Elettra Sincrotrone Trieste

Elettra Sincrotrone Trieste

TANGO Connecting things together

School on TANGO Control System

Introduction (2)

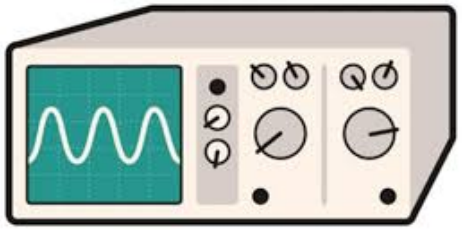
Marco Lonza

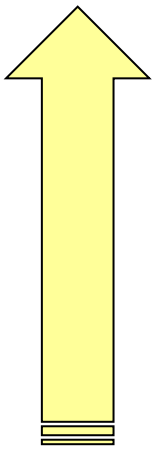
How to Control the Machine Devices of an Experimental Physics Facility

FERMI

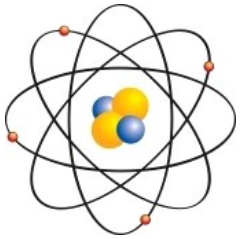
Device	Number
Magnet Power Supplies	~ 400
Vacuum Valves	109
Vacuum Pumps	230
RF Plants	16
Screens/CCDs	112
Beam Position Monitors	79
Charge Monitors	13
Beam Loss Monitors	201
Undulators	19
Stepper Motors	494
Total number of CS variables	> 60000

