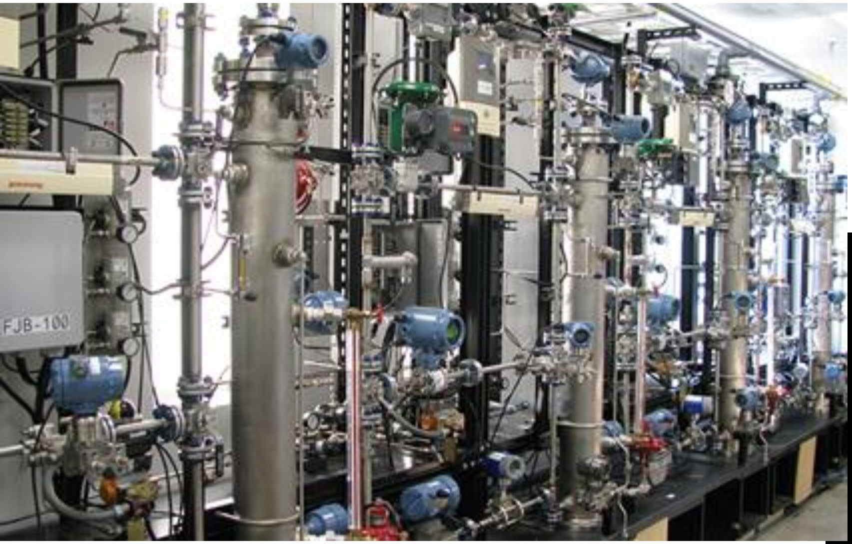
Chapter 1

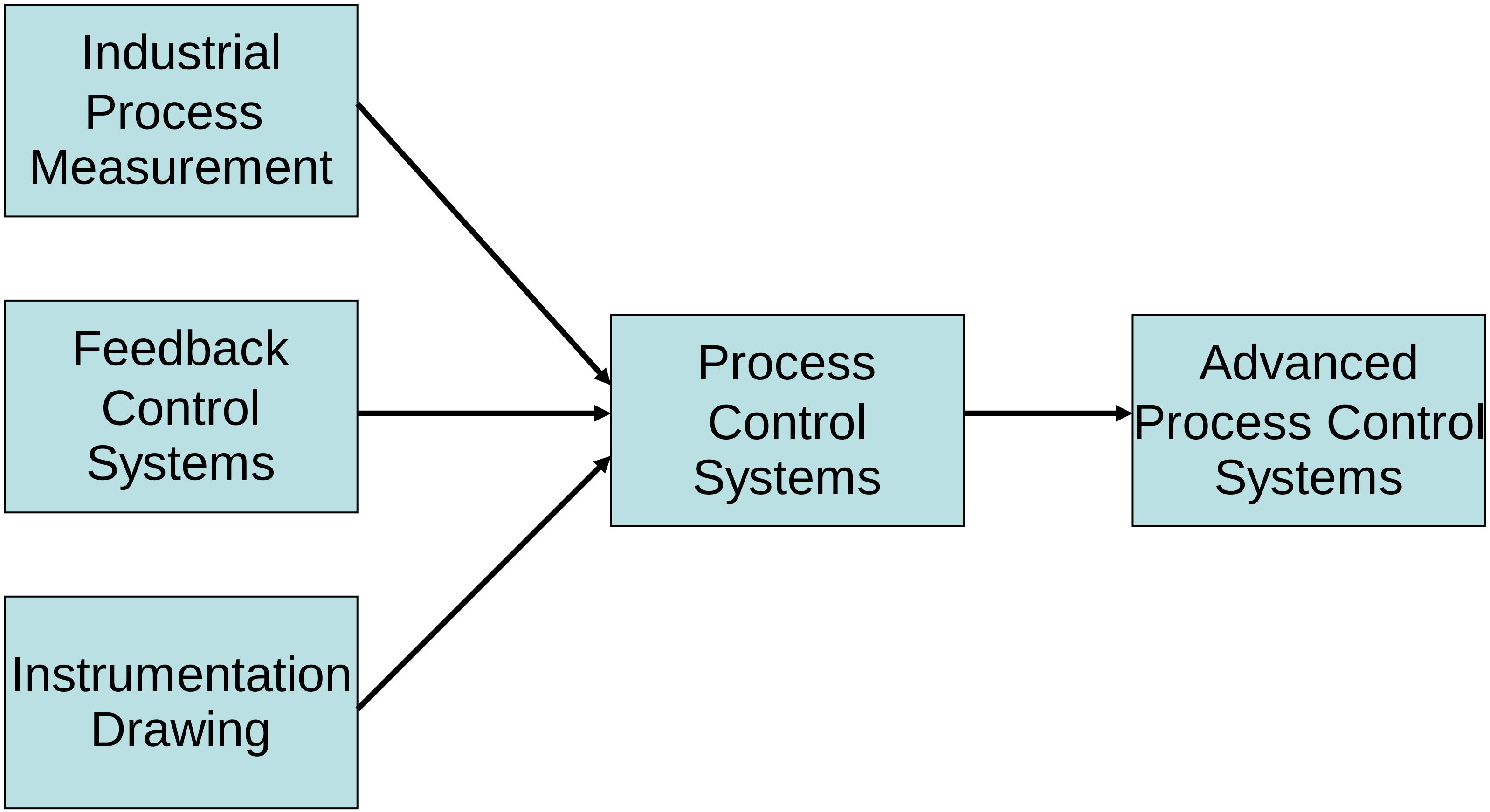
Introduction to Instrumentation and Process Control Systems



Agenda

1. Introduction
2. Process Control System
3. Integrated System
4. System Architecture
5. Industrial Internet of Things (IIoT)

Requisite subjects



discrete system

continuous system

1. Introduction : Discrete versus Continuous

discrete

continuous

- Automotive Manufacturing
- Electronics
- Machinery
- Textiles
- Pharmaceuticals
- Fine Chemical
- Food & Beverage
- Metals & Mining
- Water & Waste
- Pulp & Paper
- Vehicles
- Petrochemicals
- Oil & Gas
- Electrical Power

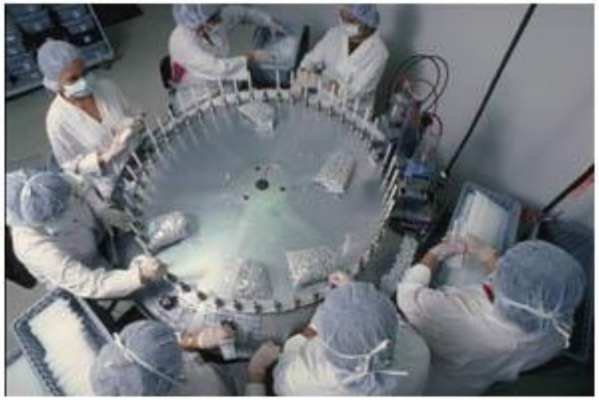
1. Introduction : Types of industrial applications

industry distinguishes the following categories of applications:

"process control": continuous processes, associated with fluids, for instance
sewage water treatment, petrochemical process, cement…

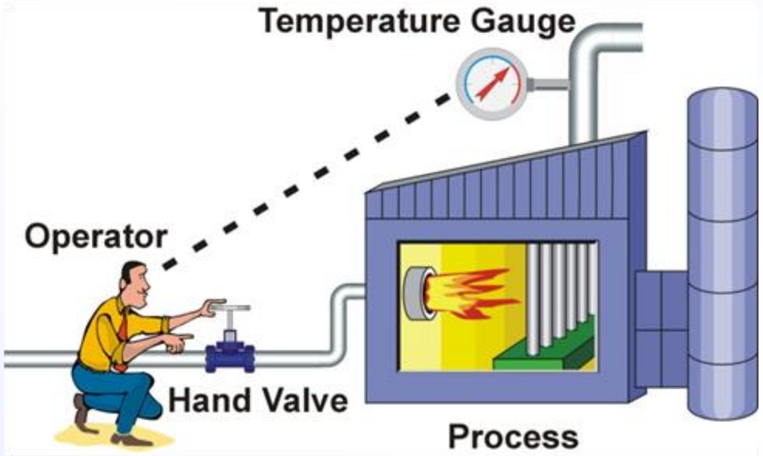
"batch control": semi-continuous processes, associated with individual products,
for instance chemical, pharmaceutical, brewery…

"manufacturing": discrete processes, associated with transformation of parts,
e.g. automobile industry, bottle-filling, packaging

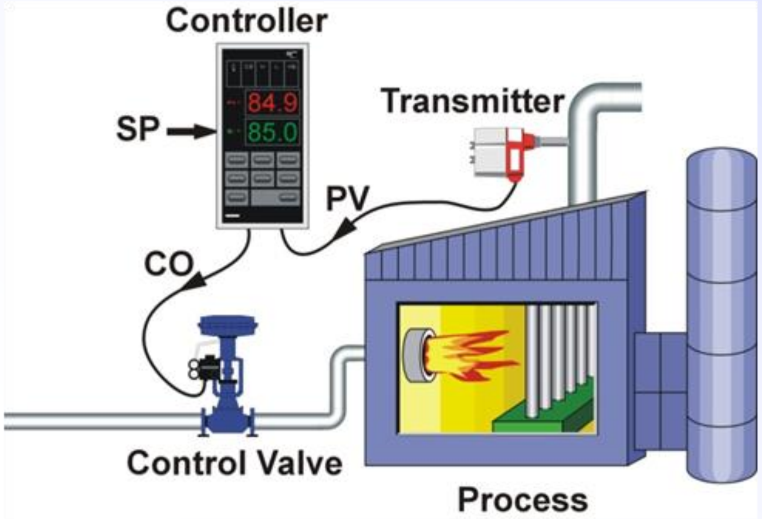


Note. Batch production is a method of manufacturing where the products are made as specified groups or amounts, within a time frame. A batch can go through a series of steps in a large manufacturing process to make the final desired product

Why automation?



Manual Control

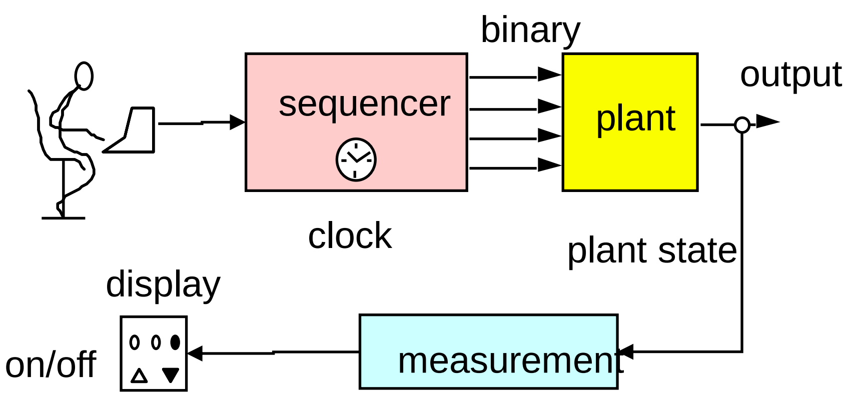


Automatic Control

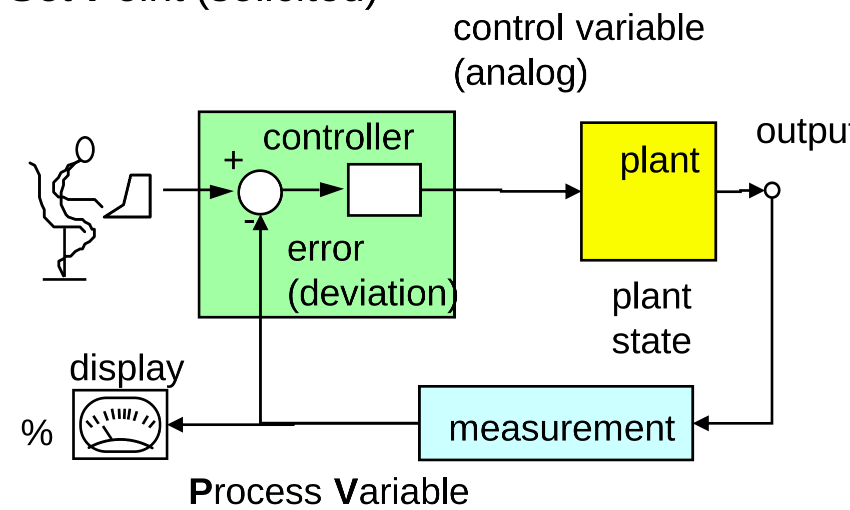
- Safety
- Quality
- Controllability
- Cost saving (Long term)

1. Introduction : Open-loop versus Closed-loop control

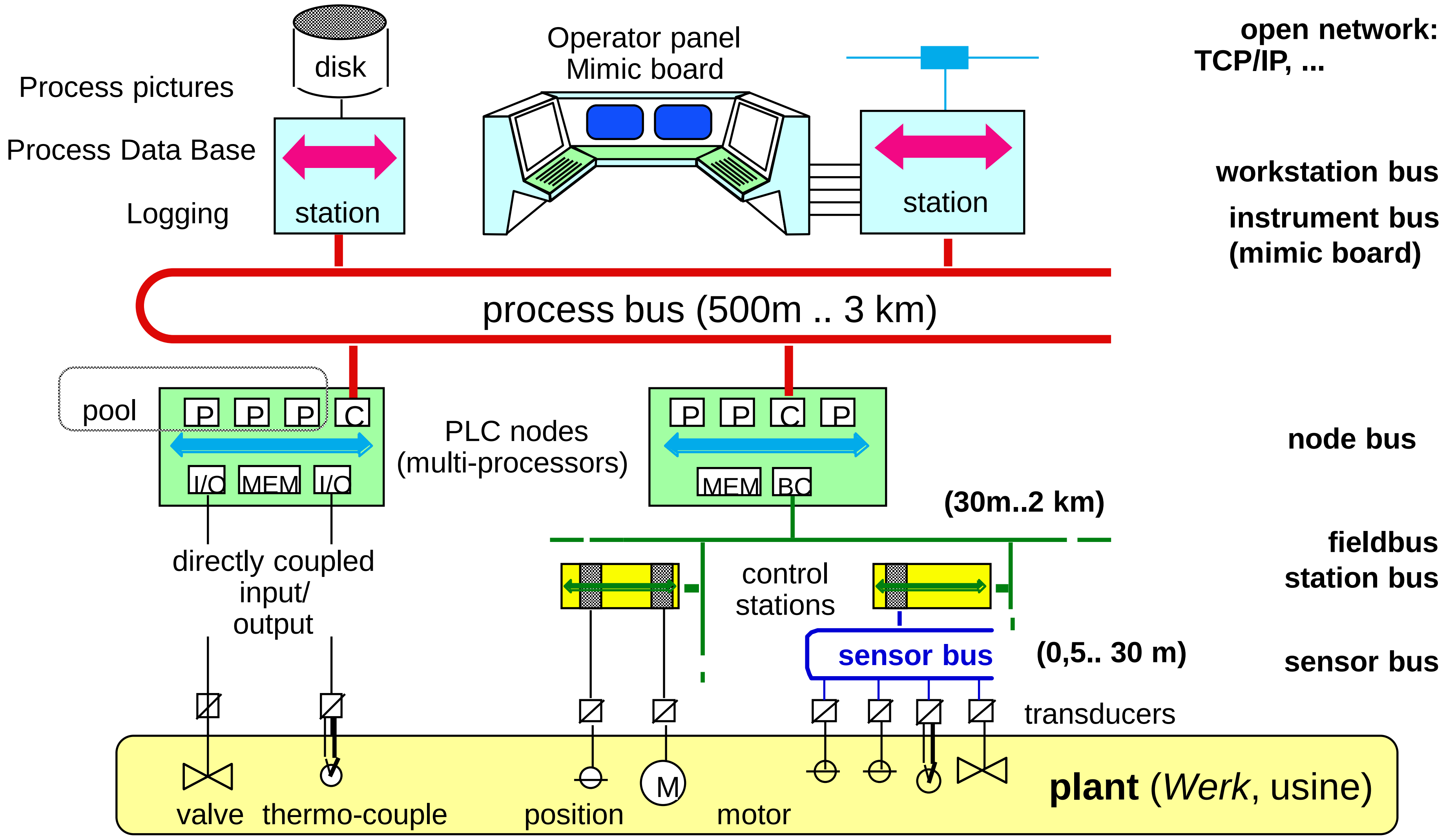
open-loop control / command	closed-loop control / regulation
keywords: sequential / combinatorial, binary variables, discrete processes, "batch control", "manufacturing"	keywords: feedback, analog variables, continuous processes, "process control"



