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Institut national de **physique nucléaire**
et de **physique des particules**

***Systèmes de Contrôle-Commande sous LabVIEW
pour grandes installations***



Etat de l'art du domaine en recherche

16 octobre 2017

Patrick Stassi – LPSC

V02

Plan de la présentation

- *Définition du « domaine » traité*
- *Bilan des besoins spécifiques*
- *Solutions utilisées et proposées*
- *Le futur*
- *Conclusions*

Définition du « Domaine »

■ *Accélérateurs*

- Pour la physique des particules ou nucléaire
- Pour la recherche appliquée et industrielle
- Pour la recherche médicale



■ *Réacteurs expérimentaux, tokamak...*

- Physique fondamentale
- Energie, matériaux
- Biologie, chimie



ETC...

Définition du « Domaine »

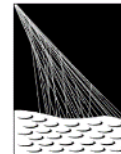
■ *Télescopes et radiotélescopes*

- Astrophysique et Astronomie
- Cosmologie
- Planétologie

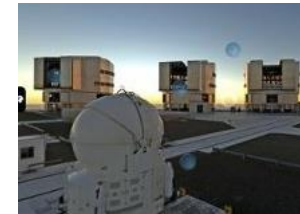


■ *Observatoires*

- Astrophysique
- Cosmologie
- Géophysique



PIERRE
AUGER
OBSERVATORY



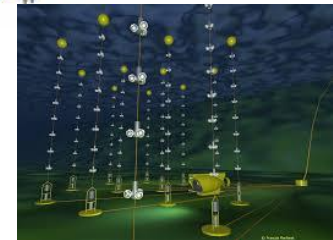
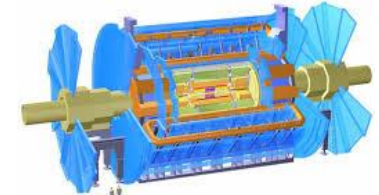
ETC...



Définition du « Domaine »

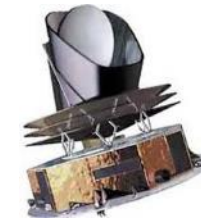
■ *Grands détecteurs de particules*

- Sur accélérateurs
- Sur réacteurs
- Autonomes, sous terre, sous-marins



■ *Autres grands instruments*

- Satellites
- Héliostats
- Laser
- Etc...



Quels sont les besoins ?

- ***Monitoring des données environnementales et techniques (HSK)***
 - Températures, pressions, etc...
 - Tensions, courants, capteurs divers
- ***Commandes et contrôle des paramètres***
 - Hautes tensions, synchronisation (GPS), etc...
- ***Commandes et contrôle de mouvements et positions***
 - Moteurs, miroirs, cameras, etc...
- ***Sécurité***
 - Des matériels, des personnes, alarmes, etc...
- ***Communications***
 - Filaire, radio, etc...
- ***Etalonnages***
 - Mesures, acquisitions, analyses
- ***Archivage des données***

Quelles solutions ?

- *Les solutions sont multiples, elles peuvent être complètement élaborées avec des produits industriels ou semi-industriels, qui peuvent être également utilisées partiellement , conjointement avec des solutions propriétaires.*
- *Cela dépend de nombreux critères, techniques, financiers ou même politiques, mais également de l'expérience des concepteurs*

Quelles solutions ? L'architecture

Pyramide CIM (*Computer Integrated Manufacturing*)

Supervision, archivages des données, communication

Gestion et interprétation des données, simulation

Solutions logicielles HMI, monitoring, pilotage

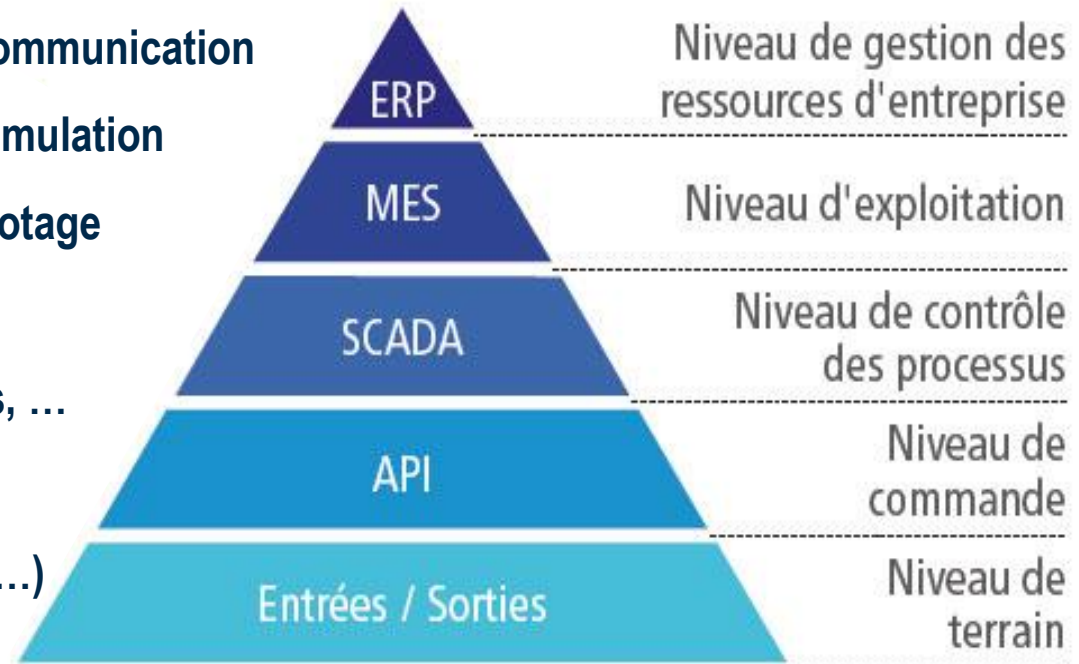
Gestion des alarmes, serveurs OPC...

Systèmes embarqués, robots, automates, ...

Réseaux de terrain (ProfiBus, etc...)

Entrées/sorties, bus de terrain (CAN, etc...)

Capteurs, actionneurs, Hardware



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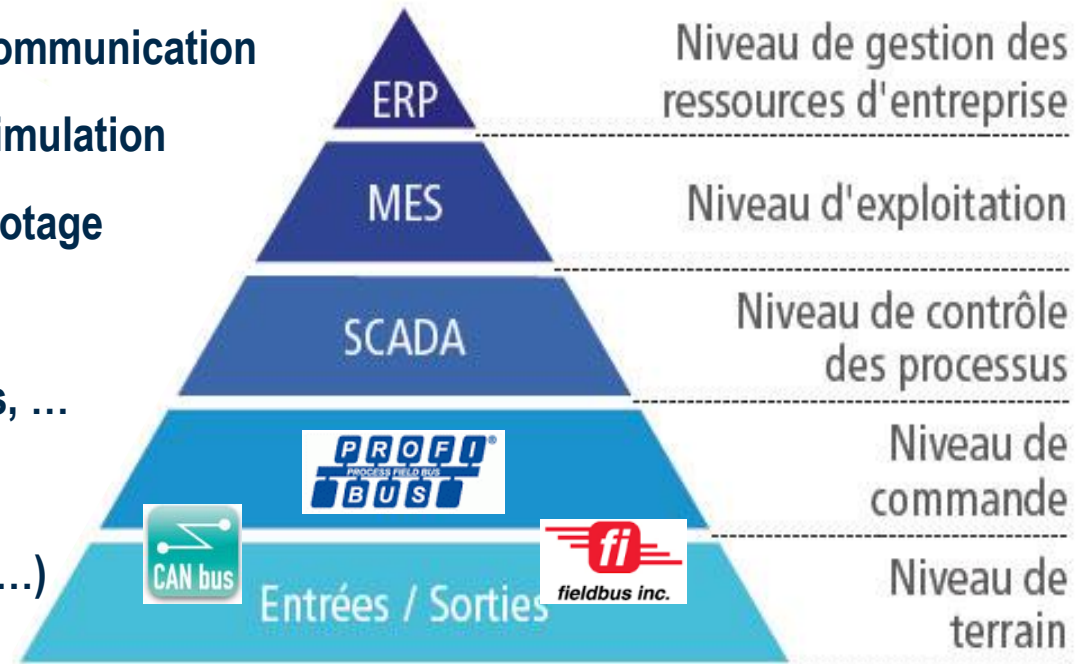
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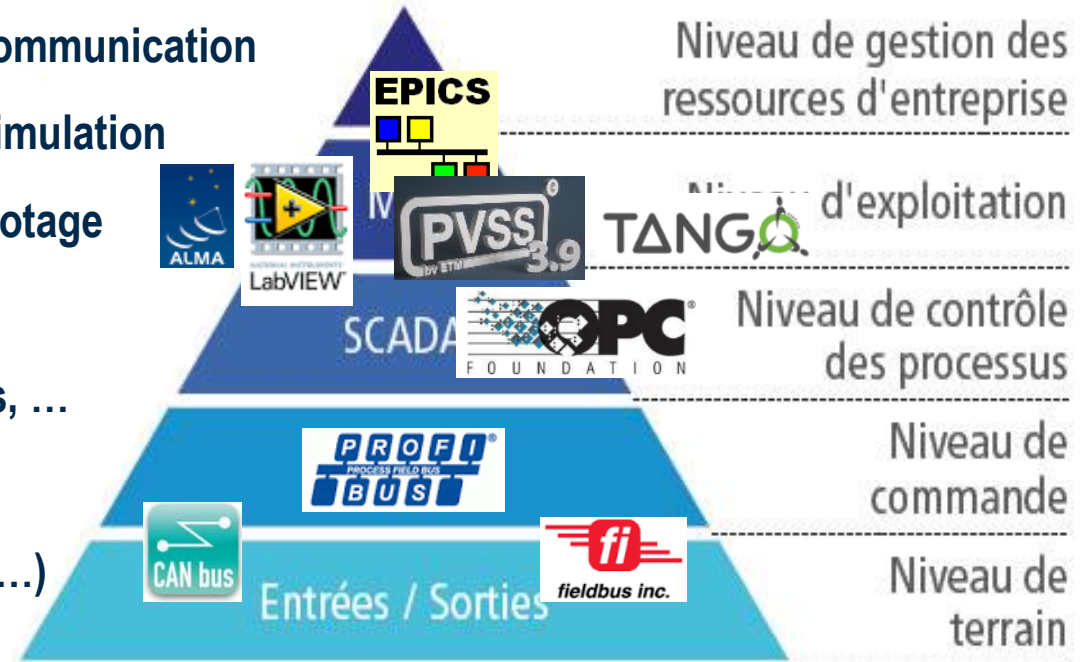
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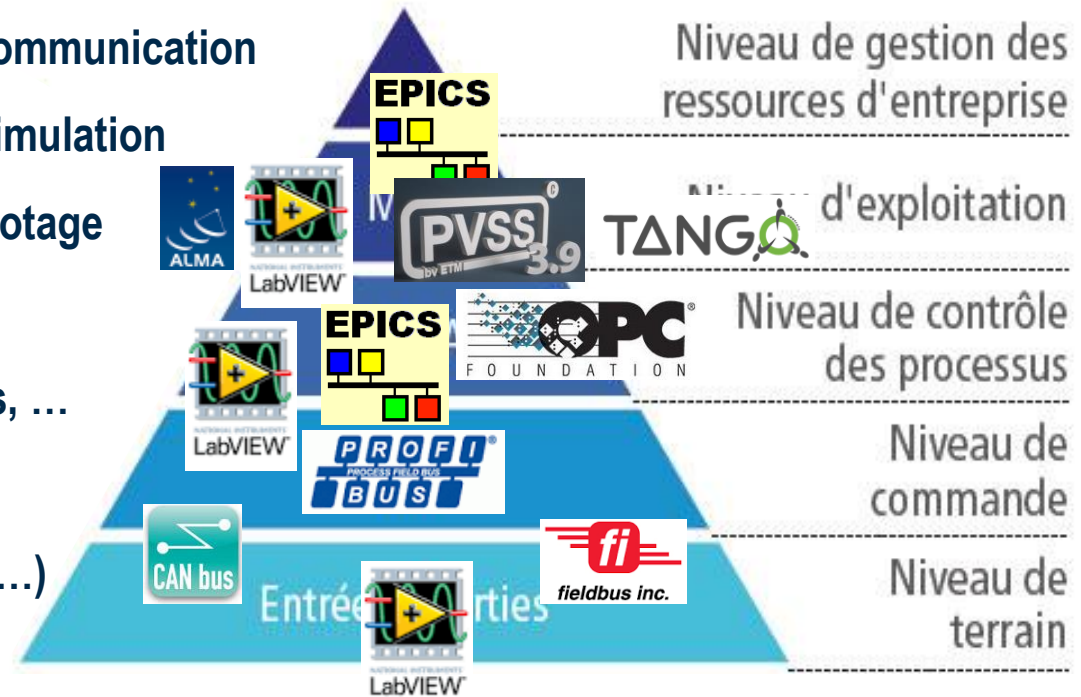
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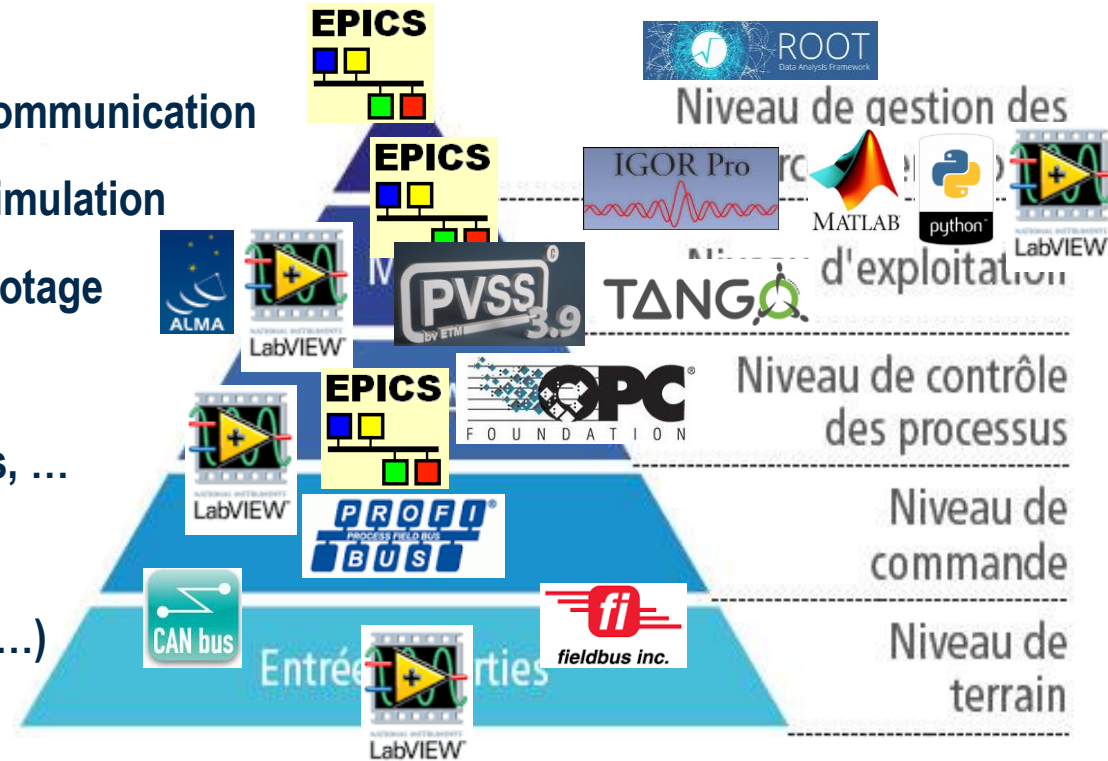
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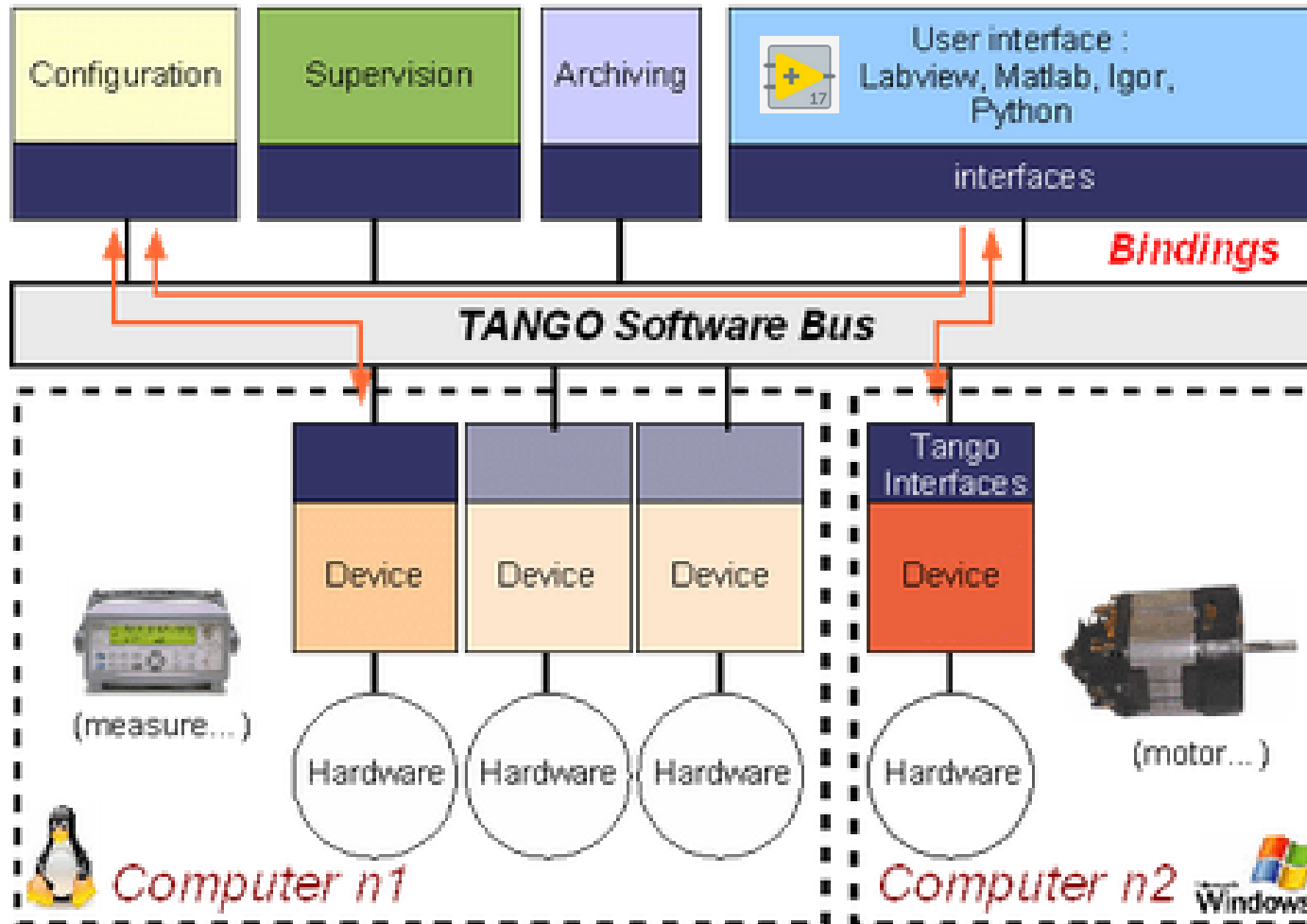
Entrées/sorties, bus de terrain (CAN, etc...)