The Analog Age

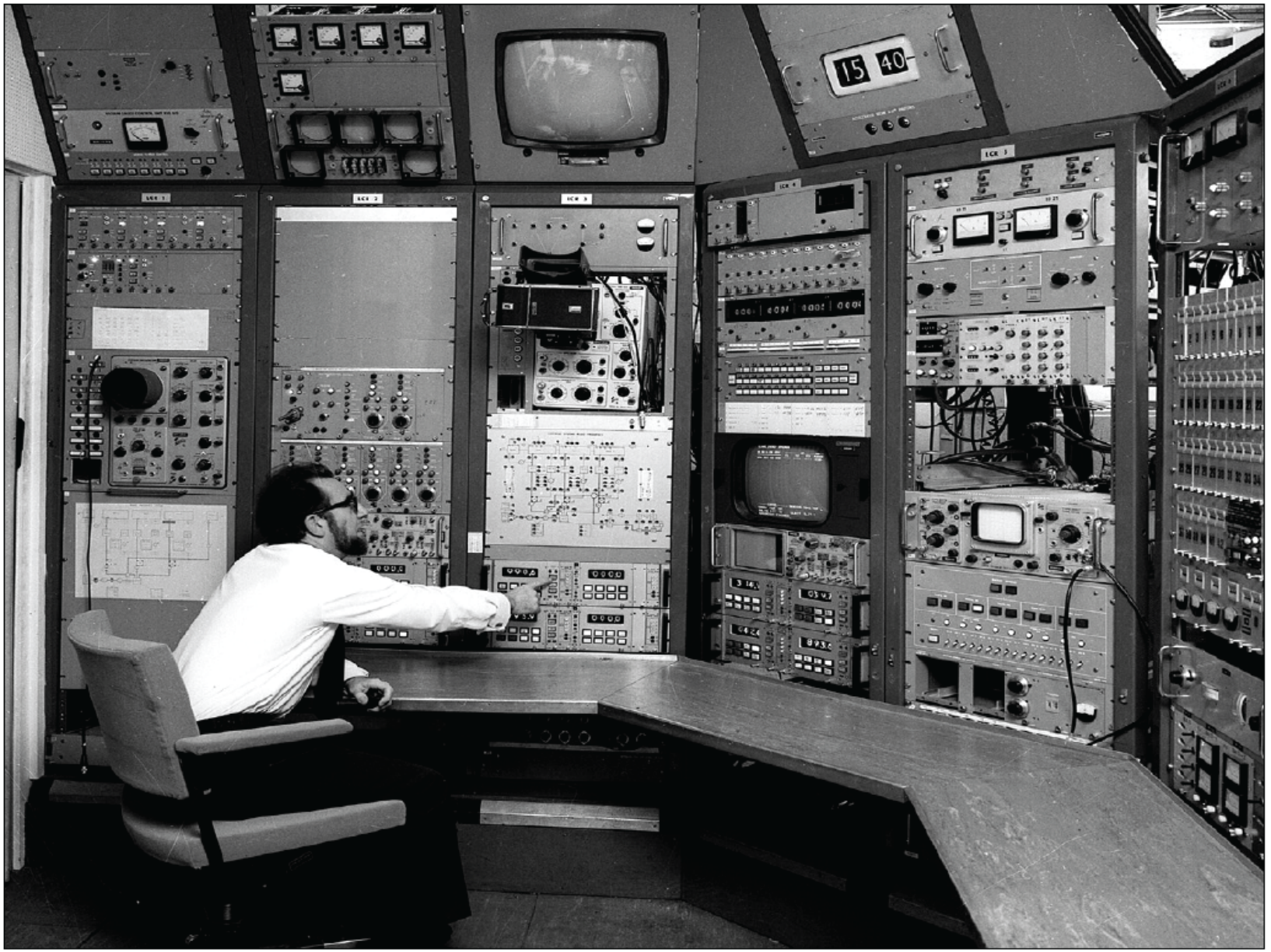




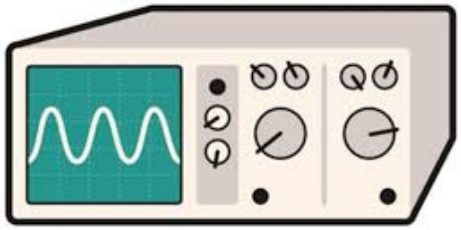
Analog
Signals



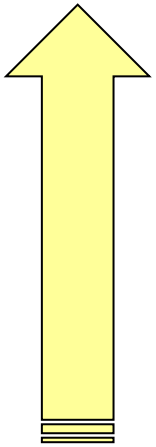
The Control Room: '70-'80



The Digital Age

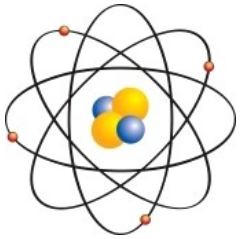


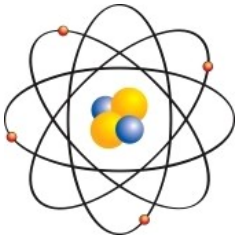
A/D - D/A
Conversion



Analog
Signals

Analog
Signals



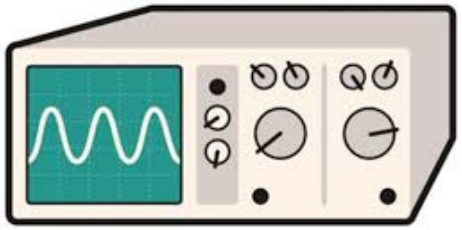


Elettra Sincrotrone Trieste

The Control Room: '80-'90

TANGO Connecting things together

The Internet Age

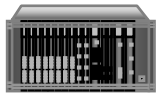


A/D - D/A
Conversion

Analog
Signals

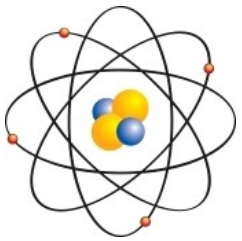
Analog
Signals

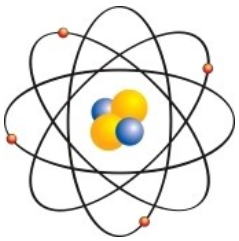
Digital
Signals

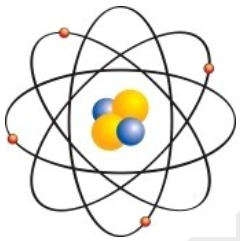


A/D - D/A
Conversion

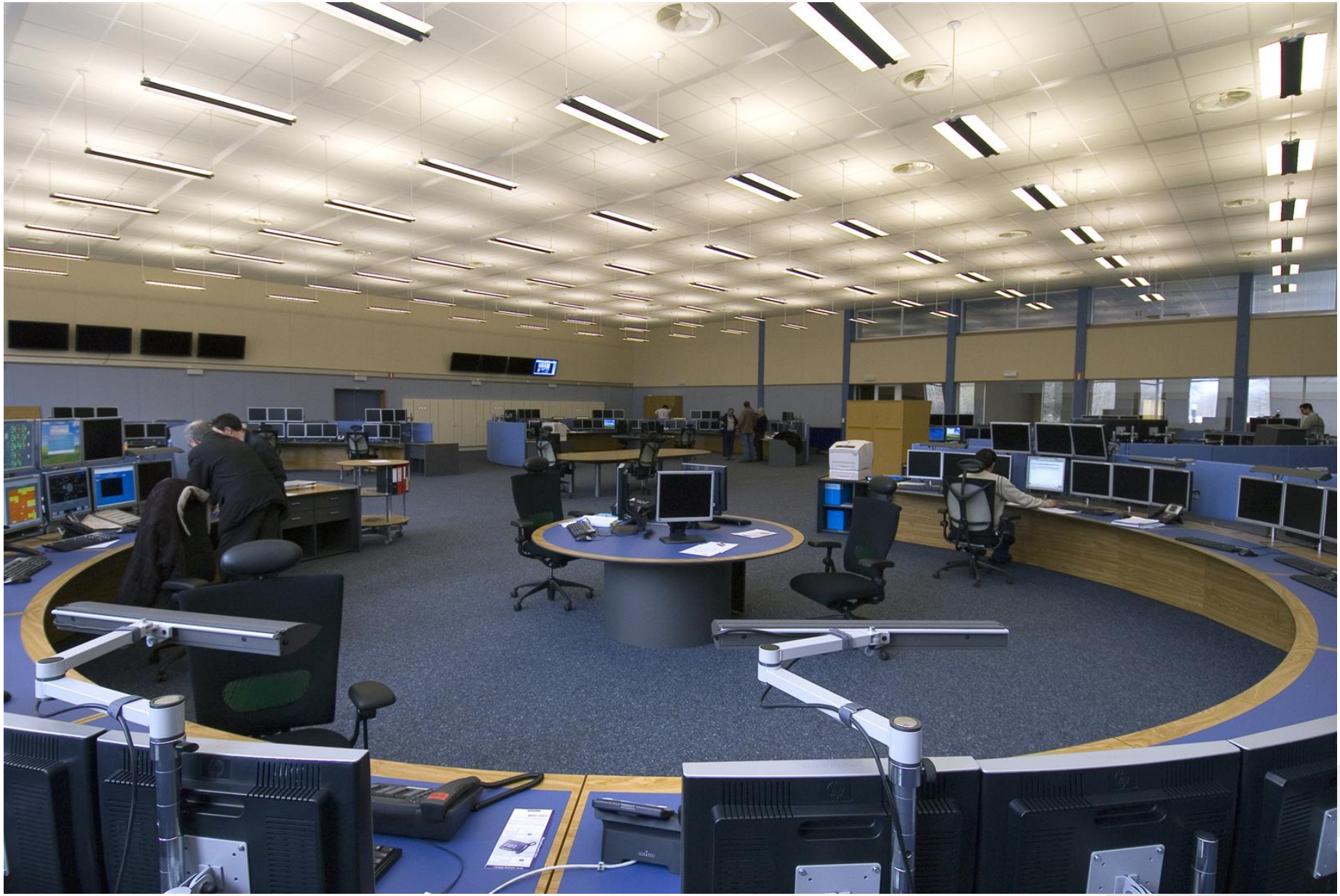
Analog
Signals



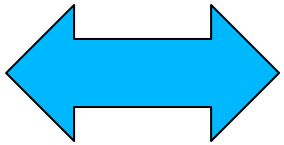




The Control Room: '90-'00

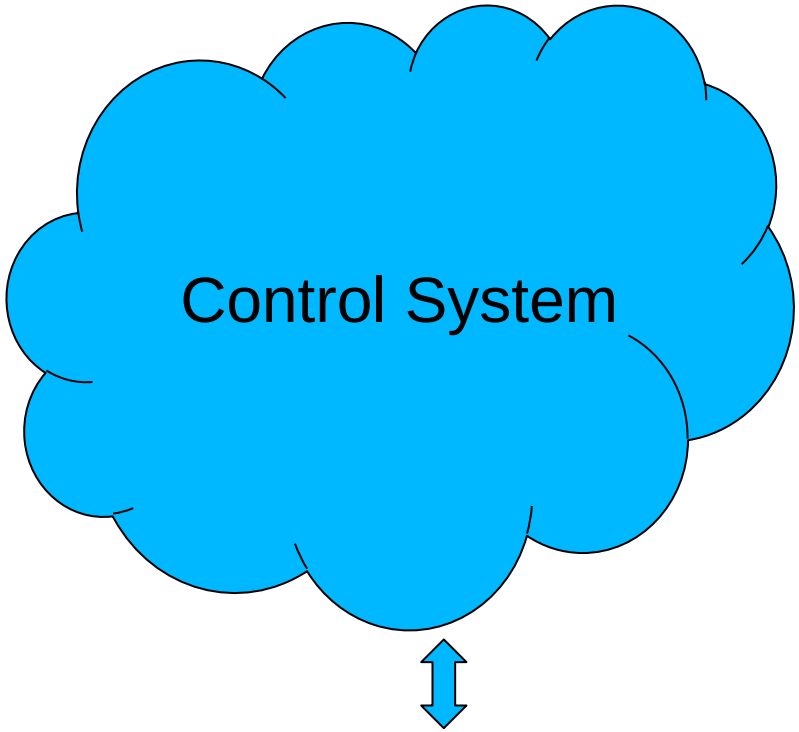


Control System Concept



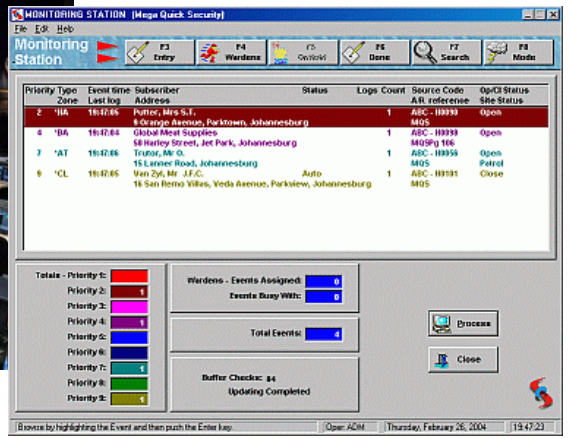
Signals

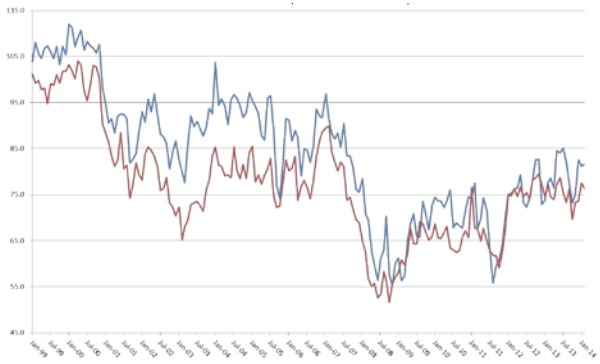
(Analog, Digital, Serial Lines, GPIB, Ethernet, ...

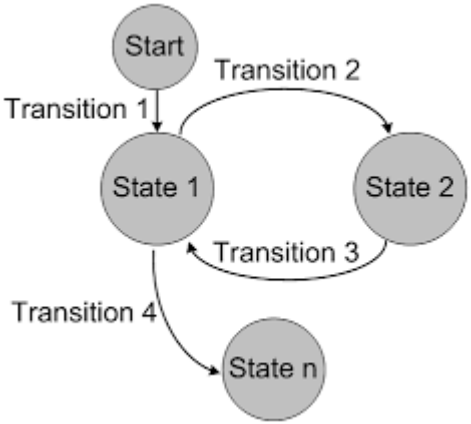


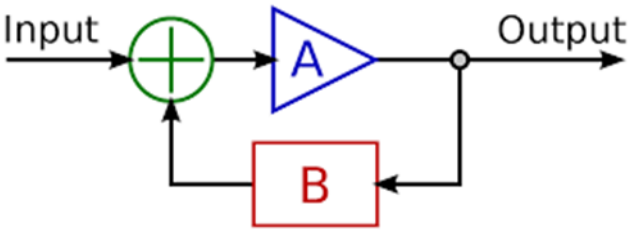
Control System Functions and Services

- ✓ Monitoring
- ✓ Control
- ✓ Alarms
- ✓ Logging
- ✓ Archiving
- ✓ Automation
- ✓ Feedbacks
- ✓ Data acquisition and management
- ✓ Equipment Protection
- ✓ Safety

