EPICS and EPICS@GSI

Peter Zumbruch

Experiment control systems group GSI

(KS/EE)

What is EPICS?

… **short answer**:

*EPICS: **E**xperimental **P**hysics and **I**ndustrial **C**ontrol **S**ystem*

… **a bit more elaborate**:

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 particle accelerators, telescopes and other large scientific experiments. (From the EPICS Home Page: http://www.aps.anl.gov/epics/)

… ***striking*** - is three things at once:

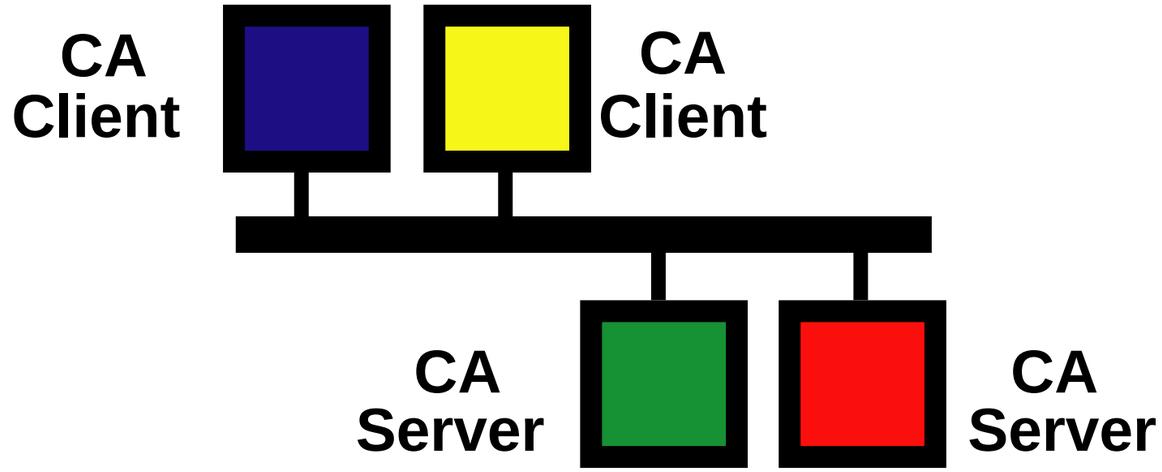
- A ***collaboration*** of major scientific laboratories and industry (> 100)
  - A world wide collaboration that shares designs, software tools and expertise for implementing large-scale control systems
- An ***architecture*** for building scalable control systems
  - A client/server model with an efficient communication protocol (Channel Access) for passing data
  - The entire set of Process Variables establish a distributed Real-time Database of machine status, information and control parameters
- A ***Software Toolkit*** of Open Source code and documentation
  - A collection of software tools collaboratively developed which can be integrated to provide a comprehensive and scalable control system

What is EPICS? (*Getting Started with EPICS: Introductory Session I*)

A Control System Architecture

Network-based “client/server” model (hence the EPICS logo)

