ISA 95
FOR BEGINNERS

A simple Introduction to
ISA 95 and its key concepts

Written by
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PREFACE

ISA-95 for Beginners

A practical introduction by Team of Swatantra

ISA-95 can look intimidating at first because it brings together production, automation, operations, business planning, and information exchange. This book was written to make that landscape easier to enter without reducing it to a list of software products or a single pyramid.

The chapters follow a practical path from the physical production process and control functions through HMI, SCADA, MES/MOM, ERP, information models, traceability, integration, digital twins, and production AI. The emphasis is on responsibilities, context, and the movement of trustworthy information between systems.

The goal is not to replace the ISA-95 / IEC 62264 standards or site engineering judgment. It is to give beginners a clear mental model, realistic examples, and enough structure to ask better questions before moving into standards text, architecture decisions, or implementation.

We hope this book becomes a useful starting point for students, analysts, engineers, manufacturing teams, and technology professionals who want to understand how the factory floor and business systems fit together.

Welcome to ISA-95 for Beginners.

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Publication Information

Edition

Edition	Publication date	Notes
First edition	July 2026	Introductory classroom and self-study edition.

How to interpret statements in this book

Label	Meaning
Standard concept	A simplified explanation of concepts or models found in the ISA-95 / IEC 62264 family. Use the official standard for normative wording and compliance.
Engineering guidance	A recommended architecture, safety, control, cybersecurity, data governance, or operational practice. It is not automatically a clause of ISA-95.
Site decision	A choice that depends on the plant, industry, regulation, risk assessment, system landscape, and accountable roles.

Technical review status

This book is an introductory teaching guide. It does not claim standards compliance or independent certification. Before using it for procurement, safety, cybersecurity, regulated quality, or production-interface design, have the work reviewed by qualified plant, controls, MES/MOM, quality, IT, and OT professionals.

Figures and tables

Unless a source is named, the figures and teaching tables were prepared for this book. They simplify real architectures and should not be treated as vendor specifications or compliance diagrams.

Why This Book Exists

Most beginners learn the names PLC, SCADA, MES, and ERP before they learn what each system should decide. The gap becomes obvious when a line stops, a lot goes on hold, or two systems report different quantities. This book follows one packaging-line problem from the first machine signal to the reviewed production result and the later business update.

About and How to Use This Book

This is a foundation guide for students, business analysts, ERP and MES team members, junior automation professionals, manufacturing managers, data specialists, and anyone entering industrial systems. No programming, controls-engineering, or standards background is assumed.

Read Chapters 1 and 2 first. They provide the map. Chapters 3 through 6 explain the system layers, and Chapters 7 and 8 cover equipment, material, people, events, and traceability. Chapters 10, 11, and 15 bring the ideas together through production decisions and integration failures. Chapters 9 and 12 can wait until a second pass. Keep the vocabulary primer nearby, and attempt the exercises before opening the model answers.

The guide does not replace the official ISA-95 / IEC 62264 standards, plant safety rules, cybersecurity requirements, vendor documentation, or experienced engineering review.

What You Will Learn

By the end of the book, you should be able to map a simple factory from Level 0 to Level 4, separate a production plan from an actual result, identify the accepted record for an important fact, and review a basic integration flow for failure handling and correction. That is enough for a beginner. It is not enough to design a safety system, claim standards compliance, select an MES alone, or implement a production interface without site review.

The labels in the opening pages distinguish a simplified standard concept from engineering guidance and a site-specific decision.

Do not try to memorize every term. Keep returning to five questions: What physically happened? Which system observed or acted? Which work, material, equipment, and time give the event context? Where is the accepted record kept? Who is allowed to approve the next action?

“Accepted record” is a governance term used throughout this book for the record a site designates as authoritative for a particular decision; it is not a formal ISA-95 object class.

Running Example: One Packaging Line

The example line fills, caps, labels, weighs, and packs bottles against an order for 10,000 units. By mid-morning, the checkweigher is rejecting underweight bottles. Ravi wants to keep the line stable. Anita will not release the lot without reliable evidence. Kumar suspects instrument drift. Priya is watching an afternoon shipment.

The People in the Story

Ravi is the production supervisor. Anita works in quality. Kumar represents maintenance, and Priya represents planning. Their questions are drawn from ordinary production meetings, although the people themselves are fictional.

They are not formal ISA-95 roles. They appear only when a role helps explain a decision or a handoff.

Abbreviations Used in This Book

AAS - Asset Administration Shell | AI - Artificial Intelligence
API - Application Programming Interface | BOM - Bill of Materials
CMMS - Computerized Maintenance Management System | DCS - Distributed Control System
EAM - Enterprise Asset Management | ERP - Enterprise Resource Planning
HMI - Human-Machine Interface | IEC - International Electrotechnical Commission
ISA - International Society of Automation | MES - Manufacturing Execution System
MOM - Manufacturing Operations Management | MQTT - lightweight publish/subscribe messaging transport protocol
OEE - Overall Equipment Effectiveness | OPC UA - OPC Unified Architecture
OT - Operational Technology | PLC - Programmable Logic Controller
QMS - Quality Management System | SCADA - Supervisory Control and Data Acquisition
WIP - Work in Process | WMS - Warehouse Management System

Factory Vocabulary Primer

Read this short primer before Chapter 1 if manufacturing language is new to you. The definitions are deliberately practical; later chapters add the ISA-95 context.

Term	Plain-English meaning	Term	Plain-English meaning
Interlock	A control condition that prevents or stops an action when required conditions are not safe or valid.	**Sublot**	A smaller traceable portion of a lot used when the plant needs finer tracking.
Disposition	An authorized quality decision about what happens to nonconforming material: release, rework, scrap, return, or another approved outcome.	**Detailed scheduling**	Turning a broader production requirement into a practical sequence of work using available equipment, materials, people, and time.
Genealogy	The traceable relationship between input materials, process steps, equipment, and the output lots or units produced.	**Reason code**	A controlled label used to explain an event such as downtime, scrap, hold, or delay.
Process segment	A reusable description of a kind of work and the resources it requires, such as filling, inspection, mixing, or packaging.	**Sparkplug**	A specification used with MQTT to add industrial topic structure, state awareness, and consistent payload conventions.
Lot	A traceable quantity of material produced, received, stored, consumed, or shipped under a shared identity.	**Asset Administration Shell (AAS)**	A structured digital representation used to describe an asset and exchange information about it; it complements rather than replaces ISA-95 responsibilities.

Chapter 1: Why ISA-95 Matters for Beginners

At 7:00 a.m., Priya releases an order for 10,000 bottles. By 7:12, Ravi is asking whether the line is ready, Anita is checking the active weight limits, and Kumar is tracing an intermittent checkweigher fault. The same shift has already produced four different questions.

That is normal in a factory. Production, quality, maintenance, and planning do not need the same detail. Trouble starts when they use different names for the same equipment or pass numbers between systems without explaining what those numbers mean. ISA-95 gives them a common frame.

1.1 Beyond the pyramid

ISA-95 is a family of standards, not merely a familiar pyramid diagram. For a first reading, focus on responsibilities, shared identities, reusable work definitions, and the information exchanged between systems. Use the official standards when you need normative wording, detailed design guidance, or a compliance claim.

ISA-95 is closely aligned with the IEC 62264 international standards family. Some parts are IEC adoptions or jointly aligned publications, although edition dates can differ. Together, they give enterprise, manufacturing operations, and control teams a shared vocabulary. A controls engineer and a planner can still need different records, but they should not use the same word for two different things without noticing.

The pyramid is a useful starting picture:

- The physical process, sensors, actuators, and controls are at the bottom.
- Supervisory and manufacturing operations systems, including HMI, SCADA, historian, MES, QMS, WMS, and maintenance systems, fall in the middle.
- ERP and business planning systems are at the top.

A diagram does not settle an argument. The useful part is being able to name the decision, the record that owns it, and the evidence used to reach it.

On the packaging line, a sensor measures weight, the PLC rejects an underweight bottle, SCADA shows the trend, the execution system links the reject to the active order and lot, and ERP uses the reviewed result for planning and inventory. Each step adds meaning; none of the systems sees the entire story alone.

1.2 The danger of data without context

A modern factory brings together automation, production, quality, maintenance, warehousing, finance, and supply-chain teams. They share the same physical day, but they do not all need the same record or make the same decision.

Integration becomes brittle when each system names the same equipment or material differently. A filler may have one identifier in maintenance, another in SCADA, and a third in ERP. The same material may be called an item, SKU, batch, lot, or inventory record.

ISA-95 gives those teams a common vocabulary for equipment, material, people, capabilities, and production work. That common language reduces the chance that two systems exchange a value while attaching different meanings to it.

A factory can collect millions of tag readings and still be poorly prepared for analytics or AI. Until a reading is tied to equipment, time, product, work, and data quality, it is mostly a number in storage.

Imagine that a screen shows only the number 503.

Before anyone acts, they need to know what 503 measures, where it came from, when it was recorded, which product was running, what range was expected, and whether the source was healthy.

Once those details are attached, 503 becomes usable information instead of an unexplained value.

Ravi sees 503 and asks whether the line is safe. Anita asks whether it is inside the product specification. Kumar asks whether the sensor can be trusted. The number has not changed; the decision changes because the context changes.

Raw item	Missing question	ISA-95 style context
503	503 what?	Unit, equipment, product, and specification.
Line stopped	Why and for how long?	State interval, reason code, work order, and owner.
Reject count high	Which product and lot?	Operation, material lot, quality rule, and disposition.

Raw item	Missing question	ISA-95 style context
Work order delayed	What caused delay?	Schedule, actual output, downtime, material, quality, and maintenance.

1.3 What you'll actually learn here

This book will not turn you into an ISA-95 compliance auditor. It will give you enough structure to:

- place Levels 0 through 4 by responsibility and time horizon;
- distinguish PLC, HMI, SCADA, historian, Level 3 execution applications, and ERP;
- separate planned work, machine evidence, execution records, and business results;
- turn a raw tag or state change into a contextual production event; and
- review a basic integration flow for ownership, security, failure handling, and correction authority.

Exercise: choose one factory problem—a stoppage, quality hold, shortage, or delayed order. Explain it in four sentences: Where did the first observation appear? Who responded? Where was the final status accepted? Which business decision changed, or might change, because of it? (Model answer: A.1.)

Chapter 2: The ISA-95 Pyramid and the Five Levels

The ISA-95 pyramid is easy to misread. Level 4 is drawn at the top, but it is not "above" Level 1 in importance. A safety response at the machine may be immediate; an ERP update can wait. The levels separate responsibility and time horizon.

Use the diagram as a map, not as an organization chart and not as a catalog of software products.

M1 - LEVELS	LEVEL 0 Physical process	LEVEL 1 Sensing / manipulation	LEVEL 2 Monitoring / control	LEVEL 3 Operations	LEVEL 4 Business planning

2.1 Reading the map

Figure 2.1: ISA-95 responsibility, information flow, and typical time horizons.

Read the five levels as a path between the physical process and business planning.

- Level 0 is the physical process.
- Level 1 is sensing and manipulating the production process.
- Level 2 is monitoring and supervising control.
- Level 3 is manufacturing operations management.
- Level 4 is business planning and logistics.

Two directions of travel

Plans, schedules, and controlled instructions move toward execution. Status, observations, reviewed results, and exceptions move back toward operations and the business.

The lower levels sit closer to the physical process and usually have to respond faster.

The higher levels handle broader operational and business questions over longer periods.

Real plants also exchange information sideways: quality with production, maintenance with scheduling, and one Level 3 application with another. The pyramid is a learning map, not a wiring diagram.

Reaction times across the levels

- A sensor may detect a part in milliseconds.
- A PLC can respond in milliseconds or seconds.
- SCADA may show alarms and trends over seconds or minutes.
- MES may coordinate work over minutes, hours, shifts, or days.
- ERP may schedule purchases, inventory, demand, and financing over a period of days, weeks, or months.

Level	Plain meaning	Typical time horizon
Level 0	Physical process: material, equipment, energy, motion, temperature, pressure, weight, and flow.	Process-dependent: from very fast electrical or mechanical changes to slow thermal, chemical, or material changes.
Level 1	Sensing and manipulating the production process: sensors, smart devices, valves, actuators, and other devices that sense or affect production.	Process-dependent: sensing and actuation may be very fast or slower according to the process.
Level 2	Monitoring and supervising control: PLC (Programmable Logic Controller), DCS (Distributed Control System), and other control or supervisory functions.	Milliseconds to minutes, depending on the control or supervisory function.
Level 3	Manufacturing operations: MES (Manufacturing Execution System) / MOM (Manufacturing Operations Management), quality, maintenance, warehouse operations, and performance.	Minutes to shifts and days.

Level	Plain meaning	Typical time horizon
Level 4	Business planning: ERP (Enterprise Resource Planning), finance, procurement, inventory, customer demand, and planning.	Days to months.

2.2 A simple production order journey

A production order for 10,000 units begins as a business requirement in ERP. The execution layer turns that requirement into work orders, operation sequences, resource checks, quality requirements, and production records.

HMI and SCADA help operators supervise the line. PLCs run the machine logic.

Sensors and actuators deal with the physical process itself.

After the run, the records come back together. Control systems provide machine evidence. SCADA and the historian preserve operating detail. The execution layer records output, downtime, quality, consumption, and genealogy. ERP receives the confirmed result it needs for inventory, cost, planning, and customer commitments.

In practice, teams spend most of their time on that handoff: sending a usable requirement down and returning a reviewed result.

2.3 The pyramid is not about importance

Urgency and responsibility are different. Keep these boundaries in mind:

- PLCs handle fast control. Customer promises and inventory value are settled in business workflows.
- SCADA supervises operations and preserves operating detail. Making it the production record for a site is a deliberate design choice, not a default.
- MES can request and coordinate work while validated machine logic remains in control of equipment behavior.
- ERP can state what the business needs; it should never open a valve, drive a motor, or clear an interlock.

These are architecture boundaries used in this book, not a claim that each sentence is a normative ISA-95 clause. Other standards, regulations, risk assessments and site procedures govern safety, alarm management, cybersecurity and regulated quality.

2.4 When products cross levels, follow the function

One product can perform functions at several levels. Place the function first; add the product name afterward.

Place the function instead: sensing a condition, executing deterministic control, supervising an operator, recording production, or planning business demand.

On paper: draw five rows for a real or imaginary plant and place one decision in each row. If an entry contains only a product name, replace it with the function being performed. (Model answer: A.2.)

Chapter 3: Levels 0-2: Physical Process, Sensors, Actuators, and PLCs

Ravi presses Start. The photo eye sees a bottle. The PLC checks the guard, air pressure, and line permissives, then starts the conveyor. A few milliseconds later it is already waiting for the checkweigher result. No business system is involved in that decision.

This chapter stays at the machine: what is measured, what moves, and what the controller must decide without waiting for the rest of the plant.

3.1 Level 0: the physical process

Level 0 is the factory as it physically exists: material, equipment, movement, temperature, pressure, weight, position, flow, vibration, speed, energy, and state.

Examples from the physical process

- A bottle is present or not present.
- A motor is rotating or stopped.
- A package weighs within tolerance or does not.
- A valve is open or closed.
- A tank is filling, emptying, heating, mixing, or waiting.

In other words, Level 0 is the world that software observes or changes—machines, materials, workers, tools, utilities, products, containers, and the production environment.

3.2 Level 1 sensing: how the real world becomes a signal

Sensors translate physical conditions into signals. A photo eye detects presence, a load cell measures weight, a temperature probe senses heat, and an encoder tracks position or speed. Flow meters, pressure transmitters, proximity sensors, and vibration sensors do the same for other conditions.

A clean number is not proof that the measurement is sound. Dirt, drift, poor installation, communication loss, or failed calibration can change the signal. Later systems therefore need the equipment, work, material, time, and data-quality details used to judge it.

3.3 Level 1 manipulation: how commands become movement

Actuators turn control commands and available energy into physical action. Motors move conveyors, valves and cylinders change position, pumps move fluids, heaters add energy, reject arms remove bad units, and robots grip, weld, assemble, or inspect.

Safe control boundaries

Actuators move real equipment and can affect people and product. Their movement therefore remains under validated control logic. A higher-level application may request work, but it must not improvise motor, valve, cylinder, or robot commands.