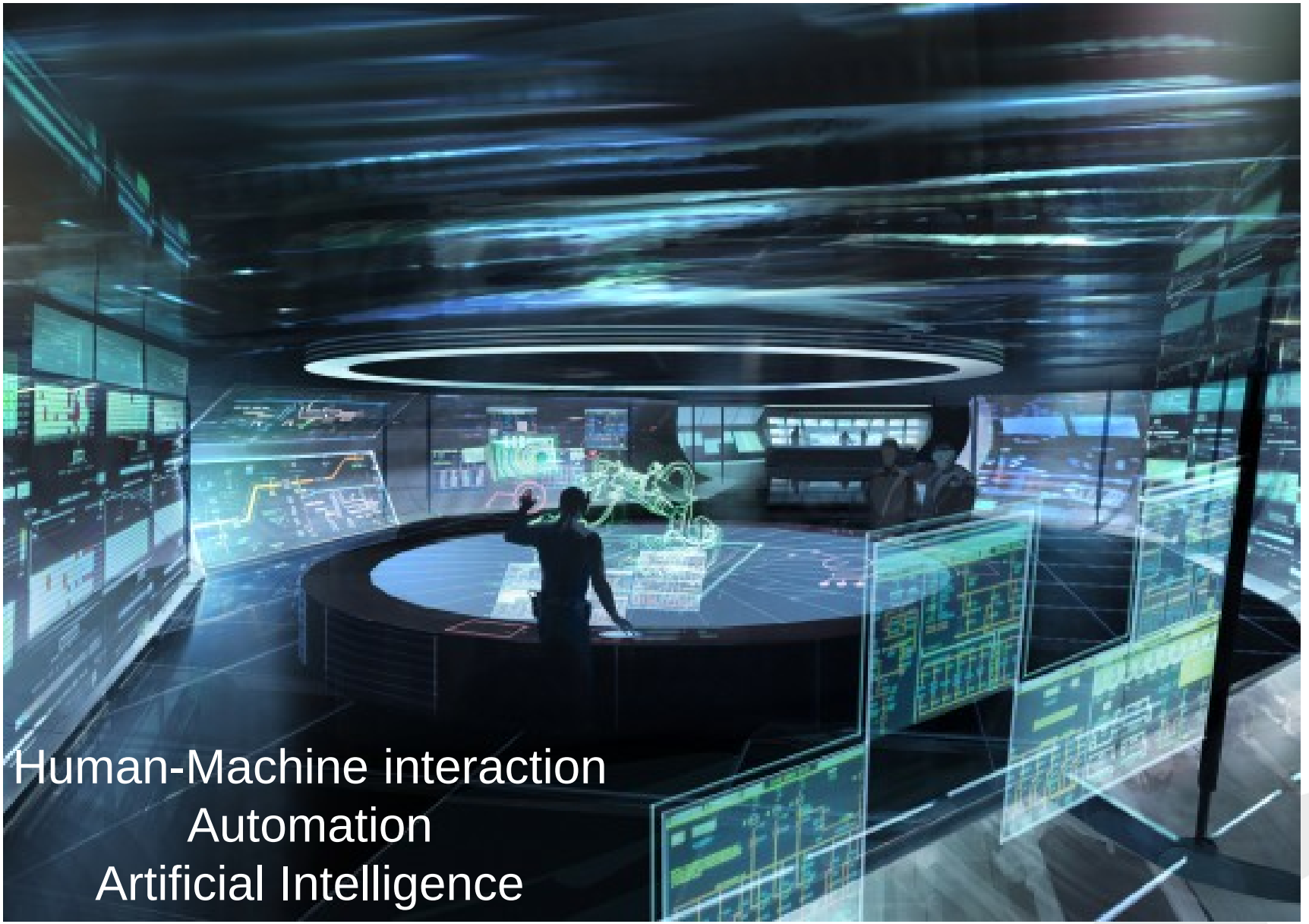




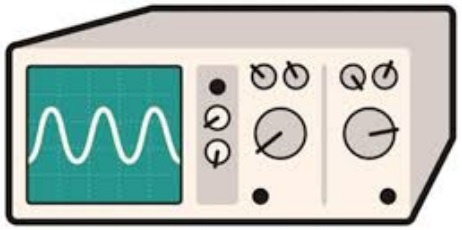




Control Room: the future

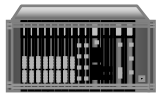


Structured Control System



A/D - D/A
Conversion

Digital
Signals

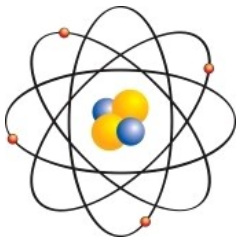


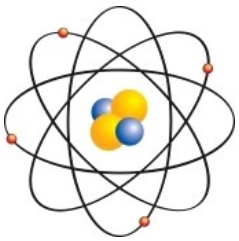
A/D - D/A
Conversion

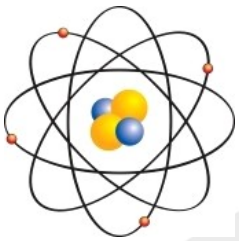
Analog
Signals

Analog
Signals

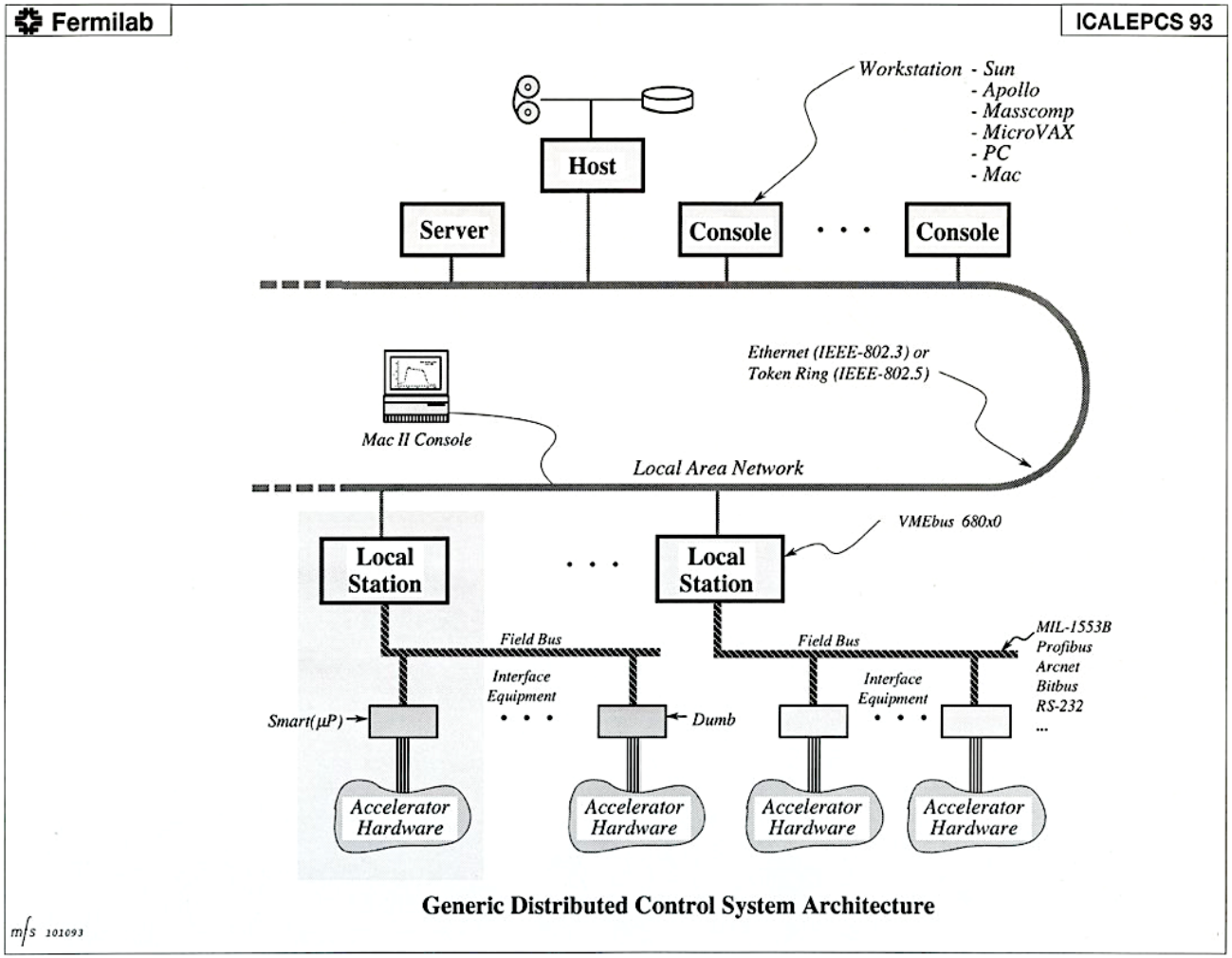
Analog
Signals







Distributed Architecture



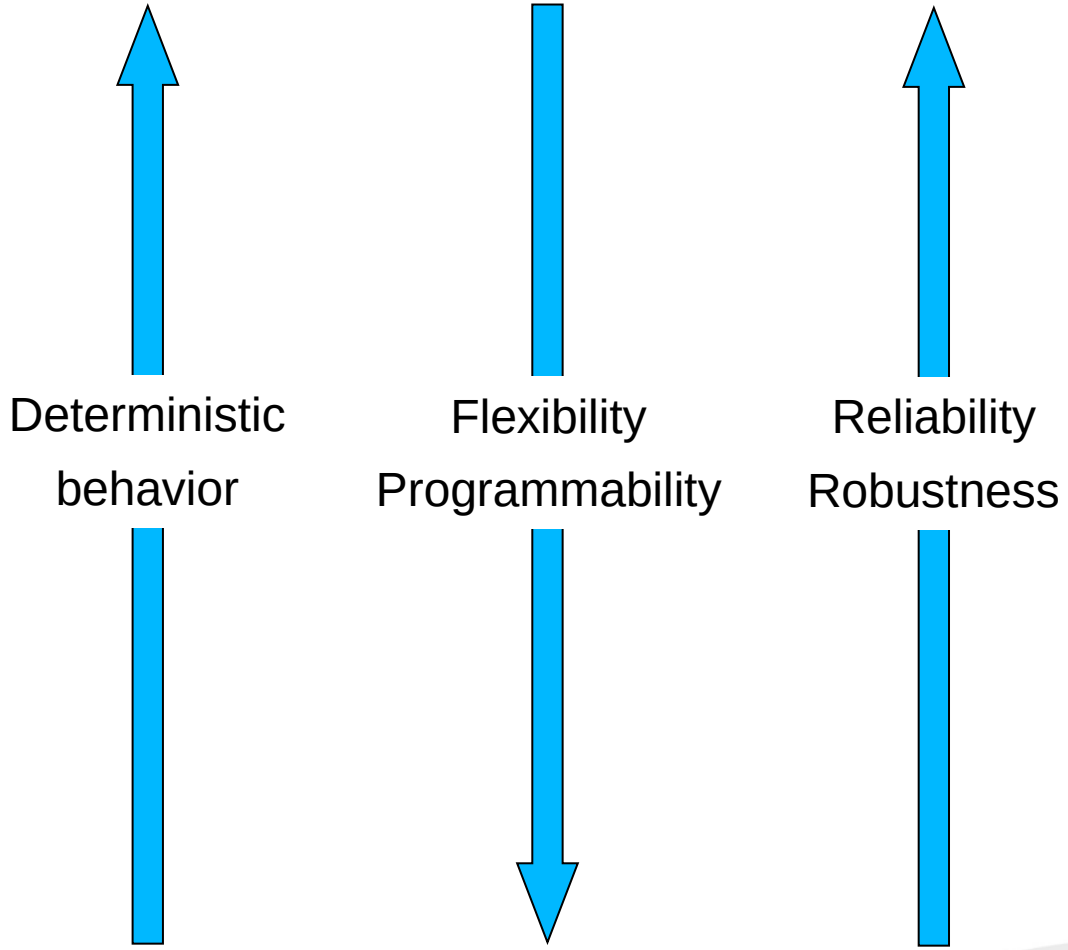
- ✓ Distributed system
- ✓ LAN
- ✓ Levels or Tiers
- ✓ Field-bus
- ✓ Local/Field/Low-Level Computers
- ✓ Consoles/Workstations
- ✓ Hosts/Servers

Technologies: selection guidelines

- ✓ Performance
- ✓ Reliability & availability
- ✓ Modularity & flexibility
- ✓ Standardization
- ✓ Off-the-Shelf components (COTS)
- ✓ Comsumer/commodity
- ✓ Stability and long lifetime
- ✓ Free and Open Source software (and hardware)
- ✓ Cost

Digital Technologies

- ✓ Analog electronics
- ✓ ASIC
- ✓ FPGA
