# Standardization of Industrial Ethernet – the next battlefield?

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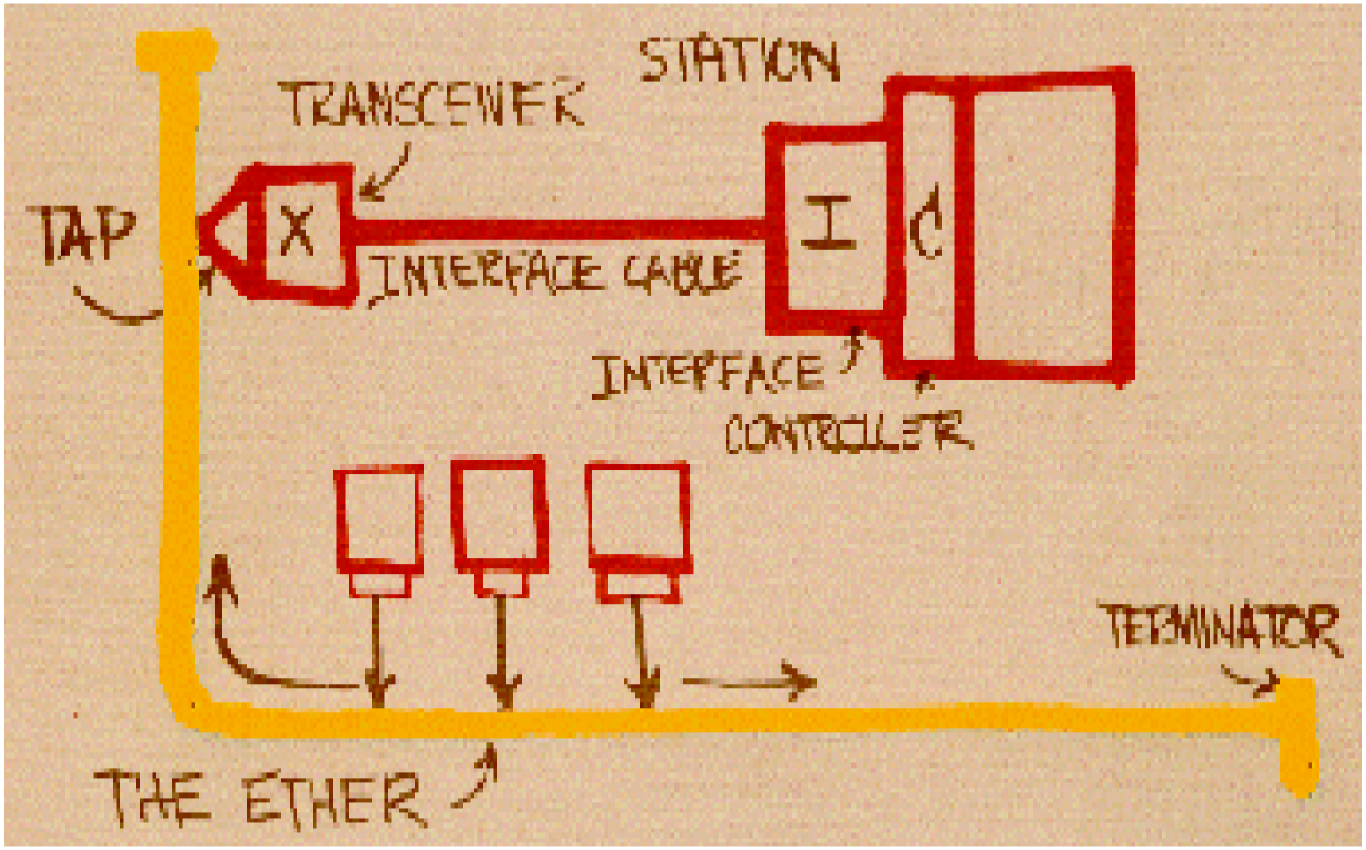
# Ethernet is more than 30 years of history…

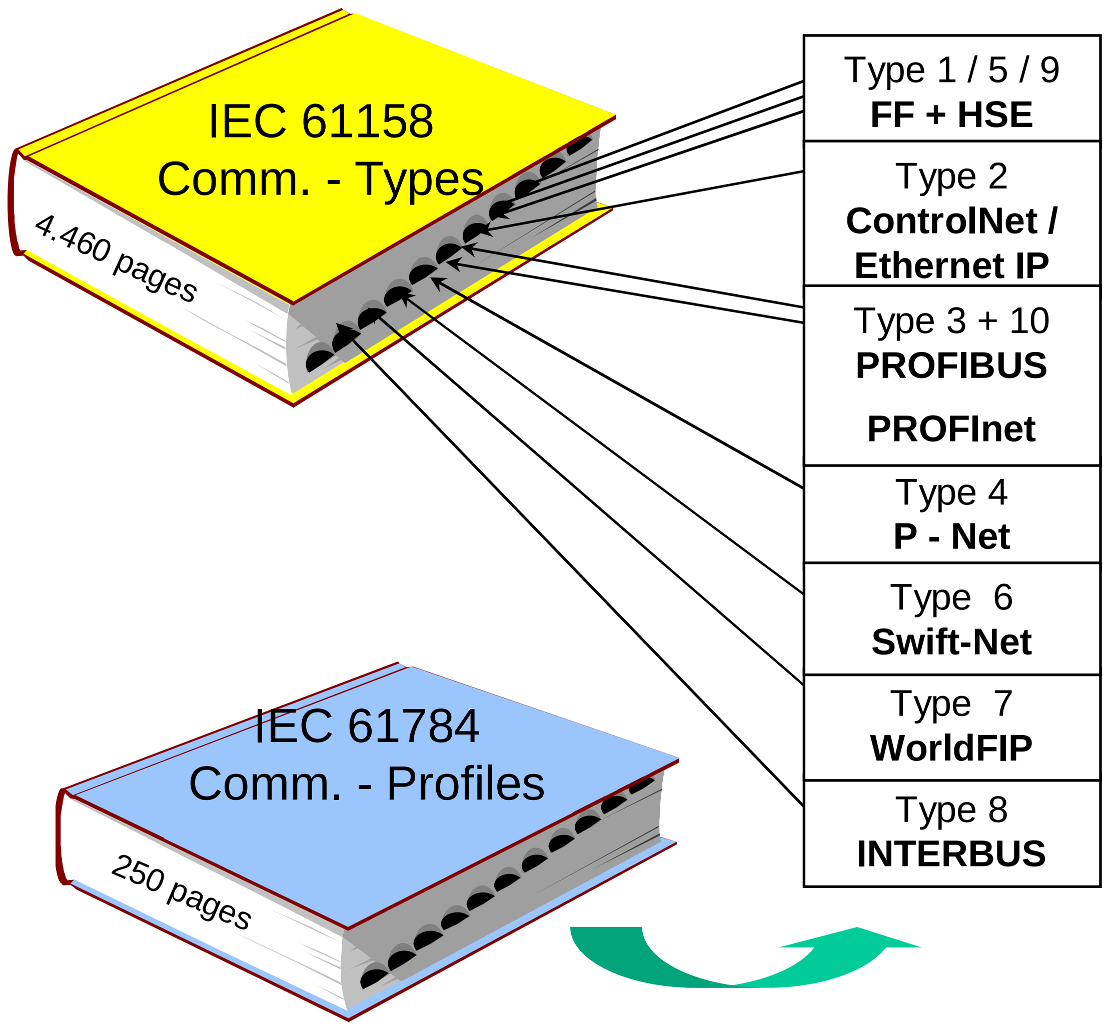



*Designed by Bob Metcalf at PARC in 1972/ 3*

# Why Ethernet in automation?

- Ethernet is already the office world standard
- Ethernet is already used for higher level communications in the automation world
- Ethernet may also be used for communication between controllers and field devices
- IT functionality could also be applicable to automation applications
- **Advantage**:
  - Vertical integration of field communications with Manufacturing Execution Systems (MES)
- **Challenge:**
  - Protect existing fieldbus investment
  - Bring real time functionality to Ethernet