3.4 Level 2 monitoring and control: PLCs and controllers

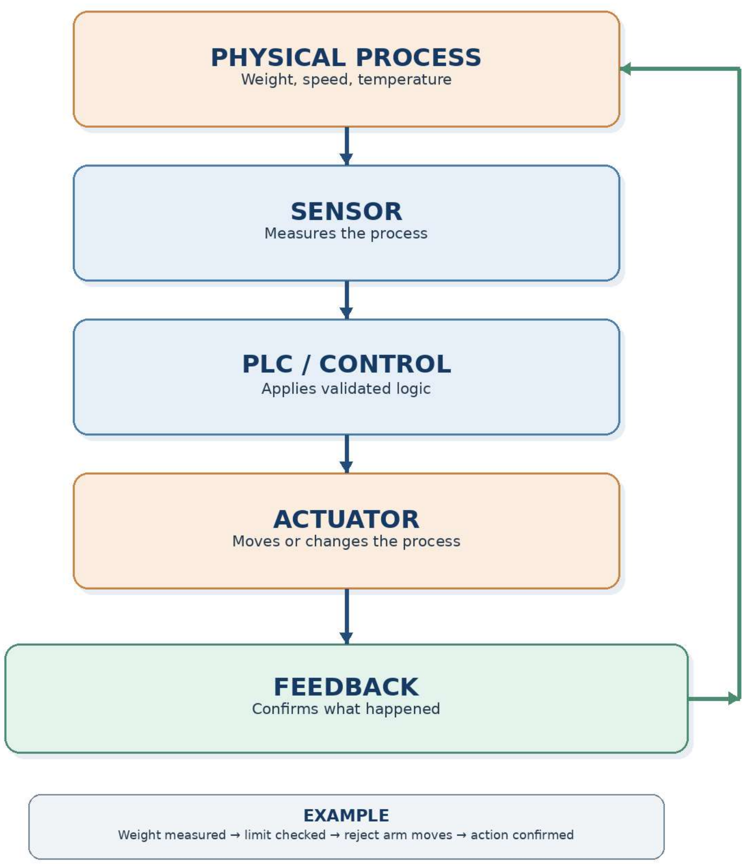

Figure 3.1: Sensor to PLC to actuator flow. In ISA-95 terms, sensing and actuation are Level 1 functions, while PLC monitoring and control functions are commonly associated with Level 2.

A Programmable Logic Controller, or PLC, is a rugged industrial controller close to the machine. In the ISA-95 functional model, PLC and DCS control functions are commonly associated with Level 2 monitoring and supervising control. A PLC works through a relentless scan cycle: read the inputs, execute the logic, update the outputs, and repeat. That speed makes it a machine-level decision engine.

A motor may be allowed to run only when the machine is in automatic mode, the safety guard is closed, a part is present, and pressure is within the permitted range. The PLC checks those conditions continuously.

Safety forms a hard boundary. If a guard opens or a safety device changes state, the validated safety architecture must bring the equipment to the required safe condition. That may involve safety-rated circuits, relays, or a safety PLC. ERP, MES, dashboards, cloud services, and AI models are not substitutes for that function. ISA-95 does not design the plant safety system.

PLC (Programmable Logic Controller) responsibility	Not PLC (Programmable Logic Controller) responsibility
Read machine inputs and execute fast logic.	Long-term business planning.
Apply interlocks, sequences, and equipment control.	Customer order commitment.
Send status, alarms, and tags upward.	Financial posting or payroll.
Protect equipment according to validated logic.	Replacing MES (Manufacturing Execution System) production records.

Decision check
A guard opens while a conveyor is moving. The safety-rated control architecture must bring the machine to a safe condition. ERP, MES, a dashboard, or an AI service must not make or delay that decision.

3.5 Example: a checkweigher reject

At Level 0, a package moves through the physical checkweighing process. At Level 1, the load cell senses weight and the reject actuator manipulates the process. The PLC control function that evaluates the measurement and commands the reject is commonly associated with Level 2. The immediate result is physical: the unit stays on the line or is removed.

That physical action still does not explain the production impact. Higher levels must identify the active work order, applicable specification, affected lot, reject quantity, quality status, and any verified effect on inventory or shipment.

Machine check: choose one machine. Name three sensors, two actuators, and the actions controlled by the PLC. Ask whether it remains safe if the plant network or Wi-Fi fails for an hour. Then decide which facts should travel upward and which decisions must stay near the machine. (Model answer: A.3.)

Chapter 4: Supervisory Functions: HMI, SCADA, Alarms, Trends, and Historian

At 10:12 a.m., the operator waves Ravi over. The reject trend is climbing. The local HMI shows the machine state, SCADA shows the line, and the historian shows when the drift began. HMI, SCADA, and historian are product or technology categories rather than fixed ISA-95 levels; classify the function they perform. None of those records, by itself, says what should happen to the lot.

4.1 HMI and the local machine view

HMI stands for Human-Machine Interface. It is usually the local panel or screen an operator uses to understand and work with a machine. It may show states, alarms, modes, setpoints, permitted controls, counts, messages, and short trends.

An HMI should make an abnormal condition easy to see, show the current machine state, and make permitted actions clear. If an operator has to guess what the machine is doing, the screen has failed at its main job.

4.2 SCADA and the wider process view

SCADA stands for Supervisory Control and Data Acquisition. It gathers information from multiple controllers and gives operators a wider view—perhaps one line, an entire plant, a utility system, or assets spread across a large area.

Operators can see real-time status, alarms, and trends and take authorized supervisory actions. In manufacturing, SCADA often covers production lines and utilities; in other industries, it may supervise geographically distributed equipment.

HMI (Human-Machine Interface)	SCADA (Supervisory Control and Data Acquisition)
Usually close to a machine or local operation.	Usually supervises a wider process, line, area, or site.
Focused on operator interaction with a machine.	Focused on supervisory visibility, alarms, trends, and coordination.

HMI (Human-Machine Interface)	SCADA (Supervisory Control and Data Acquisition)
Often connected directly to PLCs/controllers.	Often connected to many controllers and data sources.
May be a panel, touchscreen, or local station.	May include servers, clients, historians, alarm systems, and engineering tools.

4.3 Alarms and trends

An alarm should draw attention to a condition that needs a response. It should make the priority, meaning, timestamp, current state, acknowledgment status, and expected action clear.

Too many weak alarms create alarm fatigue; operators begin to ignore the noise. Too few alarms hide genuine problems. Good alarm design is not a wall of red pop-ups. It is a disciplined way to tell a person that a decision or response is needed.

Trends show how values change over time. They can reveal gradual drift, repeated minor stops, unstable flow, slowing equipment, rising rejects, or unusual energy use. A single reading may look harmless; a three-hour trend can show that the process is steadily moving toward trouble.

4.4 Historian: industrial time-series memory

Figure 4.1: HMI, SCADA, and historian.

The historian is the plant's time-series memory. It stores timestamped temperatures, pressures, flow rates, machine speeds, motor currents, alarms, states, quality signals, and energy use.

That history is useful for troubleshooting, long-term analysis, compliance evidence, and root-cause investigation. It can preserve timestamped evidence of when a recorded value changed or an actuator state was observed to change, subject to the source timestamping and data-collection configuration.

Production, quality, and maintenance records add the context the historian does not own: which work or batch was affected, why the event mattered, who reviewed it, and what happened next.

Ravi sees a twelve-minute stop and calls it downtime. Kumar finds the fault alarm. Anita asks whether product made during the unstable period must be held. The historian preserves the timeline; the team still has to decide what that timeline means.

Common mistake
A SCADA screen can display counts, alarms, and trends, but that does not automatically make it the designated owner of work-order completion, material genealogy, or quality disposition.

4.5 SCADA should not become a hidden MES

A common shortcut is to keep adding features to SCADA: a work-order field, then lot tracking, quality checks, downtime calculations, genealogy, and production accounting. The system may keep running, but every addition makes it harder to audit, support, and change.

Suppose SCADA shows a rising reject alarm, but the screen does not tell you which lot is running or which specification applies. Start with what the alarm actually proves: the configured reject count or rate crossed a limit at a known source and time.

Important questions are still unanswered. Which batch or lot was active? Which product and specification were in force? Was the instrument healthy? Did the reject mechanism actually remove every failed unit?

Check the active production record, the applicable specification or recipe, recent quality results, and the maintenance history. The alarm tells you where to start; it does not supply the missing lot and process context. (Model answer: A.4.)

Chapter 5: Level 3: MES, MOM, Quality, Maintenance, and Inventory Operations

The bottle is already in the reject bin. Ravi wants to keep the line moving. Anita needs the lot and the active specification. Kumar needs the fault and calibration history. The warehouse wants to know whether the material can still be issued. The reject pulse answers none of those questions.

Level 3 is where those separate records are connected, reviewed, and turned into an operating result.

5.1 MES and MOM in simple terms

MES stands for Manufacturing Execution System. MOM, or Manufacturing Operations Management, is the broader operations domain that includes production, quality, maintenance, and inventory work.

For simplicity, this book often calls the main execution application MES. A real plant may divide the same responsibilities among several systems.

Level 3 answers the practical questions the floor keeps asking: Which work order is running? Which step are we on? Which machine, operator, and lot are involved? Did the quality checks pass? What was completed, rejected, reworked, delayed, or left open?

5.2 How Level 3 creates the production record

A designated Level 3 application turns production activity into a record that people can trace, approve, and correct. In many plants that application is MES; in others, the responsibility is shared.

Typical responsibilities include dispatching work, tracking operations, capturing output and downtime, recording quality events, managing work in process, linking genealogy, and confirming results.

The software product matters less than the governance. The plant must know where each accepted production value lives, who may correct it, and which history must remain visible after a correction.

The PLC may count pulses and SCADA may display speed, but the execution record tells the business story: WO-1001 produced 9,840 good units, 160 rejects, and 34 minutes of unplanned downtime on Line 2.

5.3 Four Level 3 operations areas

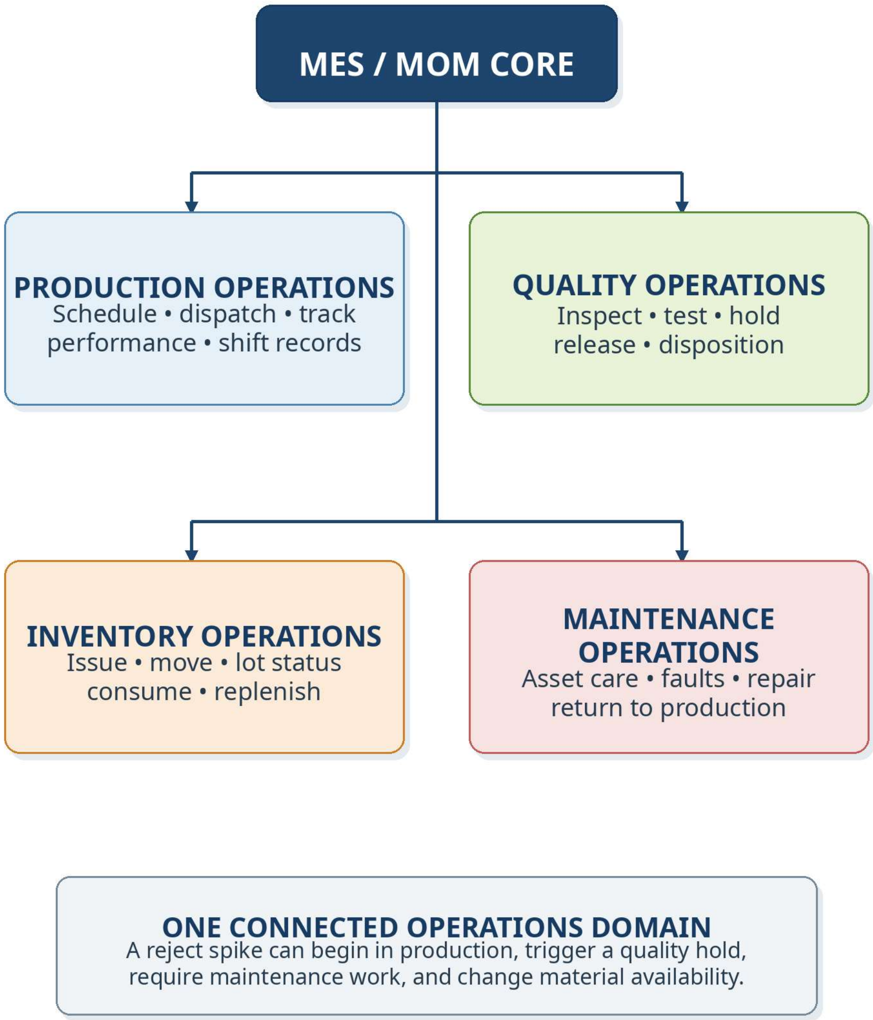

Figure 5.1: Four Level 3 operations areas.

Operations area	What it manages	Typical systems
Production operations	Work orders, dispatch, output, downtime, performance, shift records.	MES (Manufacturing Execution System), production tracking, detailed scheduling.
Quality operations	Inspection, test result, nonconformance, hold, release, deviation, disposition.	QMS (Quality Management System), LIMS (Laboratory Information Management System), MES (Manufacturing Execution System) quality module.

Operations area	What it manages	Typical systems
Maintenance operations	Equipment health, faults, repair work orders, preventive maintenance, permits, release to production.	CMMS (Computerized Maintenance Management System), EAM (Enterprise Asset Management), maintenance module.
Inventory operations	Material movement, lot storage, picking, issue, consumption, warehouse replenishment.	WMS (Warehouse Management System), tank farm systems, MES (Manufacturing Execution System) inventory functions.

In a real incident, the four operations areas collide. One reject spike can slow production, place material on hold, trigger maintenance work, and reduce what the warehouse can issue.

Decision check
The PLC reports 10,000 pulses, but MES shows 9,840 good units and 160 rejects. ERP should use the confirmed execution result, not the raw pulse count.

5.4 Work order, operation, and performance

- A work order states what must be produced. An operation or process segment describes the work. A schedule states when and where it should run. A performance record states what actually happened.

- When output is lower than expected, the target may come from ERP or a Level 3 schedule, while the accepted result comes from the designated performance record. Alarms, historian trends, quality results, maintenance tickets, and material movements provide the supporting evidence.

5.5 Why MES matters for ERP and reporting

ERP needs reliable good and scrap quantities, material consumption, inventory movements, completion status, cost variance, and quality status.

When those results come from scattered spreadsheets or uncontrolled retyping, inventory, costing, and planning become unreliable.

The execution layer turns raw machine noise into the outcomes and exceptions the business actually needs: what was made, consumed, scrapped, held, delayed, reworked, or completed.

Record check: choose a number people often dispute—good count, scrap, downtime, a quality result, or material consumption. Identify the original observation, the accepted record, and the person or workflow allowed to correct it. If that requires a meeting, the Level 3 boundary is still unclear. (Model answer: A.5.)

Chapter 6: Level 4: ERP and Business Planning

“ERP still says 10,000,” Priya says. Ravi points at the shift report: 9,840 good, 160 rejected. Neither screen is necessarily wrong. ERP is showing what the business asked for; the execution record is showing what the line produced.

Problems begin when those two numbers are allowed to overwrite each other.

6.1 ERP in plain language

ERP means Enterprise Resource Planning. It usually manages sales orders, demand, procurement, inventory value, finance, costing, purchase orders, customer commitments, and enterprise master data.

ERP asks what the business should make or buy, what is available or committed, what it cost, what can ship, and what should be invoiced.

ERP is not a machine controller

ERP works on a business time horizon. It should not make millisecond control decisions, open valves, clear PLC interlocks, or acknowledge machine alarms.

6.2 ERP to MES: business intent becomes executable work

ERP may send an order, product, quantity, due date, priority, BOM or routing reference, and material requirements to the execution application. Before releasing work, the execution application checks resource availability, material status, operation steps, quality requirements, and shop-floor sequence.

Treat this as a handoff, not a data copy. ERP sends what the business needs; the execution record is built as the work occurs. ERP may request 10,000 units, while the final result shows 8,600 good, 300 scrapped, 200 in rework, and one lot on hold. The same distinction matters in pharmaceutical manufacturing: a batch can be physically complete and still remain in quarantine until an authorized quality release makes it available.

6.3 MES to ERP: execution result becomes business fact

After production, the execution layer returns the business-relevant result: good and scrap quantities, consumption, completion status, lot status, inventory movements, labor or equipment time, and quality status.

ERP uses that result for inventory, costing, planning, customer delivery, and financial reporting.

Flow	Example information	Why it matters
ERP (Enterprise Resource Planning) to execution application	Production order, product, quantity, due date, priority.	The execution application receives the business production requirement.
Execution application to ERP (Enterprise Resource Planning)	Good quantity, scrap, completion, consumption, lot status.	ERP (Enterprise Resource Planning) updates inventory, cost, plan, and commitments.
ERP (Enterprise Resource Planning) to execution application	Material availability or reservation.	The execution application can check whether work can start.
Execution application to ERP (Enterprise Resource Planning)	Exception, delay, shortage, hold, or quality issue.	Business can replan or communicate impact.

Common mistake
A production order for 10,000 units is a plan, not proof that 10,000 acceptable units were produced. Planned quantity and confirmed good quantity must remain separate.

