Enterprise Technology Solutions

# FOUNDATION™ Fieldbus technology Introduction

THE PATH TO FIELDBUS



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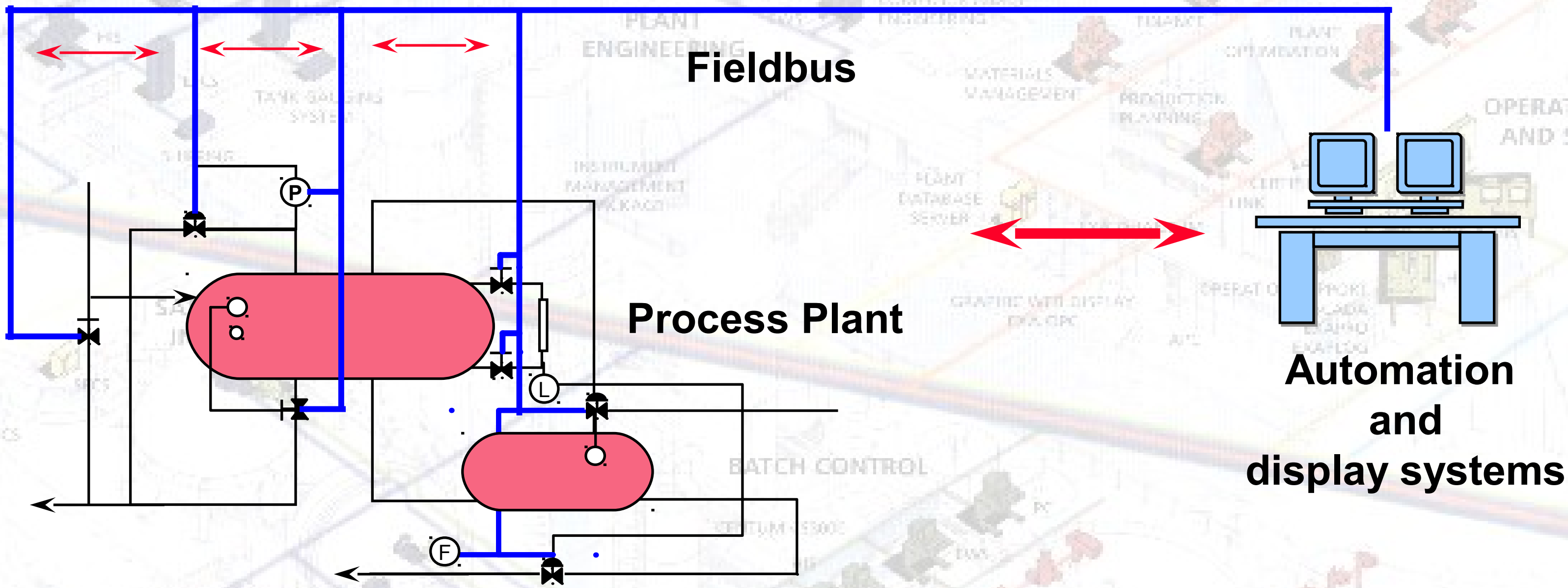
# Business environment leads to needs

- **Lower installation cost**
  - Multiple instruments on a single pair of wires
  - Faster commissioning - loop check
  - Multi-variable transmitters
- **Operational improvements**
  - More real time information “about” the process
  - Measurement validation - quality - safety
  - Tighter control by distribution of control functions
  - Mechanism for continuous innovation
- **Lower maintenance cost - predictive ...**
  - Remote access - unified tools
  - Advanced process and device diagnostics
  - Integrated plant asset management functions

# What is fieldbus




- Open, digital, bi-directional communications network
- Among field measurement and control devices and automation/display systems
- It replaces the traditional point-to-point connections



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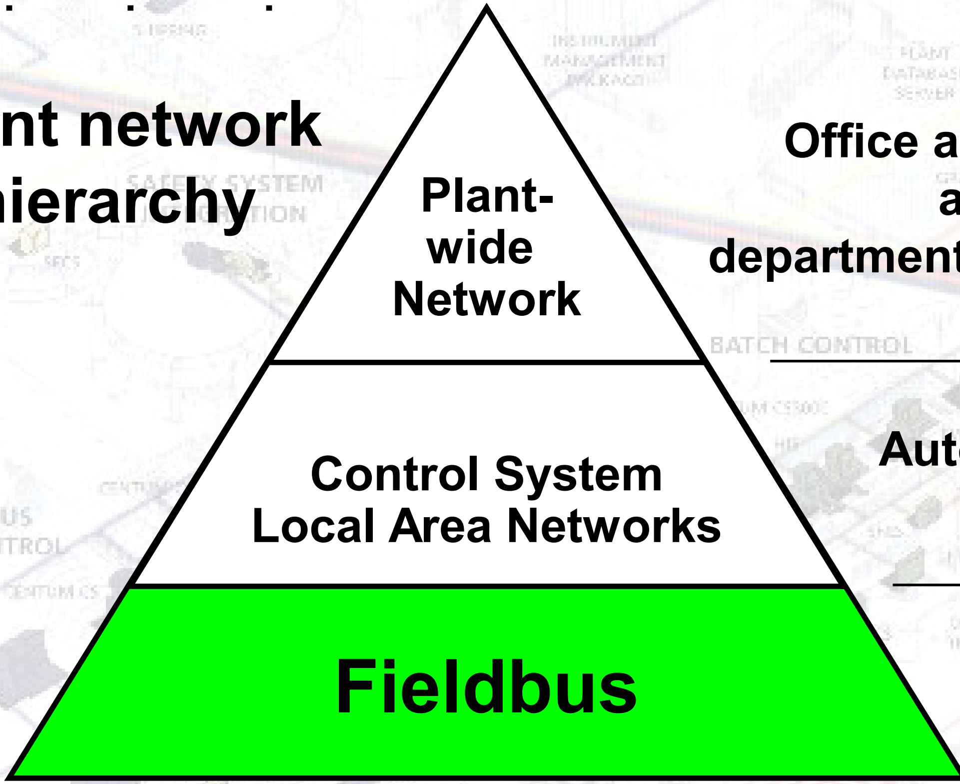
# Local Area Network for field instrumentation

**Plant network hierarchy**

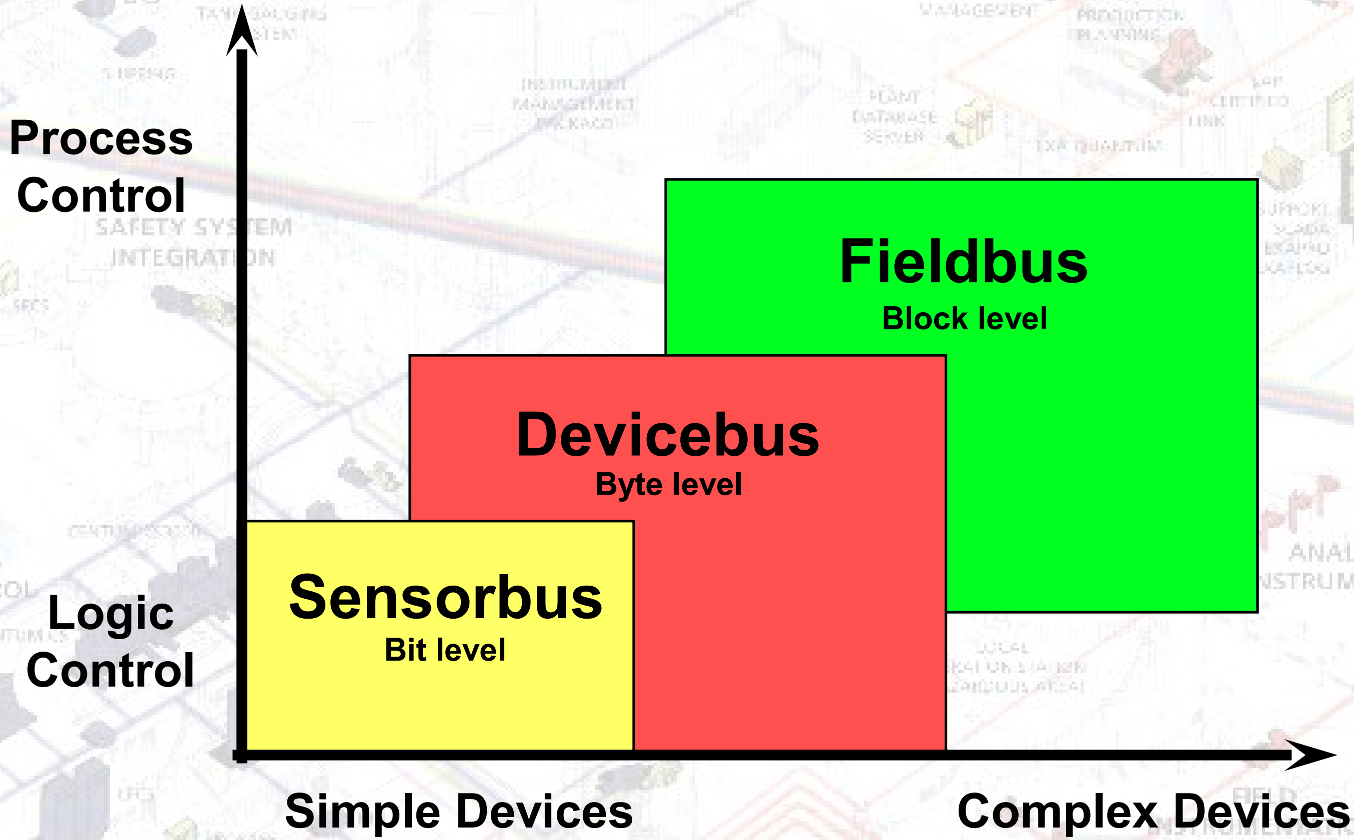



**Office automation and departmental computers**

**Automation and display systems**

**Network for field instrumentation**

# Networks for field devices - 3 types



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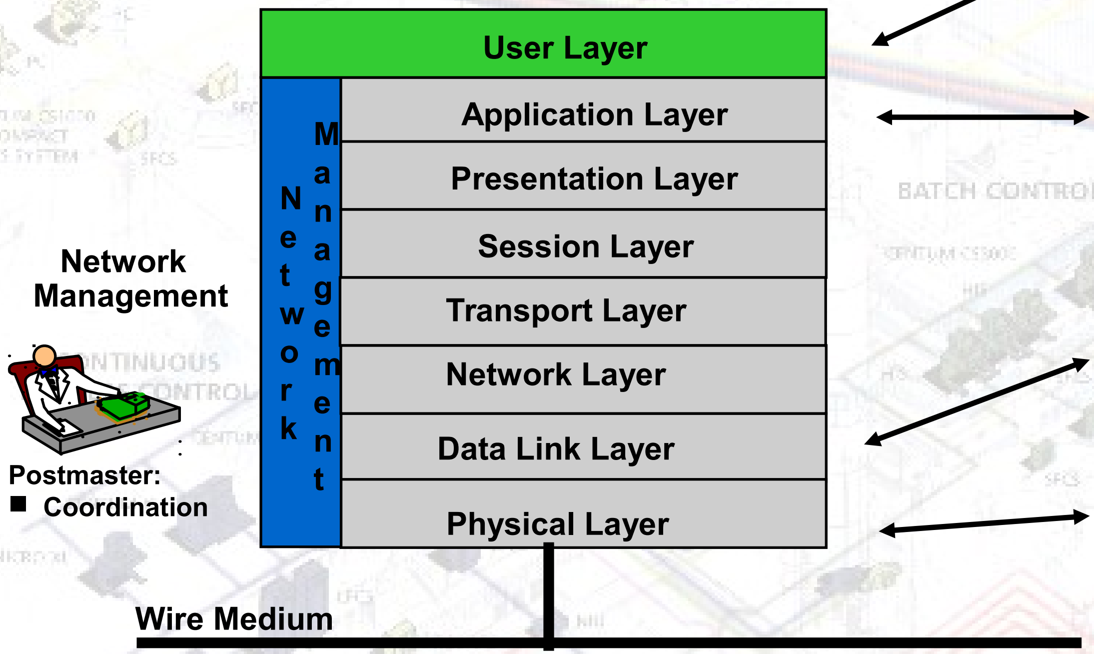
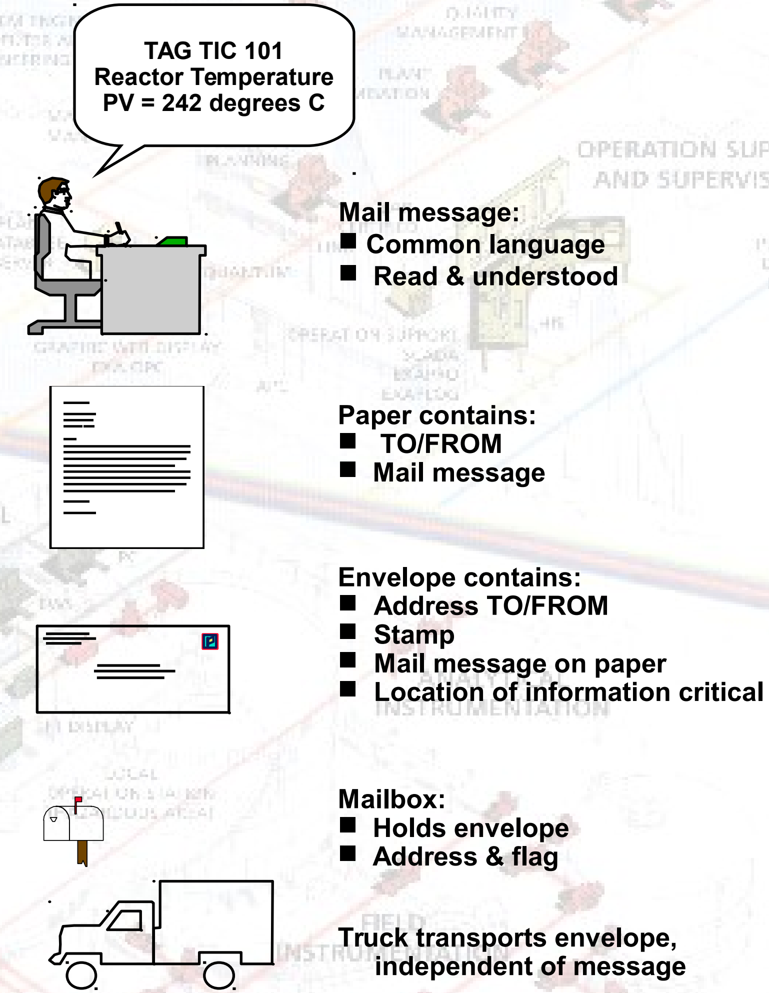
# The OSI model

- For meaningful communications between fieldbus devices and host systems a common language must be used



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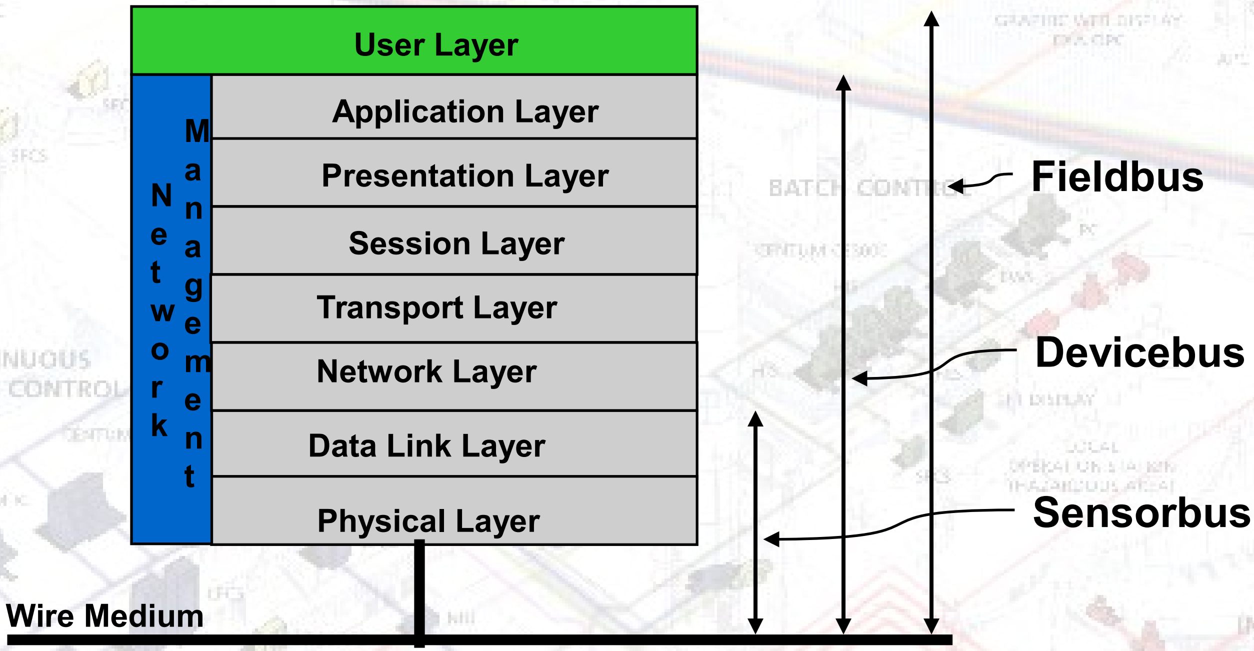
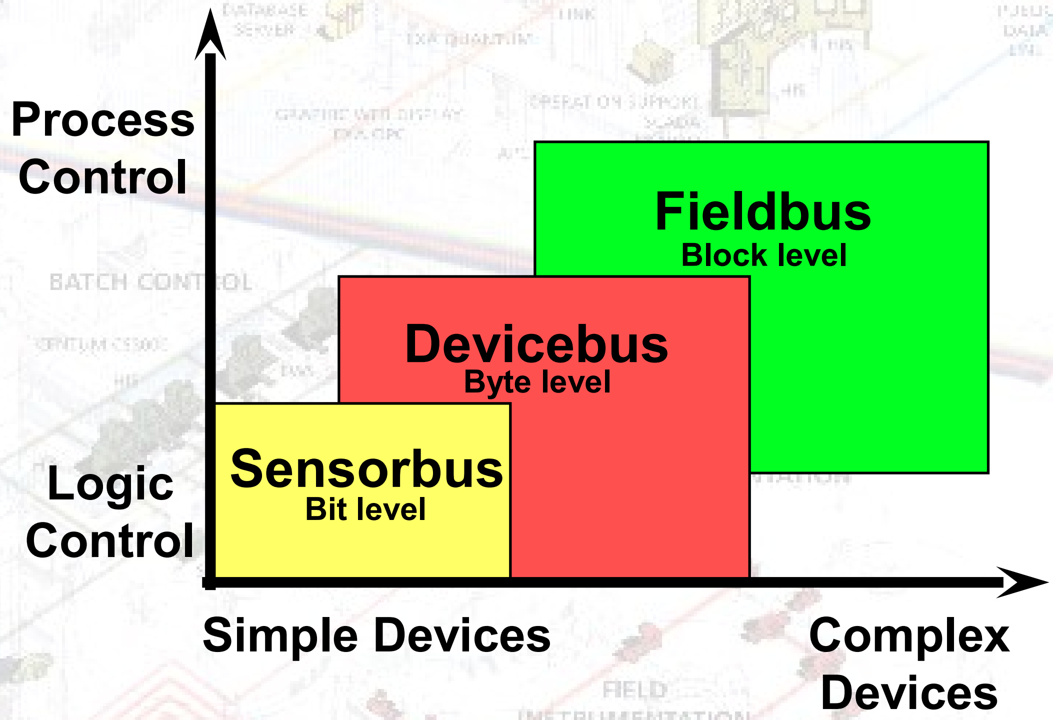
# The OSI model

- Layers 1-4 handle the communications between processors
- Layers 5-7 handle the communications between applications
- The user layer is not defined by the ISO-OSI model



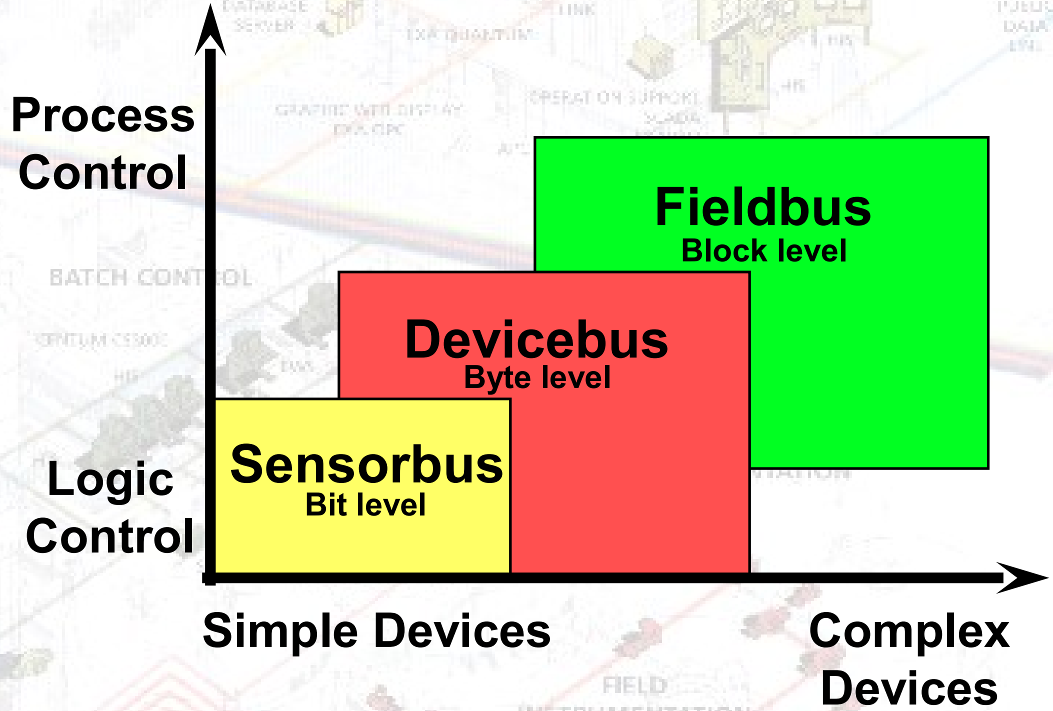
# Sensorbus - What is it?

- Simple, low cost implementation
- High speed, bit level communication
- Simple discrete devices
  - Push buttons
  - Limit switches
  - Optical sensors
- Implementations:
  - AS-i bus
  - Seriplex



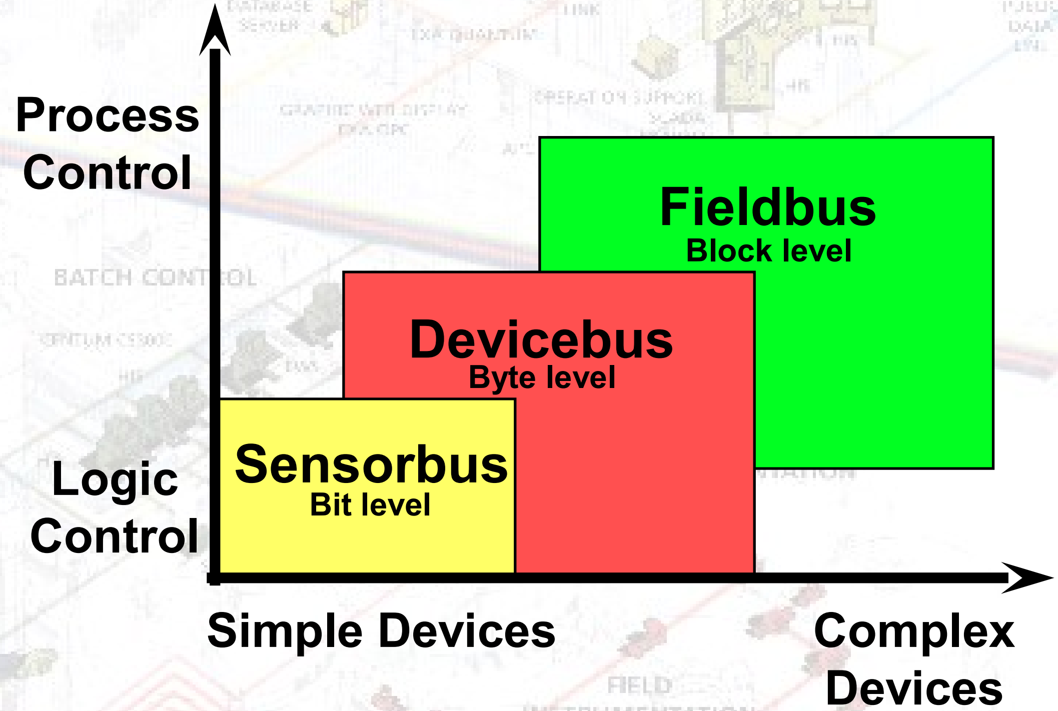
# Devicebus - What is it?