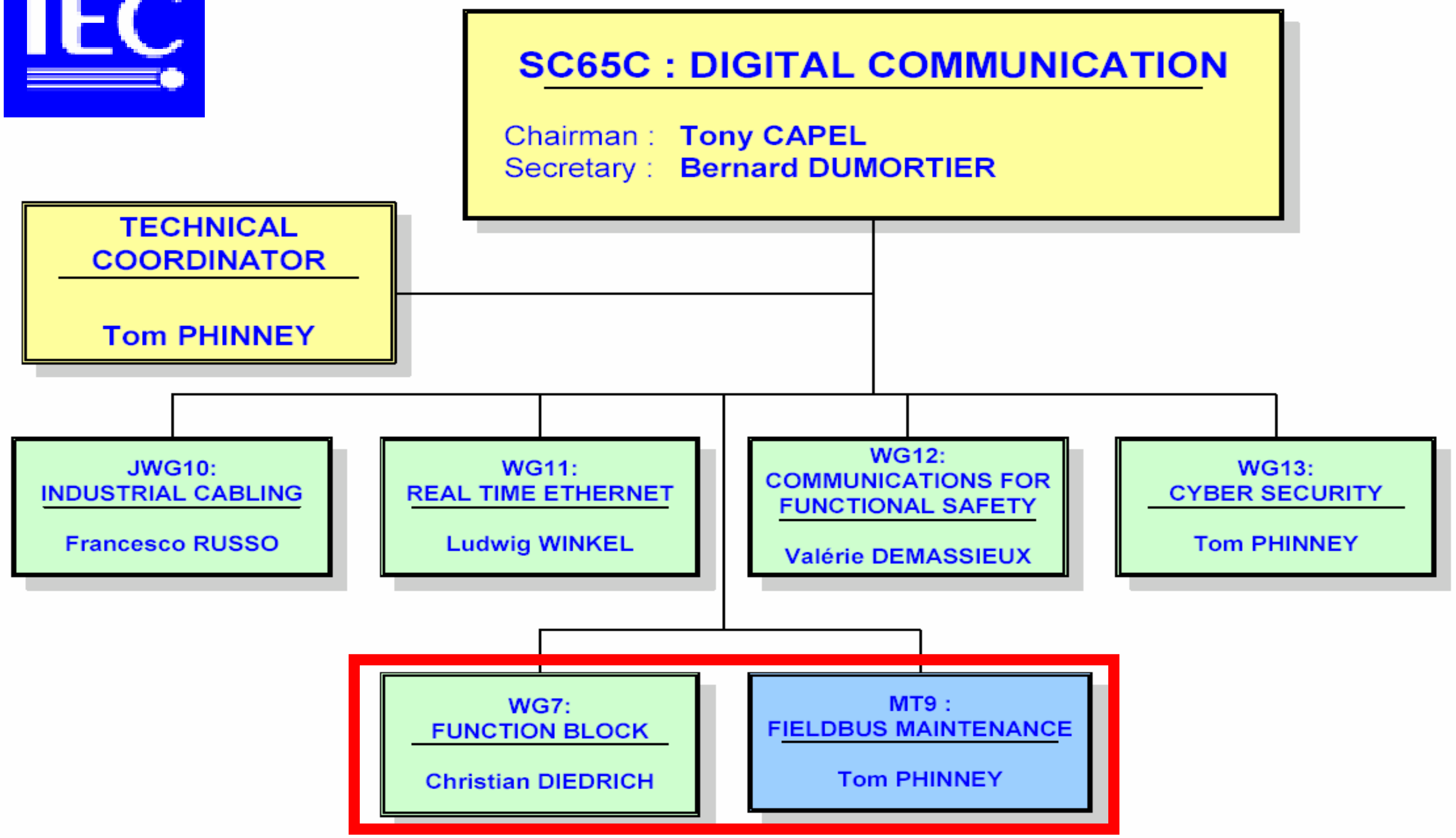
# The international fieldbus - IEC 61158



# The international fieldbus – IEC 61784-1

| | | |
|---|---|---|
| CPF1 (FOUNDATION® Fieldbus) | CP 1/1 | **H1** |
| | CP 1/2 | **HSE** |
| | CP 1/3 | **H2** |
| CPF2 (ControlNet™) | CP 2/1 | **ControlNet** |
| | CP 2/2 | **EtherNet/IP** |
| CPF3 (PROFIBUS) | CP 3/1 | **PROFIBUS DP** |
| | CP 3/2 | **PROFIBUS PA** |
| | CP 3/3 | **PROFInet** |
| CPF4 (P-NET®) | CP 4/1 | **P-NET RS-485** |
| | CP 4/2 | **P-NET RS-232** |
| CPF5 (WorldFIP®) | CP 5/1 | **WorldFIP** |
| | CP 5/2 | **WorldFIP with subMMS** |
| | CP 5/3 | **WorldFIP minimal for TCP/IP** |
| CPF6 (INTERBUS®) | CP 6/1 | **INTERBUS** |
| | CP 6/2 | **INTERBUS TCP/IP** |
| | CP 6/3 | **INTERBUS minimal** [subset of CP |
| CPF7 (SwiftNet) | CP 7/1 | **SwiftNet Transport** |
| | CP 7/2 | **SwiftNet Full stack** |

# New structure of IEC65C for Industrial Ethernet




Source: Dok 65C_322e_INF / 3.12.2003

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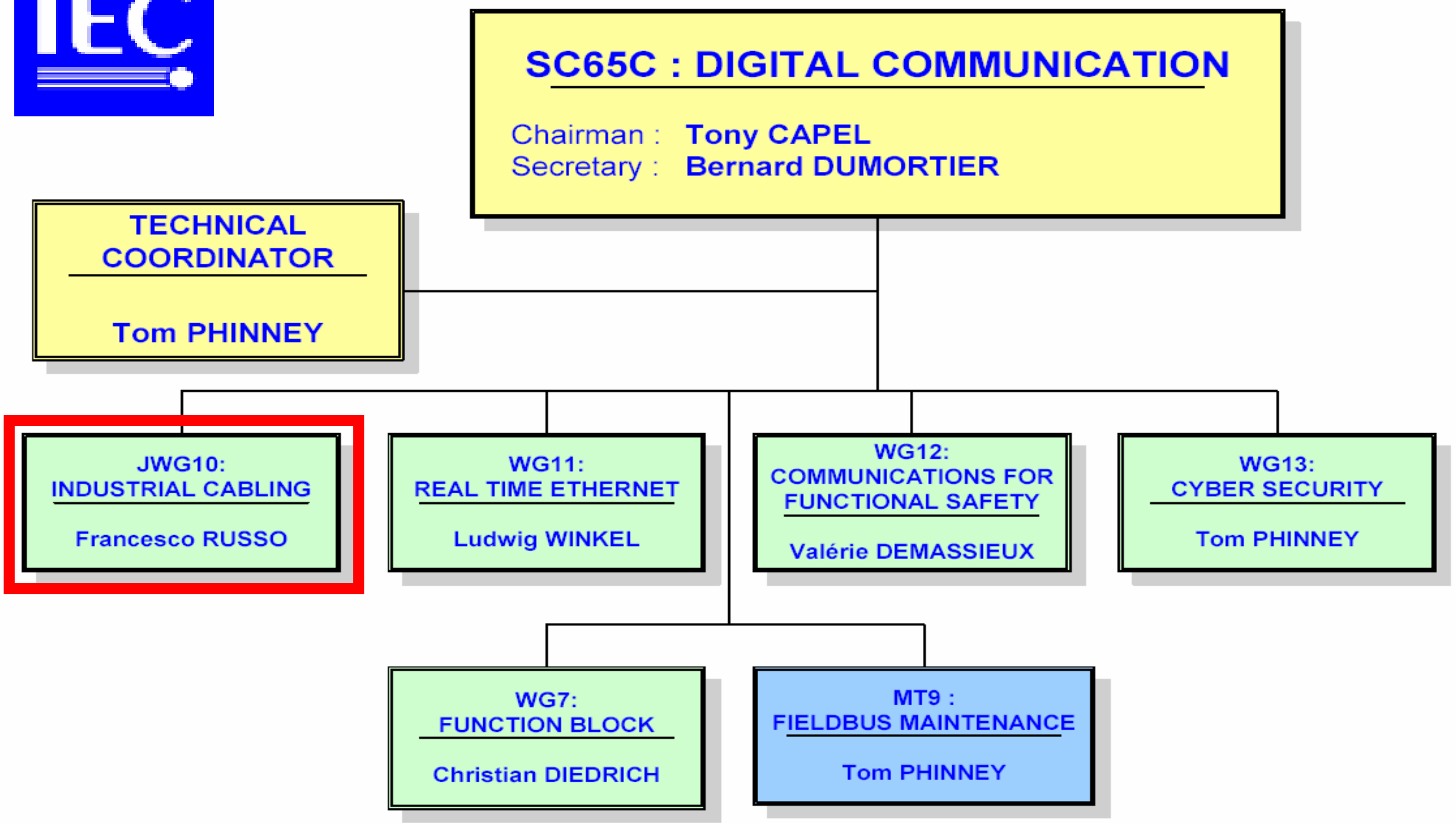


