CIM and Business Processes

Agenda

- Introduction
- Computer Integrated Manufacturing
- ANSI ISA 95
- Examples of CIM levels
- CIM and data communication
- Conclusions

Introduction

- This lesson will provide a basic framework of the role of computer systems in an industrial automation system, focused on functional architectures that have historically been defined as CIM: Computer Integrated Manufacturing
- We will try to understand the links between the characteristics of the management processes and the computer architectures that must support them.
- Many of these bonds have been standardized by ANSI and ISA
- Enterprise management processes have different characteristics both from the point of view of time resolution and management detail.
- For this reason, the supporting information systems have different computer architectures that have different characteristics and problems from the point of view of implementation and operational management

What does it mean to automate?

- Automating means to change physical or logical processes by means of automatic systems and servomechanisms.

- Information Systems are automated information management systems because they are able to acquire, use, and record data with or without minimal human intervention.

- In the same way, robotic systems have the ability to carry out movements, machining operations that are required to produce products without or with minimal human intervention.

- But before writing a software program you can just try it with "paper and pen" to understand how processes are done and how they can improve.

- Undoubtedly, it is a very effective approach when you want to experience a new process of management, but it becomes a "waste" as the process is developed and the activities become repetitive.

We often have automation systems in company plants

- ERP systems that automate management information such as order cycle, active and passive accounting, asset management etc
- SCADA systems that acquire and manage complex system information such as conditioning equipment, electrical distribution, security systems, etc.
- PLC or CNC systems that manage the automation of single machines or material handling systems such as machine tools, rollers, automatic warehouses etc.
- Automatic identification systems that allow the identity of materials and people to handle RFId systems etc

But these systems are often independent of each other

Human intervention activates the automatic systems

- Operators insert orders, invoices etc into ERP systems that automate management information
- Operators control the information SCADA Systems acquire and manage for complex systems such as air conditioning, power distribution, security, etc.
- Operators activate the PLC or CNC systems that manage the automation of single machines etc
- ... ..

Operator intervention requires resources and may cause errors and malfunctions

This reason is the origin of concept of Integration

- The systems themselves interconnect with each other by avoiding operator intervention and reducing costs and errors

- Information is acquired once and shared by all systems.

- But to do this, it is necessary to define standards without which computer systems can not exchange information

- The standards are of four types:
  - The data structure
  - The mode of communication
  - The time horizon of the data
  - Time resolution of data

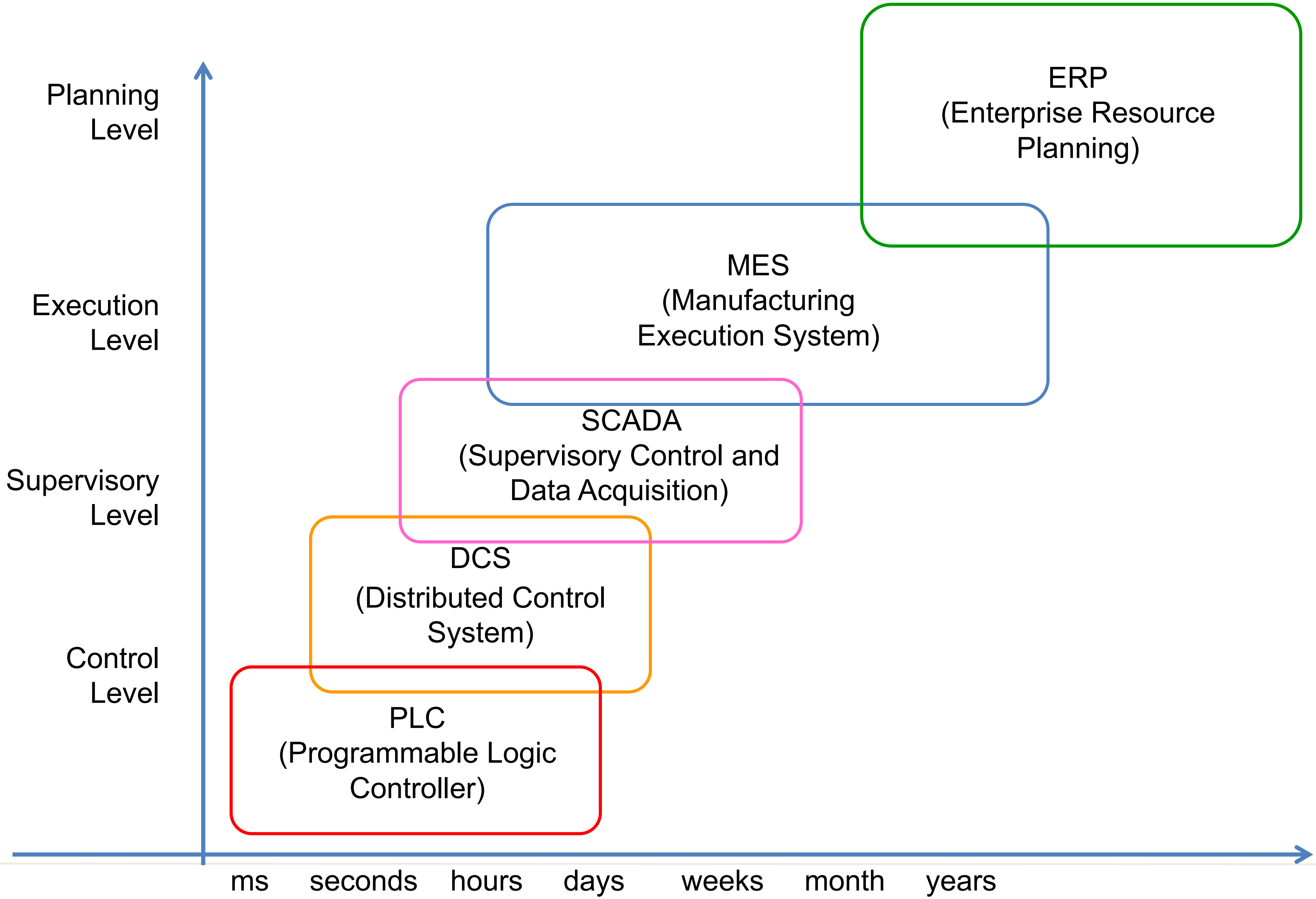
- The data structure and communication mode are technical standard

- The horizon and time resolution of data are a management standard

Horizon and time resolution of data are different for each system

- The time horizon is what we have to look to manage a system
- Time resolution is the minimum slot time of a performance
- For example, if we analyze the customer order portfolio in an ERP we can estimate that the time horizon is similar to the order response time for example 3 weeks
- Instead, the time resolution may be the day because the promise of delivery has no minor resolution
- So for an ERP we could have a four-week time horizon with a one-day Time Bucket
- For this reason a PLC management system for the finished product warehouse should receive day-to-day order portfolios

Response time and hierarchical level



Different Points of View

- <u>Business Systems</u>
  - Time Horizons
    - Long-term view
  - Model detail
    - Linear route structures
  - Control emphasis
    - Product cost and overall profitability
  - Modeling criteria:
    - Accounting reference points
    - Has inventory value changed significantly? If not, don't model separately
  - **View from the boardroom**

- <u>Manufacturing Systems</u>
  - Time Horizons
    - Real-time view
  - Model detail
    - Complex routes with rework paths
  - Control emphasis
    - Physical movement & accountability
  - Modeling criteria:
    - material movement reference points
    - Does product stop moving? If not, don't model separately
  - **View from the workcenter**

Data Quantity & Quality and Hierarchical Level

Higher Levels

- When ascending the control hierarchy, data are reduced:
  higher level data are created (e.g. summary information)
- Processing and decisions becomes more complicated (requires using models).
- Timing requirements are slackened. Historical data are stored

SCADA level

- Presentation of complex data to the human operator,
  help to make decisions (expert system) and maintenance.
- Requires a knowledge database in addition to the plant's database

Lower Levels

- Lowest levels (closest to the plant) are most demanding in response time.
- Quantity of raw data is very large.
- Processing is trivial (was formerly realized in hardware).
- These levels are today under computer control,
  except in emergency situations, for maintenance or commissioning.

Integration: The concept of Computer Integrated Manufacturing (CIM)

- Since the 1980s, the concept of Computer Integrated Manufacturing (CIM) has been established, i.e. automated integration between the various processes of a production system (design, engineering, production, quality control, production planning and marketing) minimize product development times, optimize resource management, and possibly be flexible to cover the market as much as possible.

- In this way, automation systems of different business processes are not limited to pure automation of the process but allow integration with other automated processes

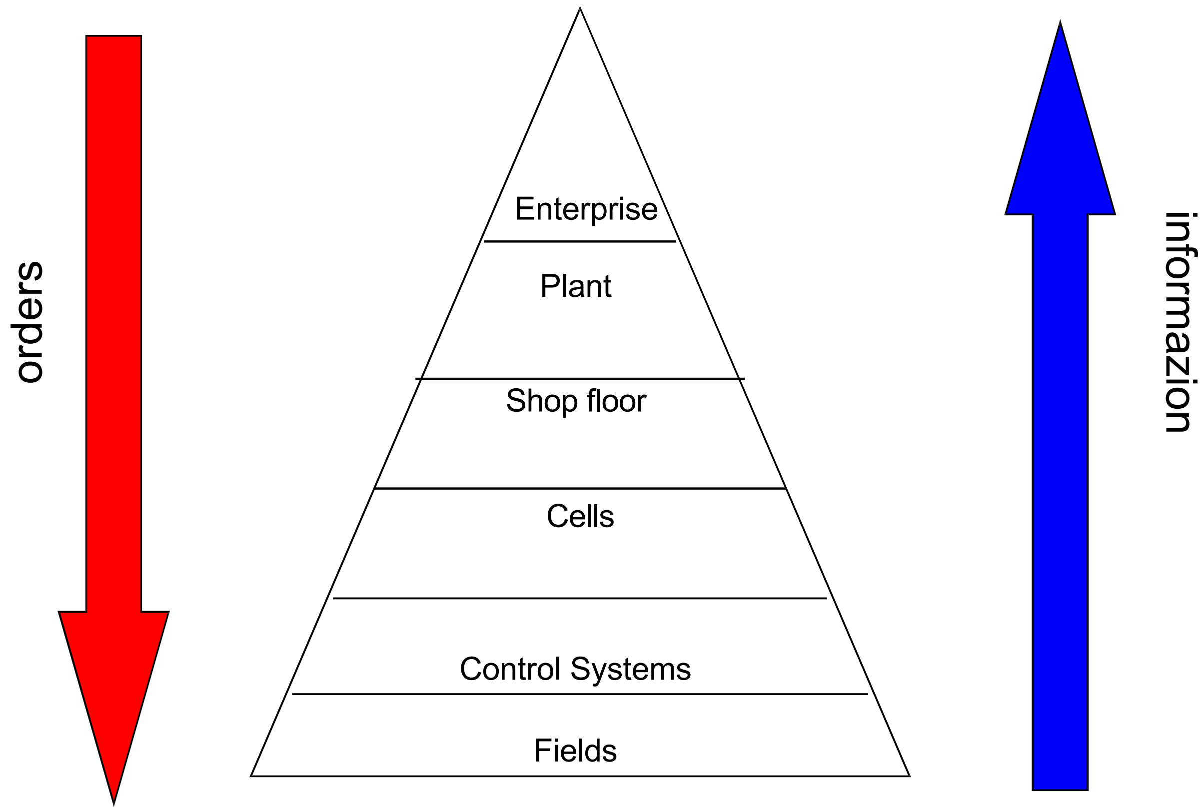
- The concept of integration is the key element of this architecture approach.

- Integrating means automatically exchanging data from one process to another according to the times and syntax that must be defined “a priori”.