Capteurs, actuators, Hardware



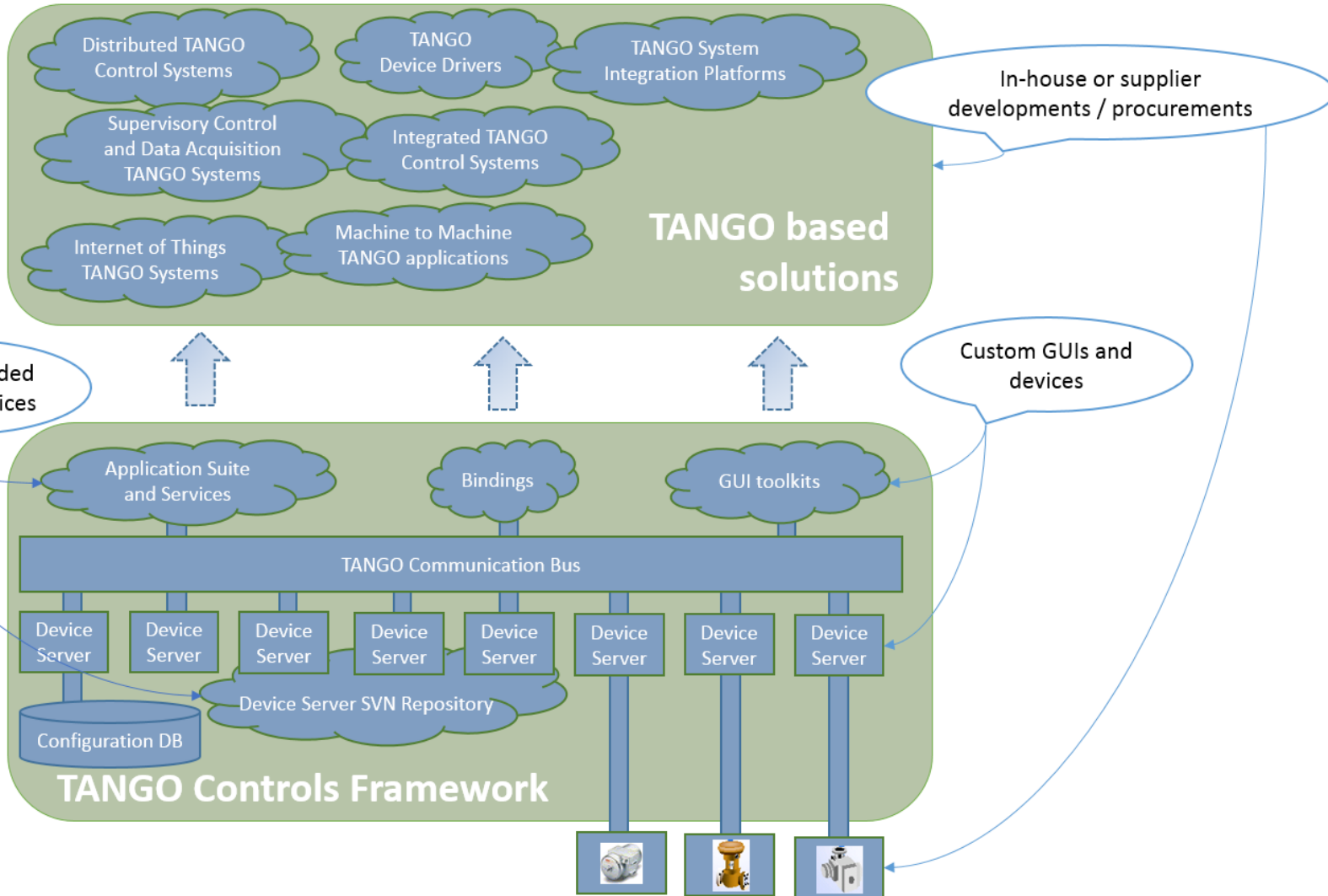
Quelques exemples de solutions

- **CEA/IRAMIS, laboratoire LION @ Saclay** *Tango*
- **Détecteur MPD @ JINR, Dubna, Russie** *Tango*
- **Accélérateur GSI @ Darmstad, Allemagne** *LabVIEW DSC*
- **Détecteur CMS @ CERN** *PVSS*
- **Détecteur BELLE @ KEK, Tsukuba, Japon** *PVSS*
- **Installation MICE @ RAL, Harwell, Grande Bretagne** *EPICS*
- **Spectromètre HADES, GSI @ Darmstad, Allemagne** *EPICS*
- **Lasers ELI @ Pragues, Rép. Tchèque** *EPICS/LabVIEW*
- **Radiotélescopes SK (ASKAP) @ Murchison, Australie** *EPICS*
- **Cherenkov Telescope Array (CTA) @ Chili & Canaries** *ACS*
- **Observatoire ALMA @ Atacama, Chili** *ACS*
- **Observatoire Pierre Auger @ Malargue, Argentine** *Propriétaire*



Laboratoire Interdisciplinaire sur l'Organisation Nanométrique et Supramoléculaire (LIONS)

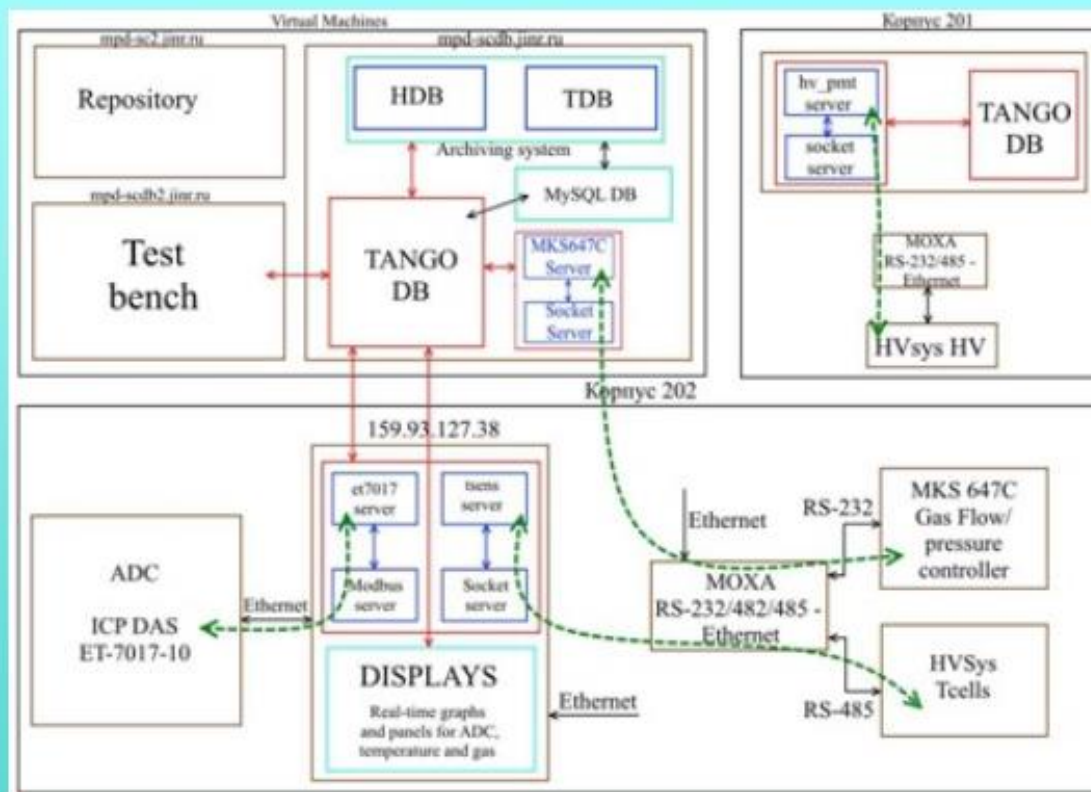
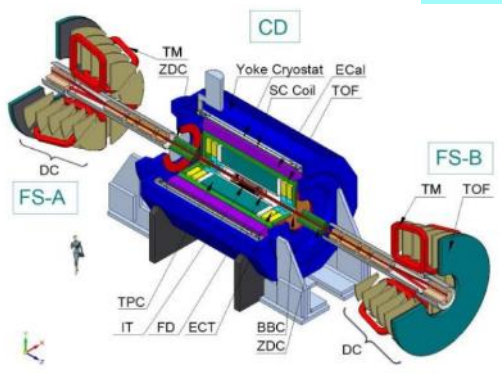
- **Tango est un "système de contrôle" permettant le contrôle informatique de divers types d'expérience et/ou d'installations.**
- **Il permet d'interfacer tous types d'équipements utilisés dans l'installation ou dans l'expérience.**
- **Tango prend également en compte l'aspect distribué des installations informatiques d'aujourd'hui.**