- High speed, byte-level communication
- Focus on Factory Automation
- More complex discrete devices
  - PLC and remote I/O sub-systems
  - Weighing systems
  - Electric drive sub-systems
- Implementations:
  - DeviceNet
  - Profibus DP



# Fieldbus - What is it?

- Digital replacement of analogue 4-20 mA signal
  - Unlocking advanced functionality
- Focus on Process Control
- Simultaneous power and signal on the bus - 2-wire
- Supports intrinsic safety
- Implementations:
  - Profibus PA
  - FOUNDATION™ Fieldbus



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# FOUNDATION™ Fieldbus
# How does it work?

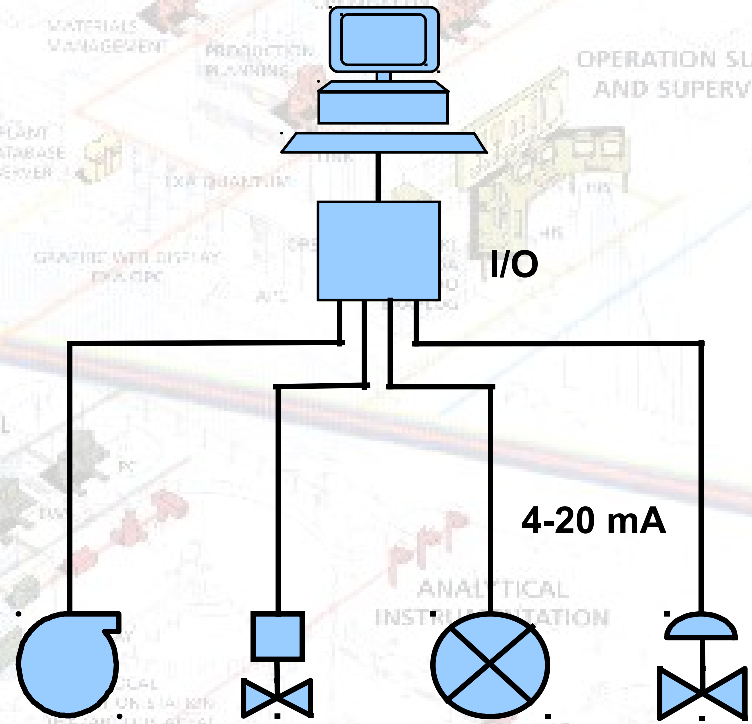
# Past - Traditional instrumentation

## Strengths

- OPEN, interoperable and interchangeable
- Broad range of equipment
- Multiple vendors
- Standard control system interfaces
- Standard support equipment

## Weaknesses

- Limited information transmitted
  - One variable, one direction
- Point-to-point wiring




Traditional analogue (4-20 mA)
and discrete instruments



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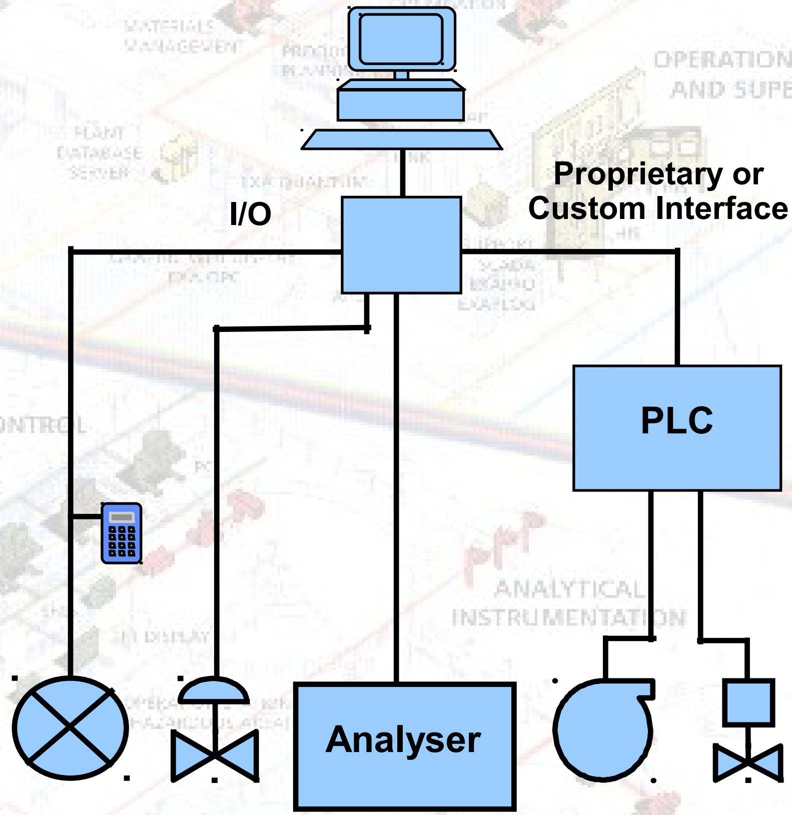
# Present - Hybrid instrumentation

**Strengths**

- More information transmitted
- Bi-directional communications
- Improved performance and availability
- Faster commissioning - ease of configuration
- Improved maintenance through on-line diagnostics

**Weaknesses**

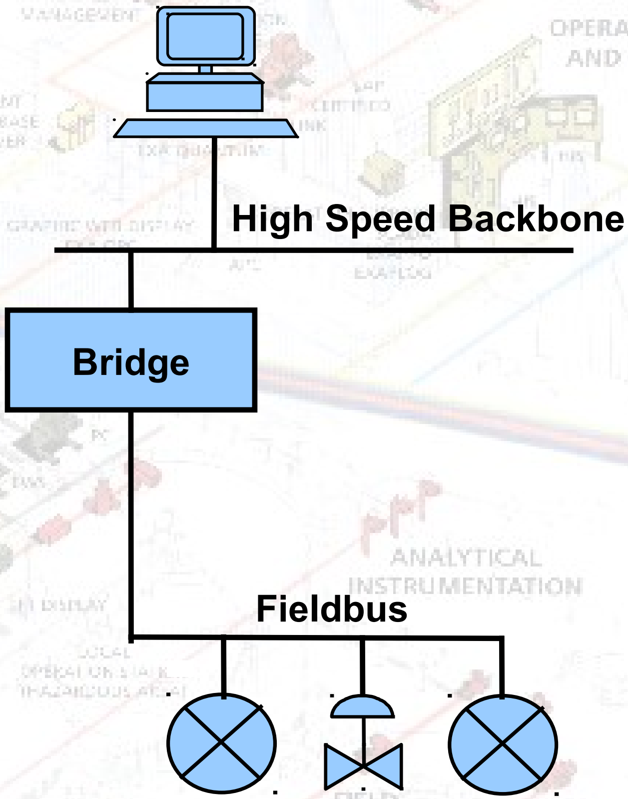
- Limited interoperability
- Manufacturer dependancy
- Lack practical multi-drop capability
- Requires special DCS interfaces




Hybrid Instruments or Intelligent Instruments with Custom Interfaces

# Fieldbus - Customer expectations

- Fieldbus is open and interoperable
  - Supports interchangeability
  - Supports various bus topologies
  - Supports control and automation functions
- Supported by multiple vendors
  - Broad range of equipment
- Standard control system interfaces
- Bi-directional communications
  - More information transmitted - alarm reporting
  - Improved performance and availability
  - Improved maintenance - on-line diagnostics
- Standard support equipment
  - Ease of configuration - single tool
  - Faster commissioning



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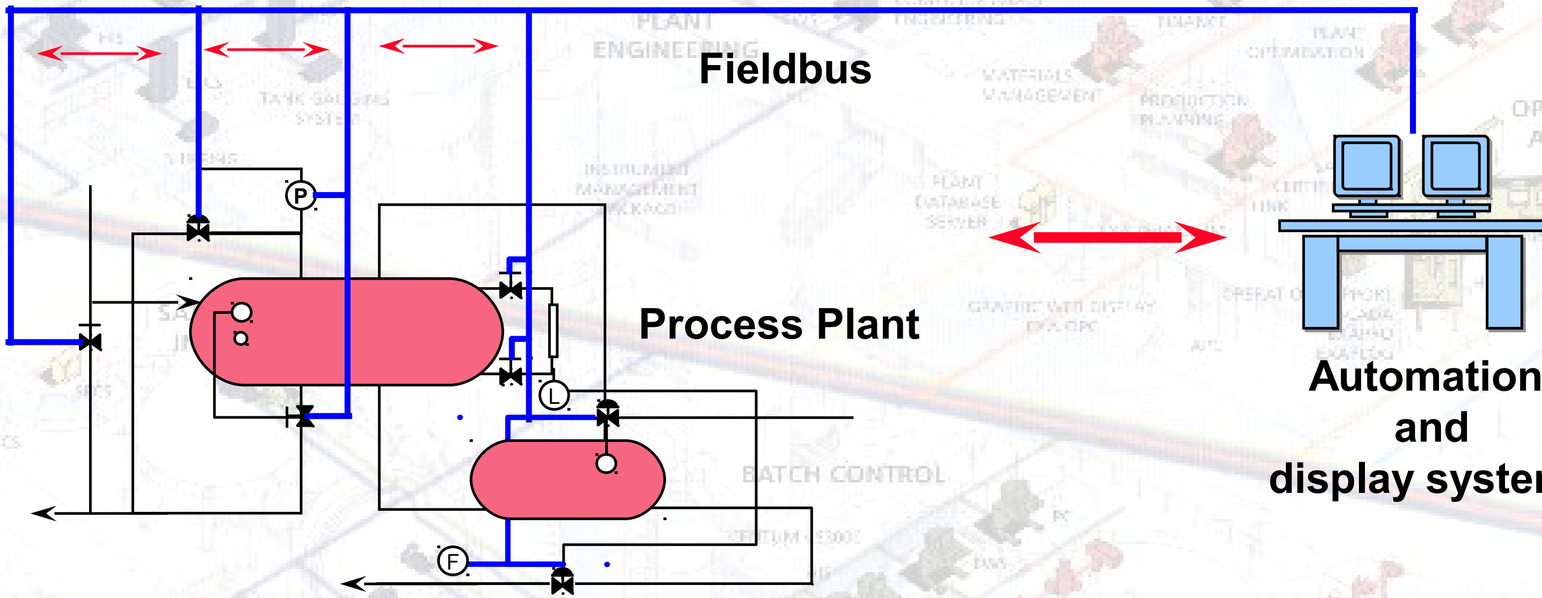
# FOUNDATION™ Fieldbus is an "Enabler"




- Designed for total plant automation - control and automation
- Vendor independent "Best in Class" solutions
- Innovation - seamless integration new device functionality



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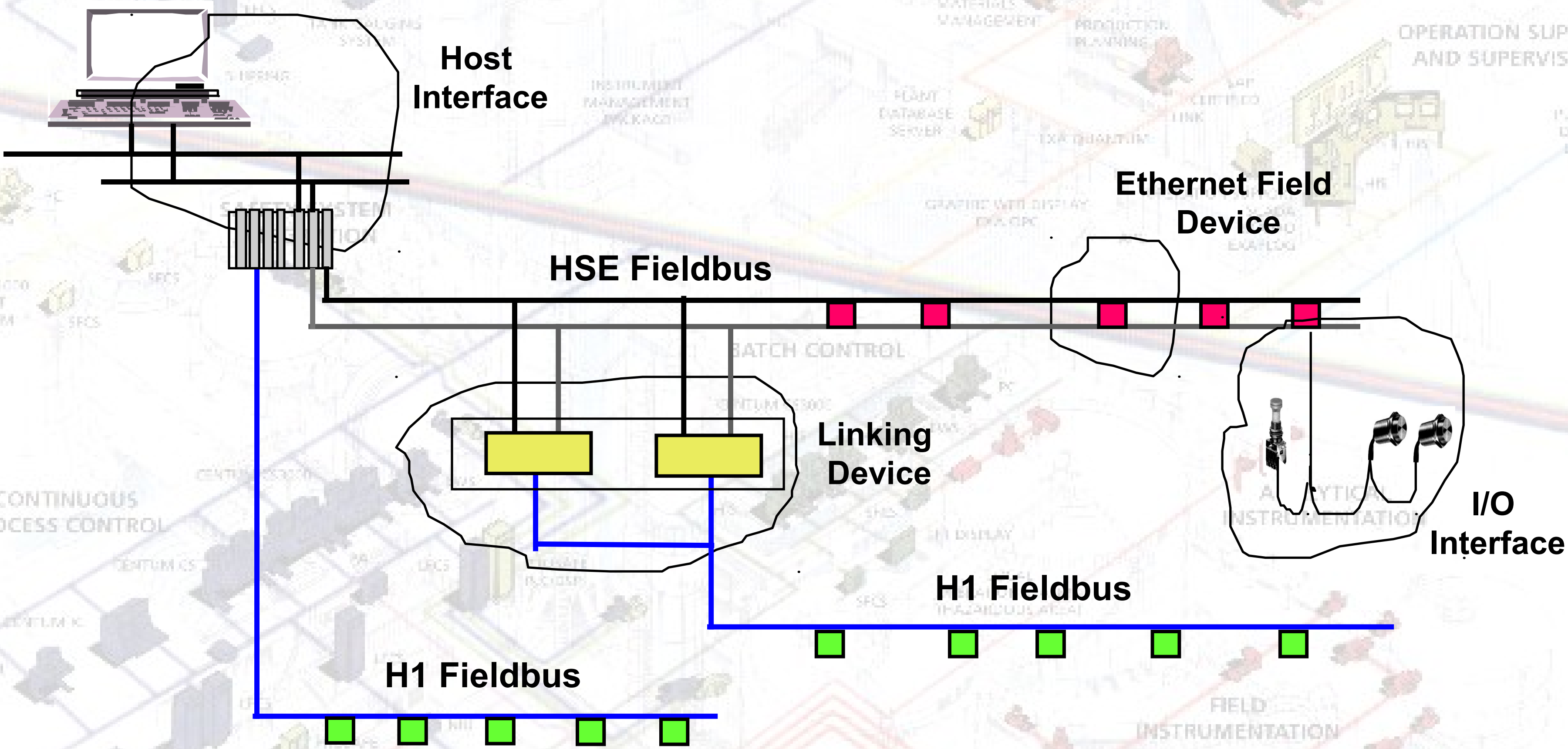
# FOUNDATION™ Fieldbus topology



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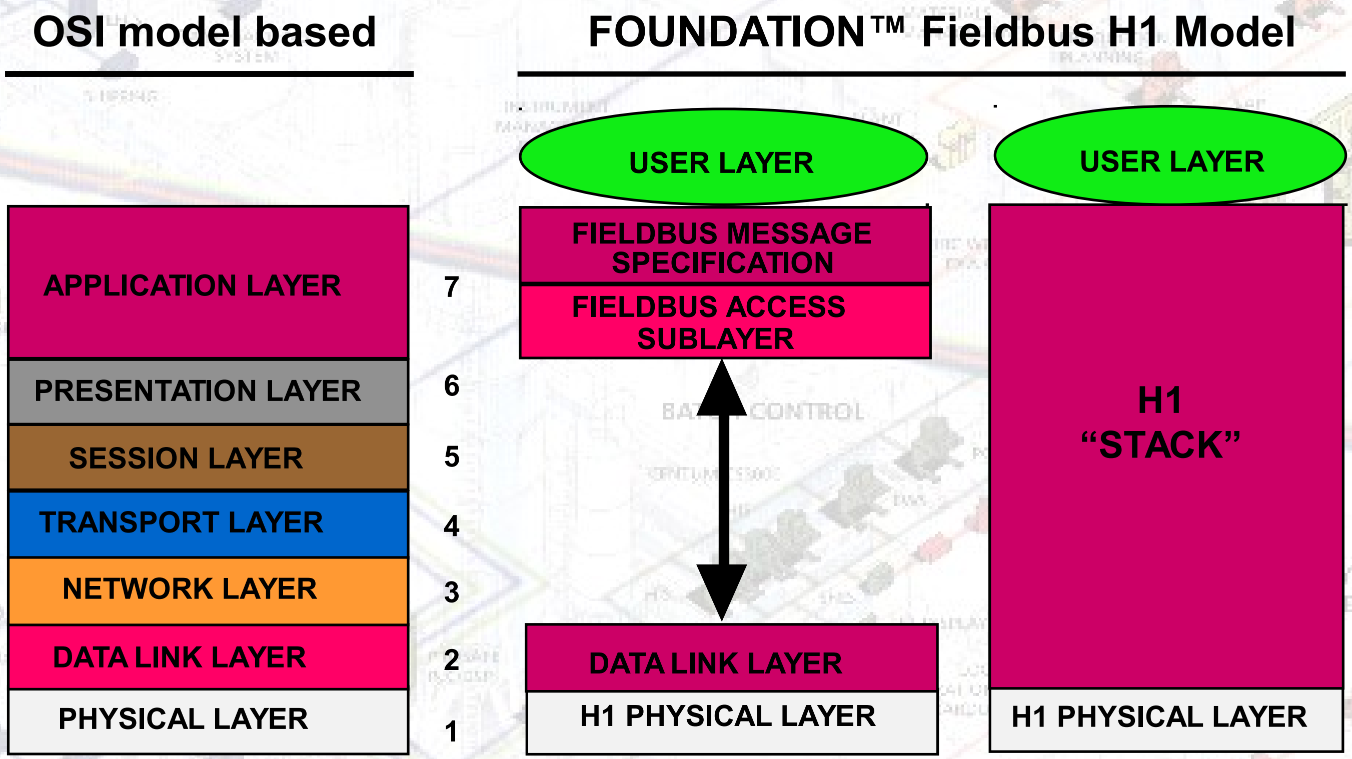
# The H1 FOUNDATION™ Fieldbus model




**The User Layer is not defined by the OSI Model**



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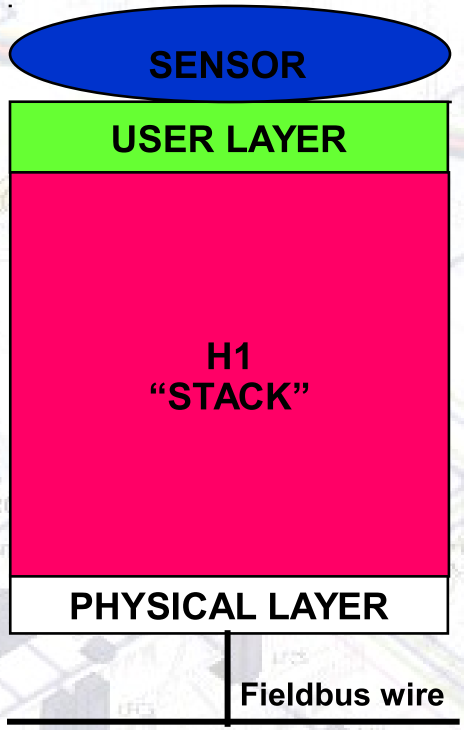
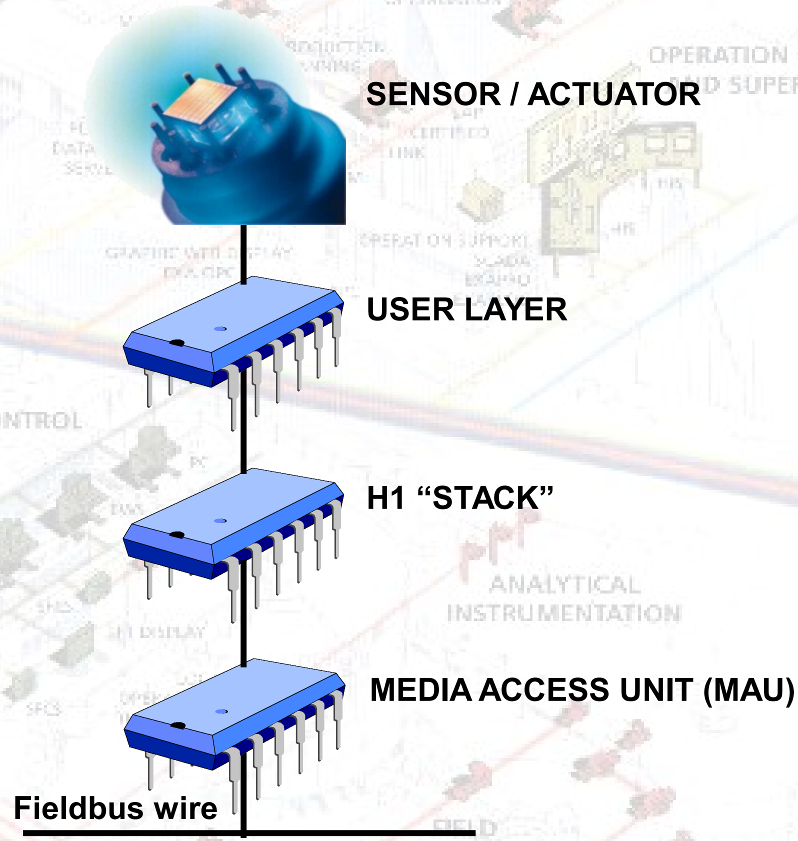
# H1 practical implementation



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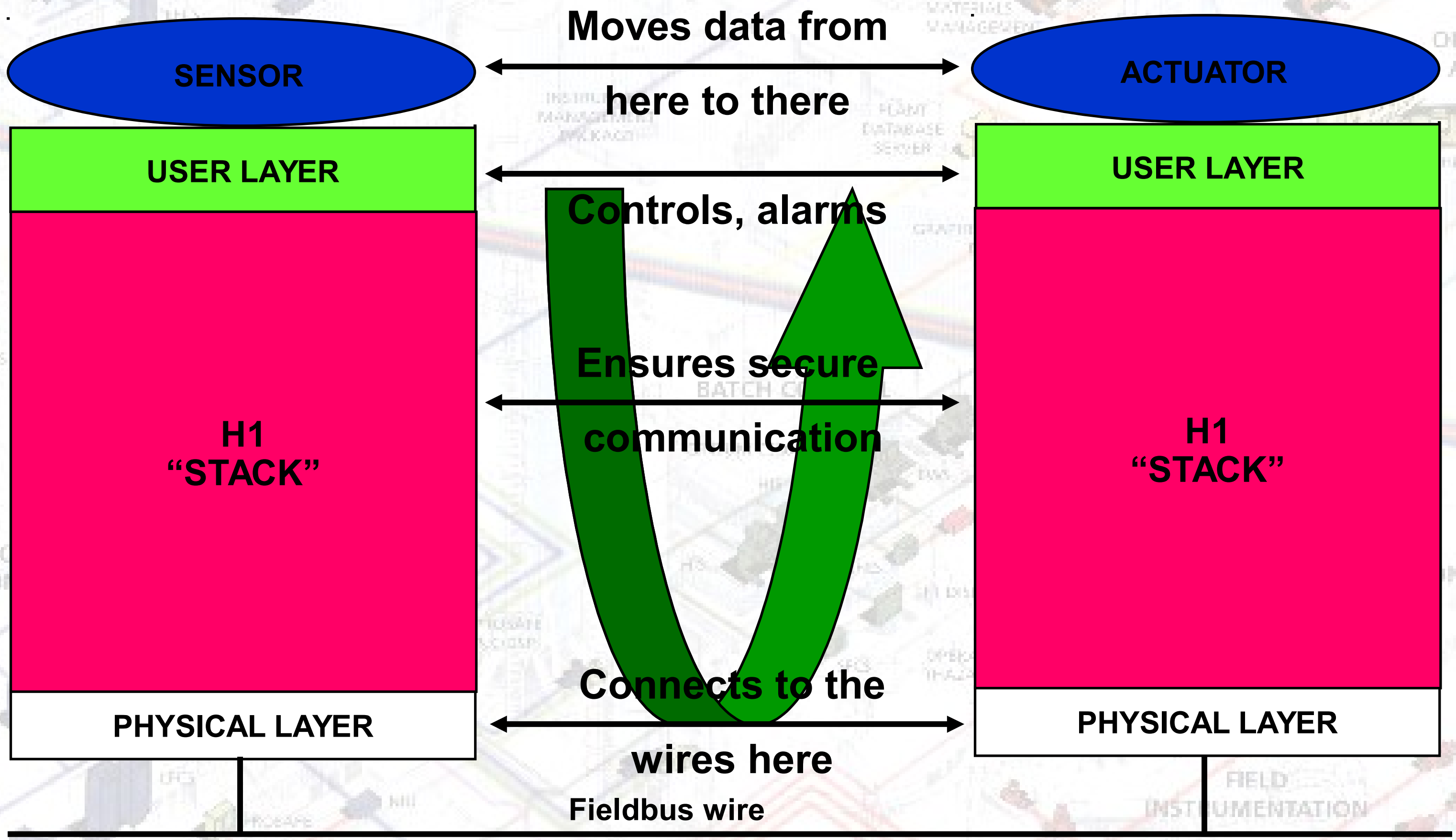
# What does FOUNDATION™ Fieldbus do?