- ✓ PLC
- ✓ DSP/Microcontrollers
- ✓ Real-time Operating system
- ✓ Operating System



Field Computers

- ✓ CAMAC
- ✓ VME
- ✓ C-PCI
- ✓ AdvancedTCA/MicroTCA
- ✓ PXI
- ✓ Industrial PC (x86)

Industrial Computers based on Standard Backplanes

Servers

Used to provide the control system with common services: software execution, distributed file system, database, external access, data storage, network services, ...

- ✓ 19" rack-mount computers: multi-core multi-processor XEON based systems
- ✓ Blade Servers
- ✓ High speed redundant network connection
- ✓ Virtualized environments
- ✓ High Availability (HA) configuration

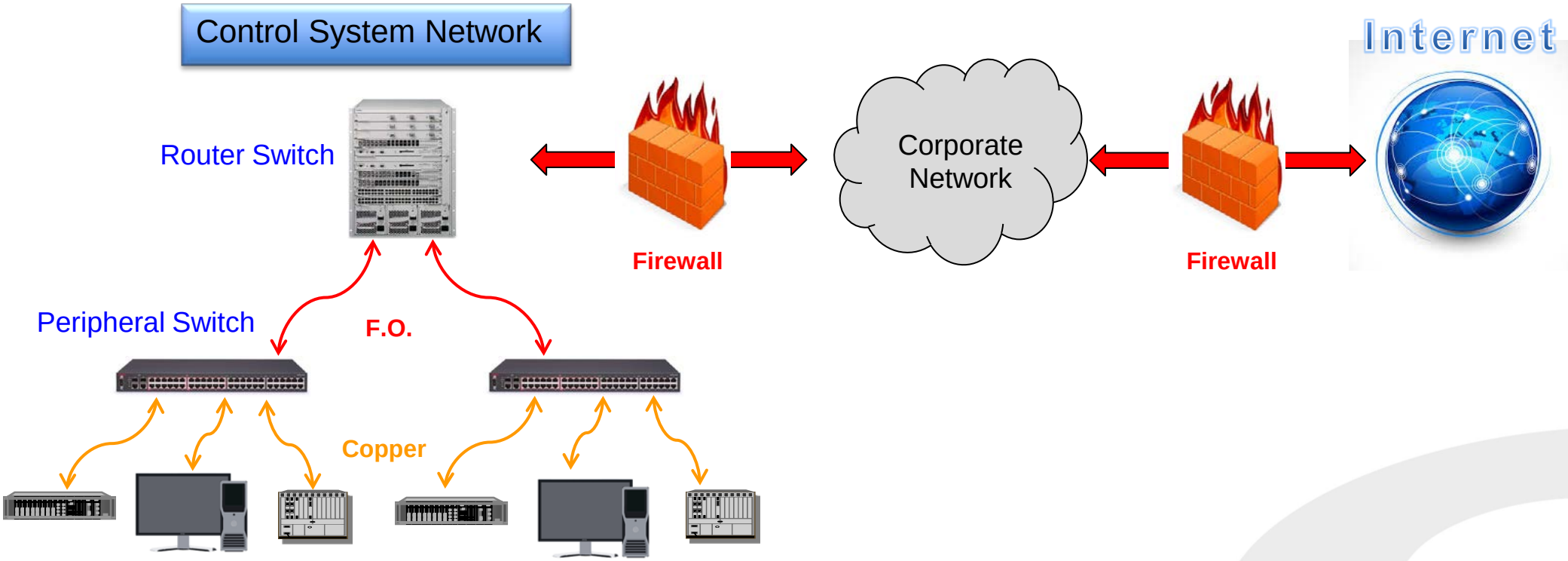
Consoles - Workstations

Used by operators and physicists as human interface to the control system

- ✓ Desktop high-end PCs
- ✓ Dedicated graphic cards with up to six screens

Data Network (LAN)

- ✓ Ethernet technology
- ✓ Switched distributed network
- ✓ Pervasive inside the plant
- ✓ Fibre optic uplinks and copper endpoints
- ✓ Speed of 100 Mbit/s to 40 Gbit/s