Layout Scheme of the part of the MPD SlowControl

TANGO

MPD Detector

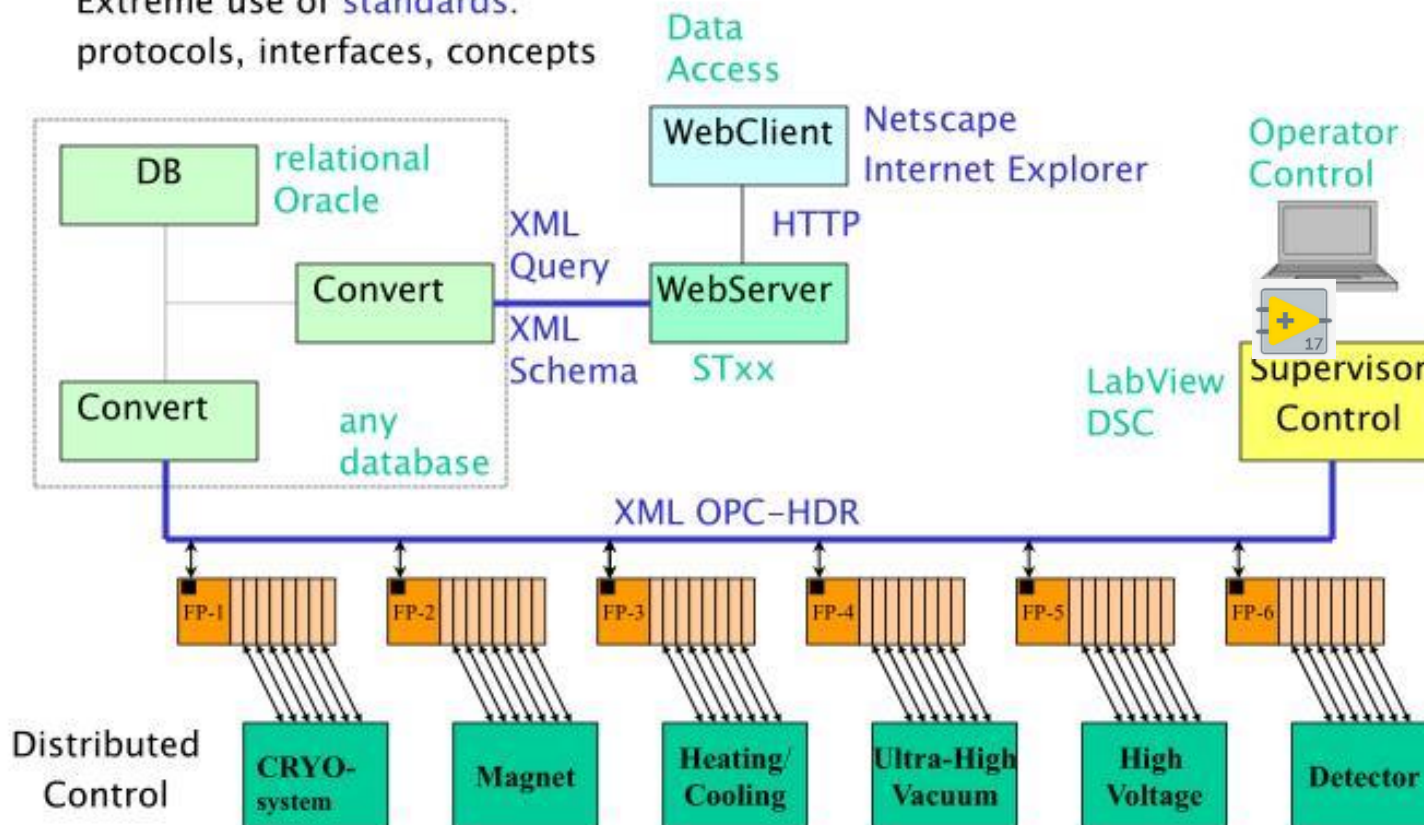


VB. Shutov
03-07.11.2015

11/21

Slow Control System Architecture

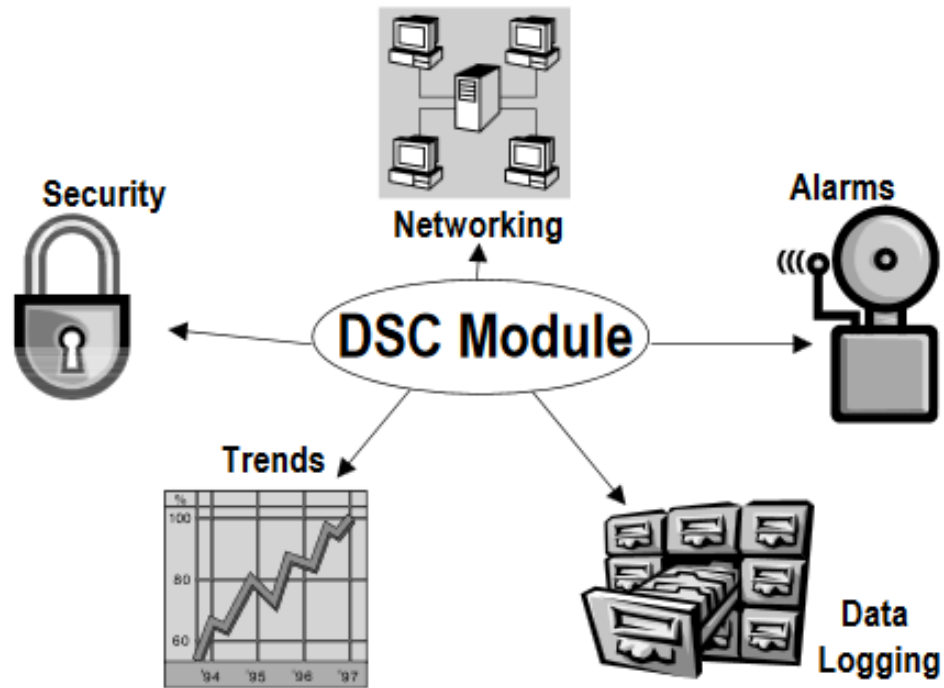
Extreme use of standards:
protocols, interfaces, concepts



LabVIEW + Module DSC



LabVIEW as a HMI/SCADA System

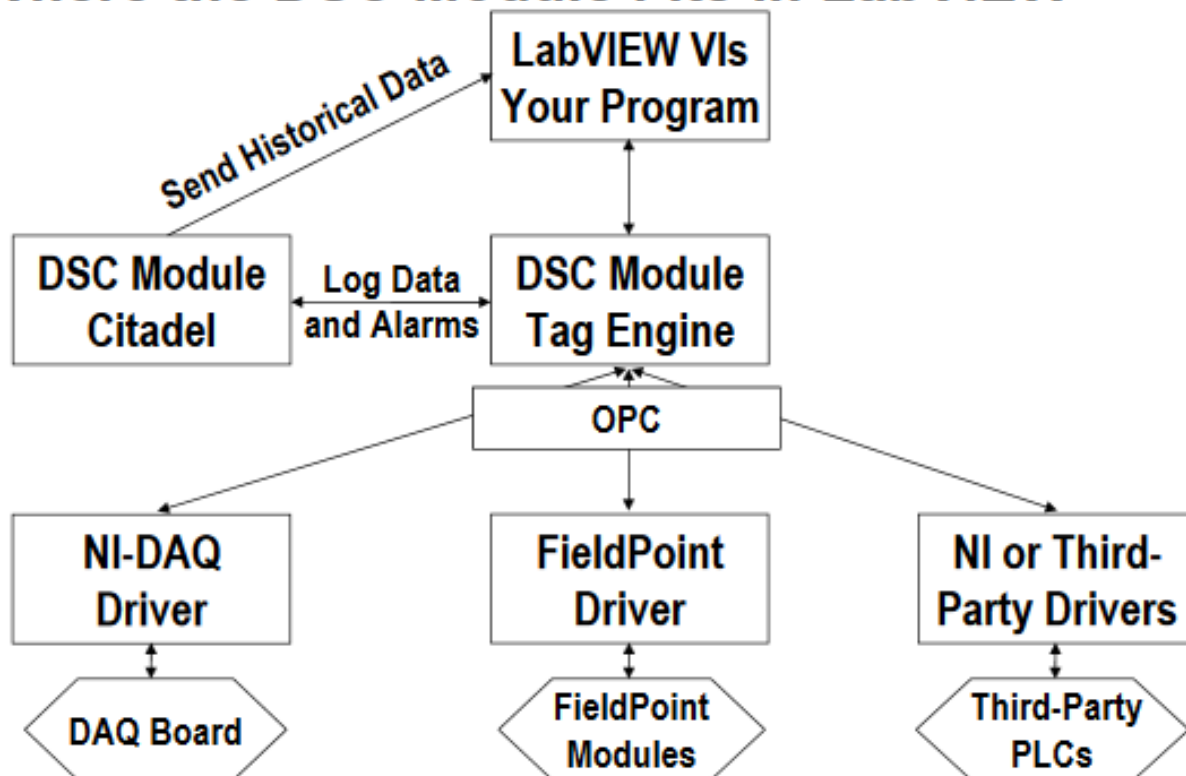


ni.com

 NATIONAL
INSTRUMENTS



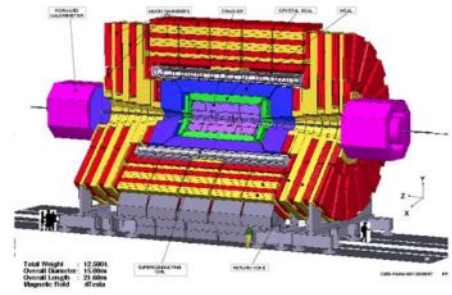
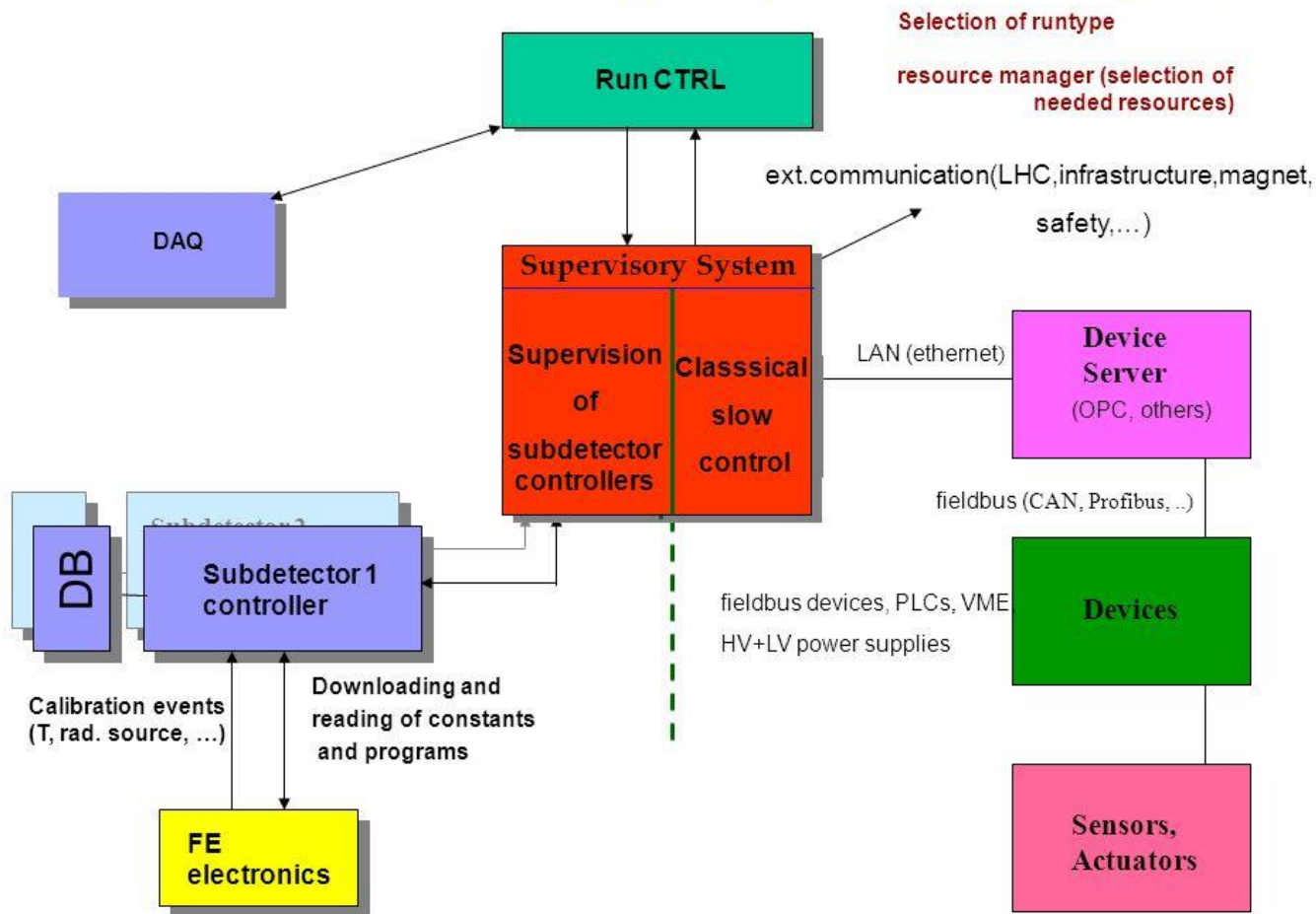
Where the DSC Module Fits in LabVIEW



