Optimization vs. Performance in the modern process control systems

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YOKOGAWA

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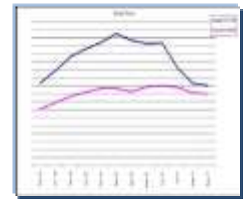
Contents

Why we are here: the Industry Challenge

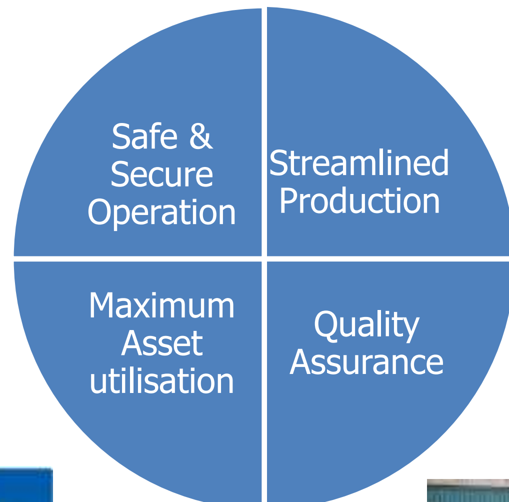
Strong competition

Increasing Regulations

Supply/Demand Fluctuation



Aging Operators

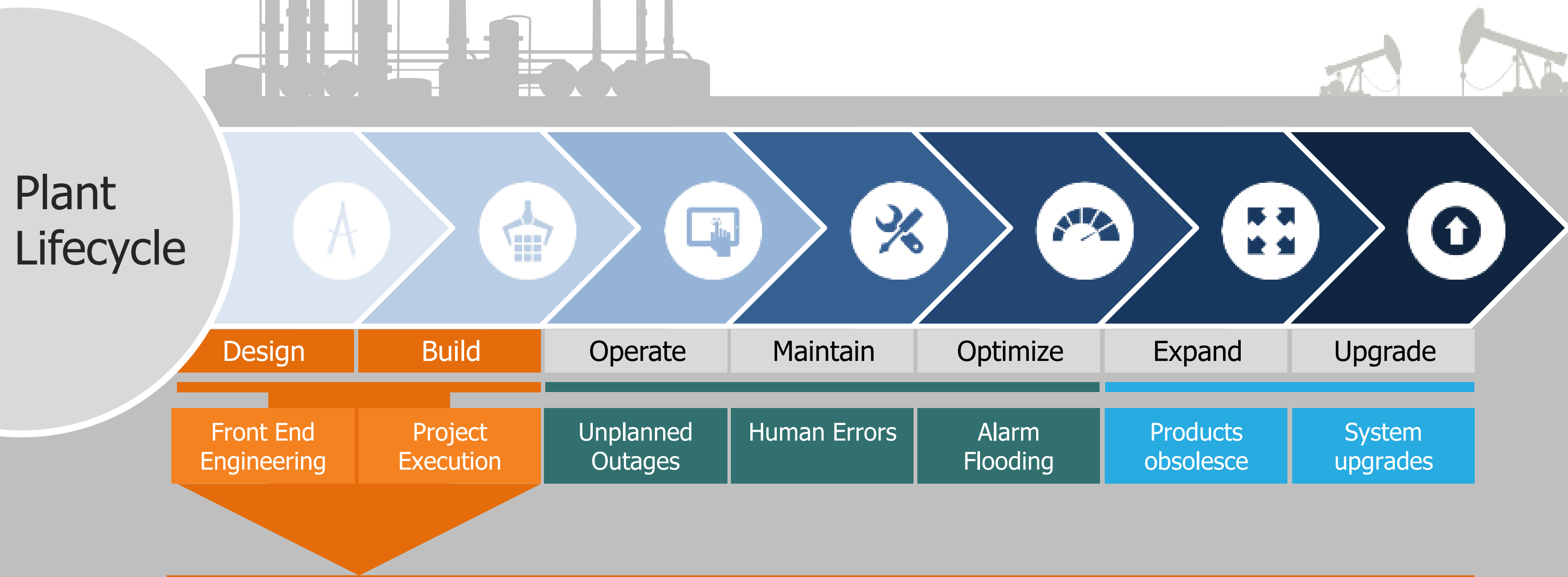


Consumer power

Environment

Aging assets

Focus on the system design and project development

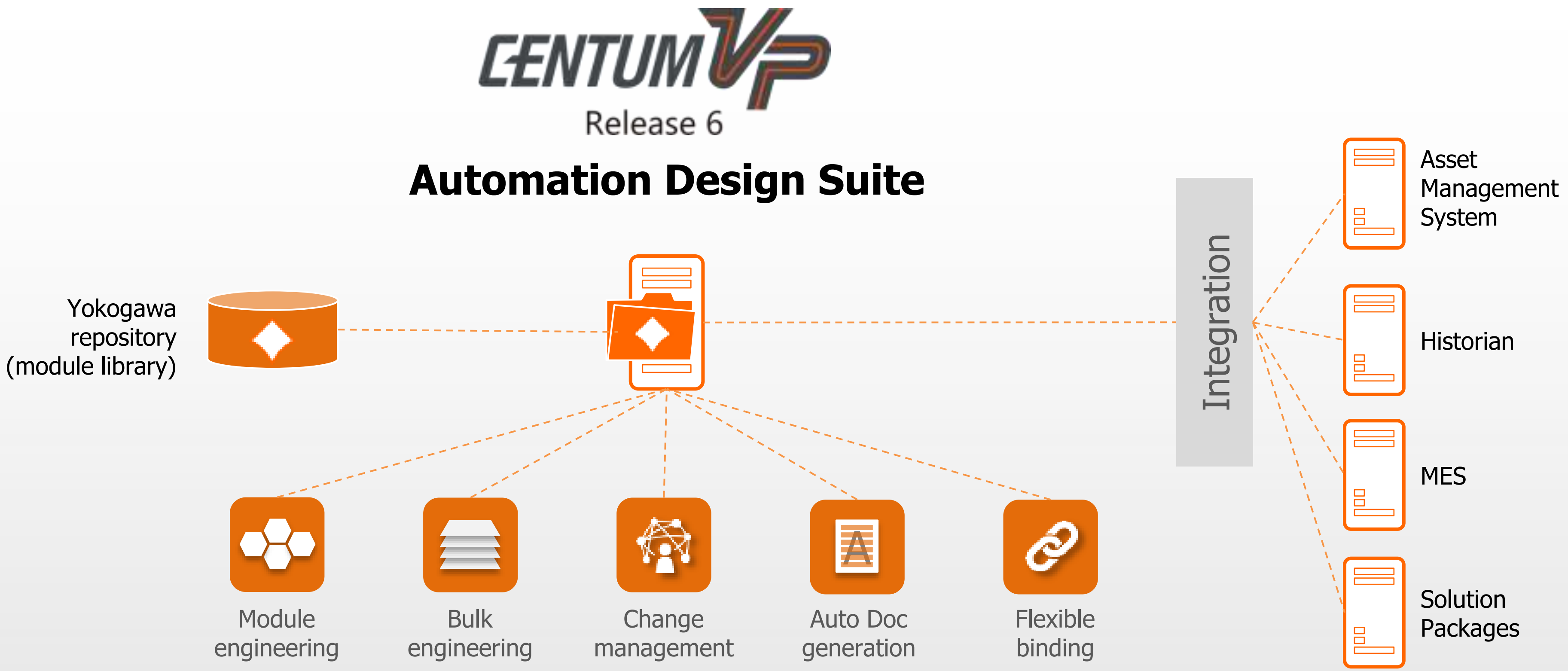


Project Execution

Managing uncertainty, project complexity, late changes, cost overruns, and deplays. The challenges gets even greater when the lack of manpower and technical resources are factored in.

Versatile Hardware and Flexible Project Execution

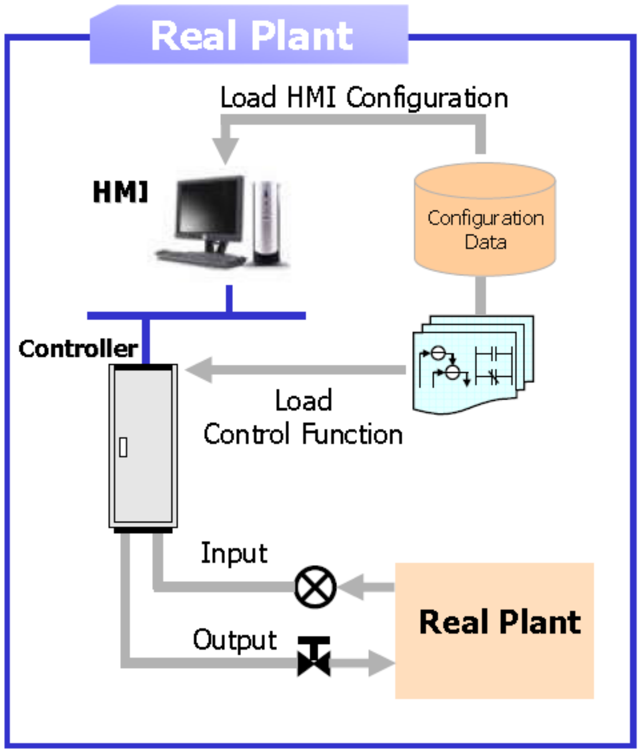
Design & development: Smart Engineering

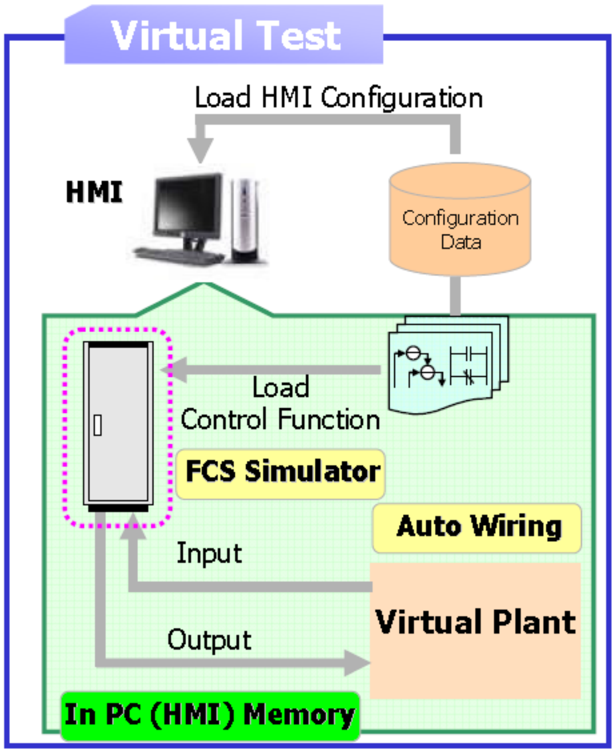


Automation Design Suite goes beyond traditional DCS engineering functionality.
An integrated platform that facilitates project execution, systems integration, and site execution, delivers certainty and confidence throughout all project phases.