6.4 The ERP-MES boundary

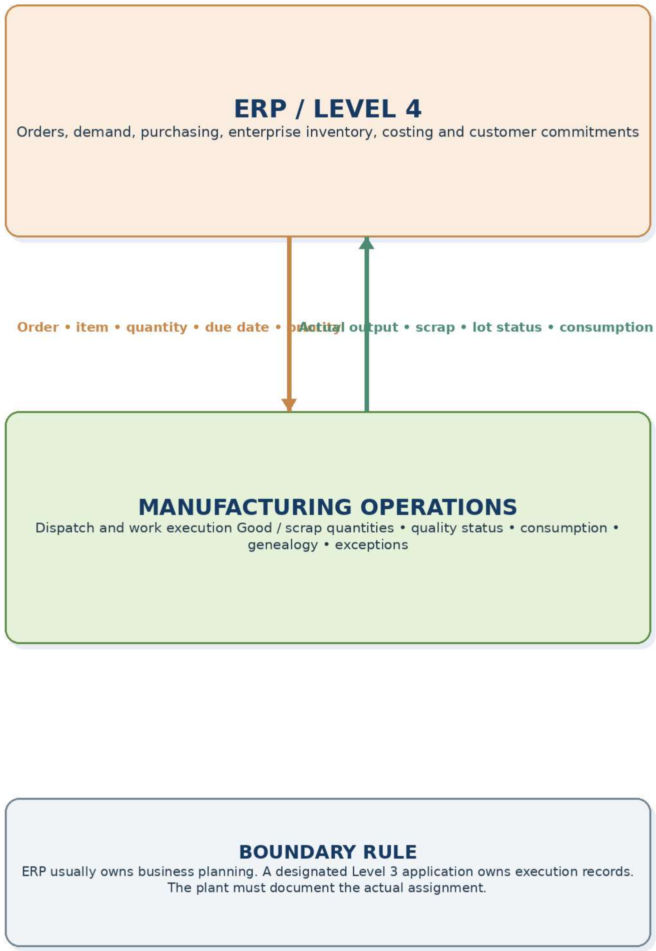

Figure 6.1: ERP and MES boundary.

When the ERP-to-execution interface is weak, the office and the factory begin working from different versions of the same day.

- ERP may show material as available when production cannot use it; finance may post incomplete results; or planners may promise work the floor cannot execute.

A dependable interface defines the information being exchanged, the timing, the changes each side may make, and the response to errors, retries, duplicate messages, and mismatched records.

Reality Check: Not Every Plant Has One MES

Some plants use one central MES. Others split Level 3 work among batch systems, QMS or LIMS, WMS, CMMS or EAM, ERP modules, and specialist applications. Instead of looking for one box called MES, trace each accepted result to the application and correction workflow that maintains it.

6.5 Business impact without business overclaiming

A stoppage may threaten a shipment, but the impact is not known until the team checks current progress, available inventory, remaining capacity, quality holds, and customer priority.

Use the same discipline for shortages. Check assigned stock, warehouse location, approved substitutes, and the live schedule before stopping production. “The shipment is at risk if recovery fails” is accurate; “the shipment has failed” may not be.

Exercise: write a two-line ERP–MES exchange for one product. In the first line, ERP sends the requirement. In the second, MES returns the actual result. Add one failure case: delayed, lost, or repeated message.

(Model answer: A.6.)

Chapter 7: ISA-95 Information Models: Equipment, Material, Personnel, and Process Segments

On the shop floor, people call it Line 2. The PLC program calls it PKG-L2. Maintenance uses asset PKG-0027, and ERP schedules work center CHN-PKG-02. A supervisor can usually translate those names without thinking. Software cannot.

The mismatch often stays hidden until a report has to combine production, quality, maintenance, and inventory data. Then the same machine appears as four unrelated records. ISA-95 information models give those records a common structure without forcing every system to use the same screen name or database design.

Chapter 7 first-pass map
On the first pass, keep four separations in view: class vs. instance • definition vs. execution • requirement vs. actual assignment • plan/evidence vs. accepted result. Sections 7.2-7.8 apply them; return to aliases, revisions, corrections, and starter-model detail later.

7.1 Why information models matter

The five ISA-95 levels explain where different kinds of work belong. Information models answer a different question: what are the records about? A production order connects equipment, material, people, and work; a downtime event connects equipment and time; a quality result connects material, a test, a measured value, and an authorized decision. Those links keep information meaningful outside the system that first created it.

An ISA-95 model is not a ready-made database schema. It separates concepts that factories often mix together. The implementation may span MES, ERP, historian, QMS, data platforms, knowledge graphs, or several connected systems. What matters is that those systems can point to the same real object and preserve the meaning of each record.

Four records that should stay separate

Record type	Question it answers	Packaging-line example
Resource	What can be used?	Filler_01, bottle lot B-118, qualified line operator
Reusable work definition	What kind of work is this?	Fill and cap a 500 mL bottle within the approved limits
Schedule or request	What work is planned now?	WO-24017, 10,000 units, Line 2, Shift A
Performance record	What actually happened?	9,840 good, 160 rejected, 34 minutes of downtime

These records are related, but they are not interchangeable. Editing the standard filling definition should not rewrite last month's production history. A work order for 10,000 units should not become proof that 10,000 good units were produced. The actual filler used on Tuesday should not be confused with the general class of equipment called "Filler."

A name is not an identity
A display label can change. A stable identifier should not. Keep local names and aliases, but map them to one governed identity for the object.

7.2 Equipment model

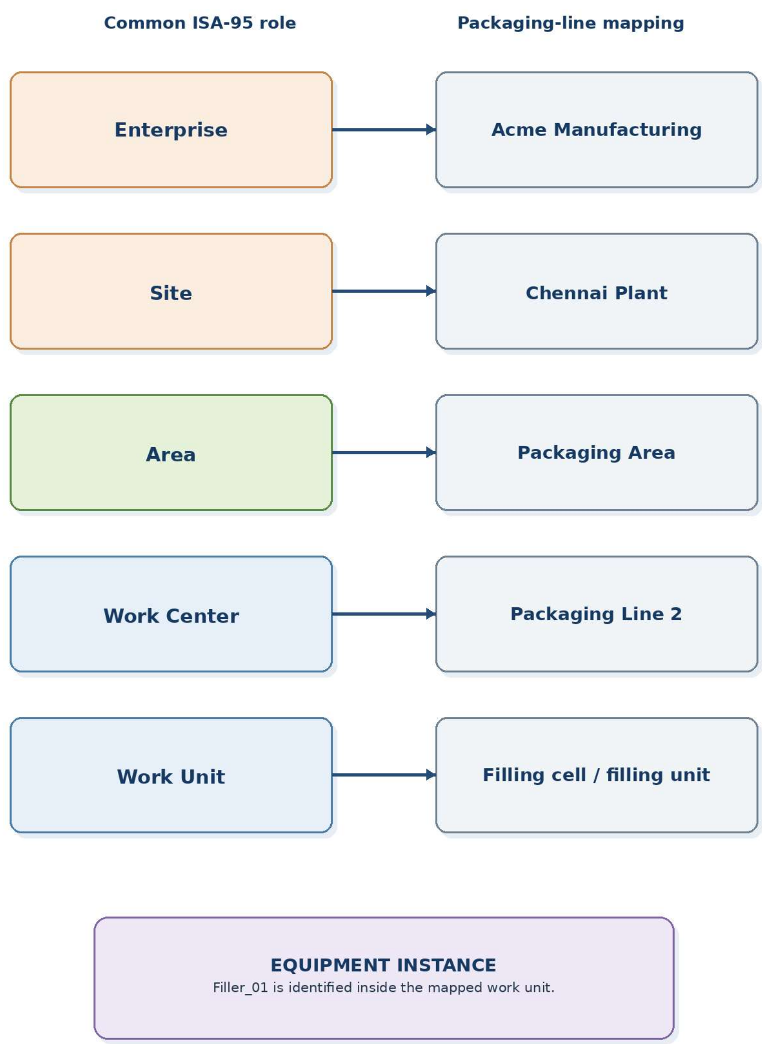

Figure 7.1: Standard ISA-95 equipment roles and one plant-specific mapping.

ISA-95 commonly describes equipment through the roles Enterprise → Site → Area → Work Center → Work Unit. The words are deliberately broad. A work center may map to a packaging line in one plant, a process cell in another, or a production unit in a continuous plant. A work unit might be a filler, mixing vessel, assembly station, or test cell.

The hierarchy does not replace local plant language. It maps local terms such as “Line 2” to comparable equipment roles.

ISA-95 role	Packaging-line example
Enterprise	Acme Manufacturing
Site	Chennai Plant
Area	Packaging Area
Work Center	Packaging Line 2, treated as a production line
Work Unit	Filling cell or filling unit, depending on the site model
Equipment instance	Filler_01, identified inside the mapped work unit

Stable identity, labels, and aliases

Equipment identity should survive ordinary renames. ERP may use a work-center code, the PLC a tag prefix, and maintenance a serialized asset number. Those aliases are legitimate when the mapping is explicit and governed. Do not use a human-readable label such as “Filler 1” as the only key; a stable identity such as EQ-CHN-PKG-00027 can remain constant while labels change.

Equipment class and equipment instance

An equipment class describes a kind of resource: filler, mixer, oven, robot, tank, packaging line, torque tool, or test station. An equipment instance identifies the installed resource that actually exists in the plant. Filler is a class. Filler_01 in Packaging Line 2 is an instance.

The distinction matters because capability is often defined at class level and history is recorded at instance level. A class may say that fillers of this type can handle 250 mL to 1 L containers. The instance record carries the serial number, installation location, calibration history, maintenance work, and current operating state for Filler_01.

Capability is not the same as availability

A machine may be capable of filling 500 mL bottles and still be unavailable because it is under maintenance, reserved, awaiting cleaning, missing a qualified operator, or blocked by quality. Capability asks “can this resource perform the work under stated conditions?”; availability asks “can we use it now?” Scheduling therefore checks both the suitable class and the state of the actual instance at release time.

What belongs in an equipment record

Information	Why it matters	Example
Stable identity	Links the same asset across systems	EQ-CHN-PKG-00027
Hierarchy position	Shows where the resource belongs	Chennai Plant → Packaging → Line 2
Class or type	Supports capability matching	Rotary filler
Capabilities and limits	Defines work the resource can perform	250–1,000 mL; maximum 120 bottles/min

Information	Why it matters	Example
Aliases	Connects local system names	PKG-L2, CHN-PKG-02, Asset 0027
Current state	Supports release and scheduling decisions	Available, cleaning, faulted, under maintenance
Tracked subcomponents	Keeps history where it is useful	Load cell, reject cylinder, drive motor

Model subcomponents only when separate identity adds value. A replaceable load cell may need its own calibration and maintenance history. A standard bolt usually does not. Creating an object for every physical part produces a model that is expensive to maintain and hard to use.

7.3 Material model

Material covers what the plant receives, stores, consumes, transforms, produces, tests, reworks, scraps, and ships. The model must distinguish the kind of material from the particular traceable quantity that moved through the process.

Material class, definition, lot, and sublot

Material level	Plain meaning	Example
Material class	A broad family used for grouping	Packaging materials
Material definition	The identified item or product type	500 mL PET bottle, item BOT-500-CLEAR
Material lot	A traceable quantity with a shared identity	Bottle lot B-118
Material sublot	A smaller traceable portion of a lot	B-118-Pallet-03
Material unit	A single serialized or individually tracked item	Controller unit CU100-00418

The amount of detail depends on the process. A bulk chemical plant may trace tank quantities and batch lots. An electronics plant may trace every serial number. A food packer may track raw-material lots, packaging lots, and finished-goods lots without assigning an identity to every individual bottle.

Material identity is not the same as inventory balance

ERP may show 12,000 bottles available, but production still needs the physical lot, release status, location, quantity, unit, and actual consumption. A total can be accurate yet unusable for the next operation. Preserve unit conversions too: ten cases, 240 packs, and 2,880 bottles may describe the same stock at different packaging levels.

Splits, merges, and transformations

Lots rarely move through a plant unchanged. A received lot may be split across two lines. Several input lots may be blended into one batch. A bulk batch may be packed into many finished-goods lots. Each split, merge, consumption, and production relationship belongs in the genealogy chain.

For example, Product bulk lot P-902, empty-bottle lot B-118, cap lot C-44, and label lot L-71 may all contribute to finished-goods lot FG-24018. If cap lot C-44 is later found defective, the plant needs to identify every finished lot that consumed it. That answer cannot be reconstructed reliably from an inventory total alone.

Material status and disposition

Material can be available, reserved, in process, quarantined, held, released, reworkable, scrapped, or otherwise controlled by the site. The exact status vocabulary is a site decision, but the owner of each status must be clear. A machine signal may provide evidence of a problem; it does not authorize release or scrap. That decision belongs to the approved quality workflow.

7.4 Personnel model

The personnel model separates a person from the role, qualification, authorization, and assignment connected to the work. This prevents a common design mistake: making the name of one experienced employee part of the process definition.

Personnel concept	What it represents	Example
Person	The individual who may be assigned	Operator 1842
Role	The responsibility required by the work	Packaging-line operator
Qualification	Evidence that the person can perform defined work	Qualified on Line 2 through 31 Dec 2026
Authorization	Permission to approve or change a controlled state	May approve line clearance
Assignment	The person linked to a specific shift or operation	Operator 1842 assigned to WO-24017, Shift A

A role is not a job title or a person. “Quality reviewer” describes what the process requires; the execution record shows who actually performed or approved the work. Qualifications are often time-bounded and scoped, so the system must check the qualification that applied when the work was performed, not only the person’s current profile.

Keep personnel data proportionate

A manufacturing record usually needs an employee or contractor identifier, role, qualification, assignment, and approval history. It normally does not need an employee’s full HR file. Linking the minimum required information reduces privacy risk and makes ownership easier to understand.

7.5 Process segment model

A process segment is a reusable description of manufacturing work and the resources it requires. Filling, inspection, heat treatment, cleaning, assembly, weighing, and final test can all be described this way. A “Fill Bottle” segment might require suitable equipment, released bottle and cap lots, a qualified operator, approved parameters, expected outputs, and an inspection dependency. It describes what the work needs; it does not claim the work has happened.

Process segment, route, request, and result

Record	Purpose	Packaging-line example
Process segment	Reusable description of one kind of work	Fill Bottle
Operations definition or route	Organizes several segments into an approved sequence	Rinse → Fill → Cap → Label → Inspect

Record	Purpose	Packaging-line example
Schedule	Places planned work against time and resources	10,000 units on Line 2 during Shift A
Work request or order	Authorizes a specific execution	WO-24017 for Product A
Performance record	Records the actual execution and outcome	9,840 good, 160 rejected, actual resources and times

Plants use terms such as recipe, route, workflow, master instruction, unit procedure, and operation. They are not always exact synonyms. The important point is to keep the reusable definition separate from the specific request and the actual result.

Parameters, limits, and revisions

A segment may identify parameters such as target fill volume, temperature, torque, dwell time, speed, or inspection frequency. The performance record should preserve the approved revision and values that applied during execution. If the target changes next month, last month's work must still point to the earlier approved revision; history is not silently rewritten.

One operation, four object families
"Fill Bottle" uses a filler (equipment), consumes bottle and product lots (material), requires a qualified operator (personnel), and follows a reusable filling definition (process segment or operation definition).