ni.com



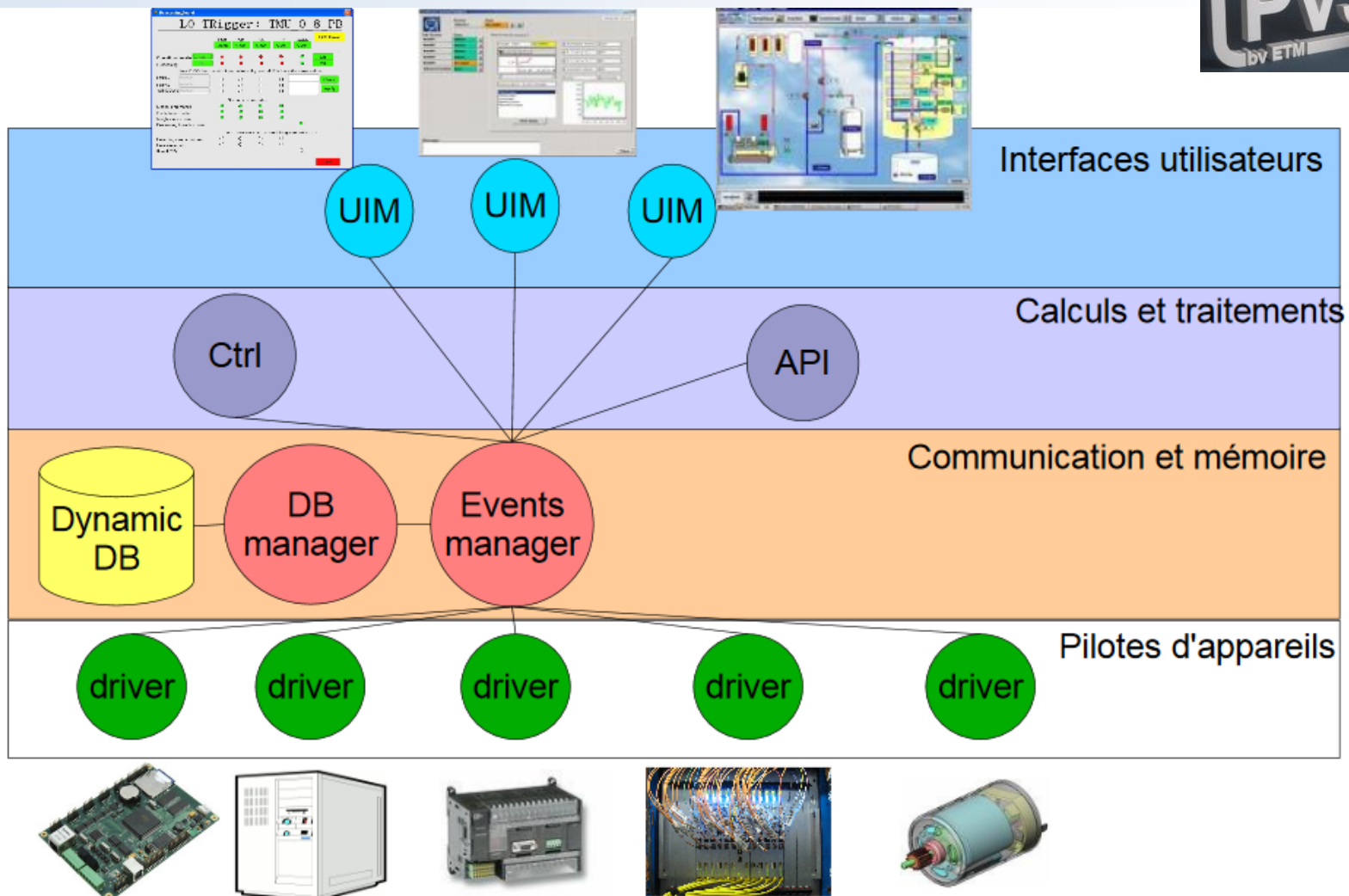
Architecture of the CMS control system (functional block diagram):

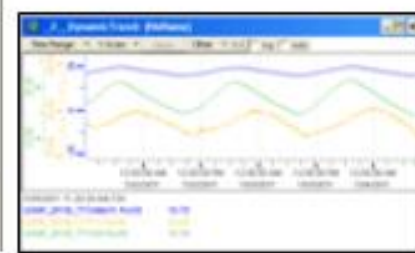
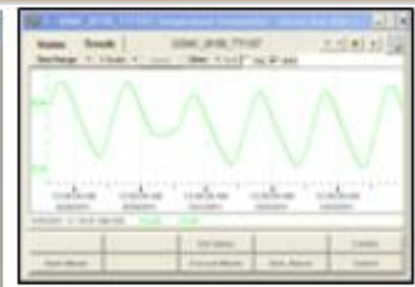
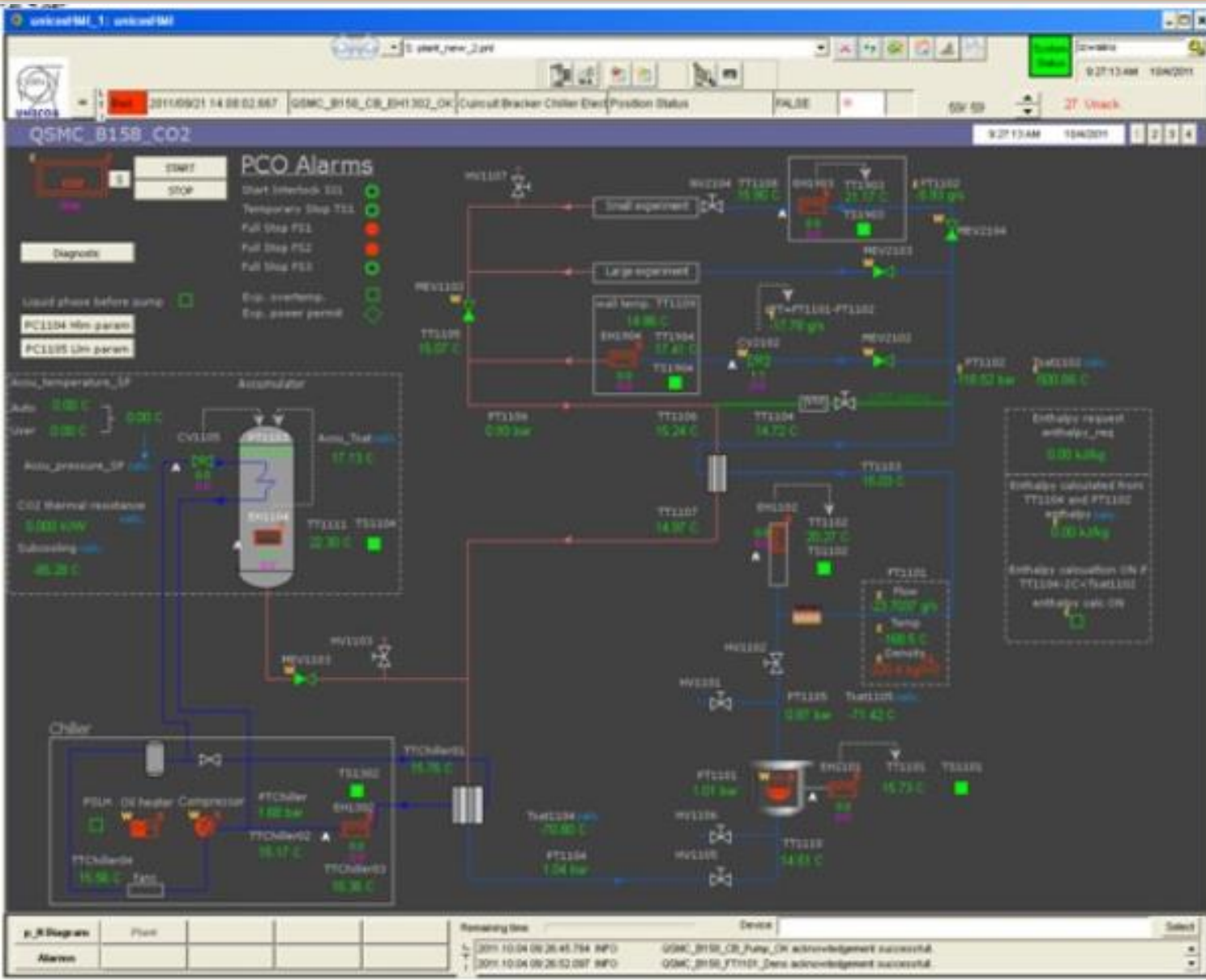


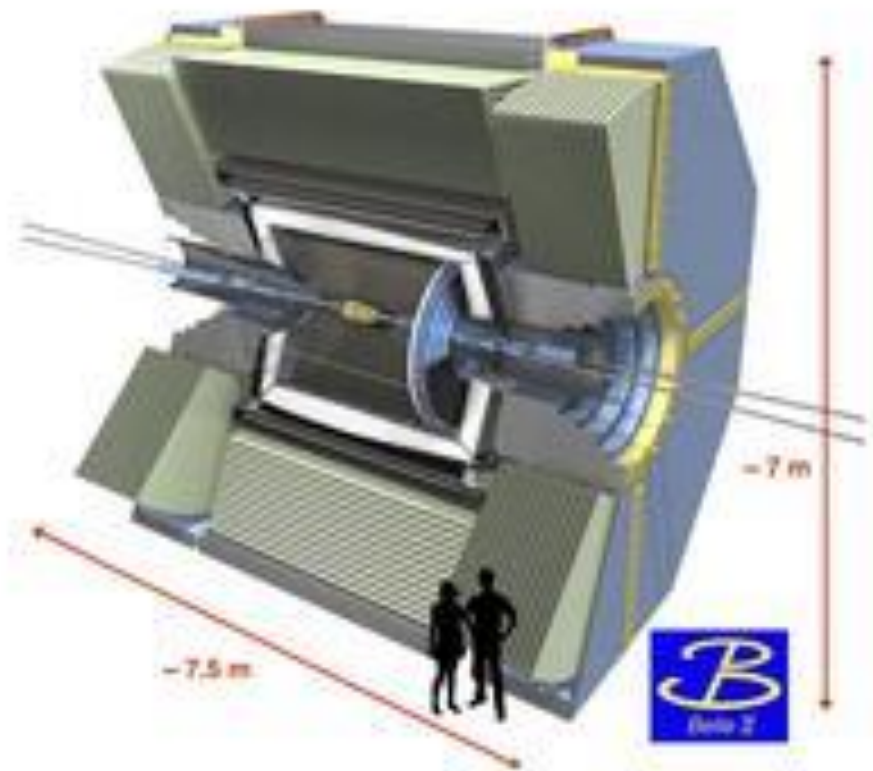
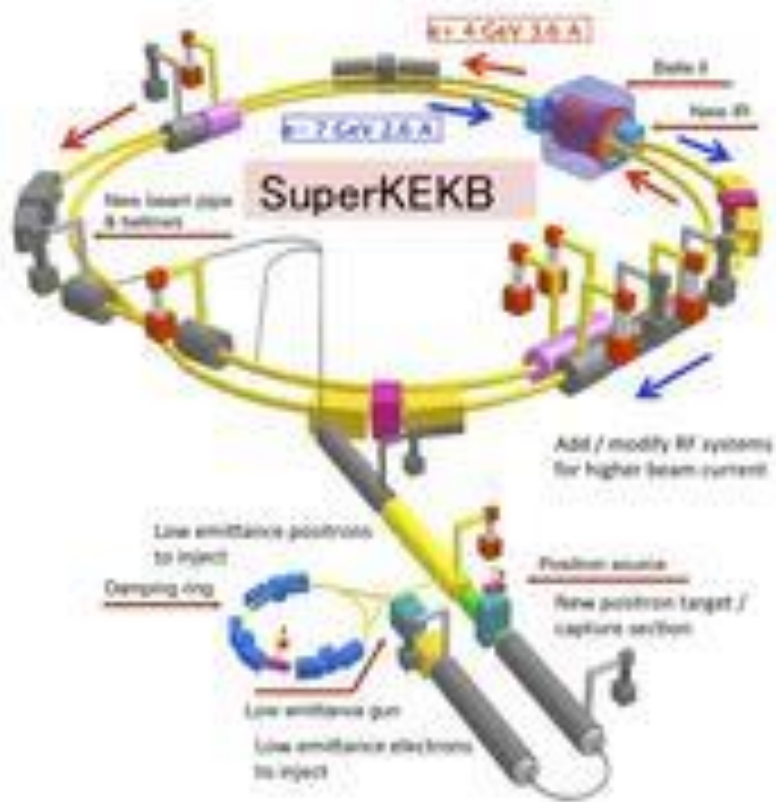


PVSS est un SCADA créé par ETM une petite société autrichienne rachetée depuis par SIEMENS

- **outil d'implantation du contrôle du LHC (accélérateur)**
- **choisi en 2000 pour implanter le contrôle des quatre expériences LHC**
- **recommandé depuis 2002 le CERN pour implanter tous les systèmes de contrôle de type SCADA des expériences au CERN.**