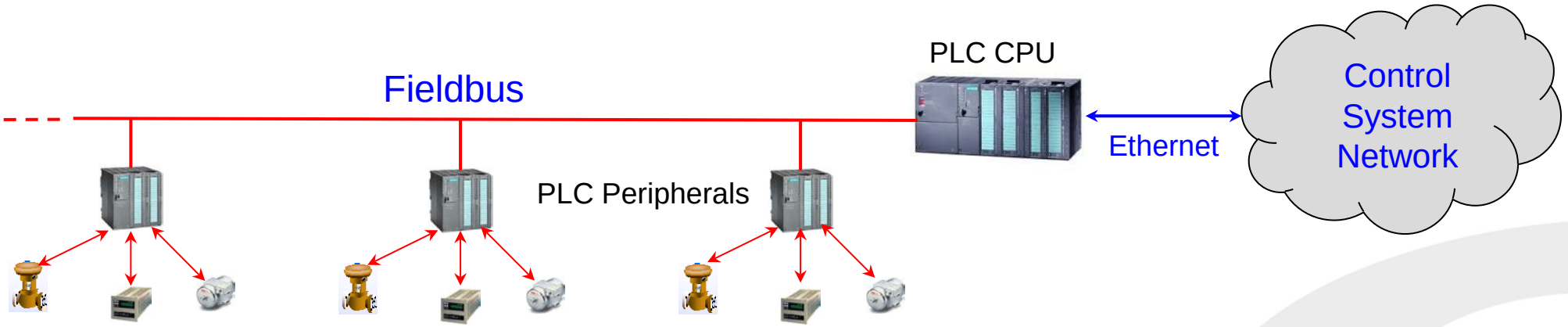


Protection and Safety Systems

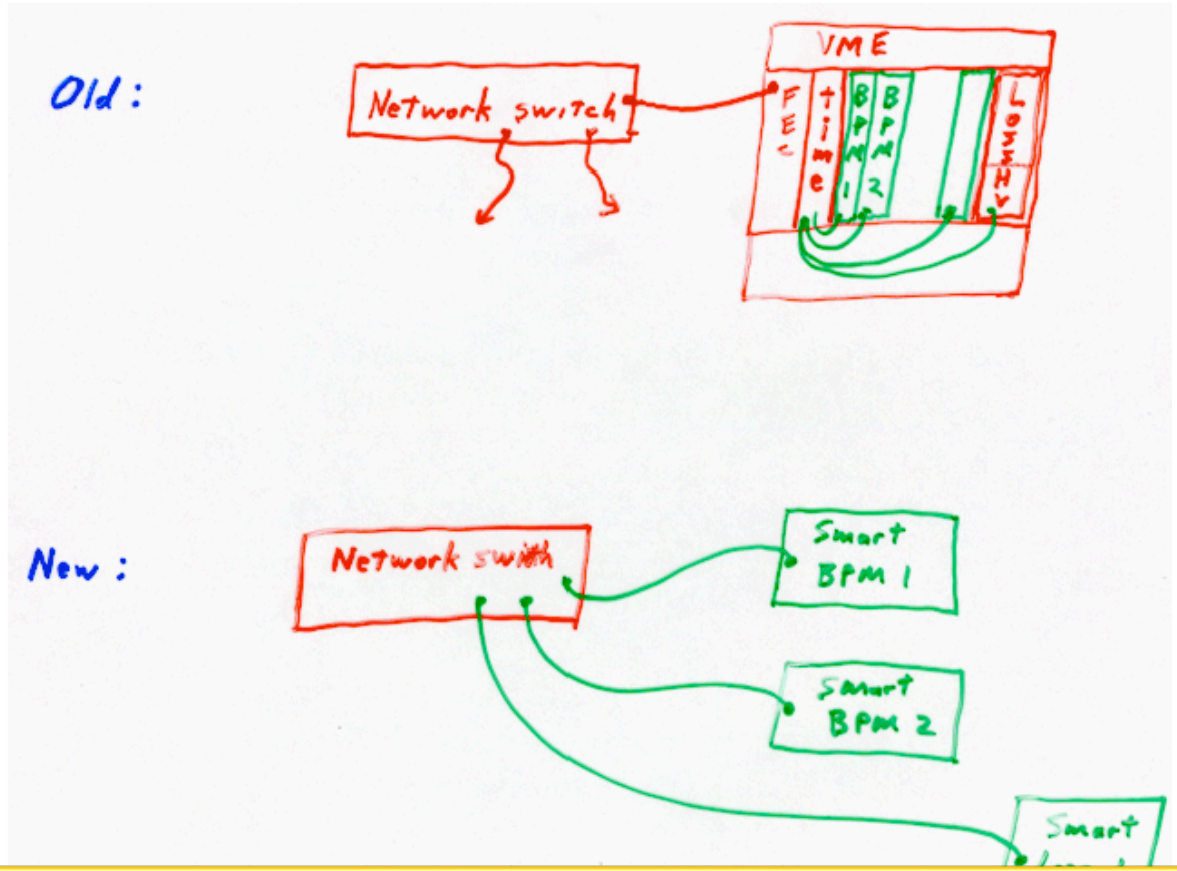
Protection Systems: protect systems and devices from damage

Safety Systems: protect people from risks related with radiations, lasers, ...

- ✓ Usually this systems are based on Programmable Logic Controllers (PLC): computers used for automation in industrial plants
- ✓ No operating system, reliable and deterministic
- ✓ Fieldbus: industrial computer network used for real-time distributed control: Profibus, CANbus, Profinet, Powerlink, Ethercat, AS-I, LonWorks, BITBUS, ...



Embedded Controllers



Courtesy of Tom Shea

Smart Devices or NAT (Network Attached Devices)

Instrumentation or devices with their own internal controller (DSP, Microcontroller, FPGA, ...) and a digital interface (Ethernet)

Low Cost Embedded Platforms

- ✓ Arduino

- ✓ BeagleBone

- ✓ RASPBERRY PI

Embedded Controller
Example: Piezo Controller

Operating Systems

Real-time system: a system which can guarantee a response within specified time constraints, i.e. can meet a deadline deterministically

- ✓ Non real-time Operating Systems (running on field computers, servers and consoles):
  - Linux, Windows, Unix, VAX/VMS, OS X, ...
- ✓ Real-time Operating Systems - RTOS (running on field computers):
  - OS-9, VxWorks, LynxOS, QNX, WindowsCE, RTEMS, ...
  - Linux RT extensions (RT-Linux, RTAI, XENOMAI), Linux + Preemptive Scheduling (Kernel >2.6)

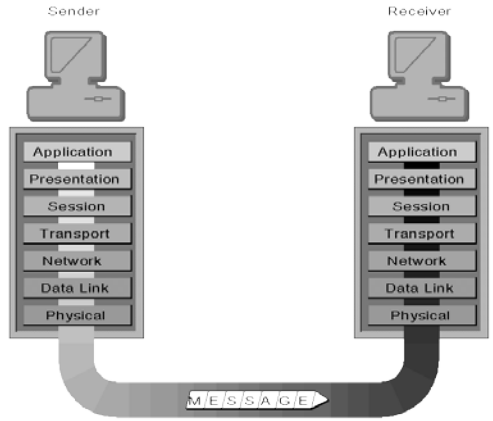
Languages and Protocols

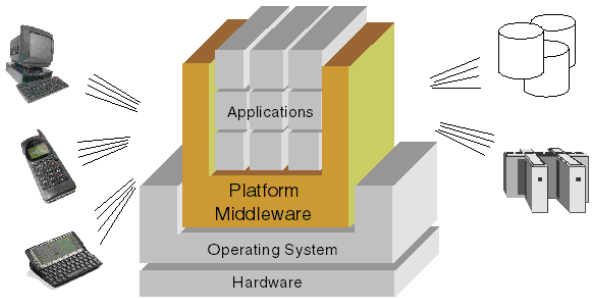
Programming Languages

Assembly
C
C++
Java
Python
.....

Communication Protocols

TCP/IP
UDP
Modbus
SNMP
.....





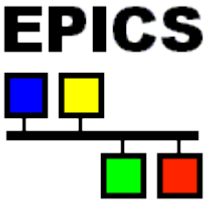
Middlewares

CORBA
OPC
DDS
ZeroMQ
.....