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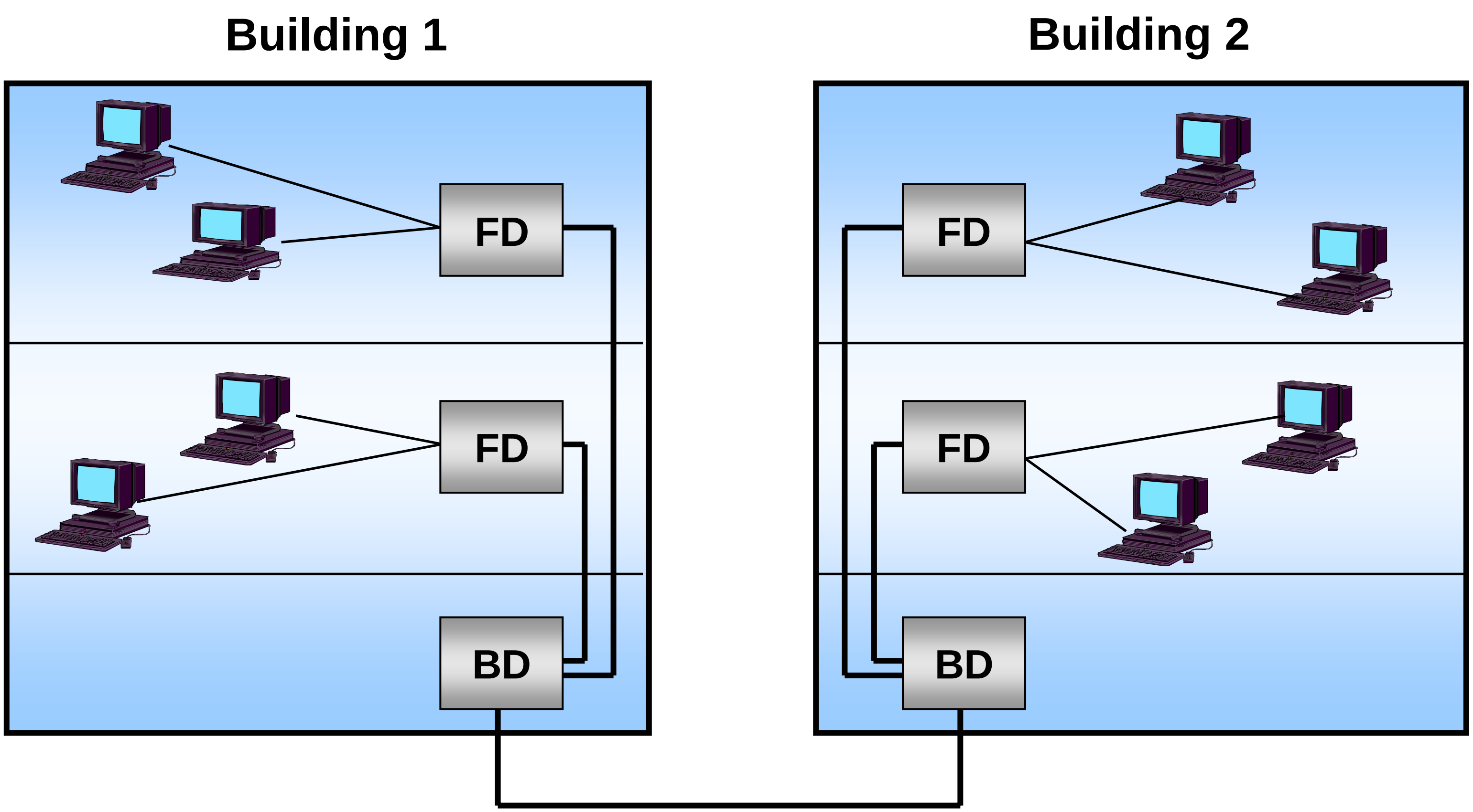
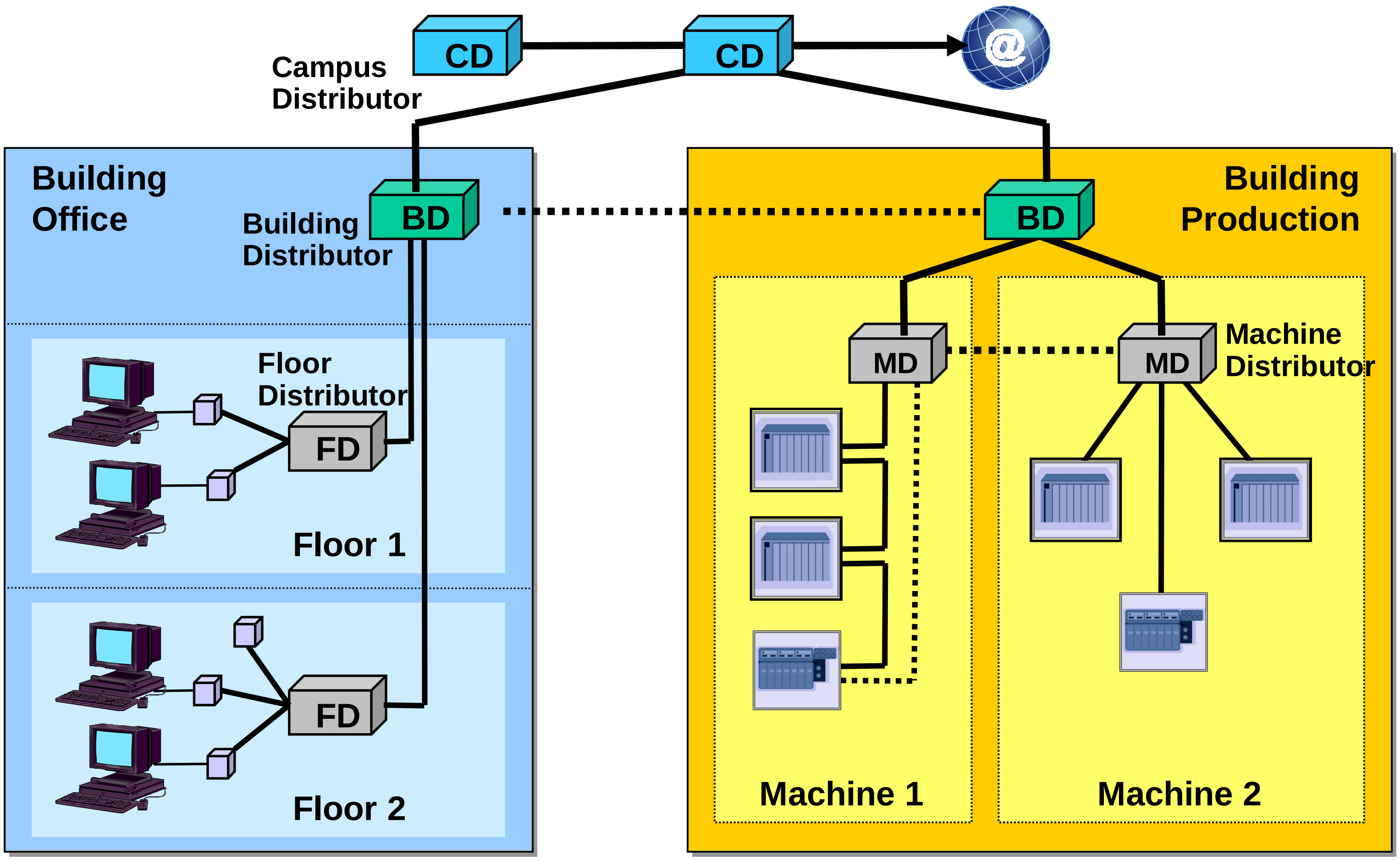
# Ethernet Networks in Office Area

- ⇨ **Tree structured net topologies following ISO/IEC 11801 with application independent cabling systems**




BD = Building Distributor, FD = Floor Distributor

# Ethernet Networks in Industrial Area

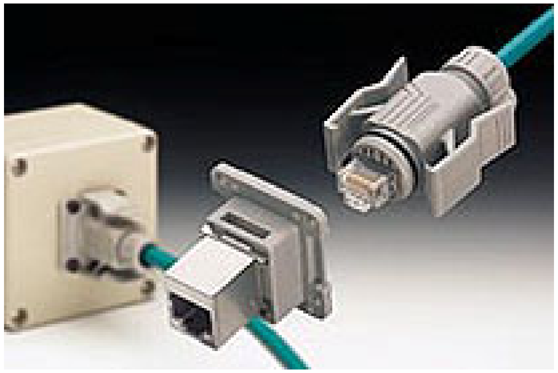



- ⇨ fixed basic installation with variable device connections
- ⇨ Star and tree structures
- ⇨ Plant specific cabling with individual net strucutre
- ⇨ Star, ring and line structures