Unified Industrial Control System Standard

Industrial Supervision Layer

Interface to operators
(Monitoring & Command emission)
Real time DB & Archiving

Operator Consoles



SCADA Servers, e.g. PVSS



Industrial Control layer

Control Logic Actions

PLC Process Control



PLC Process Control & Field interface

Industrial Field layer

control system connection to the process directly or through field-buses ("sensors")

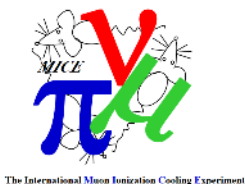
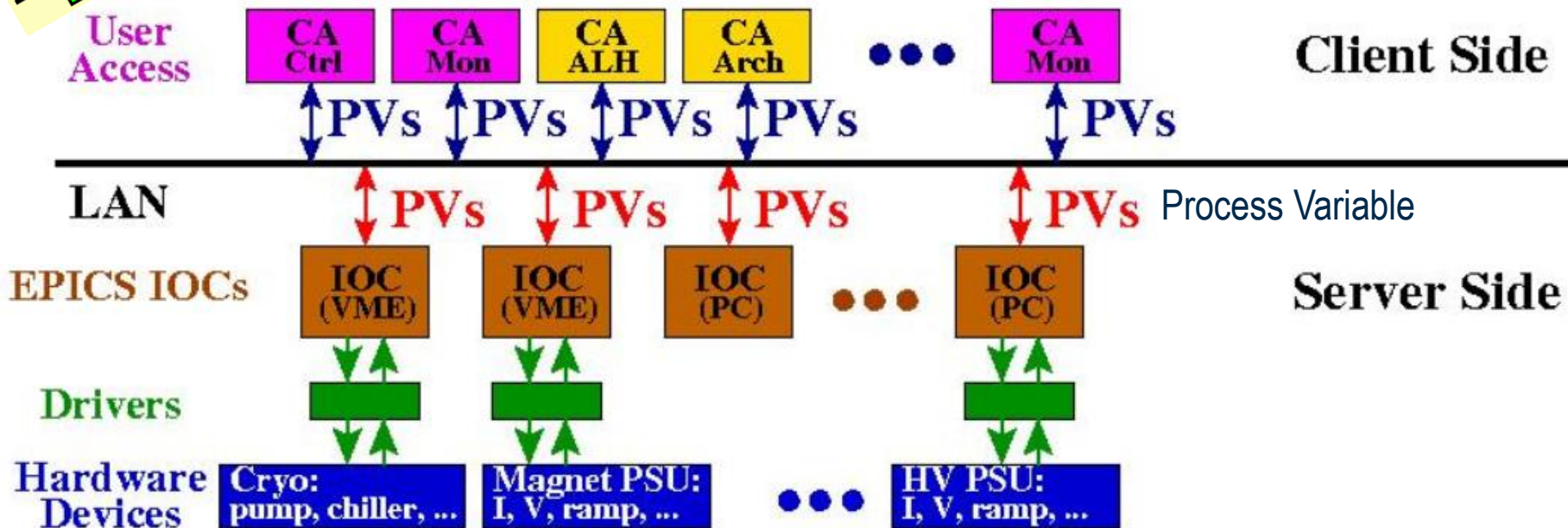
Fieldbus Networks



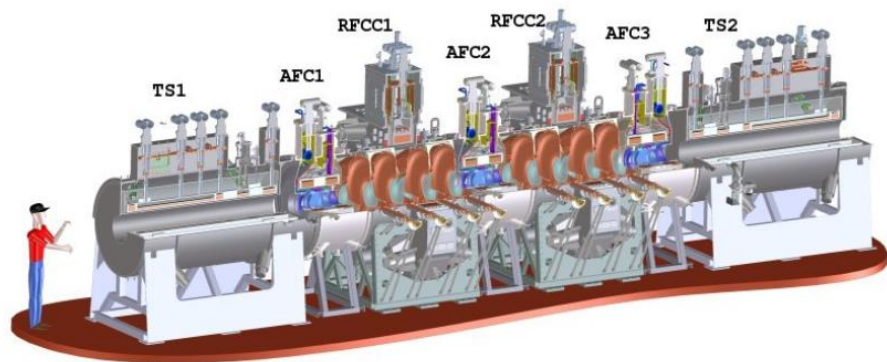
Ethernet Network & TCP/IP communication services

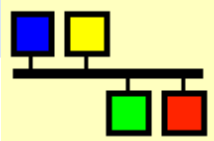


Channel Access



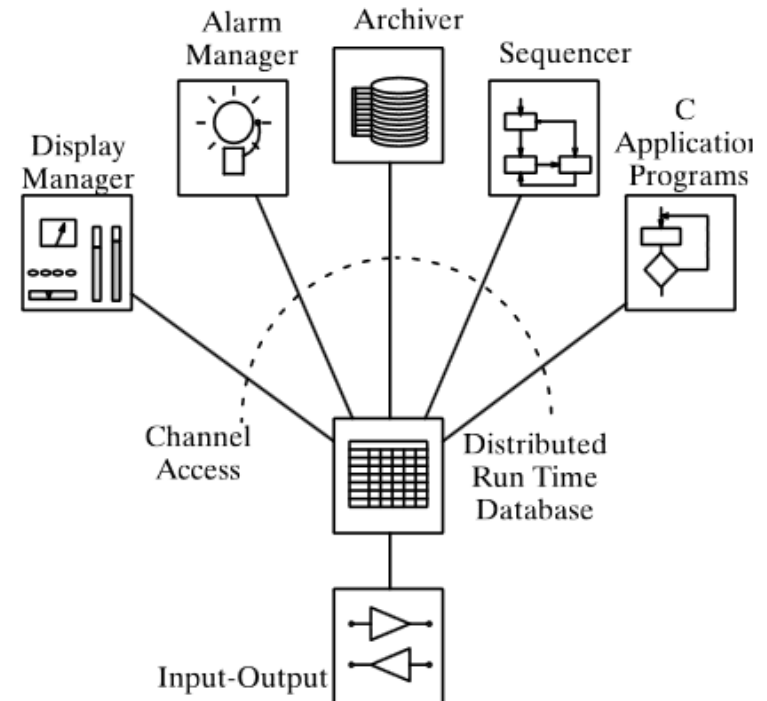
MICE
Muon Ionisation Cooling Experiment

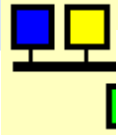




EPICS is a set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments.

- Basé sur un modèle Client/Serveur en réseau
- Un serveur distribue des variables aux programmes clients qui effectuent des opérations de supervision, ...





Accelerators:

- The Advanced Photon Source (Argonne)
- The Tesla Test Facility (DESY)
- The Continuous Electron Beam Accelerator Facility and IRFEL (TJNAF)
- The Bates Linear Accelerator (MIT)
- Next Linear Collider R&D (SLAC)
- RF and feedback for PEP-II "B-factory" (SLAC)
- Linac Coherent Light Source (SLAC)
- The HERA cryogenic plant (DESY)
- The Intense Pulsed Neutron Source (Argonne)
- Free Electron Laser (Budker INP)
- The Tesla Test Facility Injector (SACLAY)
- Racetrack Microtron (U Alabama)
- The Free Electron Laser Program (Duke)
- The Advanced Free Electron Laser (LANL)
- The Average Power Laser Experiment (LANL)
- LAMPF/LANSCE PSR (LANL)
- LEDA (for APT) (LANL)
- The Heavy Ion Fusion Test Stand (LBNL)
- Advanced Light Source (*partial*) (LBNL)
- National Laboratory for High Energy Physics B-factory (KEK)
- Berlin Electron Synchrotron Light Source (BESSY II)
- Microtron (U Athens)
- RF (PSI)
- Swiss Light Source (PSI)
- Neutron Therapy Cyclotron (U Washington)
- ISAC Radioactive Beam Facility (TRIUMF)
- Magnet test facility and Accelerator R&D (Sync Lab Barcelona/IFAE)
- SSRF synchrotron and BTCF e⁺/e⁻ collider (IHEP)
- NSRL (U Science/Tech, Hefei, China)
- IPHI (SACLAY)
- Spallation Neutron Source (Argonne/BNL/LANL/LBNL/ORNL)
- The National Spherical Torus Experiment (PPPL)
- Linac Test Bed for APT (SRS)
- Holifield Radioactive Ion Beam Facility (ORNL)
- Cyclotron(s) Controls Upgrade (MSU)
- DELTA Controls Upgrade (Dortmund)
- Pohang Light Source: Longitudinal Feedback System (PAL/POSTECH)
- KSTAR Superconducting Tokamak (NFRI, Korea)
- Steady State Tokamak-1 (Inst. for Plasma Research, India)
- Longitudinal Feedback for DAFNE (INFN/Frascati)
- MICE, Muon Ionization Cooling Experiment (FNAL/DRAL)

Detectors:

- Halls A, B, and C Slow Controls (JLab/NMSU)
- Advanced Light Source Beamlines (*partial*) (LBNL)
- Gammaphase (LBNL/Argonne/ORNL)
- Advanced Photon Source Beamlines (Argonne)
- The PHENIX detector system for RHIC Slow Controls (BNL/LANL/NMSU)
- The STAR detector system for RHIC Slow Controls (Creighton/U. Wash/Kent State/UCLA/LBNL)
- The Intense Pulsed Neutron Source Instruments (Argonne)
- The Biotechnology Beamline (SSRL)
- The BaBar detector for PEP-II Slow Controls (SLAC/LBNL)
- Structural Biology Research Group (Riken)
- Wind Tunnels (NASA/Langley)
- PRISMA and GARFIELD demonstrations (INFN/Legnaro)
- D0 (FNAL)
- High Acceptance DiElectron Spectrometer (GSI/Darmstadt)

Telescopes:

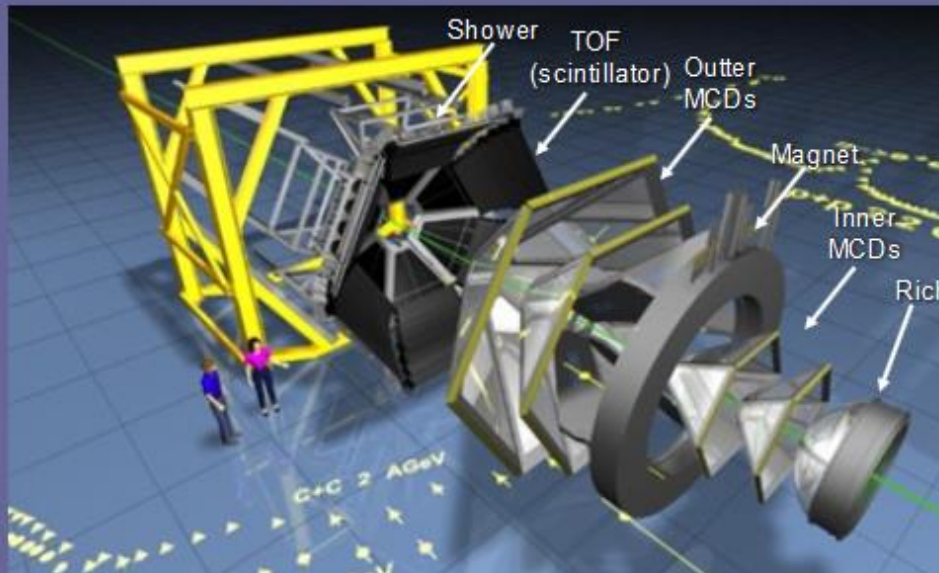
- The Gemini 8-M Telescope (AURA)
- Kitt Peak Observatory (NOAO)
- The United Kingdom Infrared Telescope upgrade (JAC)
- The William Herschel Telescope/WFFOS instrument (RGO)
- The William Herschel Telescope/ELECTRA instrument (U Durham)
- The Keck II Telescope (CARA)
- Canada-France-Hawaii Telescope Upgrade
- LIGO (CalTech)
- INTEGRAL instrument/Instituto de Astrofísica de Canarias (IAC)
- Potsdam Multiaperture Spectrophotometer (Astrophysical Inst)
- Sloan Digital Sky Survey/Telescope Performance Monitor (SDSS)

HADES EXPERIMENT



High Acceptance DiElectron Spectrometer

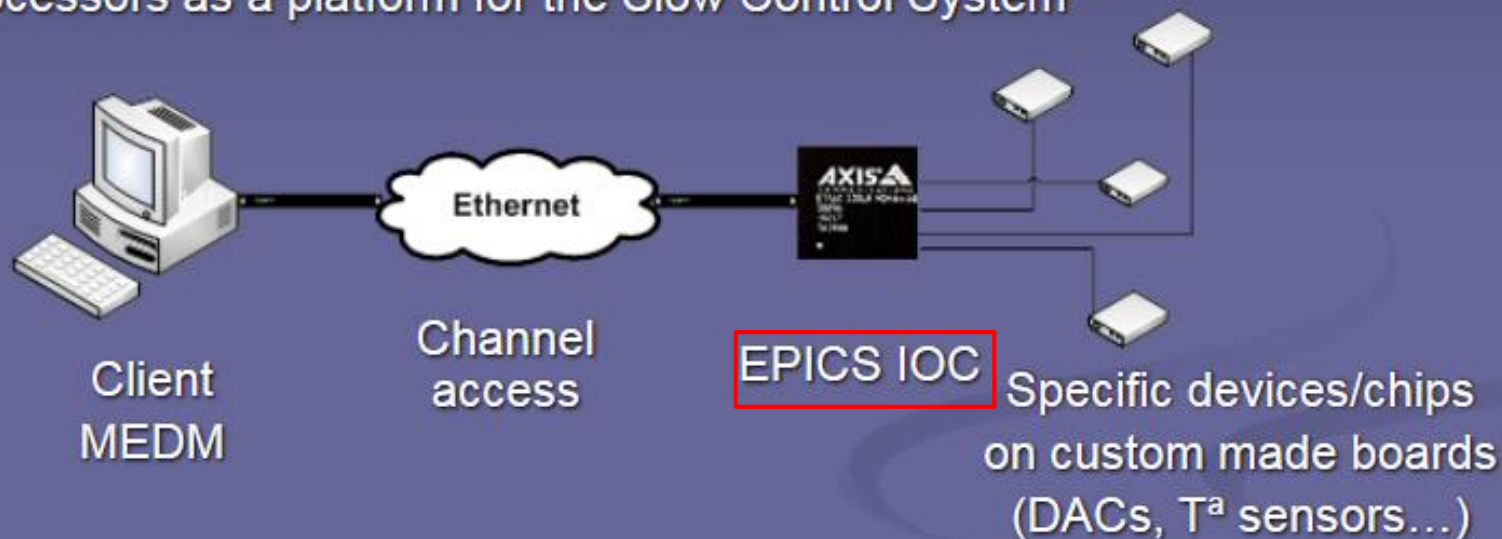
Located at GSI Helmholtzzentrum für Schwerionenforschung GmbH facility, Darmstadt (Germany)