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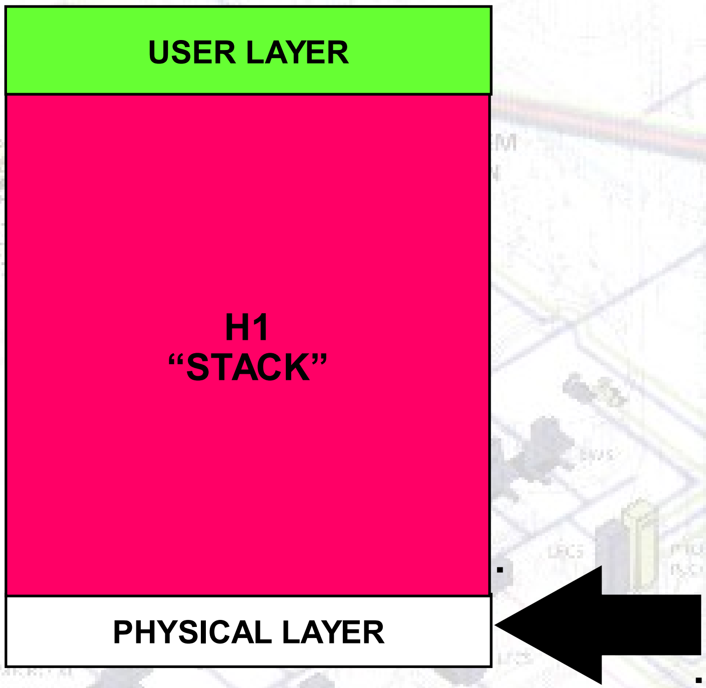
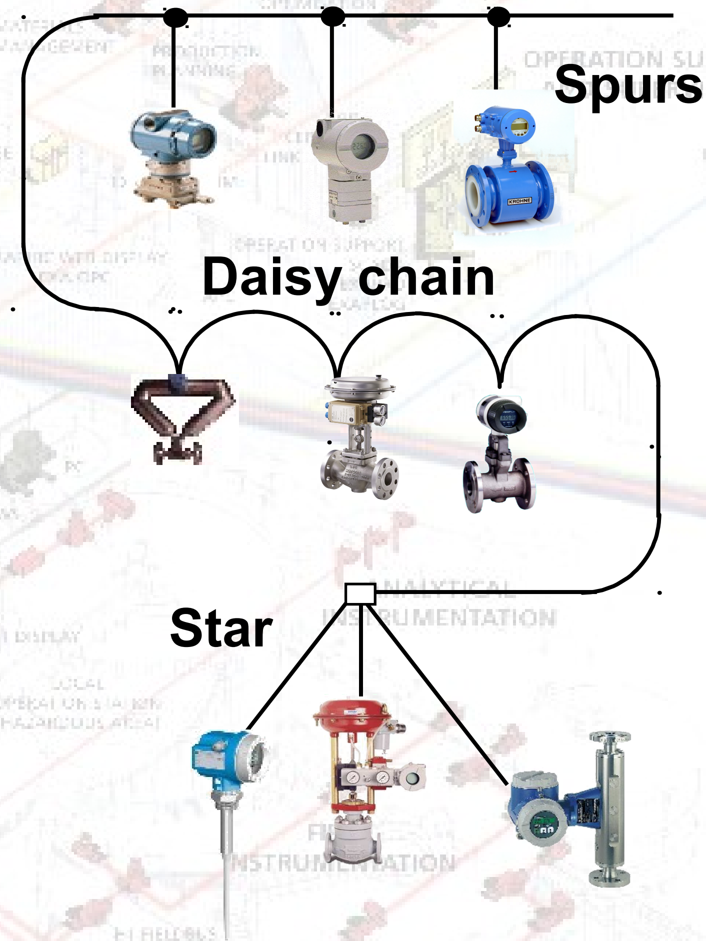
# H1 Physical Layer




- IEC 61158 compliant
- Converts data from the "Stack" to physical signals on the "fieldbus"
- Transmission is "Synchronous Serial"; the clock is encoded in the signal using Manchester coding
- Signalling rate is 31.25 kbits/sec
- Supports copper wire and optical fibres
- Supports Spur, Daisy chain and Chicken foot (star) bus topologies

# H1 Physical Layer topology

- Up to 32 devices per segment
  - Depends on several factors
- Uses (un-)shielded twisted pair cable
  - Can use existing field wiring
  - Fibre optic cable is optional
- Power down the bus
- Cable length up to 1900 m
  - Depends on cable quality
  - Up to 9500 m using repeaters
- Designed for intrinsic safety



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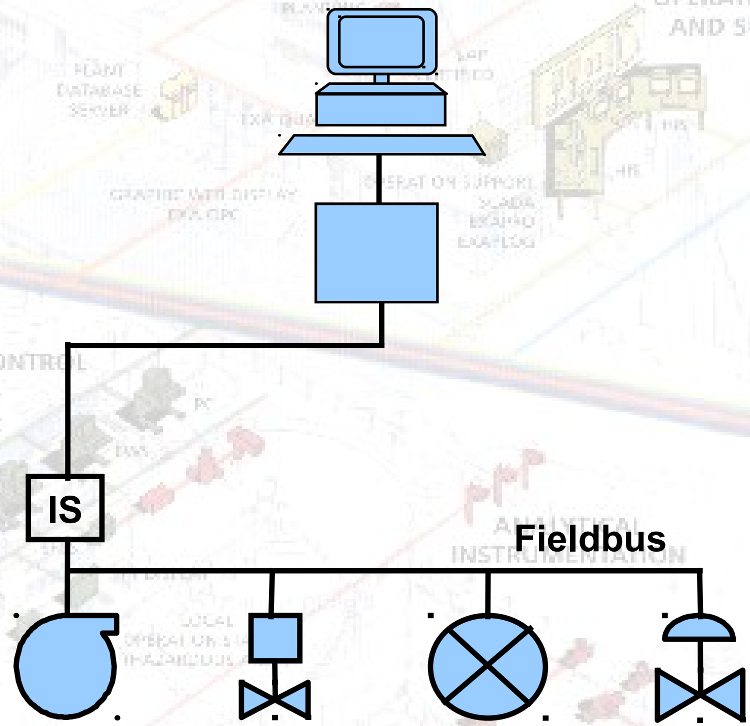
# Number of devices on a H1 segment

| | Local Power | Non I.S. | I.S. |
|---|---|---|---|
| Rate | 31.25 kbit/s | 31.25 kbit/s | 31.25 kbit/s |
| Mode | Voltage | Voltage | Voltage |
| Topology | Bus/Tree | Bus/Tree | Bus/Tree |
| Power Supply Separate | DC | DC | DC |
| Devices recommended | 2 - 32 | 2 - 12 | 2 - 6 |

**The maximum number of devices on a H1 fieldbus segment may be limited by the communication rates of the devices, the maximum number of addresses on a segment (240), or the available power.**

# Designed for intrinsic safety

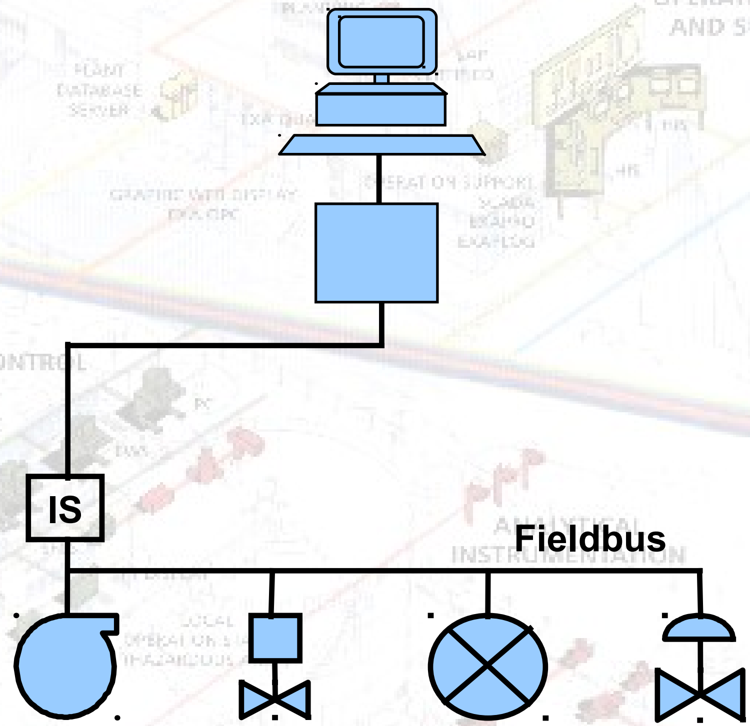
- Based upon “Entity” concept
- Bus power defined as 1.2 W max.
  - $U_S$= 10.6 V
- Current available (cable type A)
  - 60 mA on a 1900 m segment
  - 90 mA on a 400 m segment
  - Gas group IIB or IIC
- Typically 4 devices on a segment
- Multi-barrier concept available




One IS barrier, one pair for many devices

# Intrinsic safety - Future direction

- Based upon "FISCO" concept
- Bus power defined as
  - Gas group IIC - 1.9 W max.
  - Gas group IIB - 4.9 W max
  - $U_s$= 12.6 V
- Current available (cable type A)
  - 110 mA on a 750 m segment IIC
  - 200 mA on a 750 m segment IIB
- Typically:
  - 6 devices on a segment in IIC
  - 10 devices on a segment in IIB
- Multi-barrier concept available



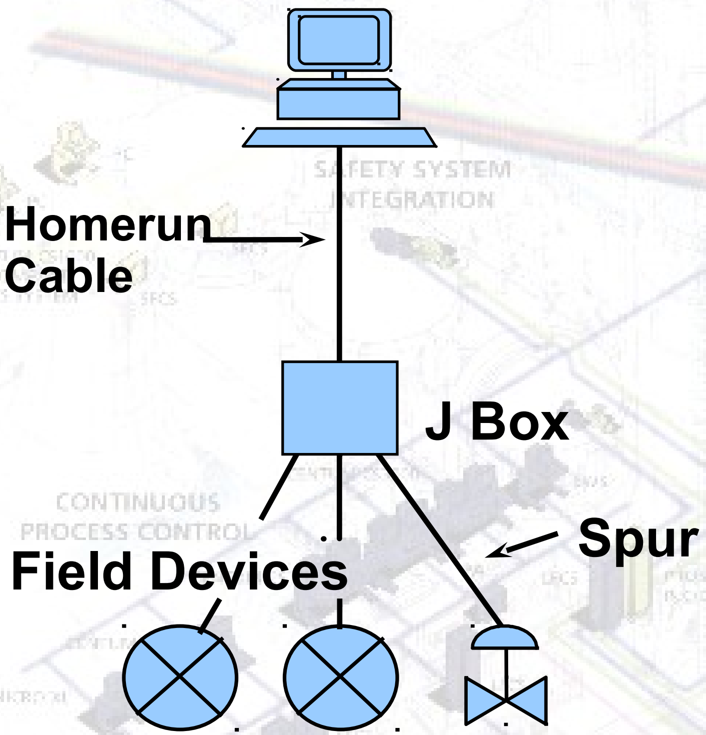

One IS barrier, one pair for many devices

# Cable type versus segment length

| Cable Type | Gauge No. | Max. Length |
|---|---|---|
| **A: Twisted-pair with Shield** | | |
| H1 (31.25 kbit/s) | #18AWG | 1900 m |
| **B: Multi-twisted-pair with Shield** | | |
| H1 (31.25 kbit/s) | #22AWG | 1200 m |
| **C: Twisted-pair without Shield** | | |
| H1 (31.25 kbit/s) | #22AWG | 400 m |
| **D: Multi-core without Shield** | | |
| H1 (31.25 kbit/s) | #16AWG | 200 m |

**Any existing, good quality #18 AWG twisted pair cable can be used for fieldbus.**

# H1 cable length calculation




| Cable type | H1 total length * |
|---|---|
| A | 1900 m |
| B | 1200 m |
| C | 400 m |
| D | 200 m |

* Total length including all spurs

| # of devices | Total max Spur length ** |
|---|---|
| 25 - 32 | 1 m |
| 19 - 24 | 30 m |
| 15 - 18 | 60 m |
| 13 - 14 | 90 m |
| 2 - 12 | 120 m |

** Maximum length of any spur



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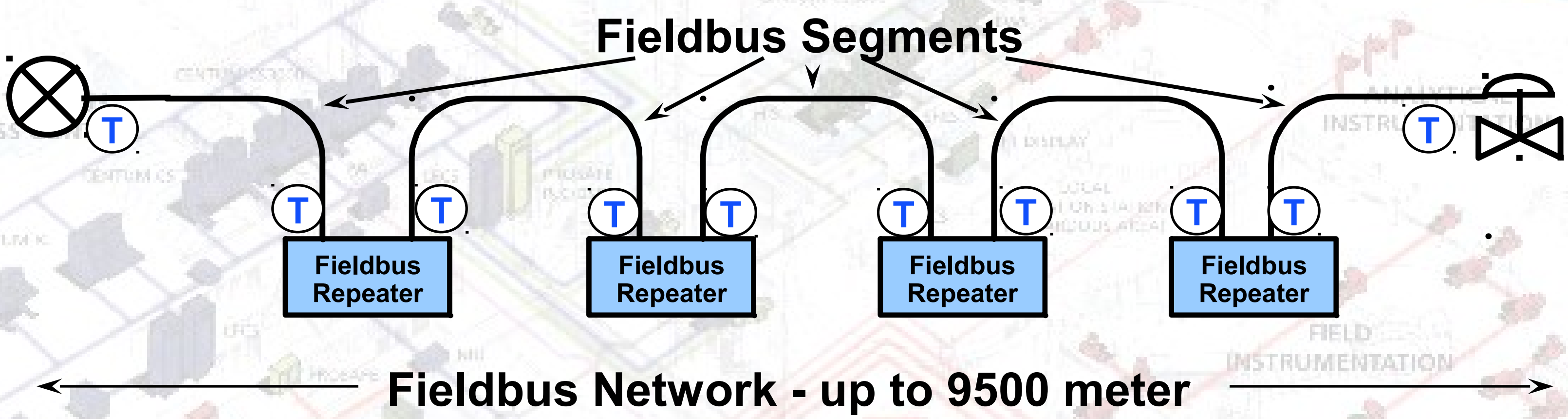
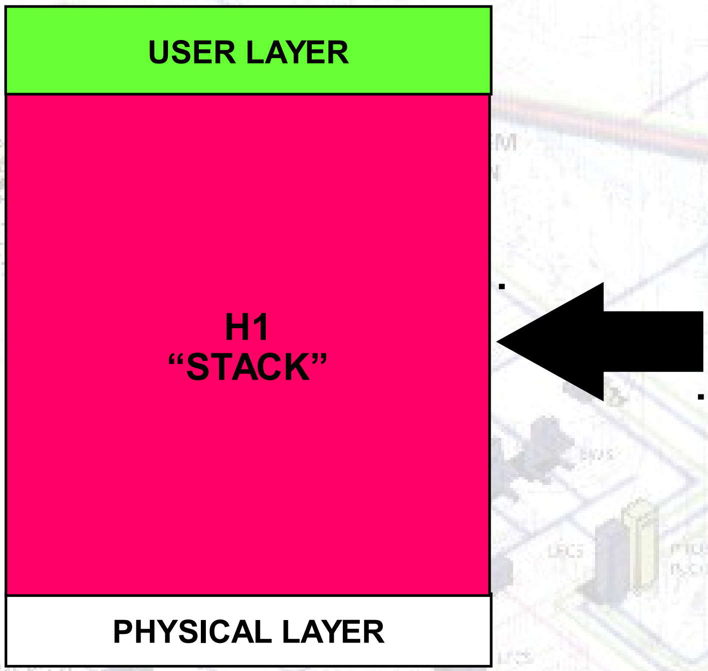
# Extending the length of a H1 segment

- **Repeaters are used to extend the length of a segment**
  - **A repeater is an active device**

- **Up to 4 repeaters can be used on a segment**
  - **Maximum distance between any two devices on the network is 9500 meters**

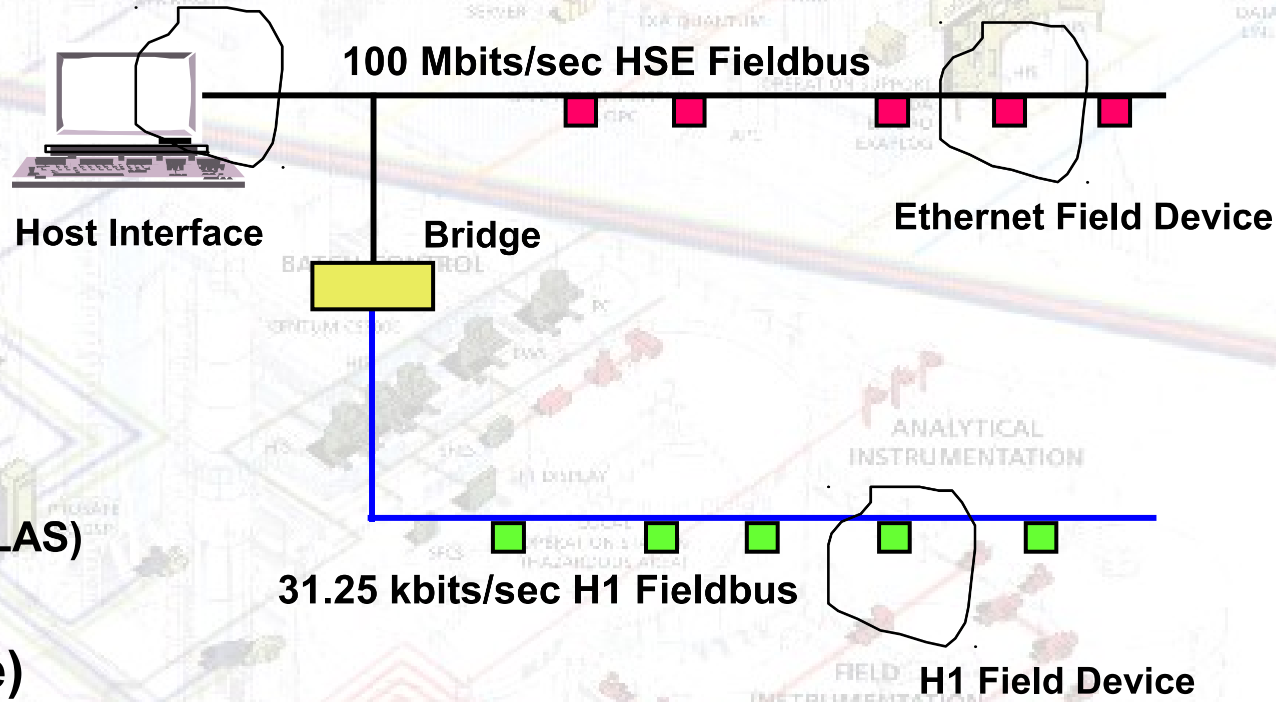


# H1 communication stack




- IEC 61158 compliant
  - Data Link Layer (DLL)
  - Application Layer (AL)
- Establishes basic communication services between fieldbus devices
  - Encoding and decoding of User Layer messages
  - Deterministic control of message transmission
  - Efficient and secure message transfer
  - Supports scheduled messaging for time critical communication (Publisher/Subscriber)
  - Supports unscheduled messaging for request/response communication (Client/Server)
  - Supports unscheduled messaging for Event Notification (multicast)
  - Publishes the “time” on the bus

# H1 device types




- Basic device
- Link Master device
  - Link Active Scheduler (LAS)
- Linking device (Bridge)



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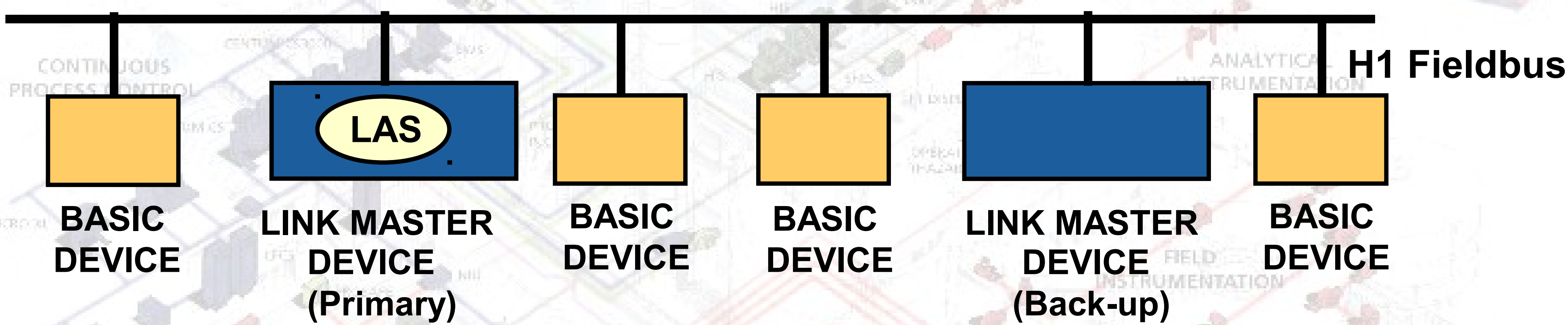
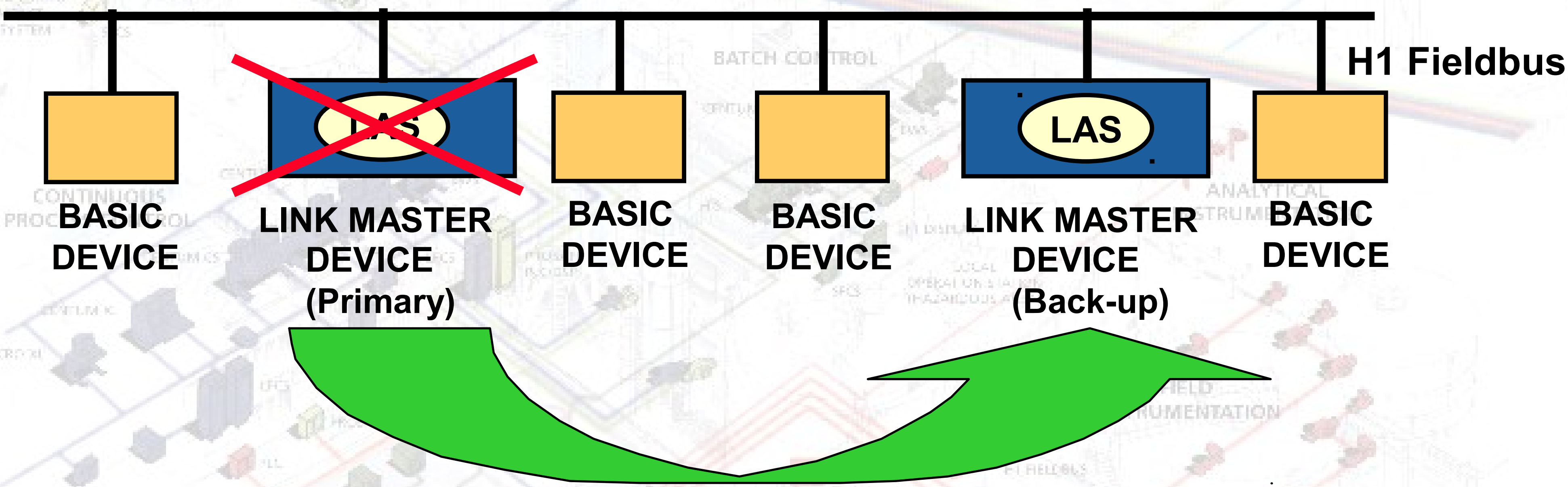
# H1 Link Master - Link Active Scheduler (LAS)

- Link Active Scheduler controls communication on the bus
  - A device may send packets of information when permitted by the LAS
- Maintains a list of all devices on the segment - “Live List”
- Distributes time to all devices on the segment



# H1 Link Master redundancy - Back-up

- LAS function transferred when primary Link Mater fails!