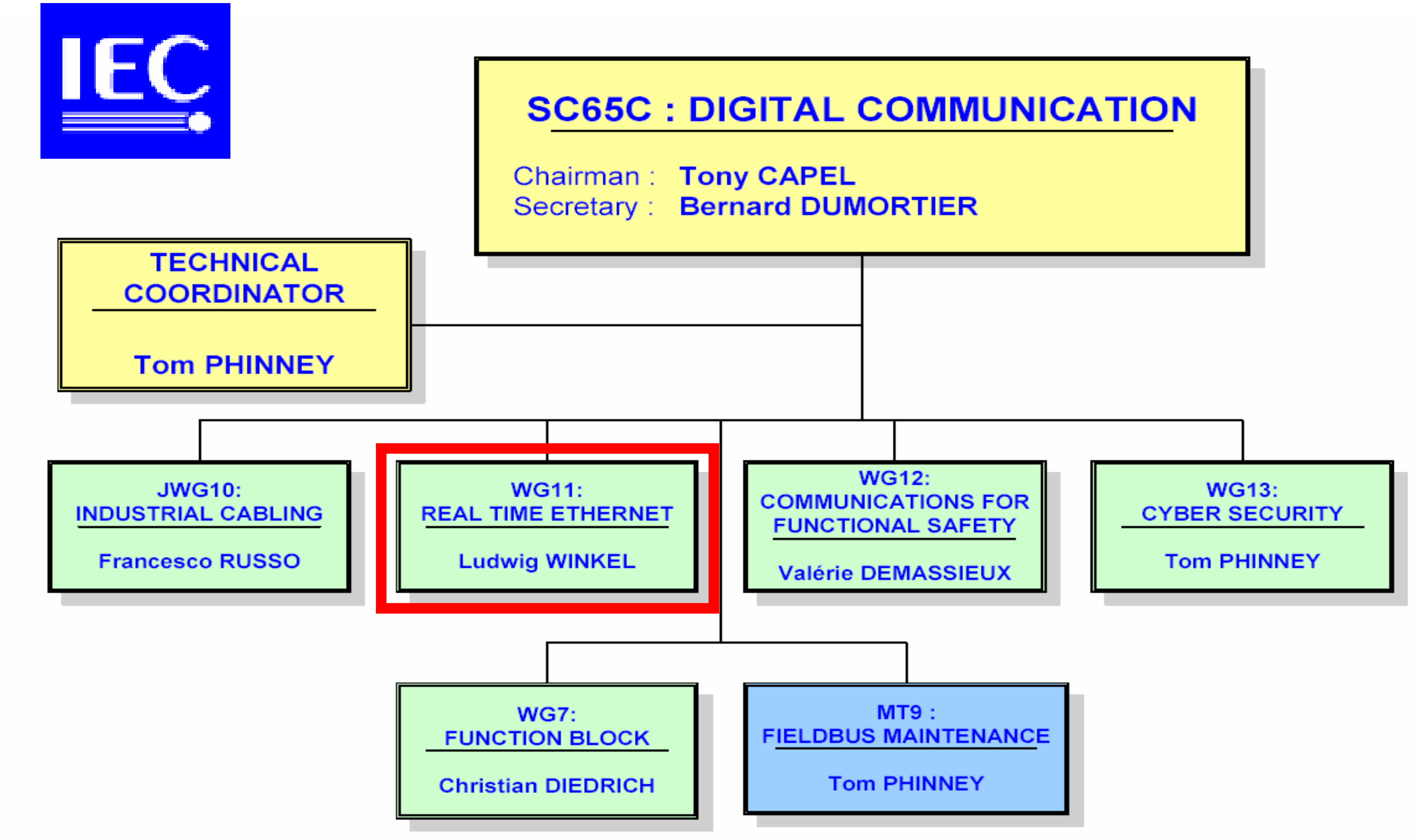
# Differences between Office and Industry

| ⇨Office Area | ⇨Production Area |
|---|---|
| ⇨**Fixed basic installation in a building** | ⇨**Largely system-related cabeling** |
| ⇨**Laid under raised floors** | ⇨**System-related cable routing** |
| ⇨**Variable device connection at workplace** | ⇨**Connection poins are seldom changed** |
| ⇨**Pre-fabricated device connection cable** | ⇨**Field-preparable device connections** |
| ⇨**Tree-shape network structures** | ⇨**Quite often: line-form network structures and (redundant) ring structures** |
| ⇨**Large data packets (e.g. images)** | ⇨**Small data packets (measured values)** |
| ⇨**Medium network availability** | ⇨**Very high network availability** |
| ⇨**Moderate temperatures (form 0 to 50°C)** | ⇨**Extreme temperatures (from -20 to +70°C)** |
| ⇨**No moisture** | ⇨**Moisture possible (IP65)** |
| ⇨**Virtually no vibrations** | ⇨**Vibrating machines** |
| ⇨**Low EMC burden** | ⇨**High EMC burden** |
| ⇨**Low mechanical danger** | ⇨**Danger of mechanical damage** |
| ⇨**Virtually no chemical danger** | ⇨**Chemical burden from oily or aggressive atmospheres** |

# Sealed RJ45 connectors



# New structure of IEC65C for Industrial Ethernet

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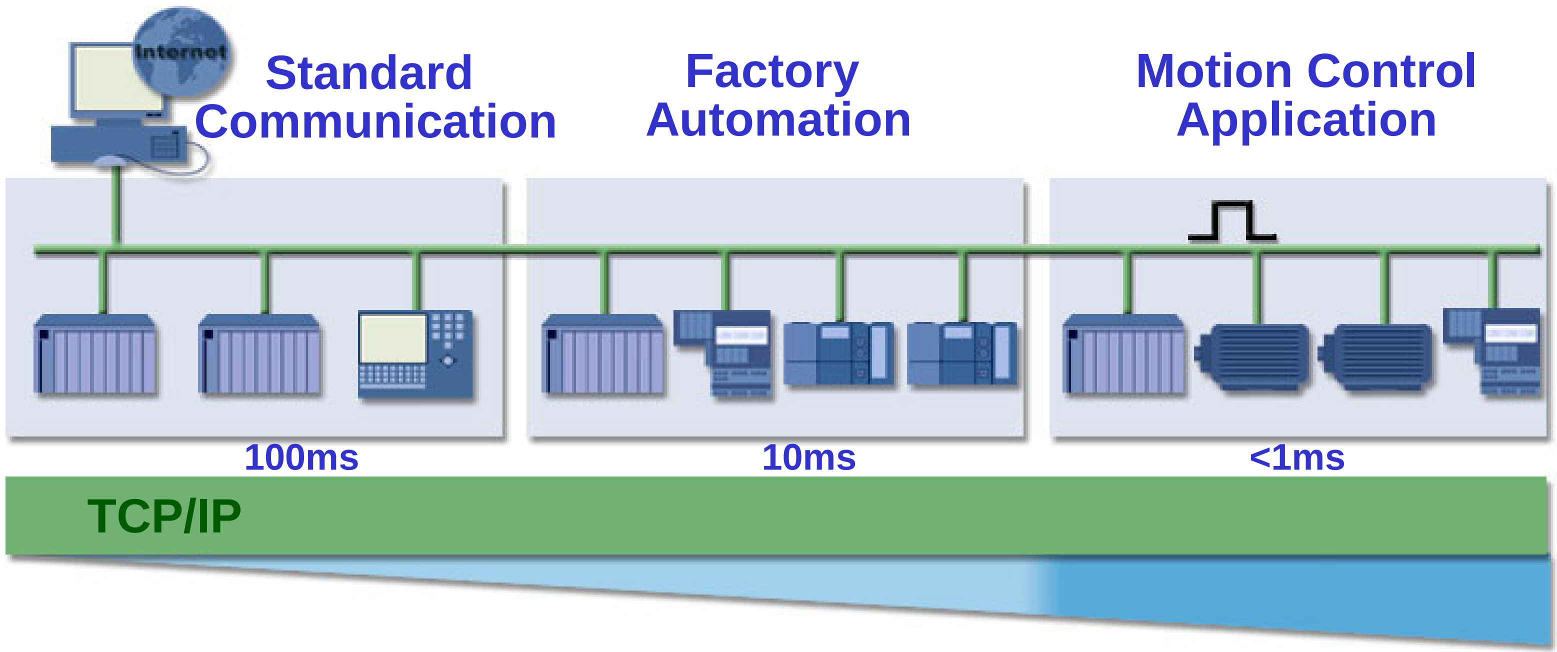
# Real-time requirements for Automation




- Coexistent use of real-time and IT communication on one line
- Uniform real-time protocol for all requirements
- Scalable real-time communication from high-performance to isochronous