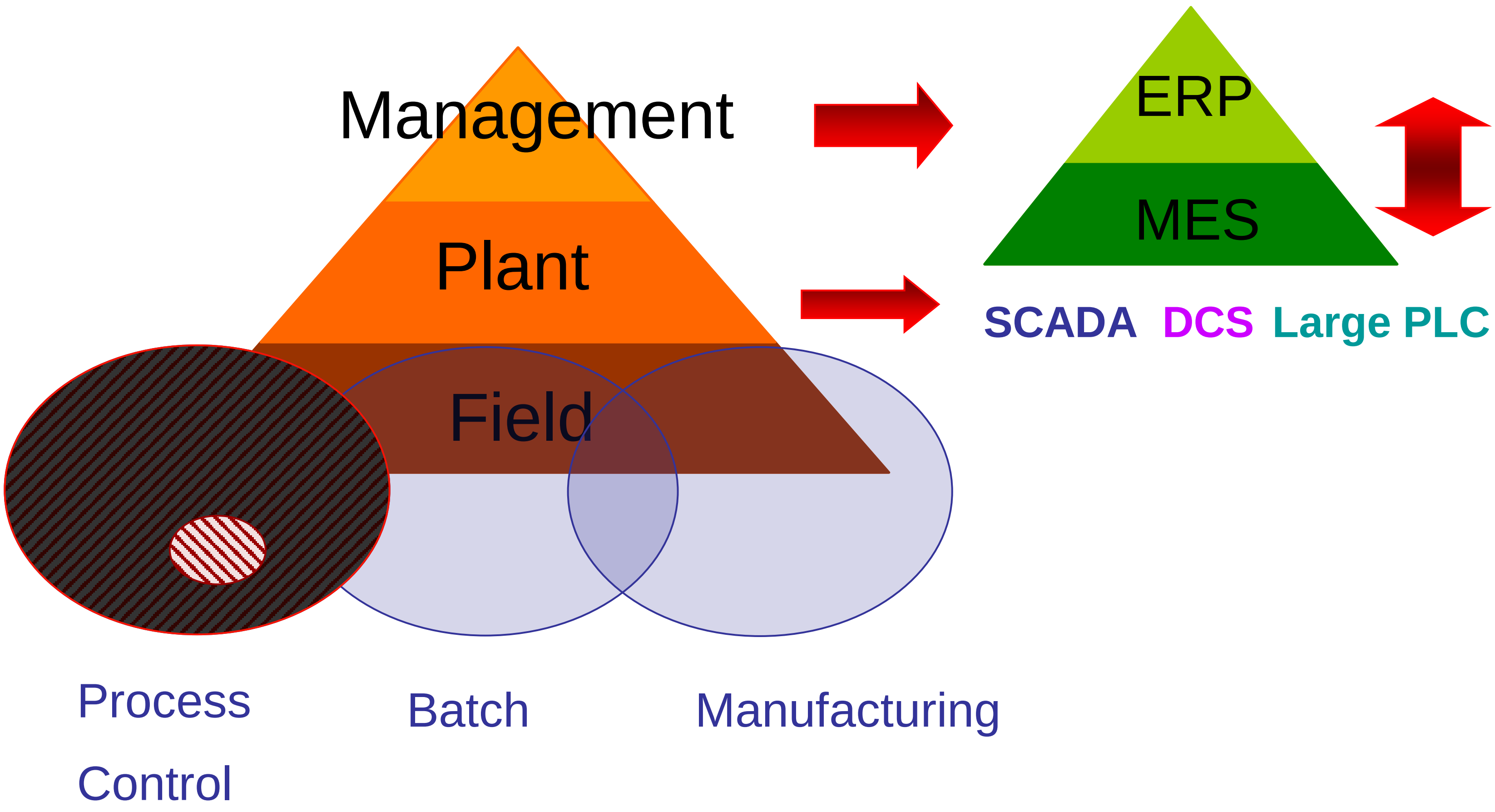
Set-**P**oint (solicited)



1. Introduction : Large control system hierarchy



1. Introduction : Large control system hierarchy



ERP=Enterprise Resource Planing
MES=Manufacturing Execution System

1. Introduction : Large control system hierarchy

5 { Planning, Statistics, Finances

4 { Production planning, orders, purchase

3 { Workflow, order tracking, resources

2 { Supervisory

SCADA = Supervisory Control And Data Acquisition

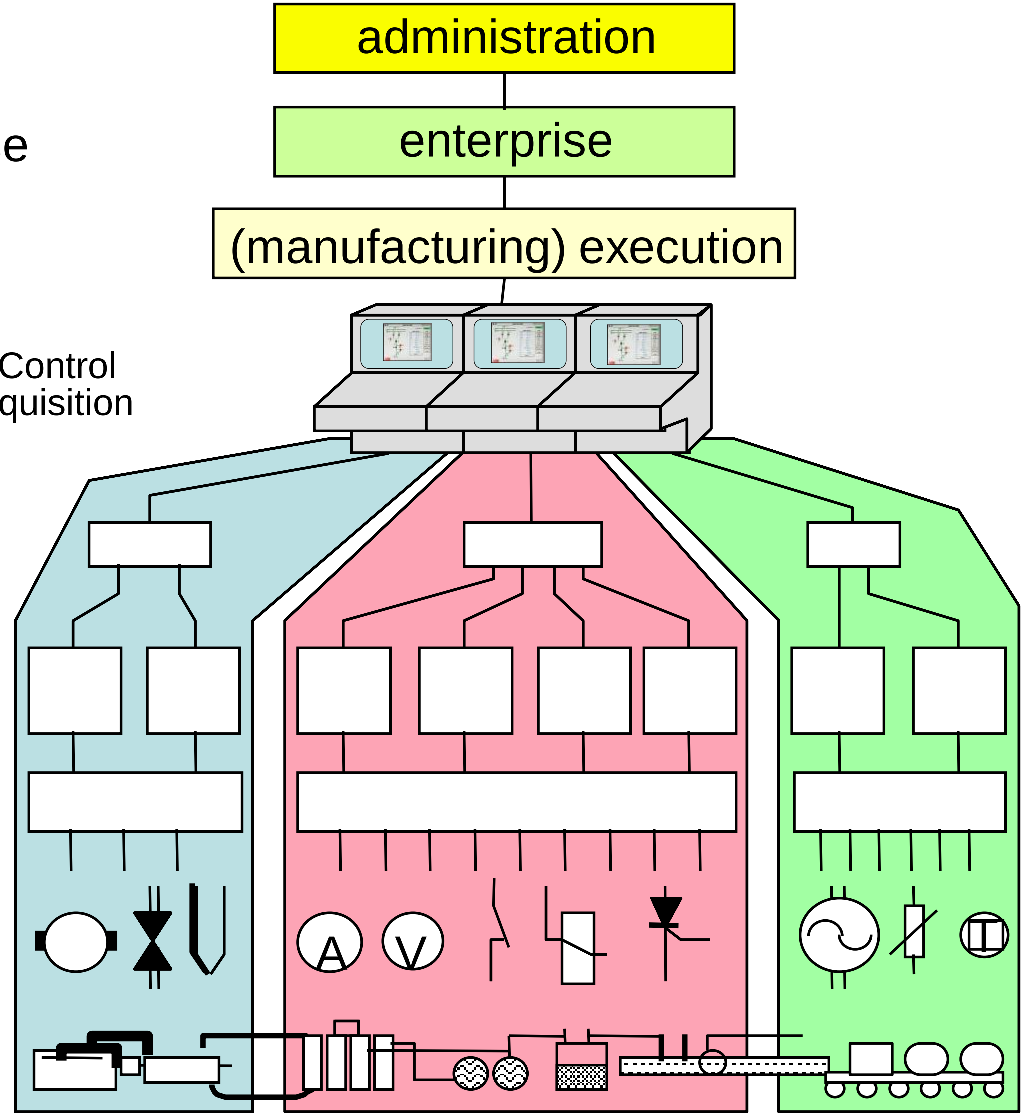
1 { Group control

Unit control

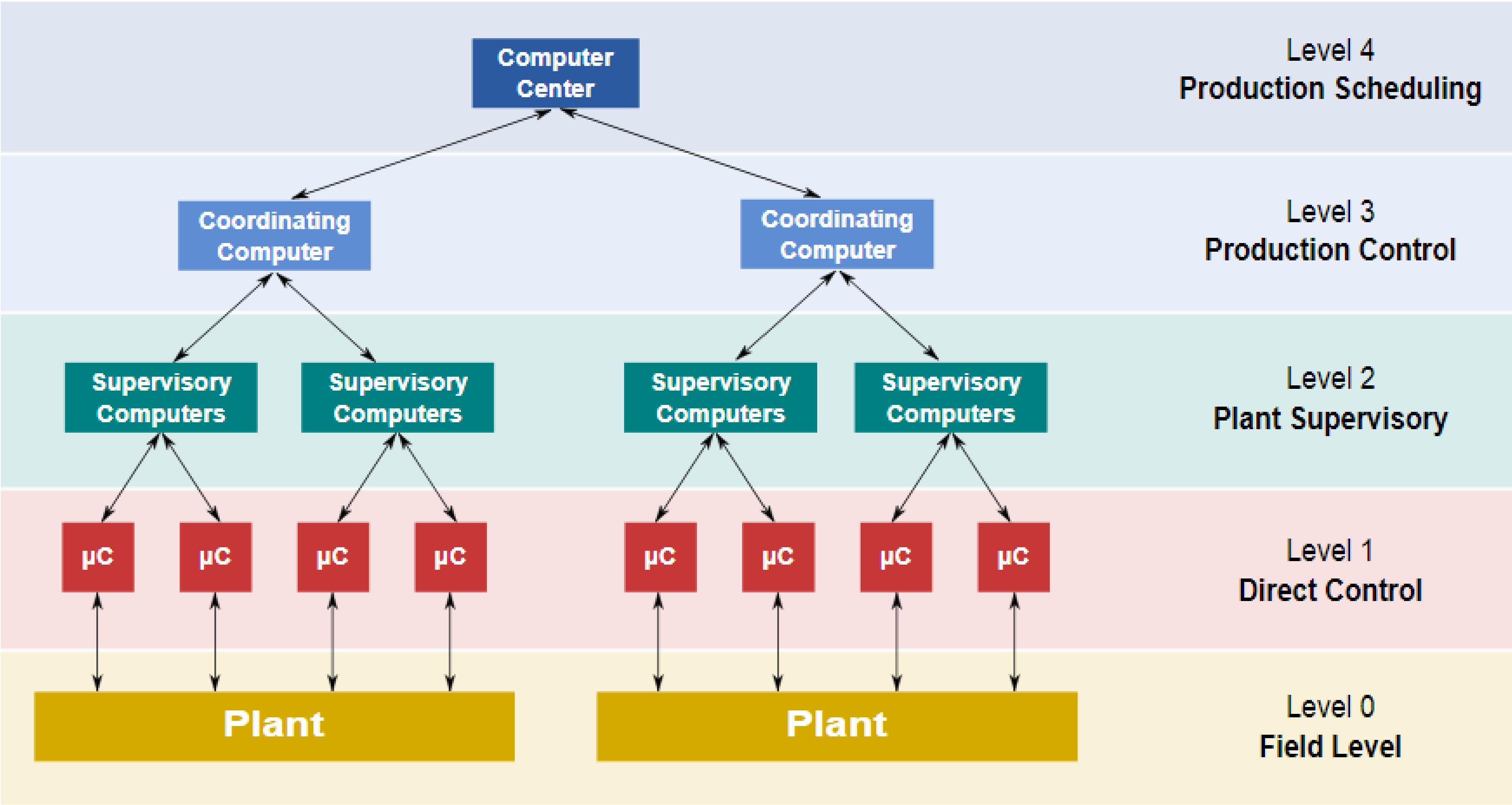
Field

Sensors & actors

0 { Primary technology



1. Introduction : Large control system hierarchy



Functional levels of a manufacturing control operation

Source : https://en.wikipedia.org/wiki/Distributed_control_system

1. Introduction : Large control system hierarchy

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

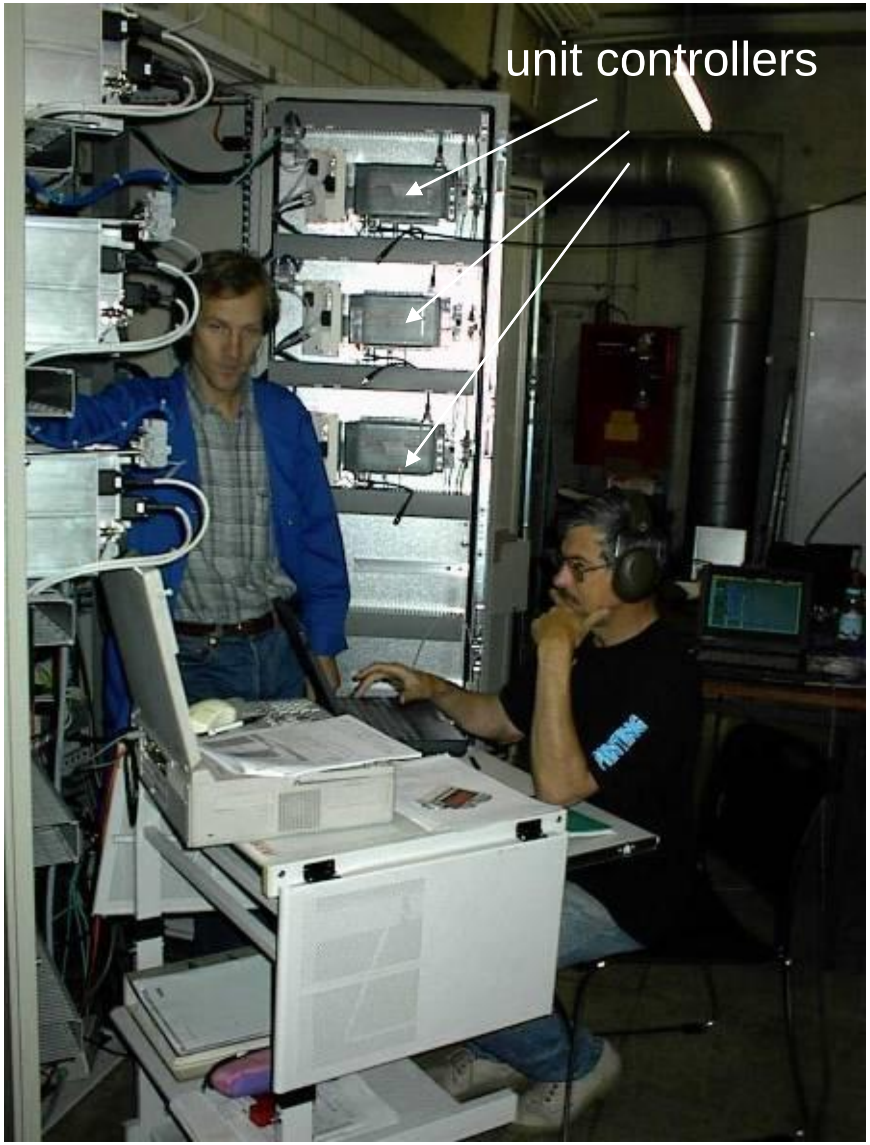
Unit (Cell) Control (regulation, monitoring and protection) part of a group
(closed loop except for maintenance)

- 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.

Field level

the field level is in direct interaction with the plant's hardware (Primary technology, *Primärtechnik*)



Group level

the group level coordinates the activities of several unit controls

the group control is often hierarchical, can be also be peer-to-peer (from group control to group control = distributed control system)

Note: "**D**istributed **C**ontrol **S**ystems" (DCS) commonly refers to a hardware and software infrastructure to perform Process Automation

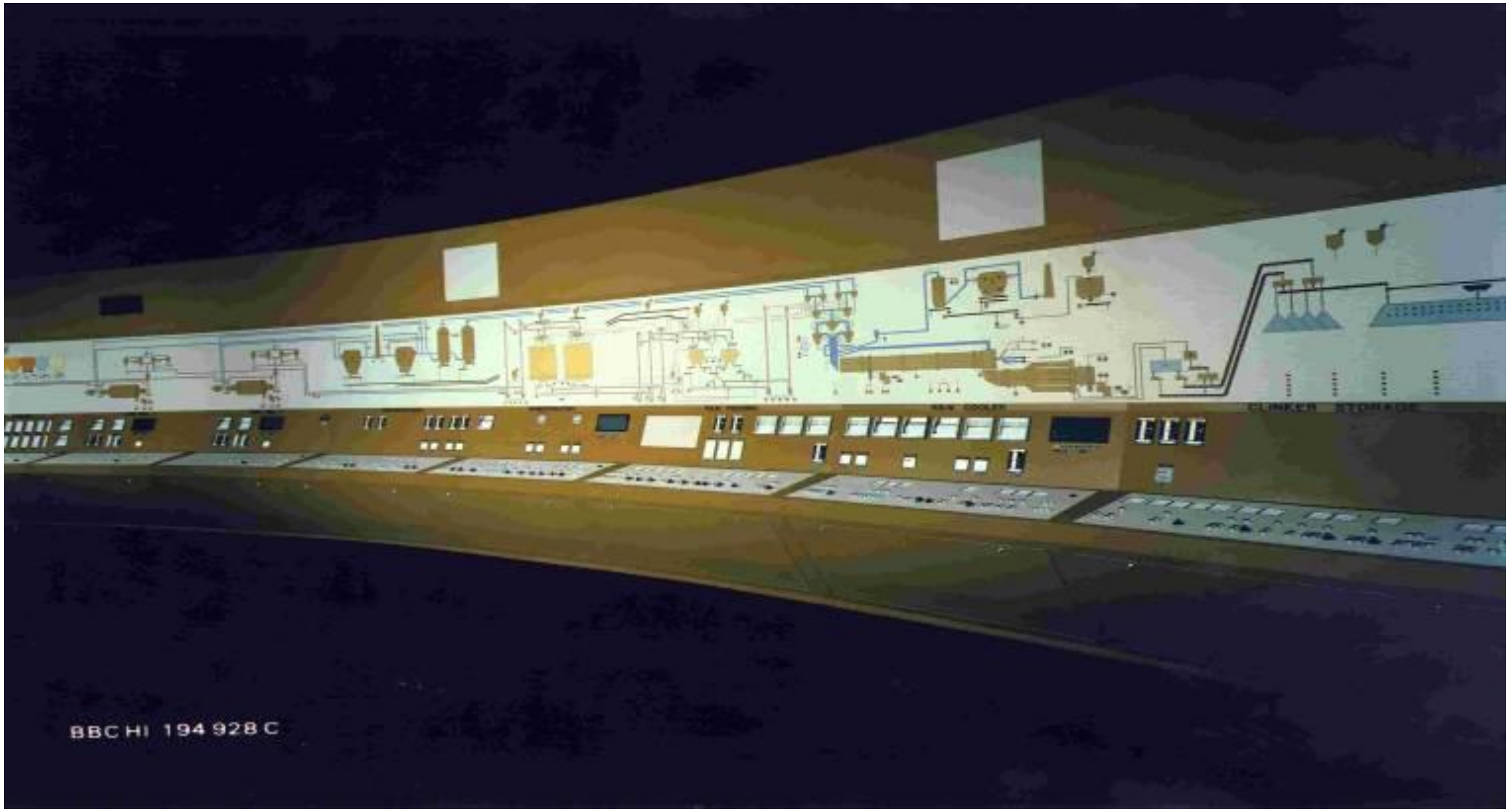
Local human interface at group level

sometimes,
the group level has its own man-machine interface or HMI (Human Machine Interface) for local operation control
(here: cement packaging)