EPICS

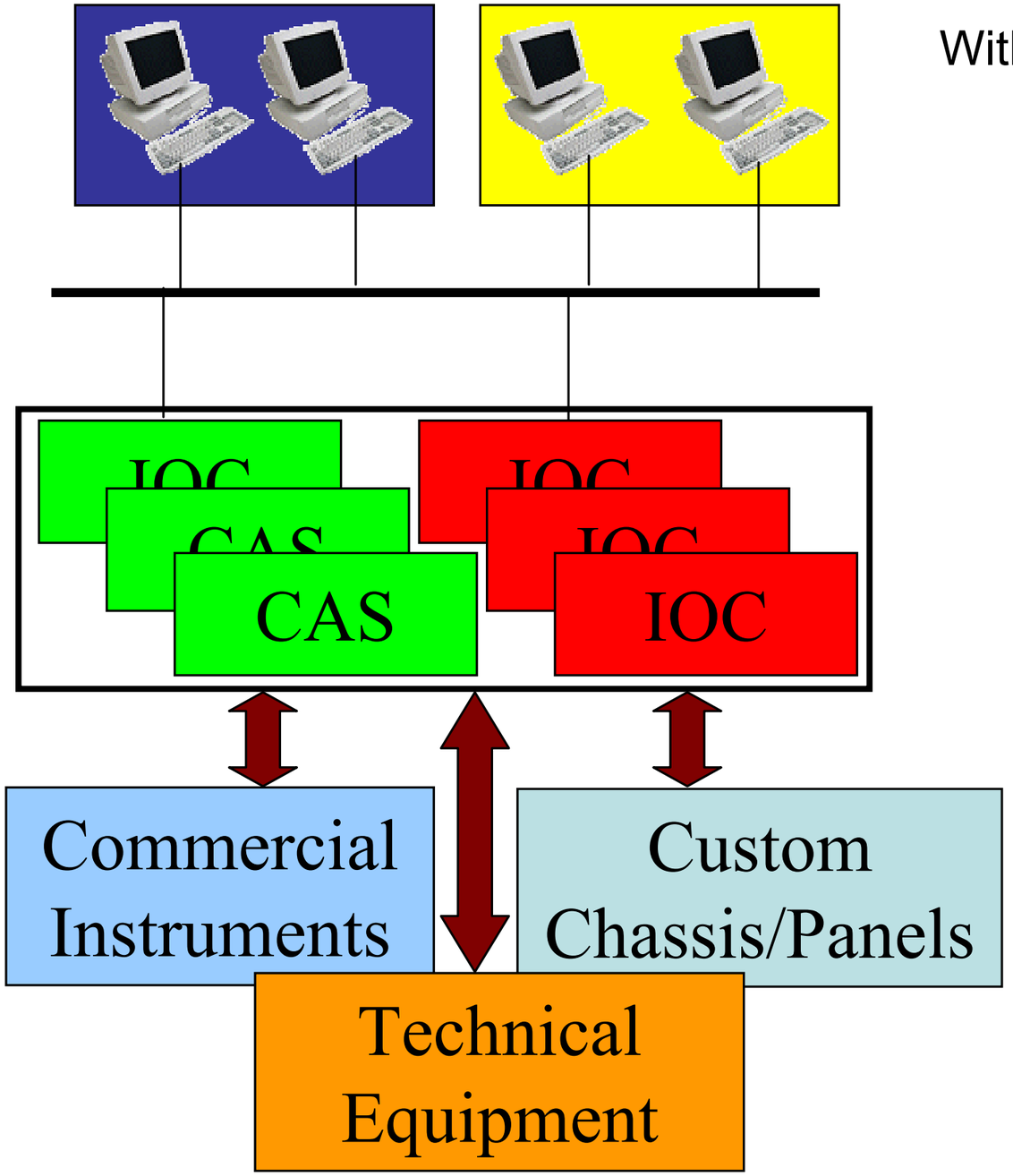


For EPICS, *client* and *server* speak of their Channel Access role

i.e. Channel Access Client & Channel Access Server

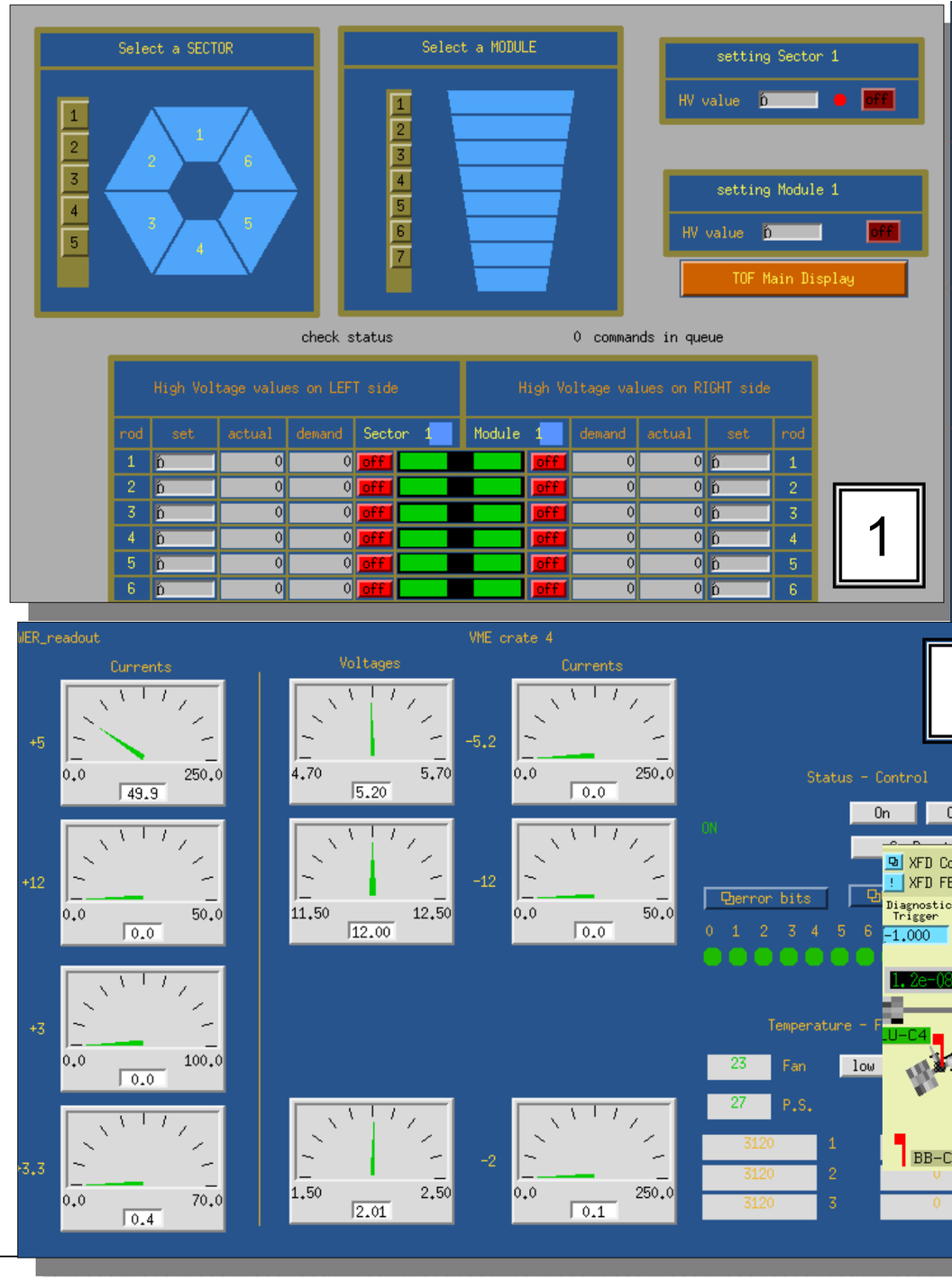
Typical Realizations of an EPICS System

(Getting Started with EPICS: Introductory Session I)

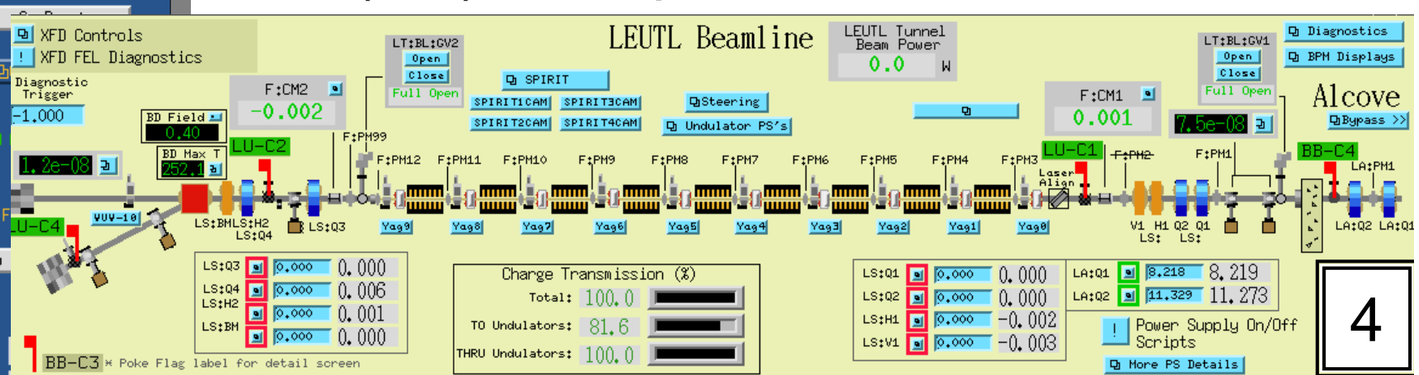


With Release 3.14, the operating system limitations for iocCore have been removed.

Displays and Controls



(1-3) Examples from HADES



interplay: CSS

Control System Studio

Eclipse and Java based

Integrated Development Environment

Developed at DESY

CSS
control system studio

From the first principle independent of EPICS

… but via DAL (cosylab: DATA Access Layer) access too many different control systems

- EPICS, TINE, (GSI beam controls,) TANGO, …
- replaces (soon) the Motif based, old EPICS GUIs
- good collaboration with developers
- css.desy.de

BUILT ON eclipse

So What Does it Do?

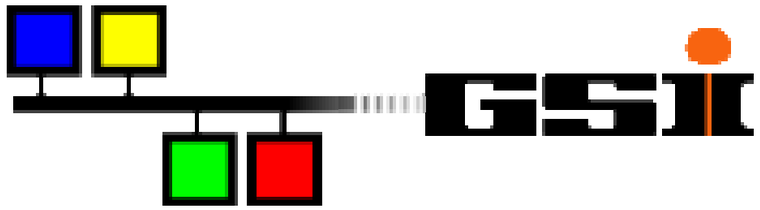
- EPICS tools are available to accomplish almost any typical Distributed Control System (DCS) functionality, such as:
  - Remote Control & Monitoring of Technical Equipment
  - Data Conversion/Filtering
  - Access Security
  - Equipment Operation Constraints
  - Alarm Detection/Reporting/Logging
  - Data Trending/Archiving/Retrieval/Plotting
  - Automatic Sequencing
  - Mode & Facility Configuration Control (save/restore)
  - Modeling/Simulation
  - Data Acquisition
  - Data Analysis

Ten really neat things about EPICS

(Getting Started with EPICS: Introductory Session I)

- It’s free
- It’s Open Source
- There are lots of users
- All a client needs to know to access data is a PV name
- You can pick the best tools out there …
- … or build your own
- The boring stuff is already done
- There is a lot of expertise available close by
- A good contribution becomes internationally known
- By following a few simple rules, you get a lot for free

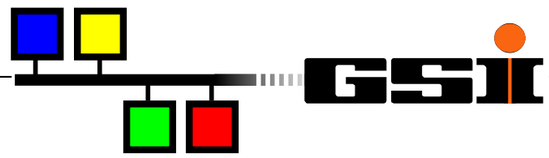
EPICS @ GSI



- Interfacing
  - Technical and Social

- Embedded Target Platforms
  - ETRAX
  - Xilinx' Virtex4/5

http://wiki.gsi.de/Epics



Interface

- Socially (Mentoring / Networking)
  - "Since controls often isn't seen as important as it later comes out not much (man)power is invested into it."
  - Therefore as EPICS@GSI is known/active in several FAIR collaborations, we try to bring control people together to share ideas and work. Or at least learn from each other.
  - Call it Synergy, Networking, Mentoring, Interfacing, ...