# Possible structures of Industrial Ethernet

**7. Application Layer**

**6. Presentation Layer**

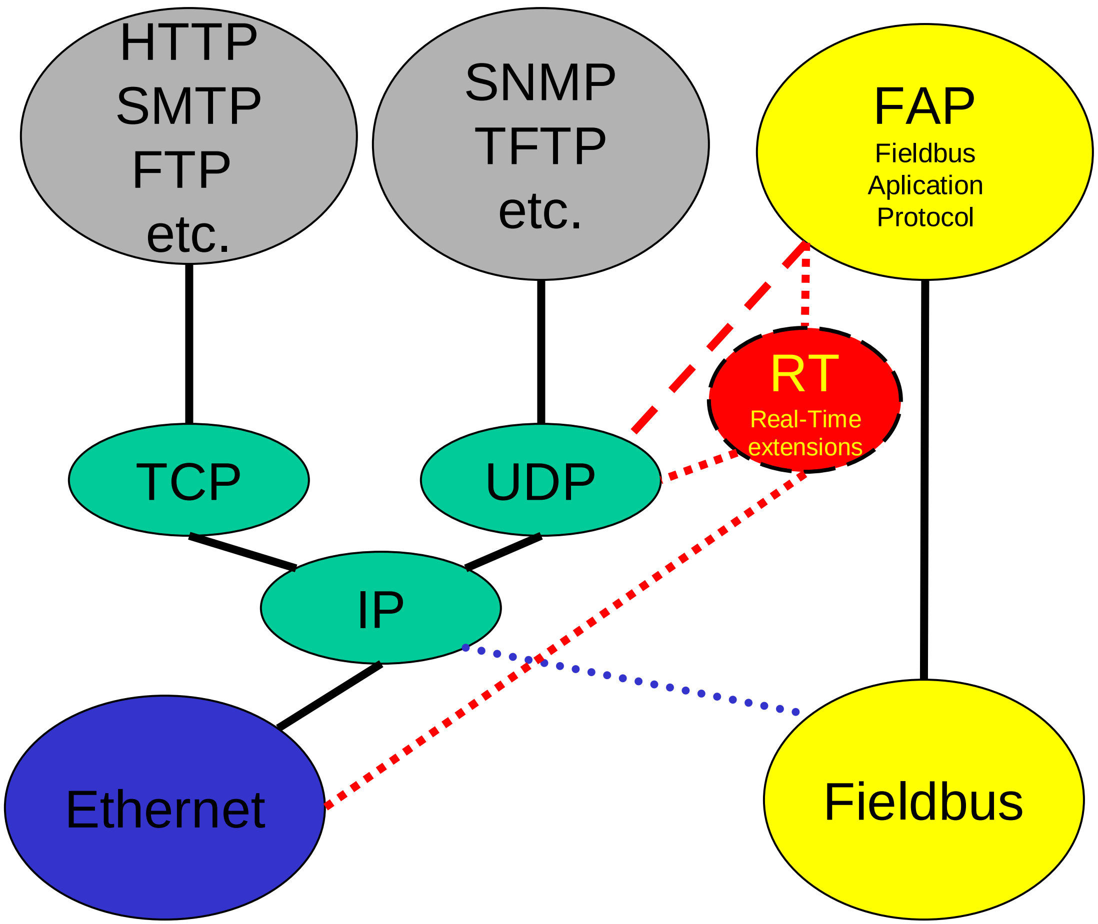
**5. Session Layer**

**4. Transport Layer**

**3. Network Layer**

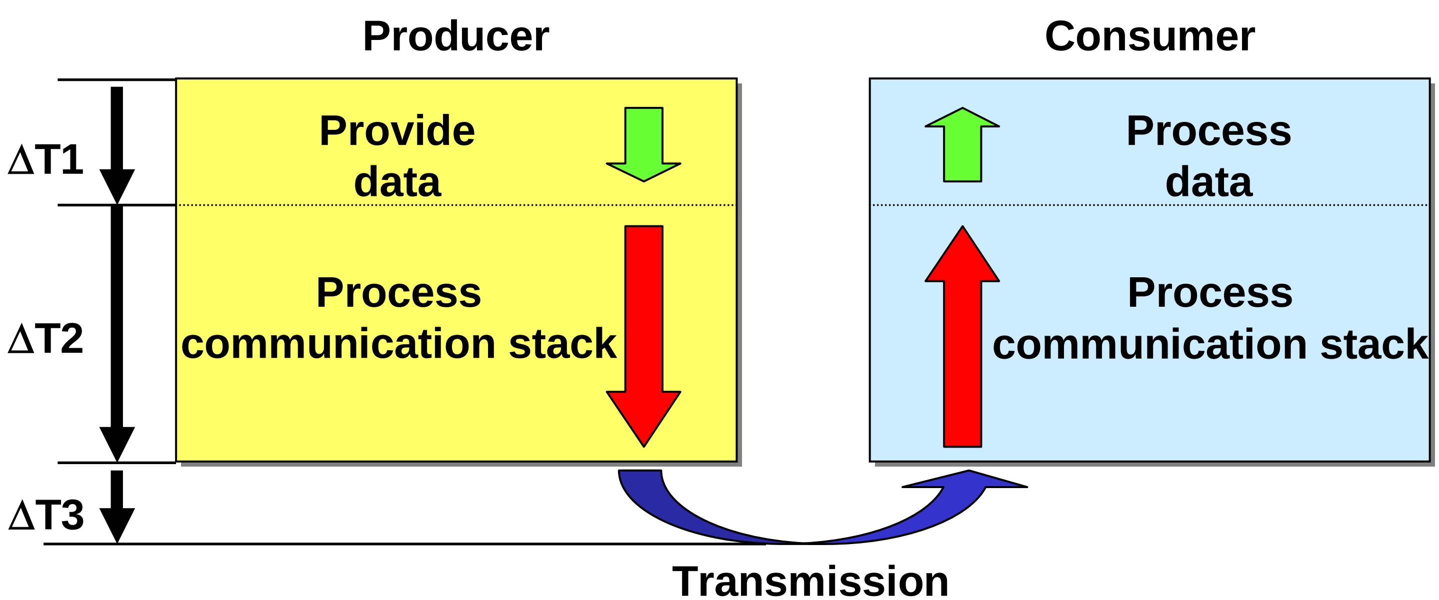
**2. Data Link Layer**

**1. Physical Layer**

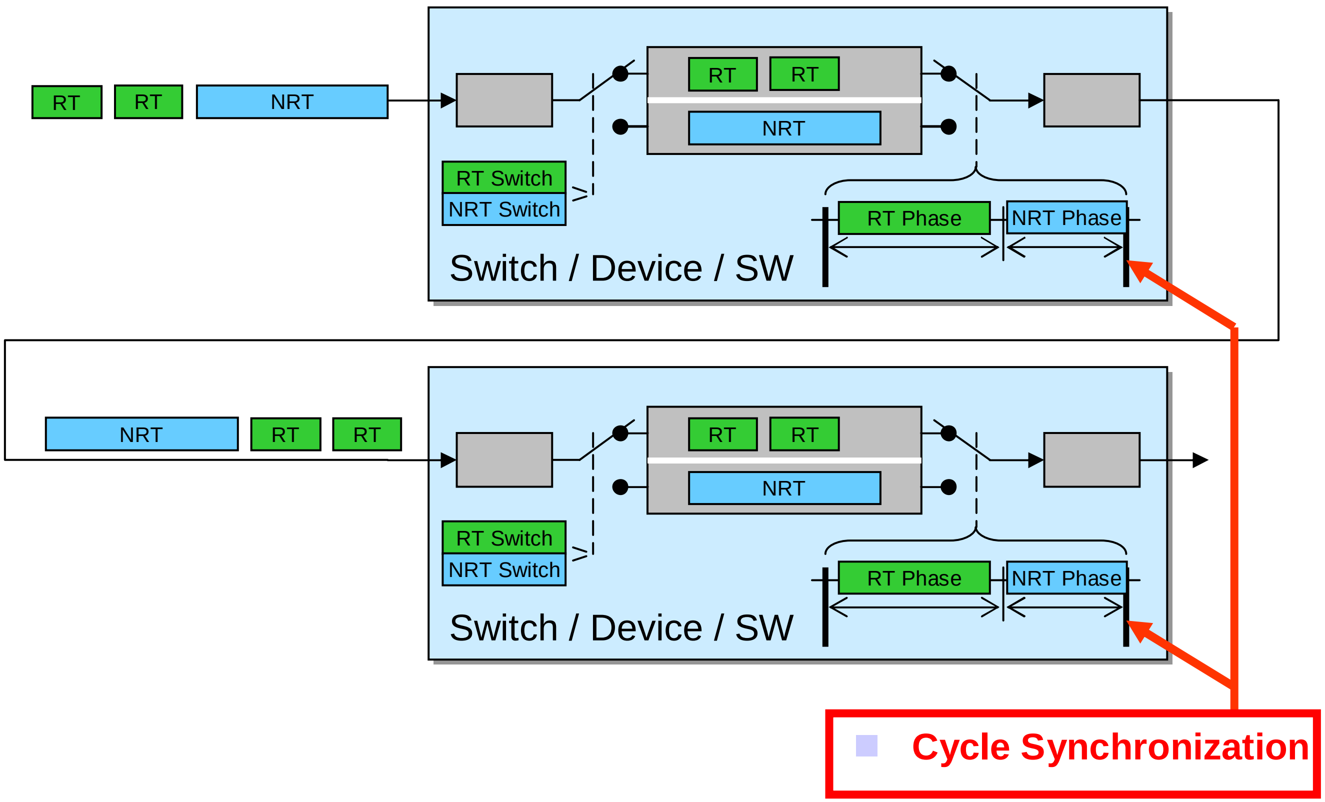


# Improving Performance in the Communication Stack

- The time needed for the provision and processing of the data is independent of communication
- Improved performance is possible through optimization of the turnaround times in the communication stack
- Reaction time less than 1 ms only if access method is modified
- Three solutions:
  - ✓ Best effort / Reduced communication stack / Modified access method



# General Behavior of Realtime Ethernet




- **Realtime data is transmitted in different timeslots than non realtime data**
  - ✓ **The differentiation is done in the switching hardware**
  - ✓ **The differentiation s done in the device hardware**
  - ✓ **The differentiation is done in the device software**

# Rules for IEC 61784-2

The classification of a RTE communication network shall be described within the technology specific subclauses using:

- ⇨ a class specific list of indicators – optionally with their limits or ranges – to show the capabilities of a CP
- ⇨ a set of lists with consistent indicators of the capabilities. Each of the tables has one indicator as a leading constant and showing the related limits of the indicators.
- ⇨ an optional graphical representation of the typical ranges of values and the associated equations.