also for maintenance:
console / emergency panel

1. Introduction : Large control system hierarchy

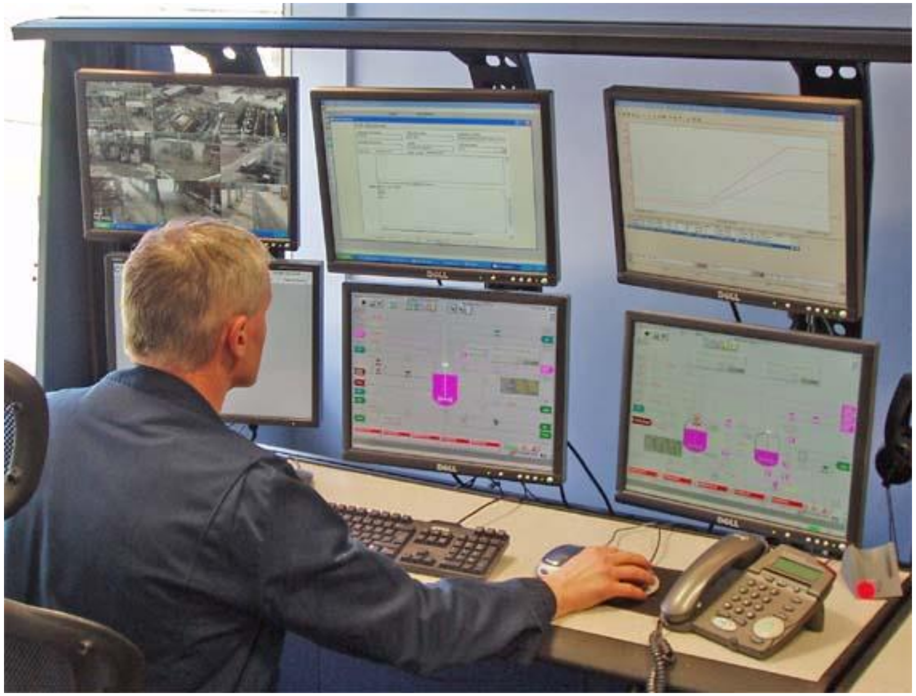
Supervisory level: Man-machine interface

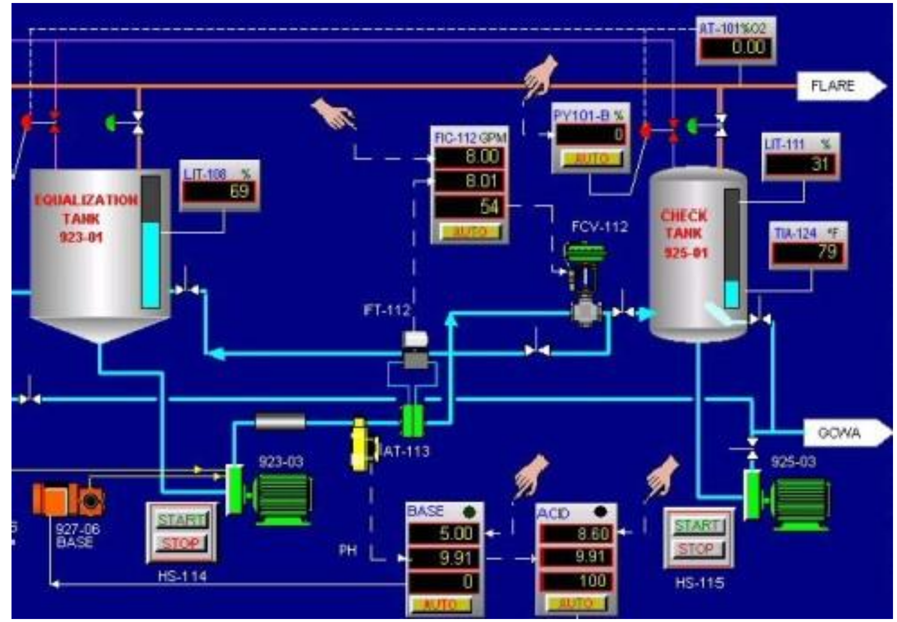


control room
(mimic wall)
1970s...

formerly, all instruments were directly wired to the control room

Supervisory level: SCADA

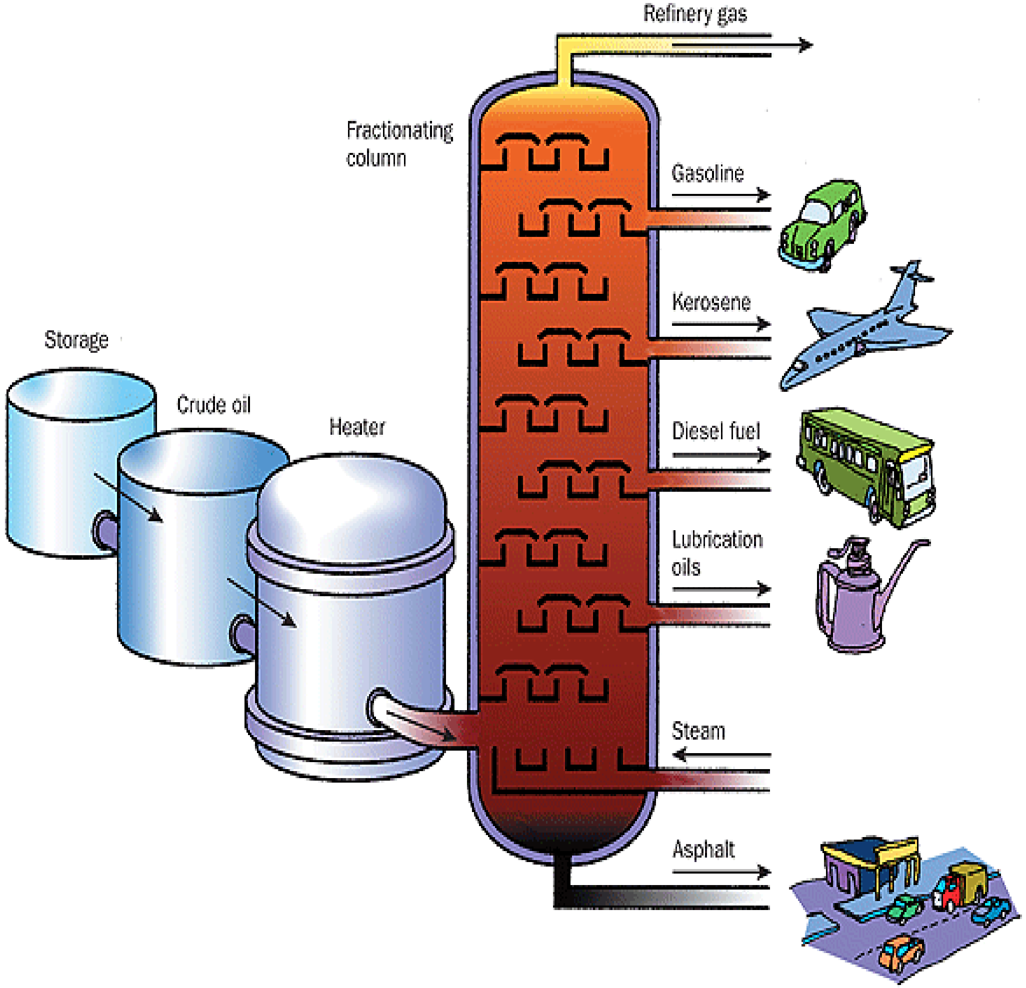


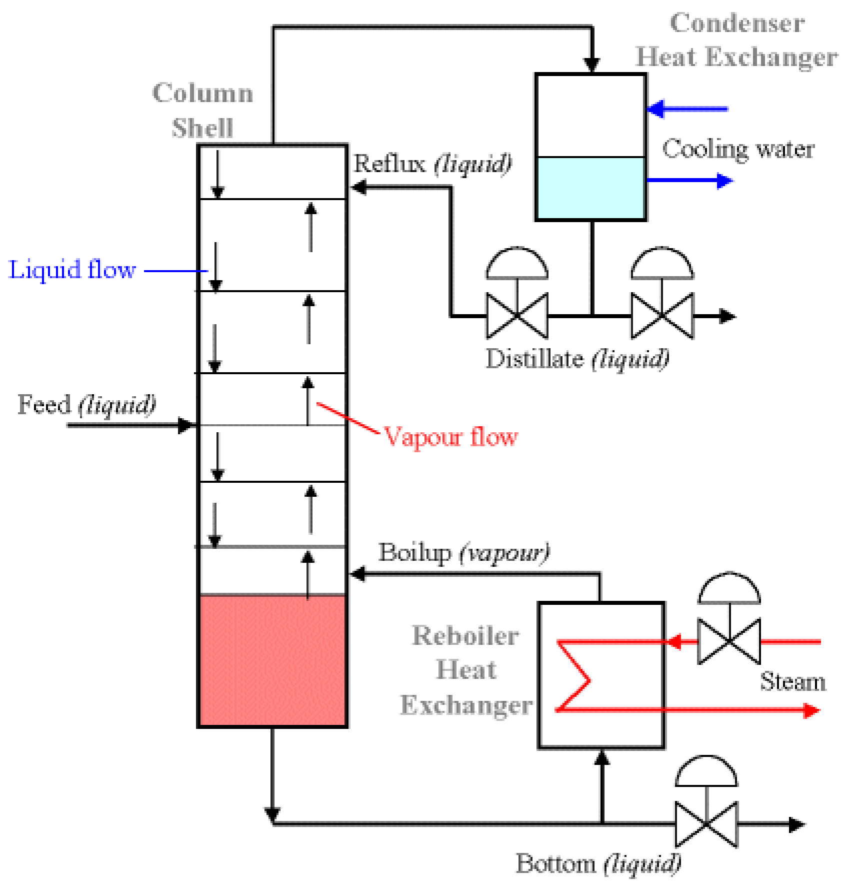


- displays the current state of the process (**visualization**)
- display the alarms and events (**alarm log, logbook**)
- display the trends (**historians**) and analyse them
- display handbooks, data sheets, inventory, expert system (**documentation**)
- allows communication and data synchronization with other centres

2. Process Control Systems

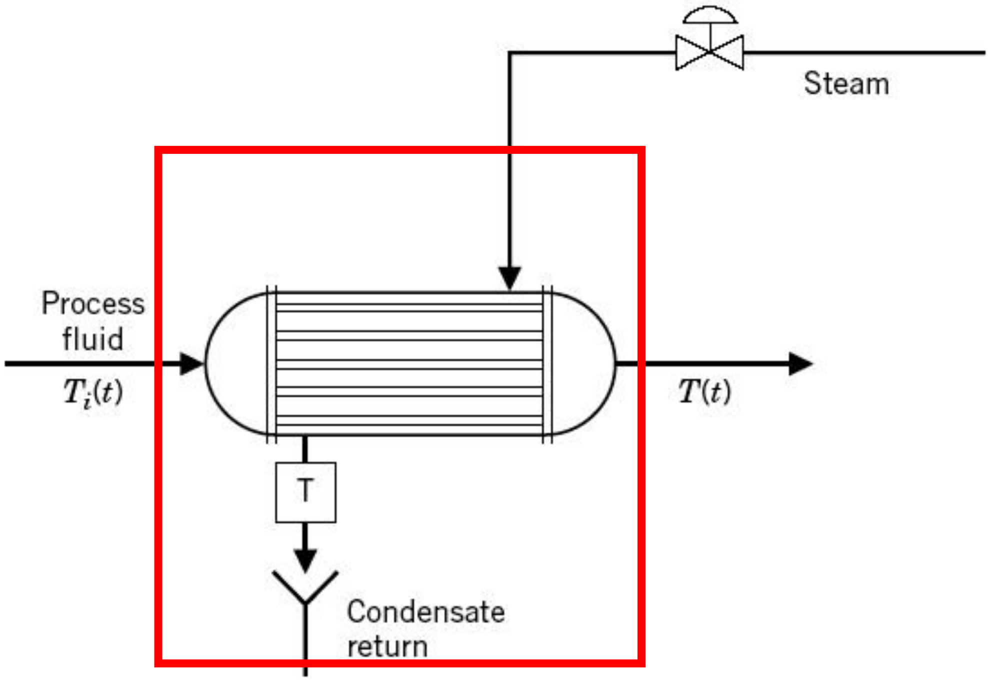
2. Process Control Systems



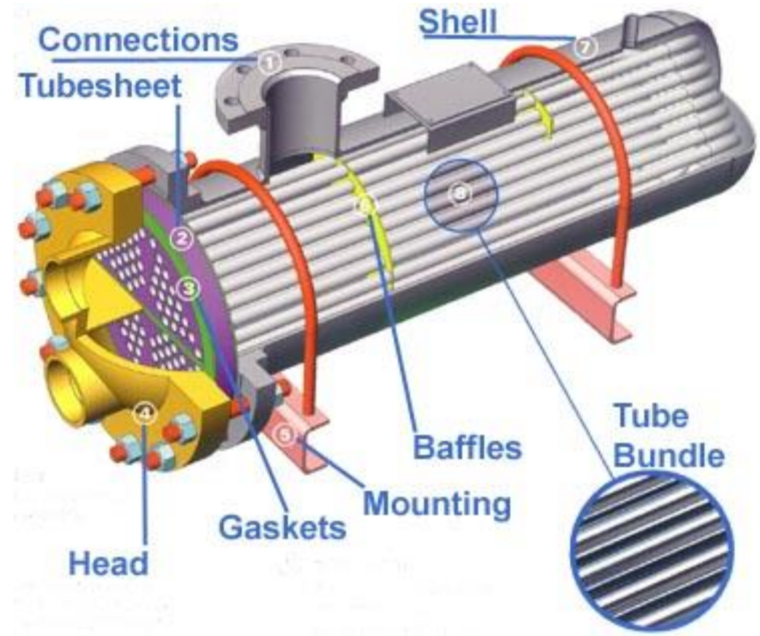


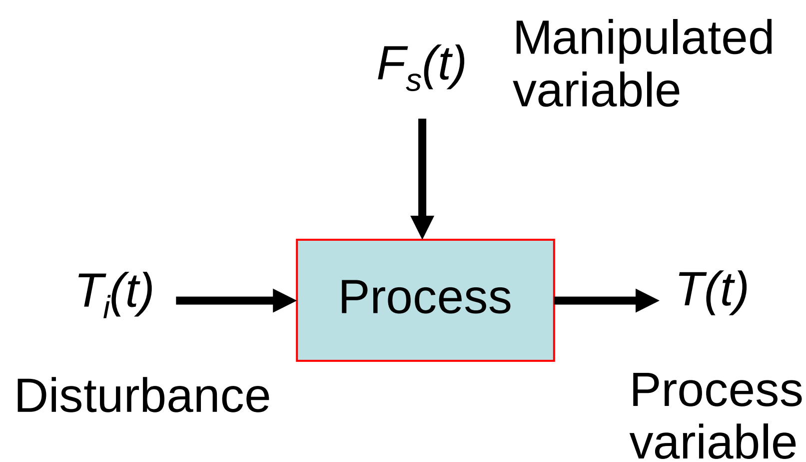
Example of process control

2. Process Control Systems



Heat exchanger.





2. Process Control Systems

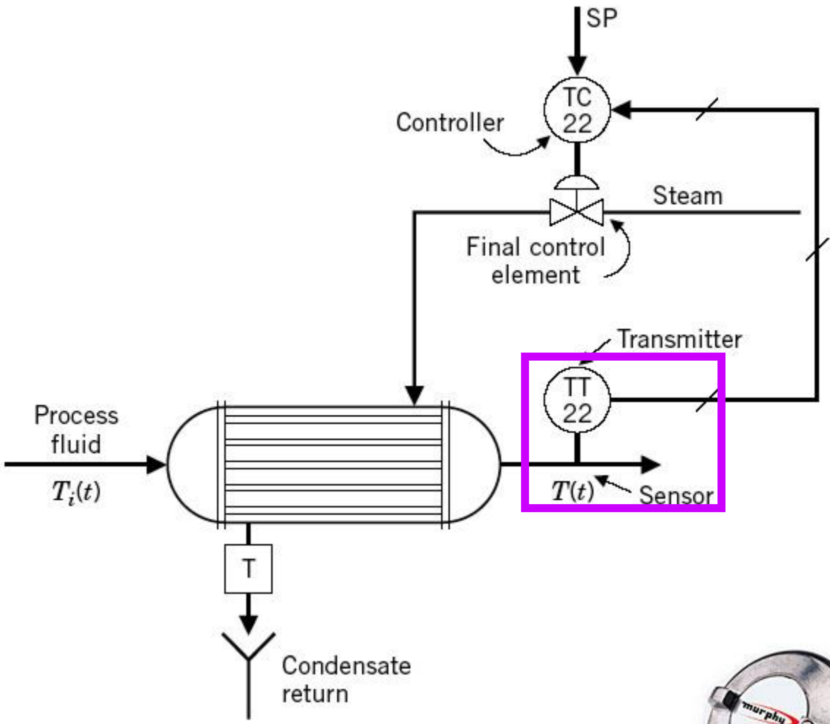


Figure 1-1.2 Heat exchanger control loop.