Experiments @ FAIR

Experiment	Scientific Area	Research Program	Technical Facility	Members	Institutes
R3B	NUSTAR	Nuclear reactions in inverse kinematics reaction studies with relativistic radioactive ion beams	Large reaction set-up allowing complete kinematics reaction experiments	178	54
HIS DE					
LA					
MA					
ILI					
EX					
AIC					
EL					
NC		site) neutron capture studies			
EXO-pbar	NUSTAR	Measurements of proton-neutron abundance at the nuclear surface of nuclei far off stability	Reaction experiment of very low-energy radioactive ions with antiprotons stored in a Penning trap	20	5
PANDA	QCD	QCD and hadron physics studies with cooled high energy antiproton beams at the HESR	Large state-of-the-art internal target detector system covering almost the full solid angle	344	70
CBM	QCD	Studies of the QCD phase diagram in high-energy nucleus-nucleus collisions	Large state-of-the-art fixed target detector system covering almost the full solid angle	357	63
PAX / ASSIA	QCD	QCD and hadron physics studies with polarized antiproton beams	State-of-the-art collider detector system covering a large solid angle	170/ 85	33 / 12
HEDge-HOB/ WDM	APPA	Investigations of warm and dense bulk matter produced by intense ion and/or laser pulses	Various plasma physics experimental stations	162 / 55	50 / 19
FLAIR	APPA	(Precision) studies with low energy or stopped antiproton ion beams	Various stations including an ultra-low energy electrostatic storage ring, a Penning trap, low energy antiproton target stations	142	54
SPARC	APPA	Atomic physics spectroscopy and collision studies with (stored) high energy ion beams	Various fixed target and in-ring experiments	218	108
BIOMAT	APPA	Applications of ion and antiproton beams in biophysics, biology, materials research and other disciplines	Various multi-purpose target stations	49	28

Experiments @ FAIR

Collaborations showing interest in EPICS

- NuSTAR
- PANDA
- CBM

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		site) neutron capture studies			
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requirements Database (PANDA/CBM)

ProcessVariables

This is the main table. Some of the fields in this table are standardized, and you might have to edit other tables (Subgroups, Parameters, Types, Units etc.), before the desired options show up in the drop down

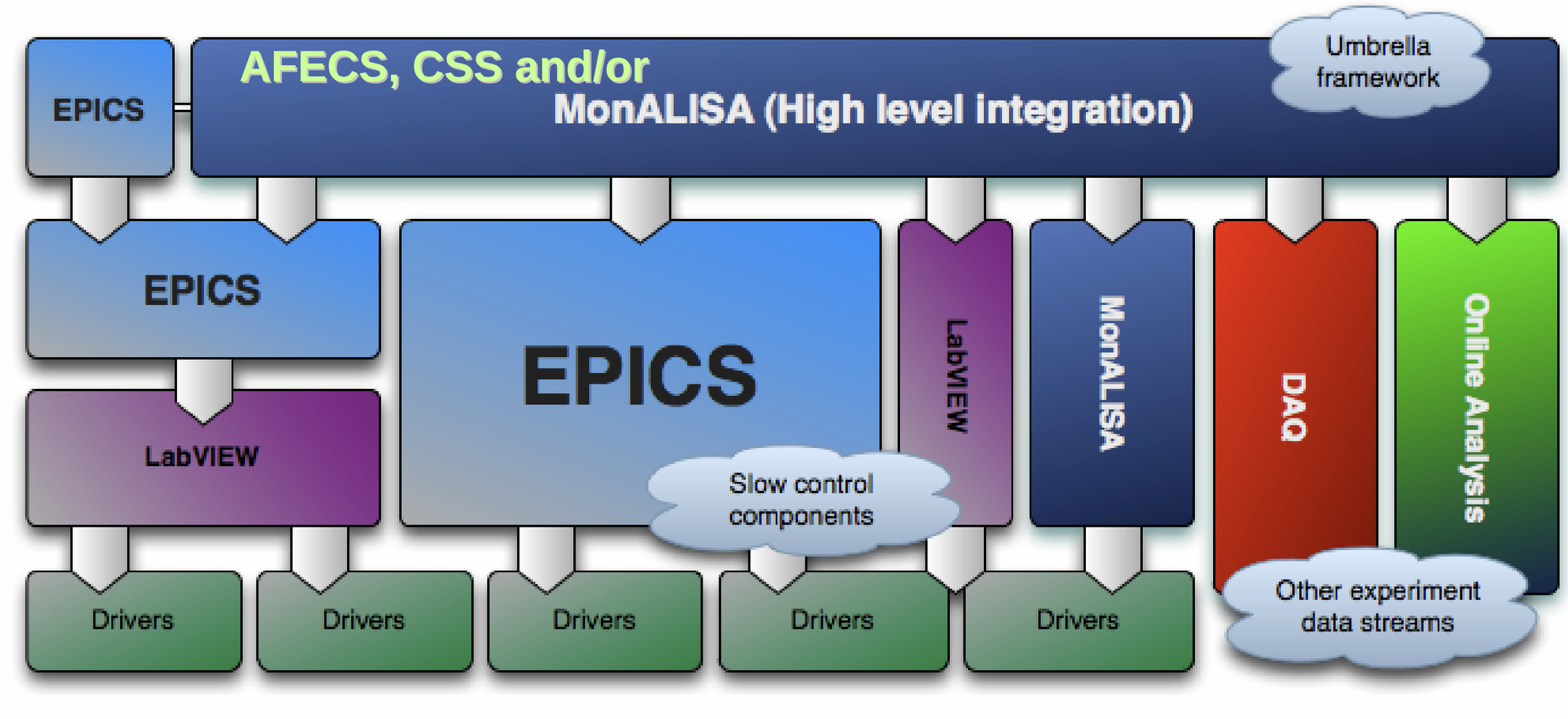
+ Table Description | Hints | Hide green columns | Stats