# RTE performance indicators (1)

## Delivery Time

- ⇨ Delivery time is the time needed to convey a SDU (message payload) from one node (source) to another node (destination). The delivery time is measured at the Application Layer SAP interface.
- ⇨ The maximum delivery time shall be stated for two cases:
- ⇨ • no transmission errors and
- ⇨ • one lost frame with recovery

# RTE performance indicators (2)

## Number of end nodes

- ⇨ **Number of end nodes states the maximum number of RTE end devices supported by a CP.**
  - ✓ **The network devices like a switch are not counted in the number of nodes.**

## Basic network topology

- ⇨ **The basic network topology supported by a CP is stated out of the topologies listed in Table 9, or as a combination.**

## Number of switches between end nodes

- ⇨ **Number of switches between end nodes supported by a CP.**

| Basic network topology | CP |
|---|---|
| hierarchical star | CP m/1 |
| loop (ring) | CP m/2 |
| daisy-chain | CP m/3 |
| NOTE A real topology could be any combination of the three basic topologies. | |

# RTE performance indicators (3)

## Throughput RTE

- ⇨ Throughput RTE is the total amount of APO data (by octet length) on one link received on related AREPs through the path per second.

## (Throughput non-RTE)

- ⇨ Throughput non-RTE is the transmission capacity for non-RTE communication in bps.
- ⇨ Throughput non-RTE is the percentage of bandwidth, which can be used for Non-RTE communication.

# RTE performance indicators (4)

## Time synchronization accuracy

- ⇨ **Time synchronization accuracy shall indicate the maximum deviation between any two node clocks.**

## Redundancy recovery times

- ⇨ **Redundancy recovery time shall indicate the high limit maximum recovery time in case of a single permanent failure.**
  - ✓ **Delivery Time with permanent failures, but not with transient failures is replaced in that case by the recovery time.**

# Example of conformance statement

| Indicators | CP 2/3 | CP 2/4 | CP 2/5 |
|---|---|---|---|
| Delivery time less then [ms] | 4 | 1 | 0,25 |
| Nodes more then [number of bridges in-between nodes] | a) 1-200, see 7.1.1<br>b) 1- 20 nodes in a star or<br>c) less then 10 bridges in between nodes | 50 nodes in a star or<br>less then 10 bridges in-between nodes | 250 nodes in a star or less then 10 bridges in-between nodes |
| Throughput RTE (90%); more then [std.-messages] | 20.000 | 20.000 | 20.000 |
| Throughput Non-RTE (90%); more then [Mbit/s] | 60 | 70 | 80 |
| Time synch. Accuracy better then [µs] | 1 | 0,5 | 0,3 |
| Redundancy (recovery times) shorter then [ms] | 10.000 | 100 | 0,25 |
| Number of data objects more then [#of objects] | 10.000 | 100.000 | 300.000 |

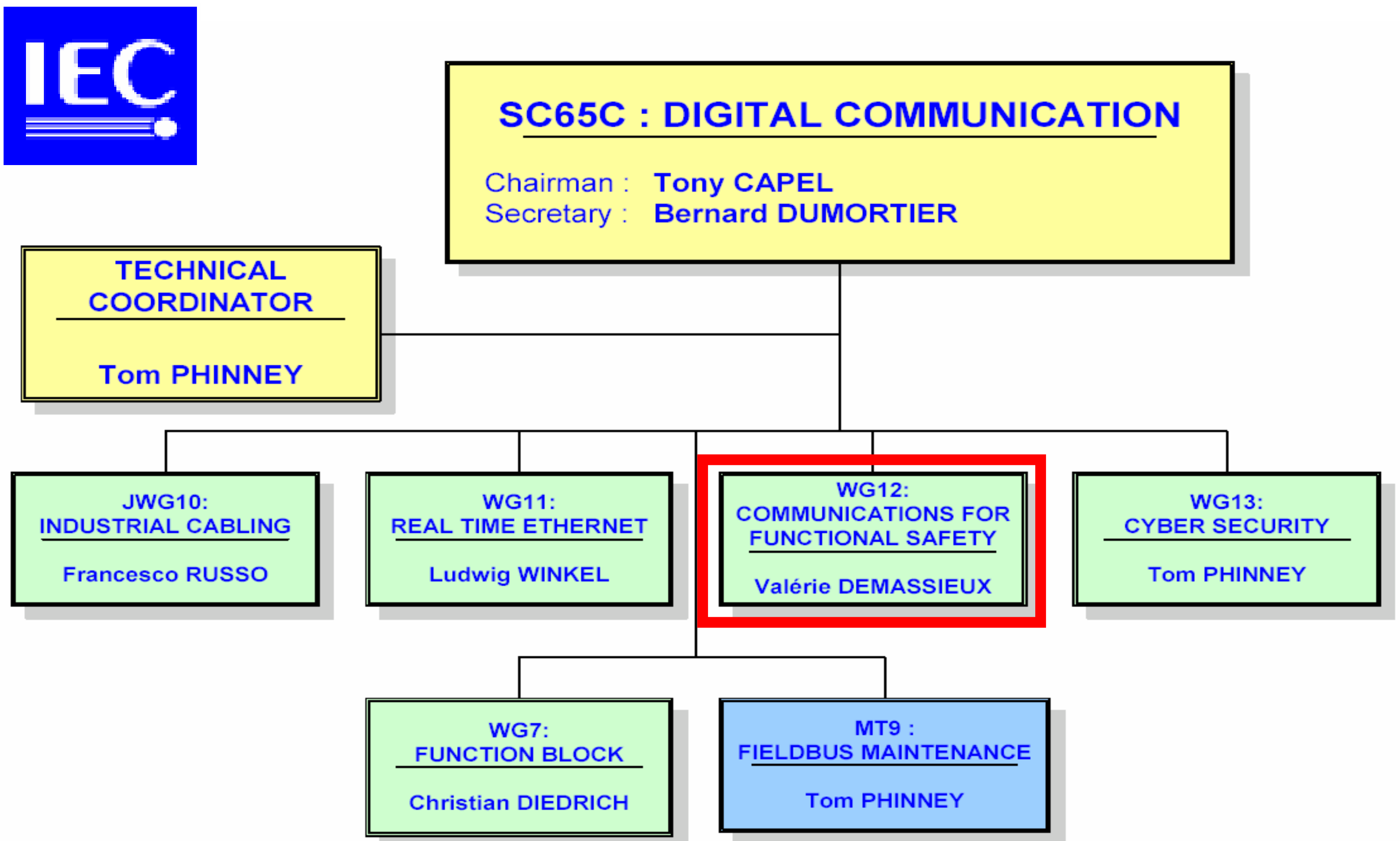
# The international fieldbus – IEC 61784-2

| | | |
|---|---|---|
| CPF2 (ControlNet™) | CP 2/2 | **EtherNet/IP** |
| | CP 2/3 | **EtherNet/IP RTE?** |
| CPF3 (PROFIBUS) | CP 3/3 | **PROFINET CBA** |
| | CP 3/4 | **PROFINET I/O** |
| | CP 3/5 | **PROFINET IRT** |
| CPF4 (P-NET®) | CP 4/3 | **P-NET RTE ?** |
| CPF6 (INTERBUS®) | CP 6/2 | **INTERBUS TCP/IP** |
| | CP 6/4 | **INTERBUS RTE?** |
| CPF10 (VNET/IP) | CP 10/4 | **VNET/IP** |
| CPF11 (TCnet) | CP 11/4 | **TCnet** |
| CPF12 (EtherCAT) | CP 12/4 | **EtherCAT** |
| CPF13 (EPL) | CP 13/4 | **Ethernet Powerlink** |
| CPF14 (EPA) | CP 14/4 | **EPA** |
| CPF15 (Modbus-RTPS) | CP 15/4 | **Modbus-RTPS** |
| CPF16 (SERCOS) | CP 16/4 | **SERCOS III** |

11 solutions will be refererenced with several profiles each!