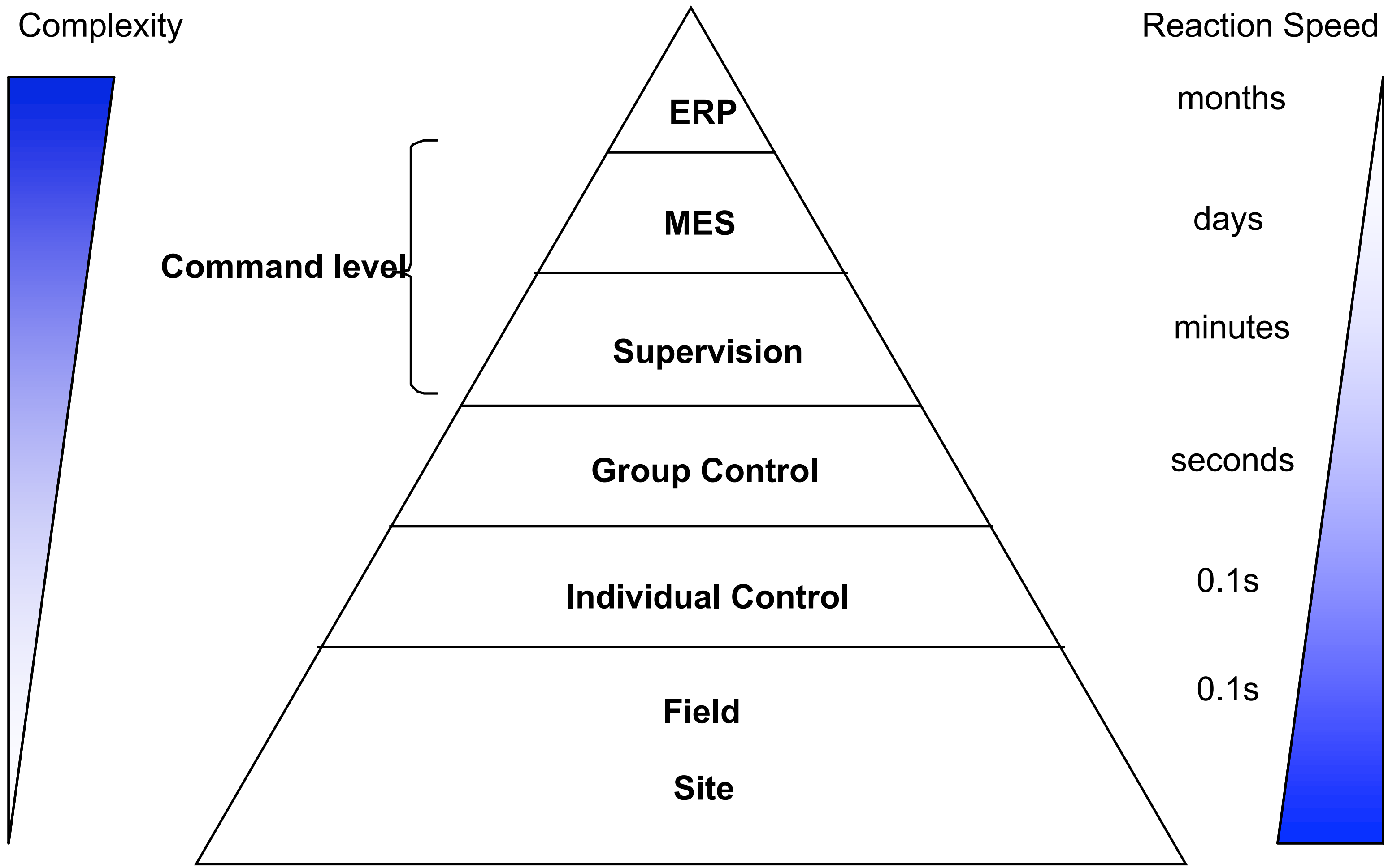
- In this way, the same data is always used by avoiding redundancies or acquisition errors and reducing the execution time

The CIM model is hierarchical

In the CIM hierarchical model, each level acquires, manages and transfers information with strategic and operational goals that go from an aggregate level to executives of lower levels.



Complexity and Hierarchical level of CIM



CIM technologies cover almost all operational processes

The CIM model envisages the integration of several interconnected technologies :

- CAD Computer Aided Design
- CAM Computer Aided Manufacturing
- CAT Computer Aided Test
- CAPP Computer-aided process planning
- MRP Materials Requirements Planning
- Robotica
- AGV
- ERP (Enterprise resource planning)
- CNC (computer numerical control) machine tools
- DNC, Direct Numerical Control machine tools
- FMS, flexible manufacturing system
- ASRS, automated storage and retrieval systems
- Automated conveyance systems
- computerized scheduling and production control
- CAQ (Computer-aided quality assurance)
- A business system integrated by a common **relational** database

Exchange standard data with standard processes: CIM and ANSI / ISA-95.00.01

- CIM models have been defined with standardized architectures from ANSI and ISA mainly from the ANSI ISA 95 standard

- ISA-95's objectives are to provide consistent terminology that is a foundation for supplier and manufacturer communications, to provide coherent information models, and to provide consistent operating models, which is the basis for clarifying application capabilities and how to the information must be used.

The ISA-95 standard is divided into 5 parts:

1-ANSI / ISA-95.00.01-2000, Enterprise-Control System Integration
2-ANSI / ISA-95.00.02-2001, Enterprise Control System Integration
3-ANSI / ISA-95.00.03-2005, Enterprise-Control System Integration
4-ISA-95.04 object models and features
5-ISA-95.05 B2M Operations

ANSI / ISA-95.00.01

- **ANSI/ISA-95.00.01-2000, Enterprise-Control System Integration Part 1: Models and Terminology** consists of standard terminology and object models, which can be used to decide which information should be exchanged.

- The models help define boundaries between the enterprise systems and the control systems. They help address questions like which tasks can be executed by which function and what information must be exchanged between applications.

- SA-95 Models
  - Context
  - Hierarchy Models
    - Scheduling and control (Purdue)
    - Equipment hierarchy
  - Functional Data Flow Model
    - Manufacturing Functions
    - Data Flows
  - Object Models
    - Objects
    - Object Relationships
    - Object Attributes
  - Operations Activity Models
    - Operations Elements: PO, MO, QO, IO
    - Operations Data Flow Model
      - Operations Functions
      - Operations Flows

ANSI / ISA-95.00.01

- **ANSI/ISA-95.00.02-2001, Enterprise-Control System Integration Part 2: Object Model Attributes** consists of attributes for every object that is defined in part 1. The objects and attributes of Part 2 can be used for the exchange of information between different systems, but these objects and attributes can also be used as the basis for relational databases.

- **ANSI/ISA-95.00.03-2005, Enterprise-Control System Integration, Part 3: Models of** **Manufacturing Operations Management** focuses on the functions and activities at level 3 (Production / MES layer). It provides guidelines for describing and comparing the production levels of different sites in a standardized way.

- **ISA-95.04 Object Models & Attributes Part 4 of ISA-95: "Object models and attributes for Manufacturing Operations Management"** The SP95 committee is yet developing part 4 of ISA-95, which is entitled "Object Models and Attributes of Manufacturing Operations Management". This technical specification defines object models that determine which information is exchanged between MES activities (which are defined in part 3 by ISA-95). The models and attributes from part 4 are the basis for the design and the implementation of interface standards and make sure of a flexible lapse of the cooperation and information-exchange between the different MES activities.

ANSI / ISA-95.00.01

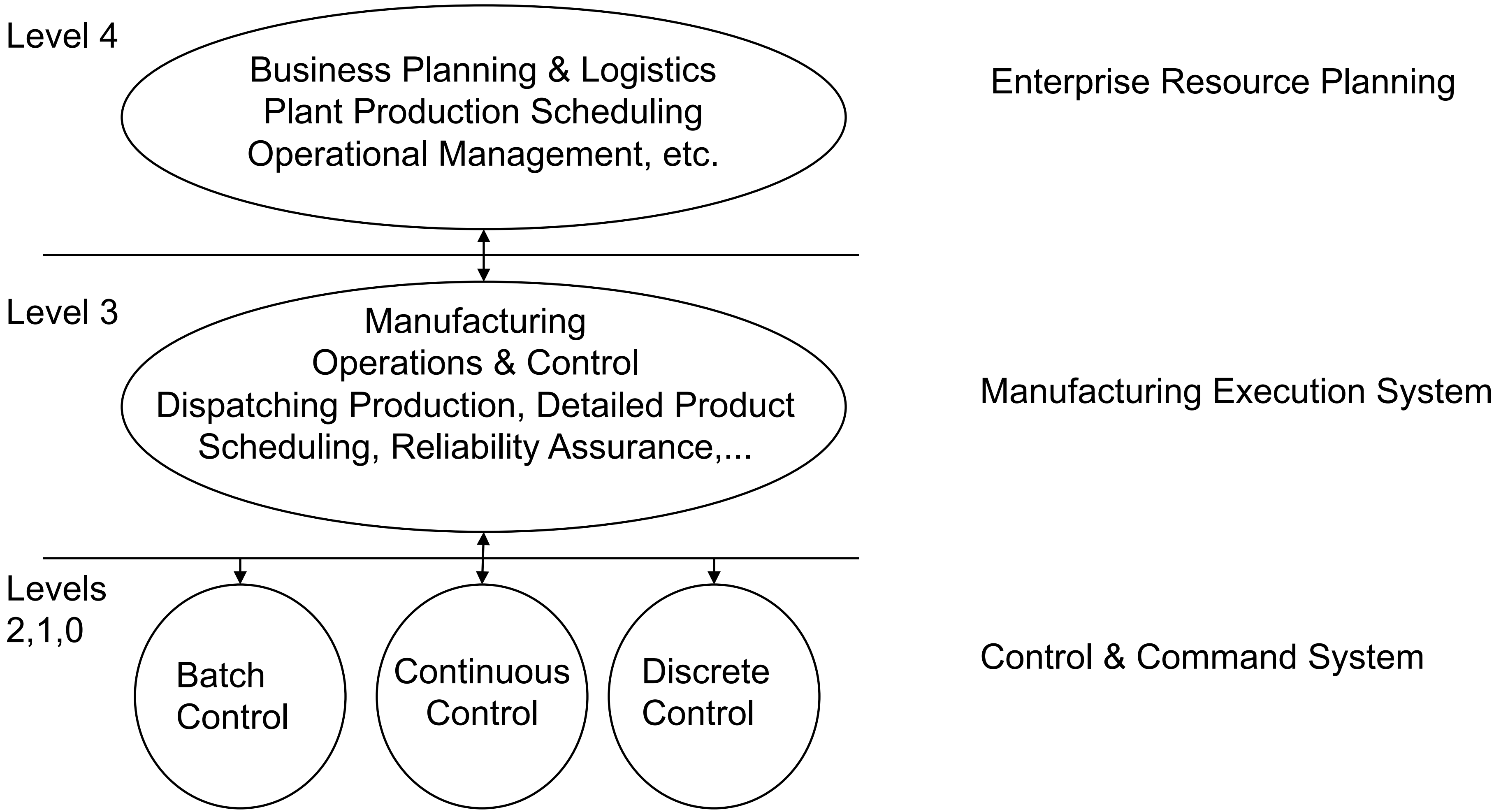
- **ISA-95.05 B2M Transactions Part 5 of ISA-95: "Business to manufacturing transactions"** Also part 5 of ISA-95 is yet in development. This technical specification defines operation between office and production automations-systems, which can be used together with the object models out part 1 & 2.

- The operations connect and organise the production objects and activities that are defined through earlier parts of the standard. Such operations take place on all levels within a business, but the focus of this technical specification lies on the interface between enterprise- and control systems. On the basis of models, the operation will be described and becomes the operation processing logically explained.

- Within production areas activities are executed and information is passed back and forth. The standard provides reference models for production activities, quality activities, maintenance activities and inventory activities.