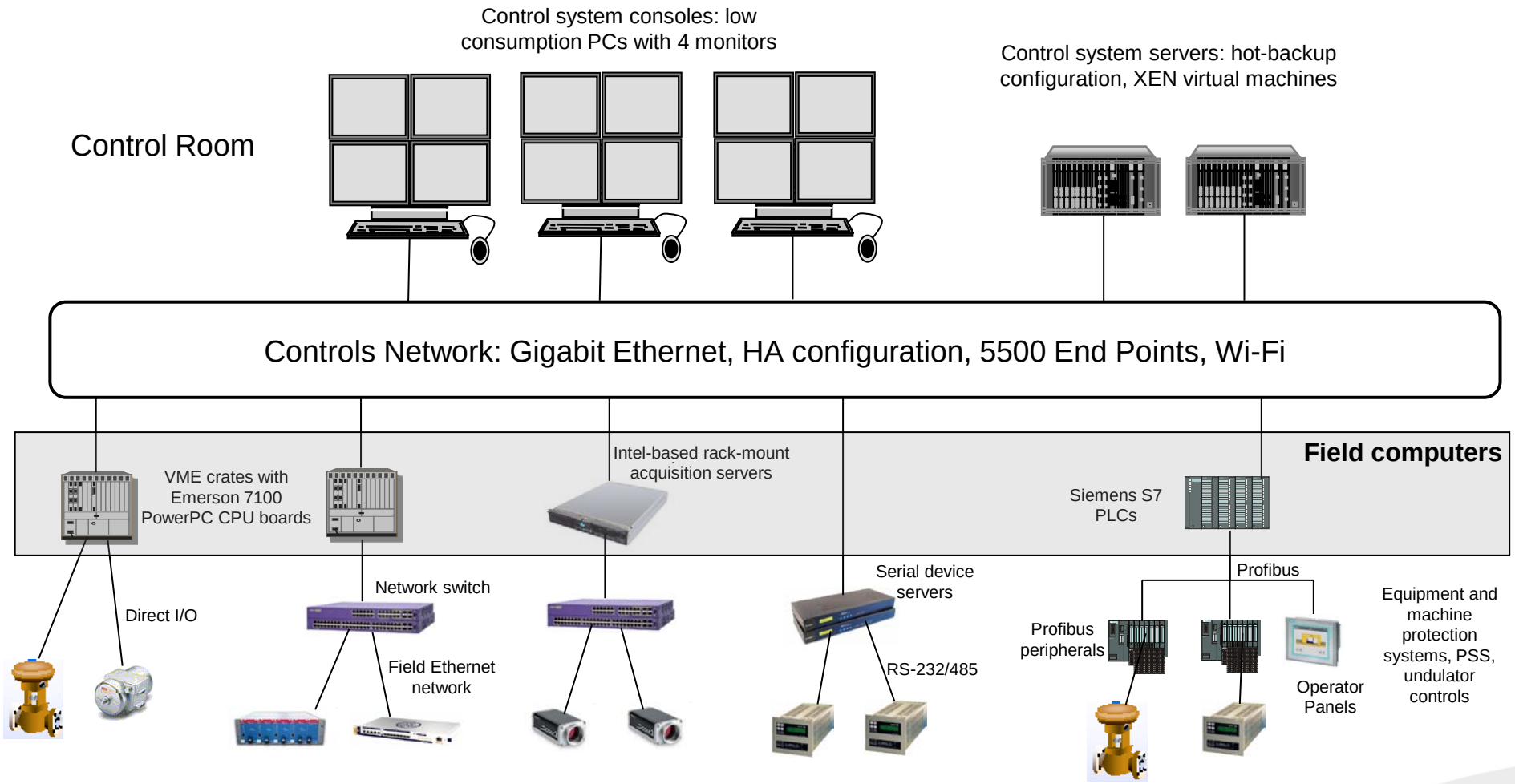
Control System Software Frameworks

Programming languages and protocols are not sufficient to develop the software for a distributed control system: a software framework is needed to help the development of client/server control applications

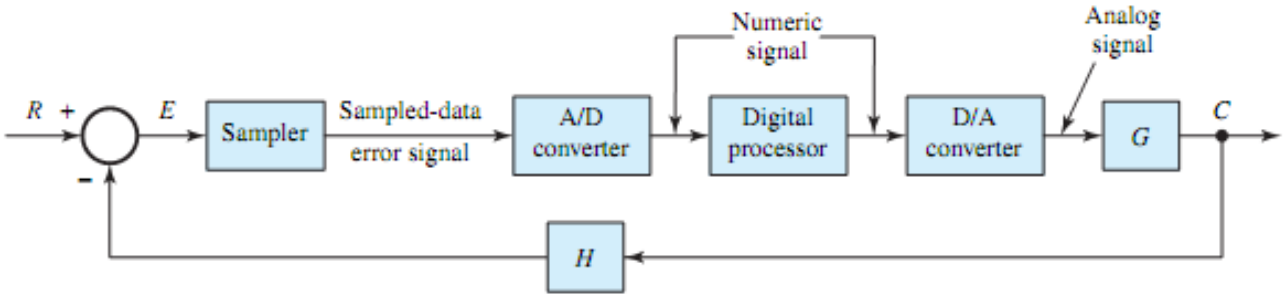
- ✓ TANGO
- ✓ EPICS
- ✓ ACS
- ✓ TINE
- ✓ DOOCS
- ✓ Karabo
- ✓ !CHAOS
- ✓ CODAC
- ✓ UNICOS
- ✓ MADOCA
- ✓ LabVIEW
- ✓ SCADAs
- ✓ ...