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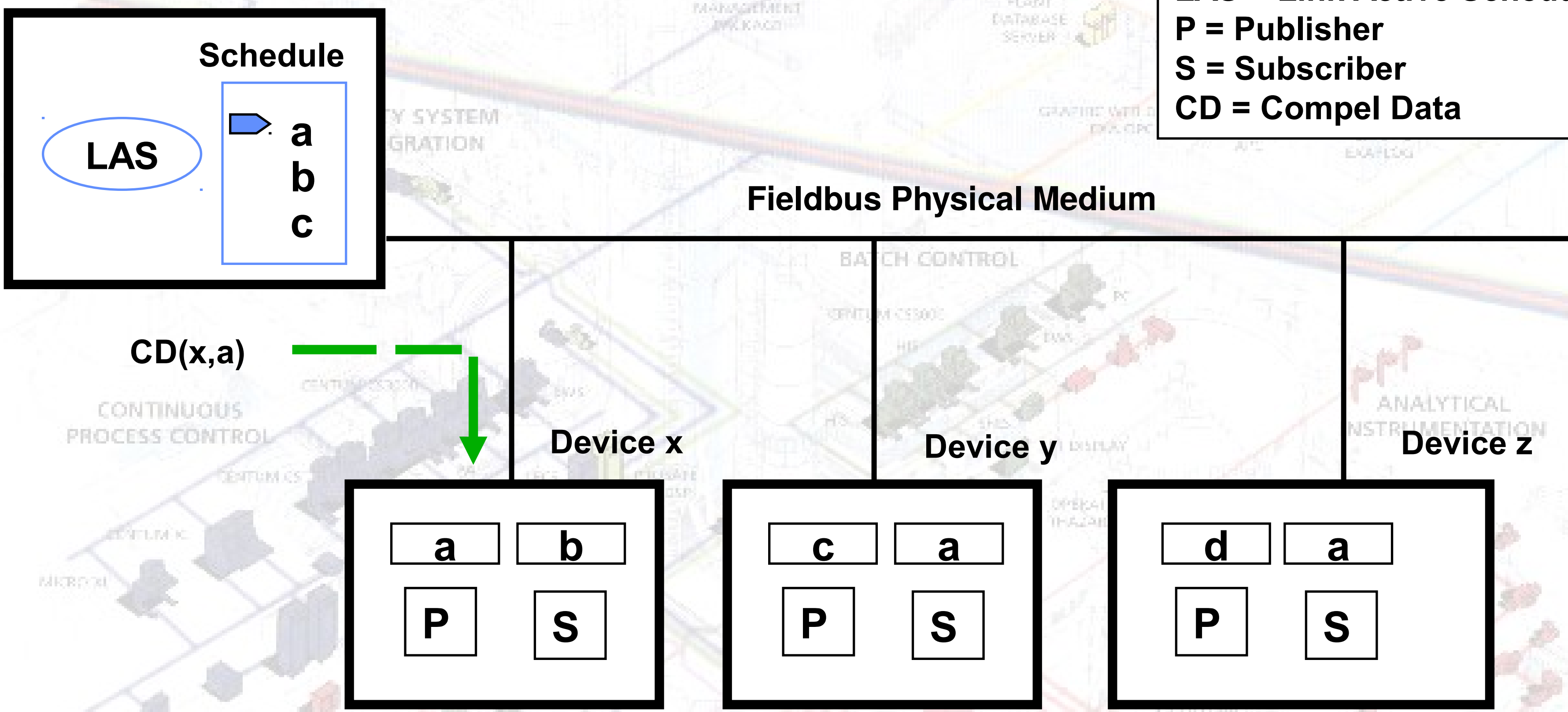
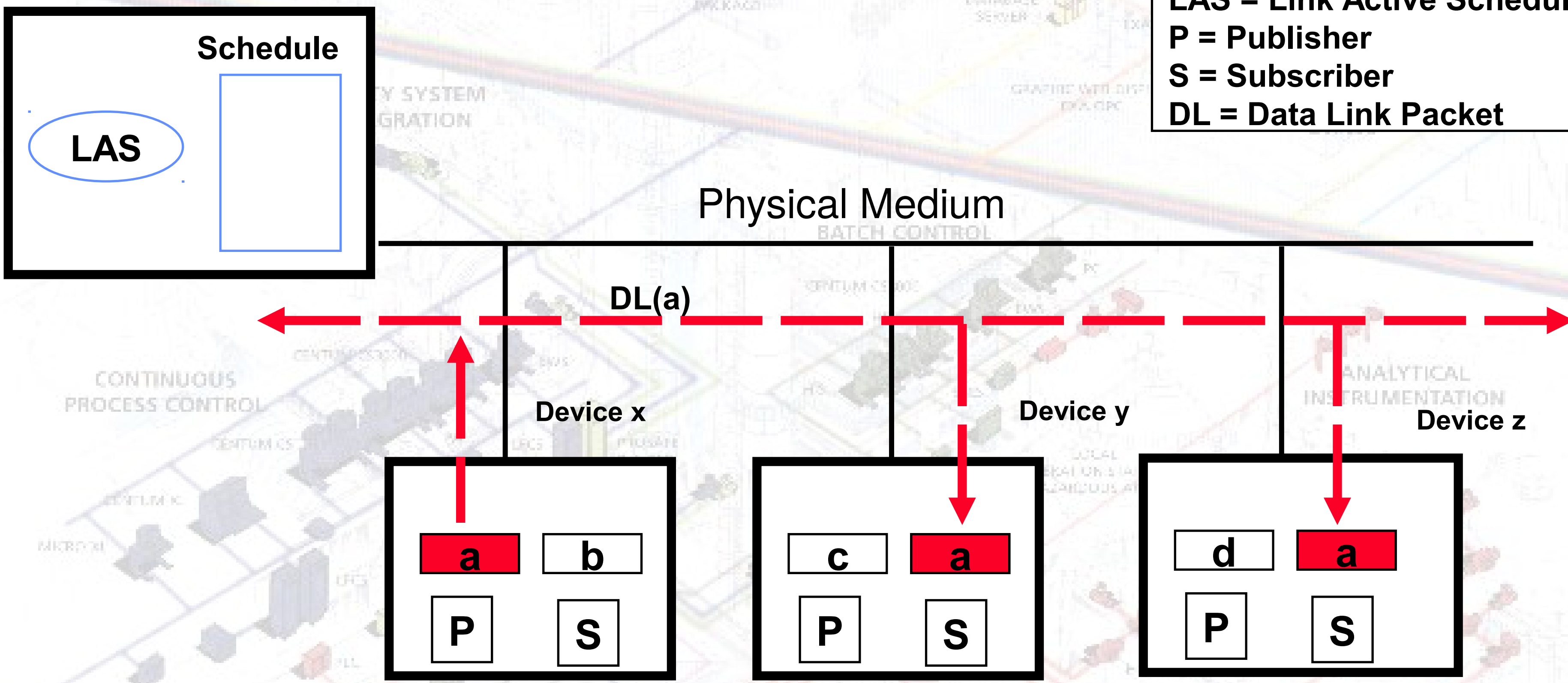
# Scheduled data transfer - step 1

LAS = Link Active Scheduler
P = Publisher
S = Subscriber
CD = Compel Data



# Scheduled data transfer - step 2

LAS = Link Active Scheduler
P = Publisher
S = Subscriber
DL = Data Link Packet



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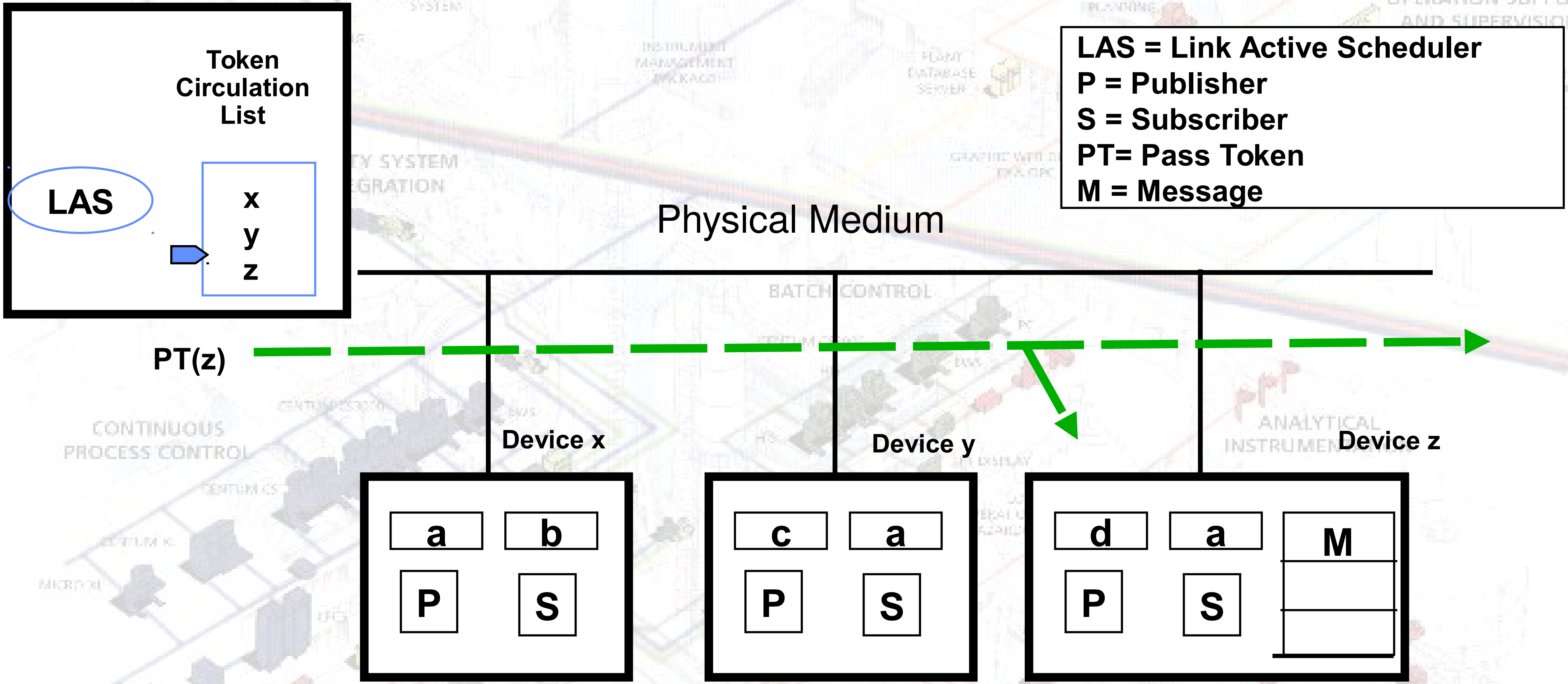
# Unscheduled data transfer step 1



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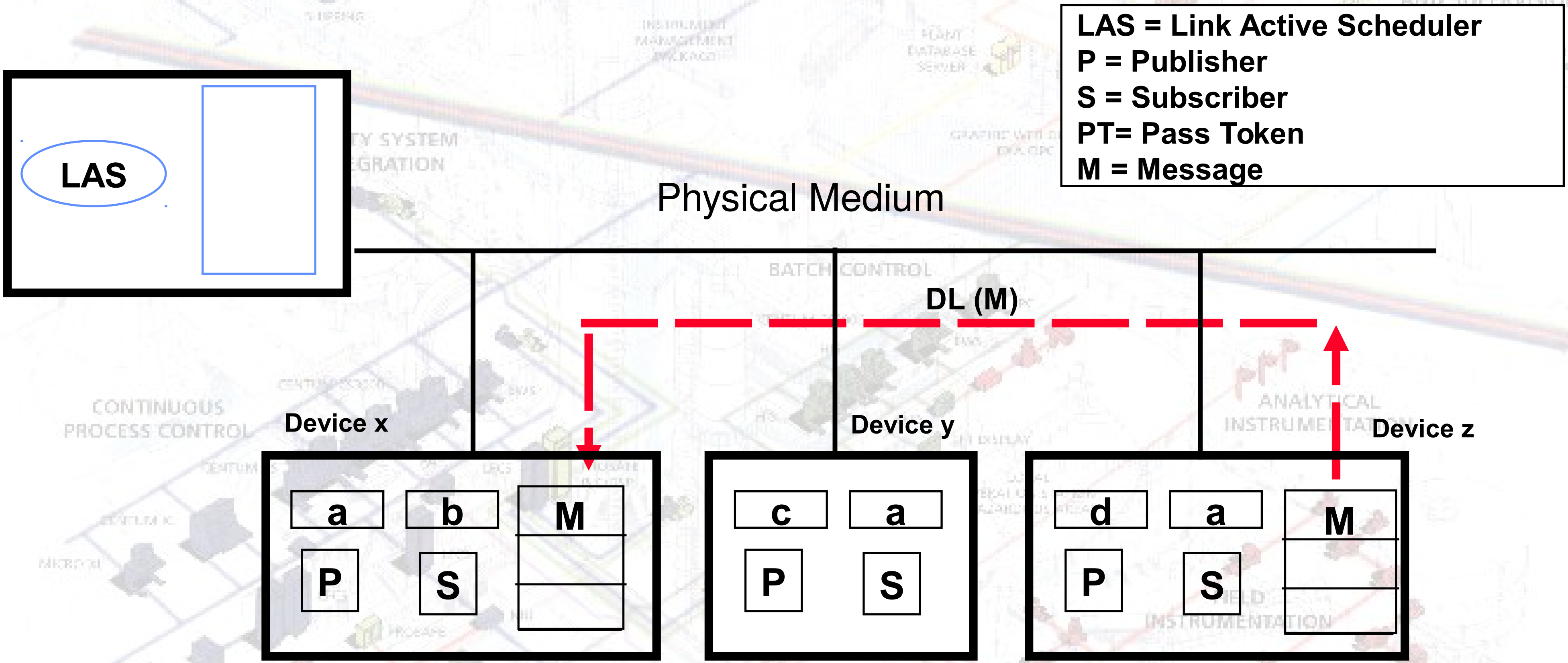
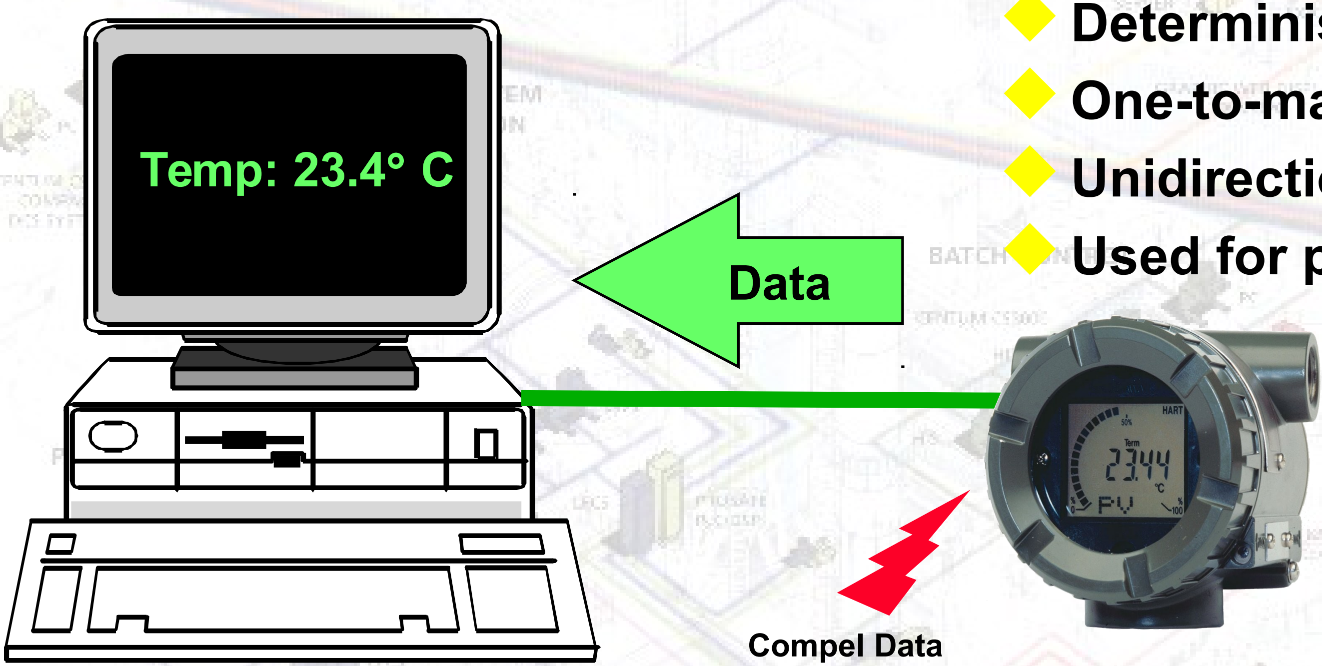
# Unscheduled data transfer step 2



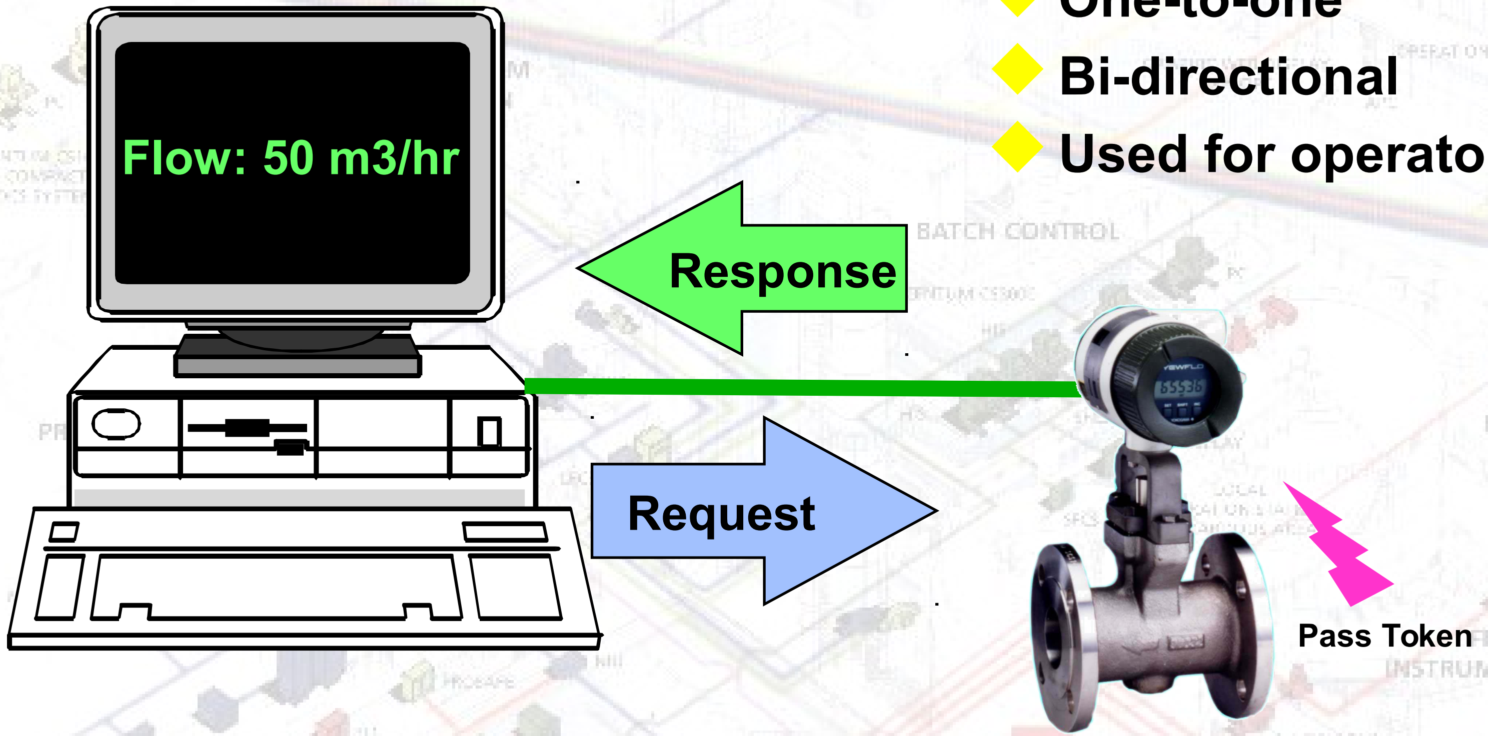
# Publisher/Subscriber

- Synchronous data transfer
- Network scheduled
- Deterministic - control
- One-to-many
- Unidirectional
- Used for publishing data



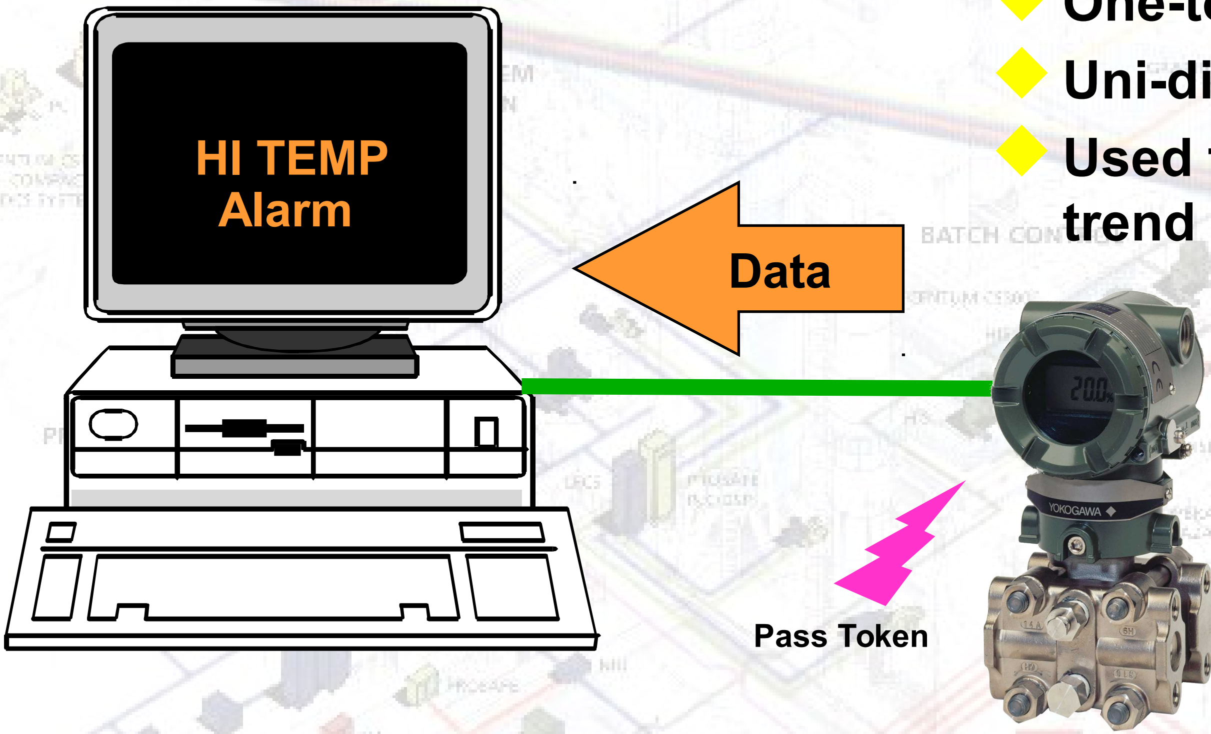
# Client/Server

- Asynchronous data transfer
- Unscheduled
- One-to-one
- Bi-directional
- Used for operator messages