7.6 Putting the models together

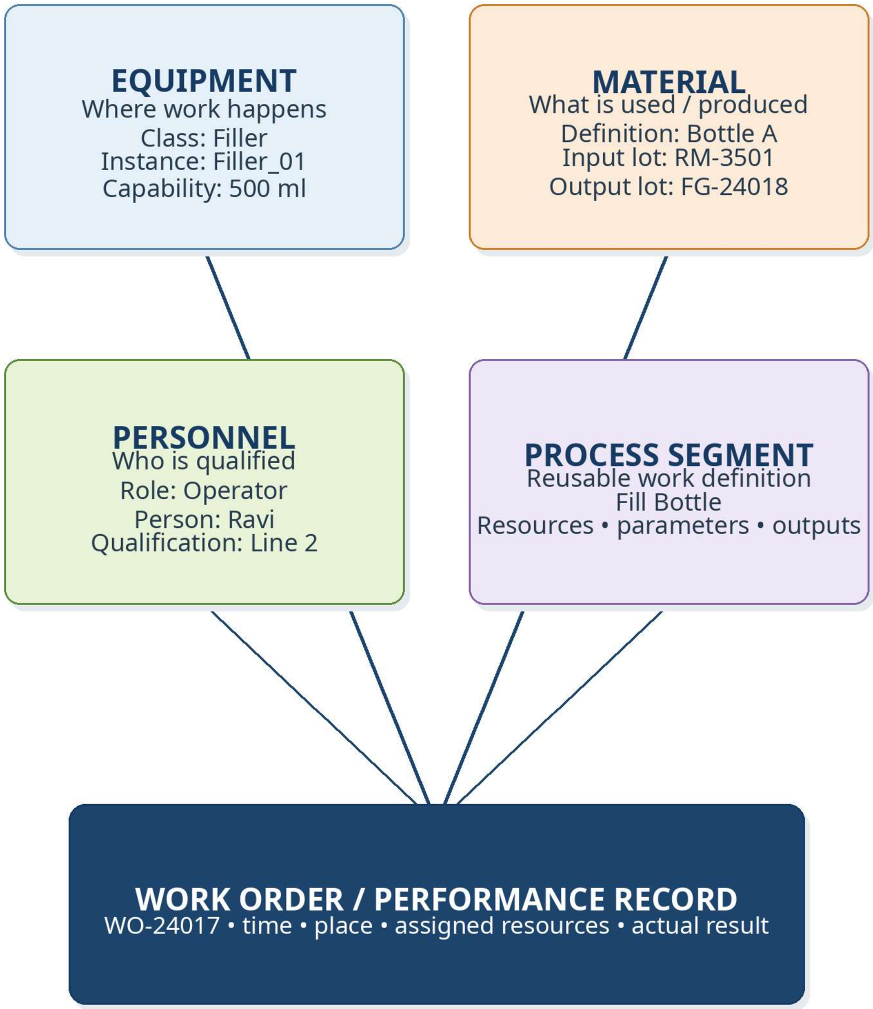

Figure 7.2: Four object families linked to a specific execution record.

The diagram is easier to read as a set of ordinary questions. Where will the work happen? What material will be consumed or produced? Who is qualified and assigned? Which approved work definition applies? What result was recorded?

Question	ISA-95 object that helps answer it
Where will work happen?	Equipment and equipment capability.
What work can be performed?	Process segment and operation definition.
What is consumed or produced?	Material definition, material lot, and material sublot.
Who can perform or approve work?	Personnel, role, and qualification.

Question	ISA-95 object that helps answer it
What actually happened?	Operations performance / work performance.

The relationships matter more than the boxes. The order requests a particular operation. The operation requires capabilities. Specific equipment and people are assigned. Material lots are issued. Machine and operator evidence is collected. The resulting performance record links all of those facts to the same execution.

Requirements and actual assignments

Before release, the system deals with requirements: a suitable filler, a qualified operator, and released material. At execution, those requirements become actual assignments such as Filler_01, Operator 1842, bottle lot B-118, and cap lot C-44. Keeping both explains why a resource was eligible and what was actually used, including an approved substitute.

Relationships should replace copied descriptions

A weak design copies full equipment, product, operator, and specification descriptions into every event, where they can drift. Store stable references to governed objects instead; retain a small snapshot only when audit or legal requirements demand it.

7.7 Worked example: from definition to verified performance

The following example follows one filling operation from the reusable definition to the reviewed result. It is intentionally small. A production implementation would include more attributes, security rules, and site-specific states.

Model element	Packaging-line example	Why it exists
Equipment class	Filler	Describes the kind of resource and its general capability.
Equipment requirement	Capable of 500 mL filling at the approved speed	States what the operation needs before an instance is assigned.
Equipment instance	Filler_01 in Packaging Line 2	Identifies the installed resource that actually performed the work.
Material definition	Product A, 500 mL bottle	Defines the item type independently of a particular lot.
Material lots	Bulk P-902; bottles B-118; caps C-44; output FG-24018	Provides traceable identities for consumed and produced quantities.
Personnel requirement	Qualified packaging-line operator	Defines the role and qualification needed by the operation.
Personnel assignment	Operator 1842, Shift A	Records who actually performed the work.
Process segment	Fill Bottle	Provides the reusable description of the work.
Approved parameters	500 mL target, approved tolerance, line-speed limit	Preserves the controlled values used for this product and revision.

Model element	Packaging-line example	Why it exists
Operations schedule	10,000 units on Line 2 during Shift A	States planned work, time, and resource assignment.
Work request	WO-24017, Product A, Fill operation	Carries the specific execution request.
Source evidence	Counts, weights, alarms, operator confirmations, state intervals	Preserves observations from PLC, SCADA, historian, and operator sources.
Operations performance	9,840 good, 160 rejected, 34 minutes downtime	Records what actually happened against the requested work.
Quality disposition	Weight evidence reviewed; FG-24018 released	Connects evidence to the authorized material decision.
Correction path	Supervisor or quality workflow with reason, evidence, and audit trail	Allows correction without silently replacing the earlier record.

How the record develops during the shift

First, the reusable filling definition and its approved revision exist before the order. When WO-24017 is scheduled, the system checks whether suitable resources and released materials are available. At dispatch, actual equipment, lots, and personnel are assigned. During execution, machine signals and operator entries become evidence. At completion, the execution workflow records good, rejected, and downtime quantities. Quality then records the lot decision.

If something changes, the model shows where the change belongs. Replacing Filler_01 with Filler_02 changes the assignment, not the equipment class. Using a different bottle lot changes the material relationship, not the material definition. Revising the target fill creates a new controlled work revision; it does not alter the values that applied to an earlier order.

What happens when the records disagree

Suppose the PLC counted 10,000 bottle detections, the checkweigher recorded 160 rejects, and the execution record shows 9,840 good units. The counts are not competing versions of one field. They are different observations and results. The model keeps the source evidence, the rule used to interpret it, the accepted performance value, and the authority that approved any correction.

7.8 Keep the plan, observations, and accepted result separate

Question	Plan	Evidence	Accepted record / decision
What should happen?	10,000 units on Line 2	Not applicable	ERP and execution schedule
What physically happened?	Not applicable	PLC counts, checkweigher values, state intervals	Evidence remains linked to its source

Question	Plan	Evidence	Accepted record / decision
What production result is accepted?	Target remains 10,000	9,840 good and 160 rejected observed	Operations performance approved through the execution workflow
Can the lot be shipped?	Expected availability	Test and genealogy evidence	Authorized quality release reflected in inventory and planning

This separation is not paperwork for its own sake. It prevents a plan from being mistaken for a result and prevents a raw observation from becoming an unauthorized business transaction. It also gives investigators a path back from the accepted result to the evidence that supports it.

Corrections should add history, not erase it

If the accepted good quantity changes from 9,840 to 9,836 after reconciliation, the system should retain the original value, the revised value, the reason, the evidence, the approver, and the time of change. Silent overwriting destroys the very traceability the model was intended to provide.

7.9 Common modeling mistakes

Mistake	What goes wrong	Better approach
Using labels as primary identity	Renames and translations break joins	Use a stable ID and maintain aliases separately
Mixing class and instance	A generic capability is treated as equipment history	Keep “Filler” separate from “Filler_01”
Mixing definition and performance	Changing a standard rewrites the meaning of past work	Version reusable definitions and link each execution to the applied revision
Assigning work directly to a named person	The process depends on one employee	Define role and qualification, then record the actual assignment
Treating inventory balance as genealogy	The total quantity is known but affected lots cannot be traced	Record lot-level consumption, production, splits, and merges
Storing current state in the master definition	A temporary fault changes what the equipment is	Keep capability/master data separate from time-varying state
Creating an object for every tag or component	The model becomes expensive and unreadable	Model only identities and relationships needed for decisions or traceability

The best test is practical: when two systems disagree, can the team identify the object, the source evidence, the accepted record, and the correction authority without inventing a new spreadsheet?

7.10 A practical starter model

Do not begin by modeling the entire plant. Choose one operation and one decision that currently causes confusion. A filling operation with a disputed good count, a quality hold, or a material-consumption posting is enough.

Start with	Minimum useful information	Question to verify
One equipment instance	Stable ID, hierarchy, class, aliases, capability	Can every system point to the same resource?
One material flow	Definitions, input lots, output lot, quantity, unit, status	Can the output be traced backward and inputs traced forward?
One personnel requirement	Role, qualification, actual assignment	Can the record show who was eligible and who performed the work?
One reusable work definition	Required resources, parameters, revision	Can it be reused without becoming an execution record?
One work request and result	Plan, source evidence, performance, disposition	Can plan, observation, and accepted result be distinguished?
One correction workflow	Reason, evidence, approver, audit history	Can a mistake be fixed without deleting the earlier record?

Exercise: choose one familiar operation. Draw the equipment, material, personnel, and process-segment objects. Add the planned request, the actual assignments, the source evidence, and the accepted result. Then mark every place where an identifier, revision, status, or approval could change. (Model answer: A.7.)

M2 - OBJECTS	**EQUIPMENT Where work happens**	**MATERIAL What is used / made**	**PERSONNEL Who may perform**	**PROCESS Reusable work definition**	**EXECUTION What actually happened**

Chapter 8: From Tags to Production Events and Traceability

At 10:42:15, RejectPulse changes to true. The signal is useful to the PLC programmer. It is not enough for Anita to decide whether a lot can ship. She still needs the measurement, equipment, work order, material, and quality rule.

This chapter adds that missing context without pretending the raw signal is more complete than it is.

8.1 What is a tag?

Ravi sees LineRunning = false on the screen. He knows the line is stopped now, but the tag alone does not tell him when the stop began, why it happened, which order was active, or how the event should be classified.

A usable tag definition needs more than a name and value. It should include the equipment identity, unit, source, scaling, refresh behavior, quality code, owner, and intended use.

Without that context, people fill in the gaps themselves. On a production line, those assumptions can lead to the wrong quality decision, an incorrect downtime reason, or a report nobody trusts.

Before a signal supports a manufacturing decision, connect it to the relevant equipment, time, unit, source, work order, material, process, and quality state.

8.2 Tag categories

The following are practical control-system tag categories used in this book; they are not formal ISA-95 object classes.

Tag category	Example	How it is used
Digital tag	MotorRunning = true/false.	State, on/off, permissive, fault.
Analog tag	Temperature = 190 °C.	Trend, process value, threshold check.
Status tag	LineState = Running/Stopped/Blocked.	State intervals and operations status.
Alarm tag	PressureHigh = Active.	Operator attention and escalation.

Tag category	Example	How it is used
Calculated tag	RejectRate = 4.8%.	Derived metric, usually needs formula review.

- Different tag types need different treatment. Analog values need trends, status values need duration logic, alarms need priorities and acknowledgment, and calculated values need a verified formula.

8.3 From tag value to event

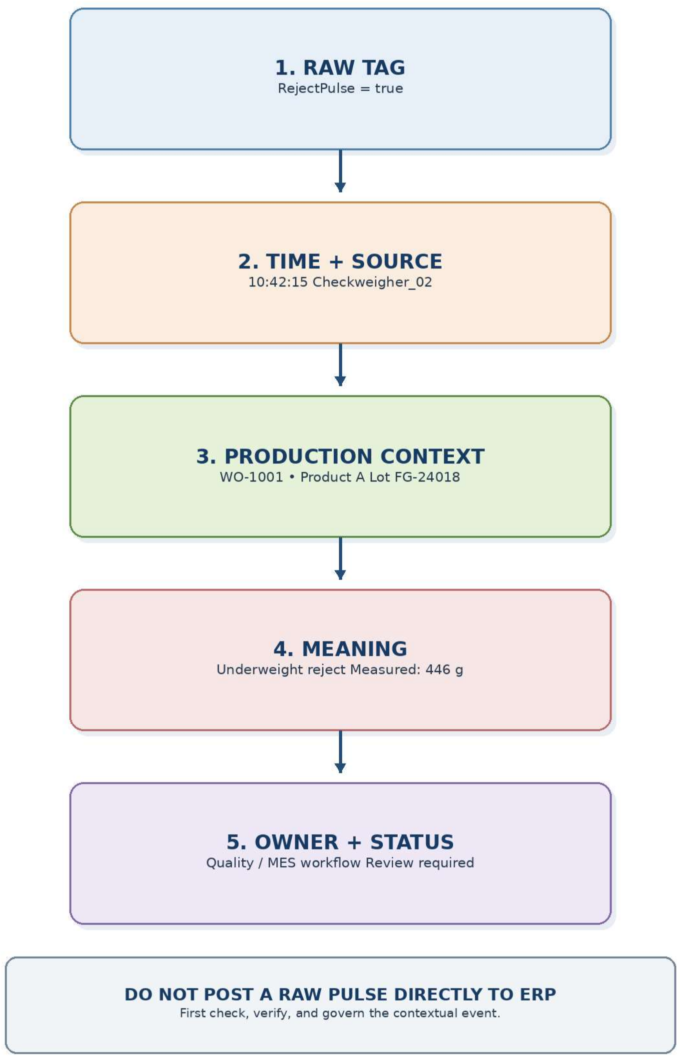

Figure 8.1: A raw tag becomes a contextual production event by adding context and ownership.

A tag value is an observation. A production event is a story.

LineRunning = false is a state. “Line 2 stopped at 10:42 during WO-1001, resumed at 10:58, and the approved reason is material shortage” is a production event.

Events can describe starts, stops, passes, failures, rejects, holds, releases, inspections, material movements, work-order completion, and downtime intervals.

A useful event identifies the object, source, timestamp, type, state, reason, and supporting data.

A reject event needs the product, operation, order, lot, equipment, and rule. A downtime event needs the equipment, work order, start and end times, reason code, and accountable reviewer.

8.4 State intervals and downtime

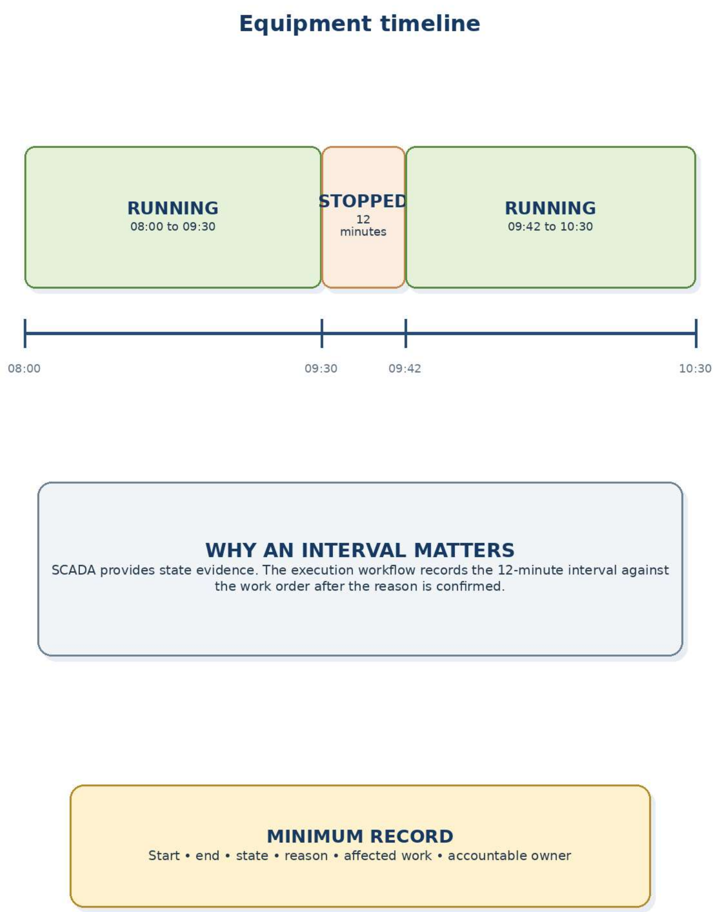

Figure 8.2: Downtime represented as a verified time interval.

Many manufacturing facts are intervals rather than single points. Equipment can be running, stopped, faulted, blocked, starved, cleaning, changing over, or under maintenance for a defined period.

If the system stores only isolated points, downtime and OEE calculations can be wrong—and the timeline may even show impossible overlaps.

Think of state intervals as the equipment timeline: running from 08:00 to 09:30, stopped until 09:42, running slowly until 10:15, and then changing over.

The same idea works in continuous manufacturing. A timeline can show stable flow, a temperature excursion, a grade transition, and a shutdown, each with a start, end, reason, and affected production.

Common mistake
A tag change is not yet a traceable production event. Add equipment, time, work order, product, material lot, reason, quality status, and ownership before treating it as a production record.