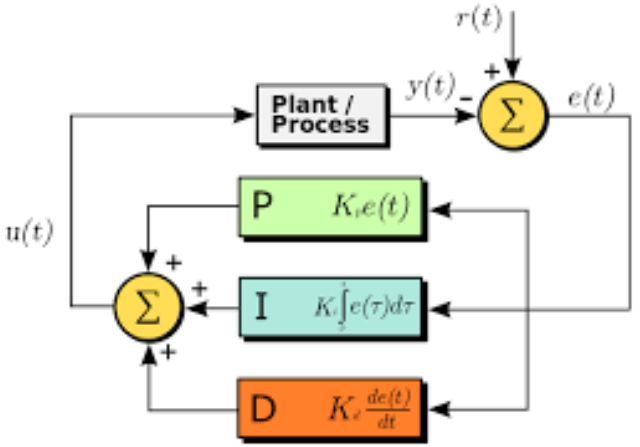


Architecture and Technologies: the FERMI control system

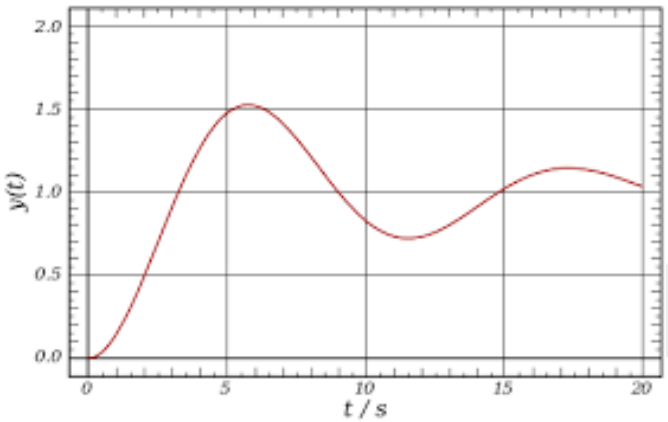


Digital Feedback Systems



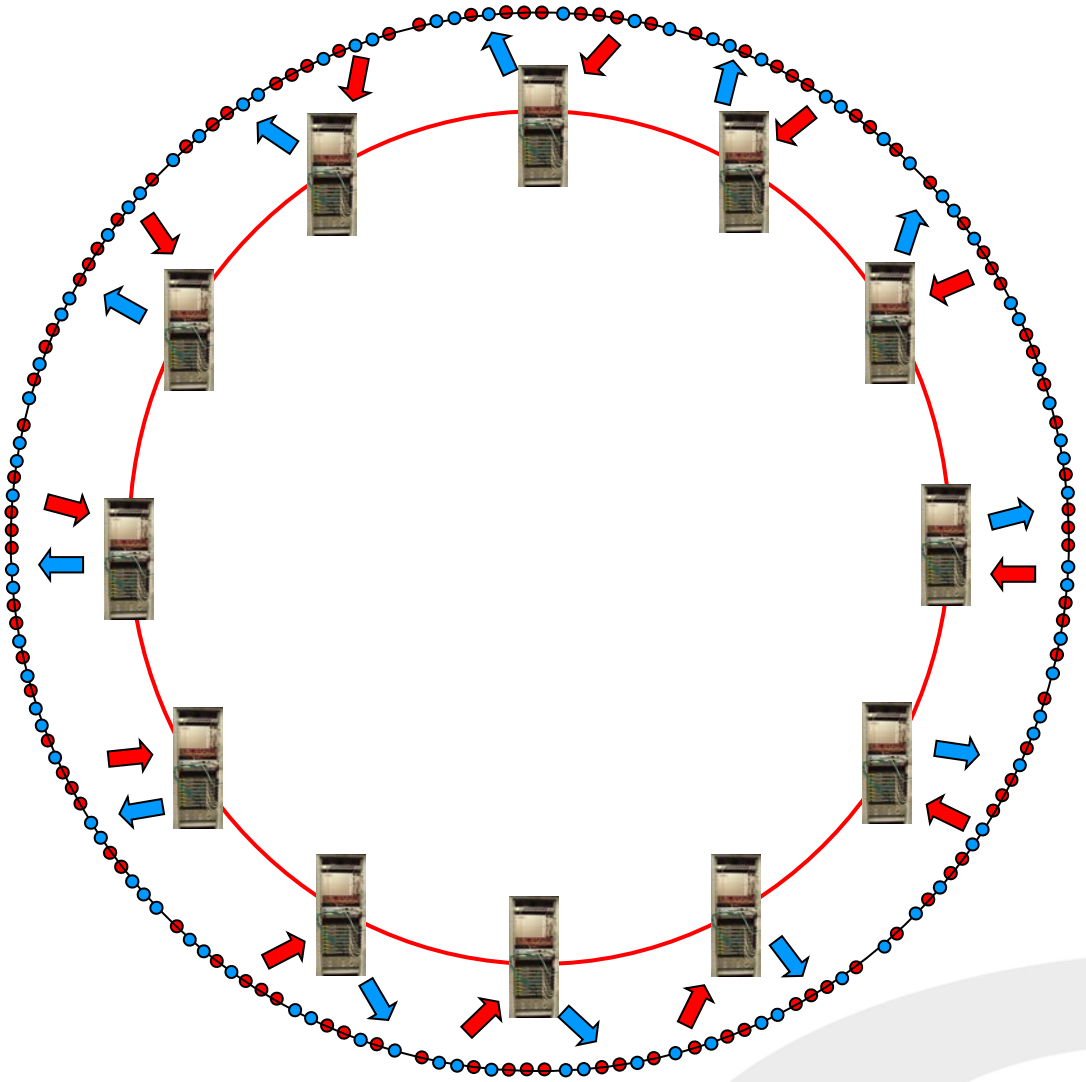


- ✓ need to keep constant a process variable: ex. electron beam trajectory
- ✓ read sensors and set actuators continuously at a given repetition rate
- ✓ processing of the sensor signals made by digital controllers
- ✓ dynamic system control theory and digital signal processing techniques
- ✓ repetition rates up to 500 MHz
- ✓ feedback systems essential to allow operability of the acceletators and assure the quality of the photon beams



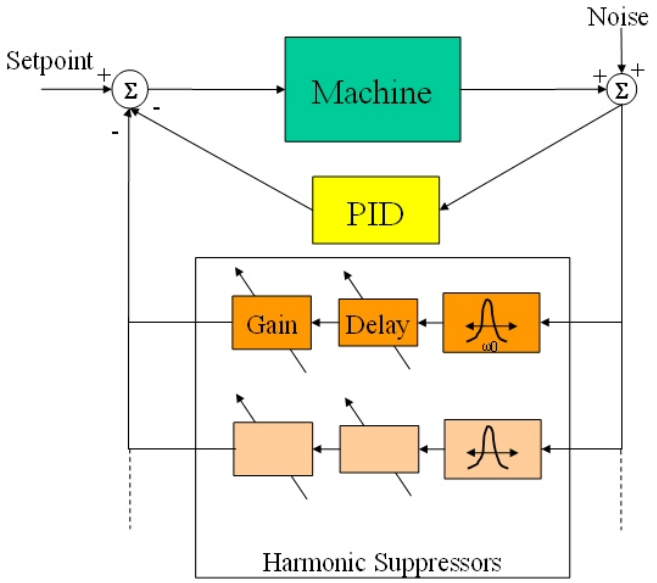
Elettra: Orbit Feedback System

- ✓ 96 Beam Position Monitors (BPM) and 82 corrector magnets
- ✓ 10 kHz repetition rate
- ✓ 12 processing units acquiring beam position data from the BPM detectors
- ✓ data shared in real-time through Reflective Memory fiber optics
- ✓ 10 kHz D/A converters generate the analog correction signals sent to the corrector power supplies

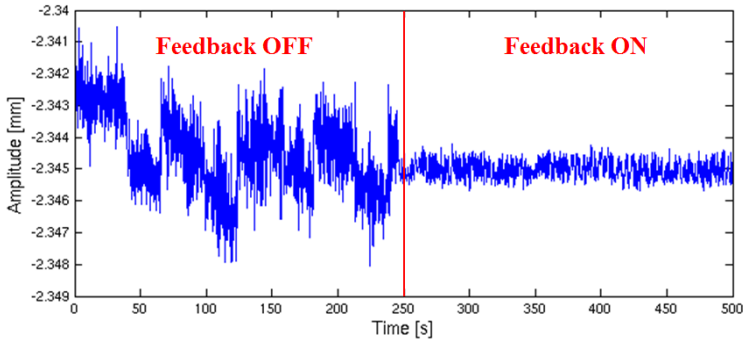


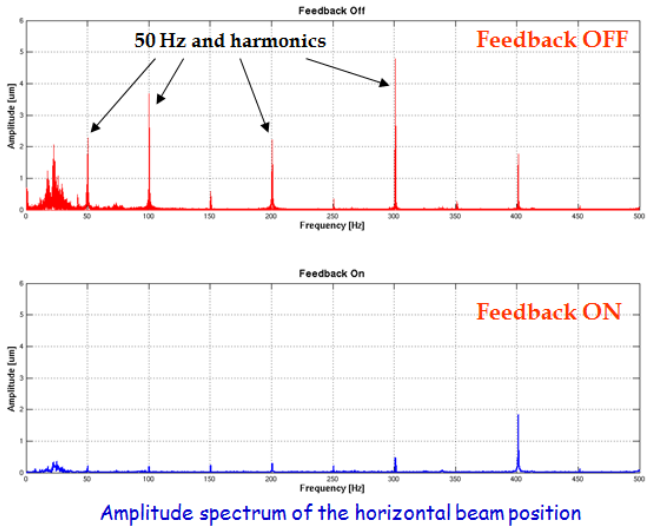
Elettra: Orbit Feedback System

- ✓ Control Algorithms:
  - PID dedicated to low frequency noise components
  - Harmonic Suppressors dedicated to periodic noise components at 50, 100, 150, 200, 250 and 300 Hz



- ✓ Results:
  - attenuation bandwidth of 150 Hz (random noise)
  - almost complete suppressions of the main 50 Hz harmonics

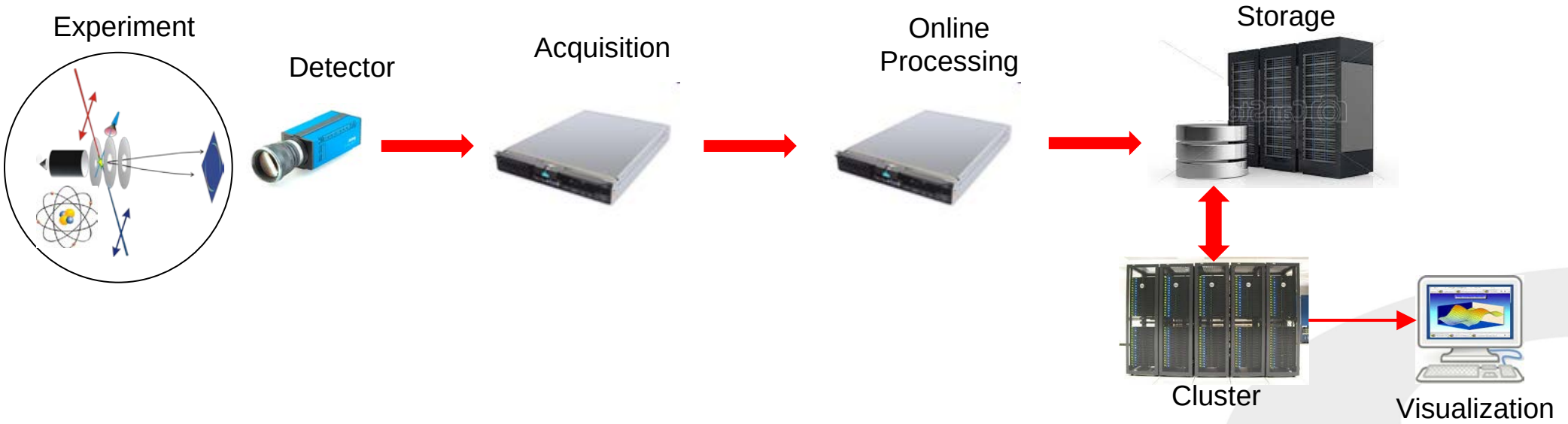




Amplitude spectrum of the horizontal beam position

Scientific Data Management

- ✓ Experimental stations generate huge amount of data to be stored and processed
- ✓ Detectors producing more than 500 MB/s (1.8 TB/h) of images, will be x10 in the next few years with the new generation of detectors
- ✓ Big challenges for data transfer, storage and processing
- ✓ Big data, data deluge