- **Detection of electron-positron pairs** produced in relativistic hadron-nucleus and nucleus-nucleus collisions with the goal of **studying vector meson properties** in nuclear matter, both normal and hot and compressed.
- Consists of several subdetectors for:
 - Triggering
 - Tracking
 - Momentum reconstruction
 - Particle identification

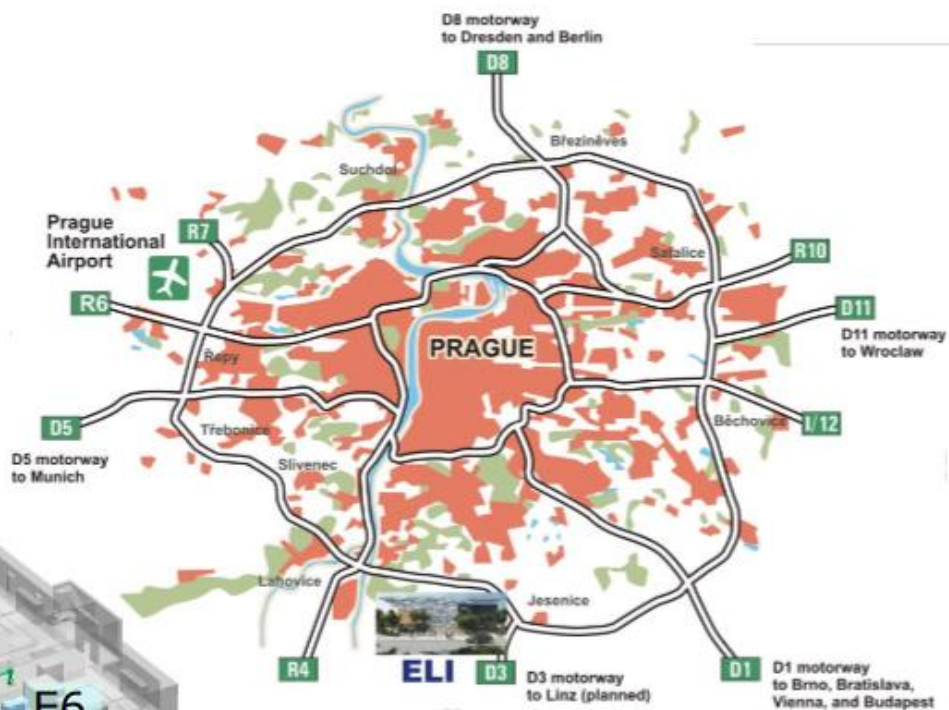
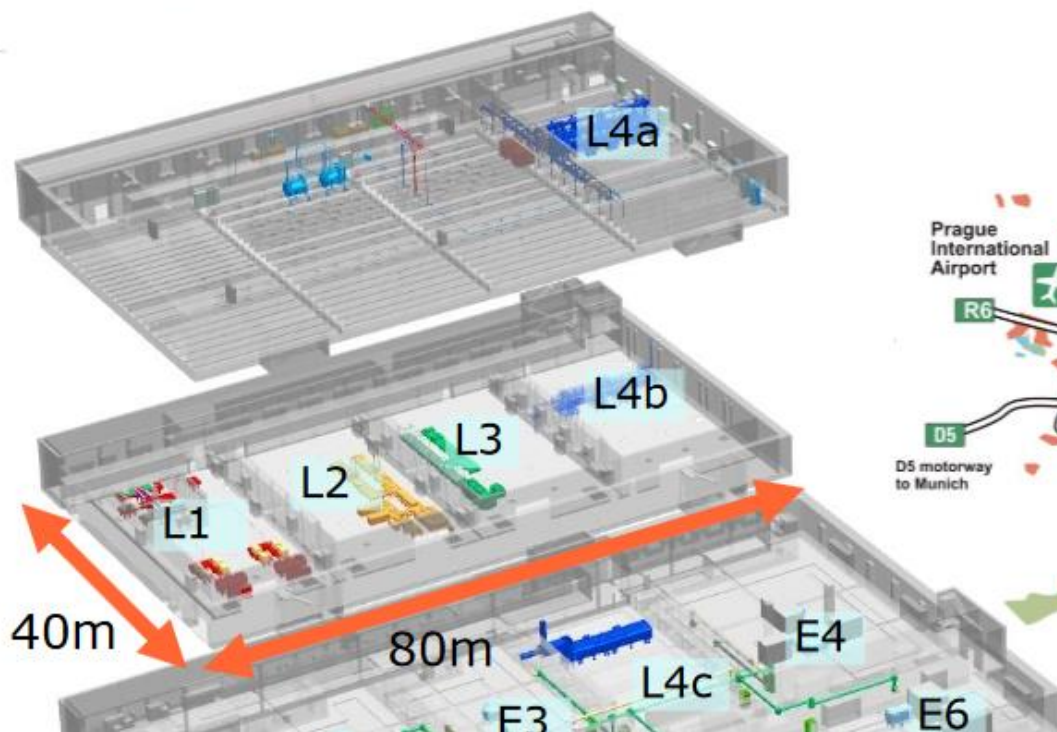
CUSTOM HW

- The SC system for the custom hardware uses a system-on-chip processors as a platform for the Slow Control System



- EPICS input output controllers run in AXIS ETRAX100LX chip processors
- Embedded LINUX-Cris kernel
- Possibility of designing distributed architectures with custom hardware

ELI Beamlines Facility in Prague



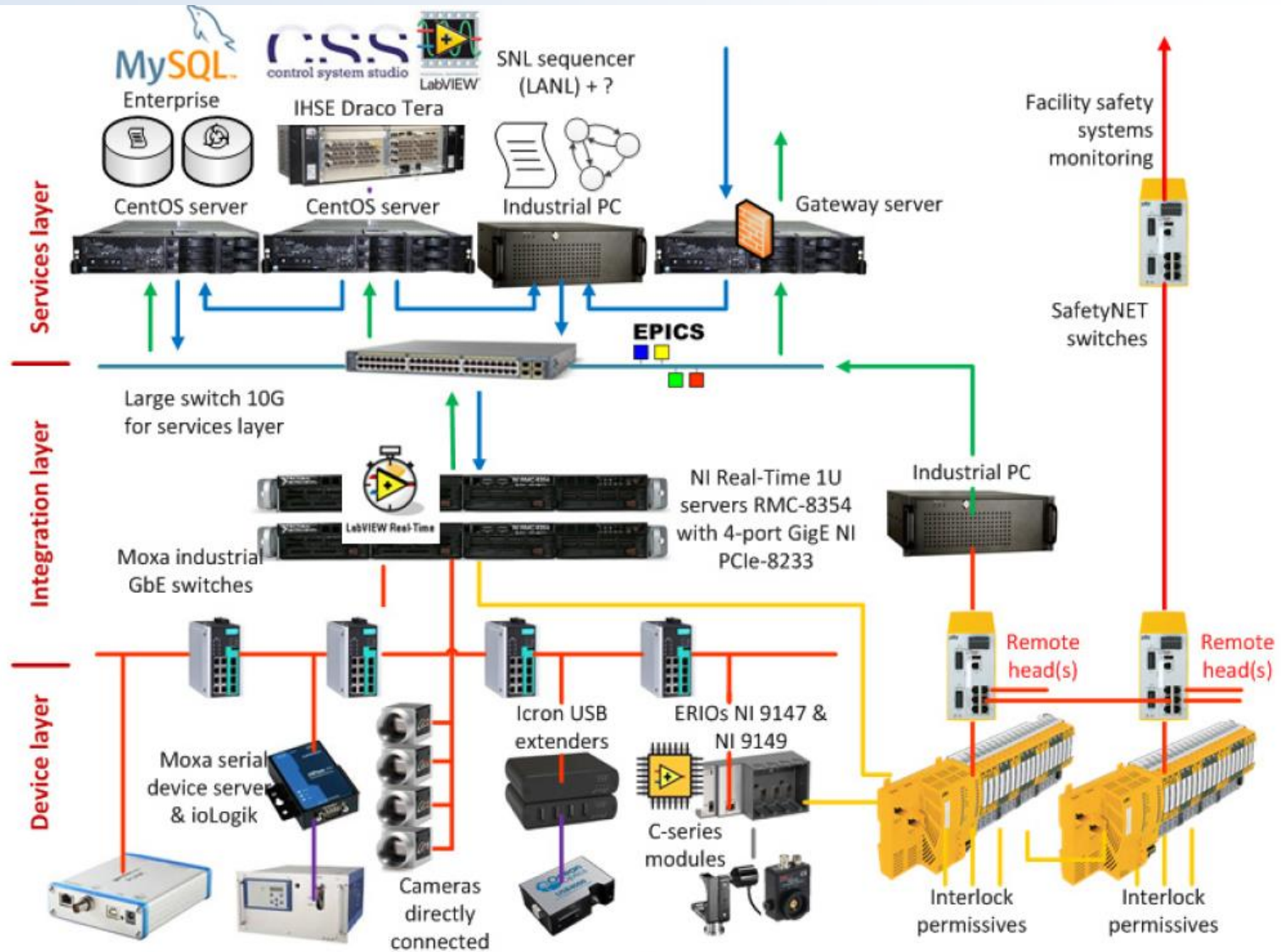


Figure 1: Control system architecture for the L1 laser – implementation view.

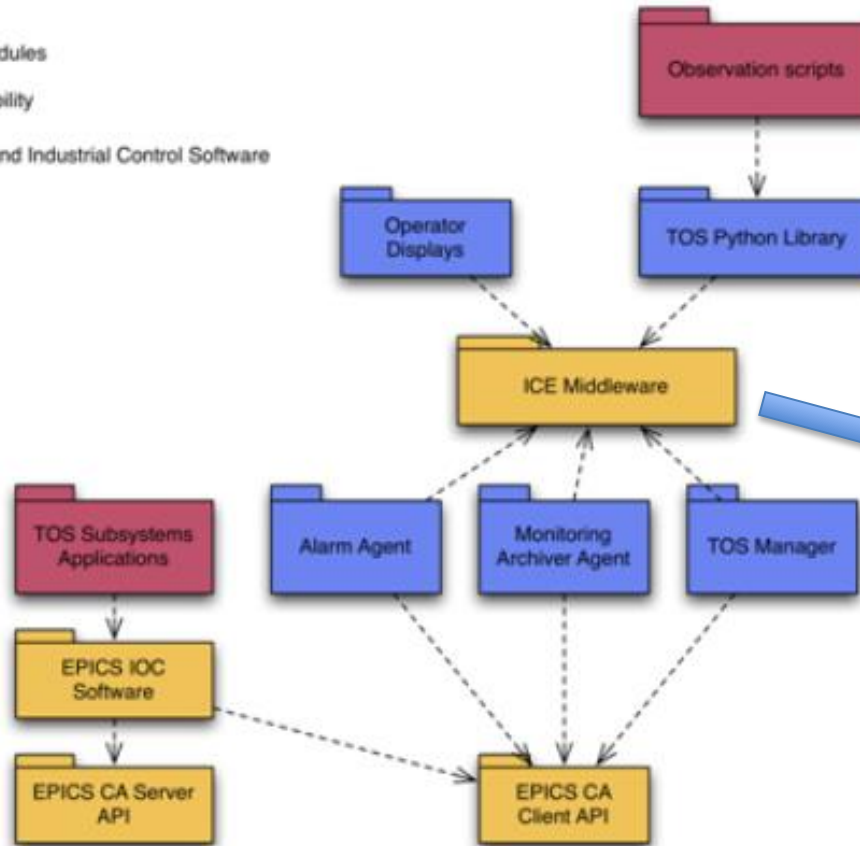


SKA (ASKAP)



- Open Source Modules
- Shared-development Modules
- Computing IPT responsibility

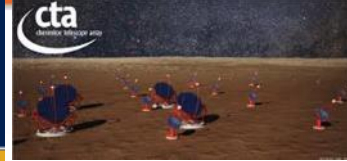
EPICS: Experimental Physics and Industrial Control Software
IOC: Input/Output Controller
CA: Channel Access



Internet Communications Engine



OPC UA – Device level abstraction



Application layer – ACS framework

ACS integrated **OPC UA client interface**

OPC UA (common abstract interface)