8.5 Traceability and genealogy

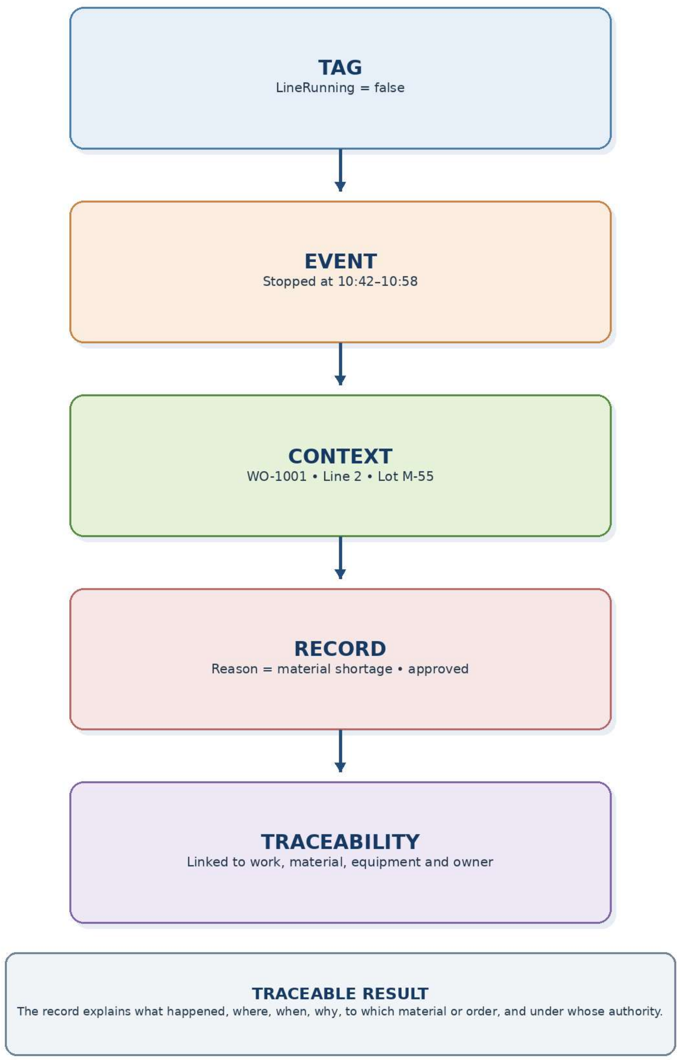

Figure 8.3: Tag to event to traceability.

Traceability follows material, operations, equipment, people, and results through production. Genealogy is the product family tree: which input lots became which outputs, through which work, on which equipment, at what time, and with which quality results.

Forward and backward traceability

Forward tracing starts with an input lot and asks where it went. Backward tracing starts with a finished lot or unit and asks where it came from. Both are essential for investigations, impact analysis, recalls, and compliance.

Exercise: choose three to five tags from one machine.

For each tag, name the event it could support and the MES or quality data still needed before the value can be used as production evidence. (Model answer: A.8.)

Chapter 9: How Data Moves: OPC UA, MQTT, Sparkplug, and Gateways (Optional)

An integration meeting can spend an hour arguing about OPC UA, MQTT, and gateways before anyone asks what information is actually being moved. That is backwards.

A protocol carries data. It does not decide what the data means or which system is allowed to change the final record.

9.1 Connectivity does not replace context

Factories move data through OPC UA, MQTT, Sparkplug, APIs, files, databases, message queues, historians, and vendor connectors. These technologies carry or expose information. The plant must still define the meaning and decide where the accepted result is maintained.

9.2 OPC UA explained

OPC UA can expose structured industrial information, including objects, variables, data types, references, and metadata. It is often used in client/server connections and can also support publish/subscribe patterns.

PLCs, SCADA systems, historians, gateways, and execution applications can use that structured view instead of relying on a flat list of tag names.

OPC UA includes security capabilities, but secure operation still depends on disciplined certificate management, authentication, access control, network design, configuration, and maintenance.

9.3 MQTT explained

MQTT is a lightweight publish/subscribe protocol. Publishers send messages to a broker, and authorized subscribers receive the topics they need.

MQTT 5.0 is the current OASIS standard, while MQTT 3.1.1 remains common in installed systems. For this beginner guide, the publish/subscribe model matters more than the version number.

MQTT is not a manufacturing information model. Topic structure, payload design, security, retention, quality of service, and data ownership still have to be designed.

9.4 Sparkplug explained

Sparkplug adds industrial conventions to MQTT, including topic namespaces, structured payloads, metrics, and state awareness. This book refers to Sparkplug 3.0; implementation teams should verify the current Eclipse specification before design or procurement.

Sparkplug helps publish industrial data consistently. ISA-95 helps relate that data to equipment, material, work, and business responsibilities.

9.5 Gateway routing and normalization

Industrial gateways can translate protocols, buffer messages, store and forward data, normalize names, filter values, and create a controlled boundary between machine networks and enterprise systems.

Do not give business applications unrestricted access to control networks. Apply least privilege, monitoring, audit, and a documented response for connection failures.

> **Transport versus meaning**
> **OPC UA and MQTT can move or expose data effectively. Neither one decides which system owns production completion, whether a lot is released, or what a business transaction means.**

9.6 OPC UA and MQTT together

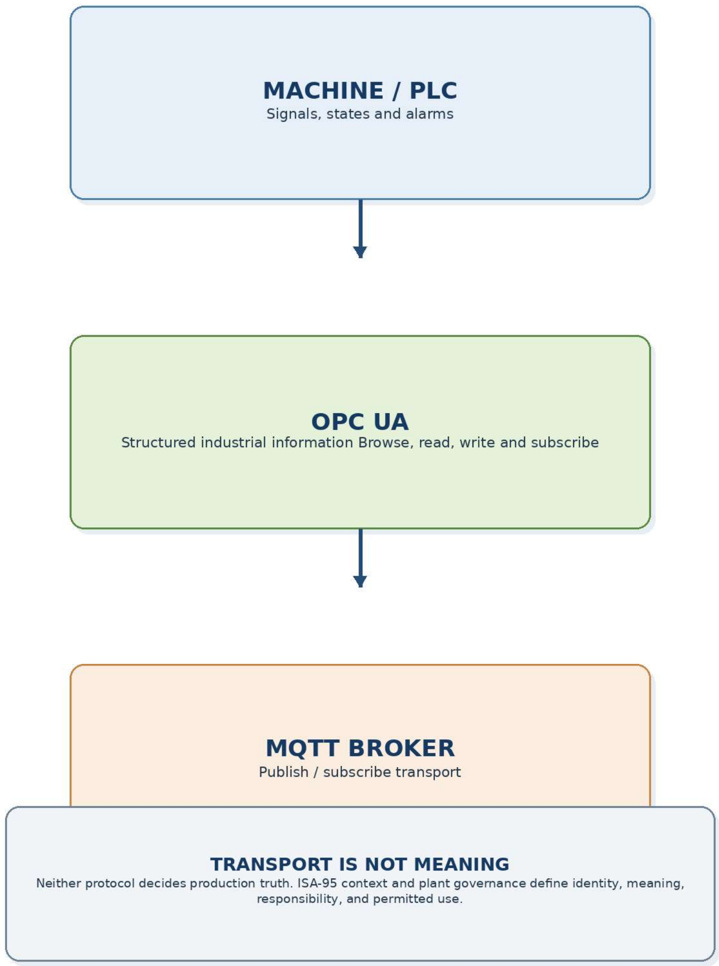

Figure 9.1: OPC UA and MQTT together.

Pattern	Useful when	Caution
OPC UA (OPC Unified Architecture) client/server	A system needs structured, typed, discoverable industrial data.	Do not treat every live value as business truth.
MQTT publish/subscribe	Many consumers need event or telemetry messages through a broker.	MQTT topics do not automatically provide semantics.
OPC UA (OPC Unified Architecture) to MQTT gateway	Structured machine data must be curated and published upward.	Map and filter values before publishing.

Pattern	Useful when	Caution
Sparkplug (industrial MQTT specification) namespace	Industrial metrics need state-aware publish/subscribe behavior.	Still need asset, operation, material, and ownership mapping.

Signal trace: follow one value from the PLC through SCADA and the historian to MES. At each handoff, note whether only the transport changed or whether the meaning and permitted use changed too. (Model answer: A.9.)

Chapter 10: OEE, Quality, Genealogy, and Maintenance Through an ISA-95 Lens

At noon, OEE is 79.2 percent. The number does not tell the team what to fix.

Ravi sees downtime. Kumar sees speed loss. Anita sees rejected units. They need the underlying records before choosing an action.

A dashboard percentage is a lead, not a diagnosis.

10.1 OEE is more than one number

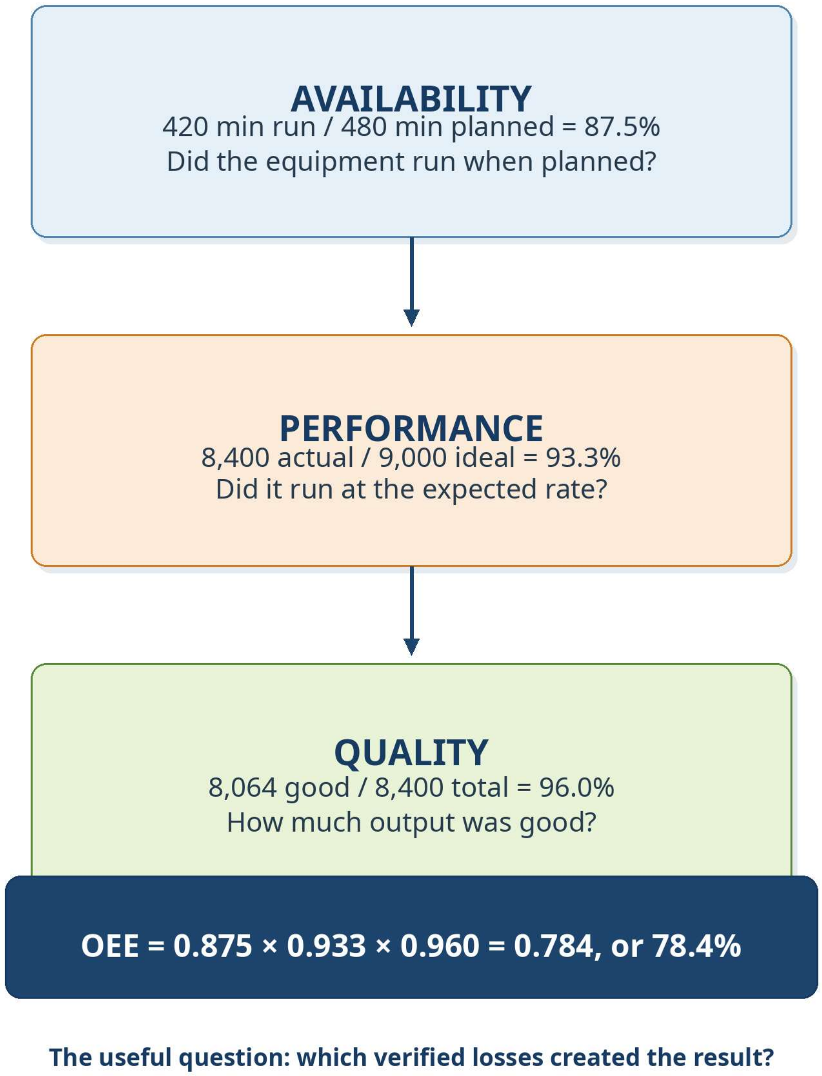

Figure 10.1: Worked OEE example using different production numbers.

Overall Equipment Effectiveness, or OEE, combines availability, performance, and quality. The multiplication is easy. Agreeing on planned time, ideal rate, and what counts as good production is usually harder.

Availability compares run time with planned production time. Performance compares actual output or speed with the ideal rate. Quality compares good output with total output.

Formula: OEE = Availability × Performance × Quality. OEE is not an ISA-95 metric definition; it is used here as an example of performance information that benefits from ISA-95 context.

OEE is useful when it directs attention to a real loss and a practical action. It is less useful when teams chase the percentage without checking the source data. Ravi sees 48 minutes of stopped time and asks what caused it.

Kumar points out that running below the expected rate created a similar loss.

Anita finds 330 units that were not accepted. One percentage has opened three different investigations, each with a different owner and response.

Why a line may have low OEE

Low OEE may result from downtime, changeovers included in planned production time, minor stops, speed loss, rejects, or rework. A quality hold affects OEE only when it changes the good-output classification or creates an applicable availability loss.

ISA-95 helps by connecting those losses to equipment, operations, work orders, material lots, and performance records.

10.2 Quality: specification, test, result, disposition

Quality follows a chain: specification, test or inspection, measured result, and authorized disposition. One out-of-tolerance checkweigher result is an observation; a repeated pattern may trigger a nonconformance or formal review.

The tag alone cannot release, hold, rework, or scrap the lot.

10.3 Genealogy and Impacted Lots

Genealogy helps the plant identify affected lots. Forward tracing follows a suspect input to its outputs. Backward tracing identifies the inputs, equipment, operations, and time windows behind a failed product.

The plant then applies the correct status, notifies inventory or ERP where required, and preserves the audit trail.

10.4 Maintenance and equipment history

Maintenance records explain how faults, breakdowns, preventive work, repairs, and return-to-service decisions affected equipment availability and output.

A process tag such as TT-101 may remain in the design after the physical transmitter is replaced. The new transmitter has a different serial number and maintenance history, while the process role and tag identity remain stable.

Decision check
A high reject count is evidence of a possible problem. It is not by itself a quality disposition. The lot context, specification, inspection result, and authorized quality decision are still required.

10.5 One integrated example

In a reject-spike investigation, SCADA shows the rising reject rate. The historian shows the weight drift. The execution record supplies the active order and lot. Quality supplies the specification and hold status. Maintenance supplies calibration history. ERP shows the confirmed inventory or customer impact, if any.

Exercise: give each system one fact from that investigation, then name the role or workflow that can approve the final action. (Model answer: A.10.)

Chapter 11: Common Integration Flows Between ERP, MES, SCADA, and Control Systems

ERP goes offline at 2:15 p.m., after MES has already confirmed the order. Production is complete; the business posting is not. The interface has to remember both facts, retry later, and avoid posting the same result twice.

That ordinary outage is a better test of an integration than a successful demonstration.

11.1 Planning flow: ERP to MES

The ERP-to-execution flow carries the business intent for production: order, item, quantity, priority, due date, BOM or routing reference, customer priority, and material needs. Information that has no purpose during execution should remain on the business side of the boundary.

Send too little and operators lack what they need. Send too much and the execution record fills with business detail that adds noise rather than control.

11.2 Execution flow: MES to shop floor and back

The execution layer sends operations, material checks, quality constraints, and controlled work information to the shop floor. Operators work through HMIs, terminals, scanners, tablets, and process documents.

PLCs still run the machine sequence. SCADA and historians show what happened. The execution application assembles the production result. Level 3 knows which product and operation should be running; the PLC controls how the machine performs the validated sequence.

11.3 Reporting flow: MES to ERP

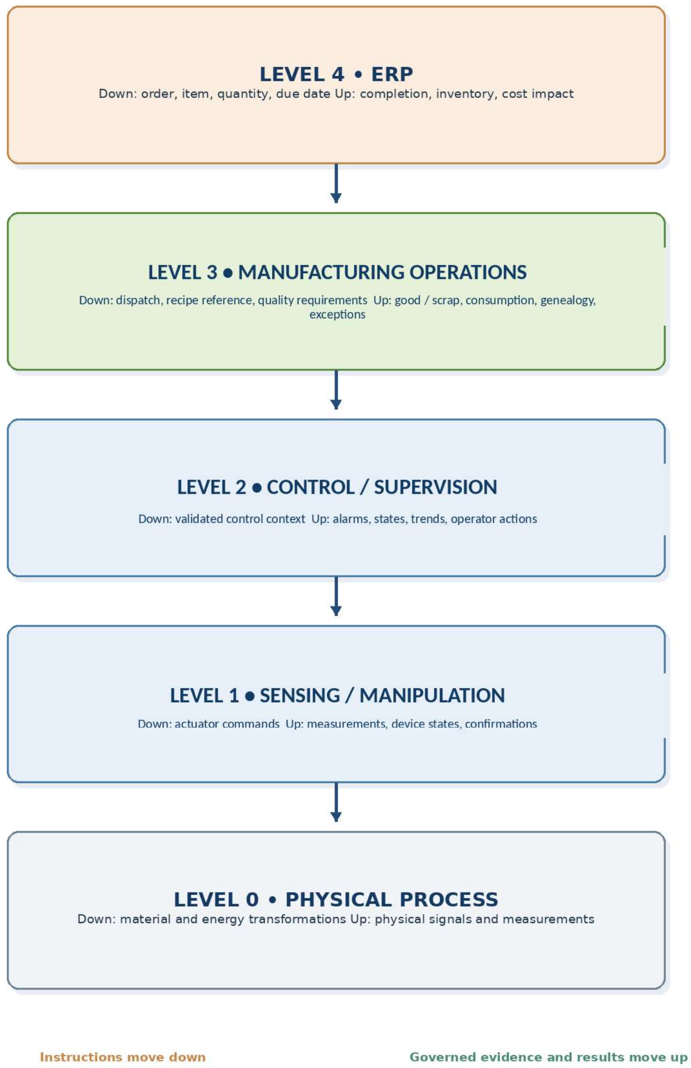

Figure 11.1: Cross-level integration flow.