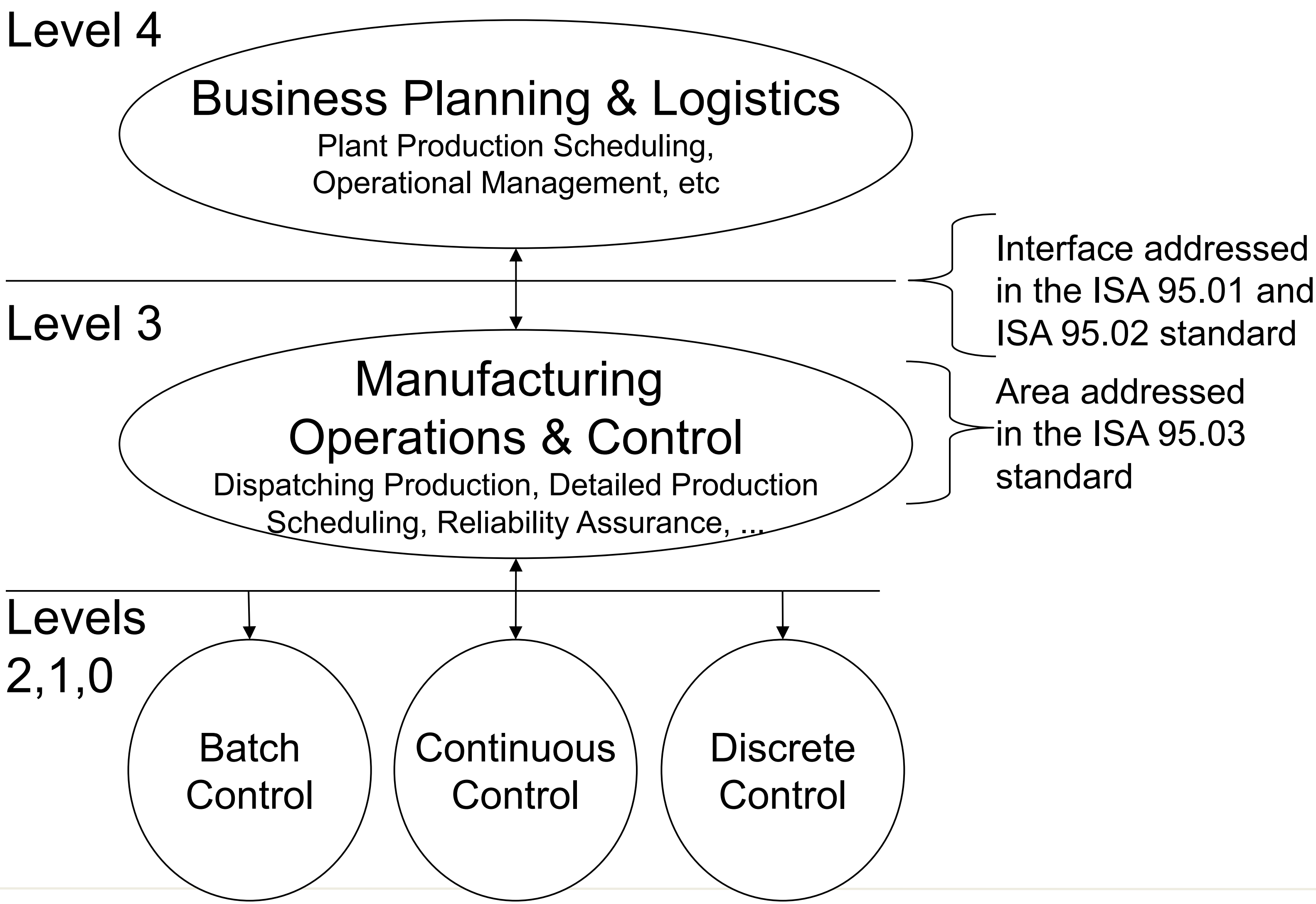
ANSI/ISA 95 is the standard classification

The ANSI/ISA standard 95 defines terminology and good practices

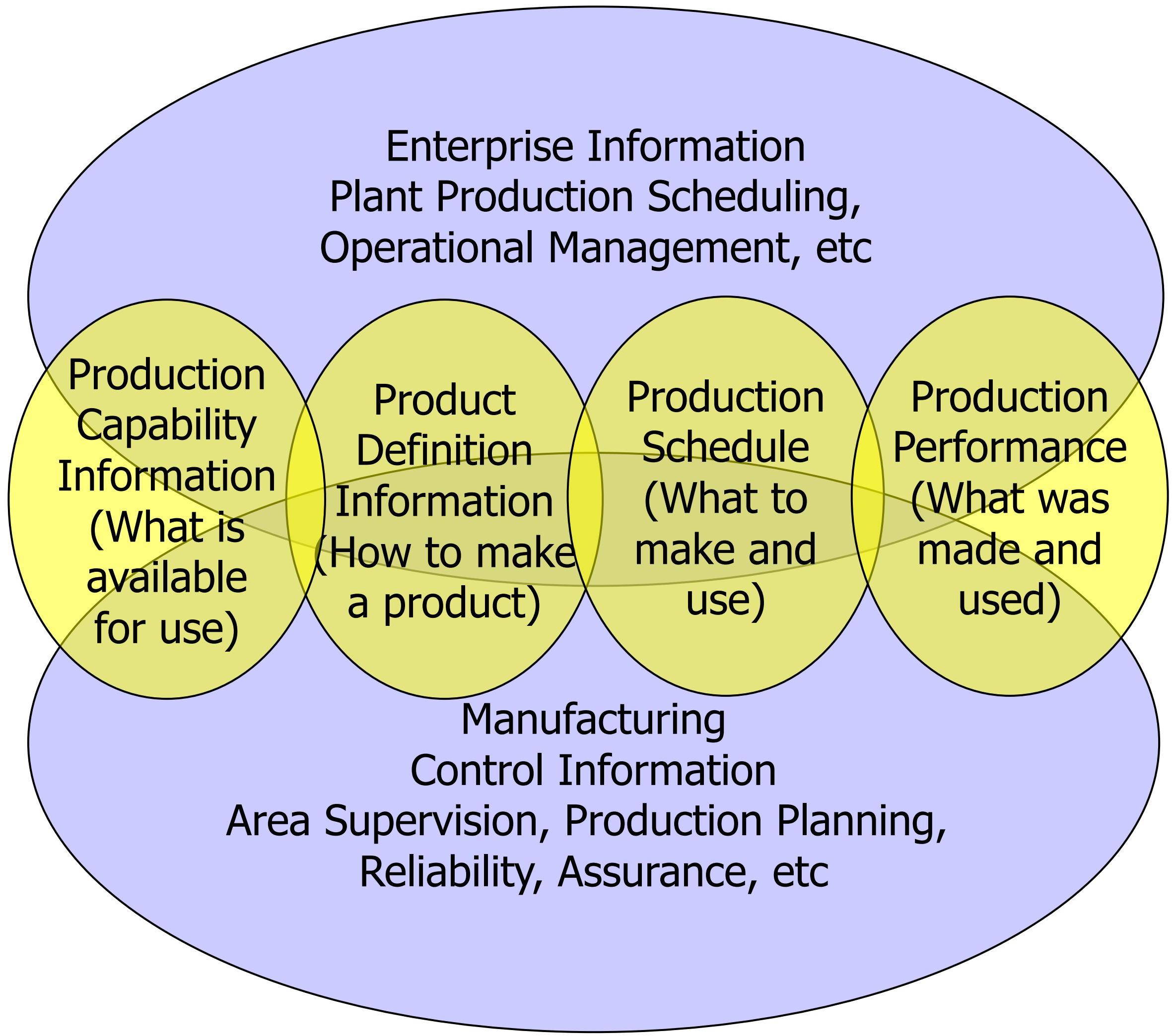


Source: ANSI/ISA–95.00.01–2000

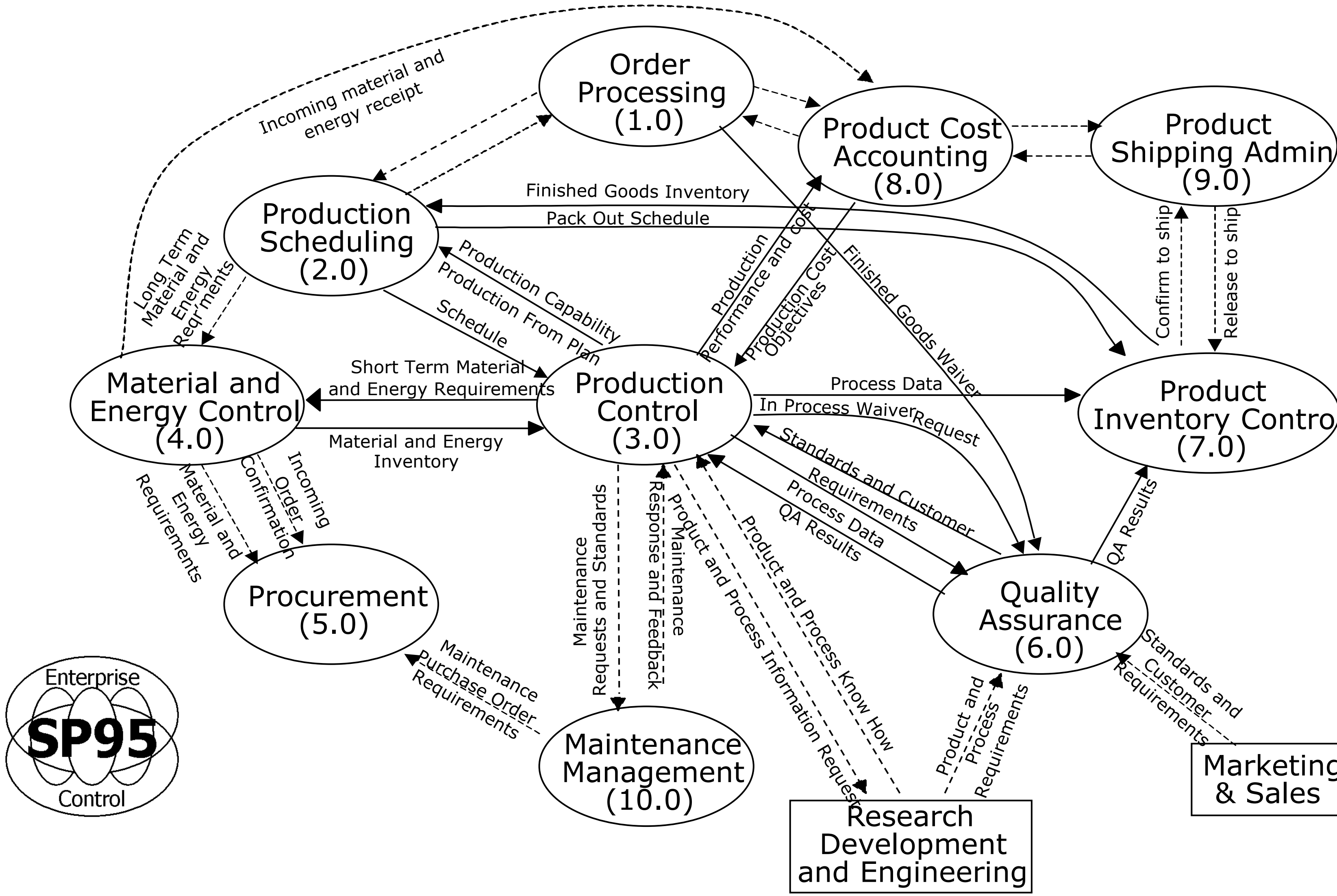
ISA95.01 Levels



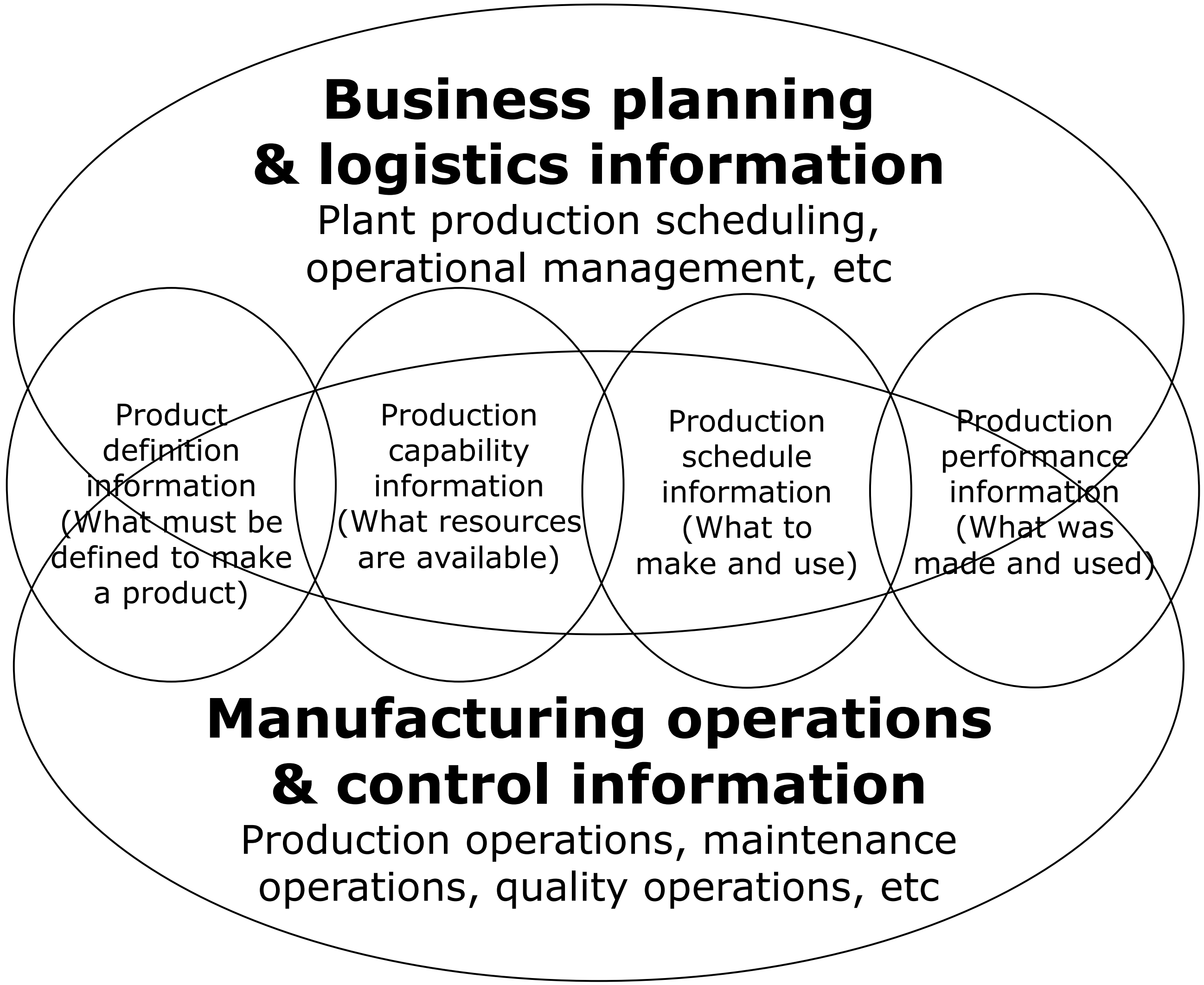
Exchanged Information Categories



This is What that Looks Like in S95-speak: Functional Enterprise Control Model: Part 1