# Event notification

- Asynchronous data transfer
- Unscheduled
- One-to-many
- Uni-directional
- Used for event notification and trend reports



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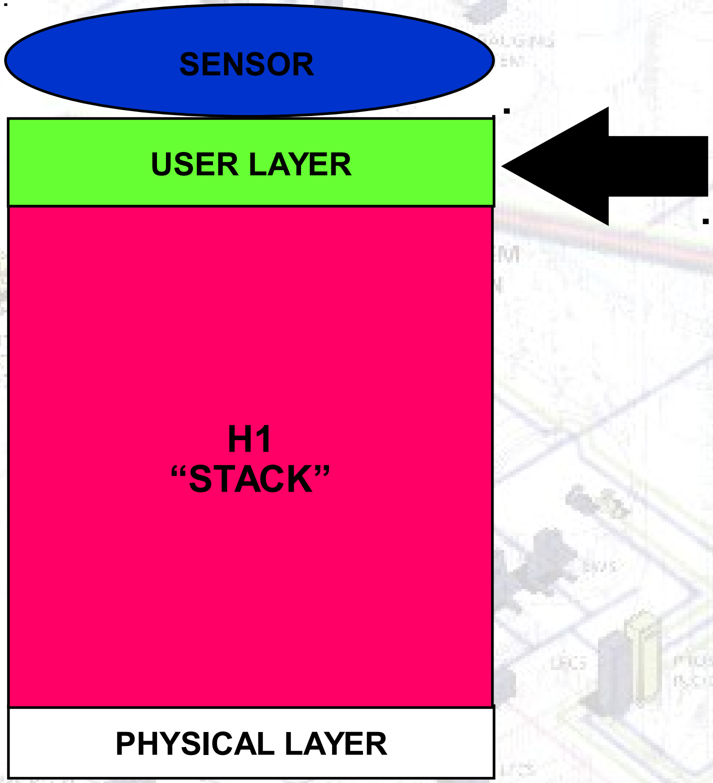
# H1 User Layer - Unique differentiator




- **Provides the interface with the process**
  - **and for user interaction with the host system**
- **Standard Function Blocks**
  - **Consistent definition of data for integrated and seamless distribution of functions in field devices from different manufacturers**
- **System Management**
  - **Deterministic scheduling of function blocks**
- **Device descriptions**
  - **Host system to operate the device without the need for custom programming**
- **Common File Format**
  - **Off-line “system” configuration by host system**

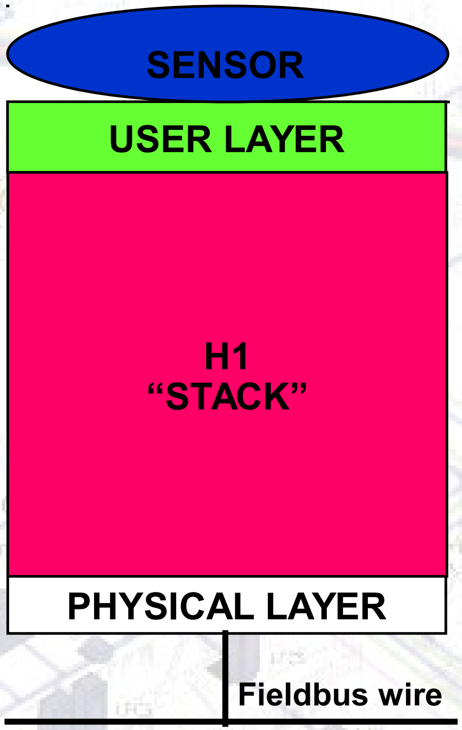
# Minimum 3 blocks reside in a device

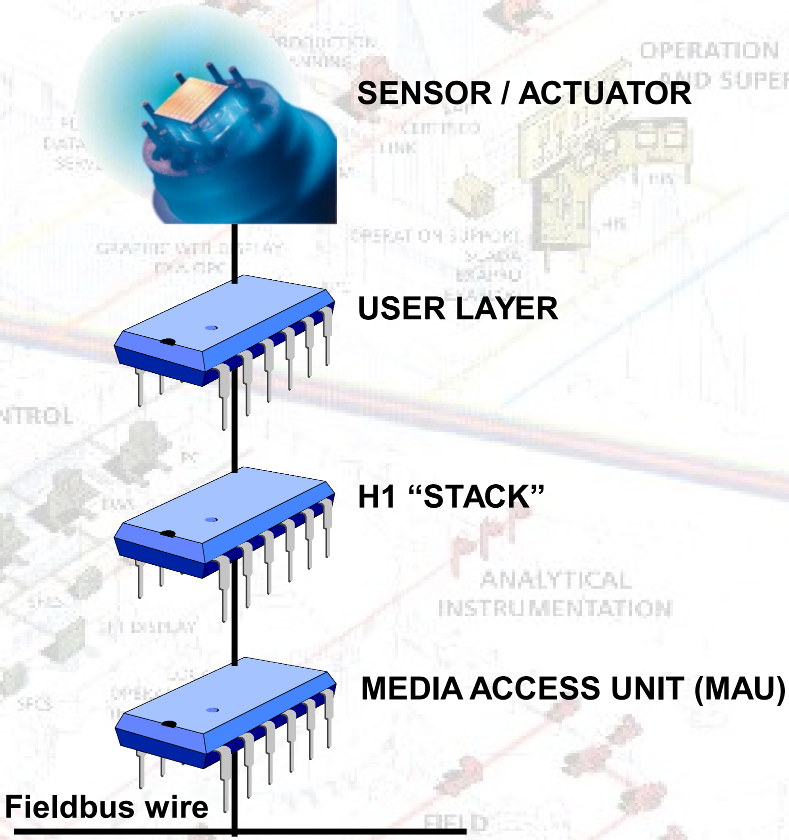
- **The Resource Block**
  - Describes the characteristics of a device
  - Contains manufacturer information

- **The Transducer Block**
  - Physical I/O interface with the actual sensor or actuator
  - Performs A/D conversions, square root extraction, linearisation etc.
  - Transmits/receives information to/from Function Blocks
  - The Transducer Block is the window to the process - diagnostics

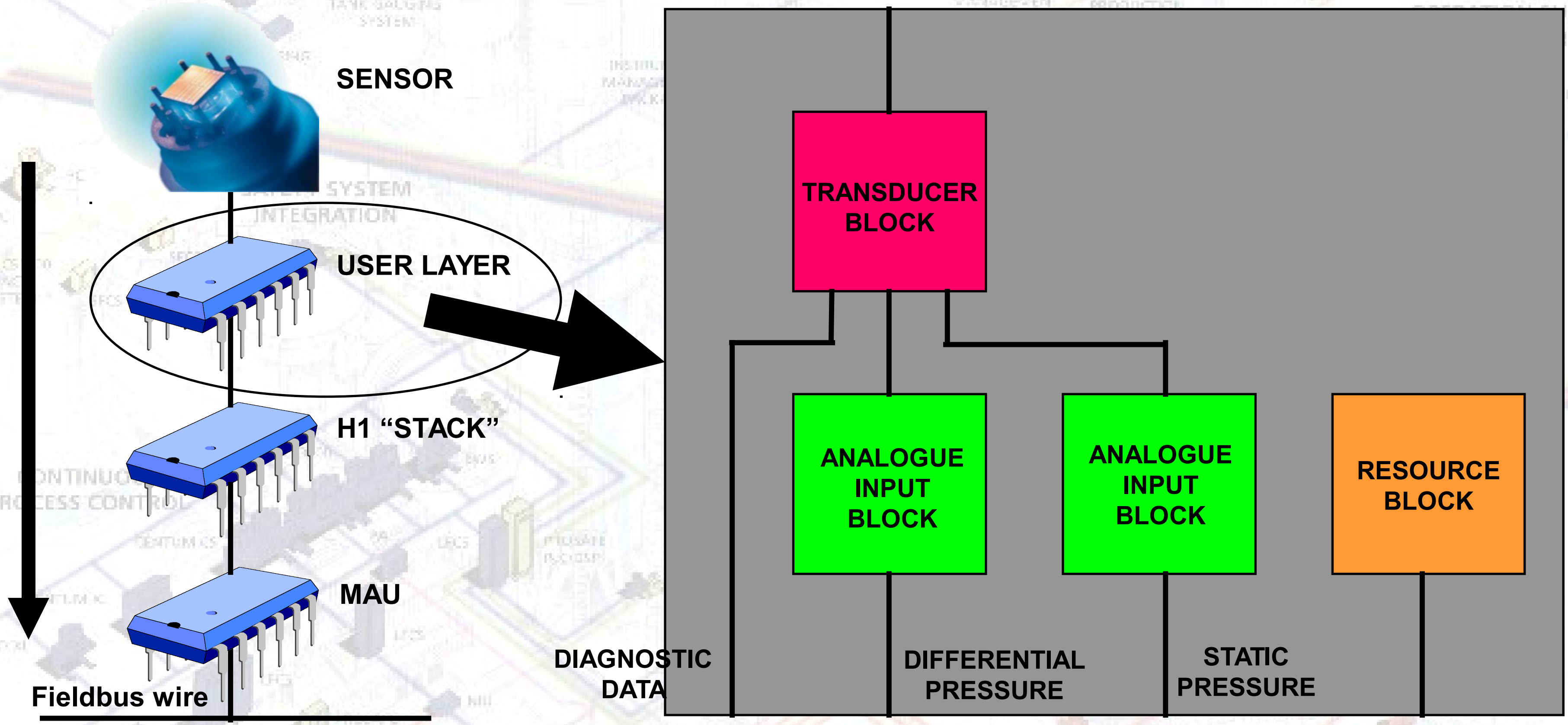
- **Function Blocks**
  - Similar to the function blocks in today's DCS and PLC systems
  - Mandatory is at least one Function Block depending on the type of device

# H1 practical implementation



# Differential pressure transmitter - example



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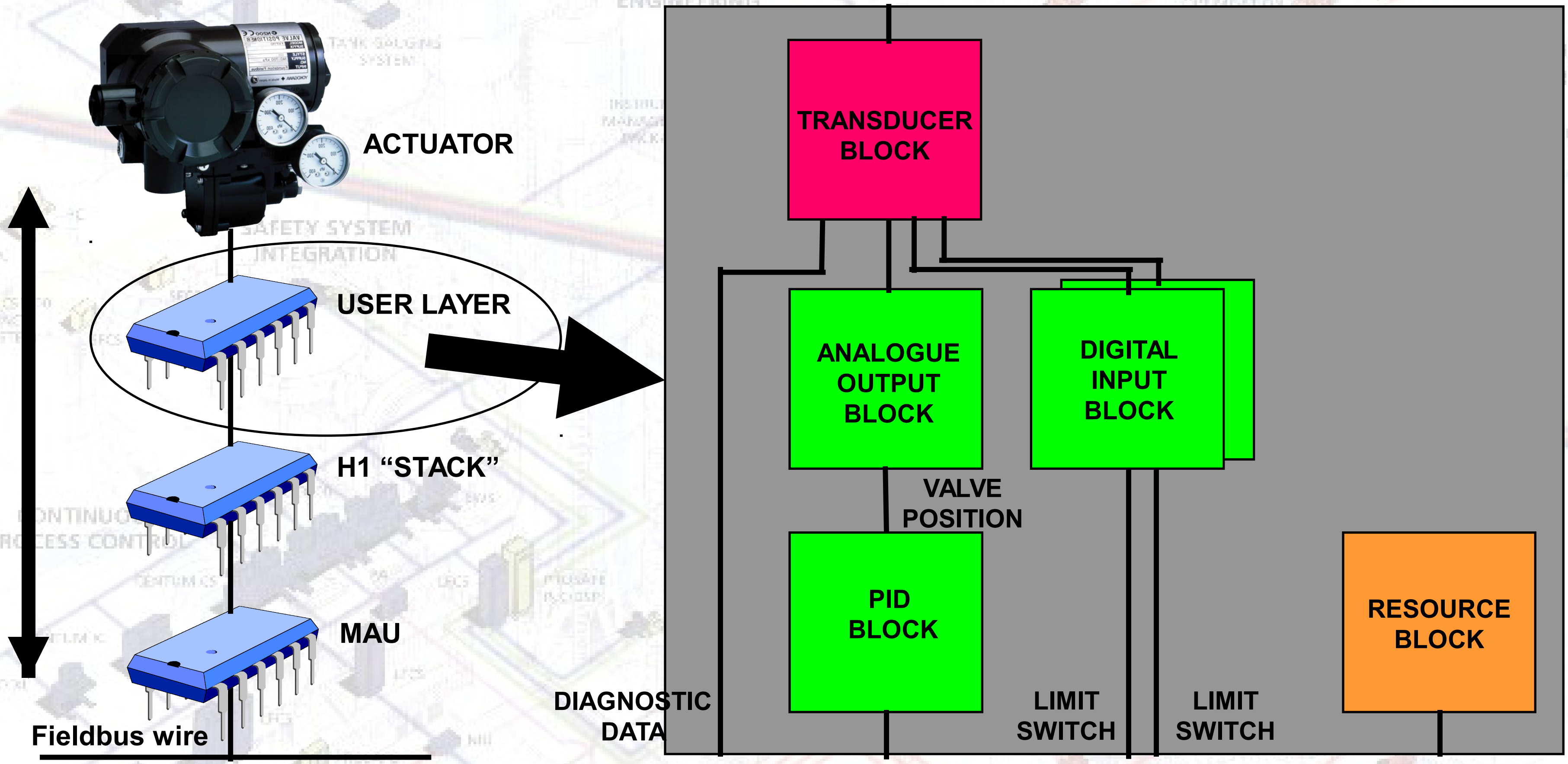
# Valve positioner - example



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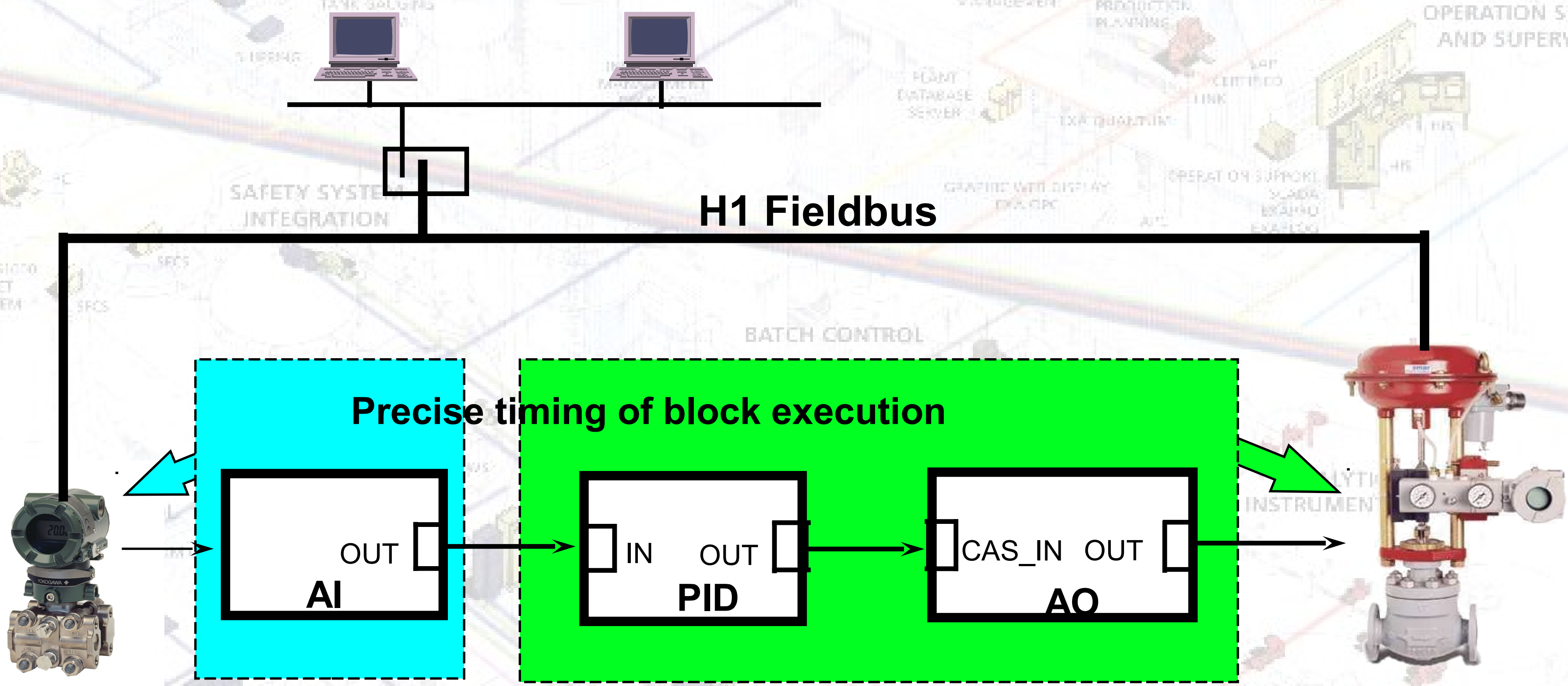
# Function Blocks

- **Monitor and control process applications**
  - **Input blocks - AI, DI**
  - **Output blocks - AO, DO**
  - **Control blocks - PID, Ratio, Signal Characteriser, Lead/Lag etc.**
- **Reside in any field device and/or host system**
  - **Simple control functions may migrate into field devices**
- **Form deterministic control schemes**
  - **Interconnect over the bus to implement an integrated control strategy**
  - **Interconnect to blocks in the host as part of an advanced control scheme**
- **Execute periodically - cyclically**

# Control functions migrate into the field



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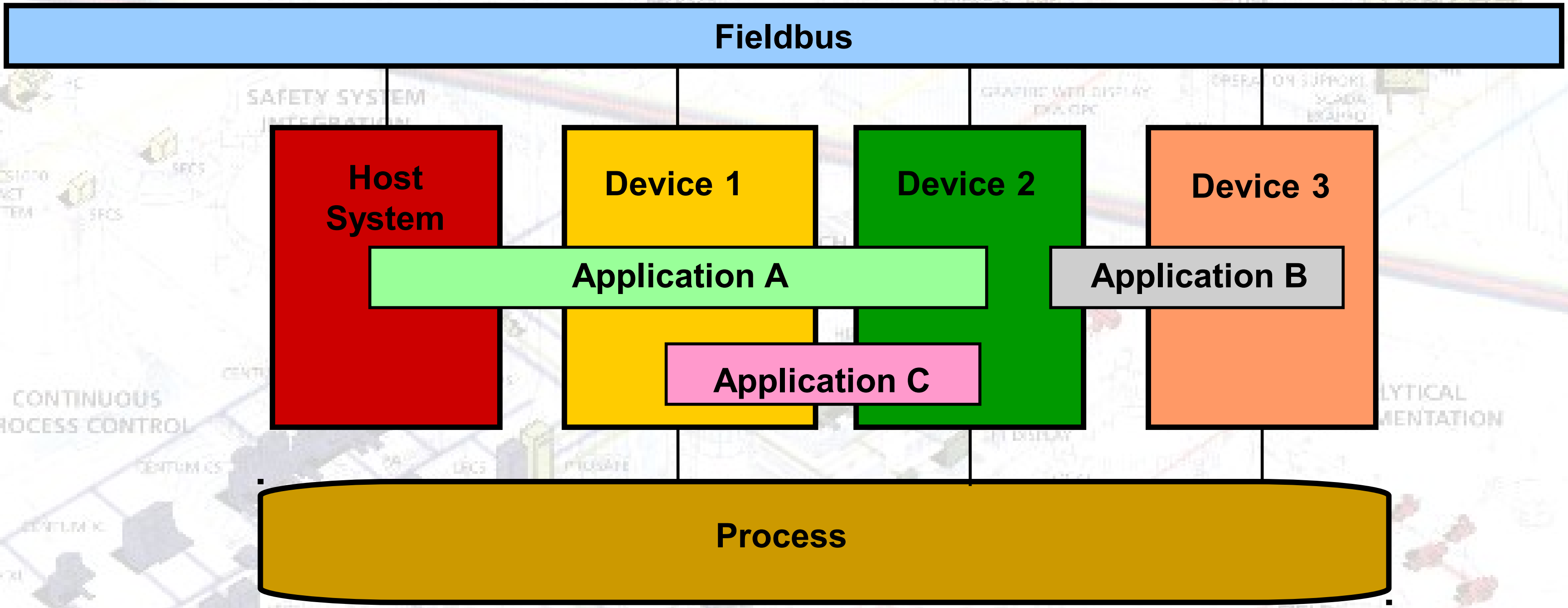
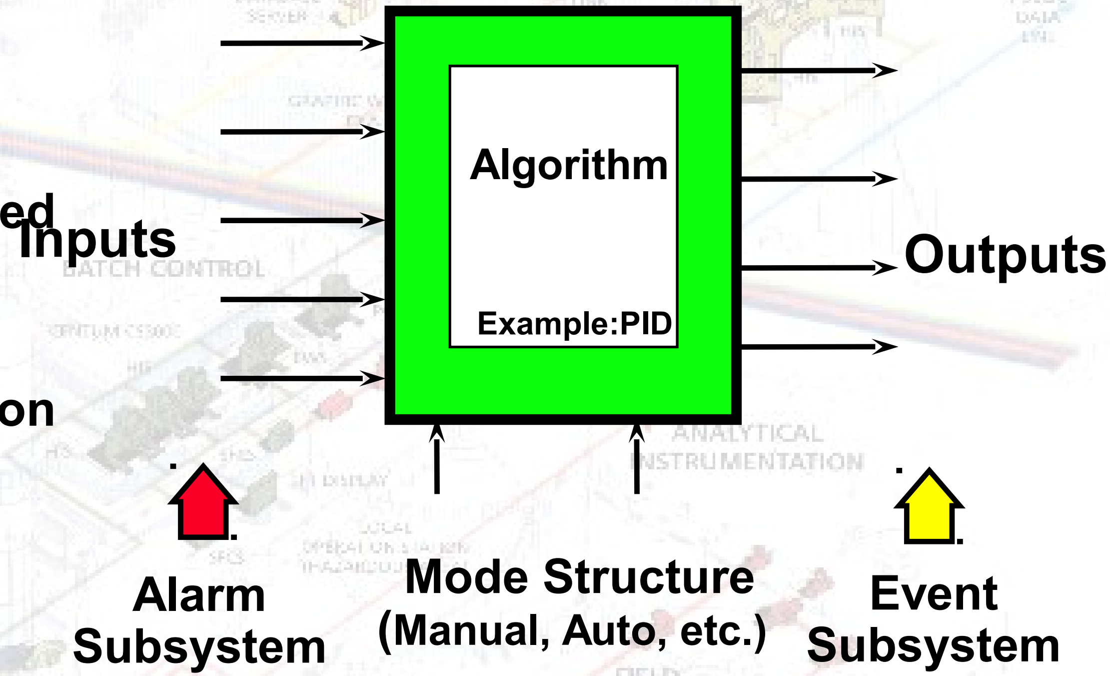
# Distributed control applications



# Function Block structure

- Block appearance is standardised
- Algorithms are vendor specific
  - Room for "differentiation"
- Consistent, easy, block oriented configuration
- Consistent definition of information being communicated
  - Standardised status indication
- Common set of modes
  - Standard method of mode propagation