Tables: Contacts | Hardv

Subgroup	Parameter	Unit	Type	Channels	Nominal value	Accuracy	Range min	Range max	Warn min	Warn max	Alarm min	Alarm max	Update rate	Is monitored	Is controlled	Gen interlock	Description	Contact	H
Solenoid Magnet	LV	V	Continuous	1	20								1	yes	yes	no	Voltage in supercond. coil	Inti Lehmann	c
Solenoid Magnet	T_F	K	Continuous	5	77									yes	yes	yes	Nitrogen circuit	Inti Lehmann	c
Solenoid Magnet	T_F	K	Continuous	8	4.3									yes	yes	yes	Liquid He circuit	Inti Lehmann	c
Solenoid Magnet	I_c	A	Continuous	1	2000								1	yes	yes	no	Current in supercon. coil	Inti Lehmann	c
Endcap DIRC	LV	V	Continuous	128	5		4	6	4.9	5.1	4.8	5.2	0.1	yes	yes	no	Readout LV supply	Matthias Hoek	c
Endcap DIRC	Humidity	%	Continuous	1	0		0	100	0	5	0.2	10	0.016	yes	no	no	Humidity control	Matthias Hoek	u
Endcap DIRC	N_Flow	l/s	Continuous	1	1		0	1	0	0			0.1	yes	yes	no	Dry Nitrogen Flow	Matthias Hoek	u
Endcap DIRC	HV	V	Continuous	128	1		0	1	0	0	2300	2700	1	yes	yes	yes	PMT HV supply	Matthias Hoek	
Endcap DIRC	T_R	℃	Continuous	128	20		0	100	10	40	0	50	1	yes	no	no	Readout temperature	Matthias Hoek	c
Dipole Magnet	T_R	℃	Continuous	4	35		0	60	15	40	10	50	1	yes	no	no	Dipole coil temperature	Guangliang Yang	c
Dipole Magnet	P_F	kPa	Continuous	1	400		200	800	300	600	200	800	1	yes	no	no	Colling water pressure	Guangliang Yang	u
Dipole Magnet	T_F	℃	Continuous	1	25		0	50	20	30	15	35	1	yes	no	no	Cooling water temprature	Guangliang Yang	u
Dipole Magnet	H_2O_Flow	l/s	Continuous	4	4		2	6	3.5	5	3	6	1	yes	no	no	Cooling water flow	Guangliang Yang	u
Dipole Magnet	I_c	A	Continuous	1	1500		100	1800	1499.98	1500.02	1499.95	1500.05	0.1	yes	yes	yes	Dipole coil current	Guangliang Yang	c

http://nuclear.gla.ac.uk/DCS/interactiveTable.php?name=ProcessVariables

DCS (PANDA)



AFECS for FAIR Workshop: http://www.doodle.com/participation.html?pollId=ef8dwz8weba4wqma

Technical interfacing of EPICS

Idea: "*Let EPICS talk to other systems*"

- Many Interfaces already available for EPICS,
but DIM was missing

→ EPICS – DIM Interface

What is DIM?

"DIM is a communication system for distributed / mixed environments. It provides a network transparent inter-process communication layer."

- **Protocol**
- Distributed Information Management System
- Originally built for DELPHI
- http://dim.web.cern.ch/dim/

Some Properties:

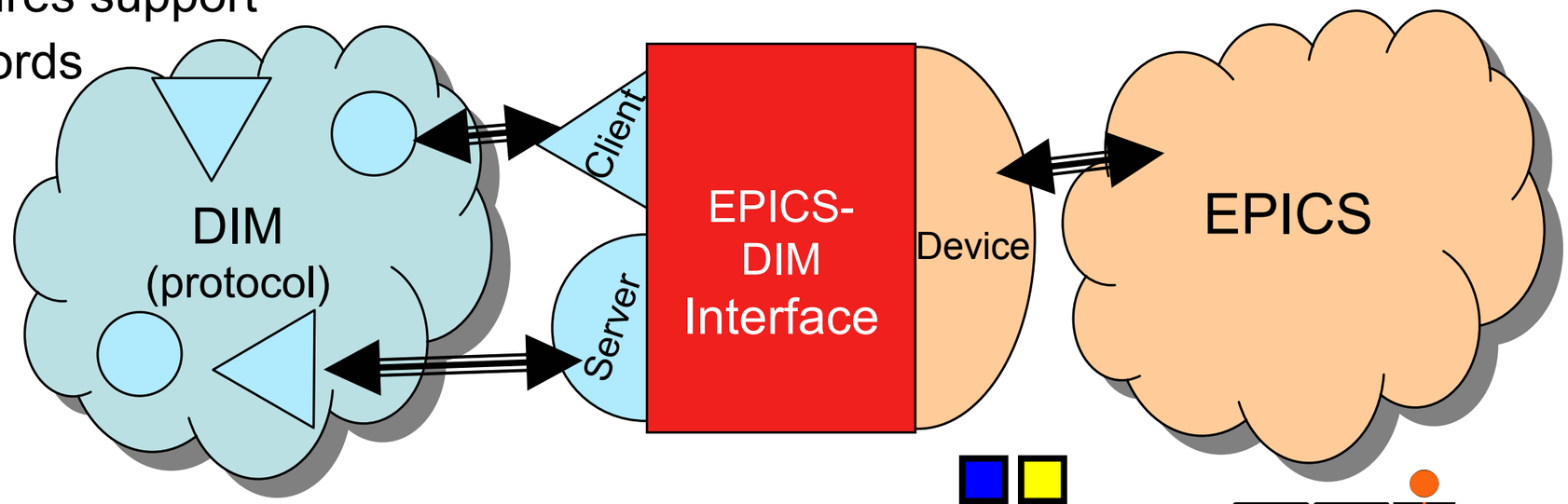
- Small / Tiny
- Many platforms
- No (not yet) inherent access security
- No logic
- Dynamic

- name based publisher/subscriber mechanism for services and commands

Used as network protocol for *CS Control system (GSI) and DABC Gateway to LabVIEW*

EPICS DIM Interface

- Implementation as "*device support module*"
- Running
  - DIM SERVER
    - Providing read/write access to EPICS variables
  - DIM CLIENT
    - Interfacing DIM services and commands for single variables to EPICS process variables
  - Successfully used 5 weeks continous HADES beam time
- On demand
  - String transport mode (DIM provides strings converted by the Interface to single data types, easier to handle by EPICS)
  - Array and structures support
  - More EPICS records



DAL DIM Interface

Outlook: (Martin Feldmann, GSI)

DAL – Data Access Layer

- Data Abstraction Framework to abstract connections to several control systems (TINE, TANGO, EPICS, ...) in order to access them all the same way.
- Used in CSS Control System Studio (css.desy.de)
- Plan: DAL DIM Interface

connecting to LabVIEW

http://wiki.gsi.de/Epics/ConnectingLabVIEWandEPICS

LabVIEW DIM Interface ⇔ EPICS - DIM Interface

LabVIEW Data Logging and Supervisory Control Module, NI

LabVIEW Shared Memory Interface to EPICS IOC by SNS

LabVIEW ActiveX CA by Kay Uwe Kasimir, ORNL

EPICS embedded

- Project:

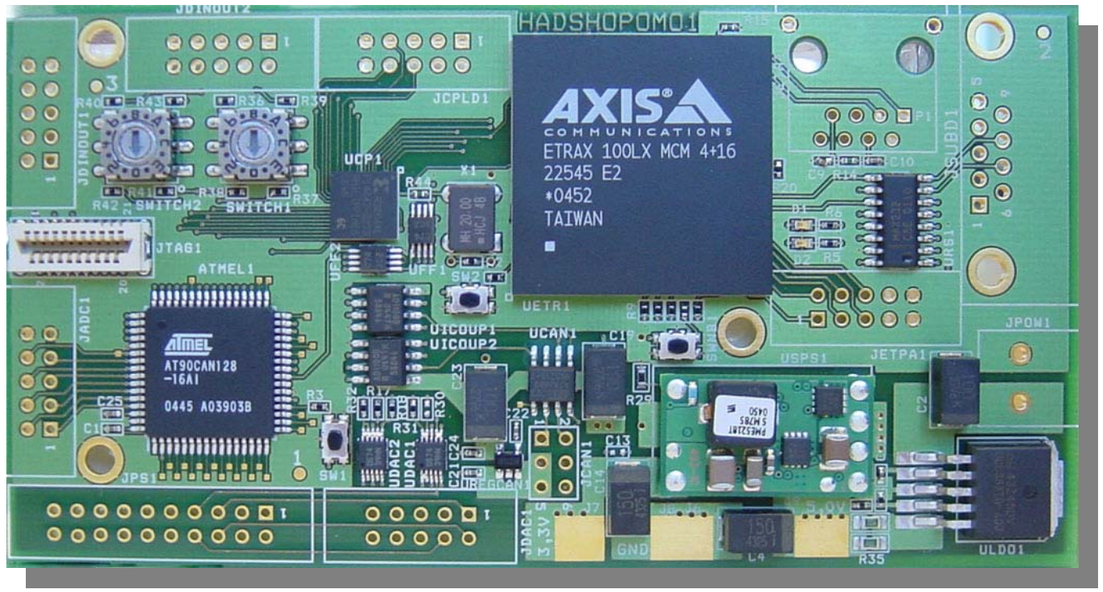
  EPICS running on embedded systems

- Aiming at two architectures:
  - ETRAX based CRIS architecture
    - HADControl (aka: **HAD**ES **SHO**WER **PO**WER **MO**NITOR)
    - TRBv2
    - HADES, CBM, Panda
  - Outlook:
    - Xilinx FGPA: Virtex 4/5, Spartan
      - CBM

Platform: ETRAX 100LX MCM / FS by AXIS

For HADES GSI's Experimental Digital Electronic group (M.Traxler) has developed:

- HADControl (HADSHOPOMO (HADES SHOWER POWER MONITOR))



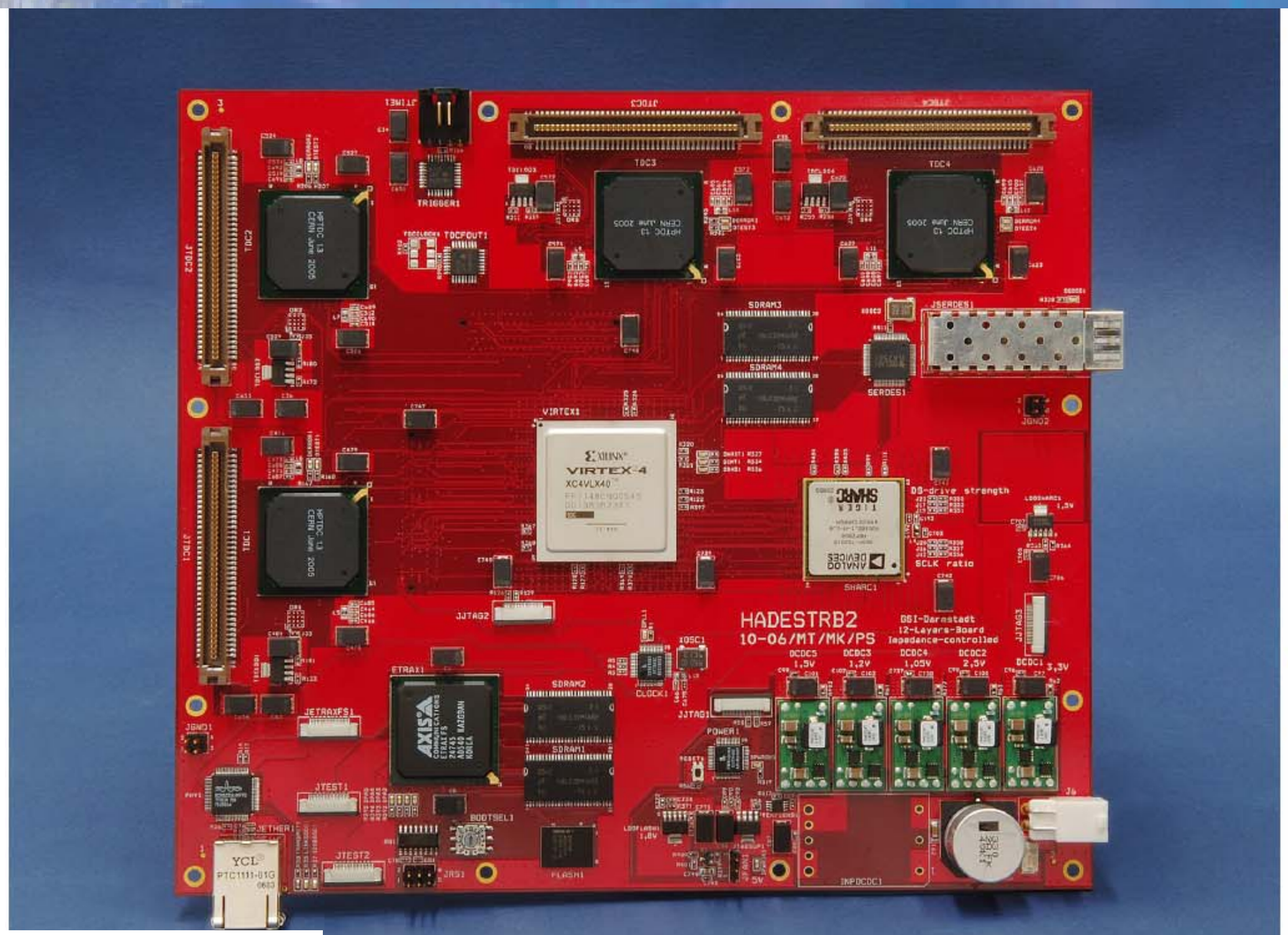
"Multi-purpose control/monitor device developed for HADES […] is based on the ETRAX 100LX MCM4+16 and runs the "Experimental Physics and Industrial Control System, EPICS".

http://developer.axis.com/showroom

  - some implementations:
    - single wire bus temperature measurement for HADES
    - Monitor system for Driftchamber pressure

- HADES TRB - Trigger Board, DAQ and Slow Control (ETRAX)

TRBv2



- successor of TRBv1, which is used in the experiment
- larger FPGA
- faster CPU (x3)
- Tiger-Sharc DSP
- 2 GBit/s optical link for trigger and data
- Add-on connector
- TRBv1 functionality given

Current Applications:

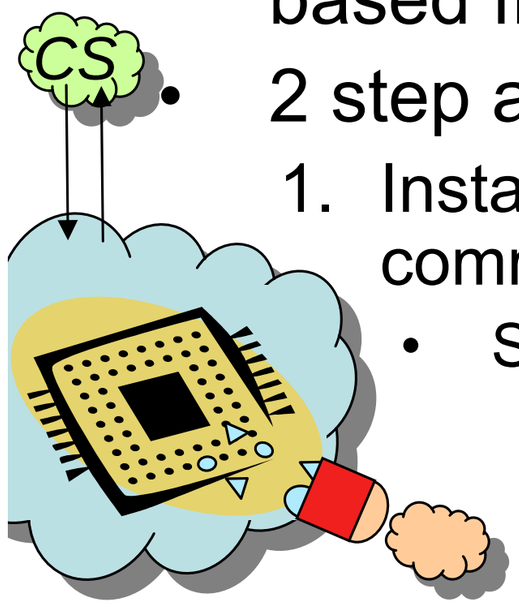
HADES complete DAQ upgrade, PET Readout Coimbra, PANDA, KVI,…