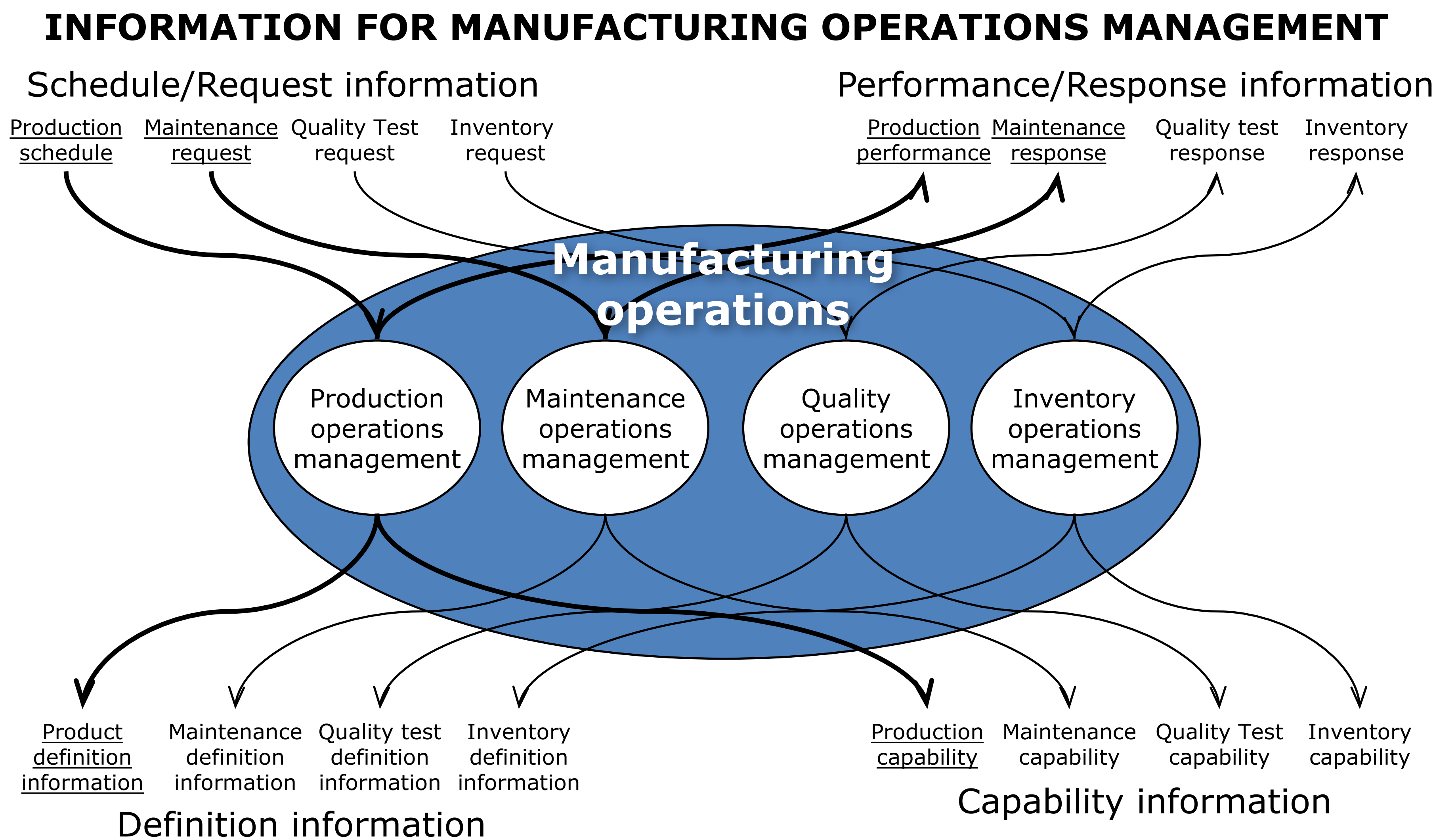


Parts 1 and 2…

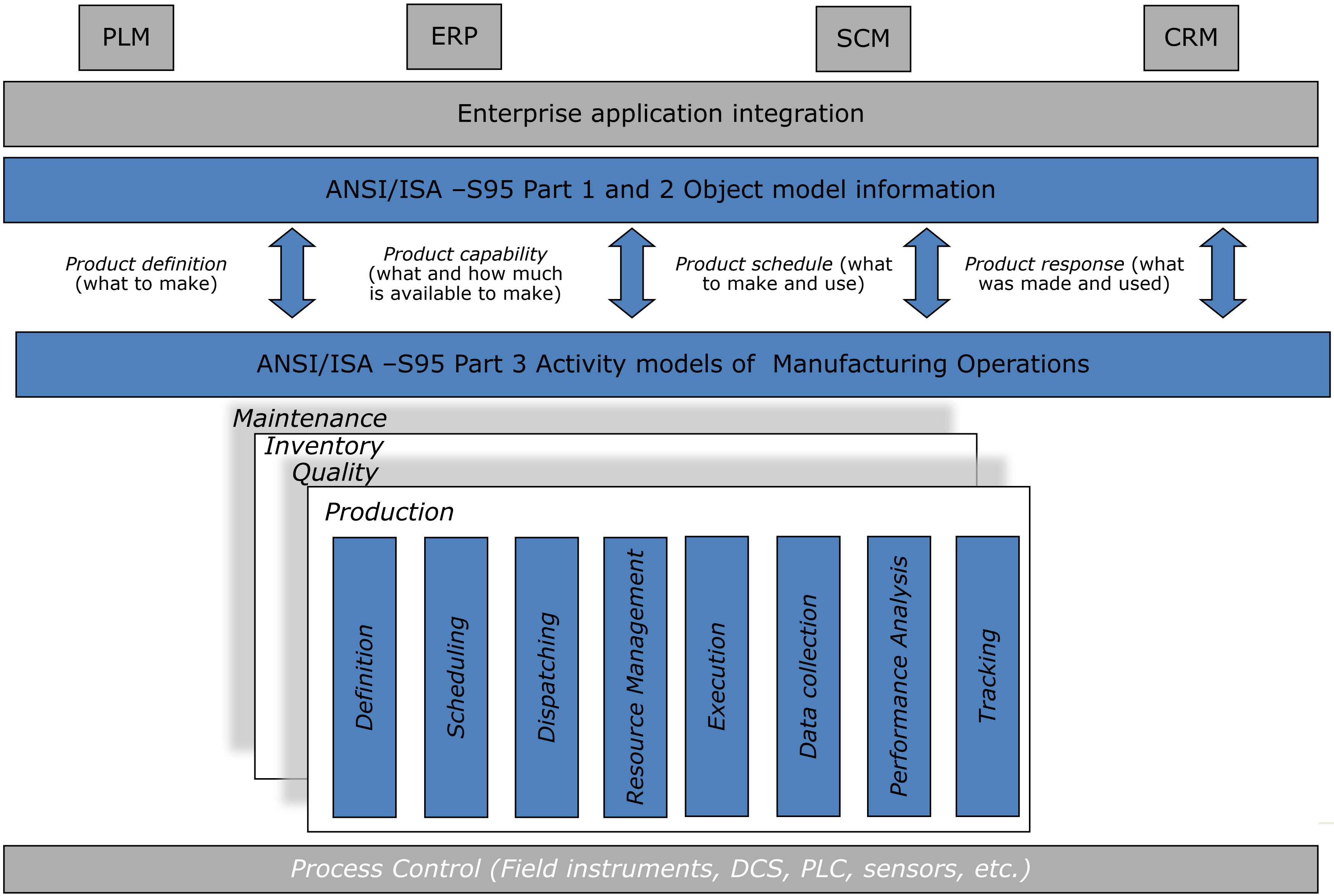


Business planning
& logistics information
Plant production scheduling, operational management, etc
Product definition information (What must be defined to make a product)
Production capability information (What resources are available)
Production schedule information (What to make and use)
Production performance information (What was made and used)
Manufacturing operations
& control information
Production operations, maintenance operations, quality operations, etc