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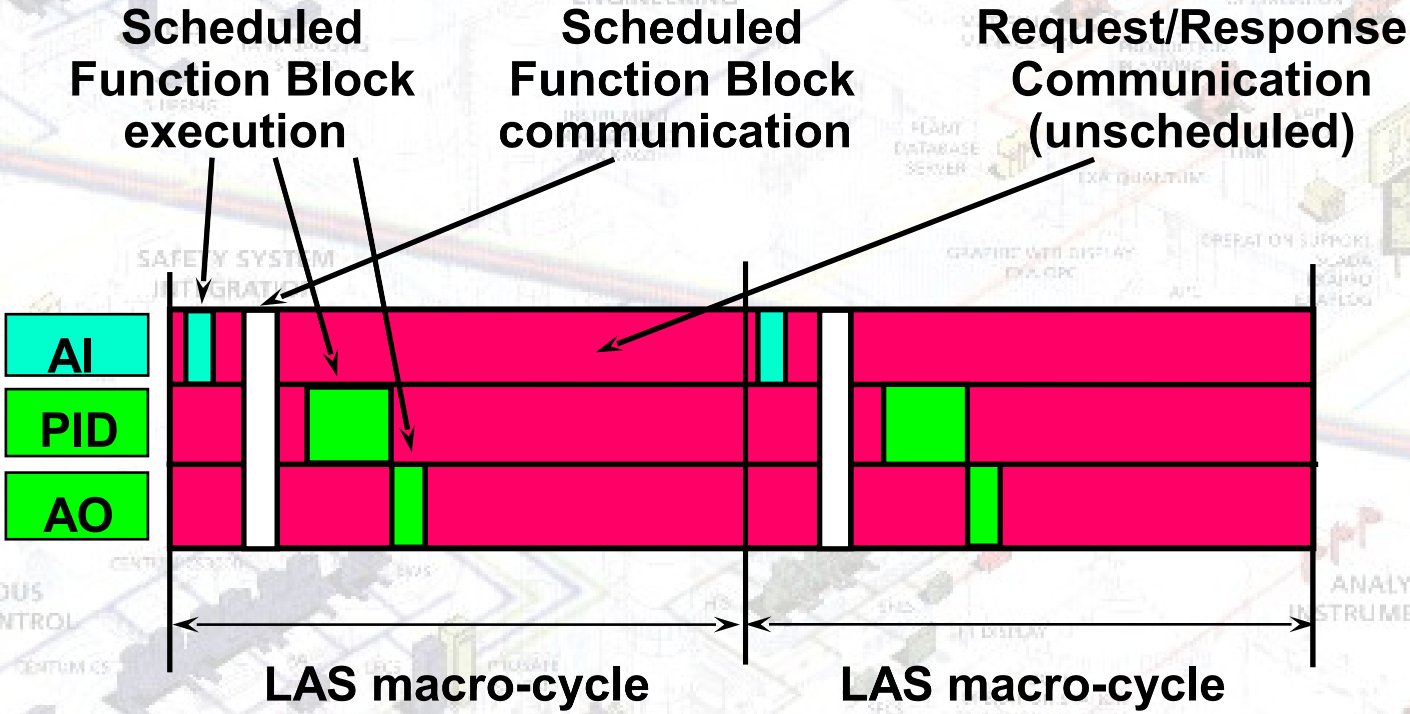
# H1 Function Block execution scheduling




- Precise timing of block execution - cyclic
- Function Block communication over the bus is immediate



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# Device Descriptions (DD's)

- Extended description of the capability of a field device
- Written in a standard Device Description Language (DDL)
- DDL technology implements the FF interoperability concept
- Interpreted by host system and provide the information needed by the host to see and use field devices
  - Provided on CD or floppy or may be uploaded from the field device
- Standard and Incremental DD's
  - Standard DD's for standard Fieldbus Foundation device profiles, including Function Blocks and Transducer Blocks
  - "Incremental" DD's to define manufacturer-specific extensions

# Common File Format (CFF)

- Describes the functions and capabilities of a field device
- In conjunction with Device Descriptions allows data exchange among device manufacturers, system builders and end-users
  - Capabilities File
    - Electronic form of device specification - used for device configuration
  - Value File
    - Data to be downloaded
    - Uploaded data from devices
  - Both are standard ASCII text files for human readability
- Enable a host system to configure the system off line
  - Yokogawa complies - Yokogawa's main contribution to FF specifications

# What is "Interoperability"?

- The ability to implement control strategies on a system implemented with devices from multiple vendors

- Delivered by:
  - Standard Physical Layer
  - Standard communication protocol (Stack)
  - Standard function blocks
  - Device descriptions
  - Common File Format

- Freedom for end-users to chose "Best in Class" solutions

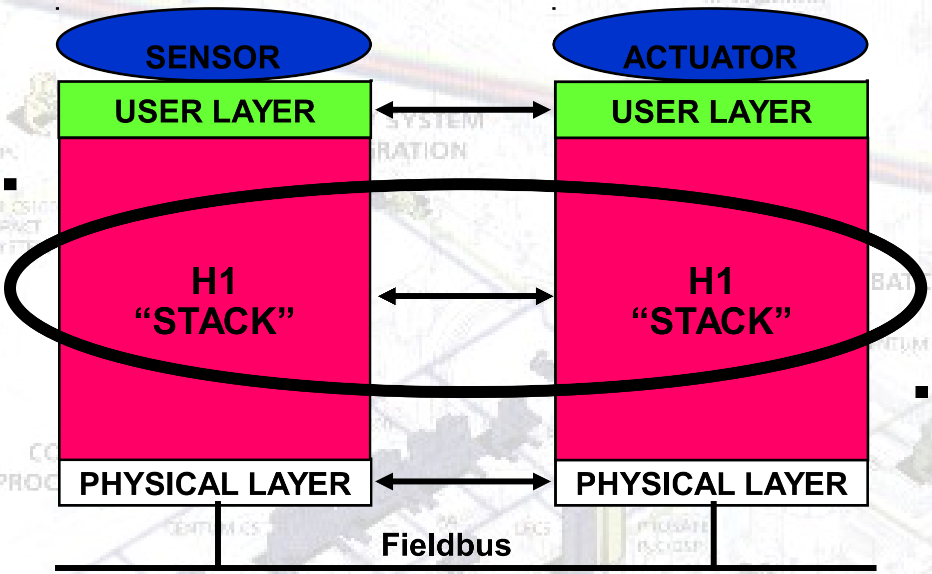
- The ability to substitute a field device from one vendor for that of another vendor without loss of functionality …..

# Interoperability fulfils the expectations of ...

- **Basic interfacing**
  - Interconnectivity
- **Support for innovation**
  - Seamless integration of new device features
- **Substitution**
  - Replacement of similar devices from different manufacturers
  - Expectation established by the analogue 4-20 mA standard
  - Substitution requires re-configuration
- **All layers of the OSI model plus User Layer must interoperate**
  - Physical Layer, Communication Stack and User Layer

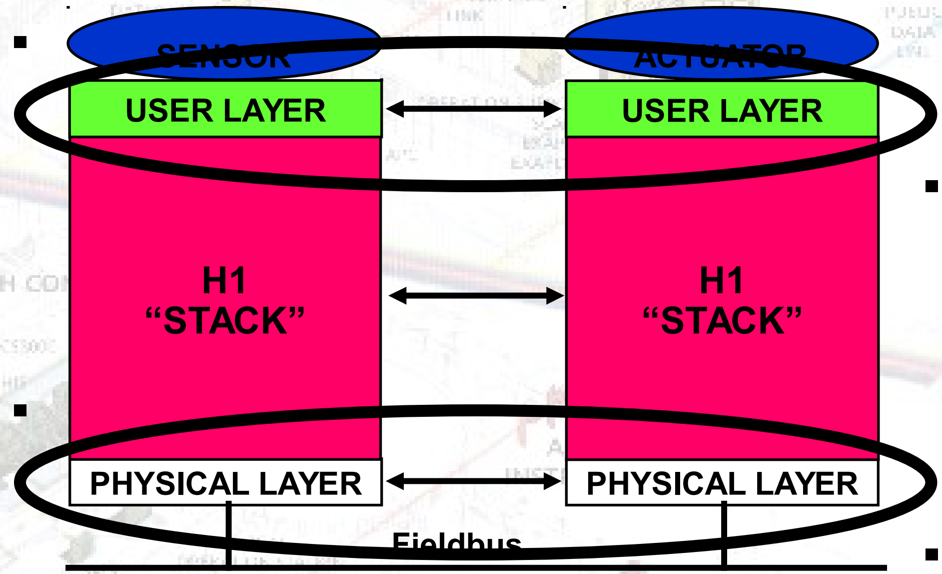
# Conformity and Interoperability test procedure

## Stack conformity testing




- Stack registration
- 20 different stacks registered
  - Basic and Link Master devices

## Device interoperability testing




- Device registration
- 100 different devices registered
  - Key to interoperability



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# Will "interoperability" improve

- Not all layers interoperate - tighten the specification
- Capabilities File imperfections - vendors to fix
  - Response time; device expects to have a response within "x" seconds
- Bug's in stack conformity tester - to be fixed
- Lack of capability - parameters not in non-volatile RAM
  - Problem reoccurs at power up; requires down load - vendors to fix
- Host System testing being debated
- Common File Format is key to interoperability
  - Yokogawa complies - Yokogawa's main contribution to FF specifications



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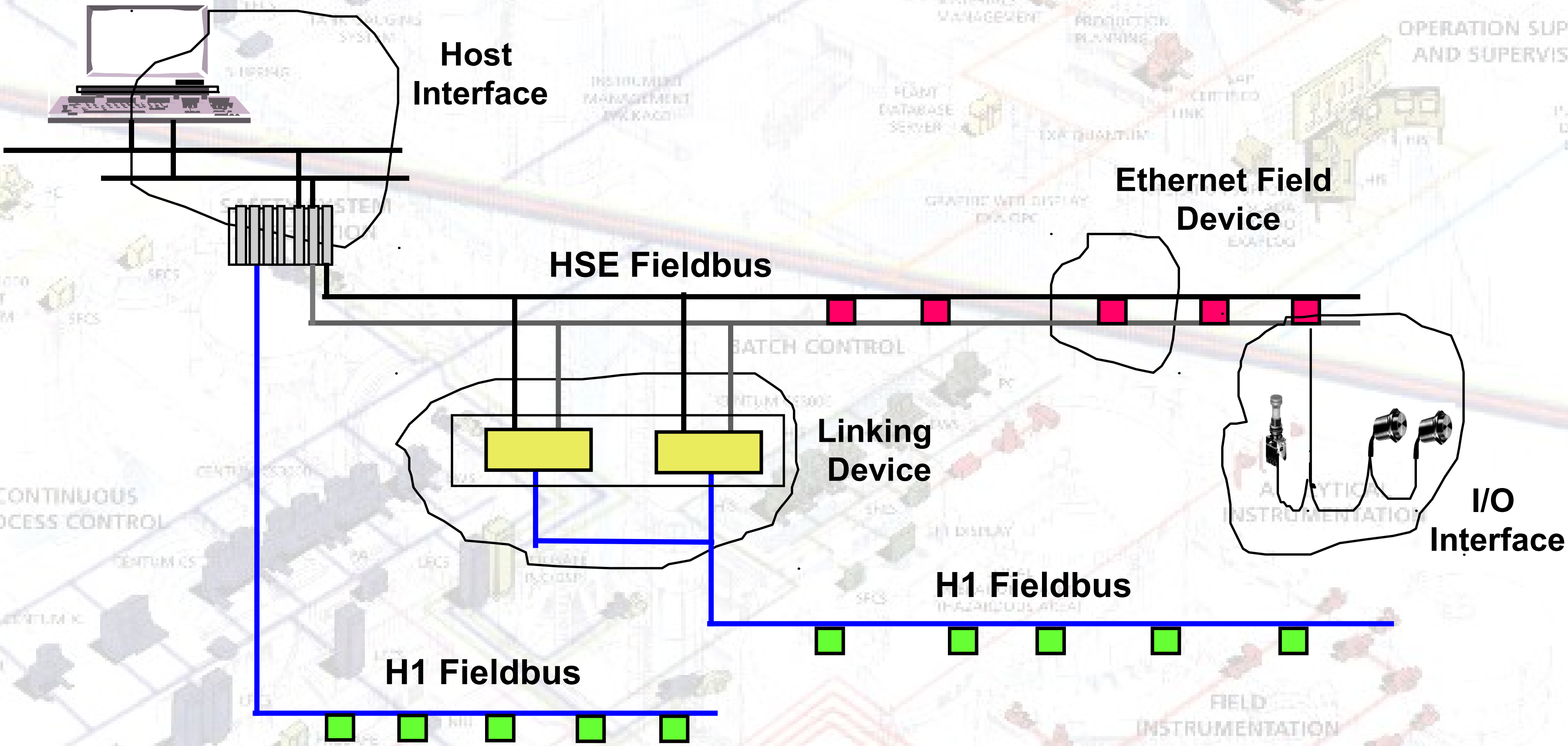
# FOUNDATION™ Fieldbus High Speed Ethernet

# *FOUNDATION™ Fieldbus topology*



# The HSE FOUNDATION™ Fieldbus model

## OSI model based

COTS
Commercial Of The Shelve
Ethernet equipment

STANDARD ETHERNET STACK

PHYSICAL LAYER

## FOUNDATION™ Fieldbus HSE Model

USER LAYER

HSE APPLICATION PROTOCOL

STANDARD ETHERNET STACK

PHYSICAL LAYER

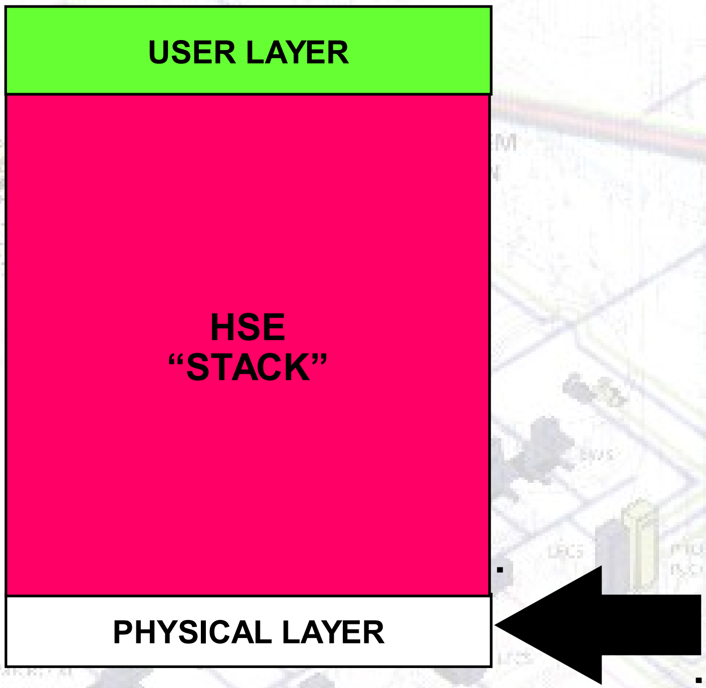
USER LAYER

HSE "STACK"

HSE PHYSICAL LAYER

**The Application Layer is not defined in Ethernet**

# HSE Physical Layer




- **High speed backbone**
- **Converts data from the “Stack” to physical signals on the “fieldbus”**
  - **Uses standard Ethernet electronics**
  - **Supports redundant media and devices**
  - **Provides interface to other protocols**
- **Transmission is TCP/IP**
  - **Collision detection**
- **Signalling rate is 100 Mbits/sec**
- **Supports copper wire and optical fibres**
  - **Up to 100 m using shielded twisted pair cable**
  - **Up to 2000 m using optical fibres**



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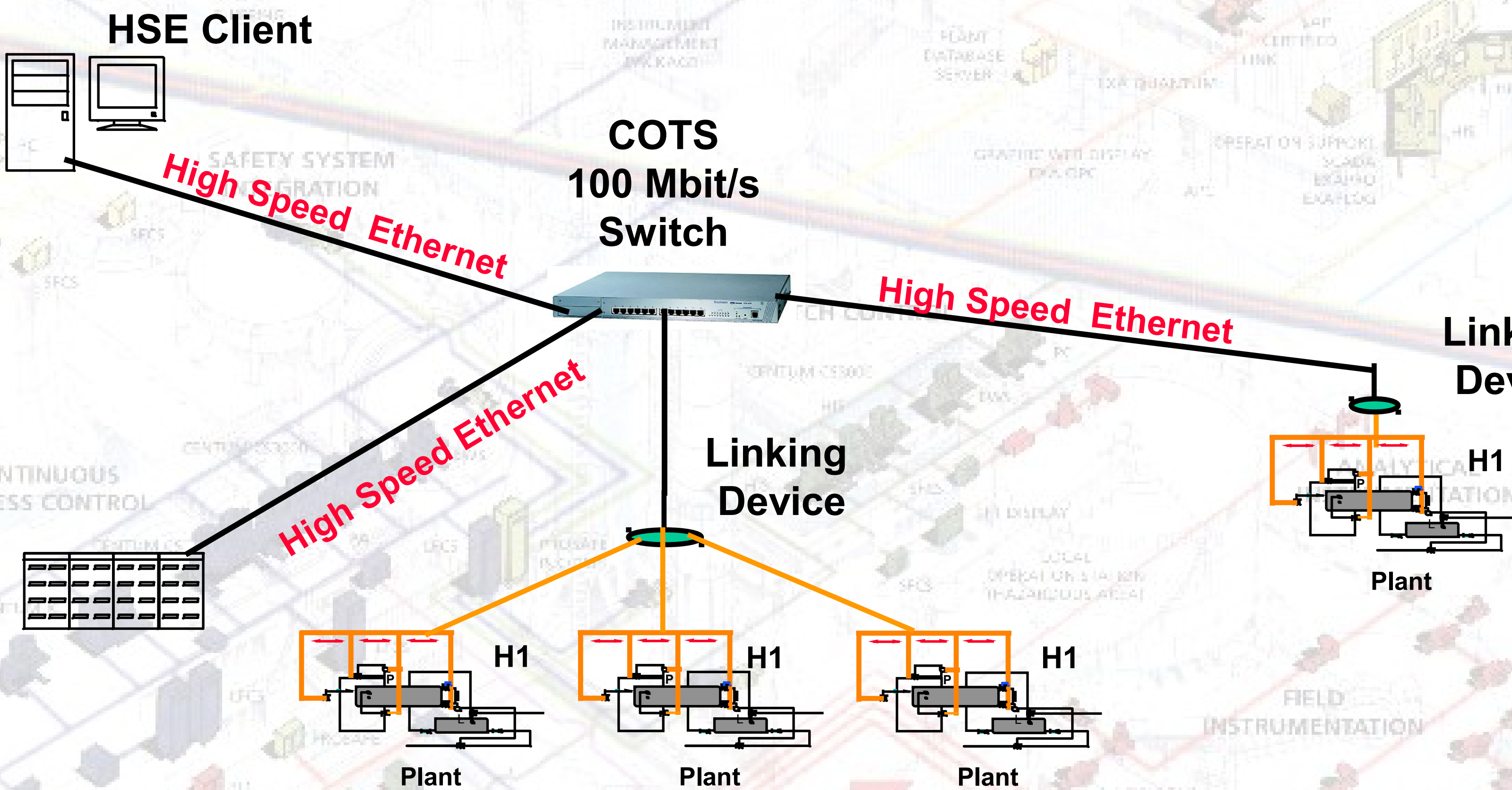
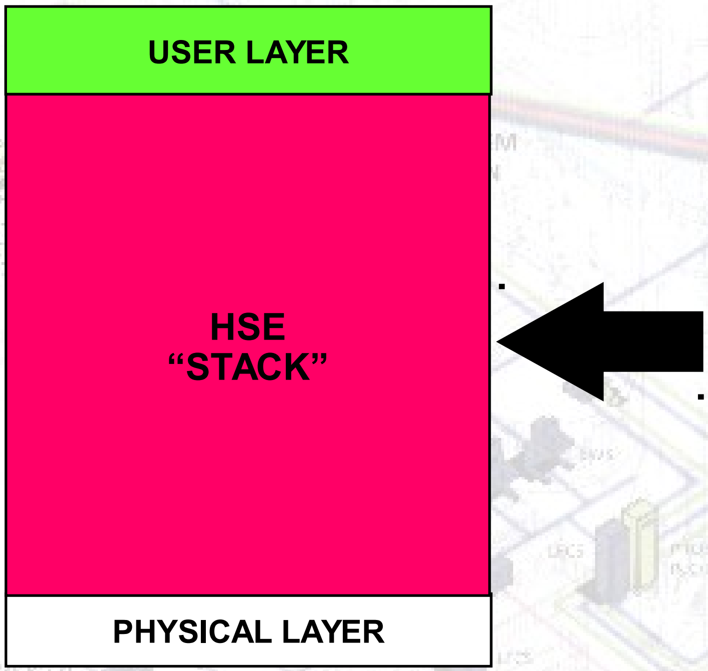
# FOUNDATION™ Fieldbus integrated network

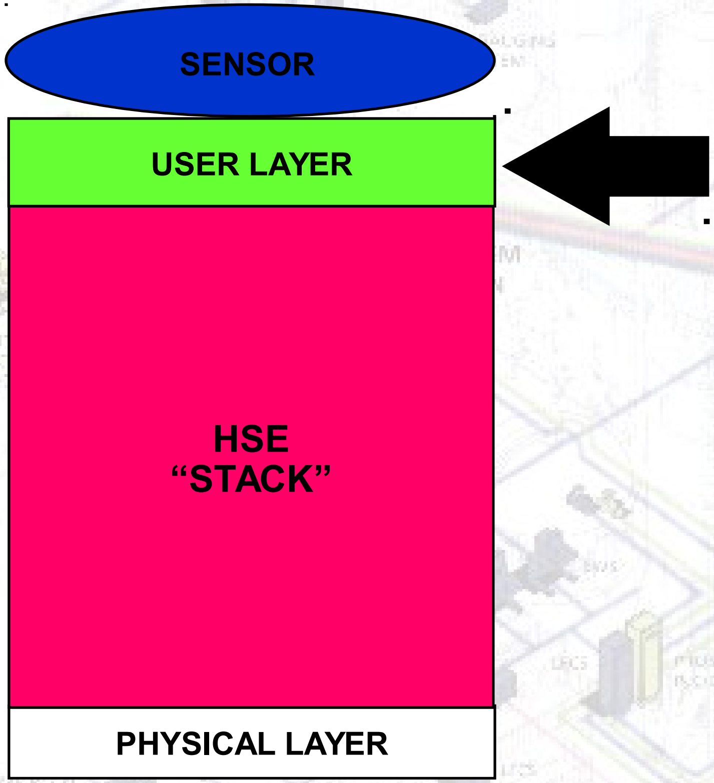


# HSE communication stack




- HSE stacks consists of
  - Standard Ethernet stack
  - FF-HSE Application Protocol
- Establishes basic communication services between Ethernet devices
  - Encoding and decoding of User Layer messages
  - Deterministic control of message transmission
  - Efficient and secure message transfer
  - Supports scheduled messaging for time critical communication (Publisher/Subscriber)
  - Supports unscheduled messaging for request/response communication (Client/Server)
  - Supports unscheduled messaging for Event Notification (multicast)
  - Provides Bridging and Redundancy

# HSE User Layer - Unique differentiator




- Provides the interface with the process
  - and for user interaction with the host system
- Standard Function Blocks
  - Consistent definition of data for integrated and seamless distribution of functions in Ethernet (field) devices from different manufacturers
- System Management
  - Deterministic scheduling of function blocks
- Device descriptions
  - Host system to operate the device without the need for custom programming
- Common File Format
  - Off-line “system” configuration by host system