The return flow carries confirmed good and scrap quantities, material consumption, lots, operation and order status, inventory movements, labor or equipment time, and quality status.

ERP uses those confirmed results to update inventory, costing, planning, procurement, and customer commitments.

Delayed, incorrect, or manually retyped results make those business records unreliable.

11.4 Exception flow: when things go wrong

Exceptions—stoppages, shortages, holds, faults, failed inspections, missing components, and delays—are often the most important information flows in the entire design.

For each exception, record what happened, where and when it happened, which work and material were affected, who owns the next action, and what the latest verified status is.

Exception	Source evidence	Likely owner
Material shortage	MES (Manufacturing Execution System)/WMS (Warehouse Management System)/ERP (Enterprise Resource Planning) stock and allocation.	Warehouse, planning, production.
Quality hold	QMS (Quality Management System) / MES (Manufacturing Execution System) test result and disposition.	Quality.
Equipment fault	SCADA (Supervisory Control and Data Acquisition) alarm, historian trend, CMMS (Computerized Maintenance Management System) ticket.	Maintenance/OT (Operational Technology).
Production delay	MES (Manufacturing Execution System) performance, downtime, schedule, ERP (Enterprise Resource Planning) priority.	Production planning/supervisor.

The execution application confirms WO-3027 with 2,460 good units, but ERP is unavailable. The interface must retain the result, retry safely, prevent a duplicate posting, reconcile the final state, and identify who resolves any conflict.

11.5 Design questions before integration

Before building an interface, ask:

- What decision does this data support?
- Where did the source fact originate?
- Where is the accepted state maintained?
- How fresh must the data be?
- Is it a raw signal, validated event, production record, or business transaction?
- What happens if the receiving system is down?
- Who can correct the record?
- How will retry, audit, and monitoring work?

Protocol choice comes later. An integration can still fail because a transaction is unexplained, master data does not match, an error has no owner, or two teams use the same term differently.

Exercise: build an exchange matrix for a production order, material request, production result, quality hold, downtime event, and inventory movement. For each row, name the sender, receiver, owner, and verifier. Pick one row and state what the operator sees when the receiver is unavailable. (Model answer: A.11.)

Do not approve an interface for production until the team can explain acknowledgment, retry, duplicate handling, reconciliation, monitoring, and correction in plain language.

M3 - INFORMATION FLOW	REQUIREMENT ERP intent	EXECUTABLE WORK Level 3 dispatch	EVIDENCE PLC / SCADA / historian	REVIEWED RESULT MES / quality / maintenance	BUSINESS UPDATE Inventory / cost / commitment

Chapter 12: Industry 4.0, Digital Twins, and Production AI (Optional)

The digital-twin demonstration looks good. The checkweigher turns red on a 3D model, and an AI assistant recommends maintenance. Priya asks whether the result is written back to ERP. Kumar asks which source the model is reading. The presenter does not have a clear answer.

The animation is not the hard part.

Identity, data freshness, permissions, and ownership of the final decision are.

12.1 Industry 4.0 needs meaning, not only connectivity

Industry 4.0 commonly describes connected, data-driven manufacturing built with IIoT, cyber-physical systems, digital twins, cloud platforms, analytics, AI, and interoperable data spaces.

Those technologies create value only when the data is connected to the correct machine, product, lot, operation, and accepted operating record.

A cloud dashboard still has to identify the machine, the running product, the affected lot, the active operation, and the system or workflow that holds the official result.

12.2 Digital twin in plain language

A digital twin is a digital representation associated with a specific physical asset, process, line, plant, or manufacturing entity and connected to information that allows its state, behavior, or lifecycle to be represented or analyzed.

It may include asset models, live operational data, simulation, or 3D views; a static model or 3D visualization alone should not automatically be treated as a digital twin.

Its value depends on two basic facts: which real object it represents and which source owns each state shown in the twin.

12.3 Production AI and assistants

AI can summarize information, find patterns, classify exceptions, answer questions, draft reports, and recommend next actions.

It cannot repair poorly understood source data or invent legitimate authority. Production-grade AI needs stable source records, consistent identities, work-order status, maintenance history, quality information, business context, a defined permissions model, and tightly bounded actions.

An AI assistant may explain a fault, recommend an inspection, or draft a work order. It should not control machinery, bypass safety logic, approve a quality disposition, close maintenance work, or post inventory outside the approved workflow and authorized role.

AI boundary check
An AI assistant may explain a fault or recommend a next action. It must not bypass safety control, approve a quality disposition, close maintenance work, or post inventory without the approved workflow and authorized role.

12.4 Why ISA-95 still matters

Tools will change. Reviewers will still have to ask: What object is this? Which source recorded it? How old is the information? Has the state been reviewed? What action is permitted?

Modern technology	ISA-95 question it still needs
IIoT (Industrial Internet of Things) platform	Which equipment, material, and operation does this data represent?
Digital twin	Which real asset or process is mirrored, and who owns each state?
Cloud analytics	Is the data live, historical, calculated, or verified?
AI (Artificial Intelligence) agent	Which source systems were read and which workflow owns the final action?
Unified namespace	Does the namespace map to a meaningful manufacturing hierarchy and object model?

Exercise: take one digital-twin or AI claim and test it against the factory story. Name the real object, the sources read, any stale or incomplete information, and the actions that still require an approved person or workflow. (Model answer: A.12.)

Chapter 13: Common Mistakes, Confusions, and Industry Examples

At the morning review, SCADA shows 10,000 counts, MES shows 9,840 good units, and ERP shows the order complete. Asking "Which number is correct?" misses the issue. Each number may be correct for a different purpose.

The mistakes in this chapter begin when teams ignore that distinction.

13.1 Mistake 1: treating raw sensor data as business truth

A sensor reading is a physical observation. It becomes a production or business fact only after the required context and review are added.

A temperature, pressure, speed, or reject signal needs equipment, work order, product, specification, time, unit, data-quality code, and source.

Without that context, raw data can mislead dashboards, analytics, and production decisions.

Start with one use case and trace it end to end: raw value, tag, equipment, operation, work order, material, and final result. Do not begin with a plant-wide model before one decision works reliably.

13.2 Mistake 2: using SCADA as a hidden MES

SCADA is excellent for supervision, alarms, trends, and operator visibility.

The design becomes risky when SCADA quietly absorbs work-order execution, quality disposition, genealogy, and production accounting.

What looks convenient at first becomes difficult to audit, support, and integrate with ERP.

Keep SCADA as the supervisory source and name the application or workflow that records what was made, consumed, scrapped, held, released, or completed. In many plants that is MES; in others, the function is distributed.

13.3 Mistake 3: poor master data ownership

Integration fails when material codes, equipment IDs, personnel roles, reason codes, work centers, and locations do not line up across systems. One machine may have four names.

A product may use one code in ERP and another in MES. A warehouse may split a lot without production seeing the change. A role may exist in HR but not in MES authorization.

Define canonical identities, aliases, owners, change procedures, and review rules. ISA-95 Part 7 alias concepts are useful precisely because real systems often use different identifiers for the same object.

13.4 Mistake 4: choosing technology before use case

Teams often begin with "Should we use OPC UA, MQTT, cloud, a lakehouse, or a knowledge graph?" The better opening question is: Which decision must the system support?

Then identify the required facts, their sources, freshness, conflict rules, and correction process.

Once those answers are clear, the protocol and platform choices become much easier.

- OPC UA may be strong for structured industrial data.
- MQTT may be strong for publish/subscribe telemetry and events.
- APIs may be strong for transactional system exchange.
- A historian may be strong for time-series evidence.
- A designated execution application may be the system of record for work-order status, production quantities, and material genealogy.

> **Fast architecture test**
> **Ask one question: if two systems disagree, which system and authorized workflow can correct the final record? If the answer is unclear, the integration is not ready.**

13.5 Design checklist

Design question	Why it matters
What exact decision or evidence is moving?	Prevents vague data collection.
Which level owns the source fact?	Avoids treating all data as equal.
Which system owns final state?	Prevents false completion and wrong reporting.
What object is affected?	Connects data to equipment, material, work, or role.
How fresh must data be?	Prevents stale decisions.
What happens on failure?	Forces retry, audit, and exception design.

A useful review is a practical conversation among OT, IT, production, quality, maintenance, planning, and business users. They must agree on records, boundaries, and correction paths before the integration becomes expensive.

Exercise: prepare a one-page integration checklist for one project. Include meaning, owner, level, object, protocol, freshness, failure behavior, and security. (Model answer: A.13.)

When two systems disagree, someone must know which value to use, what evidence supports it, and how to correct it without deleting the earlier record.

13.6 Confusions that survive the first reading

Many design errors begin when a product name is treated as a fixed level or a live observation is treated as a final decision. The table below addresses the assumptions that cause the most confusion.

Confusion	Common assumption	Better correction
Level versus product brand	A product name always belongs to one level.	Place the function first. A product can contain functions that touch more than one level.
HMI versus SCADA	Both are just screens.	HMI is usually local machine interaction. SCADA supervises a wider area with alarms, trends, and controlled visibility.
Historian versus MES	Historian data is the final production record.	A historian stores time-series evidence. The designated execution application owns the production record and its work context.
MES versus ERP	ERP and MES both manage production, so one can replace the other.	ERP handles business planning and commitments. The designated execution application converts plans into work records and confirmed results.
Tag versus event	A tag value is already a production event.	A tag becomes useful when connected to timestamp, equipment, work order, material, reason, quality status, and owner.
Planned versus actual	The planned quantity is the production result.	The result must come from confirmed execution records: good, scrap, rework, hold, and completion status.
Alarm versus quality decision	An alarm automatically proves product is bad.	An alarm is evidence. Quality disposition requires rule, inspection, lot context, approval, and record ownership.
Protocol versus model	OPC UA or MQTT makes the data meaningful automatically.	Protocols move data. The model, metadata, object identity, and business rules give meaning.

13.7 How the model changes by industry

Discrete example: an electronics unit fails final test. The tester records the measurement, the execution system links it to the serial number and station, quality decides whether rework is allowed, and ERP receives the confirmed inventory status—not the raw fail bit.

Batch example: a mixed batch completes every process phase but remains in quarantine after a laboratory result fails. The batch record, input genealogy, deviation, and authorized release decision matter more than the fact that the vessel completed its sequence.

Continuous example: temperature drifts above the control band for eleven minutes. The historian preserves the curve, but the production system must identify the affected grade, time window, material quantity, and quality decision before the event changes inventory or customer commitments.

Chapter 14: A Practical Roadmap for Learning and Applying ISA-95

You do not need to read every ISA-95 document before drawing your first useful plant map. Start with one line and one disputed fact. Find where it begins, where it is accepted, and who may change it.

The 30-day plan below builds from that small exercise.

14.1 Start with the levels, then the objects

Start with the five levels. Then learn the main object families. Only after that should you study the Level 3-to-Level 4 information exchanges in detail.

The core object families include equipment, material, personnel, process segments, physical assets, operations definitions, schedules, performance, and capability.

14.2 Build a small plant map

Choose one real or imaginary production line.

Draw the physical process, sensors and actuators, PLC, HMI or SCADA, historian, execution, quality, maintenance, warehouse, and ERP systems.

For each one, write what it owns, displays, sends, receives, and must never decide.

The first map does not have to be beautiful; it has to be honest. When nobody can name the owner of a fact, write “unclear” rather than hiding the gap behind a neat arrow.

If one machine has several names, list the aliases. If someone retypes a production result by hand, mark the risk. This simple exercise often reveals more than an impressive architecture diagram.

14.3 A 30-day study plan

This is a learning route, not a certification plan and not a substitute for the standards.

Days	Focus	Output
1-5	ISA-95 purpose, Level 0 to Level 4, and responsibility boundaries.	One-page pyramid with one decision and one fact owned by each level.
6-10	Sensors, actuators, PLCs, HMI, SCADA, alarms, trends, and historian.	Machine signal and supervision map showing what is evidence and what is not the final production record.
11-15	MES/MOM, quality, maintenance, inventory operations, and ERP boundary.	ERP-to-MES and MES-to-ERP flow table for one product or order.

Days	Focus	Output
16-20	Equipment, material, personnel, process segments, work order, performance records.	Small object model for one operation with equipment, material, role, parameter, and output.
21-25	Tags, events, state intervals, traceability, genealogy, OEE, and quality context.	Tag-to-event table and one lot traceability map.
26-30	Connectivity, protocols, integration mistakes, ownership matrix, and first bounded scope.	Final beginner ISA-95 architecture summary and one safe addendum/project idea.

A sensible first milestone is being able to take one factory problem and name the object, the acting function, the available evidence, the accepted result, and the next destination for that result.

14.4 From learning to a real project

After learning the basics, apply ISA-95 to one bounded problem.

Keep the first project deliberately small: one use case, one line or process, one information flow, one ownership matrix, and one acceptance checklist.

Good first project themes

Good first projects include production-order integration, consumption posting, downtime-reason capture, quality-hold communication, historian-to-event mapping, alias cleanup, or work-order completion reporting.

Do not begin with a plant-wide transformation.

Define the source and target systems, objects, facts, owners, time horizon, protocol, failure behavior, security boundary, and acceptance criteria.

Keep the scope small enough for production, quality, maintenance, IT, and OT to review together.

Prepare a two-page ISA-95 briefing and explain it aloud to someone outside automation. Revise anything that depends on a vendor name or leaves the owner of a record unclear. (Model answer: A.14.)

Chapter 15: Complete Walkthrough: One Packaging Line from Order to Result

At the end of the shift, the records finally agree. The order called for 10,000 bottles. The line produced 9,840 good units and rejected 160. A short material-starvation stop was recorded, the lot was reviewed, and the released quantity was sent to ERP.

The walkthrough below shows how those facts were assembled.

15.1 Step 1: ERP creates the business requirement

A customer order or planning run creates a requirement for 10,000 units of Product A.

ERP holds the item, quantity, due date, customer priority, inventory position, material requirements, purchase commitments, costing, and planned-order information.

It may create or release a production order that states what the business needs.

Nothing has been produced yet. The order is a requirement, not proof that a bottle moved or a lot exists.

Keep that distinction visible throughout the walkthrough.

15.2 Step 2: MES turns the plan into executable work

For this example, MES is the designated execution application. It receives the requirement and prepares the shop-floor work.

Before dispatching the order, it checks the route, work center, material release, instructions, and quality requirements.

During execution, it tracks the active order, operation, product specification, material lot, and required evidence.

If a quality check is mandatory, the operation is not complete until that requirement has been satisfied.

15.3 Step 3: HMI, SCADA, PLC, sensors, and actuators execute and supervise

- On the line, operators use HMI screens; SCADA shows the wider process; PLCs run fast control; sensors measure; actuators move; the historian preserves time-series detail; MES records selected production events; and ERP later receives the confirmed result.

15.4 Step 4: a reject event occurs

The checkweigher detects several underweight units. At Level 0, packages move through the physical process. At Level 1, the load cell senses weight and the reject actuator manipulates the process. The PLC control function that evaluates each weight and triggers the reject is commonly associated with Level 2.

Monitoring and supervisory functions show the reject count and weight trend, while the historian stores samples and state changes. Depending on the site and function, SCADA can support Level 2 supervision or Level 3 manufacturing operations. The quality decision is still open.

MES connects each reject to the order, product, operation, lot, quantity, and timestamp.

Anita places the affected lot under review. Kumar checks calibration and fault history. Ravi holds order completion until the reject count is reconciled. Priya checks whether existing inventory protects the customer date.

Only after that review should ERP receive the confirmed inventory or shipment status.

15.5 Step 5: production result travels back upward

After the run, the execution record contains good, rejected, scrap, and rework quantities, material consumption, operation times, downtime, quality results, and genealogy.

ERP receives the completion and consumption result needed for inventory, costing, planning, and customer commitments.

If the line produced 9,840 good units and 160 rejects, ERP must not assume that 10,000 acceptable units exist. If the lot remains on hold, the inventory status must show that it is not available for shipment.

Wrong consumption produces wrong inventory and cost. If Level 3 does not hold the reviewed result, ERP receives a guess.

15.6 Step 6: what the responsibility map reveals

Layer/system	What it contributes in the example	What it should not assume by default
ERP (Enterprise Resource Planning)	Business demand, due date, inventory, cost, customer priority.	Physical machine control or detailed production evidence.
MES (Manufacturing Execution System)	Work order execution, operation status, output, scrap, downtime, genealogy.	Fast interlock logic or raw control sequence.
SCADA (Supervisory Control and Data Acquisition) / HMI (Human-Machine Interface)	Operator visibility, alarms, trends, permitted supervision.	Final production accounting or quality disposition by itself.
Historian	Time-series evidence for weight, speed, state, alarm, and trend.	Confirmed work order completion or ERP (Enterprise Resource Planning) inventory truth.
PLC (Programmable Logic Controller)/control	Fast sequence, interlock, reject command, machine response.	Business planning, customer commitment, financial posting.