2. Process Control Systems

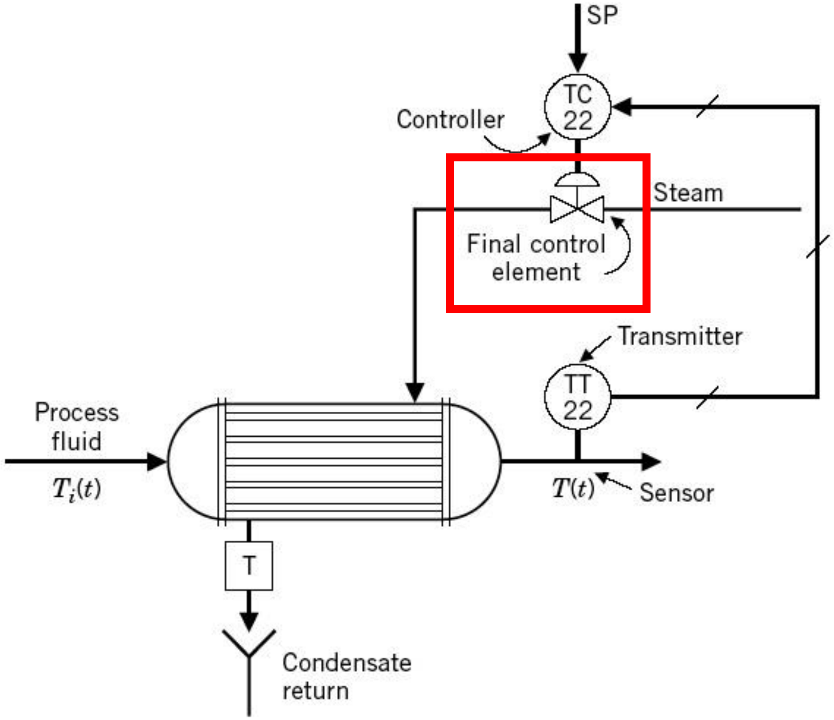


Figure 1-1.2 Heat exchanger control loop.

Standard signal → **Control Valve** → Flow

2. Process Control Systems

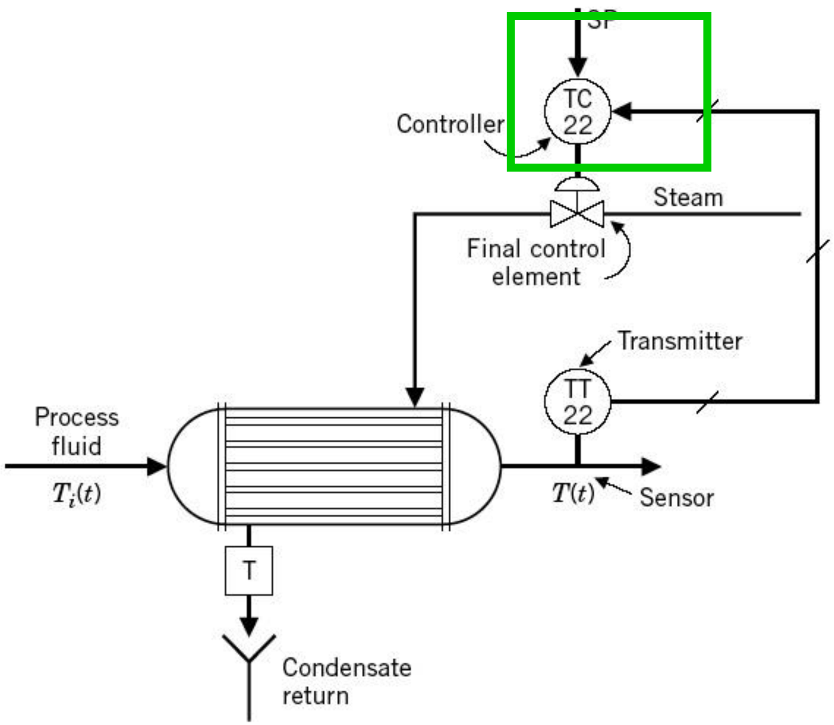
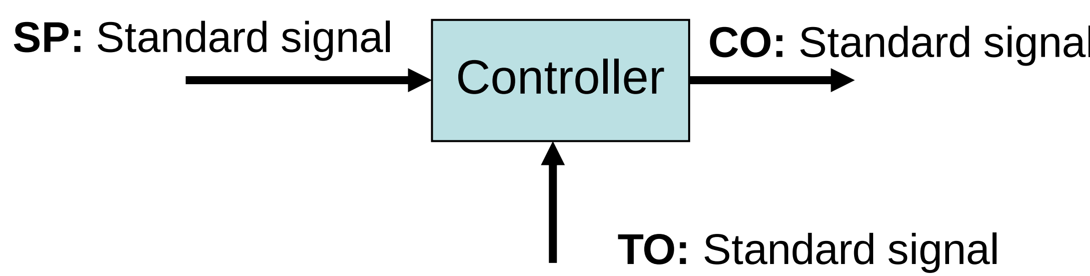


Figure 1-1.2 Heat exchanger control loop.



2. Process Control Systems

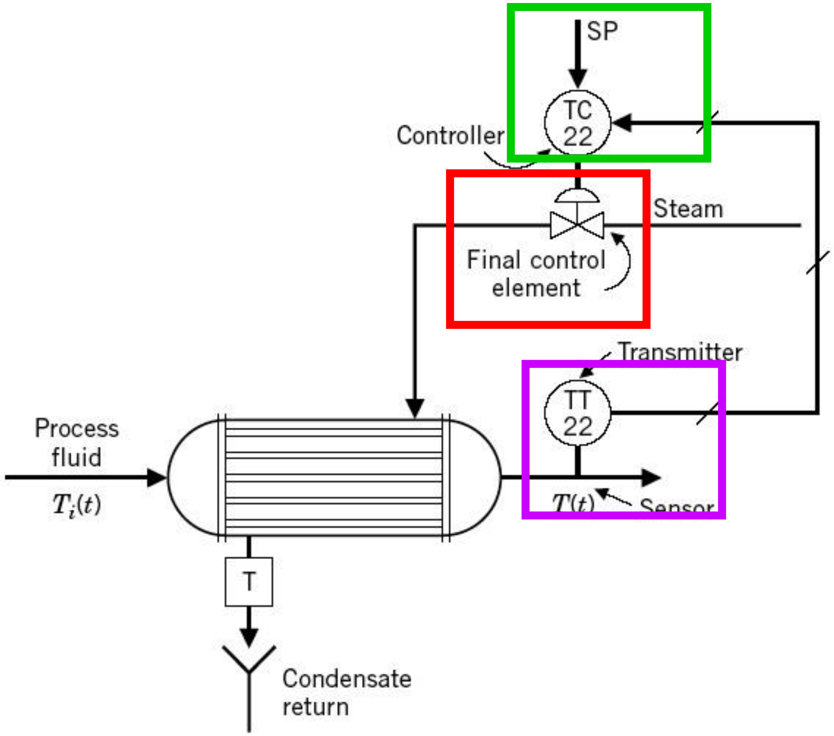
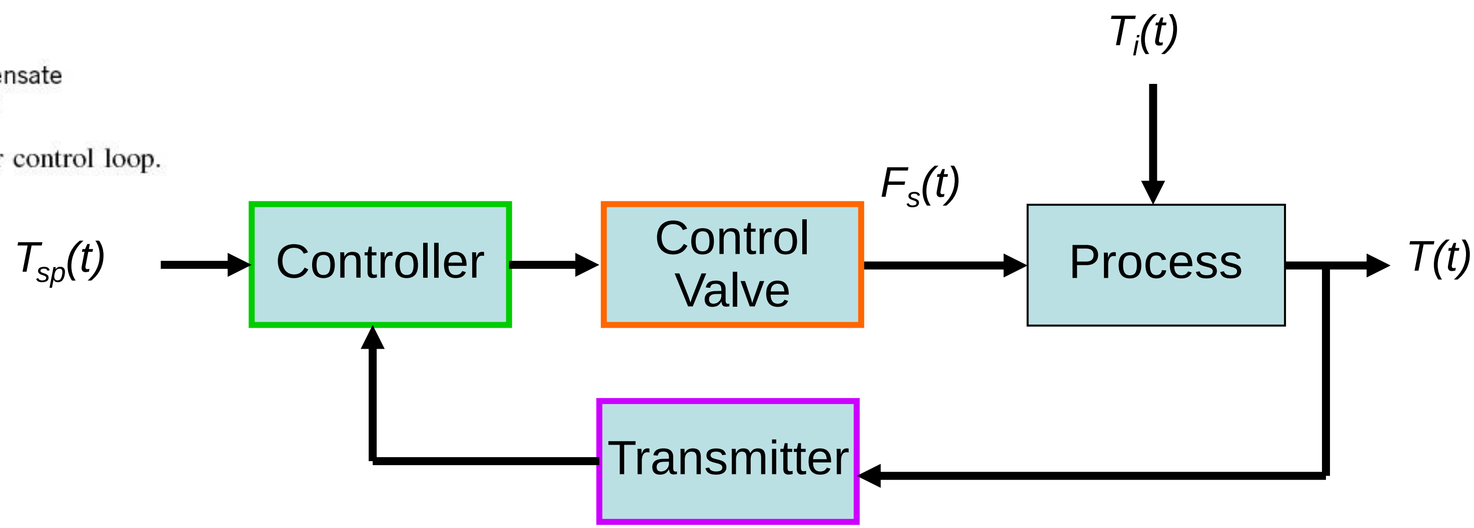


Figure 1-1.2 Heat exchanger control loop.

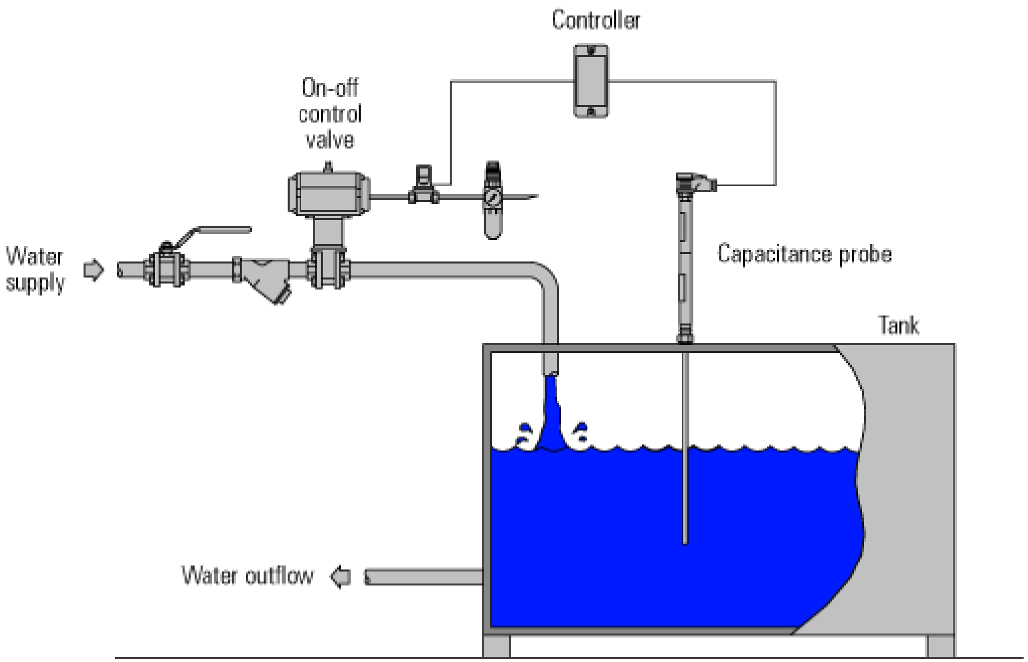
Components in Control Loop

- Process
- Sensor/Transmitter
- Controller
- Final Control Element



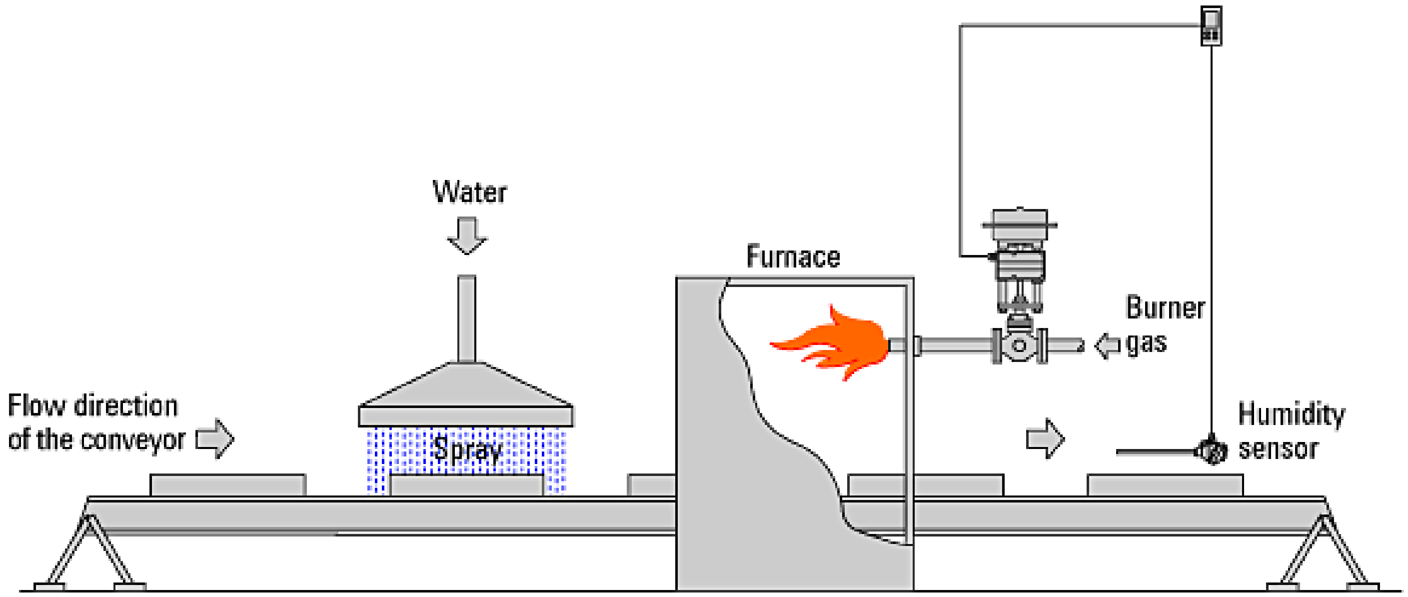
Example(1)

- From the process given in a figure below, What are PV=_______, and MV=_______ . Draw the block diagram of process control system, and also explain the functions of this process.

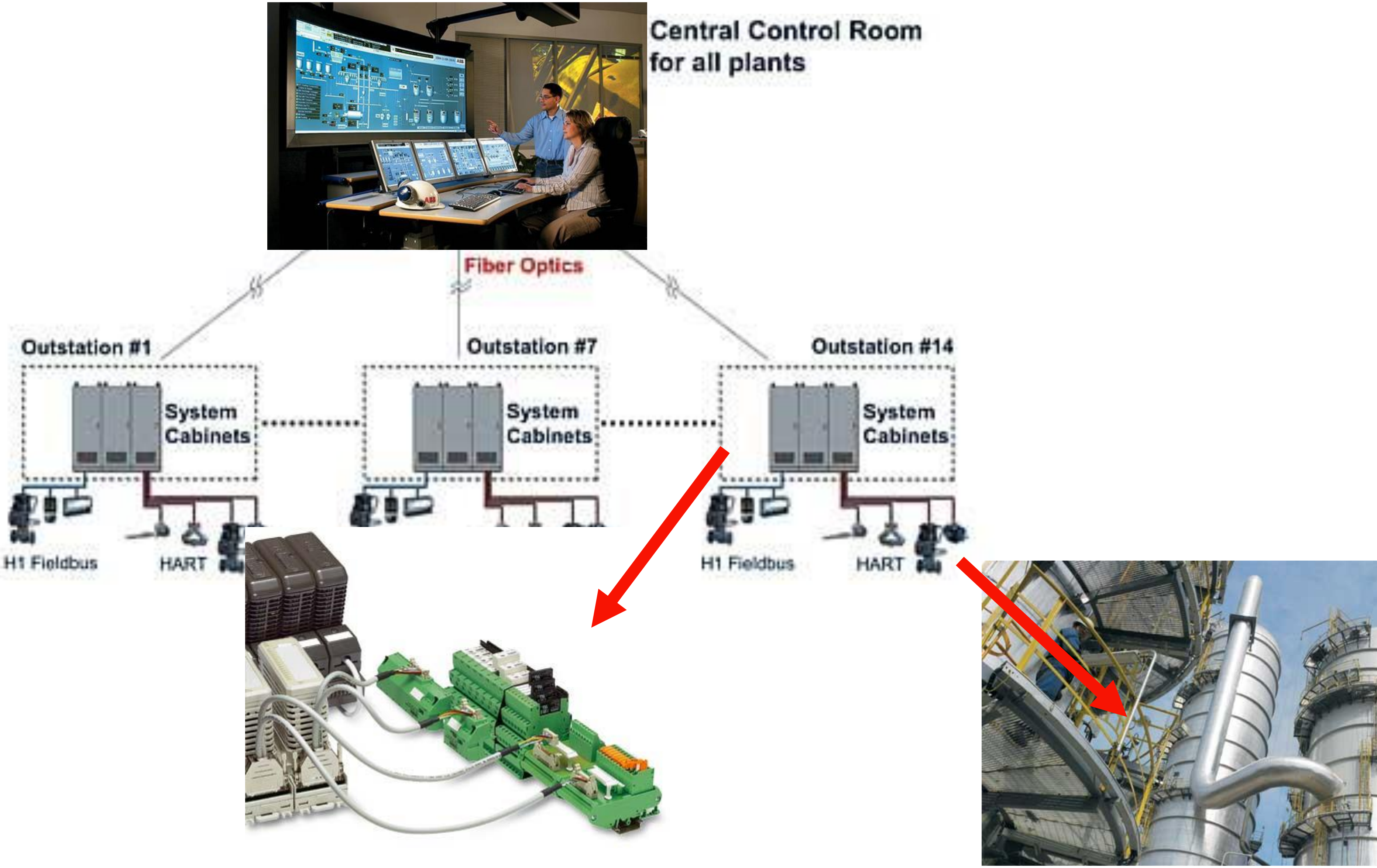


Example(2)

- From the process given in a figure below, What are PV=_______, and MV=________ . Draw the block diagram of process control system, and also explain the functions of this process.