Labview



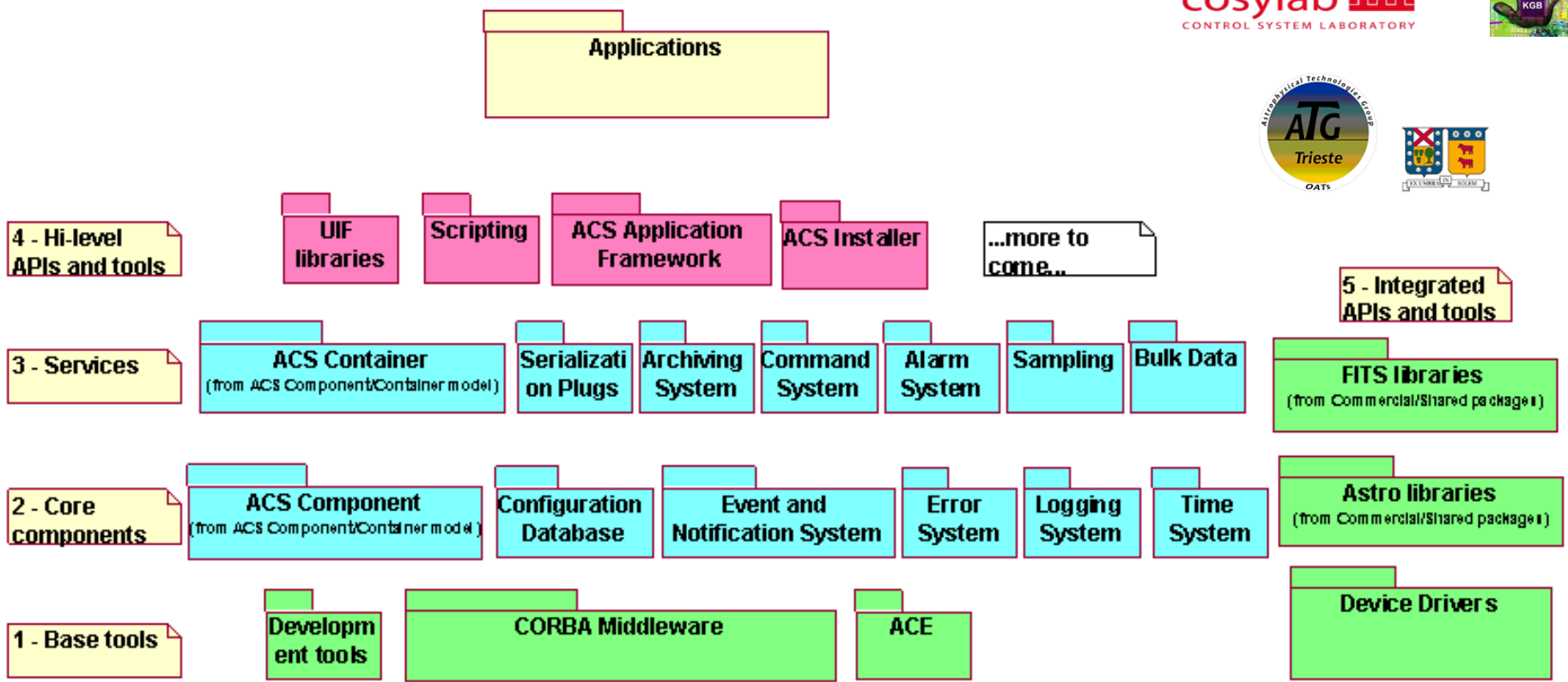
Drive PLC

Camera
Active Mirror Control
CCD cameras
Weather station
High Voltage System
Slow Control
...

CAN Bus

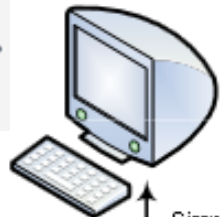
Special hardware

ALMA Common Software





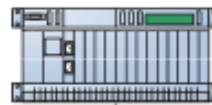
LabVIEW GUI



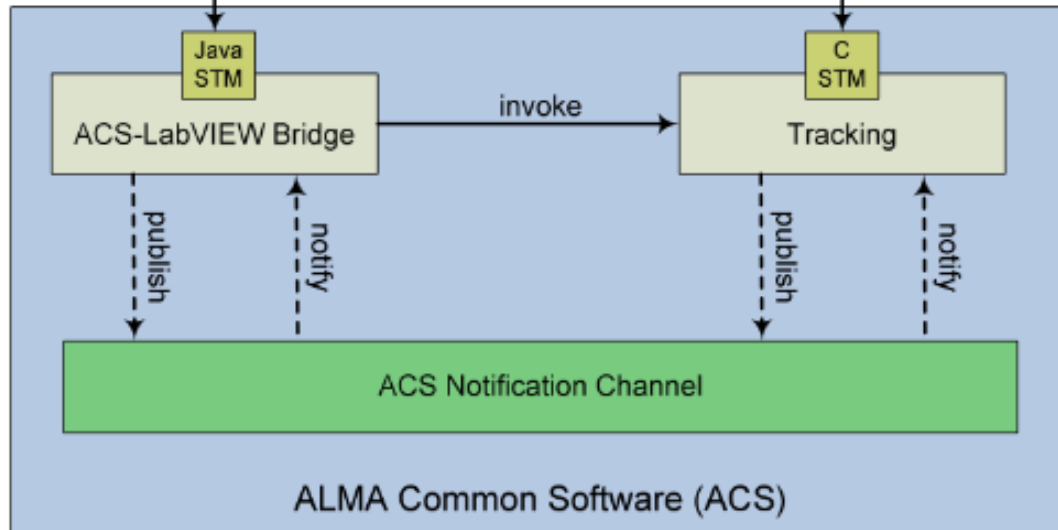
Simple TCP/IP Messaging (STM)

cRIO 9014 with:

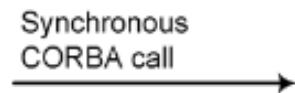
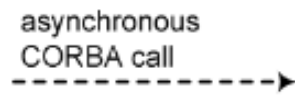
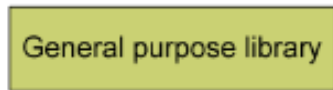
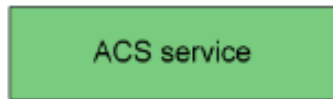
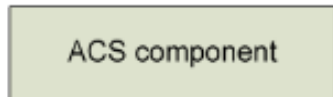
- NI 9505 DC brushed Servo Drive with Encoder
- NI 9425 32-channel Digital Input Module
- NI 9477 32-channel Digital Output Module



Simple TCP/IP Messaging (STM)

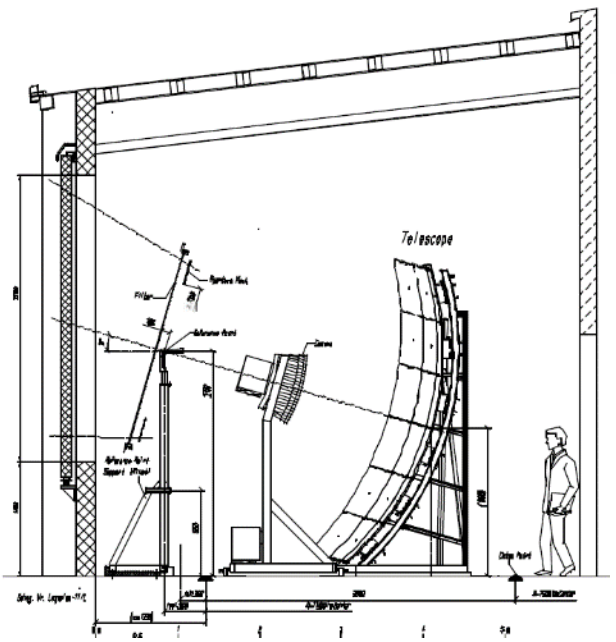
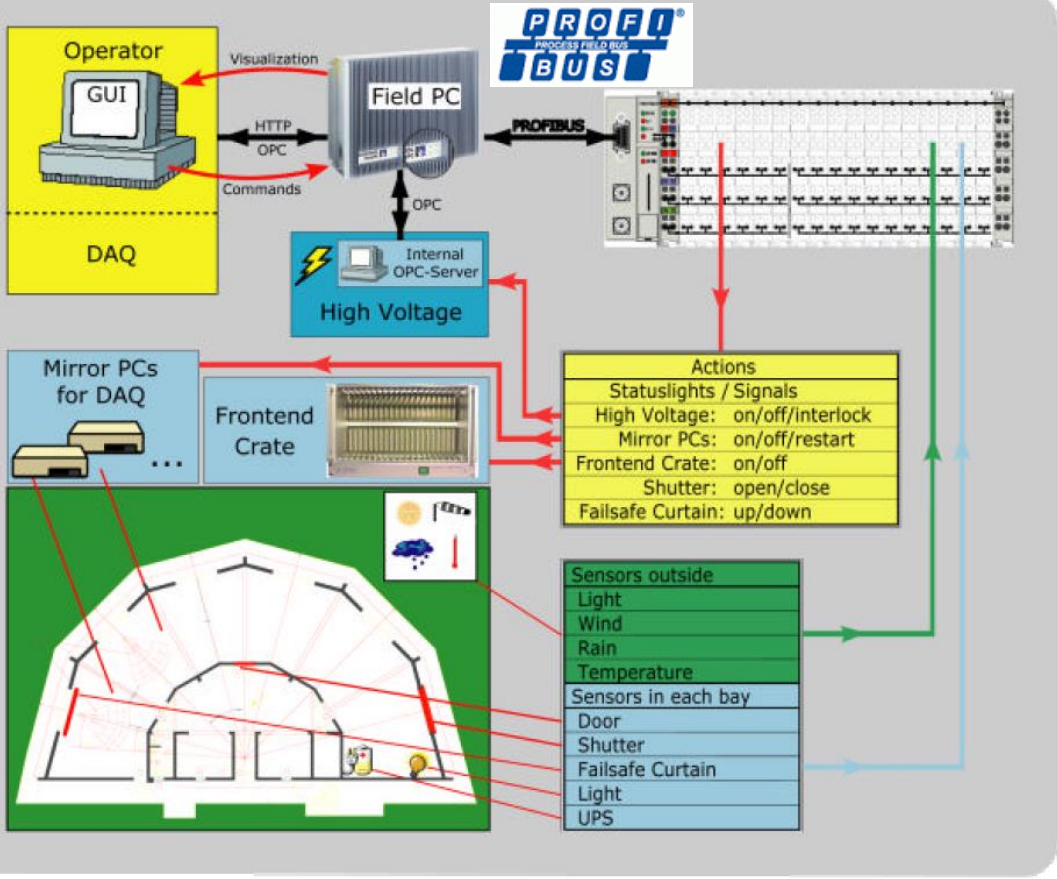


Legend

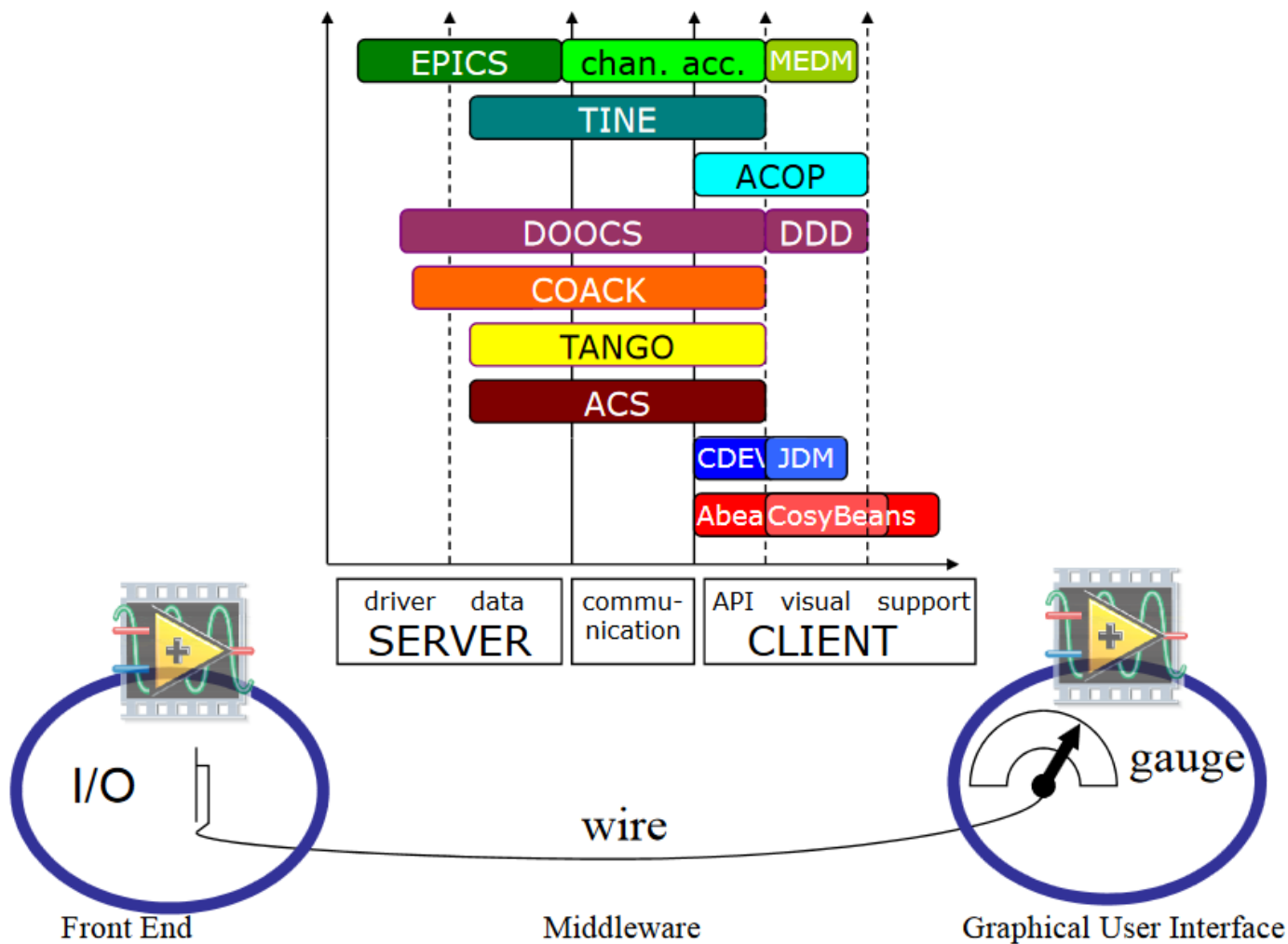


TOS Technologies: Evaluation of control software frameworks – cont.