Seeing the same event in several systems is normal. The problem begins when one system shows evidence but is treated as though it owns the final decision.

15.7 Step 7: the final traceable story

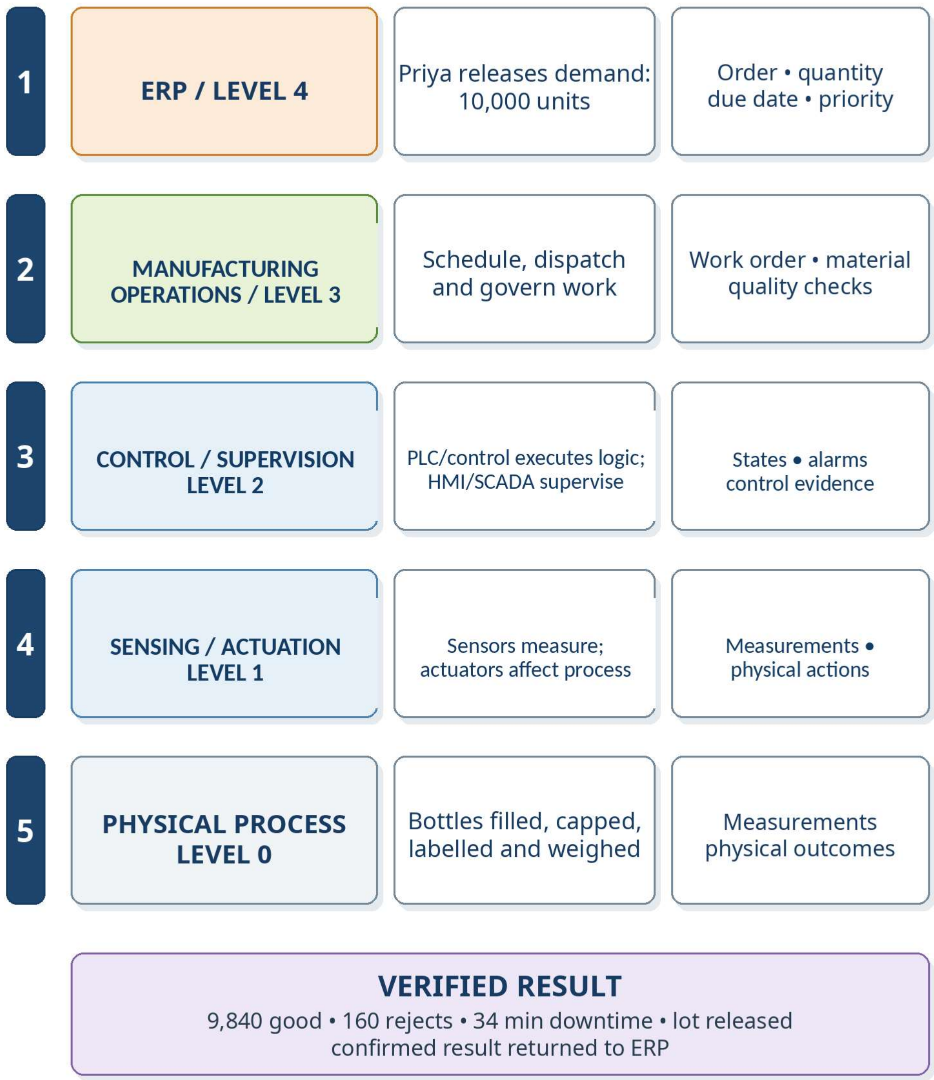

Figure 15.1: Packaging-line journey from business intent to verified result.

Read downward for the requirement and execution. Read upward for the observations, reviewed result, and business update.

“Product A was made” is not enough for a shift record.

A useful record includes:

- what was planned,

- what actually happened,
- where it happened,
- which materials were consumed,
- which equipment was used,
- which operators or roles were involved,
- what quality results occurred,
- what was rejected or held,
- what was completed,
- and what was reported back to ERP.

Once you can follow one order from plan to machine evidence to reviewed result, the level model becomes much easier to use.

Exercise: retell the walkthrough for one process you know. Connect the requirement, execution steps, machine evidence, quality or maintenance decision, reviewed result, and business impact. Write it so the next shift can follow it. (Model answer: A.15.)

M4 - COMPLETE FACTORY STORY	PLAN 10,000 units	DISPATCH WO-24017	CONTROL Run validated logic	OBSERVE Rejects + downtime	REVIEW 9,840 good / 160 rejected	UPDATE Confirmed result to ERP

Quick Reference

Use this matrix as a starting point, not a universal software assignment.

Common records and who may change them

The assignments below are common patterns, not universal software rules. For each important fact, a plant should document where the accepted value is kept, what source information supports it, and who may approve a change.

Fact or decision	Common record location	Who may change or approve it
Fast machine interlock	PLC or safety-control system	Authorized controls or safety-engineering process
Alarm visibility and process history	HMI/SCADA and historian	Authorized OT or controls role
Work-order execution status	MES or designated execution application	Authorized production workflow
Quality disposition	QMS or approved quality workflow	Authorized quality role
Maintenance work completion	CMMS/EAM	Authorized maintenance workflow
Material location and movement	WMS or ERP inventory module	Authorized warehouse or inventory role
Inventory value and financial posting	ERP	Authorized inventory or finance workflow
Customer commitment	ERP and planning process	Authorized planning, sales, or logistics role

Five questions to ask before acting

Physical event	What physically happened?
Observation or action	Which control or supervisory system observed or acted on it?
Production context	Which work order, material, equipment and time give it context?
Authoritative record	Which system or workflow owns the final production or business record?
Allowed action	What action is allowed, and who is authorized to approve it?

Glossary

The definitions below use the meaning intended in this beginner guide. Formal projects should verify terminology against the applicable standard, contract, regulation and site model.

Term	Meaning in this book
Acknowledgment	Confirmation that a message, event or transaction was received or processed.
Actuator	A device that converts a control command into physical action, such as movement, flow or heat.
Alias	An alternative identifier used by another system for the same object, together with the context needed to map it safely.
Authoritative record	The approved operational or business record that a defined workflow treats as the final value for a stated purpose.
Capability	What a resource can perform under stated conditions, such as size range, rate, qualification or process limit.
Correction authority	The authorized role and workflow allowed to amend an approved record while preserving evidence and audit history.
Decision owner	The role or workflow authorized to approve an operational or business outcome.
Detailed scheduling	Turning a broader production requirement into a feasible sequence using available equipment, materials, people and time.
Disposition	An authorized quality decision such as release, rework, scrap, return or continued hold.
Evidence source	Where an observation first appears, such as a sensor, PLC, SCADA system, historian, inspection system or another source.
Genealogy	The traceable relationship between input materials, process steps, equipment and resulting lots or serialized units.
Historian	An industrial time-series system that stores timestamped process values, states and alarms.
Idempotency	The ability to retry a transaction without creating an unintended duplicate result.
Interlock	A control condition that prevents or stops an action when required conditions are not valid.
Material lot	A traceable quantity of material produced, received,

Term	Meaning in this book
	stored, consumed or shipped under a shared identity.
MES	A manufacturing execution application or product that supports shop-floor execution records; actual scope varies by plant.
MOM	The broader manufacturing operations management domain covering production, quality, maintenance and inventory operations.
Operations performance	A record of what actually happened during manufacturing work, including quantities, timing, resources and outcomes.
Operations schedule	A planned assignment of manufacturing work to resources and time.
Process segment	A reusable description of a kind of work and the resources, parameters and outputs it requires.
Reconciliation	Comparing related system records, identifying differences and resolving them through an authorized process.
Reason code	A controlled classification used to explain an event such as downtime, scrap, hold or delay.
State interval	A start-to-end period during which equipment, material or work remains in a defined state.
System of record	The application or workflow designated to maintain an approved fact for a defined purpose.
Work center	A common ISA-95 equipment-hierarchy role that may map to a line, process cell, production unit or other site-defined resource group.
Work unit	A lower equipment-hierarchy role within a work center; a site maps its own terms such as cell, station or unit to the role.

Final Capstone with Self-Assessment

Choose one simple operation: a bakery line, bottling line, pharmaceutical packaging line, or electronics assembly line. Build a one-page ISA-95 map using the steps below. A complete sample capstone appears in Model Answer A.16.

1. Identify the physical production process at Level 0 and the sensing and manipulation functions at Level 1.

2. Identify the Level 2 monitoring and supervisory-control functions, including PLC, DCS, HMI, or SCADA functions where applicable.

3. Identify the Level 3 manufacturing operations responsibilities for work orders, quality, maintenance, inventory, genealogy, and any SCADA functions that manage manufacturing operations.

4. Identify the planning, purchasing, costing, inventory valuation, and customer-commitment responsibilities at the business-planning level.

5. Draw the downward flow of plans and instructions and the upward flow of status, evidence, results, and exceptions.

6. For five important facts, name where the accepted value is kept and explain why that location is appropriate.

Completion check

- Each important fact has a named home and a documented correction path.

- No business system directly bypasses validated machine control.

- Raw signals are connected to equipment, time, product, work order, material, and quality context where needed.

- The map separates planned work from actual performance.

- The design includes error handling, acknowledgment, and reconciliation for important exchanges.

A capstone does not need a vendor name. It does need clear responsibilities, stable identities, failure responses, and records that can be checked.

Self-assessment after the capstone

Use these questions after completing the map. A weak answer identifies the chapter that needs another pass.

Question	A sound answer should show
Can you explain ISA-95 without relying only on the pyramid?	You can explain responsibility, time horizon, object identity, and information exchange.
Can you separate Levels 0 through 4?	You can place physical process, control, supervision, operations management, and business planning.
Can you separate evidence from the approved production record?	You can distinguish PLC/SCADA/historian evidence from the designated execution or quality record.
Can you explain plan versus actual?	You can describe ERP-to-execution intent and the confirmed result returned to ERP.
Can you turn a tag into a traceable event?	You add time, equipment, work, material, reason, quality status, and responsible workflow.
Can you identify an unsafe or unreliable integration?	You can detect direct business-to-control shortcuts, hidden ownership, missing retry logic, and uncontrolled corrections.
Can you define a safe first project?	You choose one bounded flow with named systems, owners, failure behavior, security, and acceptance criteria.

References and Further Reading

For implementation, procurement, or compliance work, verify the current edition directly with the issuing organization. The references below are the principal sources used for this beginner guide.

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Standards and Source Guide

This guide shows where to continue reading. It does not reproduce the standards and should not be used as a substitute for licensed copies or current official editions.

Book coverage	Primary references	Use them for
Primer and Chapters 1-2	References 1-3	Scope, terminology, responsibility models and enterprise/manufacturing boundaries.
Chapters 3-4	References 1-3, 12, 16 and 17	ISA-95 context plus dedicated HMI, alarm-management, and cybersecurity guidance outside ISA-95.
Chapters 5-7	References 1-3, 13-14	Manufacturing operations, resources, definitions, schedules and performance objects.
Chapters 8-9	References 2-6 and 10	Identity, traceability, aliases, OPC UA, MQTT and Sparkplug.
Chapters 10-11	References 1-3 and 8-11	KPI context, quality, genealogy, maintenance, transactions and reliable exchange.
Chapter 12	References 1-3, 7 and 15	Asset Administration Shell, digital-twin context and governed AI use.
Chapters 13-15 and capstone	All references as applicable	Application review, common errors, bounded projects and end-to-end reasoning.

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Entries point to the main explanatory sections rather than every occurrence. In the digital edition, each page reference is clickable.

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Complete Model Answer Appendix

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Attempt each exercise before reading the model answer. The examples are complete enough for study, but they are not universal plant assignments. A real design must reflect the site, industry, regulation, risk, and available systems.

Most answers use the same packaging-line facts so that the records and decisions can be compared from one chapter to the next.

A.1 Four-Sentence Factory Problem (Chapter 1)

Example problem: an underweight-bottle quality issue.

1. The first observation appears when Checkweigher-03 measures a bottle at 742 g against a lower limit of 745 g and the PLC issues a reject command.
2. The PLC removes the bottle, the HMI alerts the operator, Ravi watches the reject rate, and Kumar checks whether the instrument or air-powered reject mechanism is drifting.
3. Anita reviews the active specification, measurement quality, affected work order and lot, confirmatory samples, and genealogy before the quality workflow records Hold, Release, Rework, or Scrap.
4. Priya changes the shipment or production plan only after the accepted good quantity and lot status reach ERP; until then, she reports that the shipment may be at risk rather than declaring a failure.

Why this works:

- It begins with a physical observation rather than a business conclusion.
- It separates the immediate control response from the later production and quality decisions.
- It names the record that affects inventory and planning only after review.
- It uses careful business language while the evidence is still incomplete.

A.2 Five-Level Responsibility Map (Chapter 2)

Level	Packaging-line example	Decision or responsibility
Level 0	Bottle, product, conveyor motion, weight, air pressure	The physical condition exists: the bottle weighs 742 g.
Level 1	Load cell, reject cylinder, guard sensor, other sensing/actuating devices	Sense the bottle weight and manipulate the physical process through the permitted actuator response.

Level	Packaging-line example	Decision or responsibility
Level 2	PLC/DCS control functions; HMI/SCADA supervisory functions; historian evidence	Monitor and supervise control: evaluate the measurement, command the permitted reject action, show alarms and trends, and preserve supporting evidence.
Level 3	MES, quality workflow, maintenance system, warehouse operations	Connect the reject to the active work order and lot, record quantities, investigate the cause, and approve the material status.
Level 4	ERP, planning, inventory valuation, customer commitment	Use the confirmed quantity and lot status to update inventory, cost, schedule, and shipment decisions.

Challenge test:

If a row contains only a product name, ask what that product is doing. A multi-function platform can perform tasks associated with several levels; the function and time horizon determine the placement.

A.3 Machine Signals, Actions, and Boundaries (Chapter 3)

Example machine: a checkweigher with an air-powered reject station.

Category	Examples
Sensors and inputs	Entry photo eye, load cell, conveyor encoder, reject-confirmation sensor, guard switch, air-pressure switch.
Actuators and outputs	Conveyor motor, reject cylinder, diverter gate, tower light, audible alarm.
PLC-controlled actions	Verify permissives, capture the weight at the correct position, compare with limits, time the reject, confirm removal, stop safely on a control fault.
Facts sent upward	Measured weight and unit, pass/fail result, reject confirmation, line mode and state, alarm code, counters, timestamp, and data-quality status.
Decisions kept close to the machine	Safety response, interlock enforcement, reject timing, motion sequence, and immediate equipment protection.
Decisions made later	Lot hold or release, work-order completion, approved downtime reason, maintenance return to service, inventory posting, and shipment impact.

A higher-level system may request a product, order, or operating target. It should not improvise a motor command or delay a required safe response.

A.4 What a Rising Reject Alarm Proves (Chapter 4)

Question	Model answer
What the alarm establishes	The configured reject count or rate crossed an alarm condition at a known source and time. It provides a reason to investigate.
What it does not establish	It does not identify the active product or lot, prove that the scale is accurate, confirm every reject actuator movement, determine the cause, or authorize a material disposition.
Production records to request	Active work order, operation, product, start time, planned quantity, good and reject counts, and the affected production interval.
Quality records to request	Approved weight specification, inspection plan, sample results, nonconformance or hold status, lot genealogy, and authorized disposition.
Maintenance records to request	Calibration status, diagnostic alarms, recent repairs, air-pressure history, reject-mechanism checks, and maintenance work ticket.
Immediate response	Keep the alarm visible, confirm the equipment state, preserve the evidence, and follow the site rule for slowing or stopping. Do not release the lot merely because the alarm later clears.

A.5 Resolving a Disputed Good Count (Chapter 5)

Example dispute: the PLC pulse count is 10,000, while the accepted good quantity is 9,840.

Record or participant	Value and role
PLC	Counts 10,000 bottle detections and commands 160 rejects. These are machine observations.
SCADA / historian	Shows the time sequence, reject pulses, weight trend, alarms, and line states used during investigation.
MES production record	Records 9,840 good units, 160 rejected units, the active order, operation, line, and time interval. This is the accepted production result for the example.
Quality workflow	Confirms whether the output lot is Released, Held, Reworked, or Scrapped and records the supporting evidence.
Correction process	A supervisor requests a correction with a reason and evidence. Quality participates when accepted quantity or lot status is affected. The original value, revised value, approver, time, and evidence remain visible.
ERP	Receives the approved quantity and status rather than the raw PLC pulse count.