2. Process Control Systems



Sequence Control Systems

Examples of sequence control
and Programmable Logic Controller

Sequence Control Systems

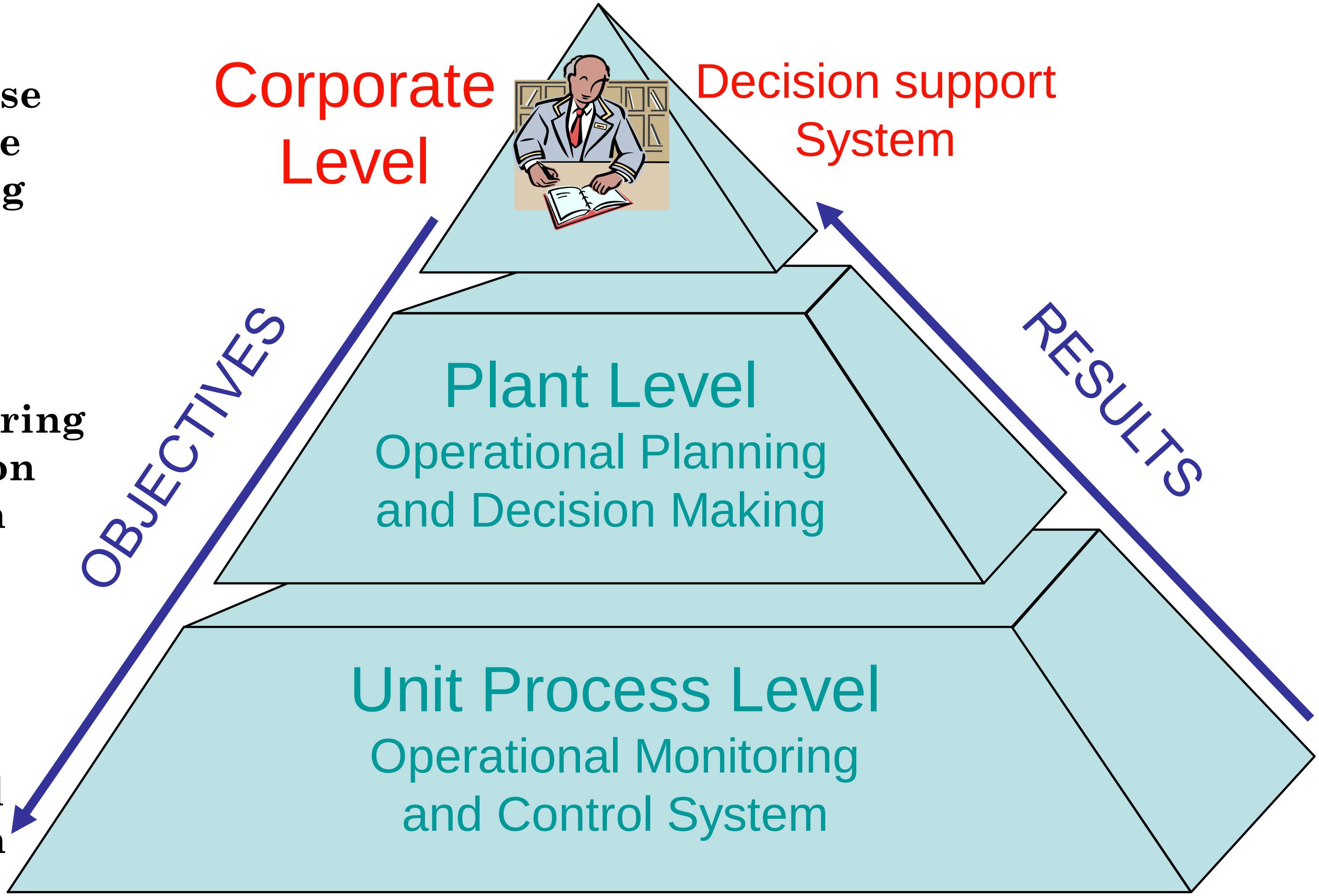
An example of PLC control panel

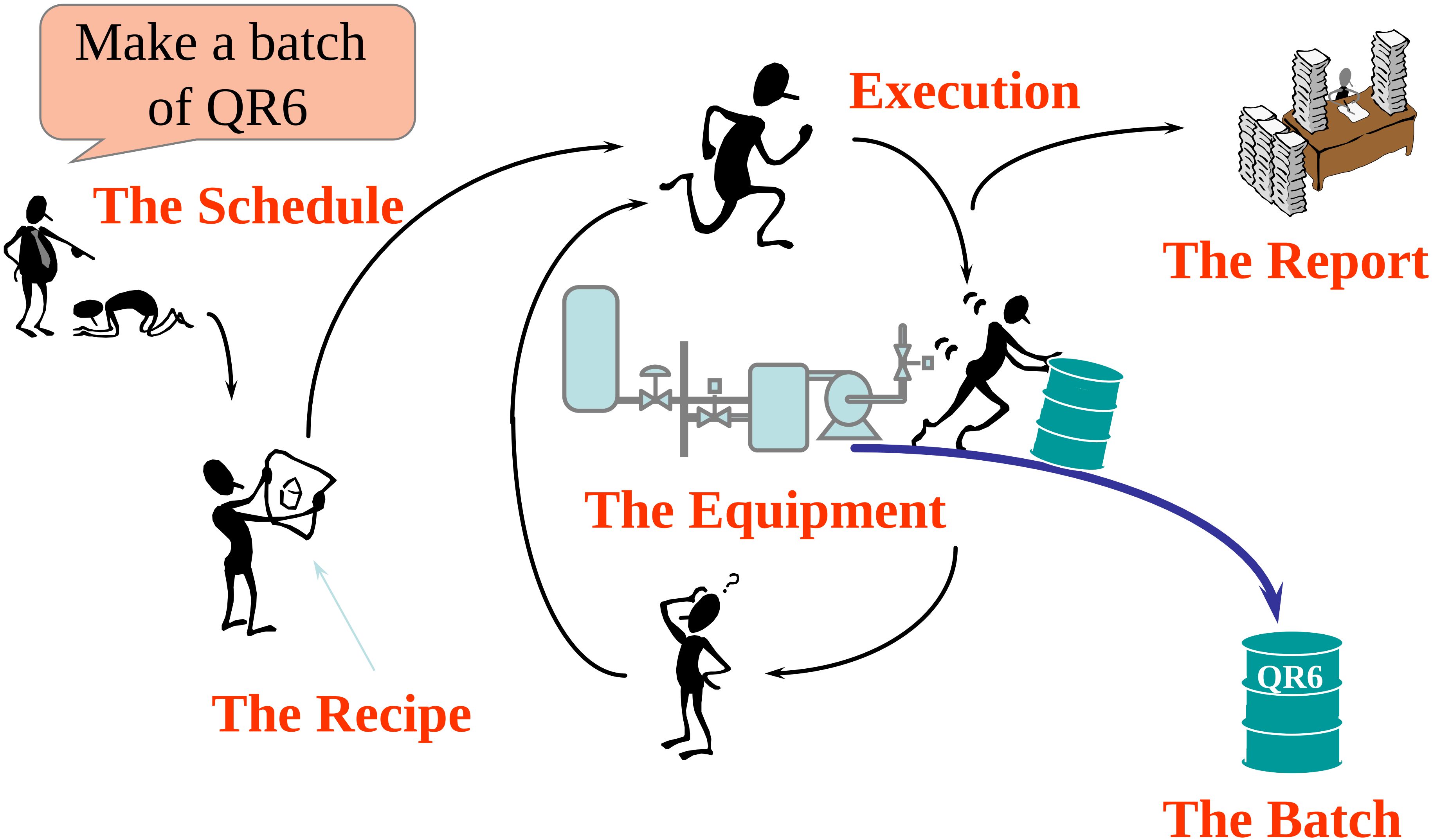
3. Integrated system : MES & ERP

ERP
Enterprise Resource Planning

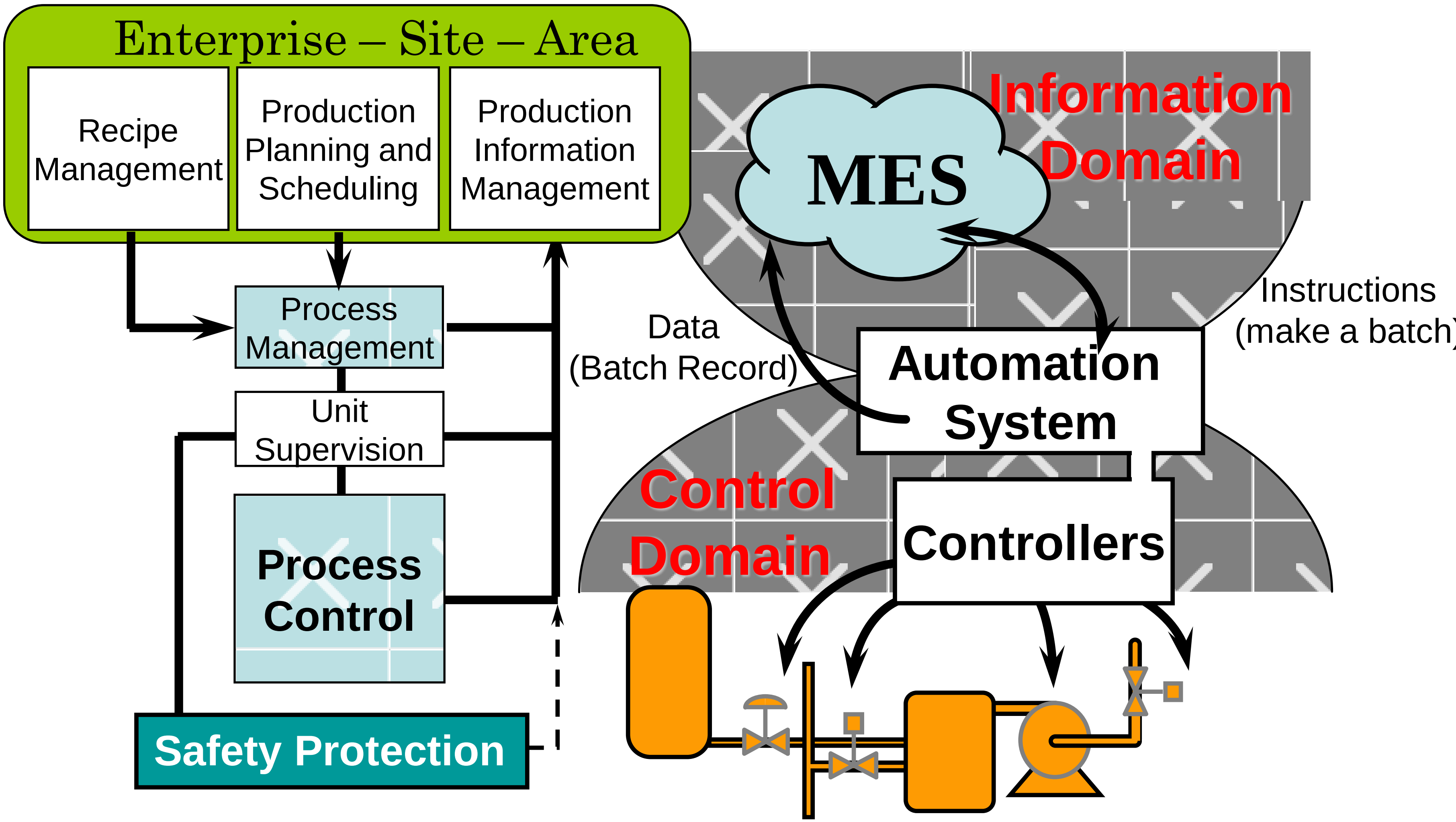
MES
Manufacturing Execution System

OCS
Open Control System

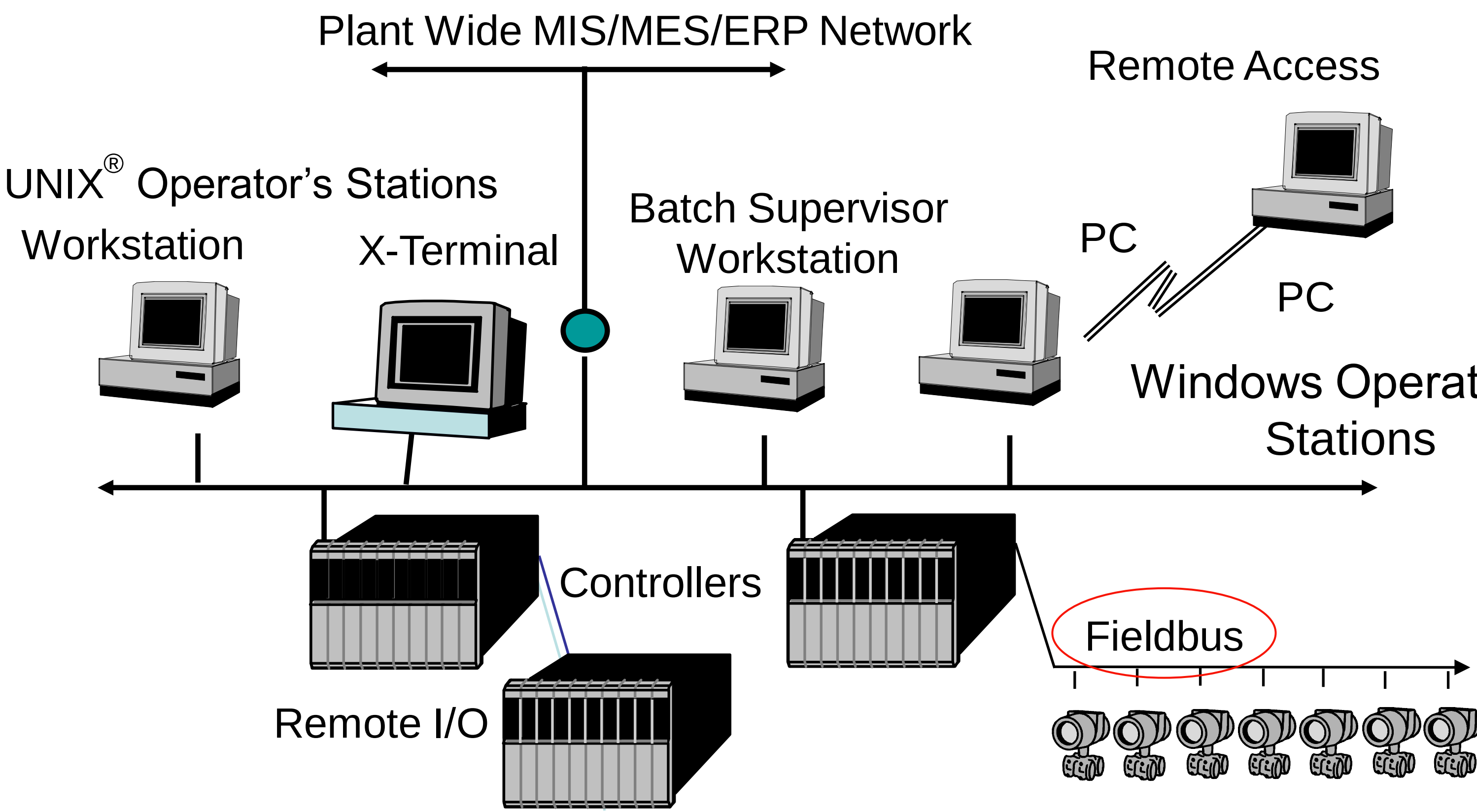



Make a batch of QR6
The Schedule
Execution
The Report
The Equipment
The Recipe
QR6
The Batch