State of the document 61784-2 8.2004

# New structure of IEC65C for Industrial Ethernet

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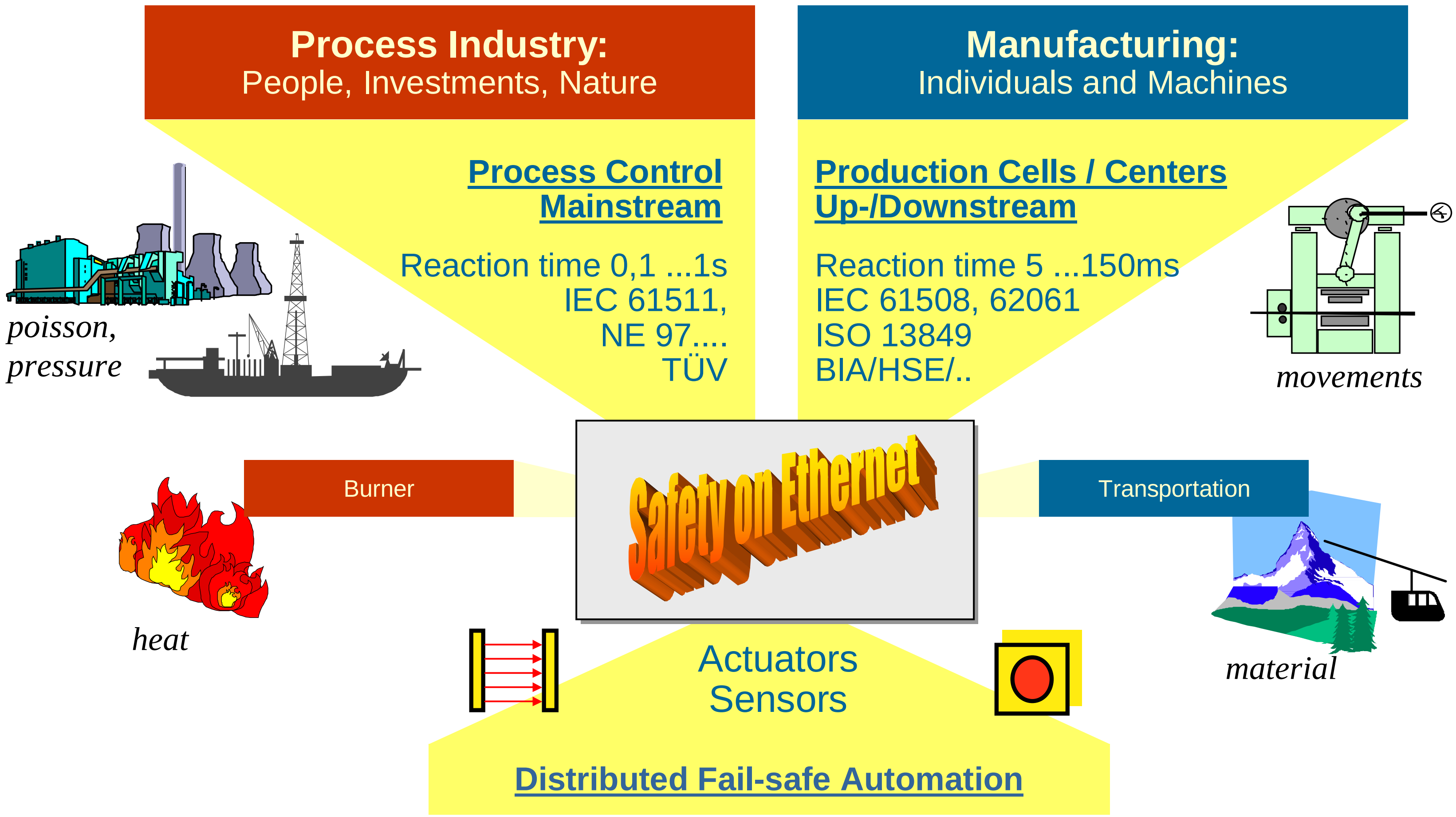
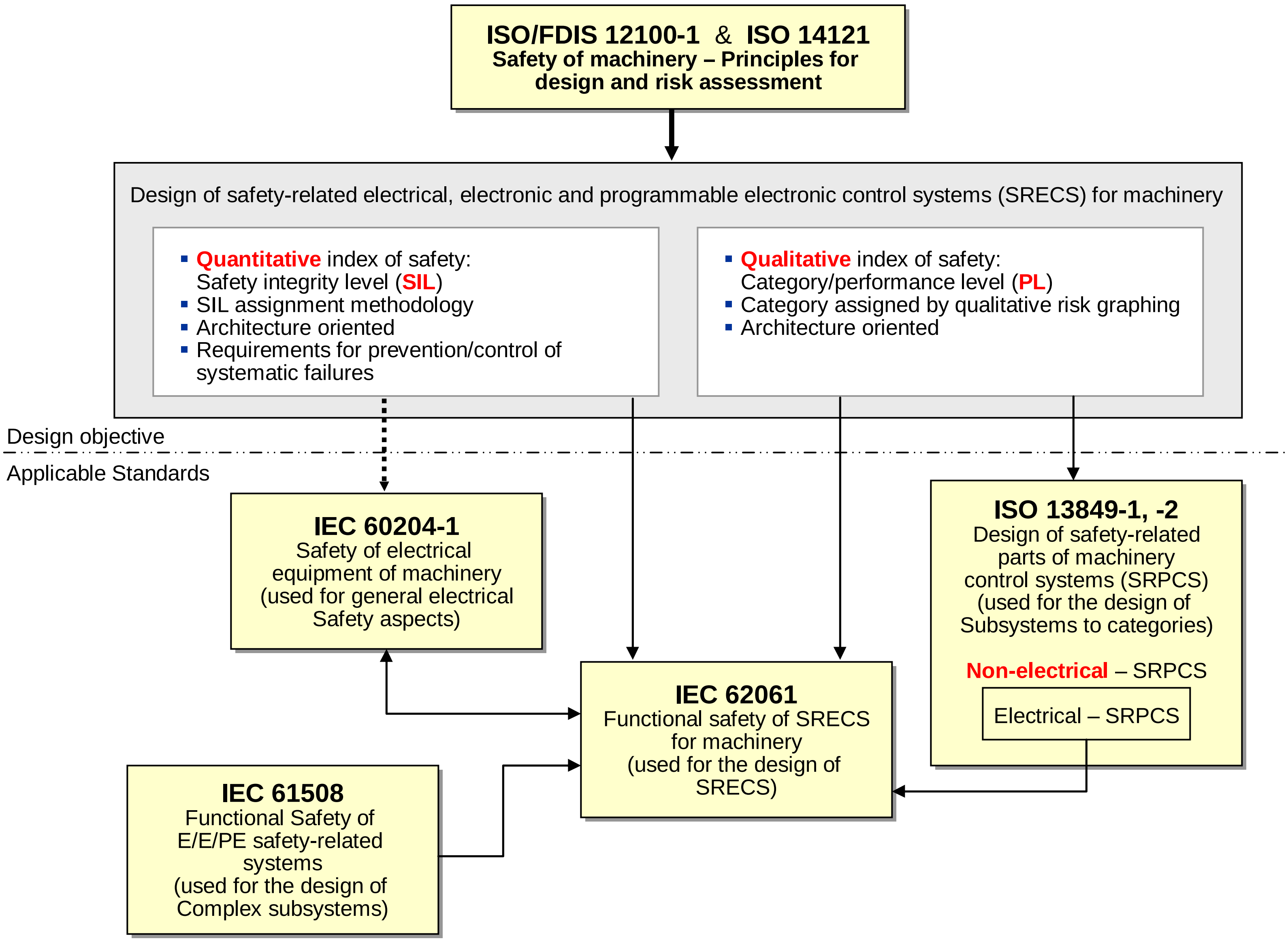
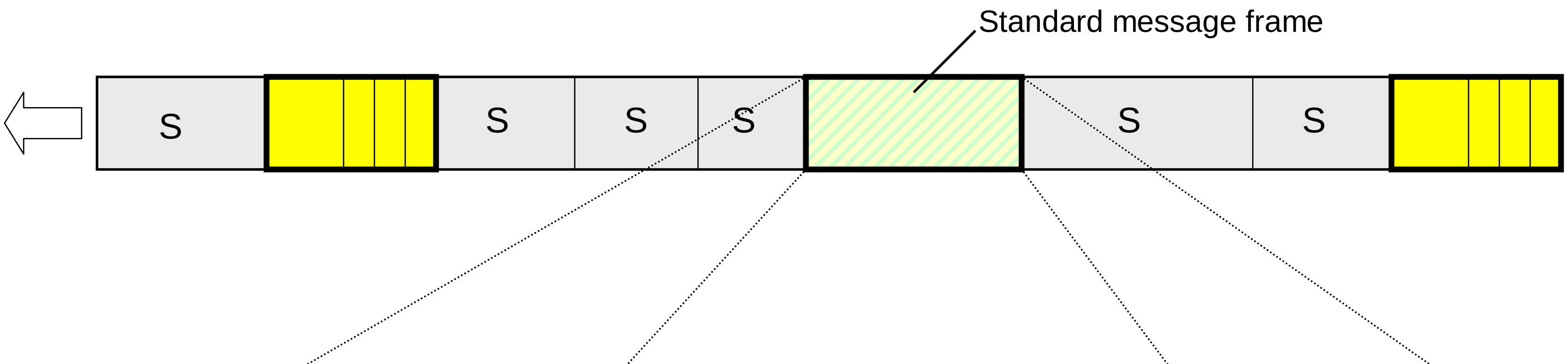
# Industrial potential Risk Areas ...