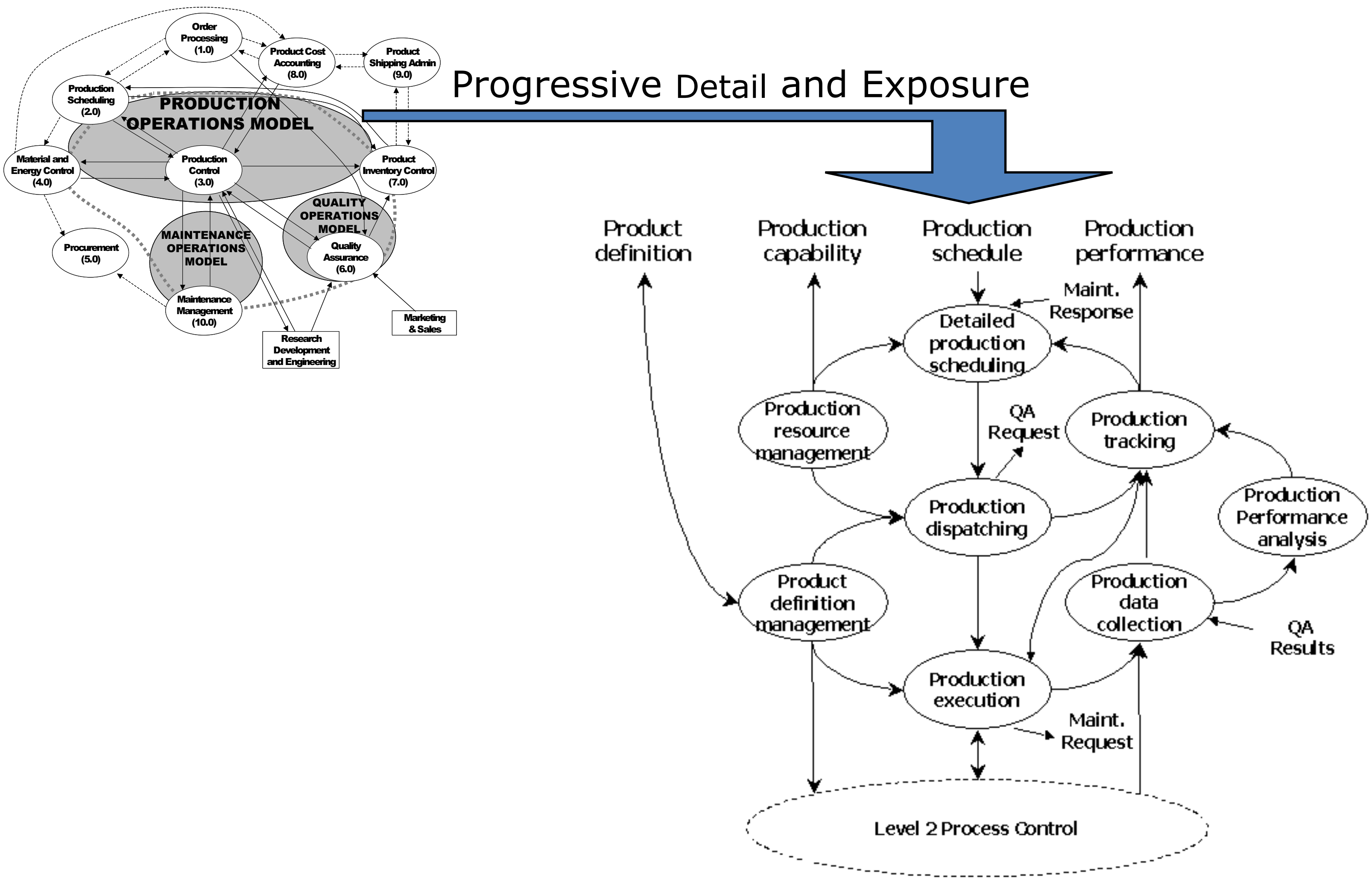
Parts 1, 2, and 3…



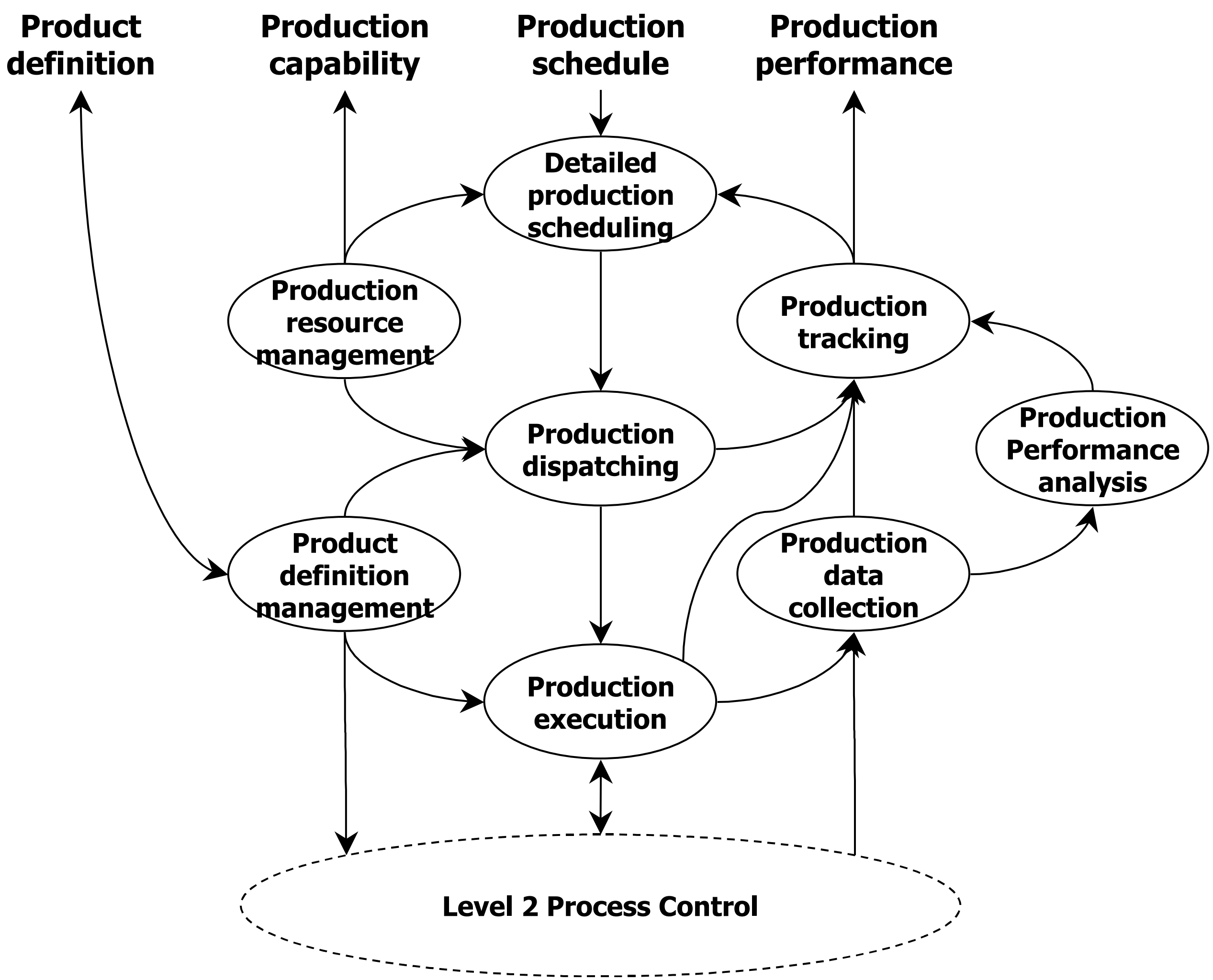
ISA S95 Manufacturing Architecture



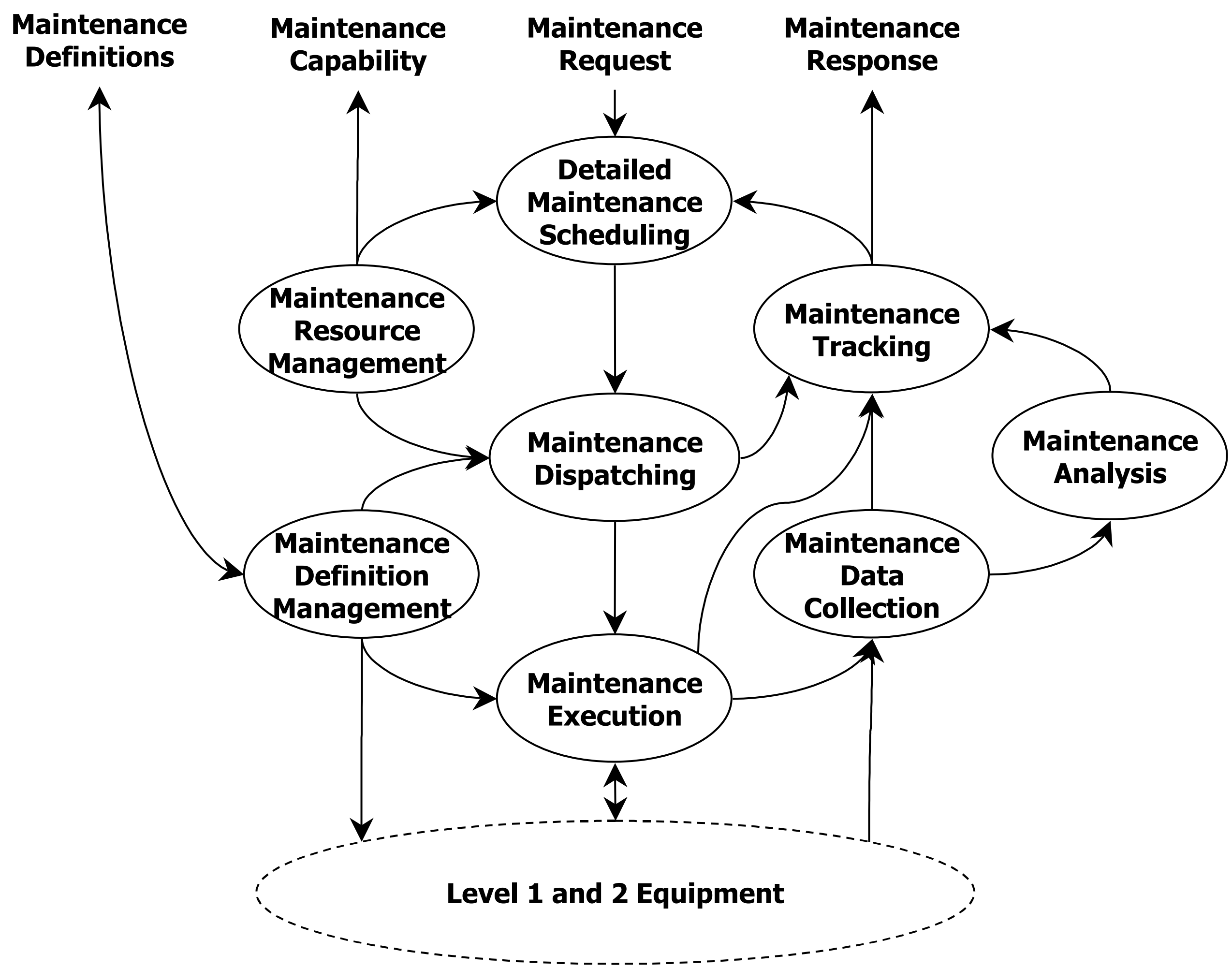
Manufacturing Operations Information Models (Part 3) Example