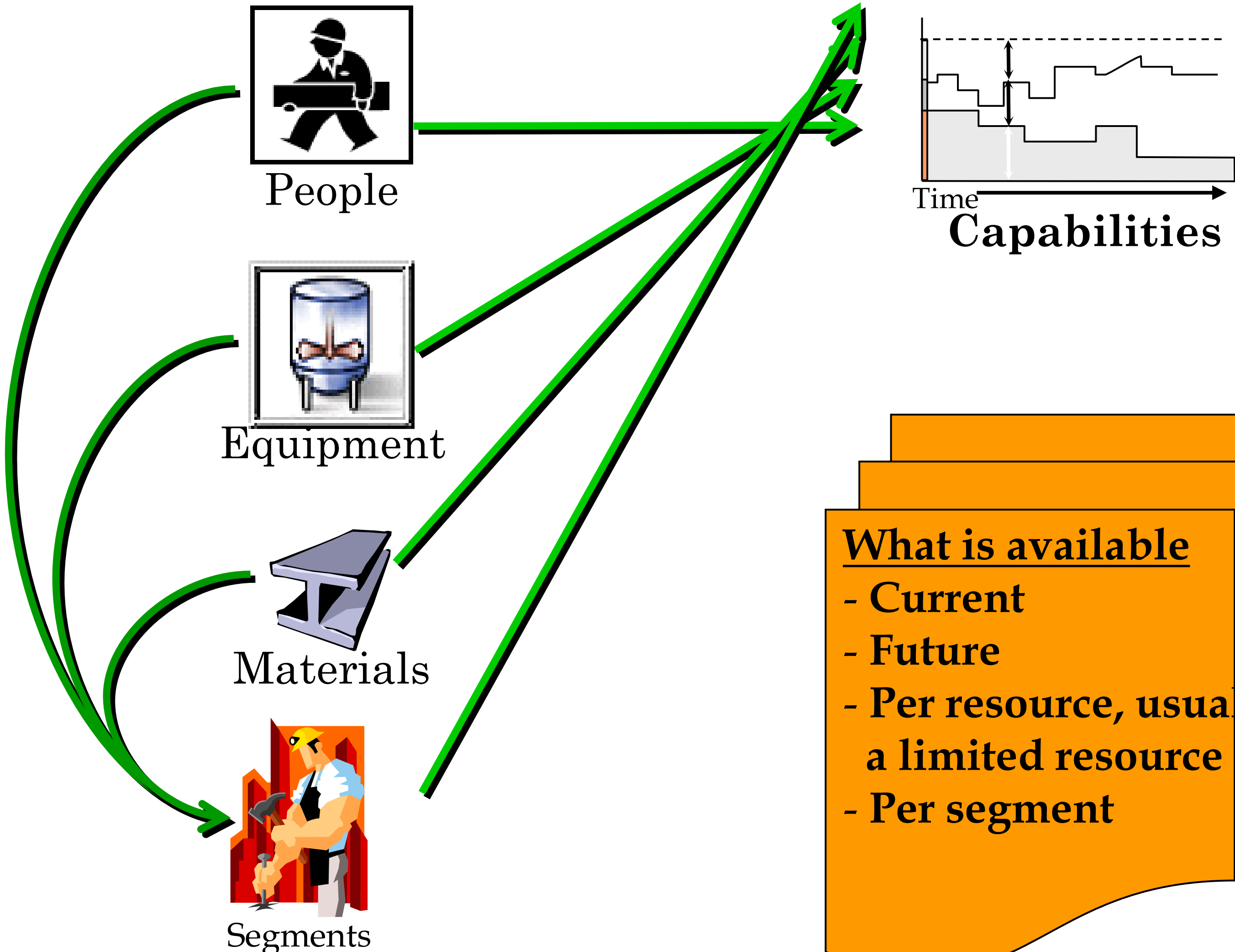
3. Integrated system : MES & ERP



Significance of Integrating ERP with OCSin the Real World

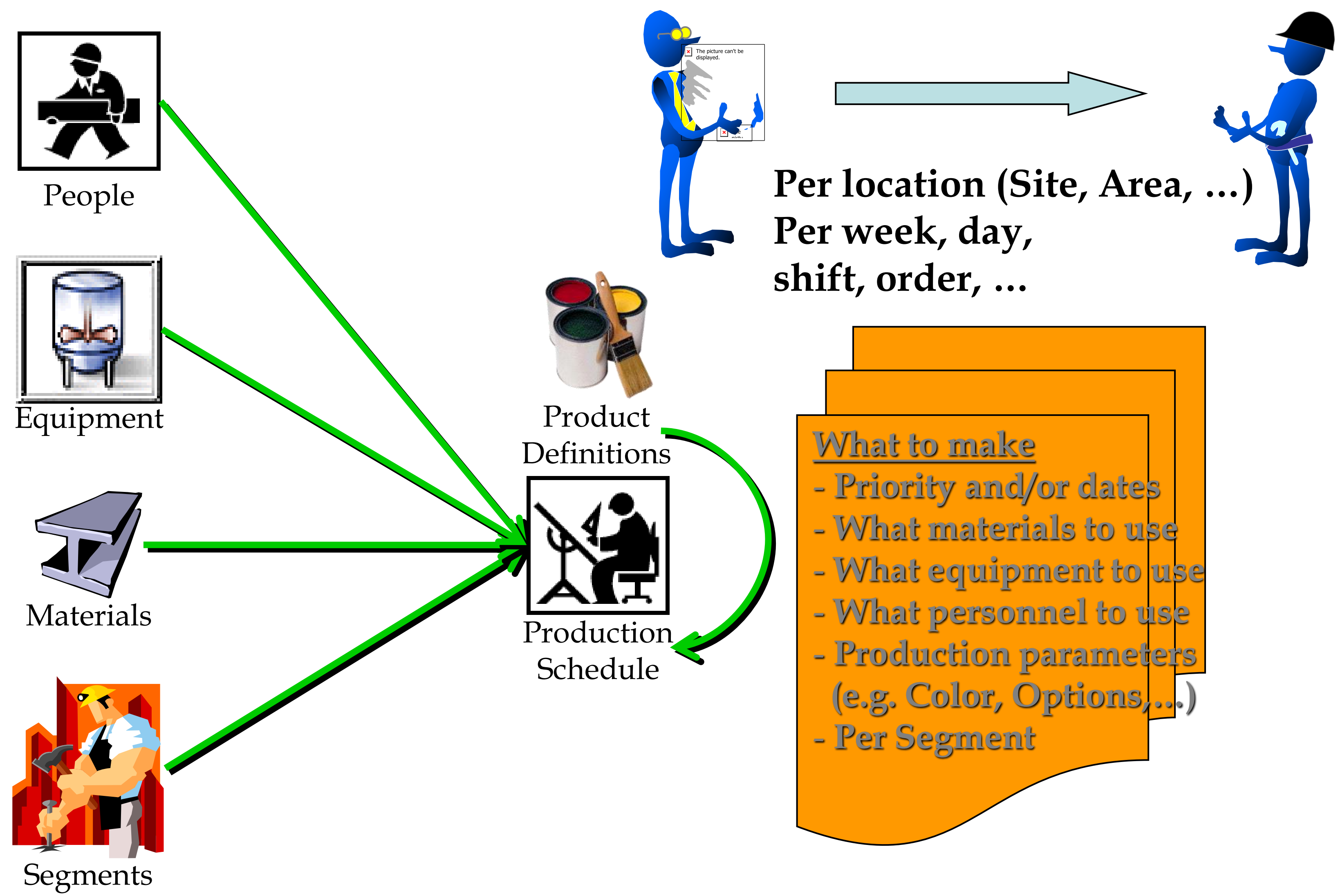


3. Integrated system : MES (Production capability)

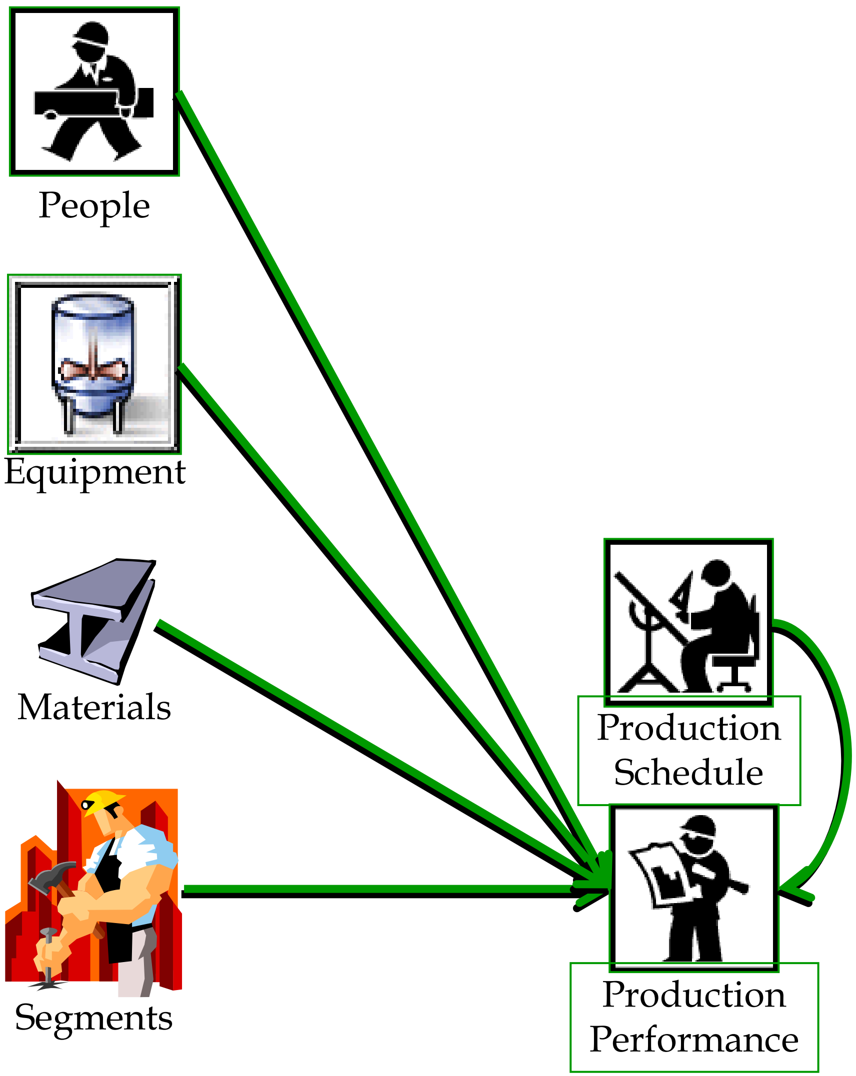


<u>What is available</u>
- **Current**
- **Future**
- **Per resource, usually a limited resource**
- **Per segment**

3. Integrated system : MES (Production schedule)



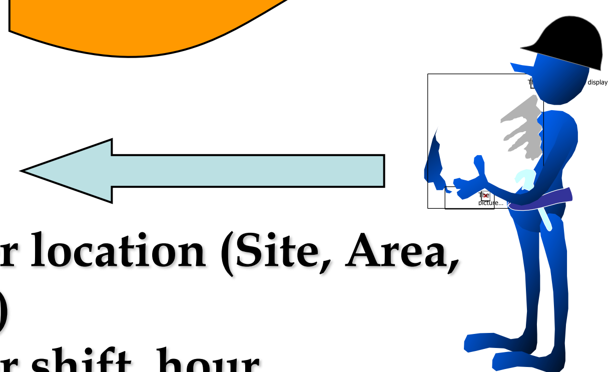
3. Integrated system : MES (Production performance)



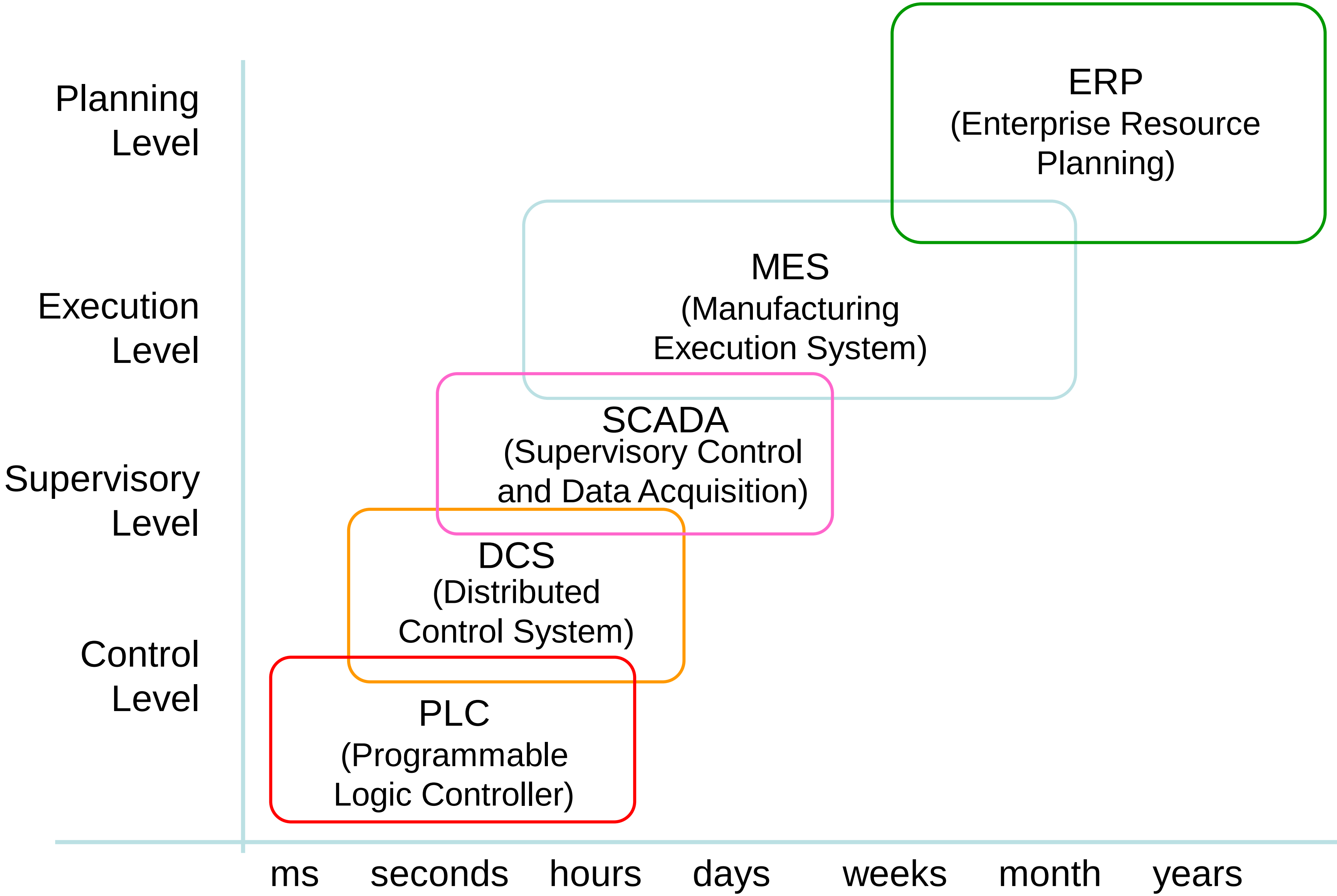
<u>What was made</u>

- What material was actually produced
- What materials were actually consumed
- Equipment used
- Personnel used
- Production data (e.g. Purity, density,…)
- Per Segment