MES does not have to own every count in every plant. The plant does have to name the accepted record, keep the supporting evidence, and prevent silent overwriting.

A.6 ERP-to-MES Exchange with Failure Handling (Chapter 6)

Normal exchange:

- ERP to execution: Order WO-31042, Product C, required quantity 6,000 units, due date 22 July, priority High, routing PKG-C, and approved material requirements.
- Execution to ERP: 5,760 good units, 120 rejected, 120 awaiting rework, input lots M-88 and C-31 consumed, output lot FG-31042 created, 18 minutes of unplanned downtime, quality status Released, and order status Complete with Rework Open.

Failure example: ERP is unavailable when the result is ready.

1. MES marks production complete locally and records the outbound business posting as Pending; it does not ask the operator to re-enter the result.
2. The interface stores the message durably with a unique transaction or idempotency key and retries according to a controlled schedule.
3. ERP acknowledges successful processing. A repeated delivery with the same key returns the earlier result instead of posting the inventory twice.
4. If the pending state exceeds the agreed threshold, support receives an alert and the operator sees that production is complete but the ERP posting is still pending.
5. A reconciliation process compares the execution result with the ERP posting and assigns any unresolved difference to an authorized support or business role.

A.7 Object Model for One Filling Operation (Chapter 7)

Example operation: fill, cap, and inspect Product A on Packaging Line 2.

Model element	Example
Equipment class	Filler
Equipment instance	Filler_01 in Packaging Line 2; alias PKG-L2-F01
Equipment capability	Approved for 500 mL bottles up to the site-defined line-speed limit
Material definitions	Product A bulk, 500 mL PET bottle, cap, label, finished bottle
Material input lots	Bulk P-902, bottle B-118, cap C-44, label L-71
Material output lot	Finished-goods lot FG-24018
Personnel role	Packaging-line operator
Qualification and assignment	Operator 1842, qualified for Line 2, assigned during Shift A
Reusable work definition	Fill, cap, label, and transfer to inspection
Approved parameters	500 mL target, approved tolerance, and line-speed limit under revision R4
Specific request	WO-24017, 10,000 units, Shift A
Source evidence	Bottle counts, checkweigher values, reject confirmations, alarms, and state intervals

Model element	Example
Performance result	9,840 good, 160 rejected, 34 minutes downtime
Quality decision	FG-24018 released after weight evidence and genealogy review
Correction workflow	Supervisor or quality request with reason, evidence, approval, and retained history

The model separates requirements from assignments. “Qualified packaging-line operator” is the requirement; Operator 1842 is the person assigned to this order. “Filler” is the equipment class; Filler_01 is the instance used during the shift. Product A is the material definition; FG-24018 is the output lot created by this execution.

The reusable work definition existed before WO-24017 and can be used again. The performance record belongs only to this order and keeps the actual equipment, people, lots, evidence, quantities, times, and result.

A later correction must not overwrite the earlier result silently. If the good quantity is revised, the record should retain the original value, new value, reason, supporting evidence, approver, and timestamp.

A.8 Five Tags Converted into Production Events (Chapter 8)

Raw tag	Possible event	Context required before production use
LineRunning = false	Line-stop interval	Start and end time, line, active order, surrounding states, approved reason code, reviewer, and whether planned time was affected.
Checkweigher.WeightPV = 742 g	Underweight observation	Instrument identity, timestamp, data quality, product, approved limits, work order, lot, and inspection rule.
RejectPulse = true	Unit reject	Reject station, triggering measurement, actuator confirmation, product or serial/lot context, reason, and counter reconciliation.
Filler.MotorCurrent = 18 A	Possible overload or abnormal load	Motor identity, operating mode, normal range, duration, speed, product, maintenance history, and related alarms.
Tank01.TempPV = 92 °C	Temperature excursion	Tank, recipe or process phase, target band, duration, material lot, sensor quality, affected quantity, and quality review.

A raw value can be valid evidence and still be incomplete. Add the object, time, work, material, rule, and responsible workflow before treating it as a traceable event.

A.9 One Signal from PLC to MES (Chapter 9)

Signal: Checkweigher-03 measured weight.

Handoff	What changes	Permitted use
Load cell to PLC	The physical force becomes a scaled weight value with diagnostic quality.	Immediate comparison and validated reject logic.
PLC to HMI / SCADA	The weight, pass/fail result, machine state, and alarm are exposed through a controlled connection such as OPC UA.	Operator display, alarm response, permitted supervision, and short-term troubleshooting.
SCADA to historian	Timestamped values and state changes are retained as a time series.	Trend analysis, incident reconstruction, calibration comparison, and evidence preservation.
Gateway or broker	Selected data may be normalized, buffered, or published through MQTT/Sparkplug.	Reliable distribution to authorized consumers; transport does not create production meaning.
Historian / SCADA to MES	The signal is linked to the active work order, product, lot, operation, specification, and result.	Production counting, traceability, exception handling, and the reviewed operating record.

Transport may change at every handoff. Meaning changes when the signal is tied to the active work and material. None of these connections should give an analytics or business system unrestricted access to the control network.

A.10 Reject-Spike Investigation as a Team Conversation (Chapter 10)

SCADA operator: “RejectRate crossed the warning limit at 12:04, and the line is still running at 82 bottles per minute.”

Historian analyst: “The average weight drifted from 750 g to 742 g over nine minutes. The trend is continuous rather than a single bad reading.”

Ravi, production: “MES shows WO-24017 and output lot FG-24018 were active. We have 330 rejected units in the affected window.”

Kumar, maintenance: “Checkweigher-03 is due for calibration. I will verify the load cell, air pressure, and reject confirmation before I release the equipment back to production.”

Anita, quality: “Place FG-24018 on hold. I will compare retained samples and measurement evidence with the approved specification, then record Release, Rework, or Scrap through the quality workflow.”

Priya, planning: “ERP shows the customer shipment due this afternoon. I will model the shortfall, but I will not change available inventory until the approved lot status and good quantity arrive.”

Decision rights:

- The PLC performs the immediate reject and safety-related control response.
- Maintenance approves equipment return to service through its authorized process.
- Quality approves the material disposition.
- Production approves the operating response within site procedures.
- ERP and planning use the approved result; they do not replace the quality or control decision.

A.11 Information-Exchange Matrix and Receiver Outage (Chapter 11)

Information	Sender	Receiver	Accepted record / owner	Verification
Production order	ERP	MES	ERP planning order	Order ID, item, quantity, revision, due date, and acknowledgment match.
Material request	MES	WMS / ERP	Warehouse or inventory workflow	Lot status, quantity, location, reservation, and issue confirmation match.
Production result	MES	ERP	MES performance record; ERP business posting	Good, scrap, rework, lots, status, transaction ID, and posting acknowledgment reconcile.
Quality hold	QMS / MES quality	MES, WMS, ERP	Authorized quality workflow	Lot identity, reason, scope, effective time, and release status are consistent.
Downtime event	SCADA / MES	MES / CMMS	MES downtime record and maintenance ticket	Start, end, equipment, order, reason, and work-ticket link agree.
Inventory update	WMS / ERP	ERP / MES	Authorized inventory ledger	Item, lot, quantity, location, movement type, and transaction identity reconcile.

Receiver-outage example: ERP is unavailable when MES sends the production result.

- The operator sees “Production complete locally - ERP posting pending,” not a false failure and not a completed ERP posting.
- The result remains in a durable outbound queue with its unique transaction ID.
- Automatic retry continues within the agreed limit; repeated delivery cannot create a duplicate posting.
- Support is alerted when the delay exceeds the service threshold.

- After recovery, acknowledgment and reconciliation close the pending state or route a mismatch for authorized correction.

A.12 Testing a Digital-Twin or AI Claim (Chapter 12)

Claim: “An AI-enabled digital twin predicts checkweigher drift and automatically improves quality.”

Test question	Model answer
Which real object is represented?	Checkweigher-03, including its load cell, reject mechanism, calibration state, line location, and equipment identity.
Which sources are read?	PLC measurements and diagnostics, SCADA states and alarms, historian trends, MES work-order and lot context, QMS limits and dispositions, and CMMS calibration and repair history.
What may be stale or incomplete?	MES may have an outdated active order, the historian feed may be delayed, a maintenance ticket may be open, or the quality limit revision may not yet be synchronized.
What may the AI do?	Summarize evidence, detect a pattern, estimate confidence, recommend inspection, draft a maintenance request, and route the issue to the correct role.
What may it not do by itself?	Change PLC setpoints, bypass an interlock, release or scrap a lot, close maintenance work, alter accepted production quantities, or post inventory.
What evidence should be logged?	Input sources and timestamps, model version, recommendation, confidence, user decision, action taken, and final outcome.

A credible demonstration identifies its sources, shows data age and uncertainty, and respects permission boundaries. A changing 3D color and a confident answer are not enough.

A.13 One-Page Integration Checklist (Chapter 13)

Example project: communicate an underweight quality hold from the packaging line to inventory and planning.

Checklist item	Completed example
Decision supported	Prevent held output from being treated as available inventory or promised to a customer.
Physical event	Checkweigher trend and confirmed underweight rejects during WO-24017.
Source evidence	PLC values and reject confirmation, SCADA alarm, historian trend, and sample inspection results.

Checklist item	Completed example
Affected objects	Checkweigher-03, Packaging Line 2, WO-24017, Product A, output lot FG-24018.
Accepted status	Quality workflow records Hold or Release for FG-24018.
Levels involved	Levels 1–2 provide evidence; Level 3 reviews and records the hold; Level 4 consumes the approved inventory status.
Exchange	Quality/MES sends lot, status, reason, effective time, and decision ID to WMS and ERP through an authenticated API or message.
Freshness	Hold must reach inventory systems before allocation or shipment; delays trigger an operational alert.
Failure behavior	Retain and retry the message, block contradictory release, show Pending status, and reconcile after recovery.
Security	Only authorized quality roles may create or release the hold; consumers have read or processing rights only.
Correction and audit	Every change preserves previous status, reason, evidence, approver, timestamp, and transaction history.
Acceptance criteria	One governed lot identity or documented alias mapping across systems; no held stock allocated; duplicate messages are harmless; outage recovery is demonstrated; audit trail is complete.

A.14 Two-Page ISA-95 Briefing and Spoken Explanation (Chapter 14)

Page 1 — The plant map

- Level 0: bottles, product, weight, motion, pressure, and the physical output.
- Level 1: sensors and actuators that sense or manipulate the production process.
- Level 2: PLC/DCS monitoring and control plus HMI/SCADA supervisory functions where they perform that role.
- Level 3: manufacturing operations management: work-order execution, production counts, quality status, maintenance work, inventory operations, genealogy, and SCADA functions where they manage operations.
- Level 4: demand, purchasing, business inventory, cost, schedule, and customer commitments.
- Downward flow: product, quantity, due date, route, and controlled work instructions. Upward flow: state, evidence, exceptions, approved quantities, lot status, and completion.

Page 2 — One bounded first project

Field	Example
Project	Quality-hold communication for underweight packaging rejects.
Scope	One line, one checkweigher, one output lot, MES/QMS to WMS/ERP.
Success	A held lot cannot be allocated or shipped, and each consumer applies the release once even if the message is delivered more than once.
Main risk	Different lot IDs, delayed status, duplicate messages, or an unauthorized release.
Failure response	Durable retry, visible pending state, alerting, and record reconciliation.
Review team	Production, quality, maintenance, warehouse, planning, OT, IT, and cybersecurity.

Ninety-second explanation:

"The PLC performs the immediate control and reject. SCADA and the historian show what happened. MES and quality connect that evidence to the order and lot, and ERP receives the reviewed quantity and status. Our first project is only the quality-hold message between those systems. We will test duplicates, outages, permissions, and the audit trail. The project is done when held material cannot be shipped and every system shows the same lot status."

A.15 End-to-End Shift Story (Chapter 15)

1. Priya releases a requirement for 10,000 bottles of Product A. ERP sends the product, quantity, due date, priority, and route reference to the execution application.
2. MES verifies the line, released materials, operator qualification, work instructions, and quality requirements before dispatching WO-24017 to Packaging Line 2.
3. The PLC controls the filler, conveyor, checkweigher, and reject station. HMI and SCADA show state and alarms, while the historian stores the weight and machine timeline.
4. At 10:42 the checkweigher begins rejecting underweight bottles. Ravi stabilizes production, Kumar checks calibration and air pressure, and Anita places output lot FG-24018 on hold while evidence is reviewed.
5. The investigation confirms 9,840 good units and 160 rejected units. Maintenance records the equipment check; quality releases the acceptable lot and preserves the test and disposition history.
6. MES records the final performance, consumption, downtime, genealogy, and lot status. ERP receives the approved result, updates inventory and cost, and Priya confirms whether the afternoon shipment can still be met.
7. The next shift receives the open rework or maintenance items, the final counts, the lot status, the pending business transactions, and the person responsible for each remaining action.

A shift handover should state what the business requested, what the machine observed, what the plant accepted, and what is still open.

A.16 Complete Final Capstone: Electronics Assembly and Final Test

Operation: assemble and test Controller Unit CU-100 on Electronics Line E2.

Level map

Level	Capstone content
Level 0	Printed circuit boards, components, solder joints, fasteners, electrical measurements, temperature, torque, motion, and completed units.
Level 1	Presence sensors, barcode reader, measurement devices, reject gate, and other sensing or actuating devices.
Level 2	PLC and torque-tool control functions, operator HMI, supervisory functions, alarms, trends, and supporting historian evidence.
Level 3	MES dispatch and serial genealogy, QMS test result and disposition, CMMS equipment work, WMS component issue, rework route, operations performance, and any SCADA functions that manage manufacturing operations.
Level 4	ERP demand, production order, component planning, inventory value, cost, promised shipment, and financial posting.

Downward information flow

- ERP sends order EO-8804 for 500 units of CU-100, due date, priority, approved BOM and route revision.
- MES dispatches the assembly and final-test operations with work instructions, component requirements, test program revision, and qualification requirements.
- The equipment receives only the controlled parameters and commands needed for the validated operation; business applications do not directly drive actuators.

Upward information flow

- The PLC, torque controller, and tester provide serial scans, torque results, measurements, pass/fail evidence, state changes, alarms, and timestamps.
- MES links the evidence to serial number CU100-00418, order EO-8804, station TEST-02, component lots, operator role, and operation revision.
- QMS records the failed electrical test, investigation, approved rework route, retest, and final disposition.
- ERP receives the reviewed good, reject, rework, consumption, completion, and inventory status.

Five important facts and their accepted records

Fact	Accepted record	Supporting evidence	Correction path
Order requirement	ERP production order EO-8804	Demand, due date, BOM and route revision	Authorized planning change with revision history
Serial genealogy	MES serial record	Scanner events, component lots, station and operation history	Controlled genealogy correction with evidence and audit
Final test result	QMS/MES quality result	Tester measurements, program revision and calibration status	Authorized quality review and retest process
Equipment return to service	CMMS maintenance release	Fault diagnostics, repair, verification and technician approval	Maintenance workflow
Finished-goods quantity	MES performance result and ERP posting	Serial outcomes, quality status and transaction acknowledgment	Supervisor/quality request followed by reconciliation

Failure and recovery example

The final-test result is ready, but MES temporarily cannot reach ERP. MES retains the approved completion message with a unique transaction ID and shows "ERP posting pending." Production does not re-enter the quantity. After ERP recovers, the message is retried, acknowledged, and reconciled. A repeated delivery cannot create duplicate inventory.

Security and action limits

- The PLC and test fixture enforce validated control and test sequences.
- Operators may execute permitted work but cannot alter the approved test program without controlled authorization.
- Quality roles approve disposition and rework release.
- Maintenance roles release repaired equipment.
- AI or analytics may explain patterns and recommend investigation, but cannot change a test result, release product, or post inventory by itself.

Completion check

- Every important object has one stable identity or documented alias mapping.
- Plan, source evidence, reviewed operating result, and business posting remain distinguishable.
- The design handles acknowledgment, retry, duplicates, outage visibility, and reconciliation.
- Roles and permissions match the decisions they are allowed to make.
- The map can be explained without relying on vendor product names.

Sample self-assessment result

A strong learner should now be able to explain why a tester fail bit is not yet a complete quality decision, why ERP should wait for the reviewed serial and lot status, how the same unit is traced across equipment and systems, and what happens when a business posting is delayed. Any weak answer points back to the relevant chapter for another pass.

About this Book

ISA-95 can feel intimidating when you first encounter PLCs, SCADA, MES, ERP, and manufacturing integration. This beginner-friendly guide explains the core ideas in plain language and shows how information moves from the production process to business planning.

Inside the book

- The five ISA-95 levels
- Core manufacturing systems and responsibilities
- Information models, traceability, and genealogy
- Integration flows, digital twins, and AI context

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