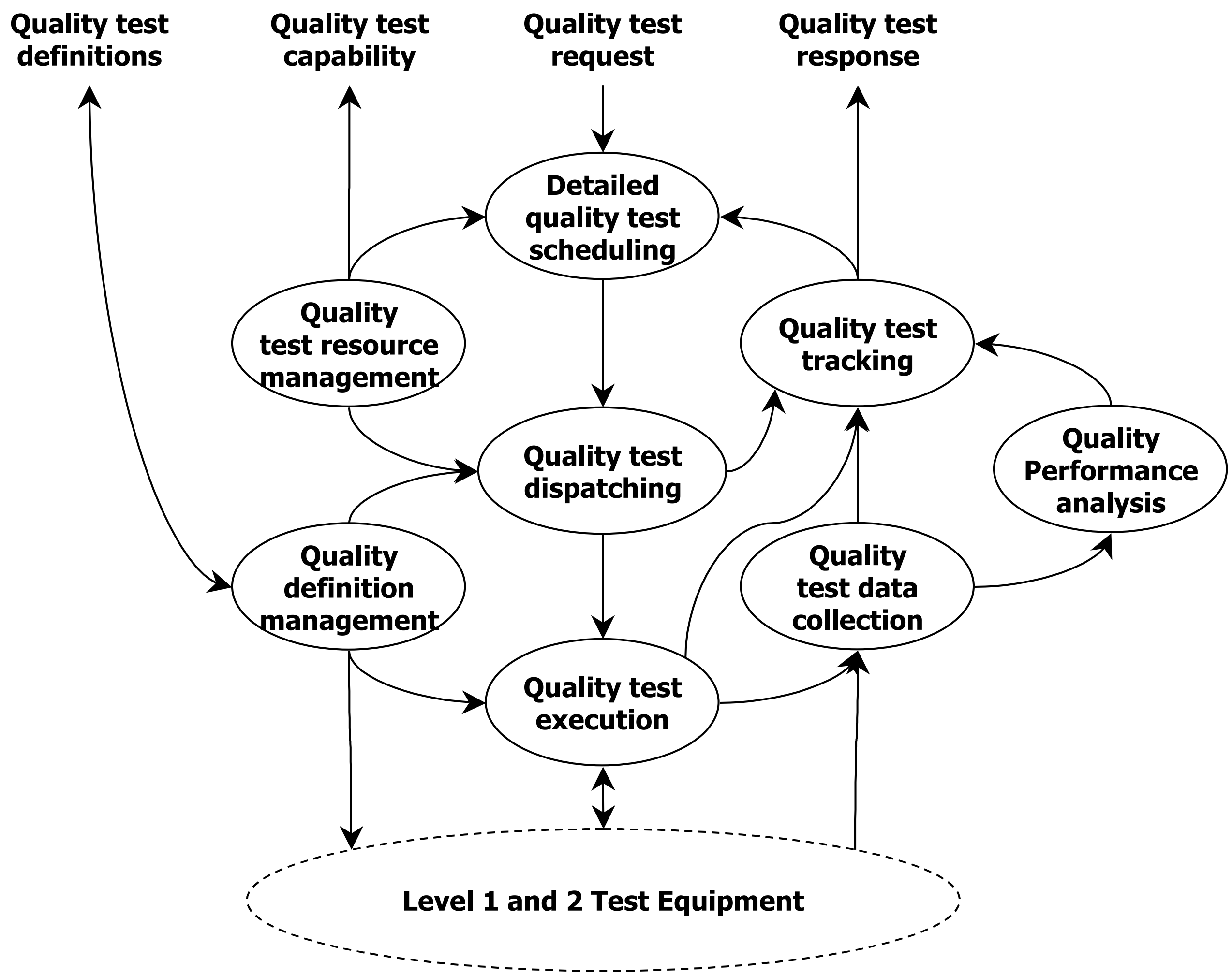
Production Model from S95, Part 3



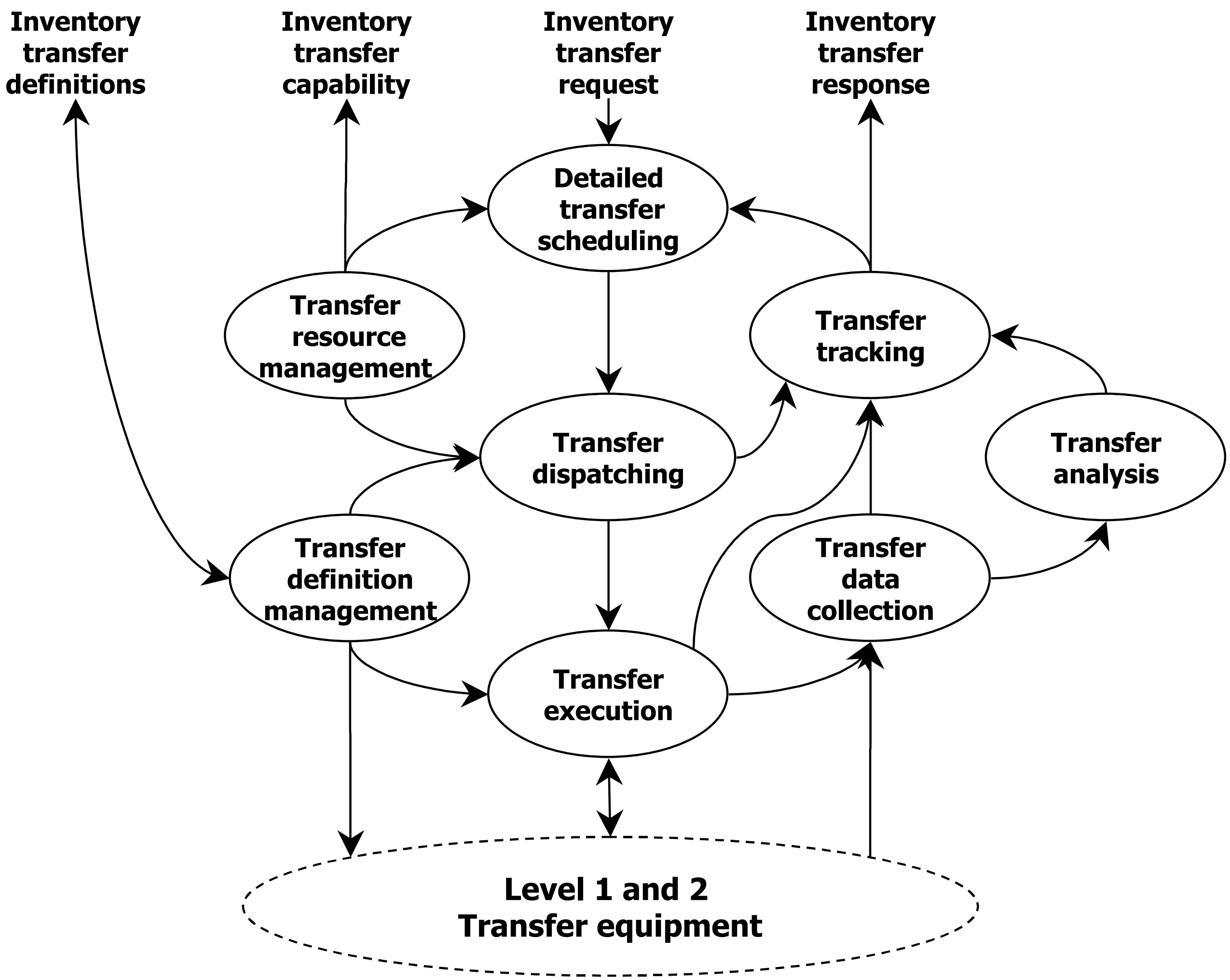
Maintenance Model from S95, Part 3



Quality Test Model from S95, Part 3

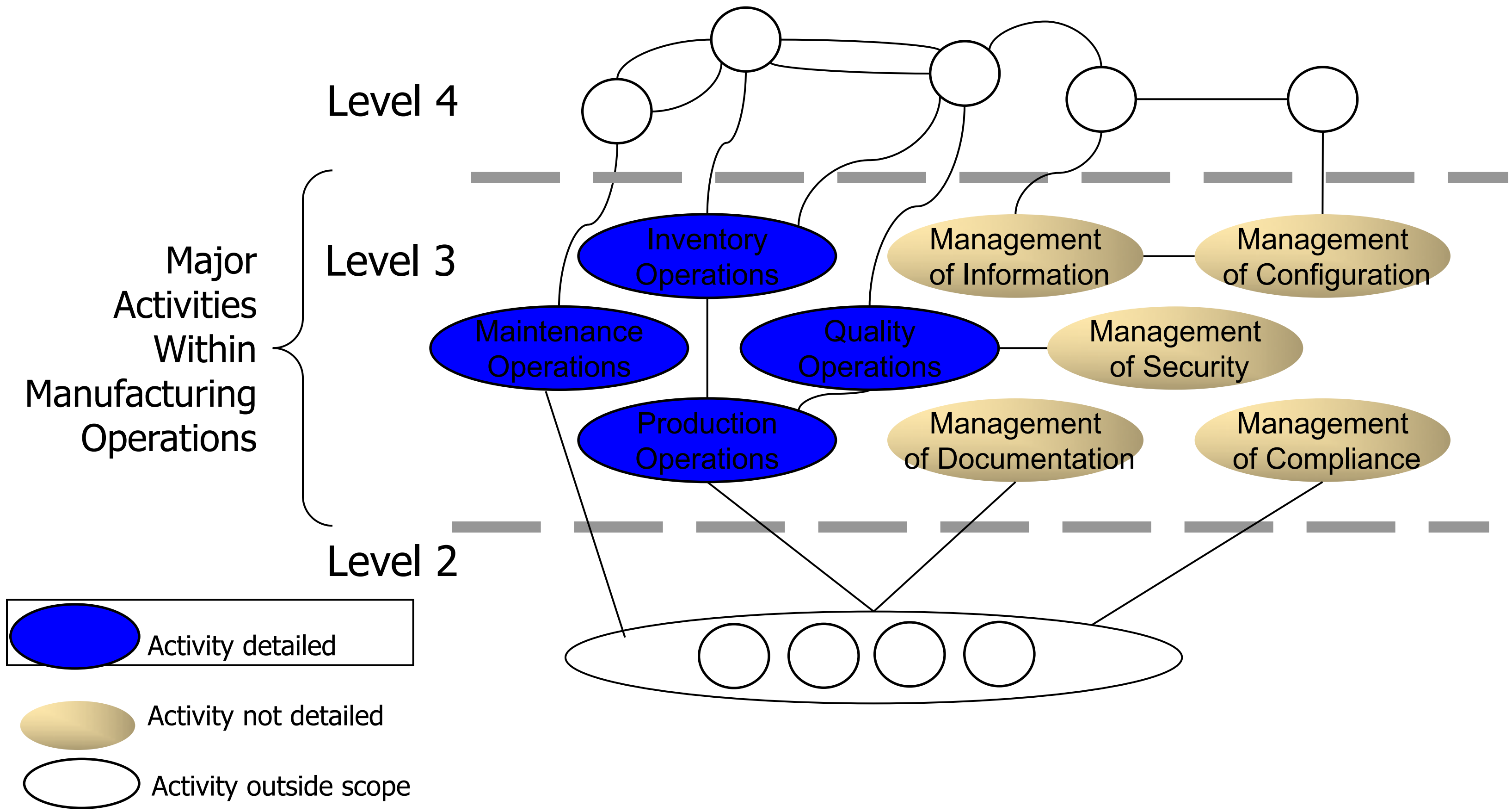


Inventory Model from S95, Part 3

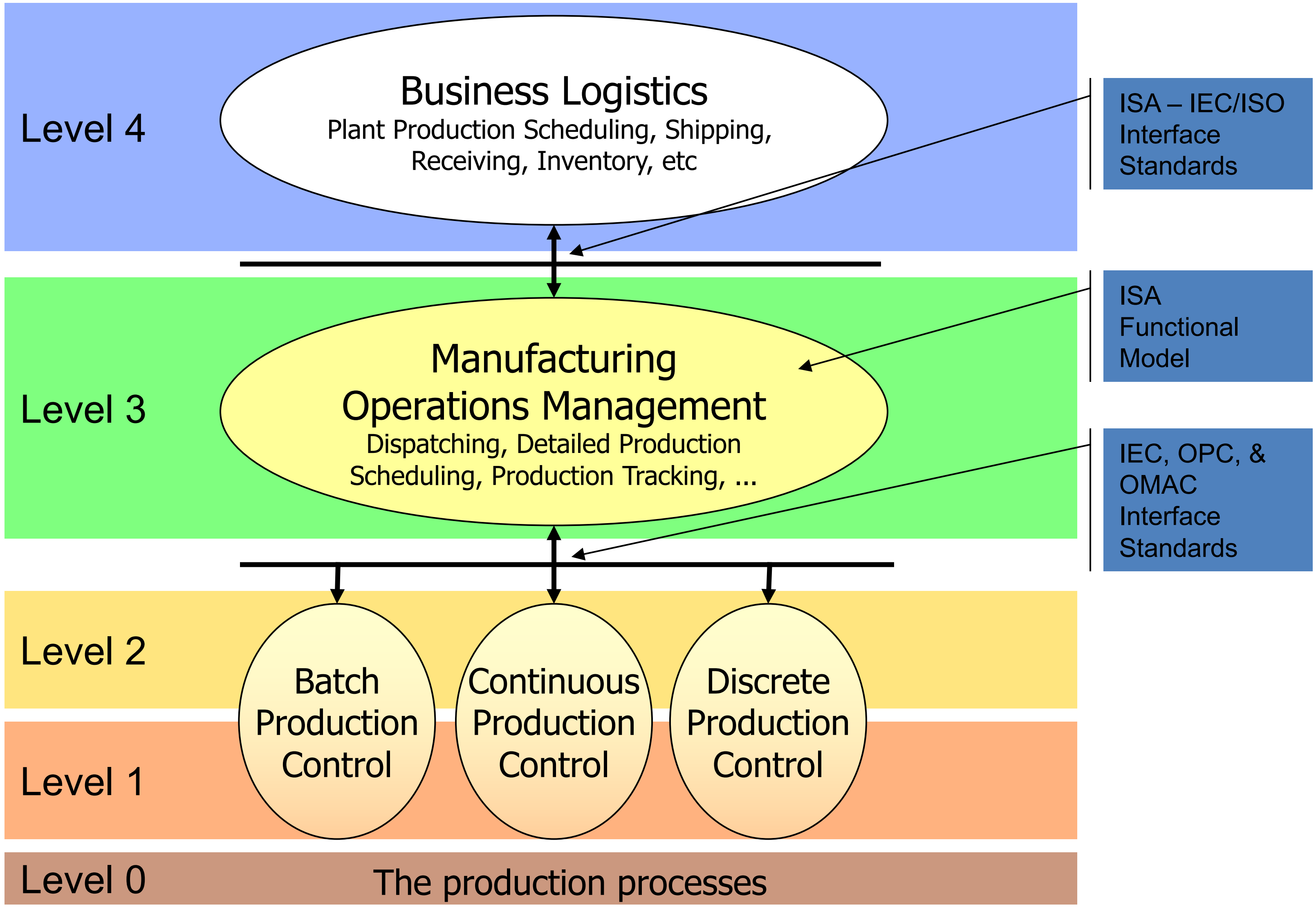


Other Enterprise Activities in Manufacturing Operations

- Some actives are not specific to manufacturing
- ISA-95.03 lists references to standards in these areas



ISA 95 Control Hierarchy Levels



Building Collaborative Manufacturing Systems

- Process Used to Develop Solution Architectures:
  - Conceptual Topology
  - Functional Areas
  - Standards and Guidelines
  - Standard Applications
  - Logical Architecture Design
  - Physical Architecture Design