Per location (Site, Area, …)
Per shift, hour, end of batch, …



3. Integrated system : Response time 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

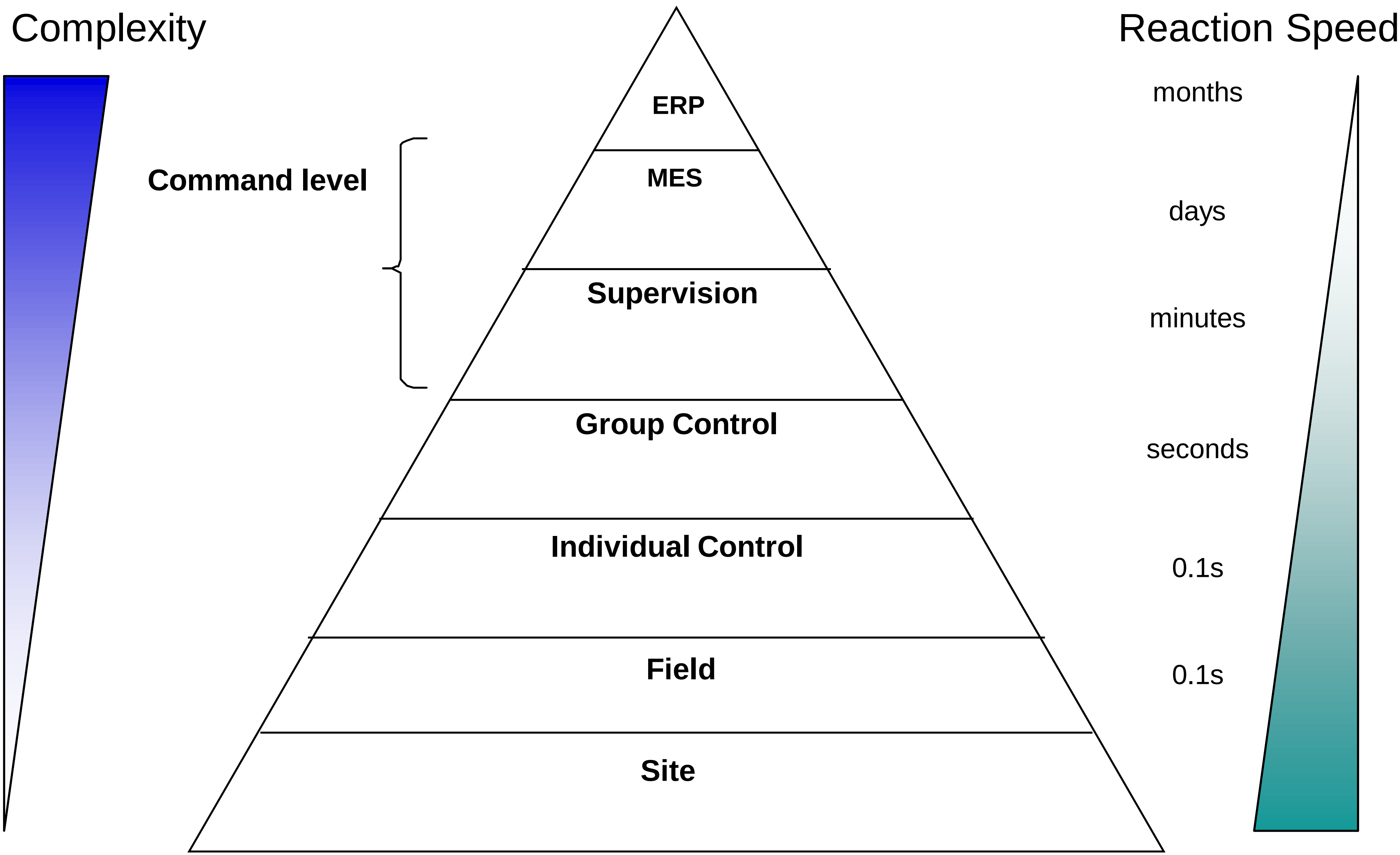
SCADA level

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

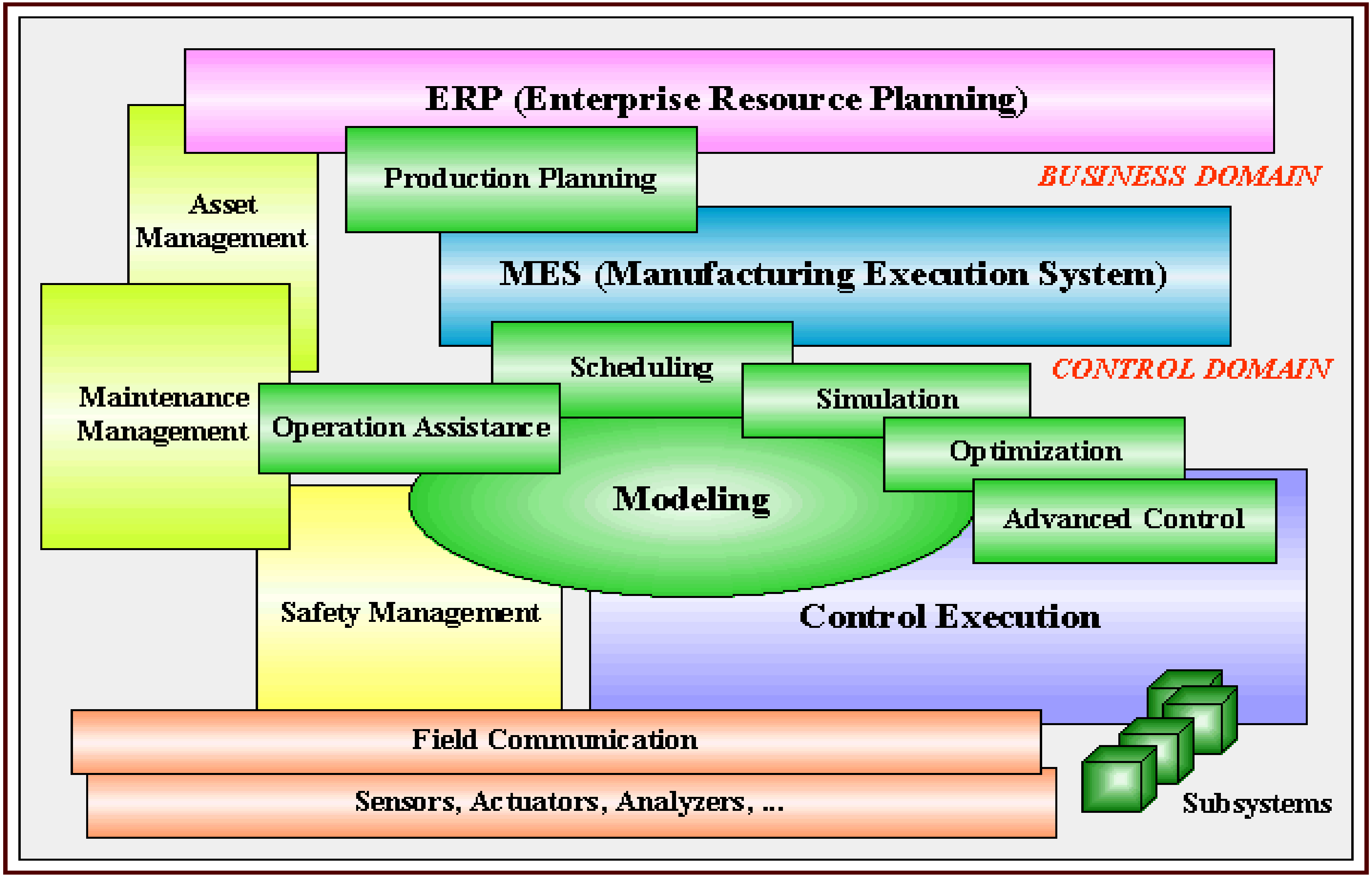
Lower Levels

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.

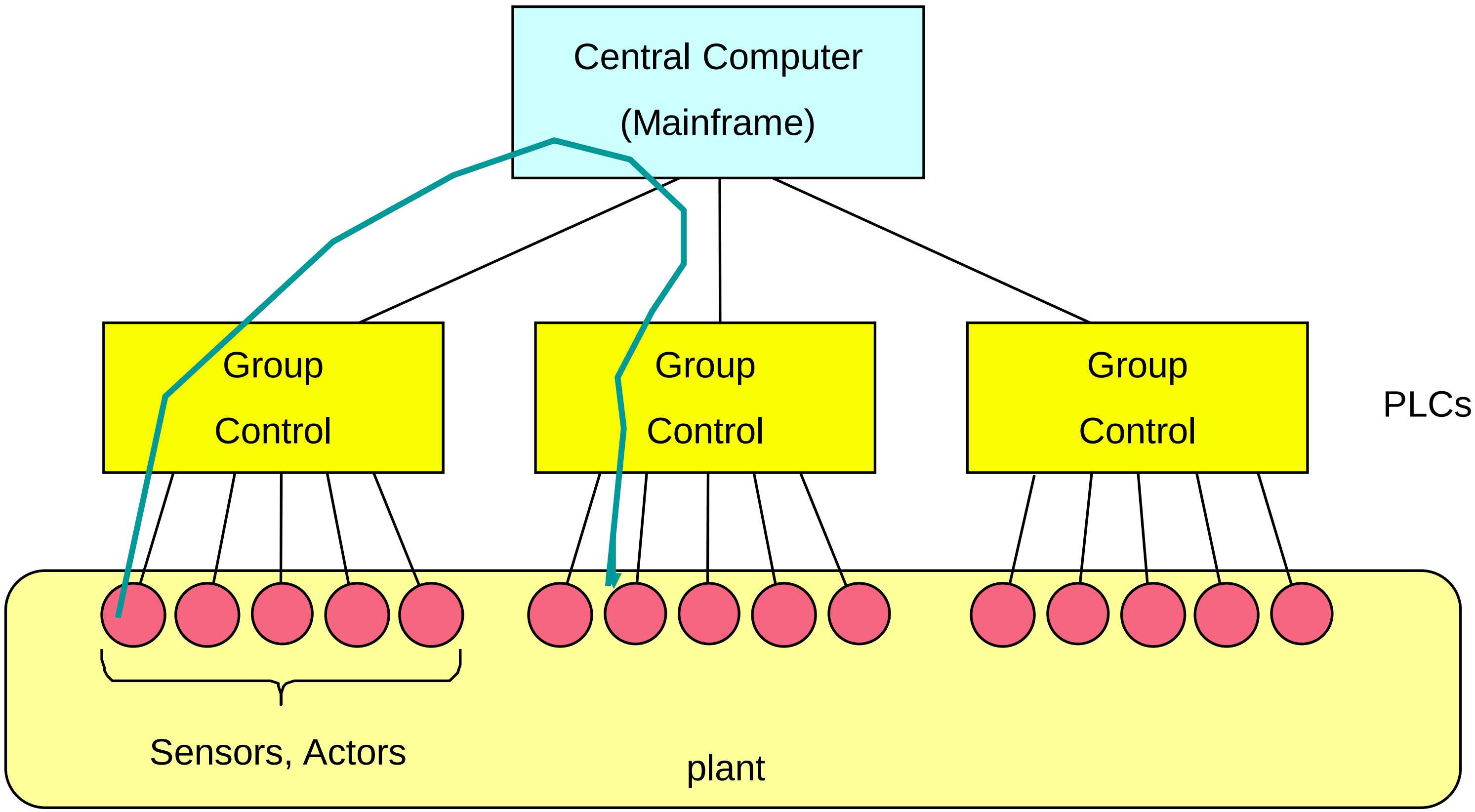
3. Integrated system : Complexity and Hierarchical level



3. Integrated system : MES & ERP



1. Centralized Control Architecture (classical)

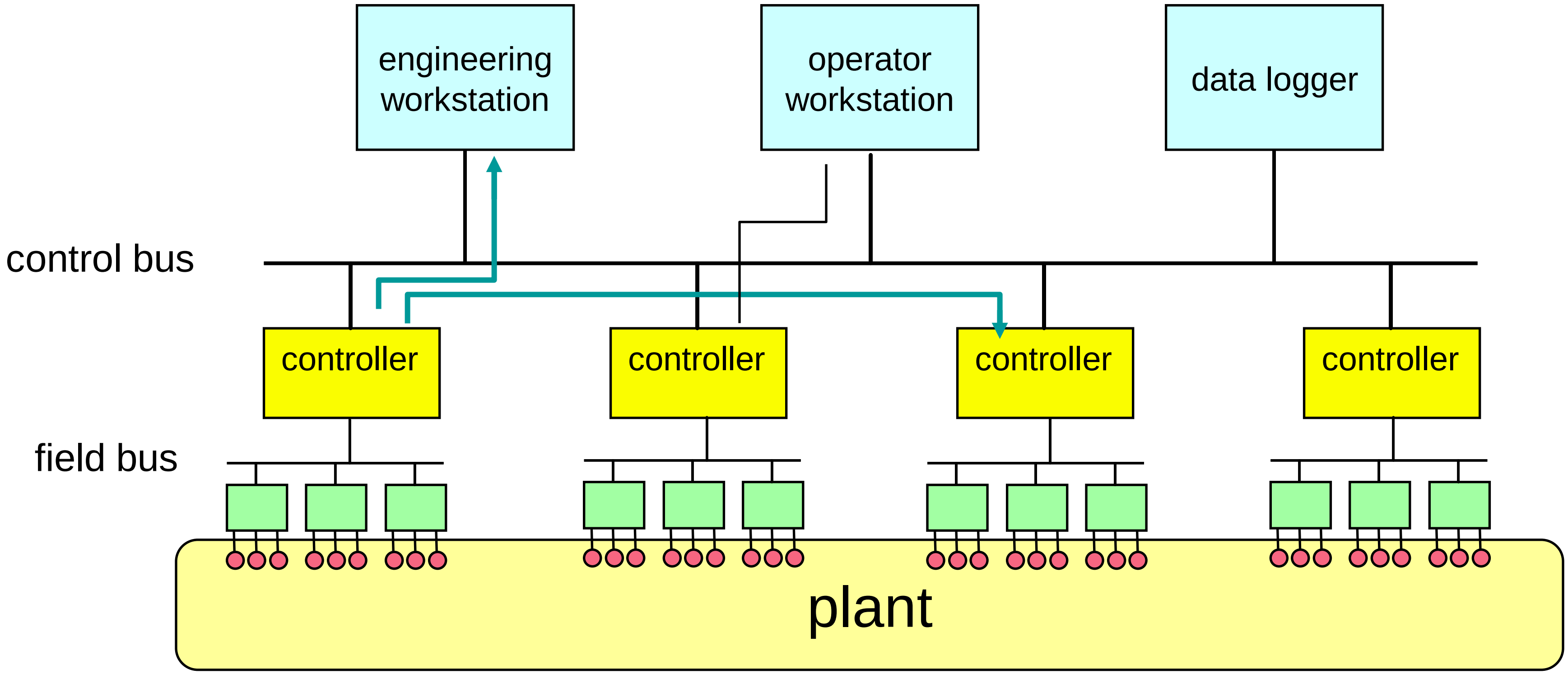


Classical, hierarchical, centralized architecture.

The central computer only monitors and forwards commands to the PLCs.

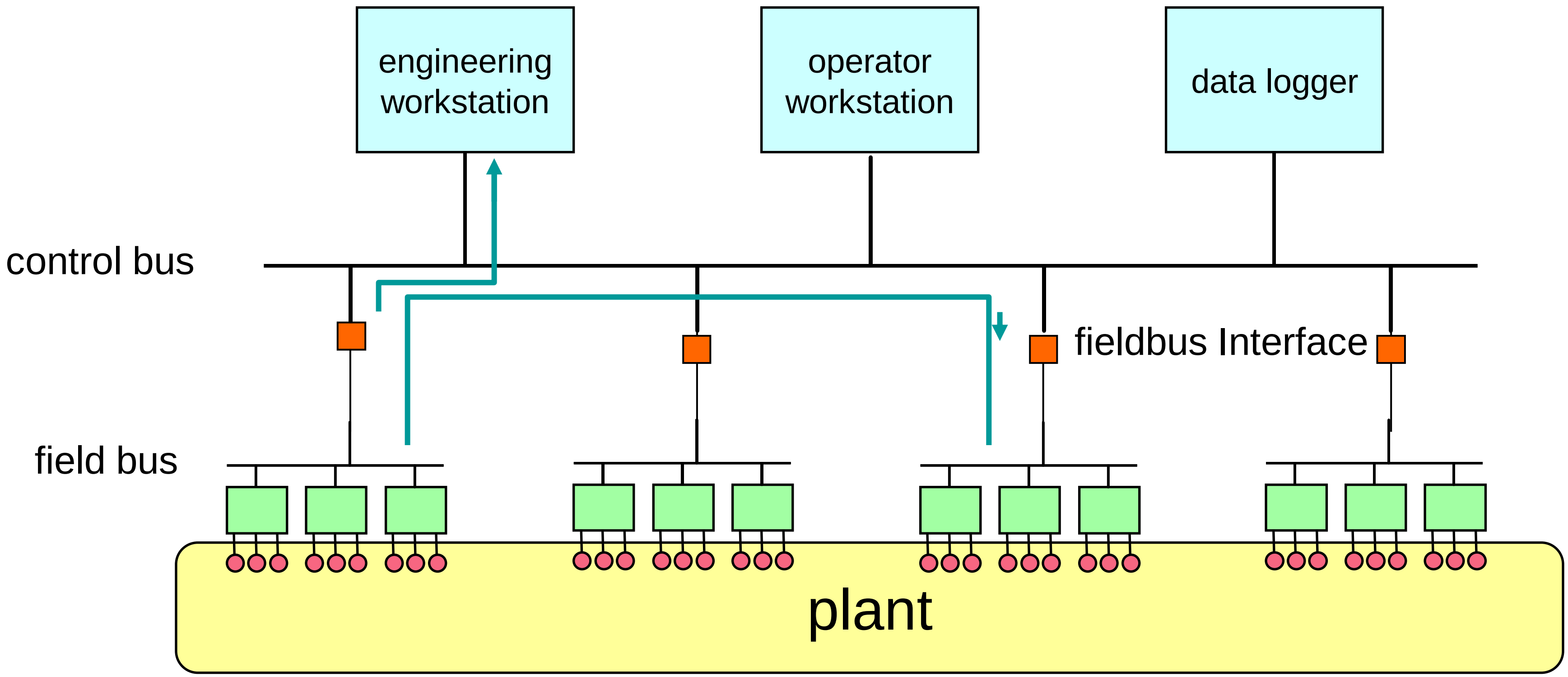
Sometimes it may be called as “Direct Digital Control” (DDC).

2. Decentralized Control Architecture



all controllers can communicate as peers (without going through a central master), restricted only by throughput and modularity considerations.

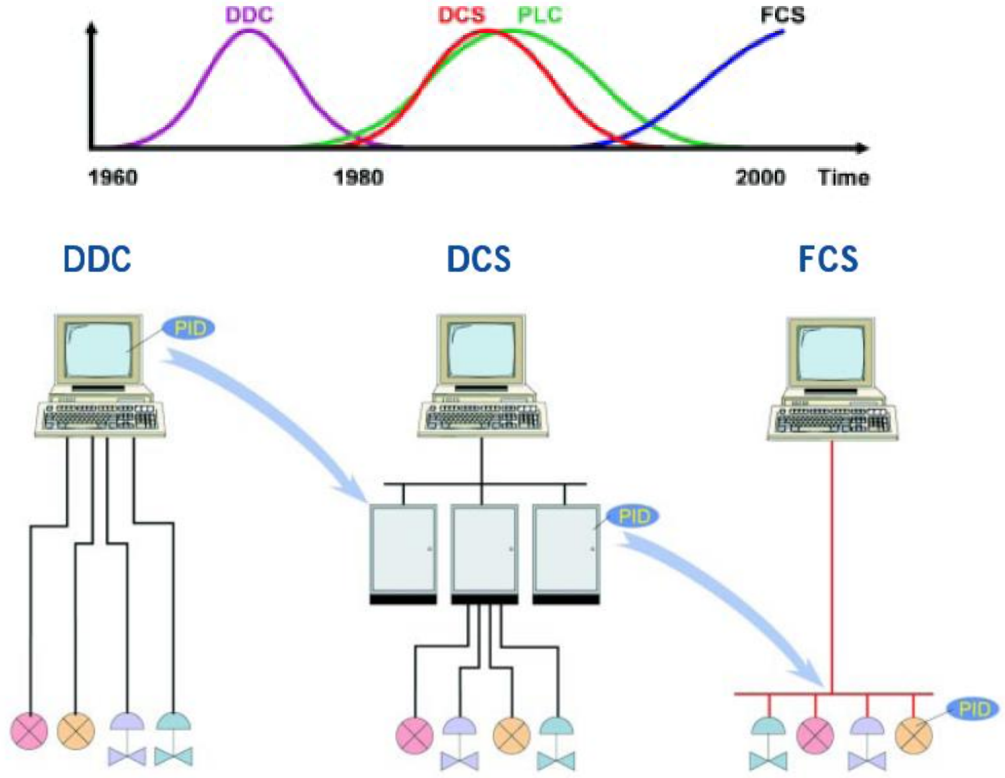
3. Field Control Architecture



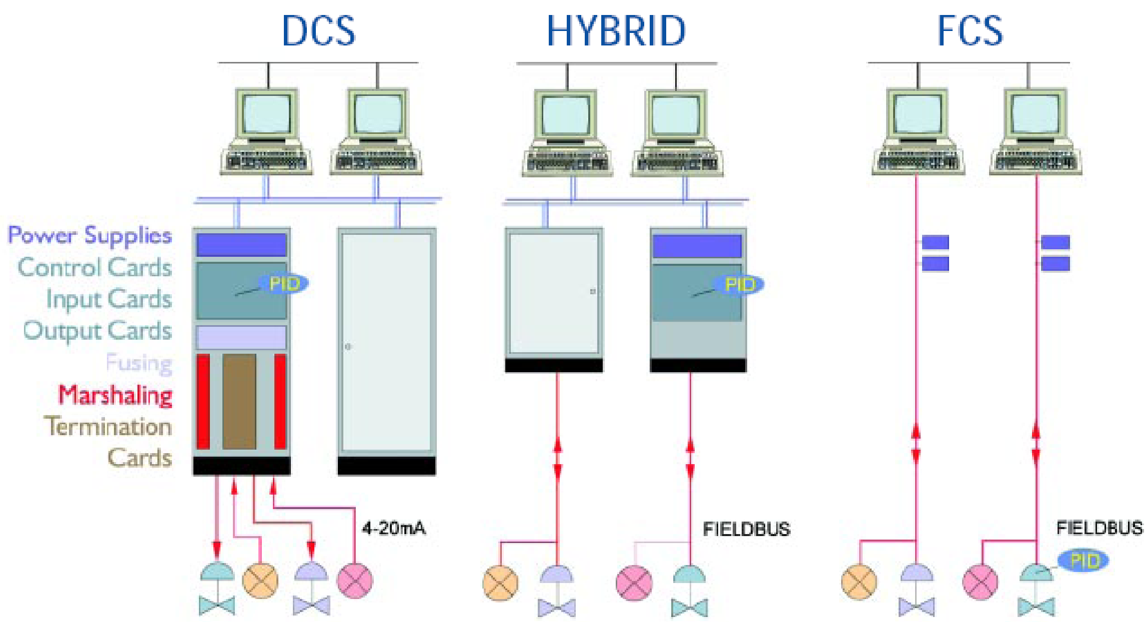
Mostly controller functions are run in field level instruments, the field information can be communicated via the fieldbus interface module.