Software debugging: Virtual Test Function

- Simulate complete DCS on computers
  - Full-scale system can be tested without target hardware
- Wireless debug (wireless Factory Acceptance Test)
- Snap shots for evaluations
- Seamless integration with training simulation models





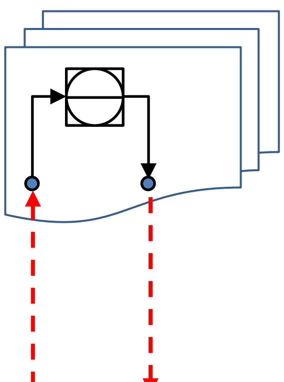
Avoiding Project Delays

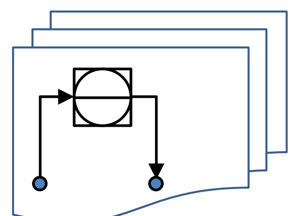
SEE CLARITY
KNOW IN ADVANCE
ACT WITH AGILITY

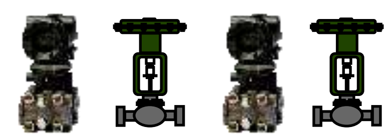
Reduce delays and be assured of starting production on schedule

Application validation during FAT

Designed & constructed on site







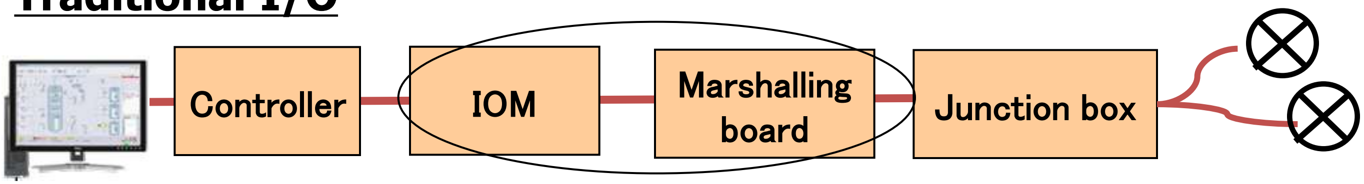
Last minute software marshaling

Virtual I/O wiring

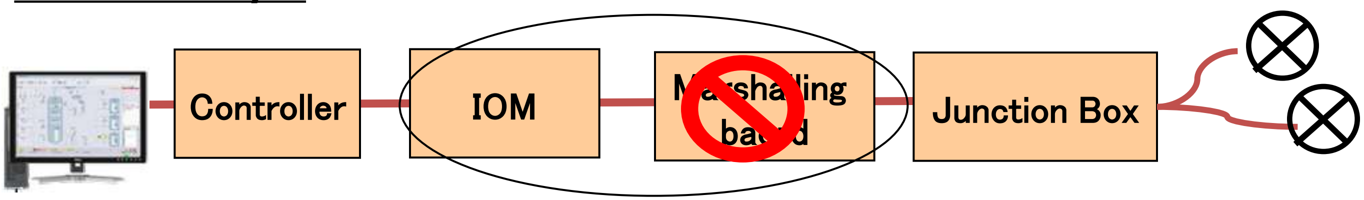
Smart Configurable IO

Hardware: Universal I/O reduces the footprint.

Traditional I/O



Universal I/O



I/O design and relative works are eliminated.

Work
*I/O list & Controller sizing
*Power, grounding & ~~fusing design~~
*~~I/O design~~
*~~Spares sizing~~
*~~Cabinet design~~
*Conduit & cable layout
*P&IDs
*Process narratives
*Installation package

Work
*~~Cabinet design~~
*~~Jumpers & terminations~~
*~~Wiring diagrams~~
*~~Cable layout~~

Work
*JB design
*Jumpers & terminations
*~~Wiring diagrams~~
*Cable layout

CENTUM VP

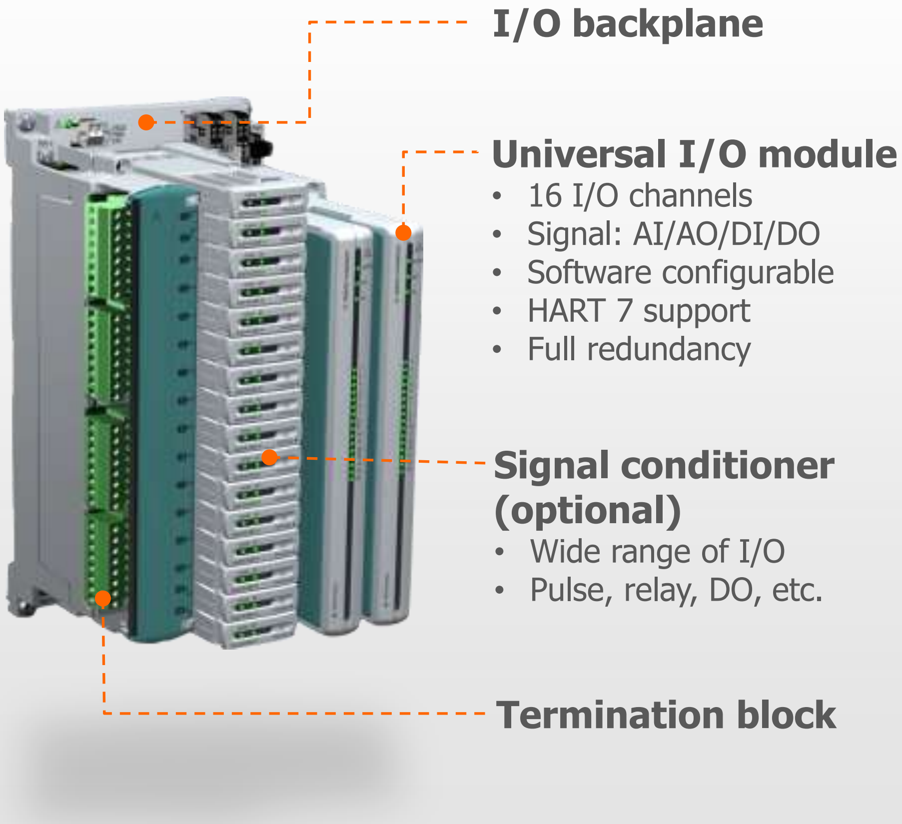
Smart Configurable I/O

"Best of both World"

Universal I/O + Signal Conditioner

Next Generation Smart I/O: N-IO (Network I/O)

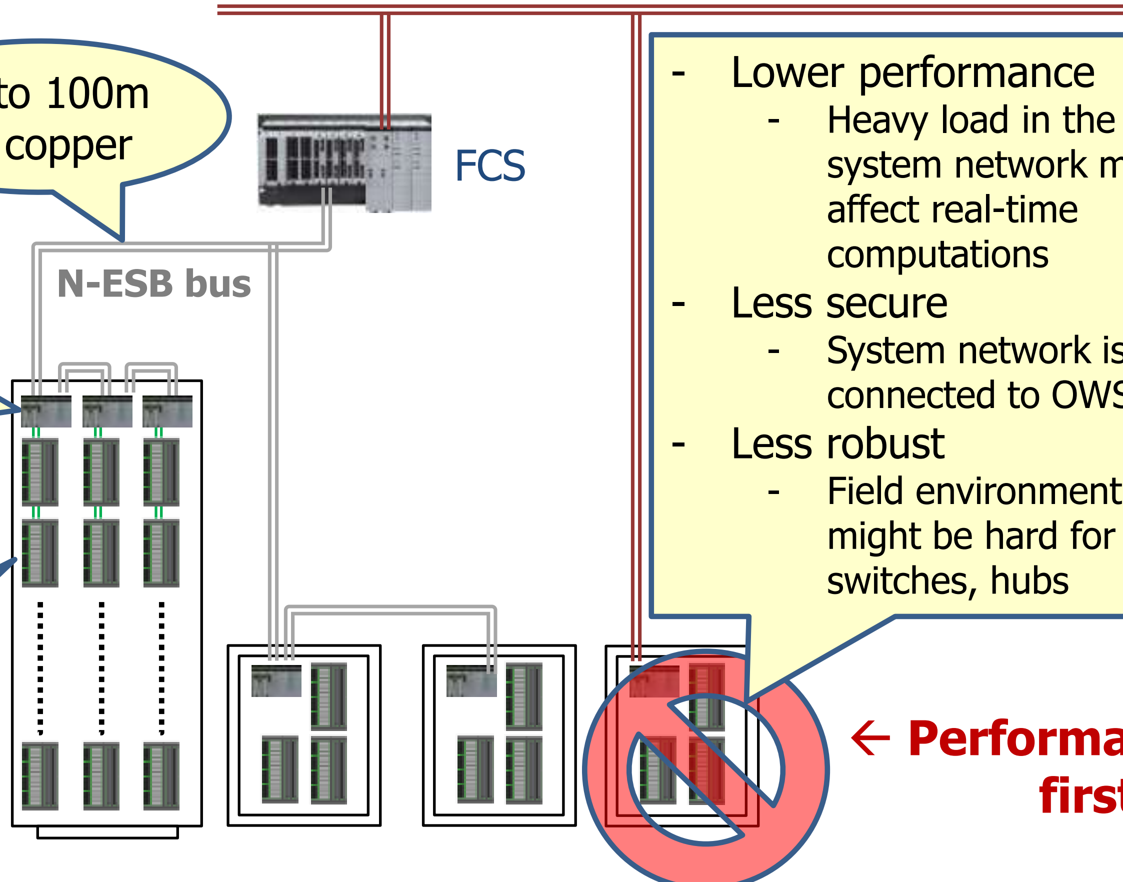
- N-IO is designed with fewer components. A single module can be configured to support AI/AO/DI/DO.
- An optional signal conditioner can be plugged in to support a wide range of I/O signal types.
- The backplane allows I/O redundancy by design, resulting in a smaller footprint.



IO network Configuration

Node Interface Unit

Up to 100m by copper



- Lower performance
  - Heavy load in the system network might affect real-time computations
- Less secure
  - System network is connected to OWS
- Less robust
  - Field environment might be hard for std. switches, hubs

← **Performance first !**

N-ESB bus

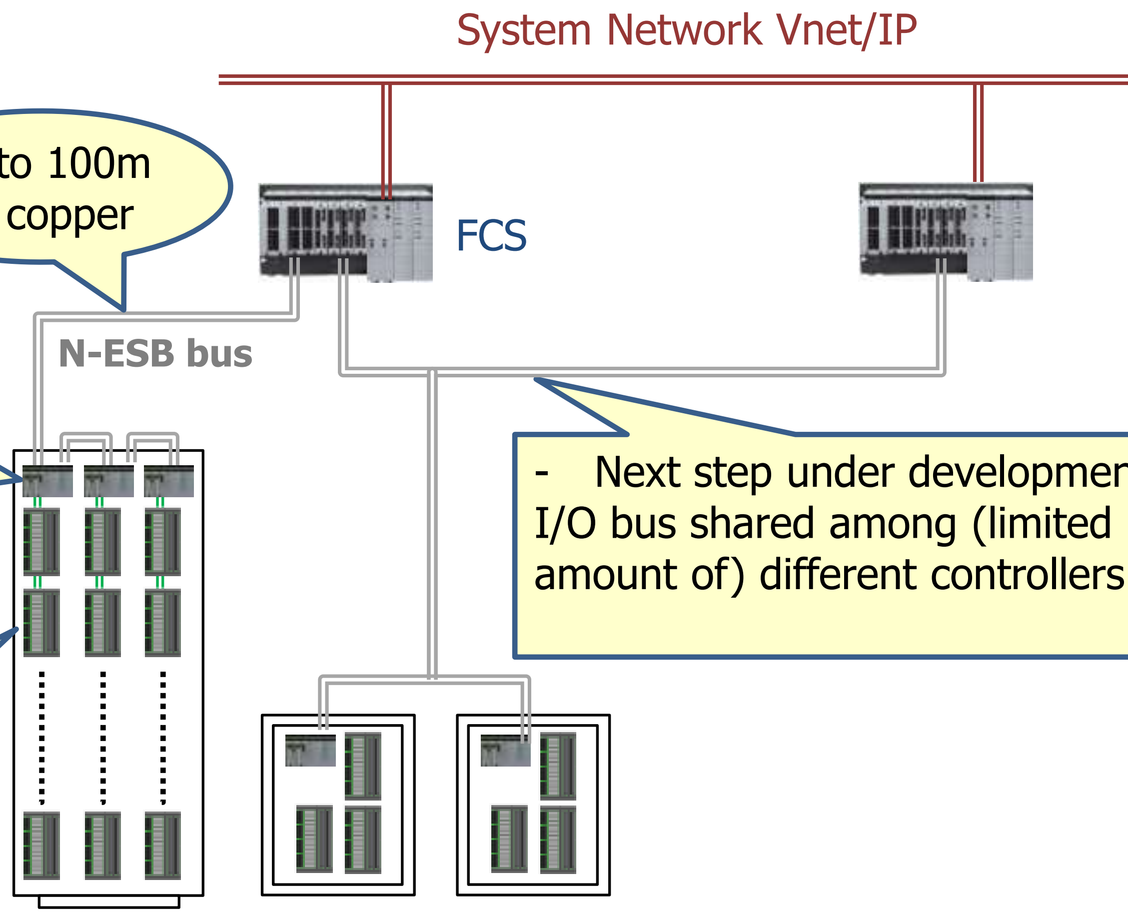
- Up to 50 Km by optical fiber, 100 Mbps
- Cat5e cable
- No hub or switch is required