# Safety Standards for Machinery Applications



# Example: PROFIsafe




| F input/output data | Status / controlbyte | Consecutive number | CRC | Standard-I/O-Data |
|---|---|---|---|---|
| | | Sender based counter | across F data and F parameter | |
| **Max. 12 / 122 Bytes** | 1 Byte | 1 Byte | 2/4 Bytes *) | (240/238 - F-Data) |

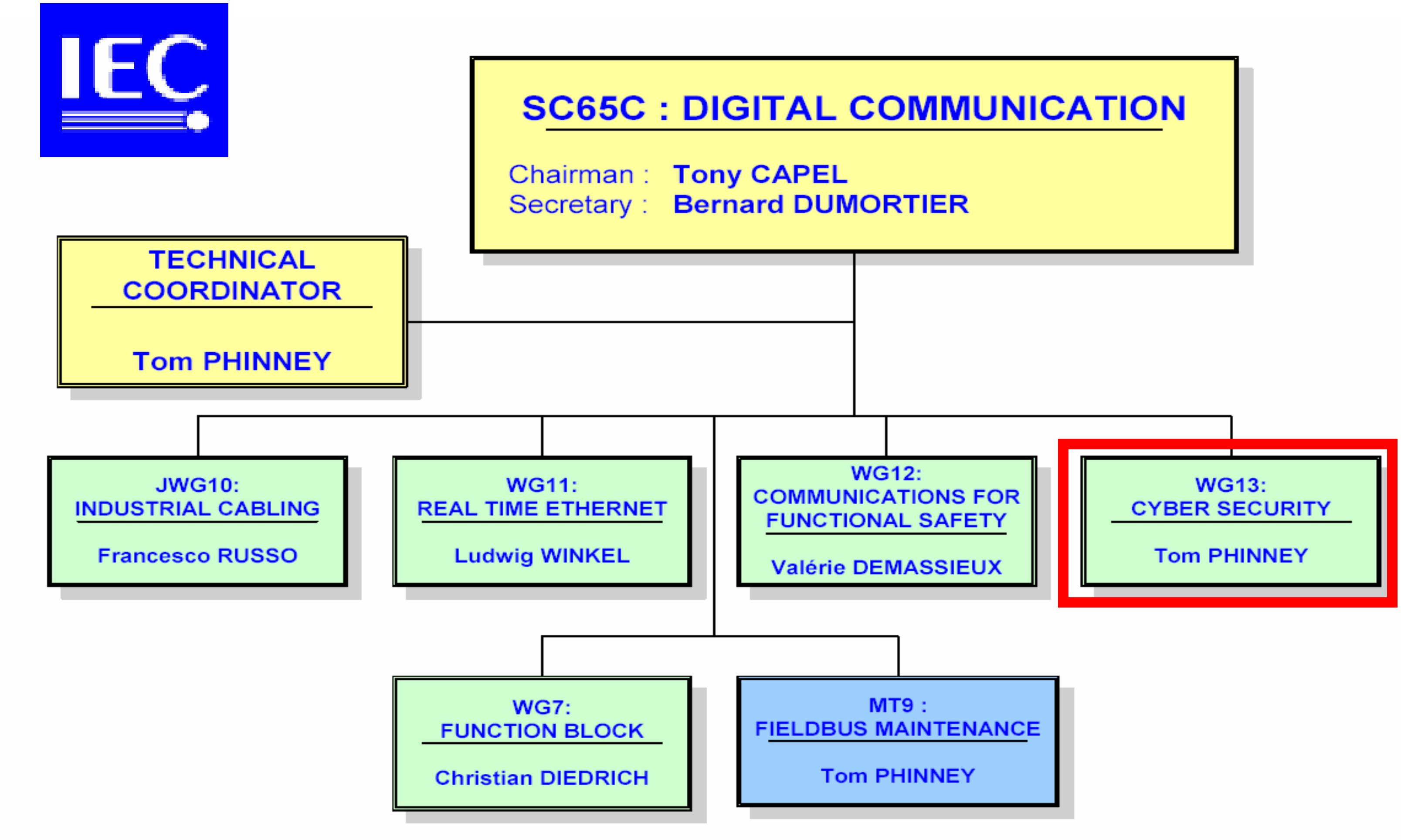
Max. 244 Bytes DP data

PROFIsafe frame

*) 2 Byte for a max. of 12 Byte F I/O data
4 Byte for a max. of 122 Byte F I/O data

There is no reason why these frame could not be transmitted over industrial Ethernet!

# New structure of IEC65C for Industrial Ethernet

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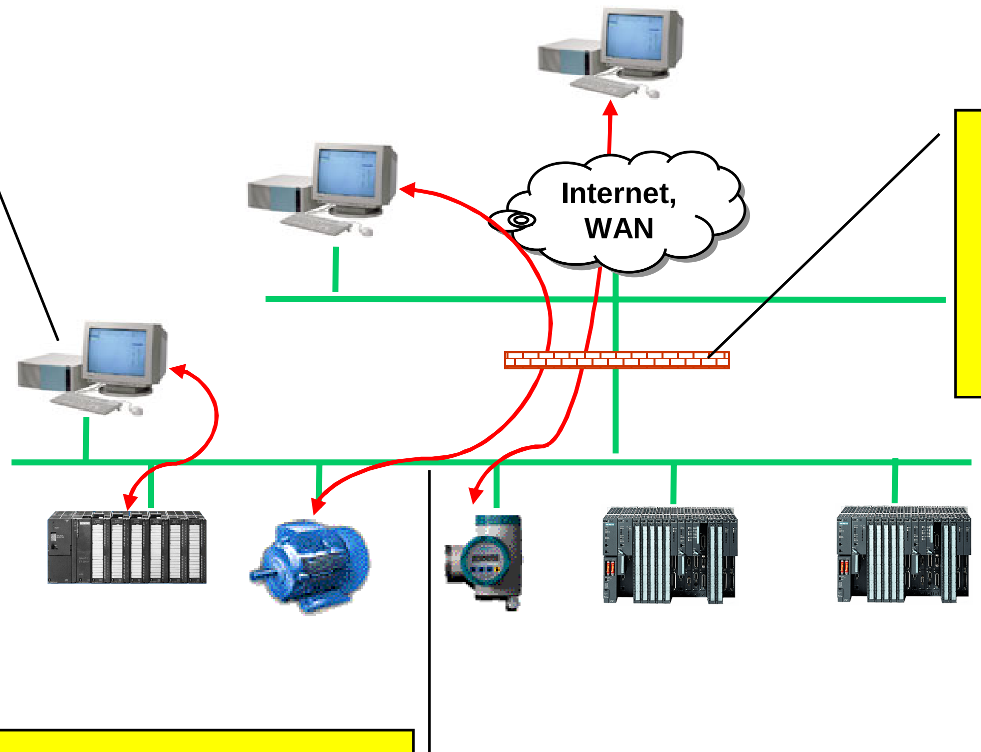
# One Ethernet technology ?

Is this dangerous?




Protection from the outside world with a firewall

Clear separation of RTE and non RTE!

# Possible conclusions

- The components and the installation rules for IT-Ethernet and Industrial-Ethernet are different
- To realize a RTE, we need different, more efficient protocols than TCP/IP or UDP/IP
- The network components like switches are different for Industrial Ethernet
- Additional security mesures have to be taken
  - ✓ RTE offers more possibilities than a fieldbus
  - ✓ RTE is not cheaper than a fieldbus
  - ✓ The additional price makes only sense, if the additional features are realy needed and used.

# Profiles are the key for future developments

- ⇨ **Example of variable speed drives**
- ⇨ **Common generic interface to the PDS**
- ⇨ **How are industrial Ethernet solutions integrated?**