2 |
| SB27B02-967 | BDPLANAR Bona Edge Planar ASM PASS6 R2 | 1 |
| SBB7A01-422 | L1 LPK WW Lenovo LPK | 1 |
| SBB7A01-520 | L1 STA M.2 SATA/NVMe 2-Bay Kit | 1 |
| SBB7A02-980 | L1 MI OB SATA RAID mode | 1 |
| SBB7A03-309 | L1 HSK SR630 V2 Std Heatsink | 1 |
| SBB7A03-864 | L1 FOD XCC Advanced to Enterprise | 1 |
| SBB7A14-753 | L1 MECH POWER PADDLE SR850V2 | 1 |
| SBB7A18-205 | L1 MI Disable IPMI-over-LAN | 1 |
| SBB7A18-652 | L1 MI SE350 Disable IPMI-over-KCS | 1 |
| SBB7A18-683 | L1 MI Security Pack Disabled | 1 |
| SBB7A20-356 | L1 CPK Brazil CPK | 1 |
| SBB7A20-707 | L1 COPT ThinkSystem 4R CPU ICX HS clip | 1 |

| | | |
|---|---|---|
| SBB7A21-643 | L1 MI N+N redundancy with OVS | 1 |
| SBB7A35-835 | L1 PKG Bona Standard PKG BOM L1 | 1 |
| SBB7A41-303 | L1 MI Efficiency - Favor Performance | 1 |
| SBB7A43-710 | L1 HD Intel S4520 480GB SATA SSD | 2 |
| SBB7A14-832 | SSD M.2 5300 960GB SATA NHS SSD | 2 |
| SBB7A44-555 | L1 MI Low voltage (100V+) | 1 |
| SBB7A45-867 | L1 PS Edge 1100WP AC PSU | 2 |
| SBB7A50-449 | L1 CA Intel I350 OCP w/ Internal Lock | 1 |
| SBB7A50-453 | L1 BASE BONA_2U_CHASSIS_ASSY-300 | 1 |
| SBB7A50-456 | L1 MECH FAN MODULE ASM | 6 |
| SBB7A50-460 | L1 MECH Bona Edge Left Riser PCBA Cage | 1 |
| SBB7A50-461 | L1 MECH Bona Edge Right Riser PCBA Cage | 1 |
| SBB7A50-469 | L1 COPT L300_2U-TO-1U_HS_FILLER_ROSA | 1 |
| SBB7A50-474 | L1 COPT BONA_PDB_COVER | 1 |
| SBB7A50-476 | L1 COPT BONA DETECT MODULE FILLER | 1 |
| SBB7A50-480 | L1 MECH REAR ANT BOX FILLER | 2 |
| SBB7A50-482 | L1 MECH OCP_CAGE | 1 |
| SBB7A50-483 | L1 MECH OCP_CABLE_BRACKET | 1 |
| SBB7A50-484 | L1 MECH BONA_2U_SSD_CAGE | 1 |
| SBB7A50-488 | L1 MECH BONA_TOP_COVER_LED | 1 |
| SBB7A50-492 | L1 MB Bona Edge System Planar | 1 |
| SBB7A50-493 | L1 MECH Kepler-OPN RoT Module | 1 |
| SBB7A50-498 | L1 COPT Label Group | 1 |
| SBB7A50-514 | L1 CBL SE450 Internl 2x1 SATA Cable | 1 |
| SBB7A50-518 | L1 CBL SE450 Riser PCIe x8 Cable | 2 |
| SBB7A50-611 | L1 MECH BE SBS M.2 ADAPTER BRACKET | 1 |
| SBB7A50-613 | L1 MECH SE450 Port Dust Cover Kit | 1 |
| SBB7A50-620 | L1 CBL SE450 PDB Sideband Cable | 1 |
| SBB7A50-622 | L1 CBL SE450 M.2 Adapter Cable | 1 |
| SBB7A50-624 | L1 LBL Bona Edge Service Label LI | 1 |
| SBB7A50-771 | L1 LBL Bona Edge Agency Label | 1 |
| SBB7A50-774 | L1 LBL Bona AC 1100W PR. ROW Label | 1 |
| SBB7A50-779 | L1 LBL Bona Edge OCP 4P Label | 1 |
| SBB7A54-938 | L1 MI TPM 2.0 & non-PFR Sec Function | 1 |
| SBB7A64-573 | L1 REGID E2201 | 1 |
| SC17B03-357 | CABLE SATA Cable C for 2*2.5"HDD w/BP | 1 |
| SC17B03-361 | CABLE Riser PCIeI Cable | 2 |
| SC17B03-378 | CABLE Led Cable for Wall Mount | 1 |
| SC17B05-132 | CABLE OCP Cable | 1 |
| SC17B05-141 | CABLE PSU Signal Cable | 1 |
| SC17B05-146 | CABLE M.2 Cable | 1 |