- 15 -

IO network Configuration

Node Interface Unit

Up to 100m by copper



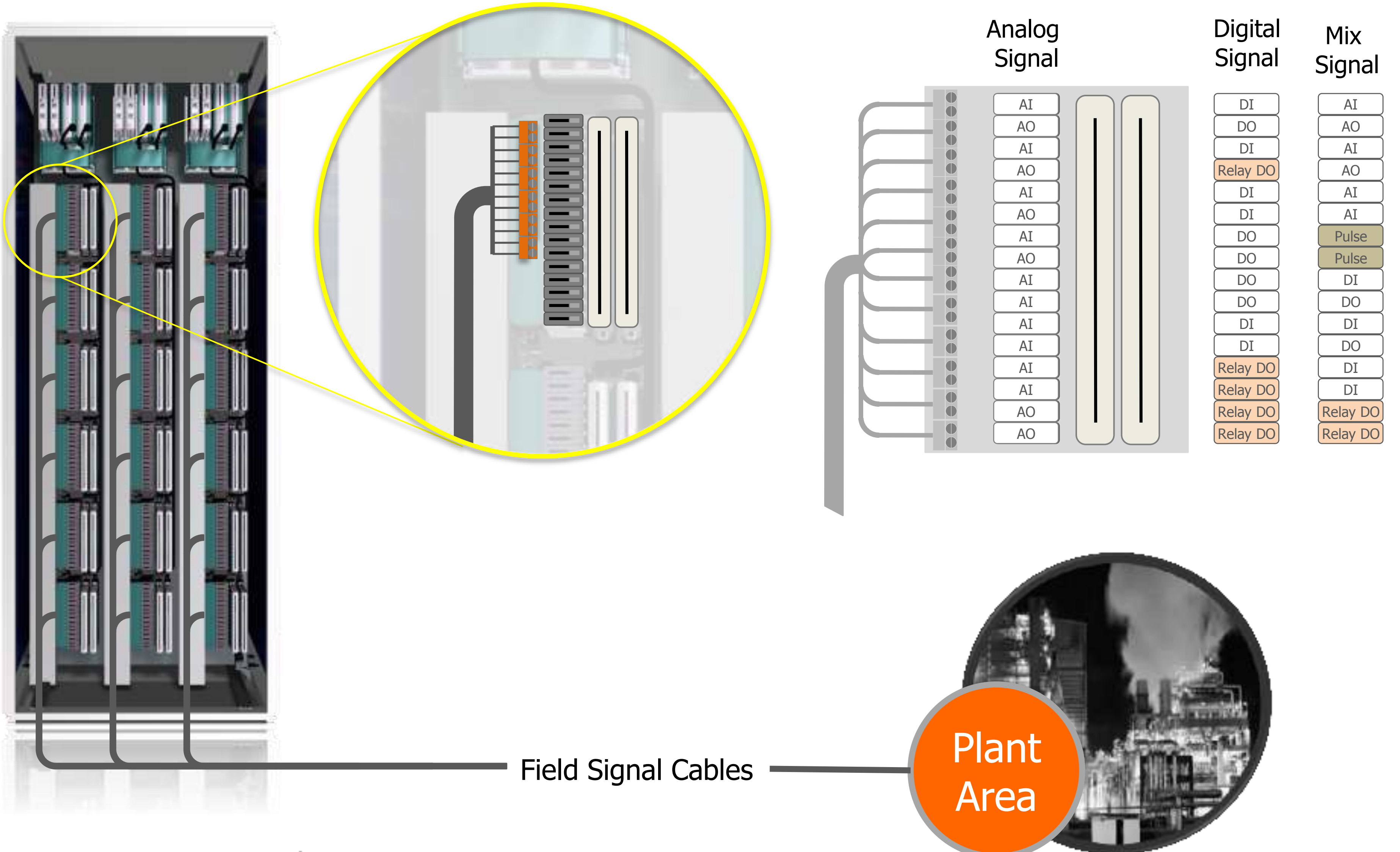
- Next step under development: I/O bus shared among (limited amount of) different controllers

N-ESB bus

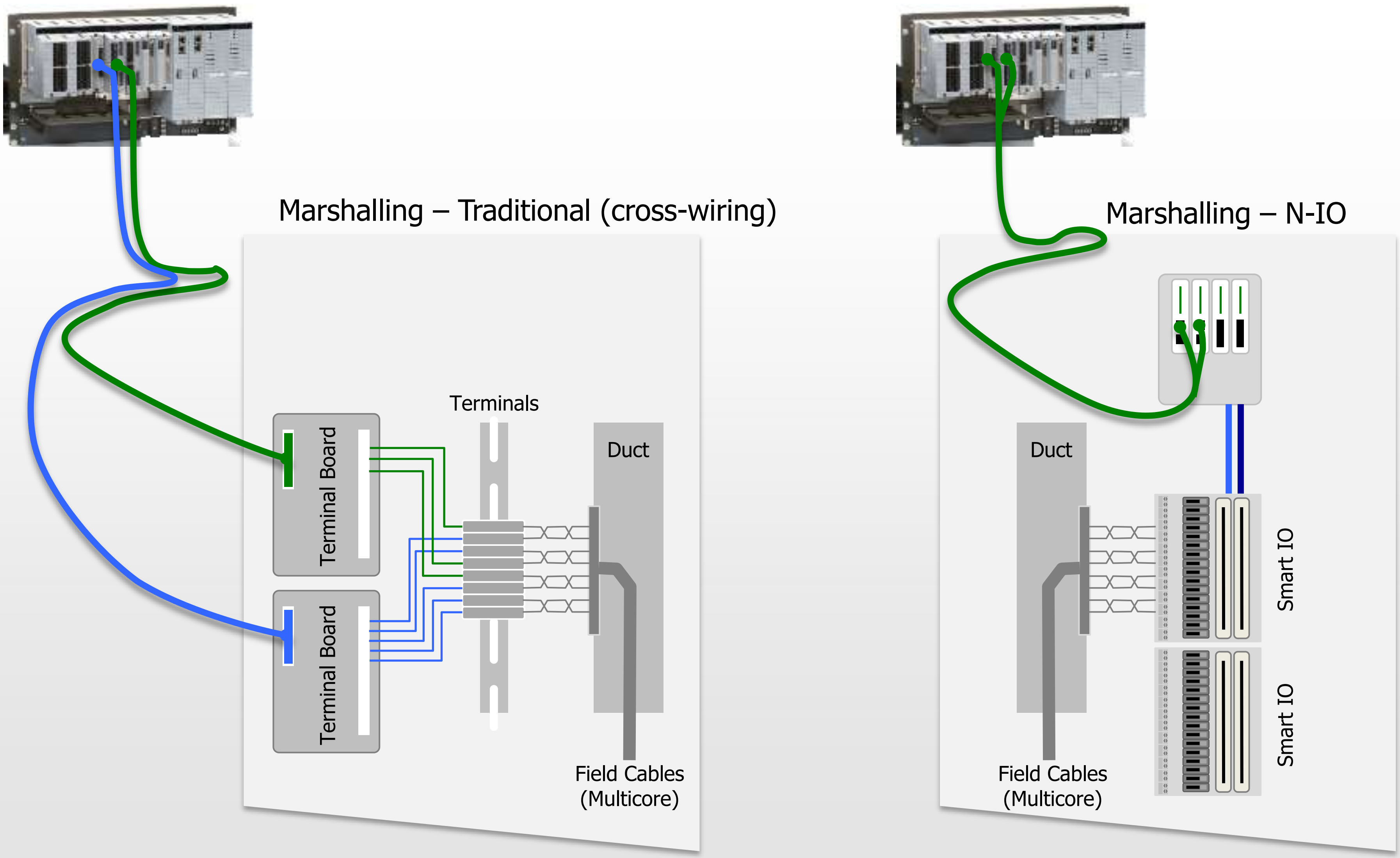
- Up to 50 Km by optical fiber, 100 Mbps
- Cat5e cable
- No hub or switch is required

- 16 -

Termination



Marshalling Comparison of FIO and N-IO



Footprint: N-IO vs. Conventional IO

A-IO: **2,000**

D-IO: **3,000**

Total: **5,000**

Conventional

System Cabinet

X 5

Analog Mar. Cabinet

X 5

Digital Mar. Cabinet

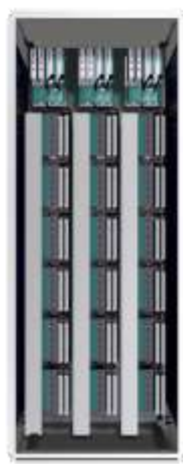
X 7

17 Cabinets

N-IO

System Cabinet

X 1



N-IO Cabinet

X 9

10 Cabinets

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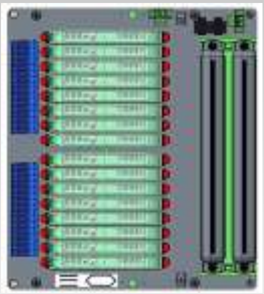
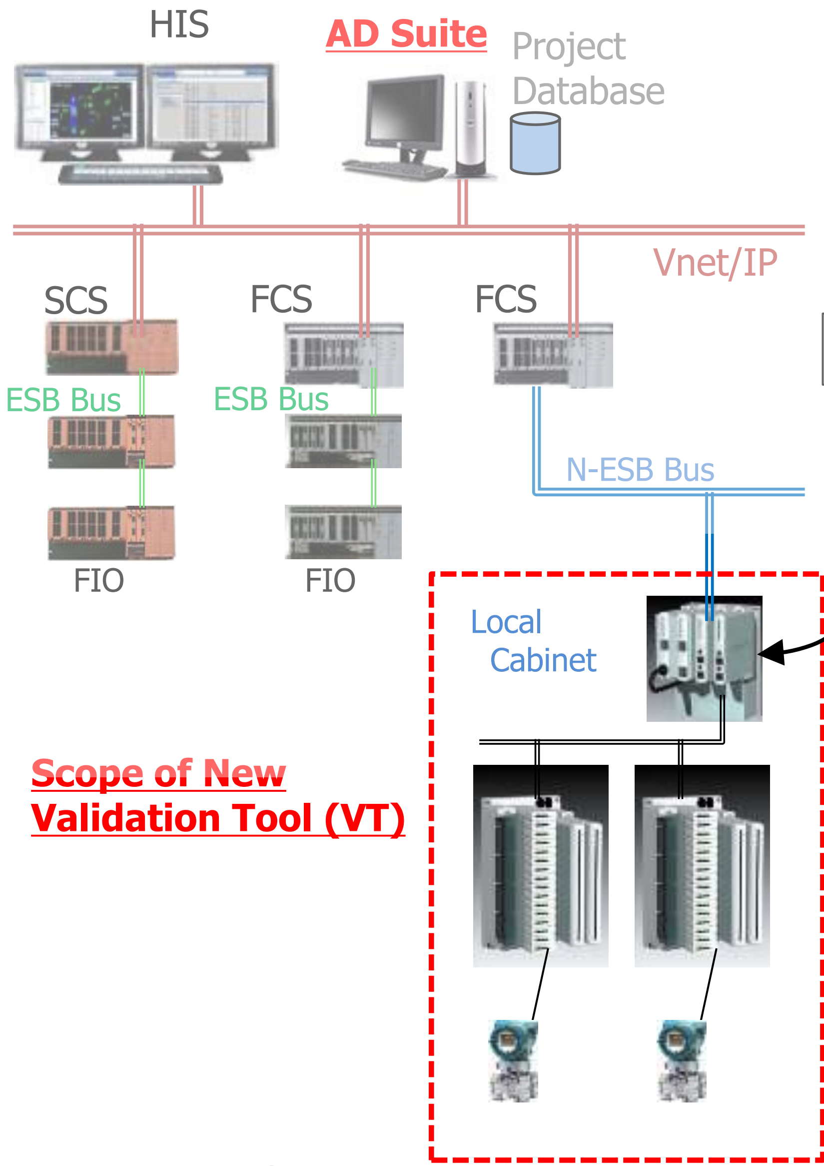
N-IO for Hazardous Applications