2007-06-04 Michael Traxler, GSI

http://www-linux.gsi.de/~traxler/GSIScientificReport2006_TRB/TRBv2_2006.pdf

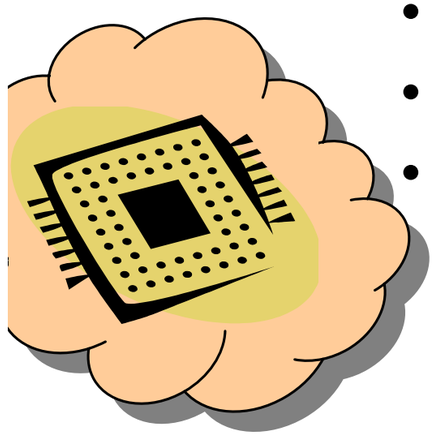
Embedded EPICS on ETRAX

- install embedded Linux on ETRAX chip CPU (axis.com) based front-end systems
- 2 step approach:



1. Install DIM on ETRAX and use EPICS-DIM Interface to communicate via network with external EPICS clients or IOCs
   - Suitable for development:
     - DIM protocol also accessible via other controls software, i.e. LabVIEW, or *CS,* etc.
     - But locally no (EPICS) logic (database, (fast) sequencing, alarming) provided

2. Install EPICS Embedded on ETRAX
   - Provides all features of EPICS
   - Local fast EPICS based logic, network independent
   - By „turning the direction of the interface“ users may still see a DIM device, mimicked by EPICS using the EPICS – DIM interface



Summary Outlook

EPICS is
…an grown-up, mature, portable control system architecture,
…a world wide active and very responsive collaboration and
…a rich collection of Open Source code and documentation

which allows to build up a large scale,
scalable control system.

EPICS at GSI

… can provide knowledge and information to build up FAIR experiment control systems or parts of it

… offers multi purpose tools which may be used

… projects/activities:

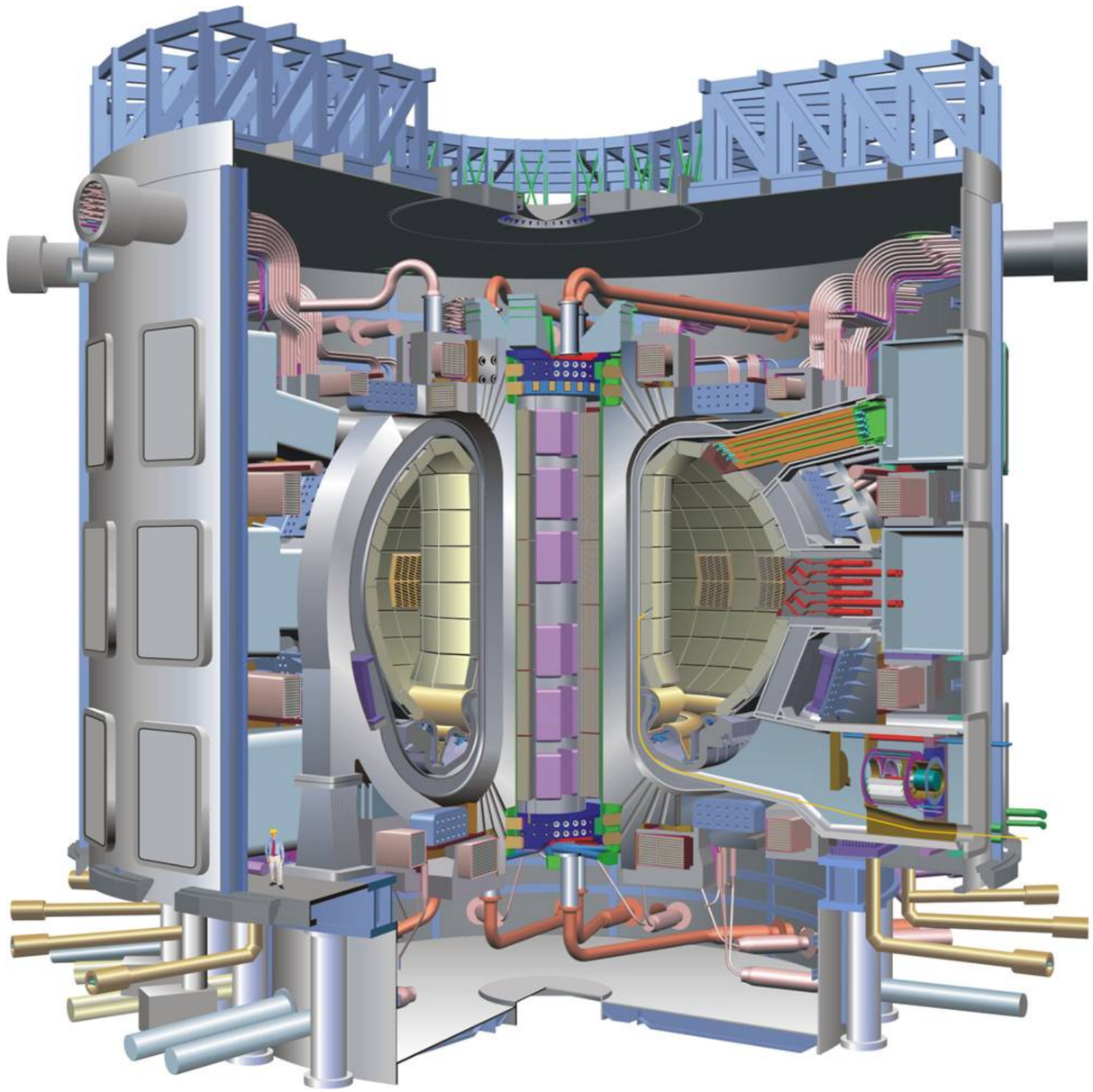
- Interfacing/Networking
- EPICS embedded (cris architecture (ETRAX), Xilinx FPGA)
- In future/today: CSS (Control System Suite):
  - IDE based on Eclipse

Summary … on GSI activities

http://wiki.gsi.de/Epics

- Platform: Axis' ETRAX
  - DIM running
  - **EPICS on ETRAX' cris architecture is done!**
  - Connection to EPICS via '2 step approach'
    - ETRAX-DIM – EPICS-DIM-Interface – EPICS
    - also suitable for other architectures (i.e. XYZ-DIM – EPICS)
  - EPICS-DIM Interface
- Platform: Outlook Xilinx' Virtex4/5
  - CBM

latest NEWS: ITER will use EPICS



To: "tech-talk@aps.anl.gov" <tech-talk@aps.anl.gov>
Subject: ITER will use EPICS
From: Di Maio Franck <Franck.DiMaio@iter.org>
Date: Tue, 10 Feb 2009 08:35:52 +0100

Dear all

We would like to share with you the following decision taken by the group in charge of the controls for ITER (www.iter.org).

The CODAC group initiated a number of actions in the first half of 2008 in order to select a software environment as a part of moving from the conceptual design to an engineering design of CODAC.