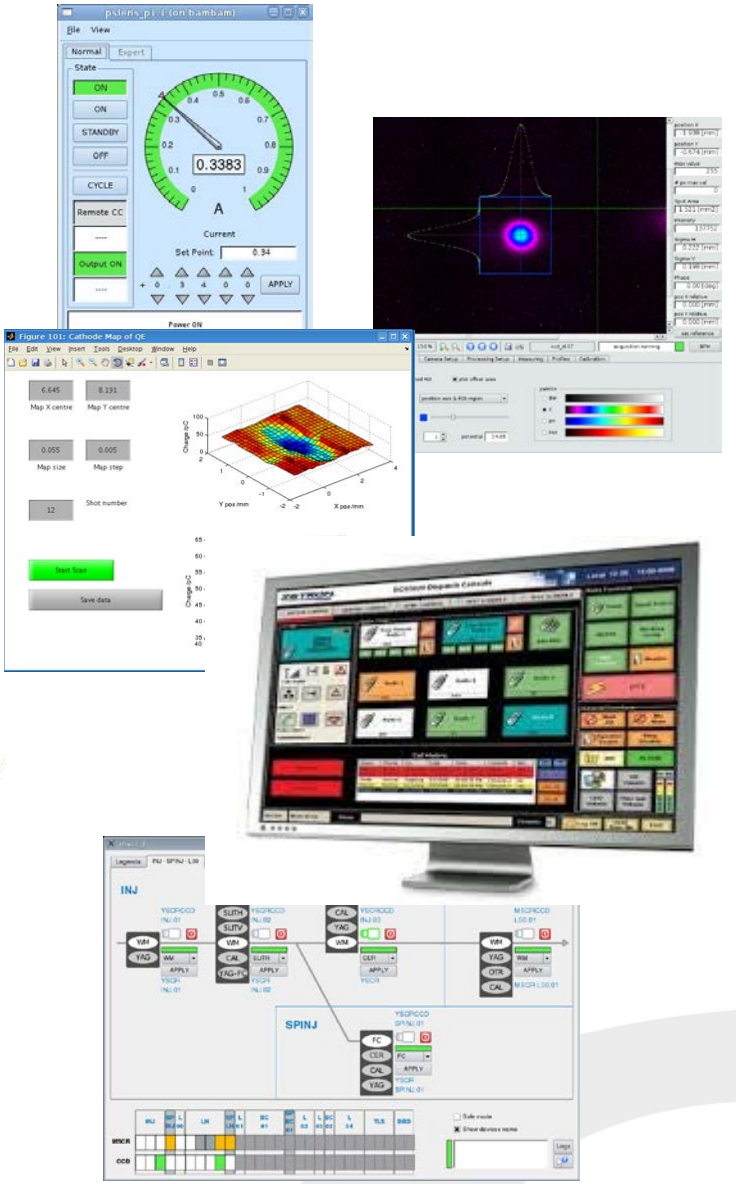


Graphical User Interfaces

- ✓ Physicists and Operators interact with the machine through software applications and Graphical User Interfaces (GUI) running on the control room consoles
- ✓ Many languages and open source widget libraries available
- ✓ GUIs must be:
  - comprehensive
  - easy to learn
  - useable
  - clear

combine all of them could be an issue

- ✓ Technology, psychology and art!

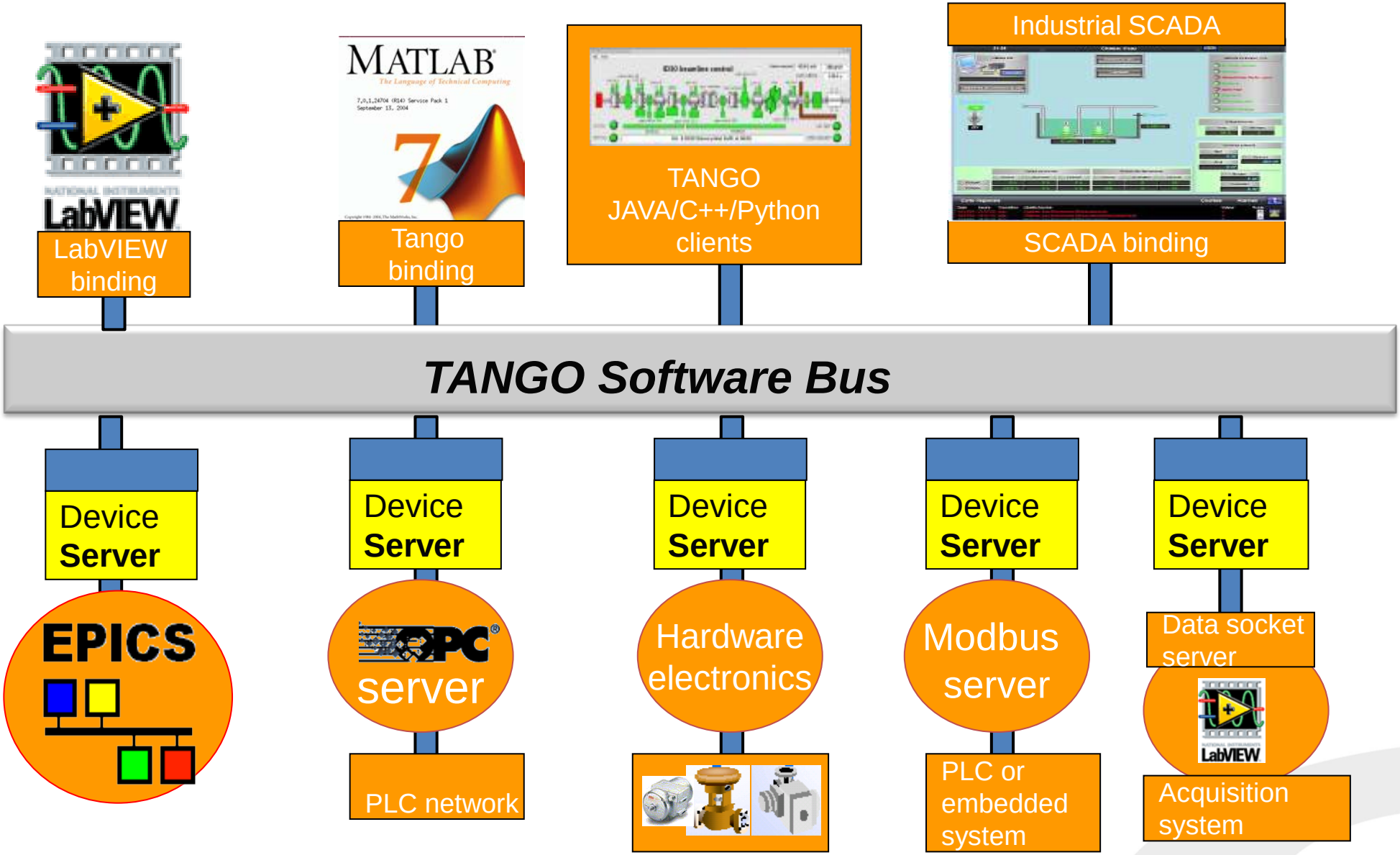


TANGO Control System Framework

TANGO is a toolkit for building distributed control systems

- ✓ Open source and free of charge
- ✓ Object oriented, topology independent, highly scalable
- ✓ Multi-platform (Linux, Windows)
- ✓ Multi language: C++, Java, Python
- ✓ Configuration tools, Administration tools
- ✓ Archiving service
- ✓ Access control service
- ✓ Logging service
- ✓ Alarm service
- ✓ GUI Toolkit for Java, C/C++, Python
- ✓ Web interface

TANGO as a software bus



TANGO Collaboration

- ✓ TANGO has been adopted by many European institutes: ESRF, SOLEIL, Elettra, Alba, ANKA, MAX-lab, DESY, Solaris, FRM-II, ELI-ALPS, ELI-Beamlines, ELI-NP, Univ. of Szeged, INAF, ONERA
- ✓ TANGO collaboration ruled by a contract presently signed by eight institutes, which defines the governance and the organization
- ✓ In March 2015 the Square Kilometer Array (SKA) decided to adopt TANGO

Other TANGO users

Softwareschneiderei

東北大学
TOHOKU UNIVERSITY

The MARS CITY Project

- ✓ MARS CITY is a program spearheaded by the Italian Mars Society (IMS) which main goal is to provide an effective test bed for field operation studies in preparation of manned missions to Mars
- ✓ The command, control and communication system of the MARS simulation station is developed in TANGO

ERAS
EUROPEAN MARS ANALOG STATION

The ELI project

- ✓ The **Extreme Light Infrastructure** (ELI) is a new research infrastructure project and part of the European ESFRI Roadmap, with an investment volume exceeding 850 million€
- ✓ ELI is the latest laser equipment in the world. Research projects studying the interaction of light with matter at intensity 10 times higher than currently achievable values. Ultra-short laser pulses of a few femtoseconds (10-100 fs) duration and power up to 10 PW.
- ✓ The facility will be based on four sites. three of them are presently being implemented in Czech Republic, Hungary and Romania

ELI-Beamlines

ELI-ALPS

ELI-NP

Dzięki!

تشكر

Thank you!

Gracias!

Grazie!

Mulțumesc!

Elettra
Sincrotrone
Trieste

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