| | | |
|---|---|---|
| SC87A98-454 | CHASSIS 2U,300MM CHASSIS | 1 |
| SG17A10-098 | GBM S/N INFO, BLACK | 1 |
| SG17A30-791 | GBM Label GBM, BLACK AGENCY LABEL | 1 |
| SH47A41-755 | HEATSINK LGA4189 1U Std HTSK | 1 |
| SL17A02-113 | LABEL Large Lenovo Label | 1 |
| SL17A03-709 | LABEL Ribbon for HDD label | 2 |
| SL17A03-725 | LABEL Lenovo Response label | 1 |
| SL17A04-177 | LABEL Memory Security label | 2 |
| SL17A06-151 | LABEL Ribbon artwork DBS 5000 | 0.166667 |
| SL17A30-639 | LABEL RIBBON, SILVER | 0.166667 |
| SL17A30-792 | LABEL SYS LABEL, BLACK | 1 |
| SL17A67-774 | LABEL HDD Security label for WTY | 2 |
| SL17A98-284 | LABEL OCP NIC LABEL 4P | 1 |
| SL17A98-287 | LABEL THINK EDGE LABEL | 1 |
| SL17A98-288 | LABEL PDB COVERING LABEL | 1 |
| SL17A98-293 | LABEL MODEL NAME LABEL | 1 |
| SL17A98-302 | LABEL AGENCY LABEL | 1 |
| SL17B02-845 | LABEL POWER SAFETY LABEL 1100W AC | 1 |
| SL17B02-851 | LABEL SSL LI | 1 |
| SM17A65-310 | MECH_ASM Europa PDB SVT | 1 |
| SM17A98-131 | MECH_ASM OCP CABLE BRKT | 1 |
| SM17B01-955 | MECH_ASM I/O FILLER GBM | 1 |
| SM17B02-177 | MECH_ASM 1U HS FILLER L300 W/ MYLAR | 1 |
| SM17B08-941 | MECH_ASM PCI RISER BRACKET LEFT | 1 |
| SM17B08-943 | MECH_ASM PCI RISER BRACKET RIGHT | 1 |
| SM17B08-944 | MECH_ASM INTERNAL HDD CAGE | 1 |
| SM17B08-948 | MECH_ASM 2U OCP COVER CAGE | 1 |
| SM17B08-950 | MECH_ASM 6056 FAN ASM AVC | 6 |
| SM17B08-982 | MECH_ASM 2U SBS M2 BRACKET | 1 |
| SM17B08-985 | MECH_ASM BEZEL DETECT BRKT FILLER | 1 |
| SM27A78-111 | MECHANICAL Lotes AZIF0193-P001C11 | 1 |
| SM27A98-171 | MECHANICAL PDB SWITCH CAP | 1 |
| SM27B09-007 | MECHANICAL REAR ANTENNA FILLER | 2 |
| SM37A92-787 | MEMORY T SMR4WEC4C4K3472SDI D4-32R | 2 |
| SMD7A93-000 | MTD MAKE TO DUMMY | 2 |
| SN37B01-921 | NETWRK_CRD Intel OCP, NETWRK_CRD | 1 |
| SP17A35-426 | PACKAGING 500m Thank you tape | 0 |
| SP17A35-426 | PACKAGING 500m Thank you tape | 0.166667 |
| SP17A69-933 | PACKAGING RFID Label | 1 |
| SP17A90-031 | PACKAGING Bona Standard PKG BOM L2 | 1 |
| SP17A90-032 | PACKAGING Bona Standard PKG BOM L3 | 1 |