Non-IS	Intrinsic safety			
				
N-IO	IS base plate	H-System	IS base plate	4500 series
Yokogawa	P+F		MTL	

Field Loop-Check wihout the controller

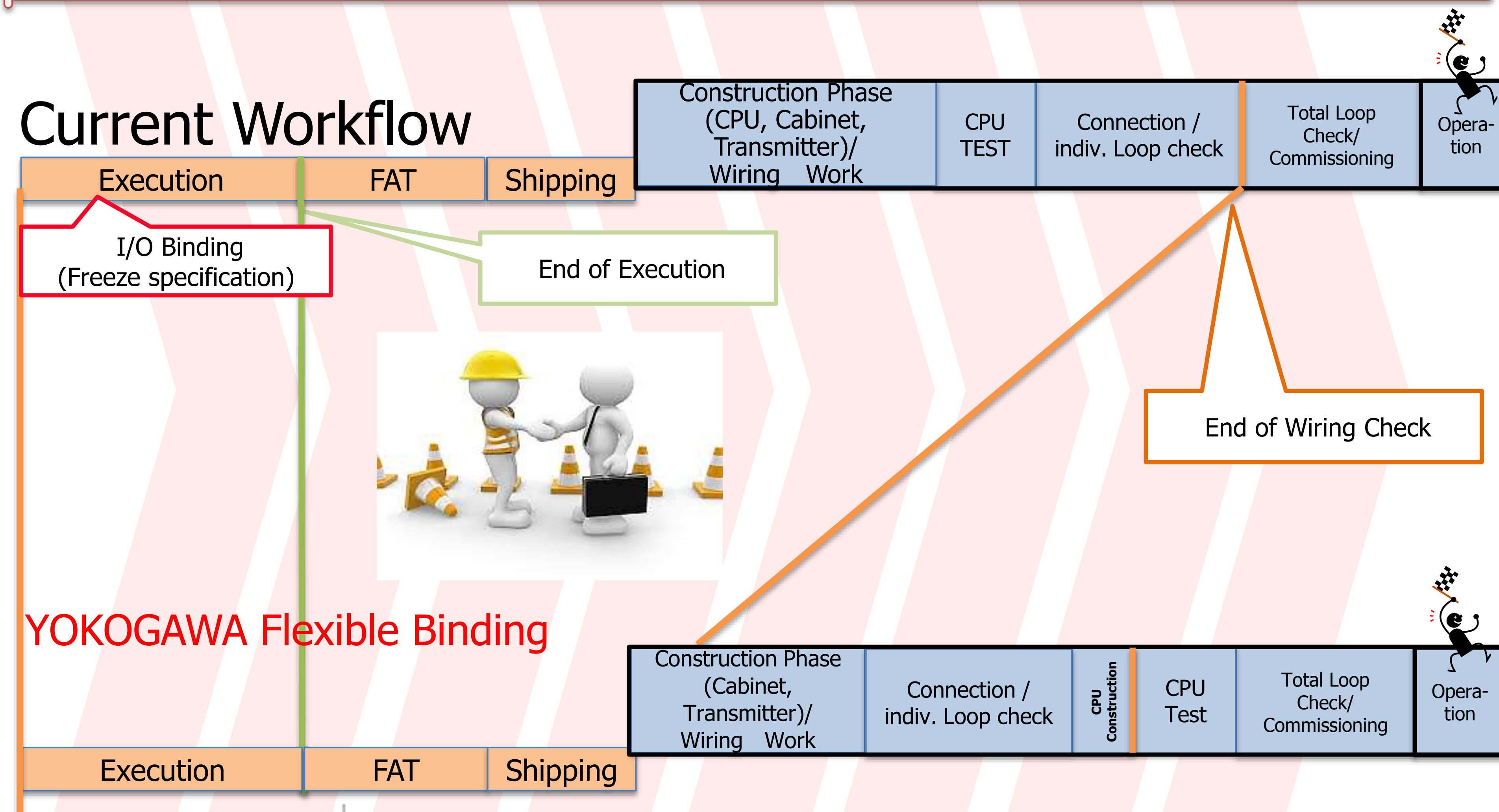


Local Cabinet can ship to site w/o FCS.

N-IO Validation Tool

Comparing With Current work and Flexible Binding Workflow

- Reduce the time span.
- Deadline of IO freezing is shifted by flexible binding



Work at site
Work in-house

Virtualization

Why virtualization in industrial plants now ?

To reduce the number of PC boxes in plants

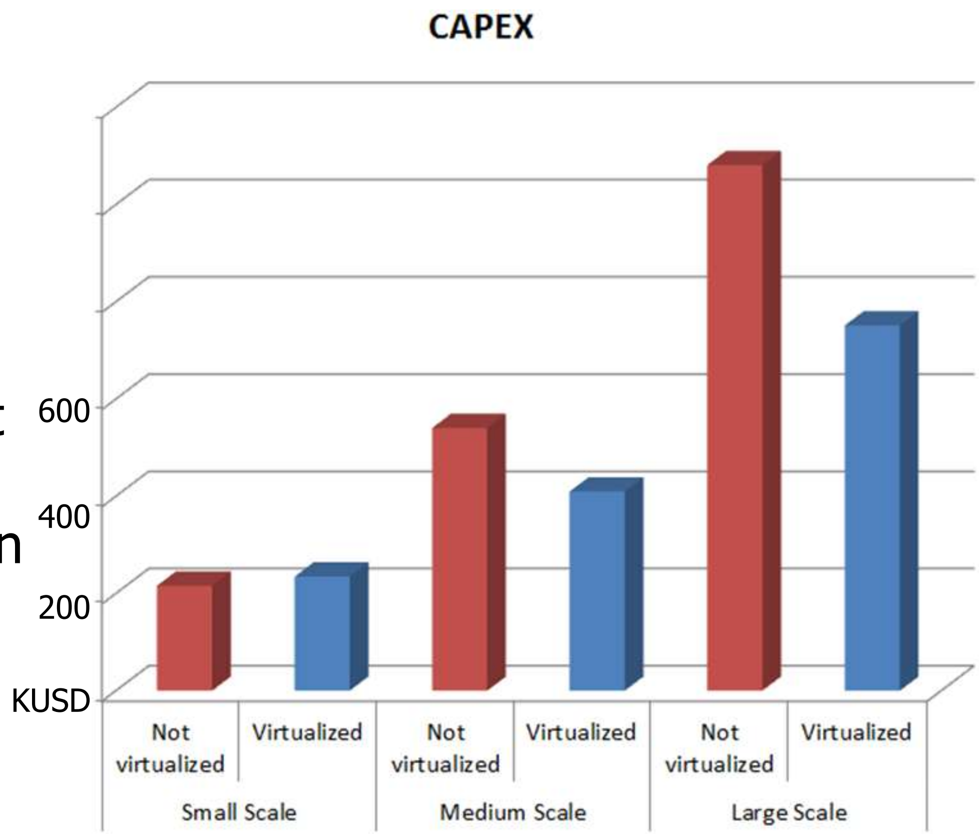
- It tends to increase the number of ?? server, ?? historian, etc.
- There is increasing of concern of both CAPEX and OPEX
  - e.g. Foot-print, OS maintenance, power consumption
- The number of server PC is a serious issue for the control systems with server-client architecture

To segregate the maintenance of hardware and software

- Windows OS is migrating every a few years and the previous OS becomes obsolete soon
- The latest PC hardware and previous OS may not be compatible
- Many of software applications in the control systems highly depend on OS and are less compatible with newer OS
  - Maintenance concern at the failure of the existing PC hardware

CAPEX Reduction - General Evaluation -

- Adopting VMware for virtualization
- 1:10 server consolidation ratio (10 virtualized machines can run in a server)*
- Lower electric power consumption and cooling cost
- Reduction of maintenance cost
- Reduction of footprint
- Smoother component migration
- Easy backup and restore



* This is an assumption, it will depend on the application for the real project

	Small		Medium		Large	
	Not virtualized	Virtualized	Not virtualized	Virtualized	Not virtualized	Virtualized
No. server	20	2	50	5	100	10

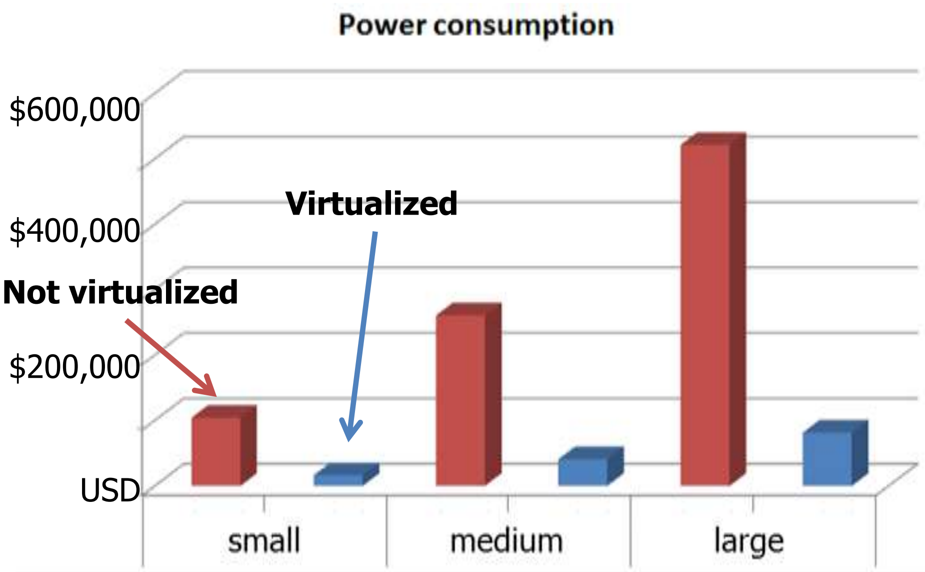
OPEX Reduction - General Information -

- Space, weight, and number of boxes/cabinets
  - Assumed that server height is 2U, and 7 servers can be installed in a cabinet

	Small		Medium		Large	
	Not virtualized	Virtualized	Not virtualized	Virtualized	Not virtualized	Virtualized
No. server	20	2	50	5	100	10
No. cabinet	3	1	8	1	15	2