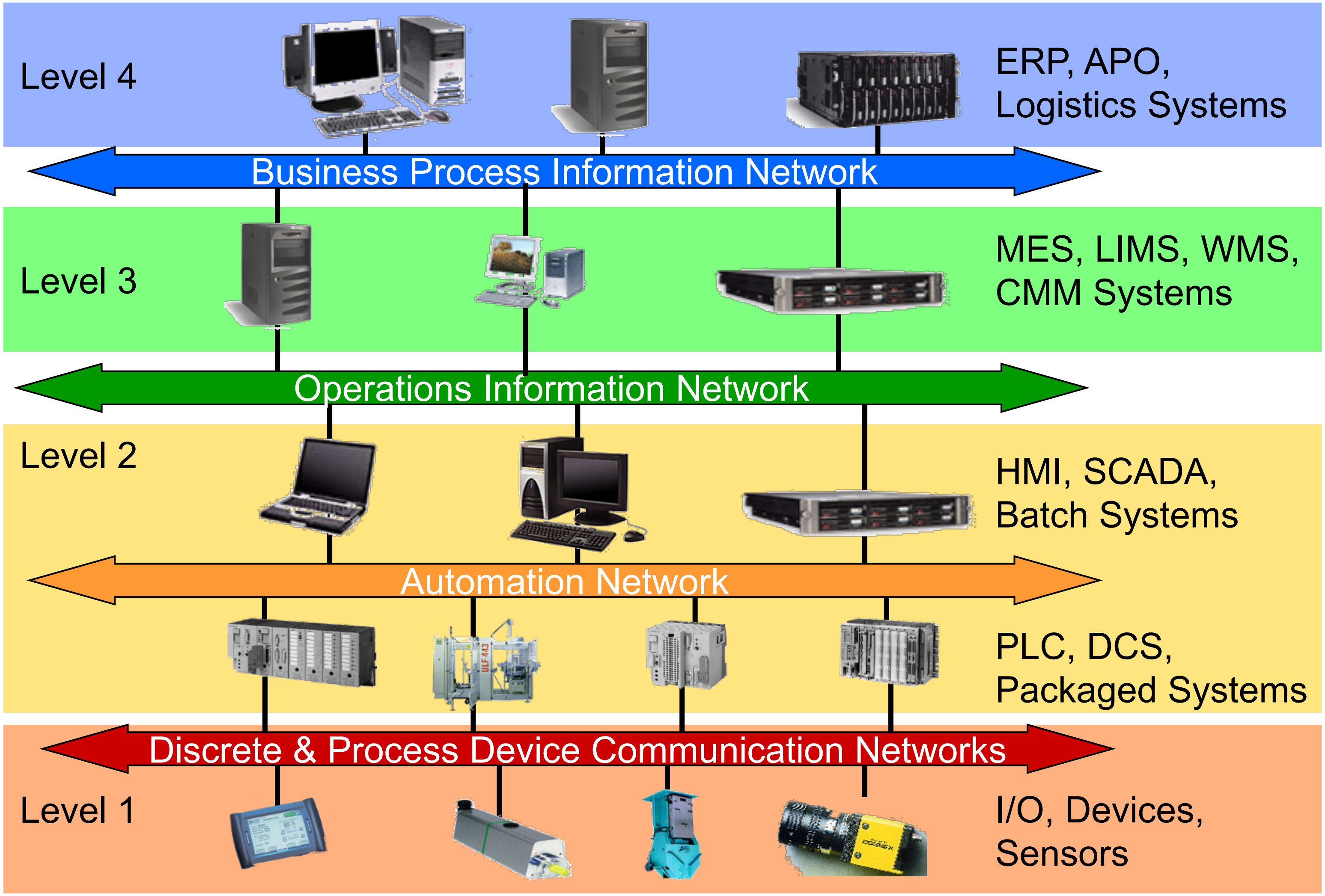
Conceptual Topology – IT View

- IT View of the ISA-95 Levels and relationship to systems and networks

- Levels 1-2
  - Control the process and provide visibility to the process
  - Electronic records are not embedded in the control layers (Level 1-2)
  - Usually some specialized hardware and possibly networks

- Level 3
  - Maintenance of production information is centralized to provide greater control and availability of the records
  - Electronic records are managed and controlled through Level 3 systems with audit trail, access control, backup, and ERP connectivity
  - Usually standard hardware and networks

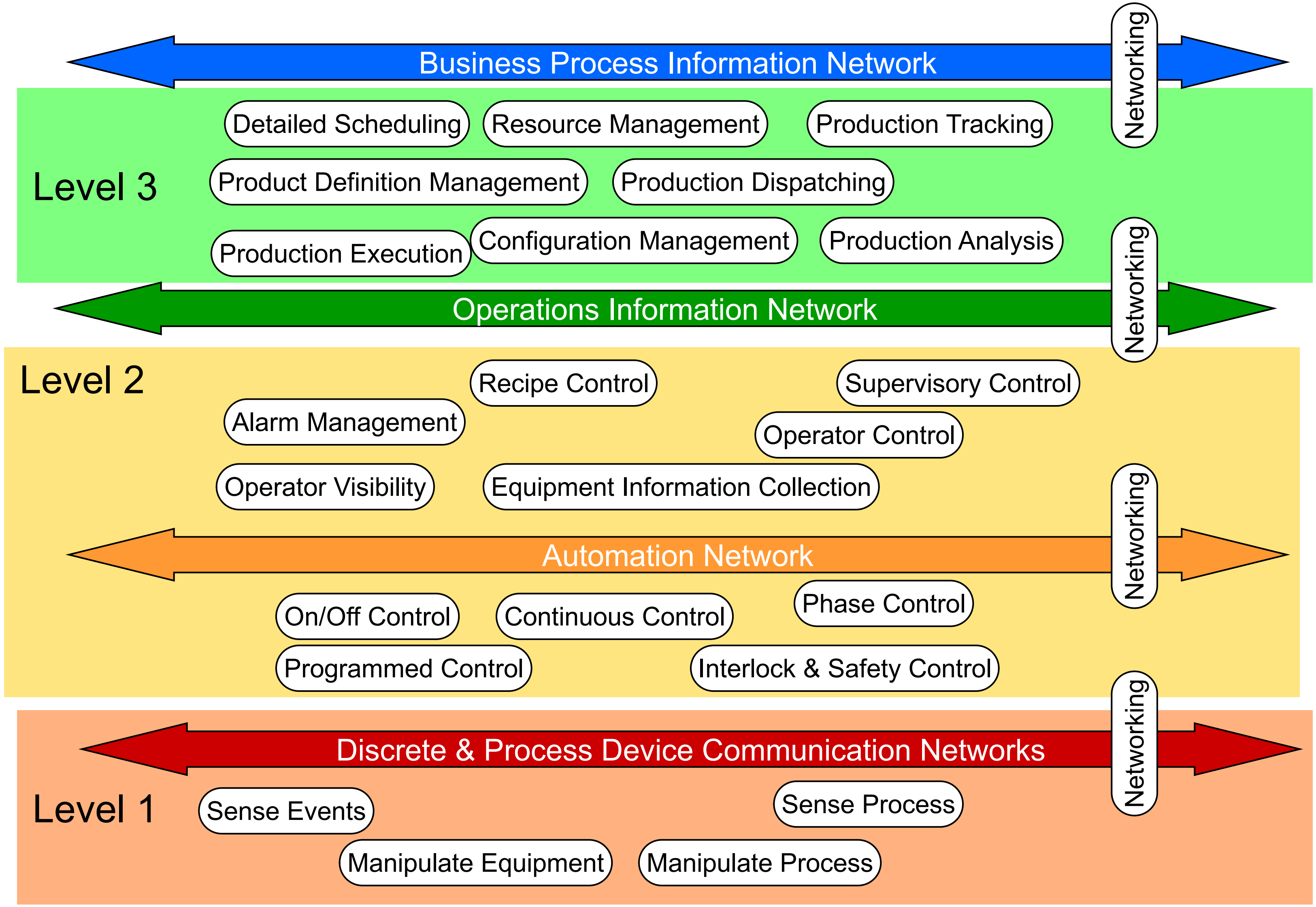
Conceptual Topology – IT View



Functional Areas

- Use the ISA 95 and ISA 88 models of functions
- Map the functions to system areas and networks
- Use the ISA 95 rules for determining what is in Level 3 (vs Level 4)
  - The function is critical to maintaining regulatory compliance.
    - Includes such factors as safety, cGMP, and environmental compliance
  - The function is critical to plant safety
  - The function is critical to product quality
  - The function is critical to plant reliability

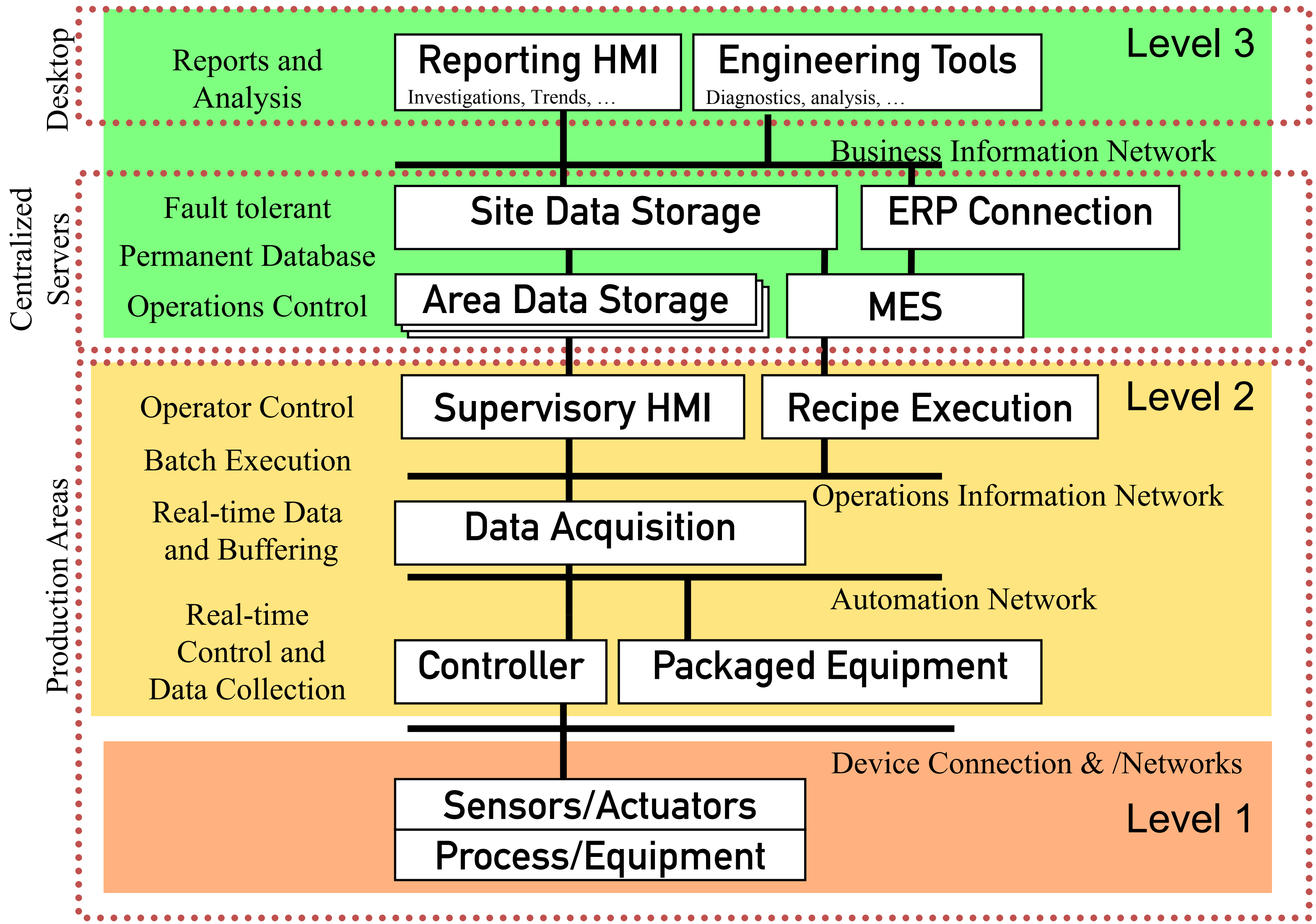
Functional Areas – From ISA 95 & 88



Logical Architecture

- Maps functional areas and data locations
  - Independent of technology
- Defines the different layers of the architecture in terms of data and control
  - These are mapped to physical networks, servers, and applications in the physical architecture
- Defines what functions are to be performed at each level, and what data is to be maintained at each level
  - To result in maintainable and robust systems
  - To provide a way to manage the life cycle of the production systems
  - Provides the structure required to grow and modify the system without compromising any of the previous advantages