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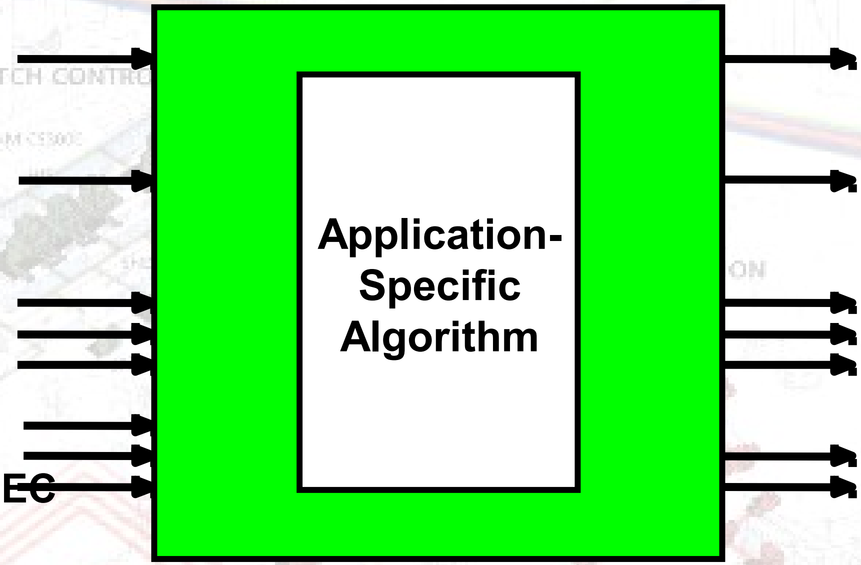
# Flexible Function Blocks

- Extends the Function Block model into Discrete Manufacturing
- Multiple I/O (MIO) Blocks
  - 8 channels per block
  - Multiple Analogue Input
  - Multiple Analogue Output
  - Multiple Discrete Input
  - Multiple Discrete Output
- Flexible Specific Blocks
  - Application specific algorithm IEC 61131 compliant

## FFB is a "Wrapper" for an Application-specific Algorithm



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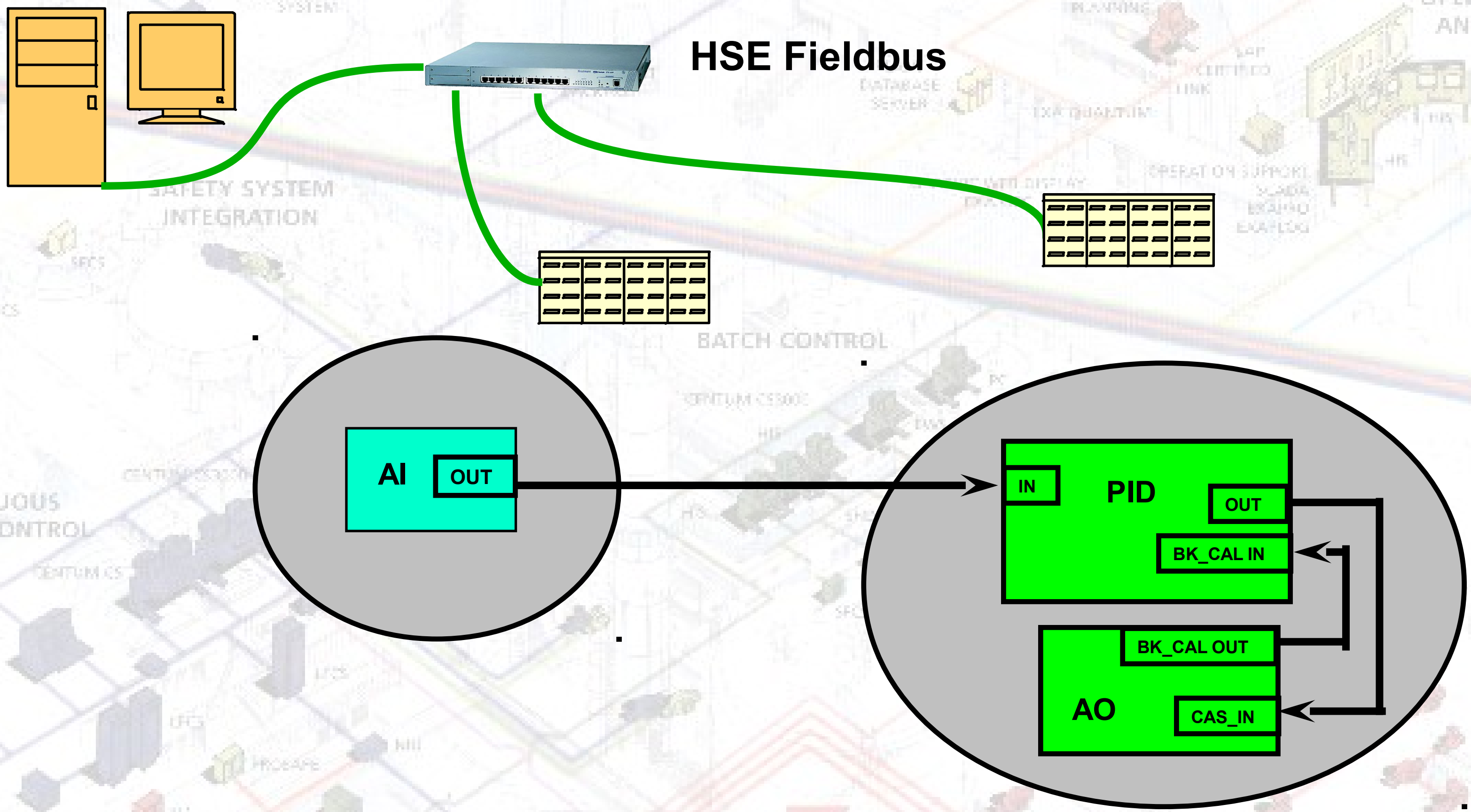
# Distributed control functions



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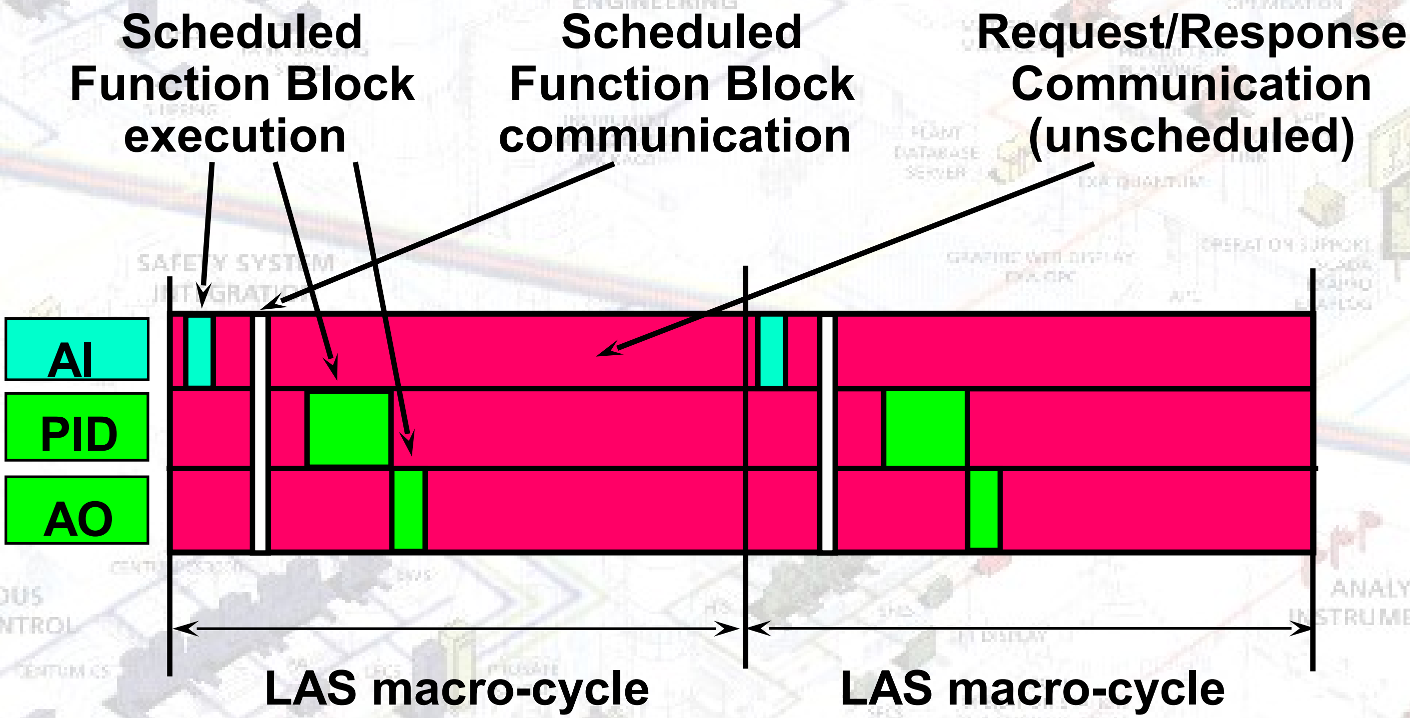
# HSE Function Block execution scheduling




- Precise timing of block execution - cyclic
- Function Block communication over the bus is immediate



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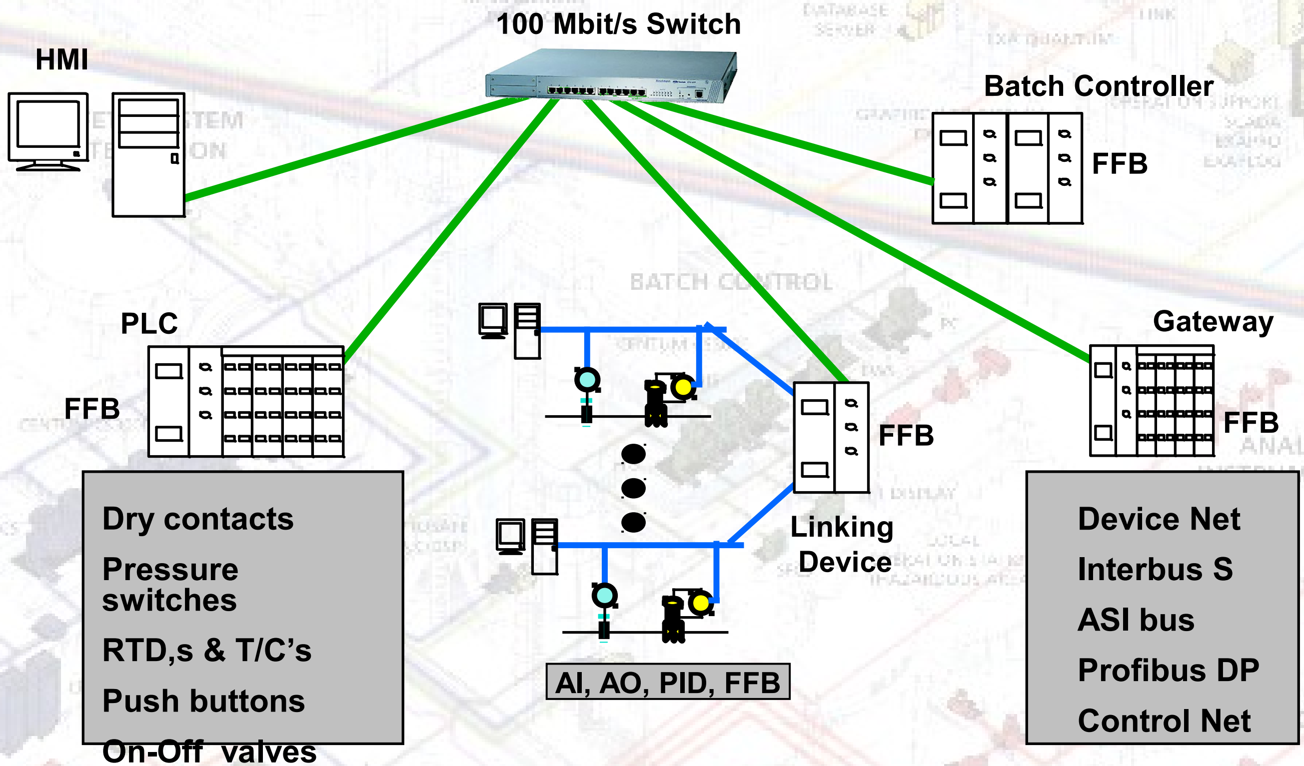
# FOUNDATION™ Fieldbus

- Designed for total plant automation - control and automation

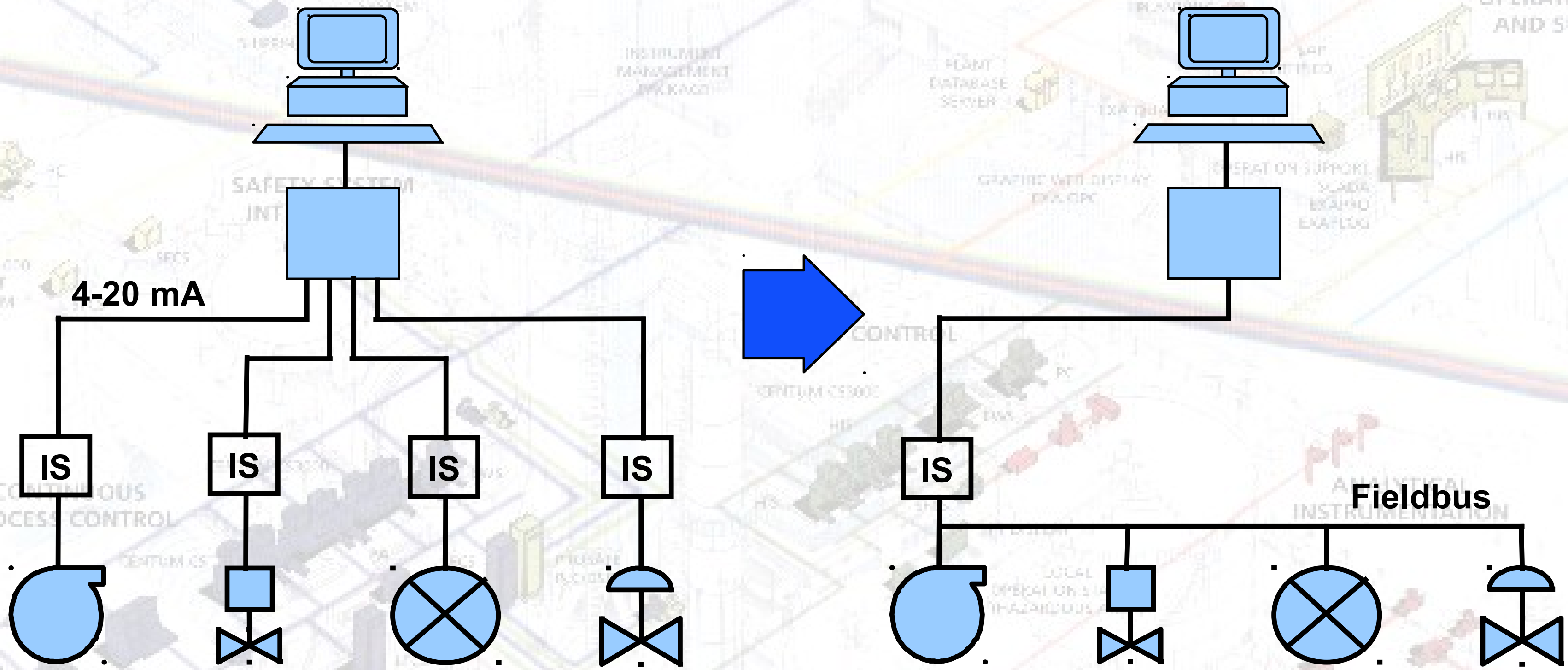


# High Speed Ethernet (HSE) - summary

- Cost-effective, high-speed, plant-wide backbone
- Standard Ethernet technology running at 100 Mbit/s
  - Availability of standard Ethernet equipment
  - Flexible Function Blocks
  - HSE field device running standard function blocks
- Fault tolerant communications and linking devices
- Bridging of multiple H1 networks on a linking device
- Interface to other protocols through gateways

# FOUNDATIONTM Fieldbus
# Impact on Engineering and Installation

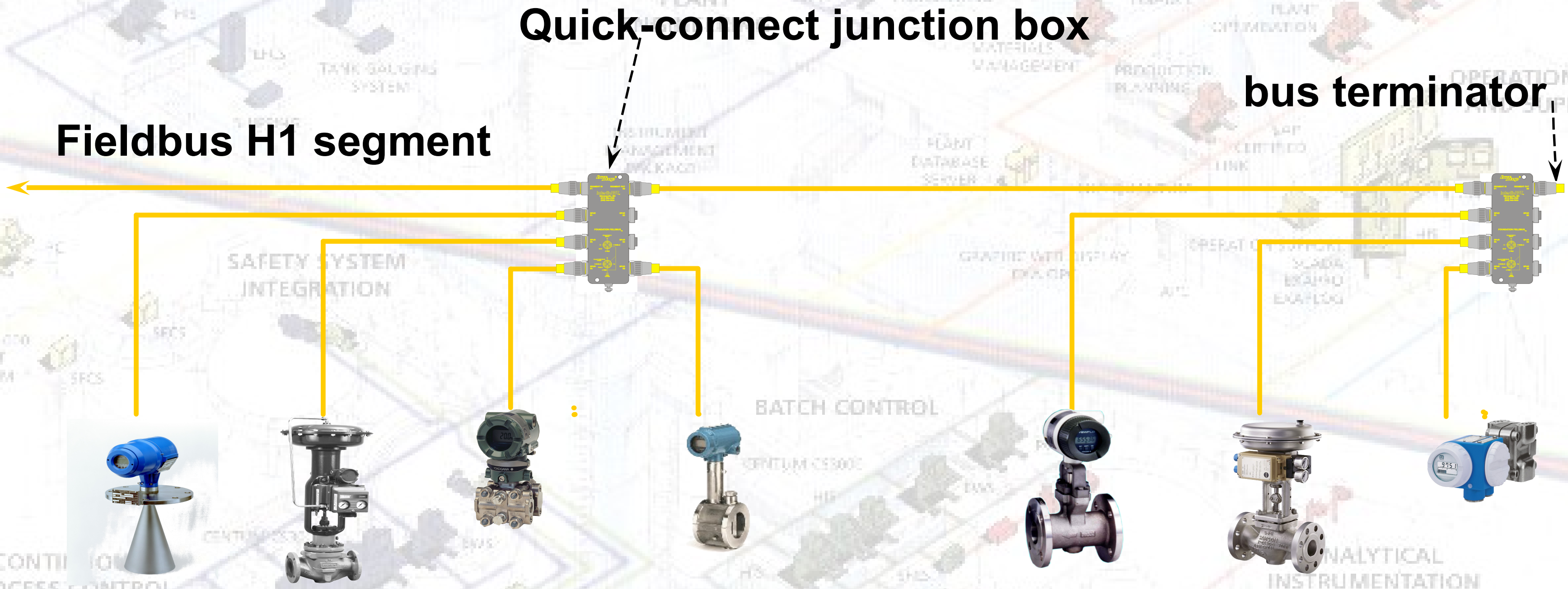
# Simplified engineering and installation




Traditional 4-20 mA wiring, one IS barrier, one pair for each device

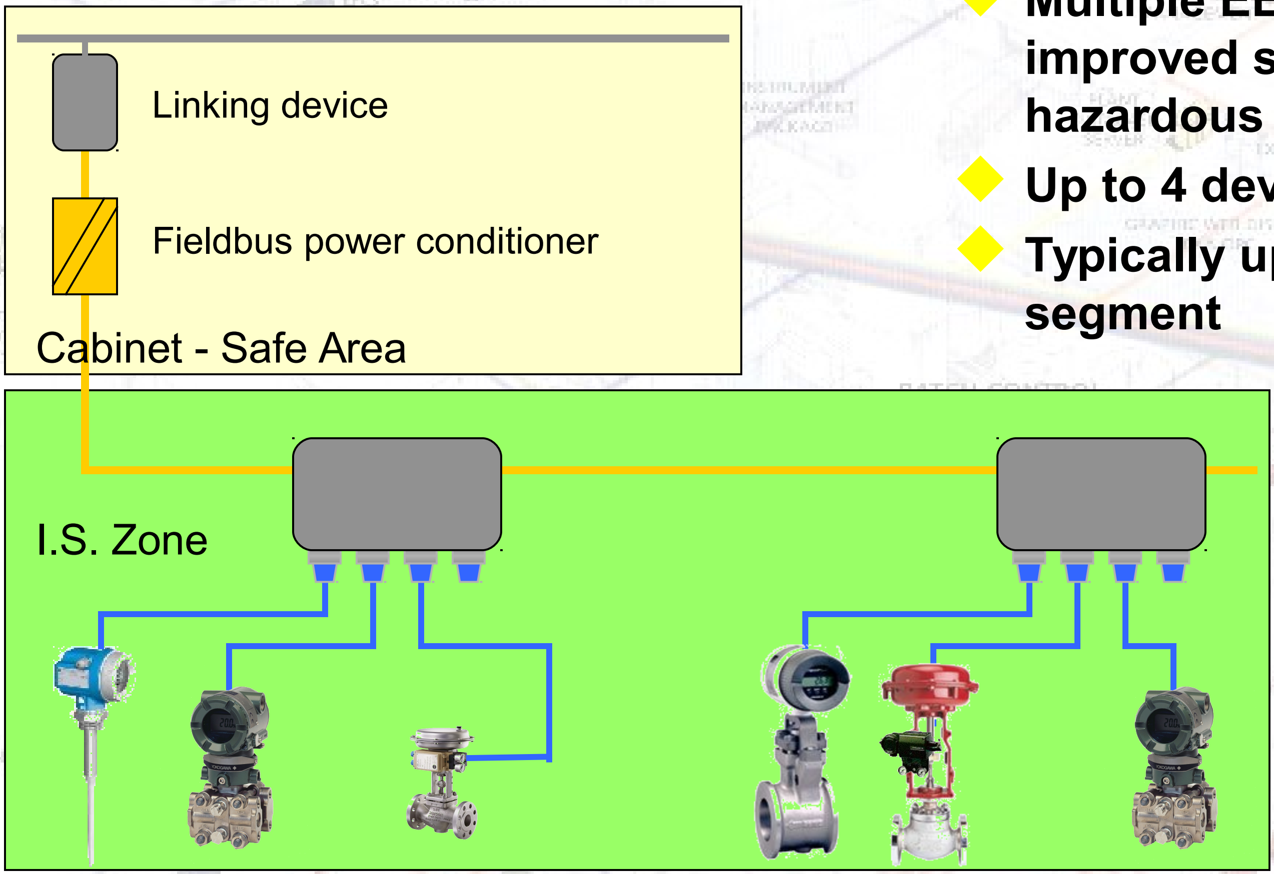
One IS barrier, one pair for many devices

# Fieldbus cabling concept




- **Provides flexibility in "Plug and Play"**
  - **General purpose and Intrinsic Safe concepts**
  - **Monitors bus voltage and current**
  - **Detects short circuits and other wiring problems**