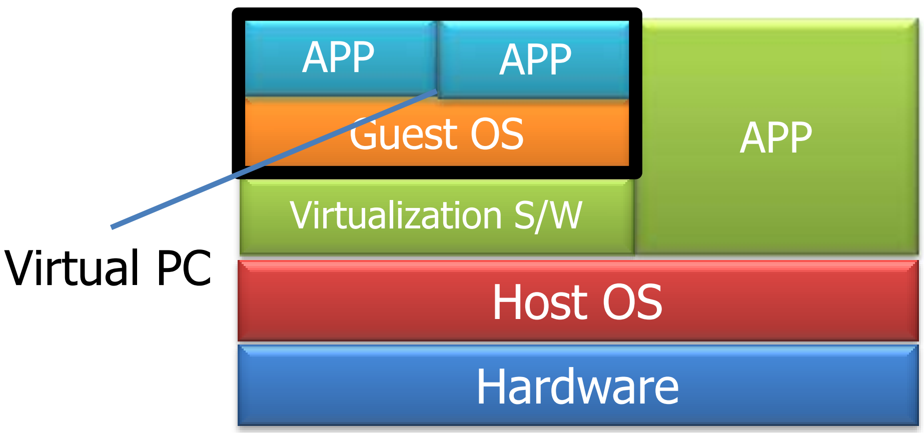
- Power consumption assumption
  - No matter the size of the project, virtualization can reduce 84% of the power consumption than non-virtualized system

Small/medium/large	
Not virtualized	Virtualized
100%	16%

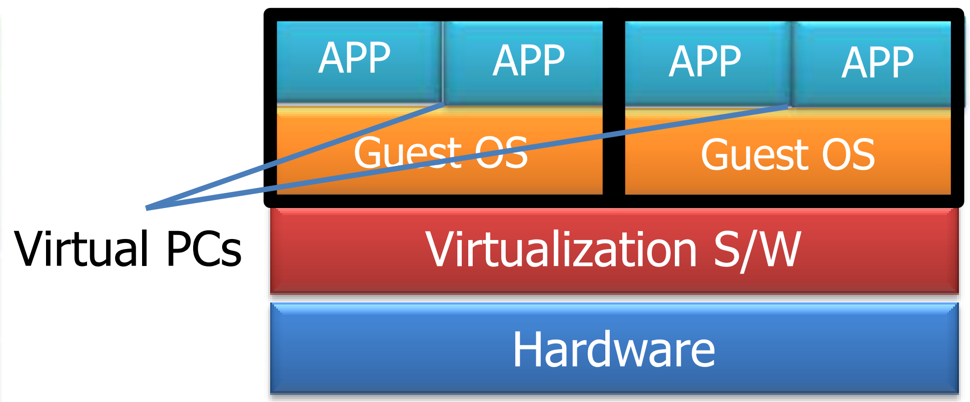


Types of Virtualization: Host type vs. Hypervisor type

- The virtualization works as an application on the host OS such as Windows, Linux
- VMware Workstation, VirtualBox, etc



- Works as the host OS
- PC resource can be consumed as much as possible for virtual PCs
  - VMware ESXi, Microsoft Hyper-V, RedHat KVM, etc.



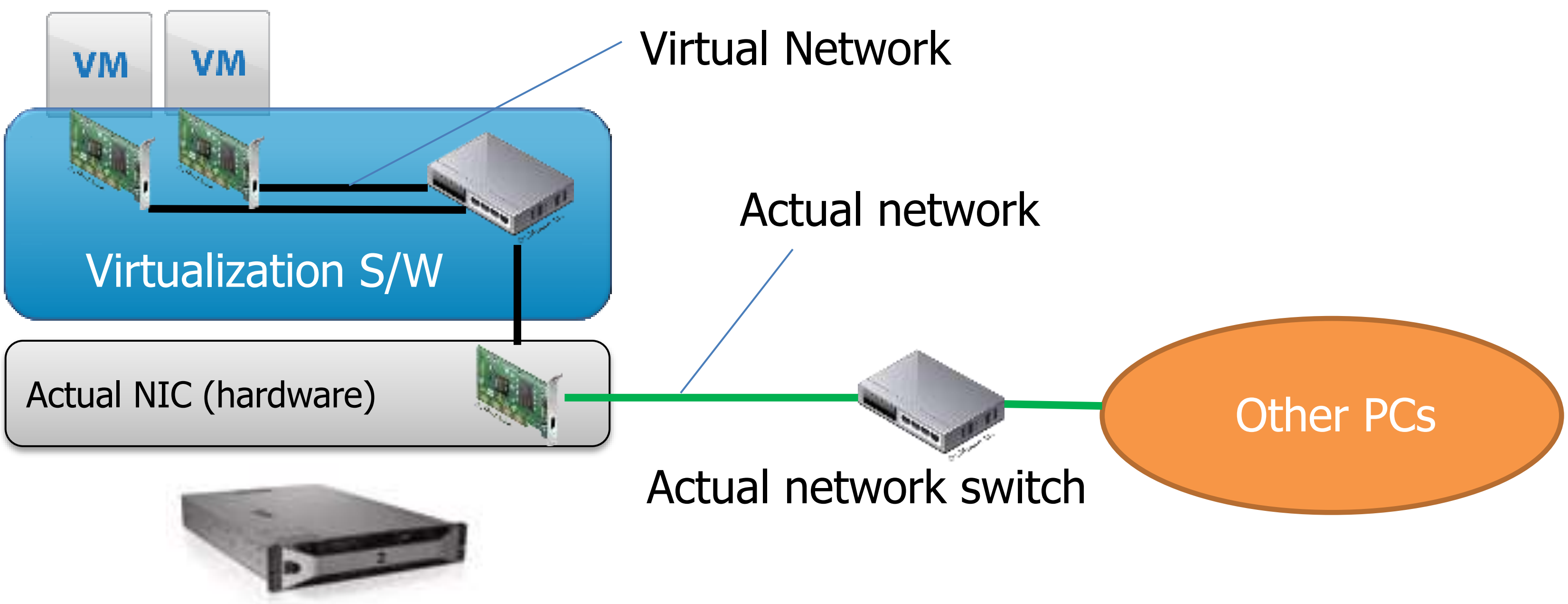
Comparison between Host type and Hypervisor type

	Host type	Hypervisor type
Acceptability	Easy to use	Some level of knowledge is required
Resource usage	Larger overhead (Lower performance)	Smaller overhead (Higher performance)
Security	Low	High
Scale	Small	Large
Performance	Low	High

- For server virtualization in working environment, hypervisor tends to be adopted
  - Official support of Yokogawa systems are also in hypervisor type
  - However using Hyper-V is not recommended for workstation with Yokogawa components inside

The performance issue

- Virtual network is working in the virtualization software
- Virtual NICs and virtual switches are working (emulating)
- **Only Physical NIC are suitable for real-time deterministic applications ← Performance first !**



The performance issue

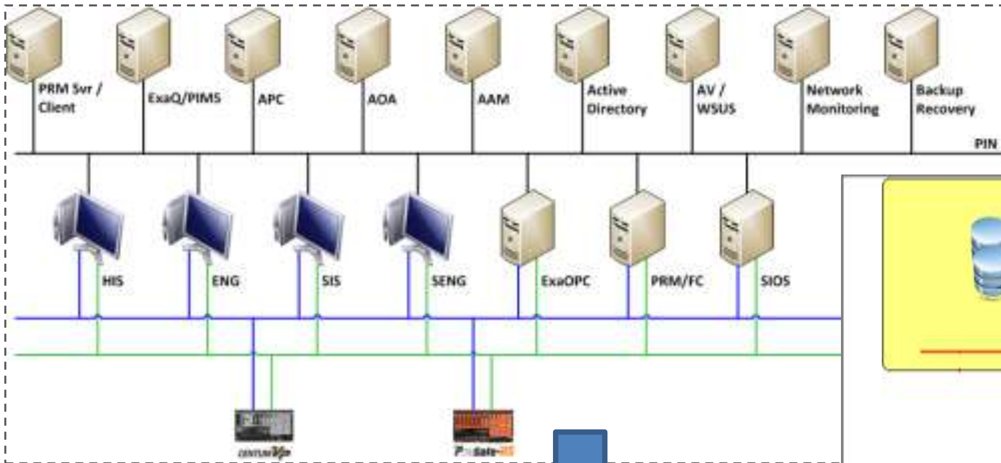
- If the PC is a quad core machine then 3 virtual machines may be the maximum to be deployed (1 core for the main application and 1 core for each of the 3 virtual PCs). If Hyper-threading is enabled, then double the number of cores are required.
  - (Number of requested cores) = (CPU reservation frequency) ÷ (Frequency of CPU of physical server) x 2 ← if HT is enabled
  - (CPU reservation frequency) = (CPU req. frequency) x (Number of cores) ÷ 2
  - Es.: Required CPU resources are 3.00 GHz and 4 cores, with 2.8GHz physical Server:
    - (CPU reservation frequency) = 3.00 GHz x 4 cores ÷ 2 = 6 GHz
    - (Number of req. cores) = (6/2.8) × 2 = 2.14 × 2 = 4.28 → 5 (rounded up)
- Condition:
- Σ [CPU reservation frequency of Yokogawa Products] x 1.25 < [CPU resource]
- Where [CPU resource] = [CPU frequency - in GHz] x [No. of cores] x [No. of CPUs]
  - Es. Sum of CPU reservation frequency = 6.00 + 6.00 = 12.00 GHz
  - the CPU resource for one server machine with frequency 2.60 GHz and 8 cores is 2.6 GHz x 8 cores = 20.8 GHz
  - 12.0 x 1.25 (VMSphere Overhead) < 20.8

The performance issue

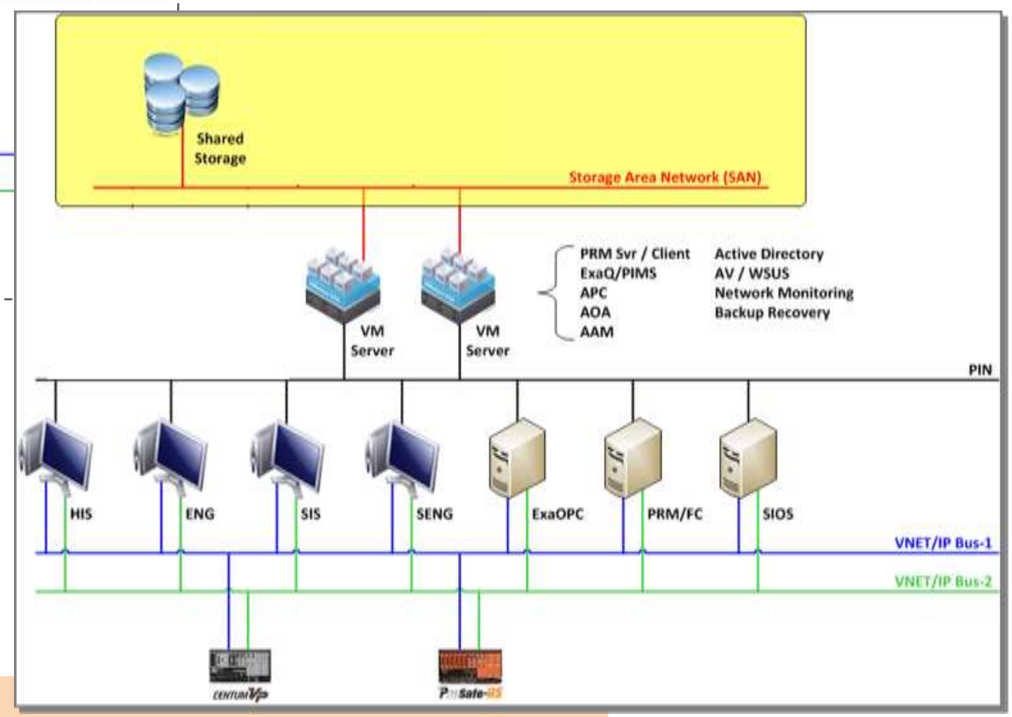
- Using SAS3 or RAID4 configuration to secure the performance is needed. Using SSD5 is not recommended because of lower endurance.
  - VMware allows three types of formatting for virtual storages. It is strongly recommended to adopt "Thick provisioning (Eager Zeroed)" with securing area in advance and with executing zero formatting. Using "Thin provisioning" causes lower performance, and Lazy Zeroed causes disk access error.
- It is mandatory to configure the Yokogawa product to use enough memory area exclusively to secure performance in both off and on-process.
- Generally the clock of guest OSs may be delayed when the load on Hypervisor becomes too high. If the demand of time synchronization is severe, the synchronization period should be set shorter.
- One physical server PC failure stops multiple server functions: highly available industrial server is recommended