Logical Architecture – IT View

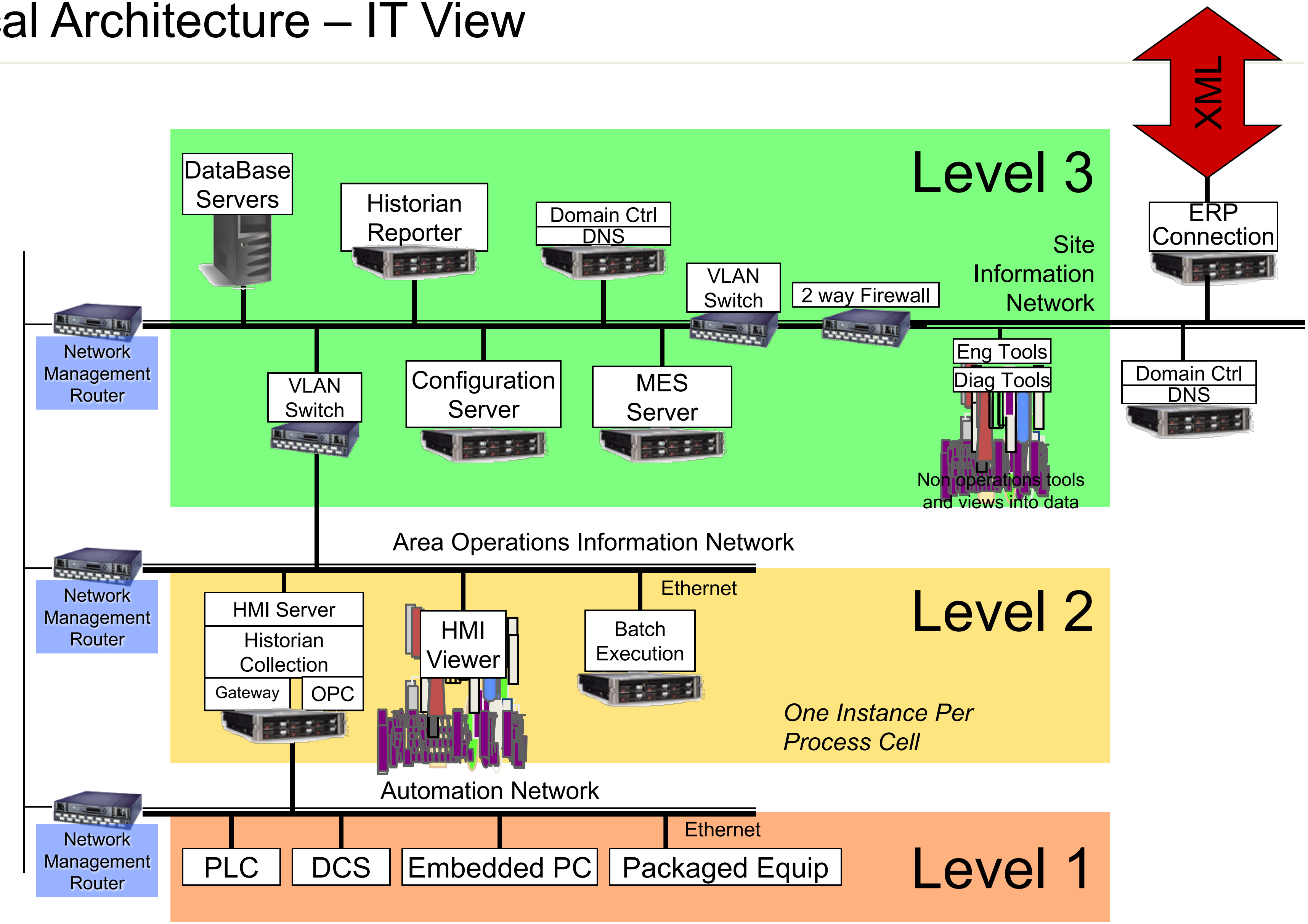


A Physical Architecture

- Defines the IT infrastructure and applications
  - Defines networks and network connections
  - Defines locations of applications
  - Defines locations of servers
  - Defines the mapping of applications to servers

- Physical architecture depends on the solution set used:
  - Vendor capabilities
  - Networks
  - Security and network management
  - …

Physical Architecture – IT View



Large control system hierarchy: key functions

5 { Planning, Statistics, Finances

4 { Production planning, orders, purchase

3 { Workflow, order tracking, resources

2 { Supervisory

1 { Group control

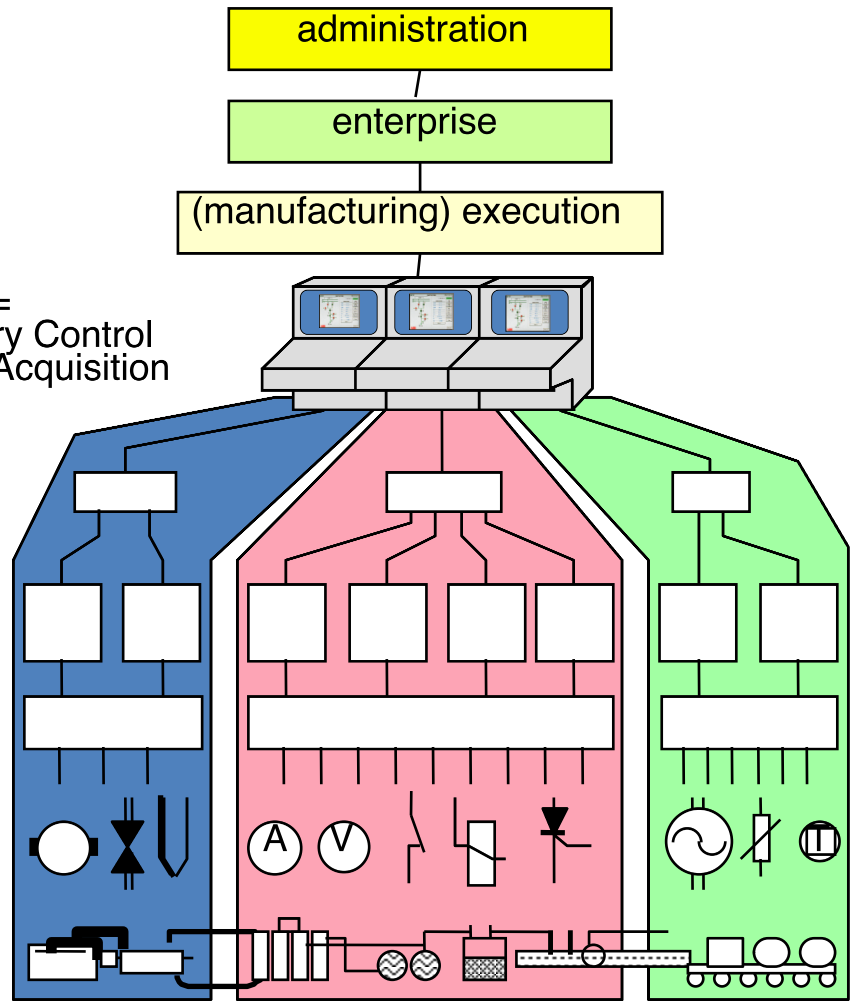
Unit control

Field

Sensors
& actors

0 { Primary technology

SCADA =
Supervisory Control
And Data Acquisition



Large control system hierarchy: the business processes

Administration	Finances, human resources, documentation, long-term planning
Enterprise	Set production goals, plans enterprise and resources, coordinate different sites, manage orders
Manufacturing	Manages execution, resources, workflow, quality supervision, production scheduling, maintenance.
Supervision	Supervise the production and site, optimize, execute operations visualize plants, store process data, log operations, history (open loop)
Group (Area)	Controls a well-defined part of the plant (closed loop, except for intervention of an operator) • Coordinate individual subgroups • Adjust set-points and parameters • Command several units as a whole
Unit (Cell)	Control (regulation, monitoring and protection) part of a group (closed loop except for maintenance) • Measure: Sampling, scaling, processing, calibration. • Control: regulation, set-points and parameters • Command: sequencing, protection and interlocking
Field	data acquisition (Sensors & Actors*), data transmission no processing except measurement correction and built-in protection.

We review the levels of the CIM

- The levels specified in the CIM pyramid are as follows:

- Company
  formed by several establishments
  decision support systems, physical (material) and financial flows (investments) planning.
- Establishment
  the various sub-sectors are integrated: production, logistics, administration, maintenance.
  is managed by the company information system.
- Department
  the production data base is managed and the various cells are coordinated to realize the entire production process.
- Cell
  in a cell, a complete production subprocess is carried out with various machines and control systems
- Control systems
  machine and process control functions
- Workshop (field)
  measurement and control functions on production processes (sensors, actuators)

Components of a CIM system

Lower level:

Actuators and sensors

Modulating Controllers (PIDs)
Logic controllers (PLCs: Programmable Logic Controller)
They handle axes, sequence of operations, protections, interactions with the operator.

Distributed Control Systems (DCS)
control systems that integrate loop-level control functions, logic control, monitoring and alarm management.

CNC (Computerized Numerical Control)
They handle multi-axis machines with interpolated axle movements

IPC (Industrial Personal Computer)
PCs structured to operate in an industrial environment, typically with real time operating systems

Components of a CIM system

At the highest level:

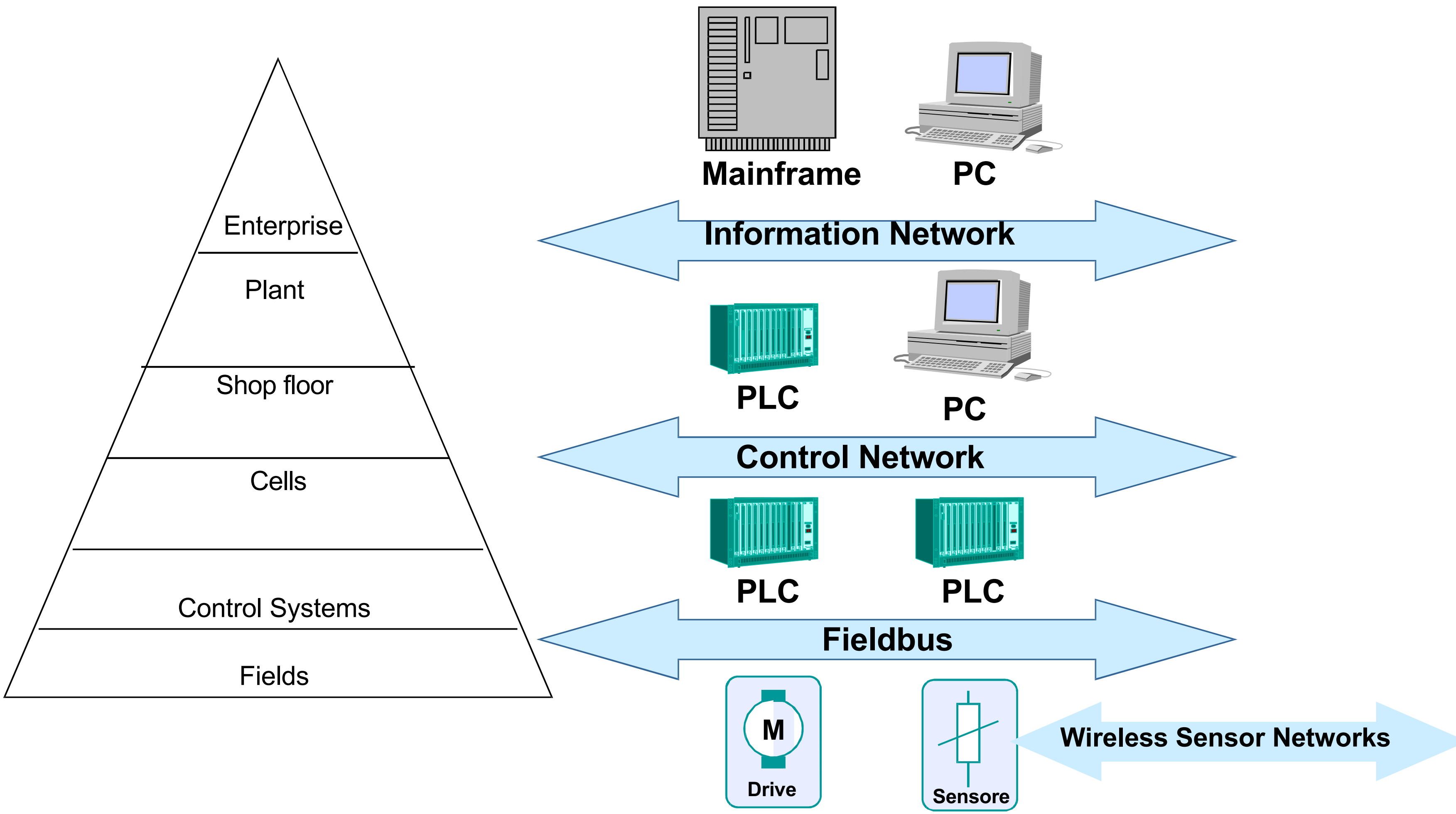
SCADA (Supervisory Control and Data Acquisition)
systems that support data capture and storage functions, man-machine interface (with static and dynamic synoptics), graphics, monitoring and alarm management, data exchange with the most popular commercial software packages on PCs, such as spreadsheets.

CAD systems (Computer Aided Design)
software that allows computer-aided design

CAE (Computer Aided Engineering) Systems
software systems that support design even in the phases of analysis and simulation

Enterprise Resource Planning (ERP) System
management system that brings together the management of all the activities of an enterprise (administration, finance, reporting, planning, production, maintenance of installations, logistics, quality control ...)

Networks and CIM



Networks and CIM

- **Networks for information**
  - link high-level information systems with other company information elements (levels 4, 5, and 6 of the CIM)
  - there are no real time specifications
  - the information is of a complex type (files, etc ..)

- **Networks for control**
  - they connect the devices devoted to the control with those of supervision (CIM levels 2, 3 and 4)
  - there are specifications of correctness and time constraints
  - the information is of a not very complex type
  - these are typically proprietary networks

- **Field Networks (fieldbus)**
  - they connect the controllers (modulants and logic) with sensors and actuators with
  - digital interface
  - time-specific specs
  - the information is simple

- **Wireless Sensor Networks**
  - connect the sensors to each other and with the access points
  - powerful stringent specification
  - the information is simple

Conclusions

- In this lesson we have defined the concept of CIM, given an example of standardization and analyzing functional architectures
- No doubt the CIM model in its evolution has focused its focus on information exchange or interfaces
- Information standardization provides powerful tools to define the nature of interfaces between different CIM levels
- The problem remains to make the interfaces with actual IT systems working
- The different characteristics of the processes and information exchanged require different modes of computer communication that we will see in the next lesson