| | | |
|---|---|---|
| SP17B02-290 | PACKAGING Bona bottom cushion | 1 |
| SP17B02-291 | PACKAGING Bona top rear cushion | 1 |
| SP17B02-292 | PACKAGING Bona top front cushion | 1 |
| SP17B02-293 | PACKAGING Bona SG box | 1 |
| SP17B02-294 | PACKAGING Form bag | 1 |
| SP17B02-295 | PACKAGING Bona MTY carton | 1 |
| SP47A36-797 | PUBS Brazilian Warranty for ThinkSystem | 1 |
| SP47A76-666 | PUBS DCG Regulatory Notices (Full) | 1 |
| SP47B35-788 | PUBS ISG epub booklet, GBM | 1 |
| SP57A97-080 | PWR_SUPPLY Delta 1100WP CFFv4 AC RF PSU | 2 |
| SR17A32-463 | RAID_CARD M.2 SATA/NVMe 2-Bay Kit | 1 |
| SS17A04-246 | SCREW M3 X 4.5L w/ Nylok #PH | 2 |
| SS17A62-738 | SCREW SCREW, M3x5_0.8_flat | 1 |
| SS17A98-311 | SCREW M3 X 4L W/ NYLOK #PH BLACK | 3 |
| SS17A98-311 | SCREW M3 X 4L W/ NYLOK #PH BLACK | 2 |
| SS17A98-313 | SCREW M2.5 X 5L | 2 |
| SS17A98-316 | SCREW SCREW M2 X 1.8L | 2 |
| SS17A98-323 | SCREW M3.5 X 4L BLACK NYLOK | 2 |
| SSA7A85-924 | SP ICX 4314 16C/2.4G/135W | 1 |
| SSD7A94-342 | SSD_ASM 2.5" S4520 480GB RI SATA TL ASM | 2 |
| SSS7A43-185 | SSD 2.5" S4520 480GB RI SATA HS L2 | 2 |
| STA7B09-585 | ECAT_TLA SE450 Riser1 PCBA PASS5 | 1 |
| STA7B09-591 | ECAT_TLA SE450 Riser2 PCBA PASS5 | 1 |
| STA7B09-595 | ECAT_TLA Kepler-OPN RoT Module, SVT | 1 |
| TEX86US-BCAPT | TE X86 CAPTIVE USB slave | 1 |
| TSTEAIR-DUCTS | TE PART AIR DUCTS | 1 |
| SA37A47-021 | ANTENNA WLAN 2.4/5/6G Antenna | 2 |
| SC17B00-767 | CABLE Bona WLAN ANT Cable, 305mm, Black | 1 |
| SC17B00-768 | CABLE Bona WLAN ANT Cable, 620mm, Blue | 1 |
| SM27A70-512 | MECHANICAL WIFI Module COVER | 1 |
| SN37B02-828 | NETWRK_CRD Bona ENM Module ASSY | 1 |
| SW17A47-039 | WIRELESS WLAN-6E/BT combo module | 1 |
| SA37A47-021 | ANTENNA WLAN 2.4/5/6G Antenna | 2 |
| | | |
| X000063-17267 | PACKAGING Stretch Wrap | 0 |
| X000073-86000 | PACKAGING Plastic Banding | 0 |
| X000073-86001 | MECHANICAL BAND SEAL | 0 |
| X000081-28003 | PACKAGING S/WRAP M/C #3 | 0 |

# 9 Abbreviations

Table 8 - Abbreviations

| Acronym | Meaning |
|---|---|
| IoT | Internet of Things |
| IIoT | Industrial Internet of Things |
| OS | Operating System |
| AI | Artificial Intelligence |
| LVD | Lenovo Validated Design |
| GPU | Graphic Processing Unit |
| CPS | Cyber-physical system |
| ERP | Enterprise Resource Planning |
| MES | Manufacturing Execution Systems |
| MOM | Manufacturing Operation Management |
| PLM | Product Lifecycle Management |
| EC | Edge Computing |
| ML | Machine Learning |
| BMC | Base Management Controller |
| CI/CD | Continuous Integration/Continuous Development |
| OEE | Overall Equipment Effectiveness |
| OT/IT | Operational Technology/Information Technology |
| RAM | Random Access Memory |
| VM | Virtualized Machine |
| IP Camera | Internet Protocol Camera |
| SSD | Solid State Disk |

# 10 Authors and Contributors

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|---|---|---|
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# 11 Resources


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# Document History

| | | |
|---|---|---|
| Version 1.0 | July 2024 | First version includes Digital Twin solutions and Quality Inspection with AI developed for Lenovo Brazil manufacturing site. |

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