- SAS (Serial Attached SCSI): The interface to connect up devices for hard disk drives to computers
- RAID : Redundant Array of Independent Disks
- SSD : solid-state drive using flash memory

Virtualization Benchmarking



Current Yokogawa System architecture



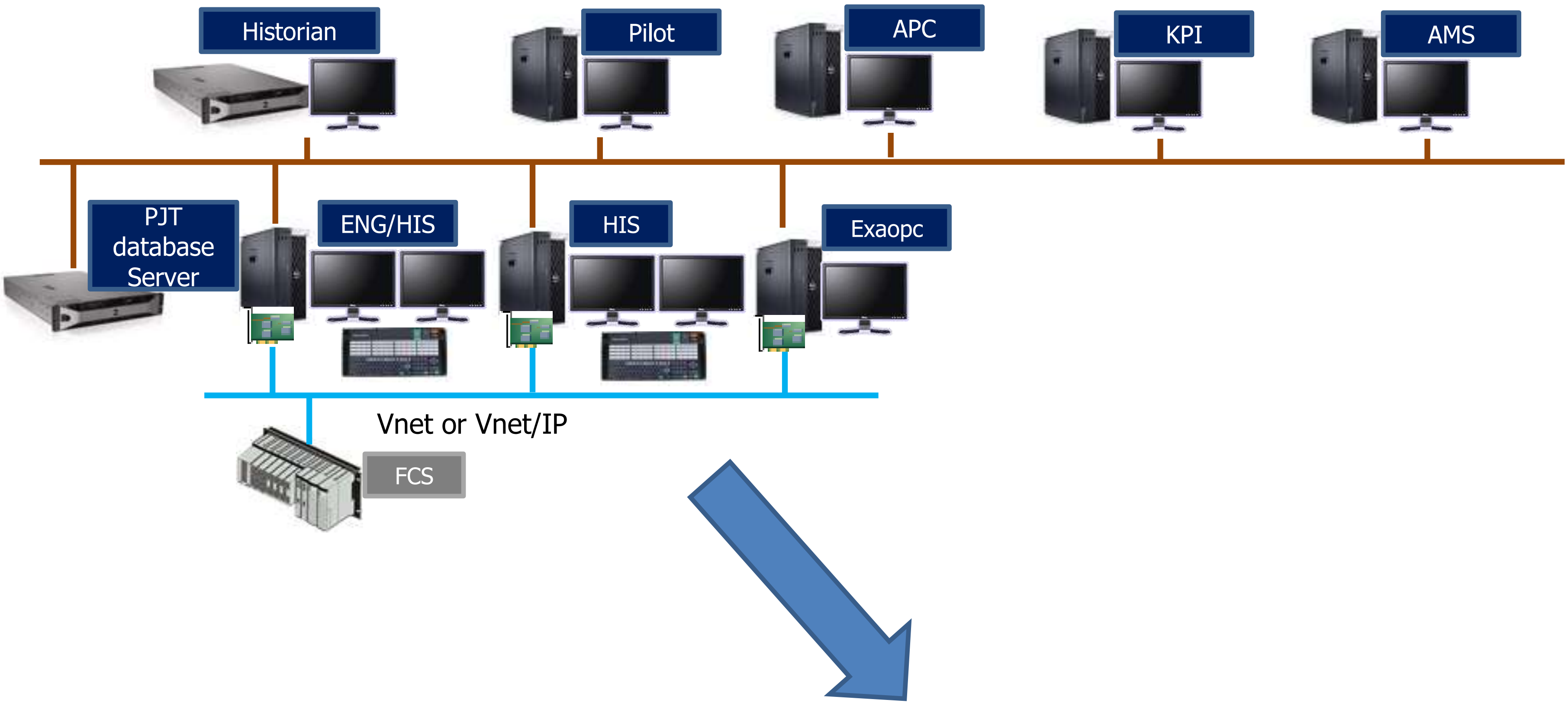
Virtualized Architecture

Benchmarking: Number of PC (Server/Workstation)