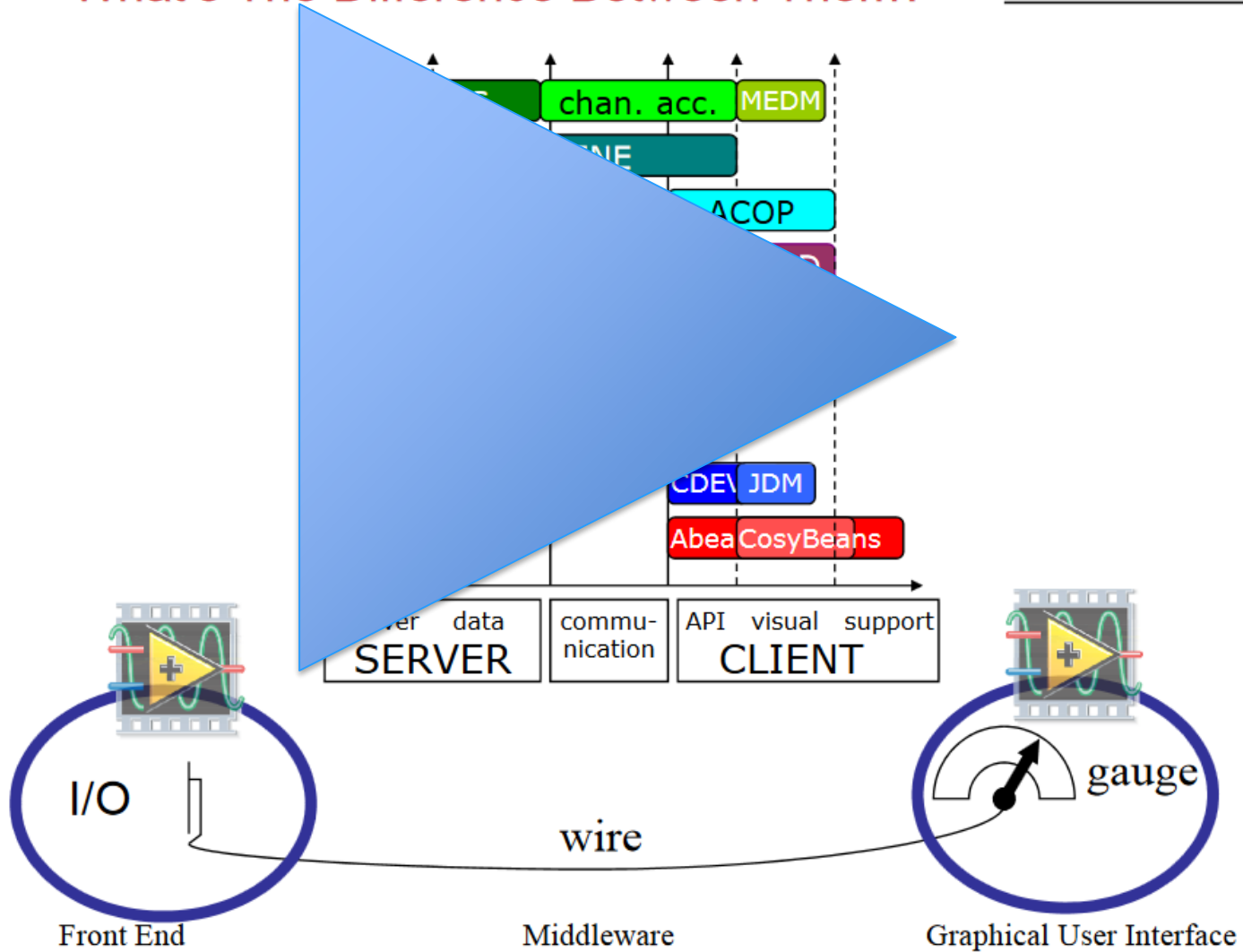
	PVSS-II	EPICS	ACS	TANGO
Developed by	ETM (Siemens)	ANL, LANL	ESO	ESRF, SOLEIL, ELETTRA, ALBA
Released	1995	1990	2000	2000
Number of projects	~ 100	~ 100	7	6
Platforms	Linux, Windows, Solaris	Windows, Linux, MacOS, Solaris, vxWorks, RTEMS	Linux, vxWorks, RTAI	Windows, Linux, Solaris
Programming Languages	C/C++, CTRL (scripts)	C/C++ (IOC); Java, Python and other (clients)	C++, Java, Python	C++, Java, Python
Middleware	N/A	Channel Access	CORBA	CORBA
Supported I/O devices	~ Hundreds	300	10 (?)	350
Database	Yes(proprietary)	Yes	Yes(XML)	Yes(MySQL)
GUI Toolkit	Yes	Yes	No	Yes
Logging support	Yes	Yes	Yes	Yes
Archiving Tools	Yes	Yes	No	Yes
Alam Handler	Yes	Yes	Yes	?
Bulk Data Support	No	No	Yes	No
Security	Yes	Yes	No	No (proposed)
Redundancy Support	Yes	No	No	No



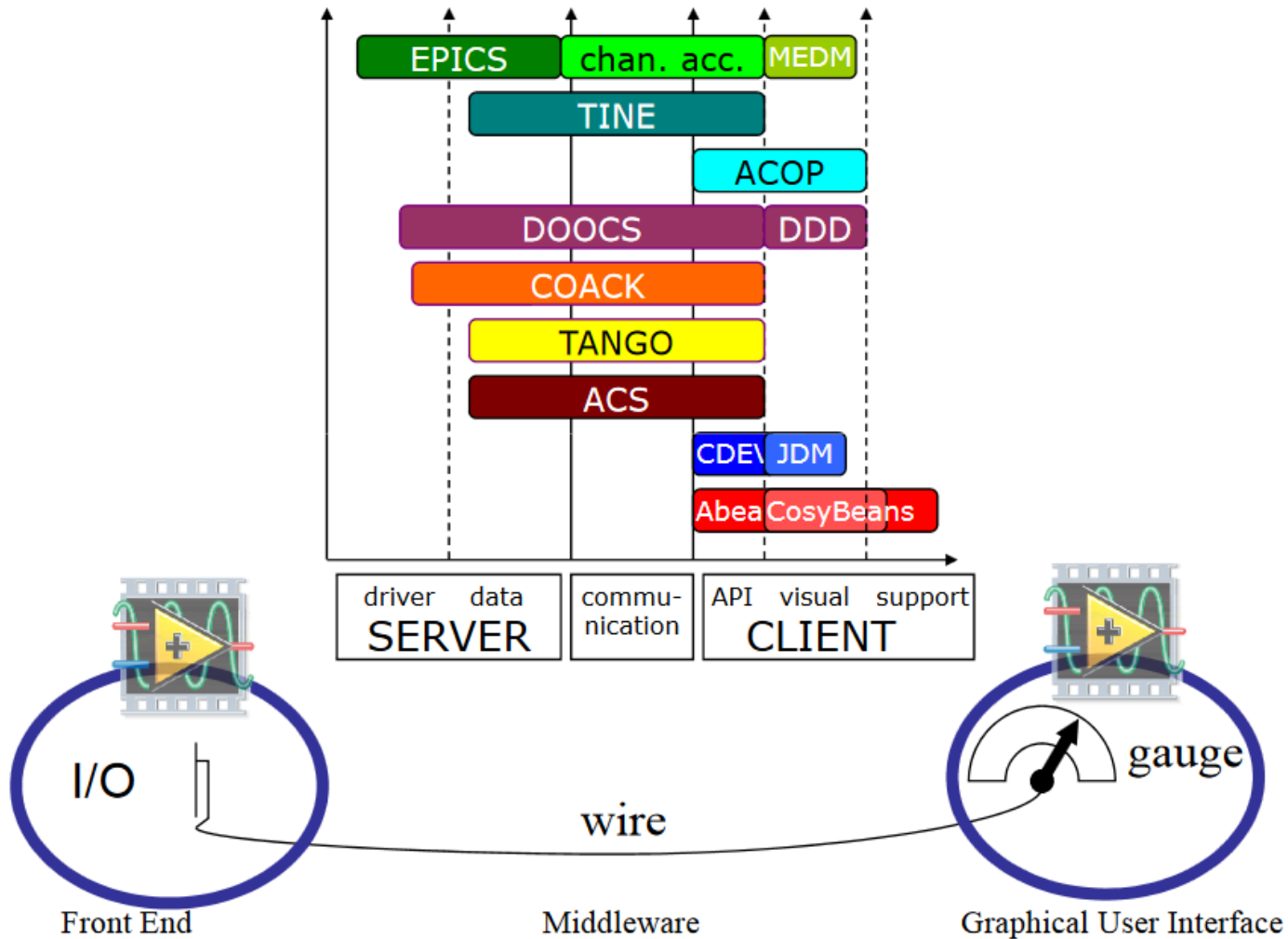
What's The Difference Between Them?



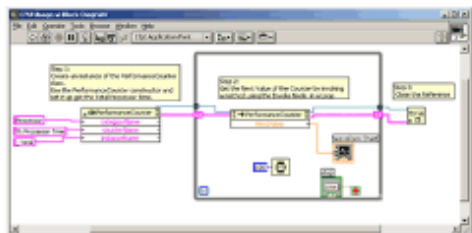
What's The Difference Between Them?



What's The Difference Between Them?



Device Engineers



LabVIEW

I/O Hardware

Control System Programmers

Alarm

Archive

Logging

GUI

CAC

CAC

CAC

CAC

LAN

Channel Access Server

IOC

Database

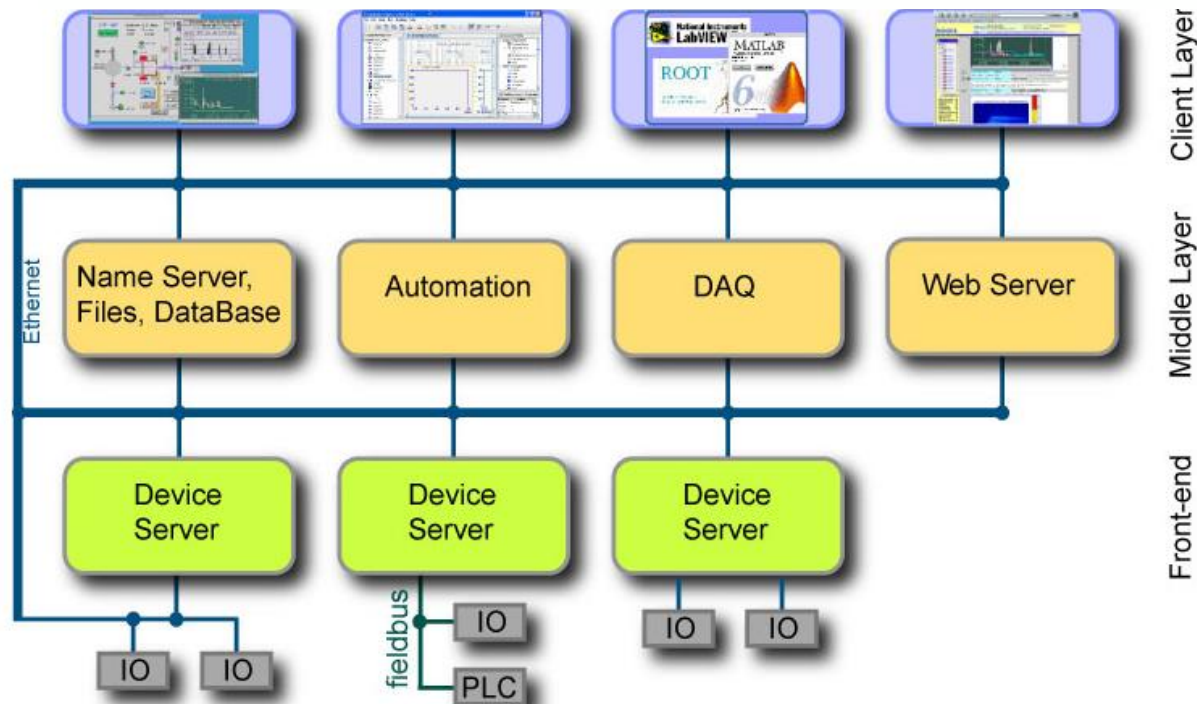
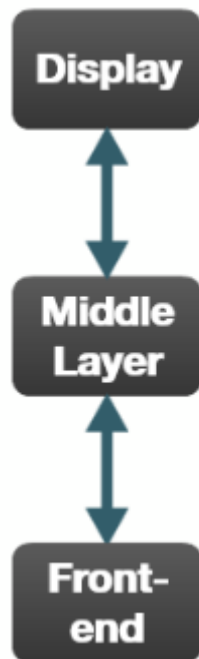
Sequencer

Device Support /Driver

Le future ?



Distributed Object-Oriented Control System



CONCLUSIONS

- *Beaucoup de produits développés pour le pilotage des grands instruments et installations*
- *Avec des caractéristiques similaires et/ou complémentaires*
- *LabVIEW y trouve toute sa place en fonction du besoin et de l'architecture*
- *Il est possible de trouver une solution pour chacun des besoins et il y a de moins en moins de solution "custom"*
- *Pas de solution universelle, mais est-ce souhaitable ?*

- *Les produits actuels sont tous en cours d'évolution pour s'adapter au future et de nouvelles solutions commencent à arriver.*