# Multi-barrier concept by Turck



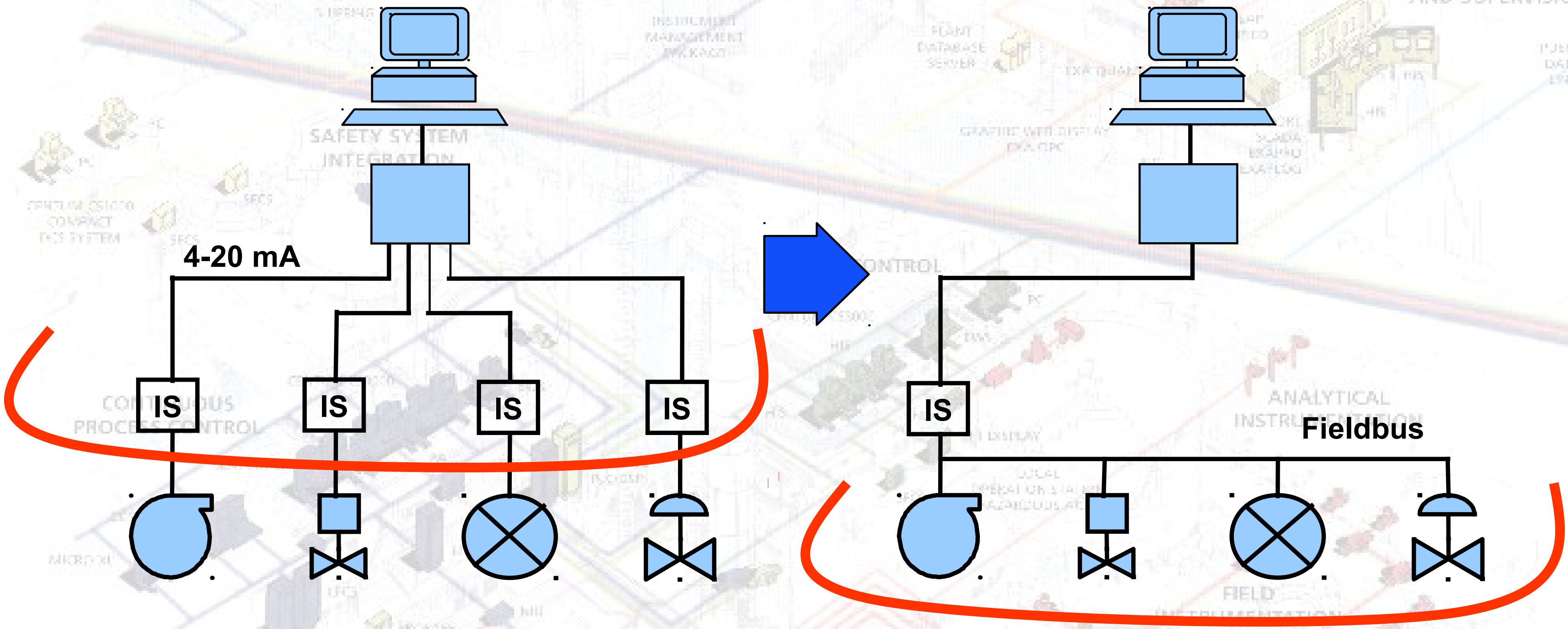

- Multiple EEx-e / EEx-i barriers for improved solutions for Zone 1 hazardous areas
- Up to 4 devices per barrier
- Typically up to 12 devices per segment

# Impact on Engineering and Installation

- **Increased capabilities due to full digital communications**
  - **Less devices required - less process intrusions**
  - **Reduced wiring and wire terminations - multiple devices on one wire**
  - **Less engineering and cabling check-out**
- **Increased freedom in selecting suppliers - interoperability**
  - **Unified configuration and device management tools - self-documenting**
  - **Download off-line configured network/device configuration**
  - **Simpler and significantly faster commissioning**
- **Reduced loading on control room equipment**
  - **Distribution of some control and input/output functions to field devices**
  - **Smaller control room footprint**
  - **Simpler engineering effort**

# FOUNDATION™ Fieldbus Impact on Operations

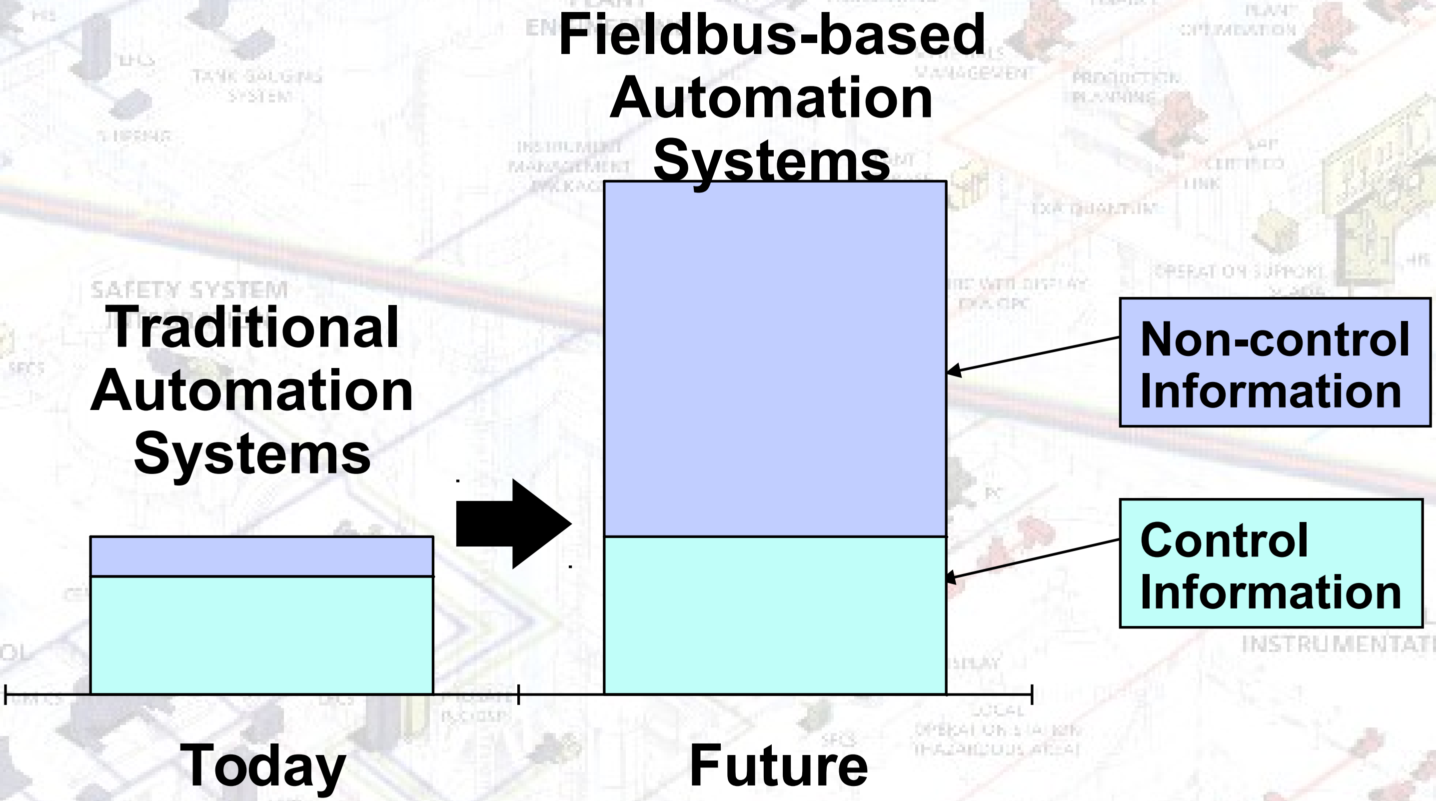
# Expanding the view of the process



# *Utilising the intelligence of the field device*

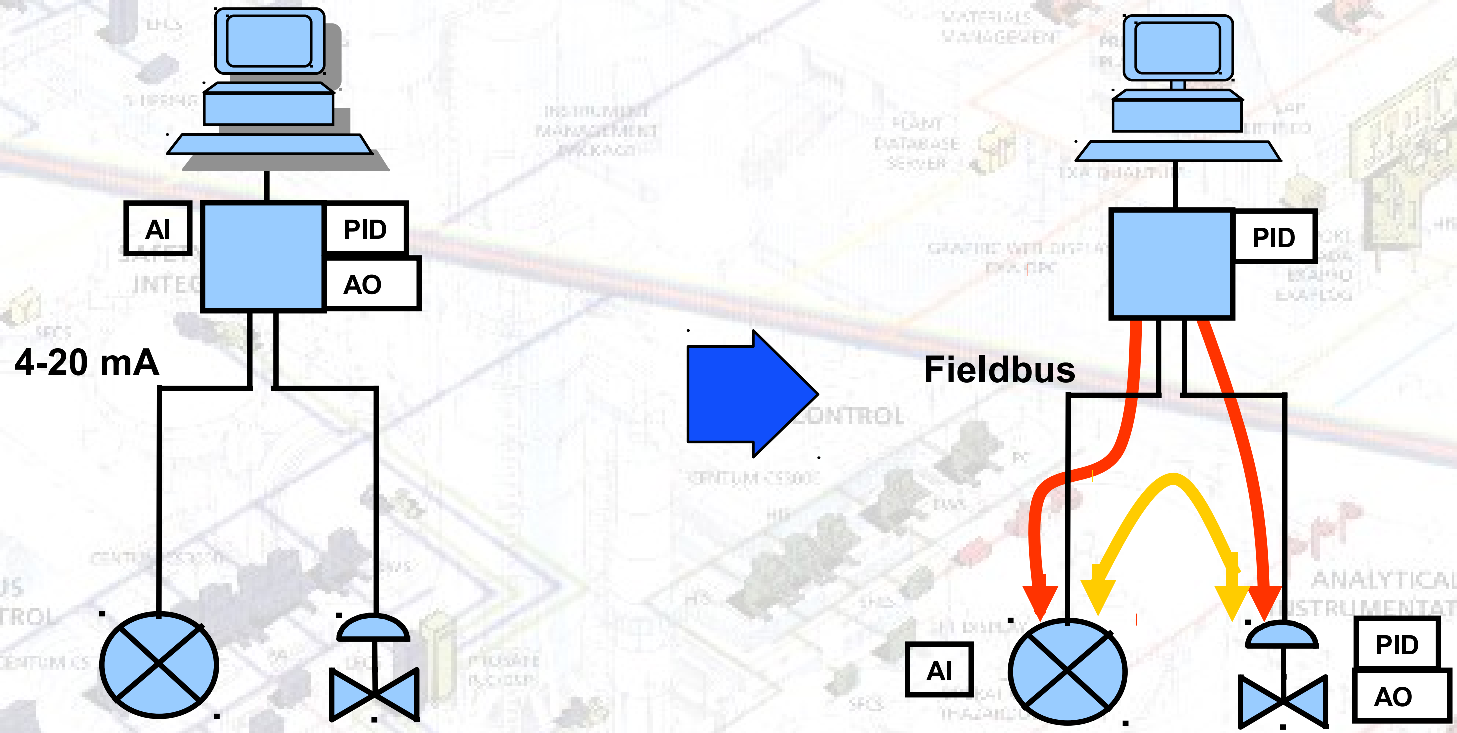
- On-board ***computing power*** enables step changes in functionality
- Become the ***window*** to the process
- Become ***"information servers"*** in the field based architecture
- Become an ***integral part of the "system"***

# *Increased process information*




- Path to integrated Plant Resource Management

# Control functions migrate into the field

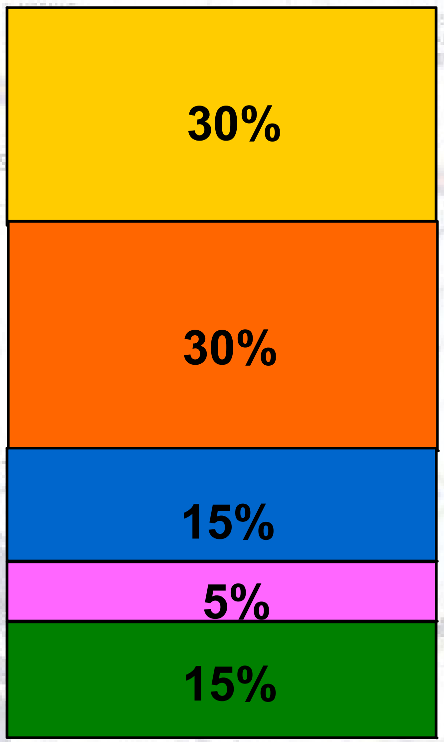



**In today's systems, control functions all reside in central controllers.**

**Fieldbus enables control and I/O functions to be distributed to field instruments.**

# Sources of process variability

**All control loops**




**Causes of variability:**

- **Poor tuning**
- **Poor field device performance**
- **Control strategy design**
- **Poor process design**
- **Running properly**

Source: Entech - Results from audits of over 300 DCS installations



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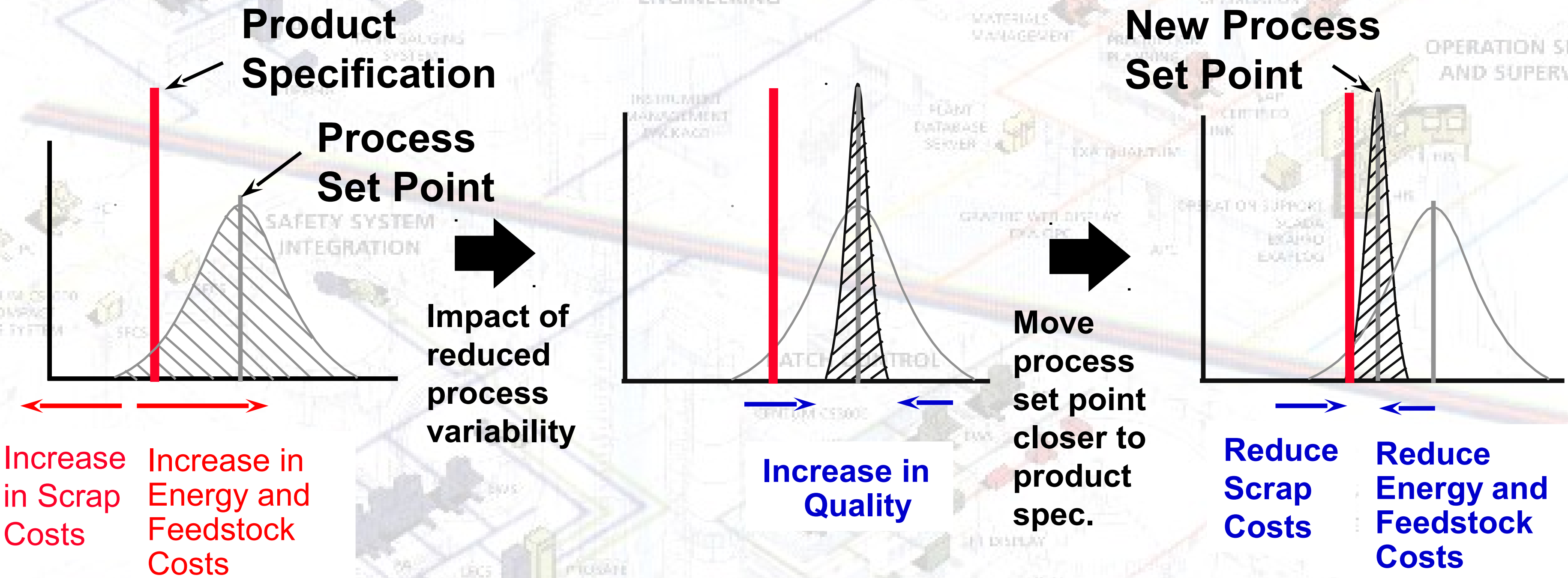
# Cost savings through improved stability




- Significant feedstock reduction; virtually no scrap costs
- Improved plant productivity
- Higher, more consistent final product quality



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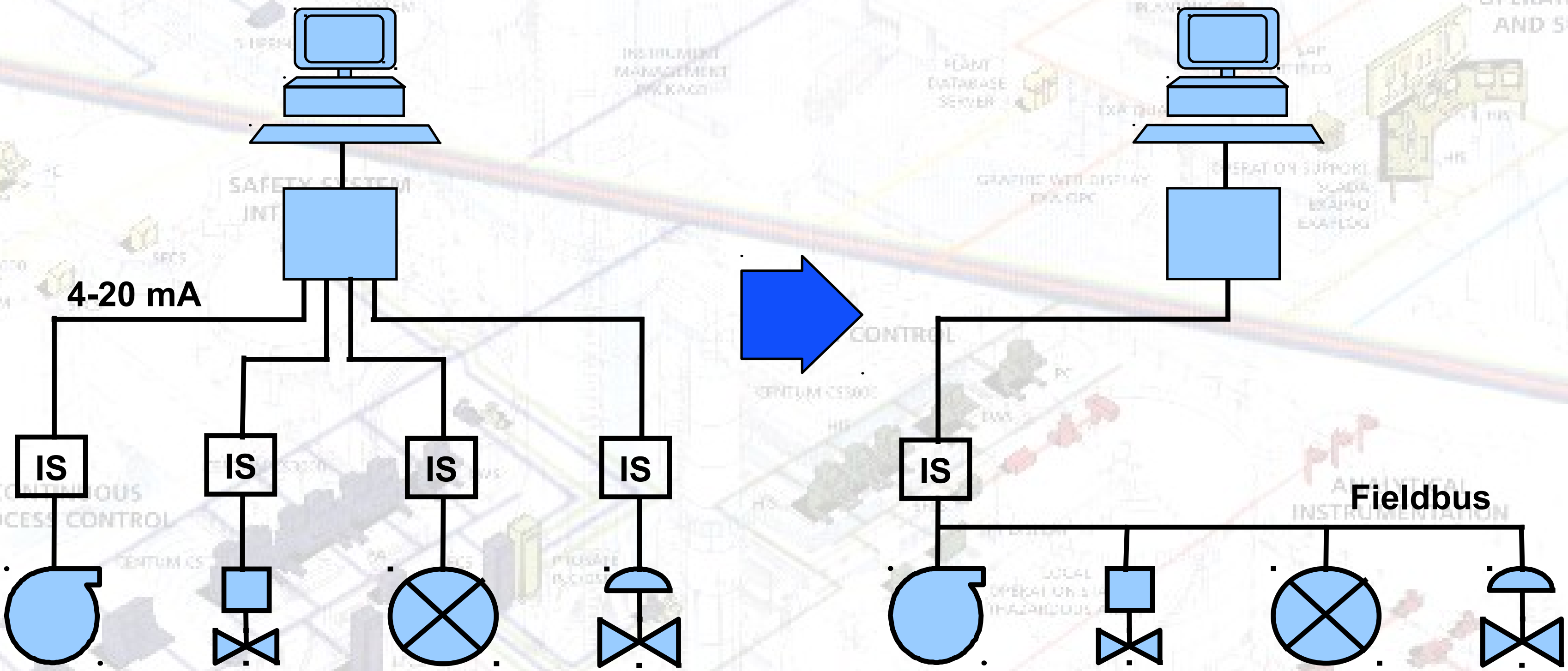
# Impact on Operations

- Improved process performance
  - Improved accuracy of measurement
- "Control Anywhere"
  - Tighter control, improved responsiveness and reduced process variability
  - Reduced raw materials usage - less wastage
  - Stabilised product quality
- Expanded view of the instrumentation
  - Real time process data includes status information
  - Improved process availability
  - Unified Device Management Tools
    - Consistent device configuration and calibration

# FOUNDATION™ Fieldbus
# Impact on Maintenance

# Simplified maintenance

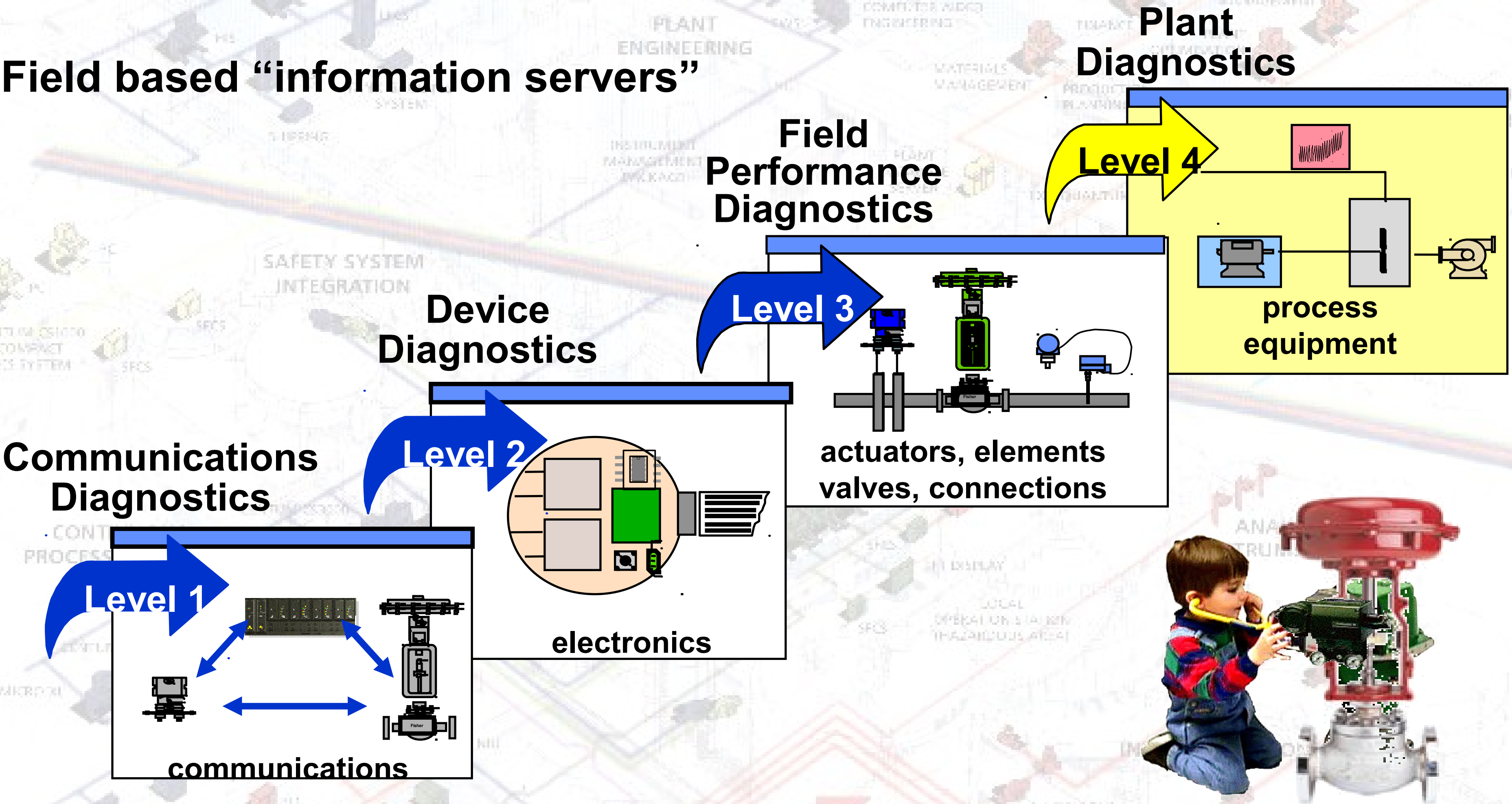



**Traditional 4-20 mA wiring, one Process Value**

**Mode, Value, Status, Alarms, Trends**

# Path to Plant Resource Management

Field based "information servers"



# *Field based information server*

- **Auto-tuning function**
  - **“Matches” positioner with the valve**
- **Actual valve position feedback**
  - **Tight shut-off**
  - **Limit switches**
- **Valve travel accumulation**
  - **Valve travel alerts**
  - **Prevents packing leakage's**
- **Air supply pressure monitoring**
- **Maintenance history**

- **25:1 “data explosion” in HART® environment**
- **200:1 “data explosion” in Fieldbus environment**



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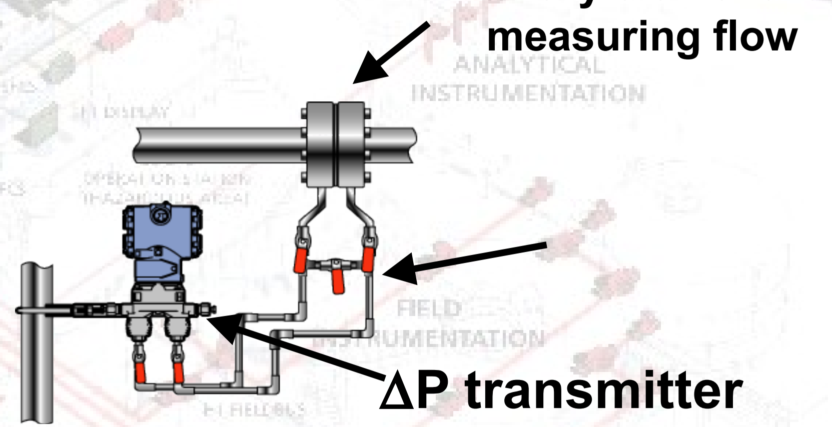
# Impact on Maintenance

- **Field device has on-board diagnostics**
  - Increased measurement reliability and availability
  - Eliminates unscheduled downtime
- **Trouble shoot field devices from central work station**
  - Eliminates unnecessary trips to the field
  - Problem identification before getting out
  - Reduced effort for field calibration
- **Advanced diagnostics**
  - Clogged impulse line detection
  - Transducer Block implementation



# Fieldbus - a revolution in plant automation