4. System Architecture : DDC, DCS and FCS

A third major trend is in the accelerating pace of the application of new technologies aimed towards completely digital systems with functionality distributed to the field reducing system complexity and cost. Fieldbus is the logical step improving on the familiar DCS - even more distributed and even more digital. It is a Field Control System (FCS).



4. System Architecture : DDC, DCS and FCS



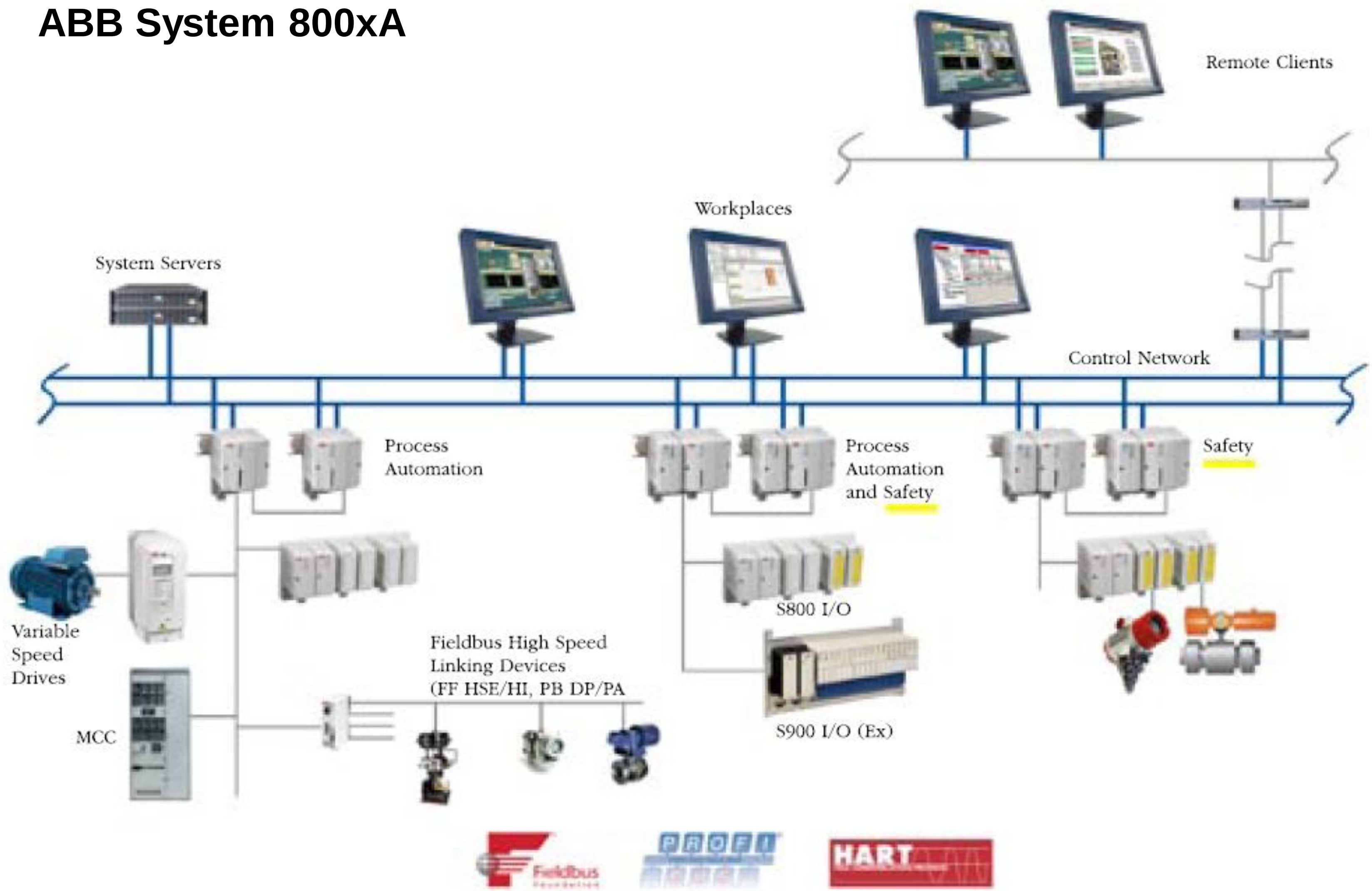
- *Lower Initial Cost*
- *Flexibility*
- *Interoperability*
- *Improved Information Availability and Integrity*
- *Lower Maintenance Cost*
- *Increased Product Quality*
- *Lower Cost of Expansion and Change*
- *Easier Operation*
- *Simplified Engineering*
- *Quiker and Easier to Learn*
- *Increased safety*

Task Distribution

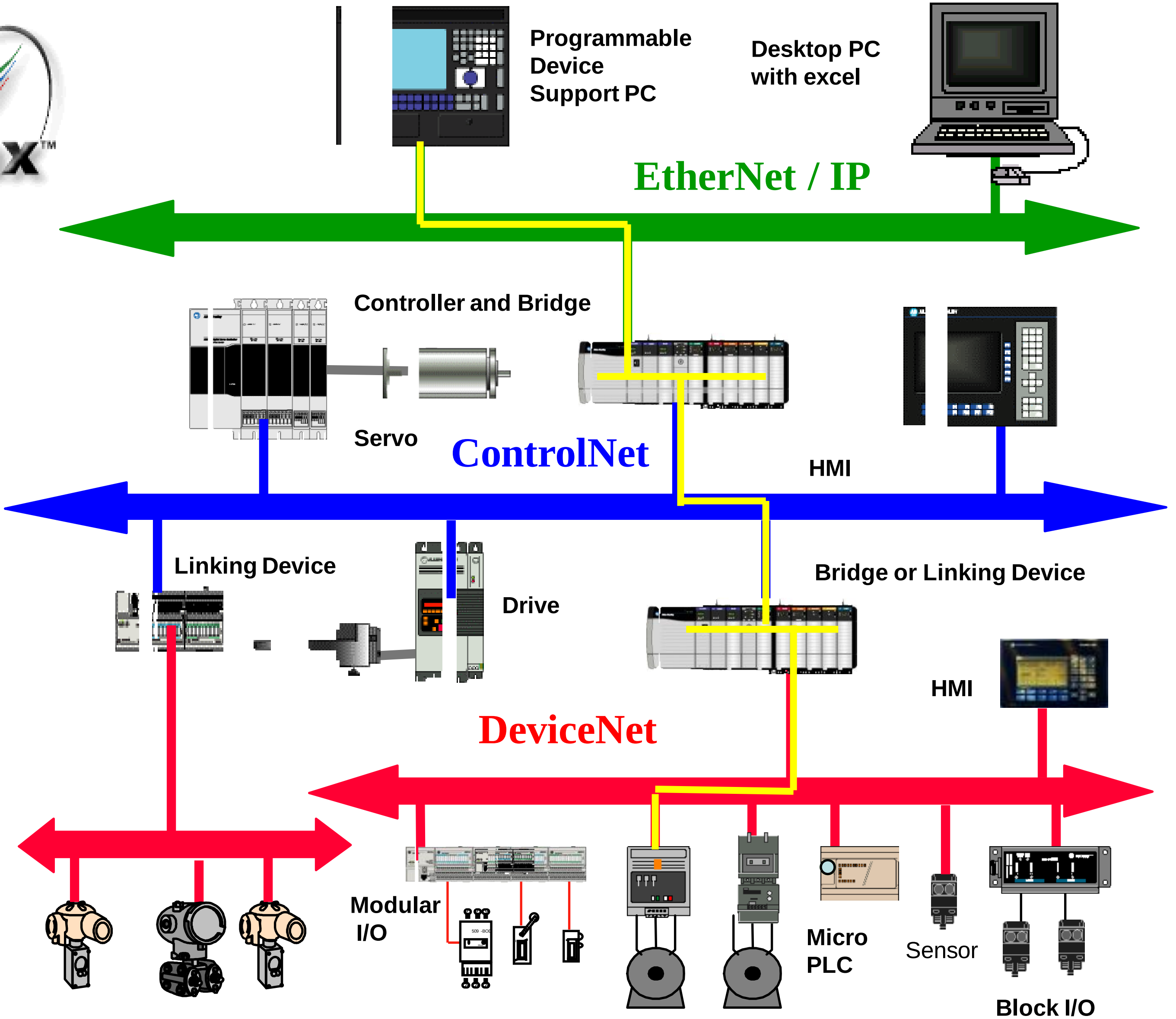
Field	Controllers	Workstation
Measurement	Control	Display
Actuation	Logic	operation
Control	Sequence	Process Flow Mimic
Computation	Computation	Trend
Selection	Selection	Alarm
Alarm	Alarm	Reports
Diagnostics	Diagnostics	Supervisory
		Batch
		Recipe
		Events
		SQC
		Database management
		Instrument management
		Optimization
		ERP - Enterprise Resource Planning

4. System Architecture : Examples of integrated system

ABB System 800xA



4. System Architecture : Examples of integrated system

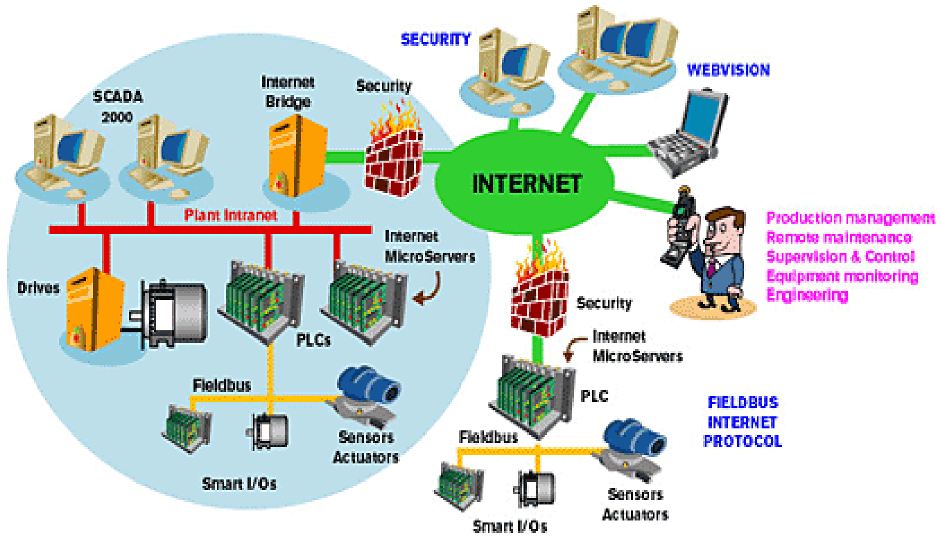


4. System Architecture : Examples of integrated system

Modern systems (2010 onwards)
The latest developments in DCS include the following new technologies:

1. Wireless systems and protocols
2. Remote transmission, logging and data historian
3. Mobile interfaces and controls
4. Embedded web-servers

Increasingly, and ironically, DCS are becoming centralised at plant level, with the ability to log into the remote equipment. This enables operator to control both at enterprise level (macro) and at the equipment level (micro) both within and outside the plant as physical location due to interconnectivity primarily due to wireless and remote access has shrunk.



The ALSTOM e-Control Architecture

As wireless protocols are developed and refined, DCS increasingly includes wireless communication. DCS controllers are now often equipped with embedded servers and provide on-the-go web access. Whether DCS will lead IIOT or borrow key elements from remains to be established.

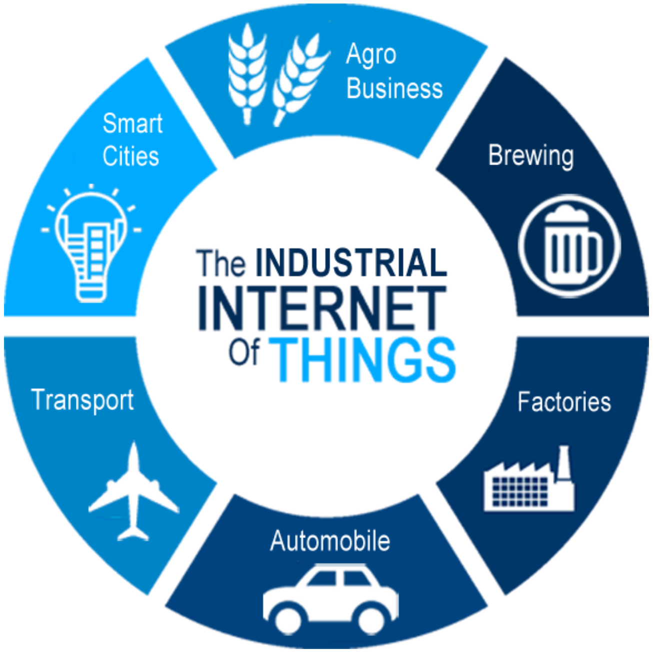
Many vendors provide the option of a mobile HMI, ready for both Android and iOS. With these interfaces, the threat of security breaches and possible damage to plant and process are now very real.

https://en.wikipedia.org/wiki/Distributed_control_system#Modern_systems_(2010_onwards)

5. Industrial Internet of Things (IIoT)

The IIoT is part of a larger concept known as the Internet of Things (IoT). The IoT is a **network** of intelligent computers, devices, and objects that collect and share huge amounts of data. The collected data is sent to a central Cloud-based service where it is aggregated with other data and then shared with end users in a helpful way. The IoT will increase automation in homes, schools, stores, and in many industries.
The application of the IoT to the manufacturing industry is called the IIoT (or Industrial Internet or Industry 4.0). The IIoT will revolutionize manufacturing by enabling the acquisition and accessibility of far greater amounts of data, at far greater speeds, and far more efficiently than before. A number of innovative companies have started to implement the IIoT by leveraging intelligent, connected devices in their factories.

"IIoT connects devices such as industrial equipment on to the network, enabling information gathering and management of these devices via software to increase efficiency, enable new services (factory automation, robotics, supply chain efficiency)…"



References: https://inductiveautomation.com/what-is-iiot
http://www.emg-pr.com/en/newsletteritem.aspx?id=122

What are the Benefits of IIoT?

The IIoT can greatly improve connectivity, efficiency, scalability, time savings, and cost savings for industrial organizations. Companies are already benefitting from the IIoT through cost savings due to predictive maintenance, improved safety, and other operational efficiencies. IIoT networks of intelligent devices allow industrial organizations to break open data silos and connect all of their people, data, and processes from the factory floor to the executive offices. Business leaders can use IIoT data to get a full and accurate view of how their enterprise is doing, which will help them make better decisions.

References: https://inductiveautomation.com/what-is-iiot

5. Industrial Internet of Things (IIoT)

IoT starts at the sensor level where pressure, level, flow, temperature, vibration, acoustic, position, analytical and other sensors collect data and send this collected information to control and monitoring systems via wired and wireless networks. The advent of sensors that are wireless, self-powered, non-intrusive, calibration free and maintenance free, production processes can now cost-effectively send information from thousands more sensors to the control and monitoring systems. These sensors help create the IoT for the facility and gives its operating and maintenance personnel a better understanding of overall plant operations. Sensing devices provide ways to automatically improve performance, safety, reliability and energy efficiency in production facilities. These improvements occur as a result of:

- *Collecting* data from sensors (things), much more cost effectively than ever before because they are battery powered and wireless
- *Interpreting* this data strategically, using subject matter expertise to effectively analyze the data, either locally or remotely
- *Presenting* actionable information, built on task-oriented human centered design principles (HCD) principles, to the right person—either plant personnel or supplier-provided experts.
- *Leading* to results in performance improvements, when personnel take corrective action

References: https://www.emersonprocessxperts.com/2015/04/internet-of-things-in-process-instrumentation-and-automation/
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SUMMARY AND QUESTIONS

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