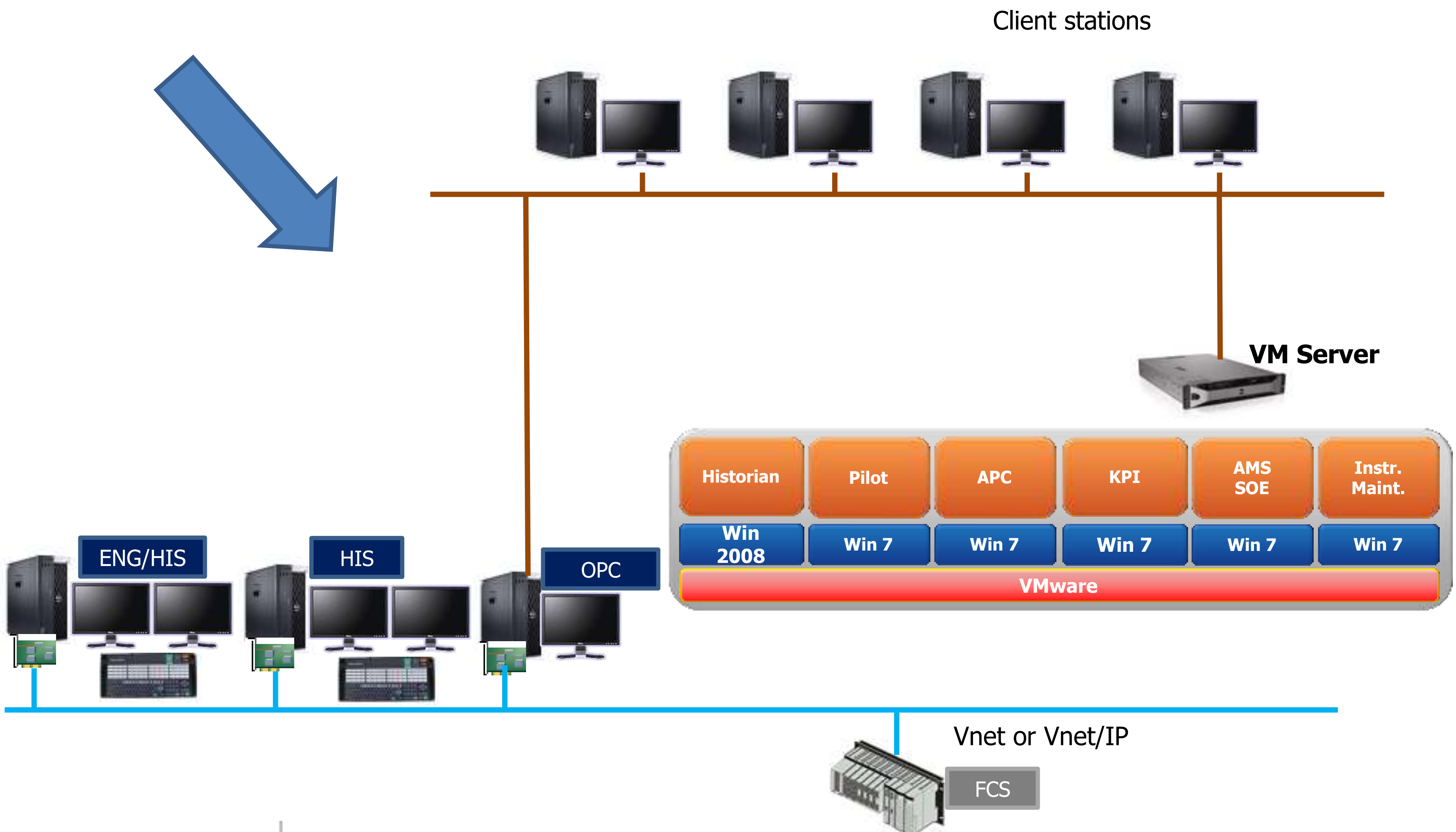
Small	Medium	Large
20	50	100

Performance First: Excluding Servers with Vnet/IP modules

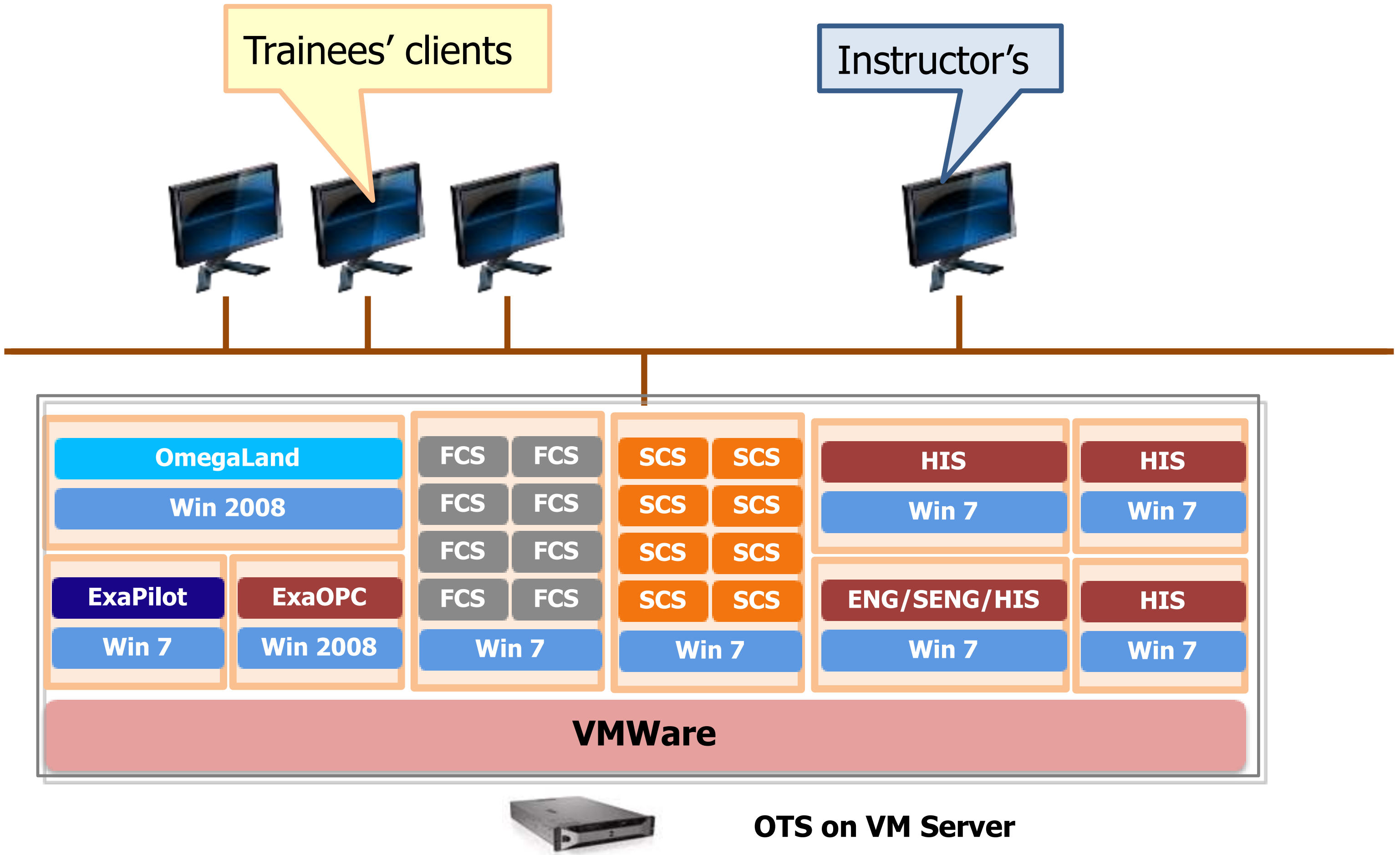
Example of on-process systems



Example of on-process systems



Example of off-process systems – Operator Training systems



Other performance vs. optimization

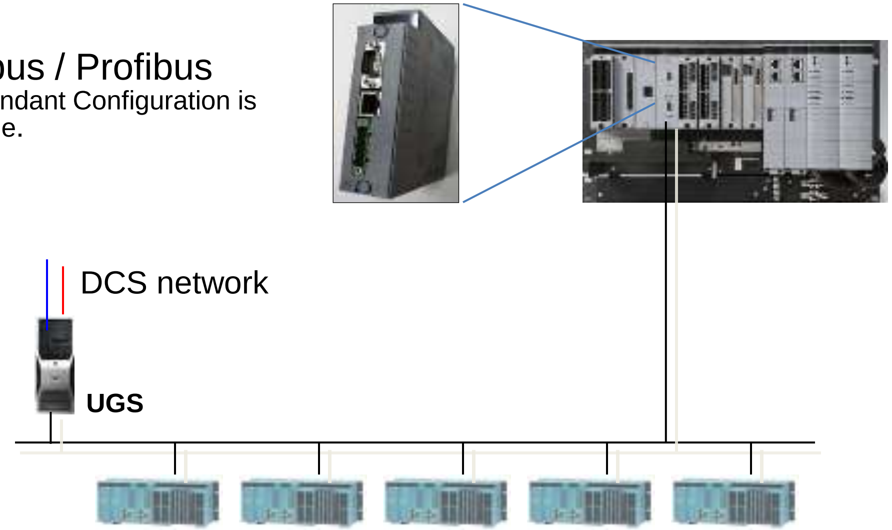
Integration with subsystems: which way ?

Sub-system communications

- Data for HMI: OPC/ModbusTCP Client (redundant) workstation can manage up to 100,000 variables
- Data for control logics: put (redundant) communication module in one rack of the related CPU in charge

Modbus / Profibus

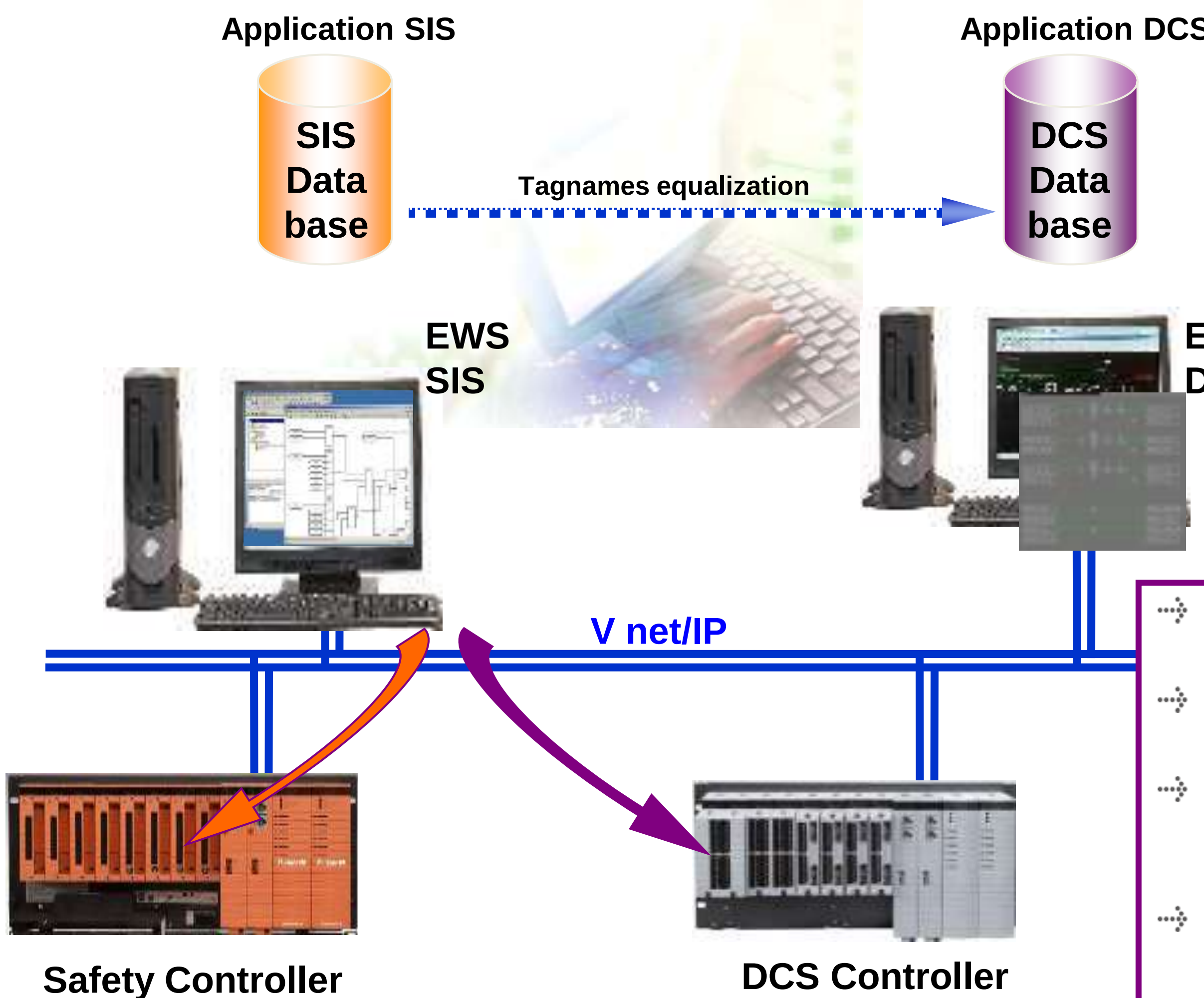
- Redundant Configuration is available.



	OPC DA+HDA (or UA)	Modbus/TCP (or RTU)
Benefits	- Lower Controller CPU load - High throughput - A&E by OPC A&E	- Simple reliable industrial solution - Subsystem data directly available in DCS controller for control/logic functions
Drawbacks	- Unreliable IT technology - Subsystem data NOT directly available in DCS controller for control/logic functions	- Affecting Controller CPU load (to be distributed among the DCS controllers) - Not supporting A&E with timestamps

Integrated Process Control & Safety System

→ Integrated Control+Safety system provides optimization + performance at the same time

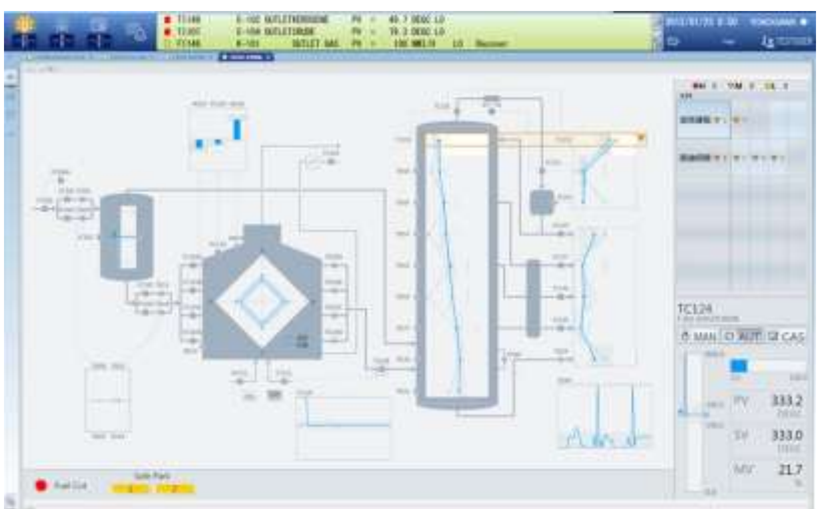


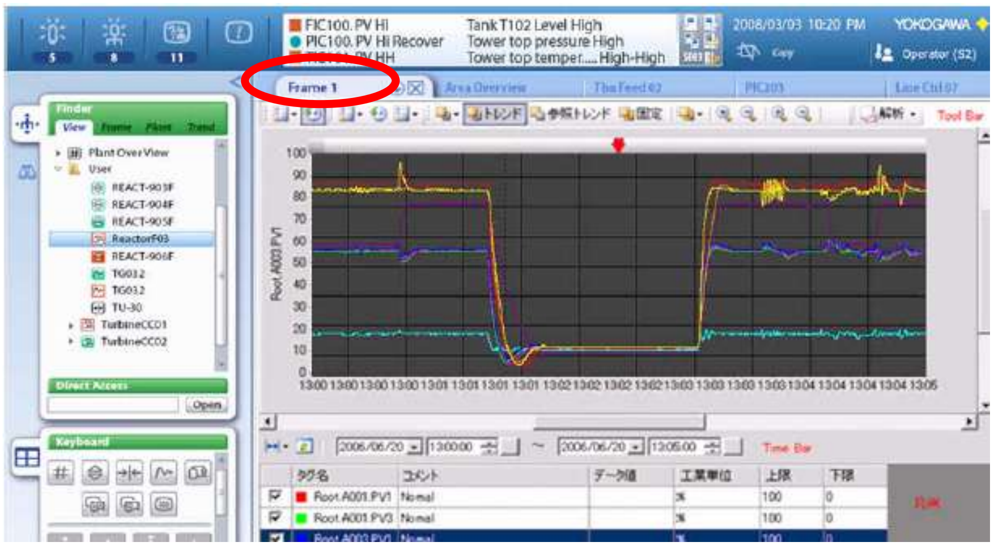
- Master station automatically assigned
- Reference time broadcasted every 10 seconds
- Time shifts are adjusted very smoothly 0.005 ms (0.05%) at 10 ms interval.
- External clock synchronization available (via time server)

Multi-monitor vs. performance

- Multi-monitor/Graphic windows
  - Each mimic call data from the system bus while one single operator cannot pay attention to more than 5÷12 windows at the same time: prevent it by limiting the number of graphic windows which can be called by the operator by FIFO mechanism.

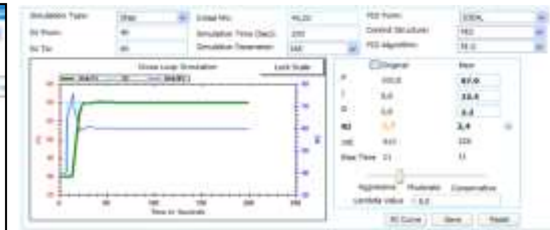
Multiple monitors

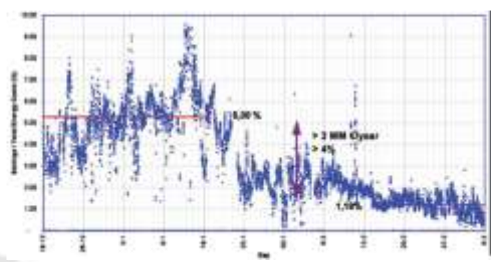




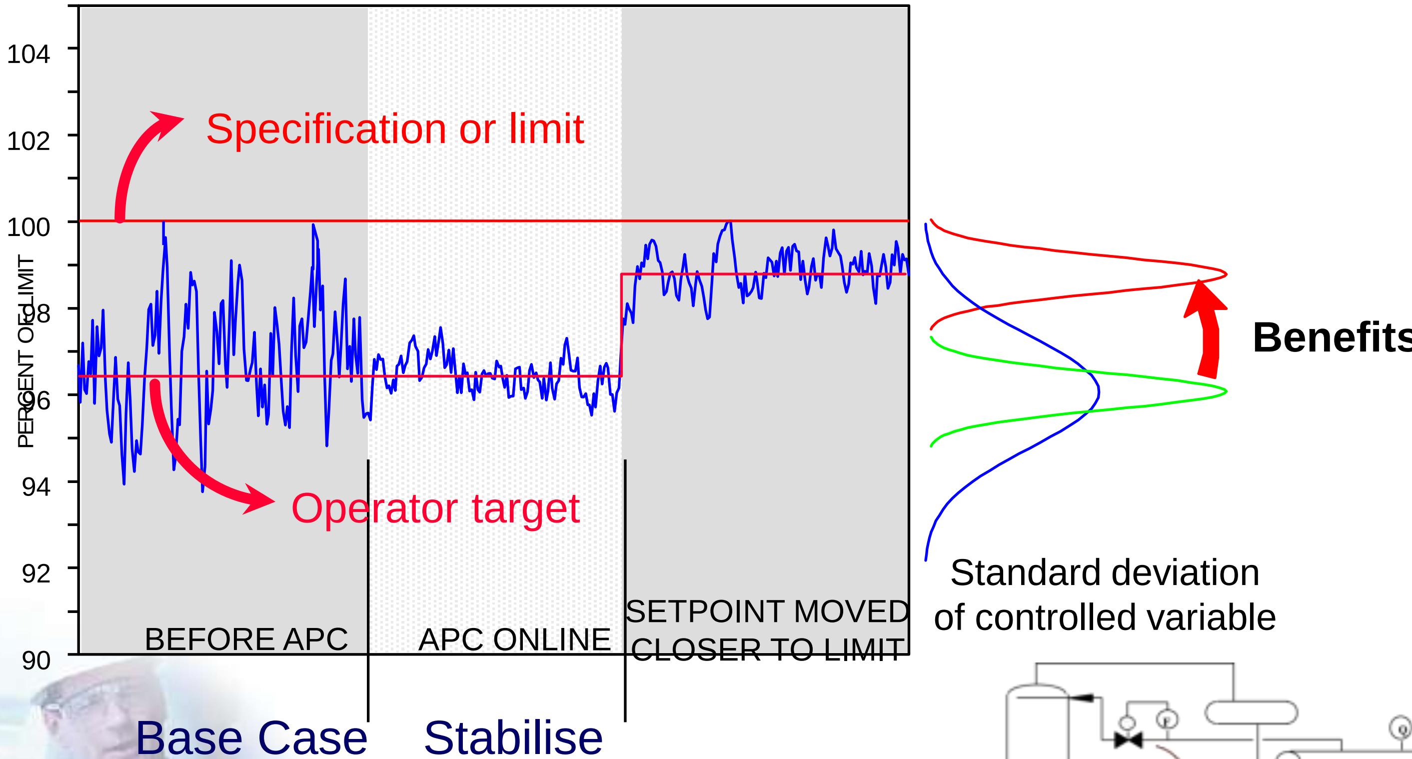
Others ways to optimization

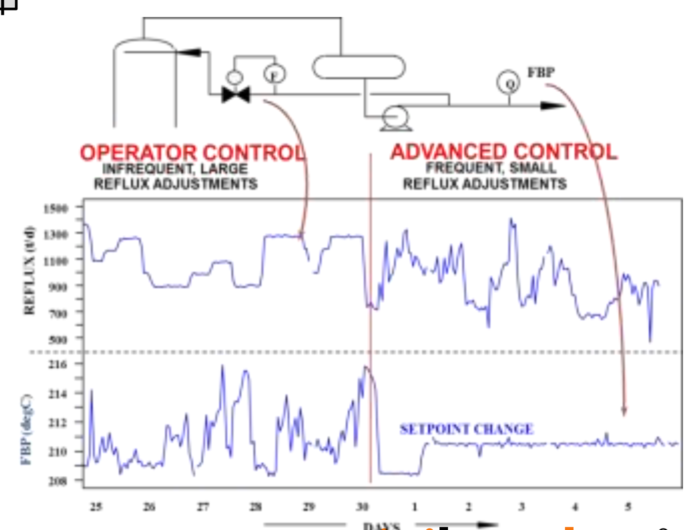
- **Alarm optimization**
  - Complying to ISA18.2 and Eemua-191 Standard
- **Control Loop Performance Monitoring**
  - Evaluate improvements through simulations
- **Best Practices Employment**
  - Operator sequences executed by flow-charts
- **Plant performance quantitative measurements**
  - KPI, Downtime analysis, Data reconciliation
  - Sequence of events and Safety Functions monitoring
- **Energy management**
  - Monitoring or optimization
- **APC**
  - Multivariable Predictive Control





APC: Multivariable Predictive Control





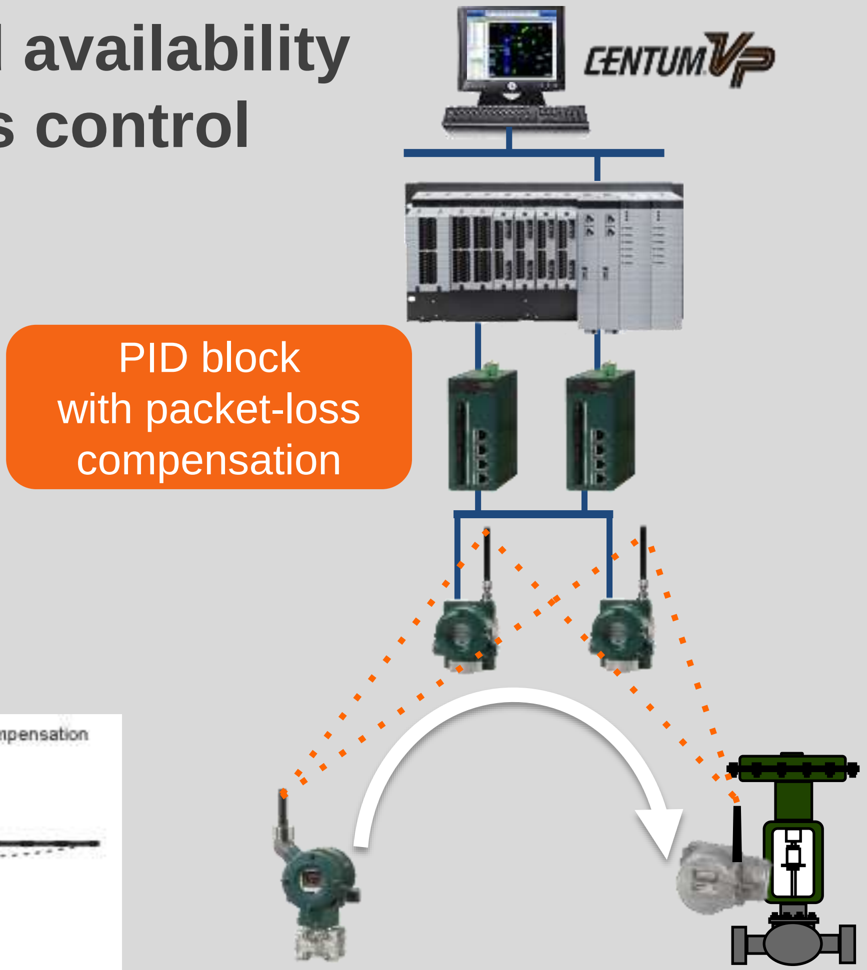
Optimization aimed solutions

Production	Asset	Energy	Safety and Security	Knowledge
Production Performance	Asset Performance	Energy Performance	Human Asset Environment Protection	Procedure Performance
Supply Chain Management Performance	Predictive Maintenance	Greenhouse Environment Control	Process Control Domain Security	Knowledge Retention
Operator Effectiveness				

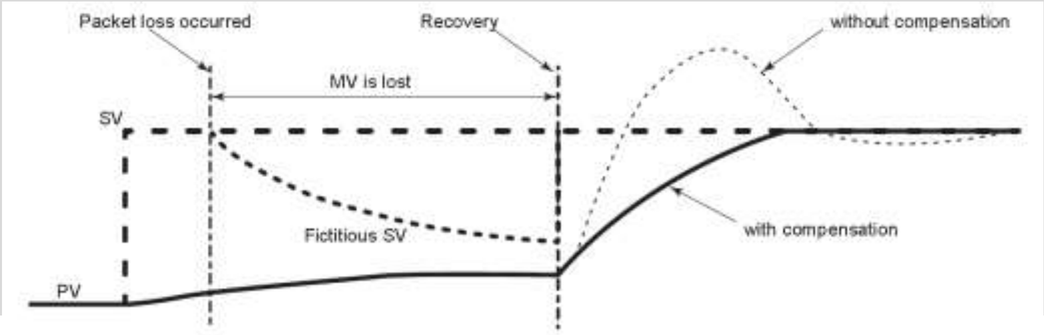
Do not load the DCS with these tasks: do it at upper level !

Wireless Transmitters: be careful with PID control

Increased plant productivity and availability with ISA100 wireless for process control

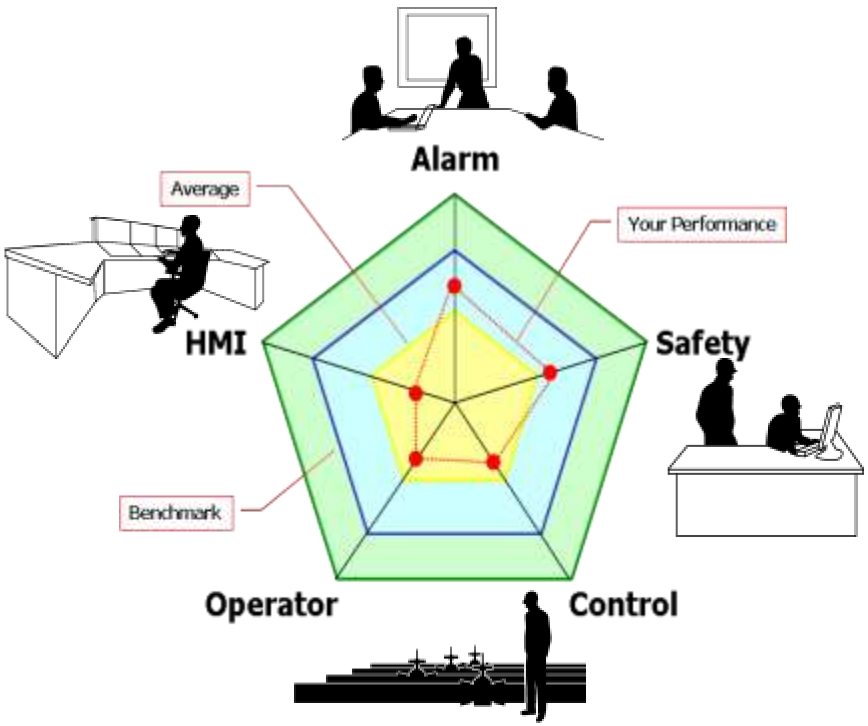


The new CENTUM VP supports a new specialized PID function block that compensates for any packet loss. With this function block, the dynamic response after signal recovery is smooth and stable. As a result, wireless control is dependable.



Conclusions

- Different kind of Optimization or Functions are attractive and may lead to significant Capex/Opex reductions…
- … but also to some performance issues.
- Clever engineering should carefully consider the right balance between optimization and performance with respect to the specific application



Thank you for your attention!

Any question ?