The conclusion of all these activities is that ITER, **being an experimental facility with a very long timeline**, **is better suited using an open source solution as compared to a commercial solution.** Further, the reports conclude that technically, any of the candidate open-source solutions would work. However, due to market share and proven record the preferred solution would be EPICS.

As a consequence, the CODAC group announces that EPICS will be used as the baseline for the software environment for the ITER control system within the scope of PCDH (Plant Control Design Handbook).

Anders Wallander, 01-Feb-2009

Notes:

- CODAC means COntrol, Data Access & Communications.
- The Plant Control Design Handbook (PCDH) is a contractual document that specifies the ITER standards for the instrumentation and control of the ITER plant systems.

ITER parties are: China, Europe, India, Japan, Korea, Russia and USA.

So, it means new users (& hopefully contributors) from these regions.

Best regards,

Franck

Franck DI MAIO
ITER Organization
CHD Department / CODAC & IT Division

http://wiki.gsi.de/Epics

Thank you for your attention.

For more information …

Have a look at the extra slides.

Vocabulary

(Getting Started with EPICS: Introductory Session I)

- EPICS
  - Experimental Physics and Industrial Control System
- Channel Access
  - The communication protocol used by EPICS
- Process Variable
  - A piece of named data referred to by its PV name
  - The primary object of the Channel Access Protocol
- Channel
  - A synonym for Process Variable
- Channel Access Server
  - Software that provides access to a Process Variable using the Channel Access Protocol
- Channel Access Client
  - Software that requests access to a Process Variable using the Channel Access Protocol

Vocabulary

(Getting Started with EPICS: Introductory Session I)

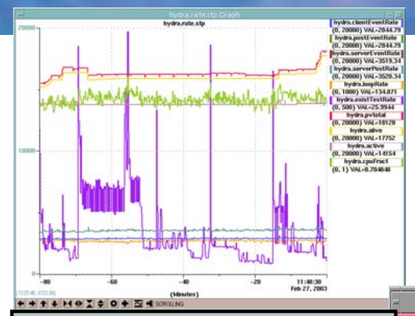
- IOC – Input Output Controller
  - A computer running *iocCore*, a set of EPICS routines used to define process variables and implement real-time control algorithms
  - *iocCore* uses database records to define process variables and their behavior
- Soft IOC
  - An instance of *iocCore* running as a process on a “non-dedicated” computer (i.e. a computer that is performing other functions as well)
- Record
  - The mechanism by which a Process Variable is defined in an IOC (using *iocCore*)
  - Dozens of record types exist, each with it’s own attributes and processing routine that describe its functionality

What is EPICS?

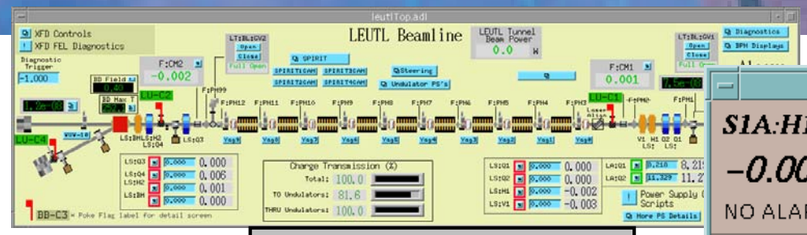
- Process Variable
  - A ***Process Variable*** is a named piece of data with a set of attributes
  - Examples of Attributes:
    - Alarm Severity (e.g. NO_ALARM, MINOR, MAJOR, INVALID)
    - Alarm Status (e.g. LOW, HI, LOLO, HIHI, READ_error)
    - Timestamp
    - Number of elements (array)
    - Normal Operating Range
    - Control Limits
    - Engineering Unit Designation (e.g. degrees, mm, MW)

How does it do it?

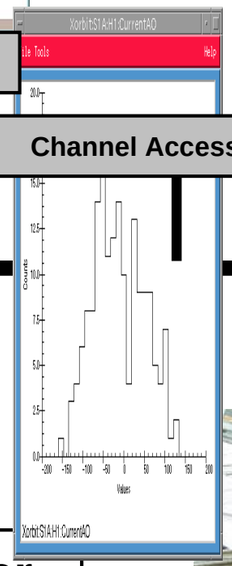
(Getting Started with EPICS: Introductory Session I)



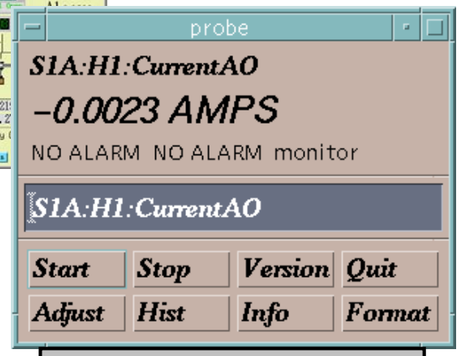
Channel Access Client



Channel Access Client



Channel Access Client



Channel Access Client

Channel Access Server

Process Variables:

S1A:H1:CurrentAO

S1:P1:x

S1:P1:y

S1:G1:vacuum

Computer Interface

Power Supply

Computer Interface

Beam Position Monitor

Computer Interface

Vacuum Gauge

Where does it do it?

(Getting Started with EPICS: Introductory Session I)

Remote Control & Monitoring

Alarm Logging/Reporting

Closed-loop Control

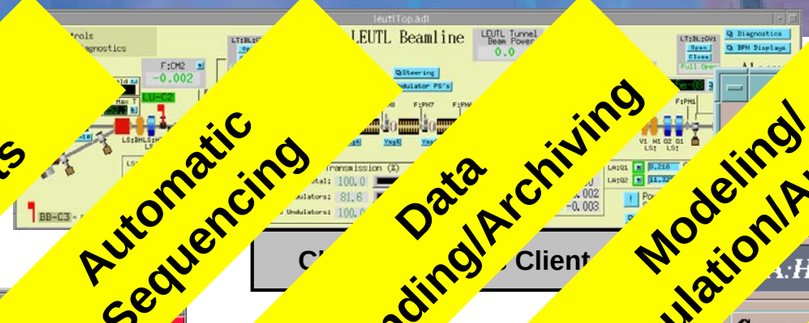
Operational Constraints

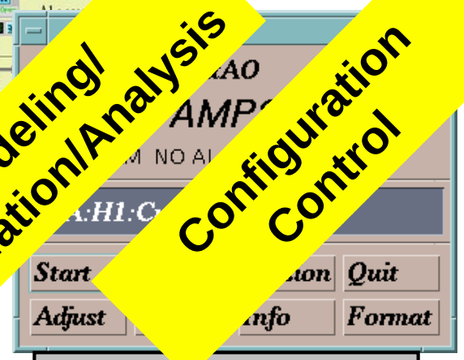
Automatic Sequencing

Data Trending/Archiving

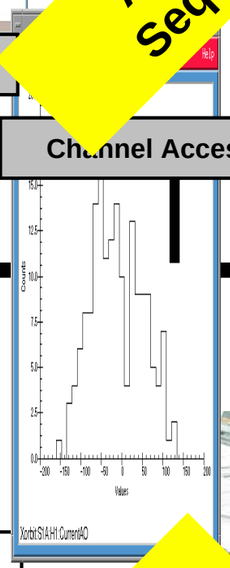
Modeling/ Simulation/Analysis

Configuration Control





Channel Access Client



Channel Access Client

Channel Access Server

Process Variables:

S1A:H1:CurrentAO

S1:G1:vacuum

Computer Interface

Beam Position Monitor

Vacuum Gauge

Computer Interface

Power Supply

Data Conversion/Filtering

Alarm Detection

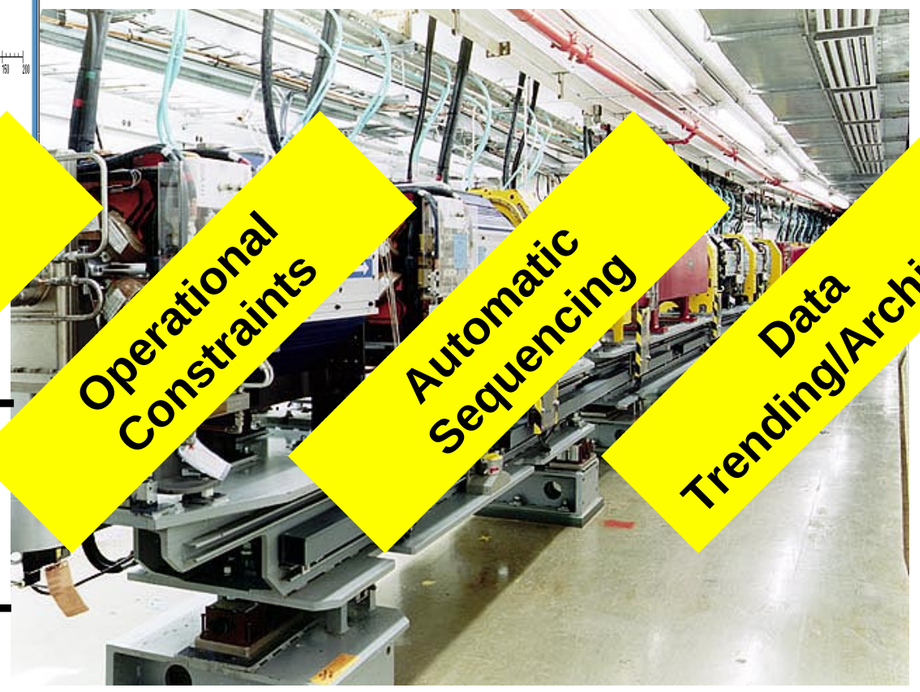
Access Security

Closed-loop Control

Operational Constraints

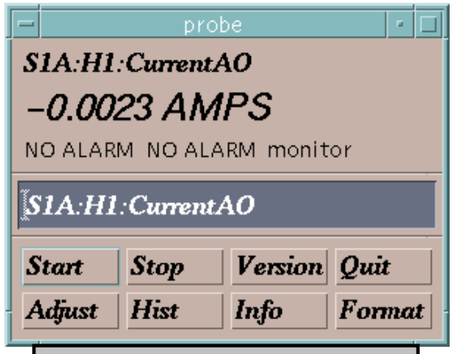
Automatic Sequencing

Data Trending/Archiving



Channel Access in One Slide

(Getting Started with EPICS: Introductory Session I)



Channel Access Client

"connection request" or "search request"

"get" or "caGet"

"put" or "caPut"

"set a monitor"

Who has a PV named "S1A:H1:CurrentAO"?

What is its value?

Change its value to 30.5

Notify me when the value changes

CA Client

CA Server

I do.

25.5 AMPS

OK, it is now 30.5

It is now 20.5 AMPS

It is now 10.5 AMPS

It is now -0.0023 AMPS

"put complete"

or

30.5 is too high. It is now set to the maximum value of 27.5.

or

You are not authorized to change this value

"post an event" or "post a monitor"

Channel Access Server

Process Variables:

S1A:H1:CurrentAO

S1:P1:x

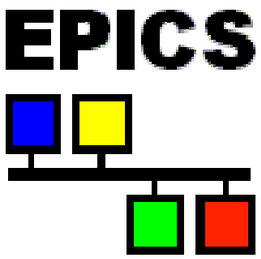
S1:P1:y

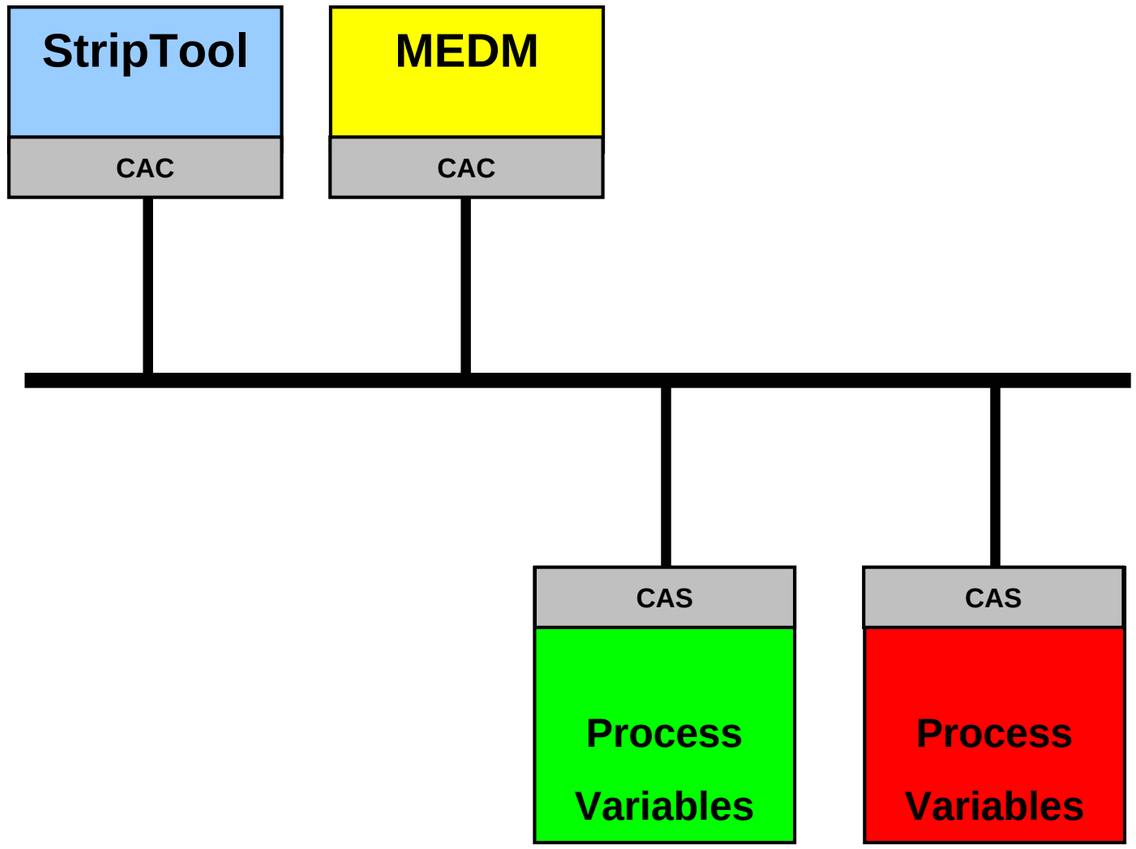
S1:G1:vacuum

What is EPICS?

(Getting Started with EPICS: Introductory Session I)

Channel Access *clients* are programs that require access to ***Process Variables*** to carry out their purpose





The "service" that a Channel Access *server* provides is access to a ***Process Variable****

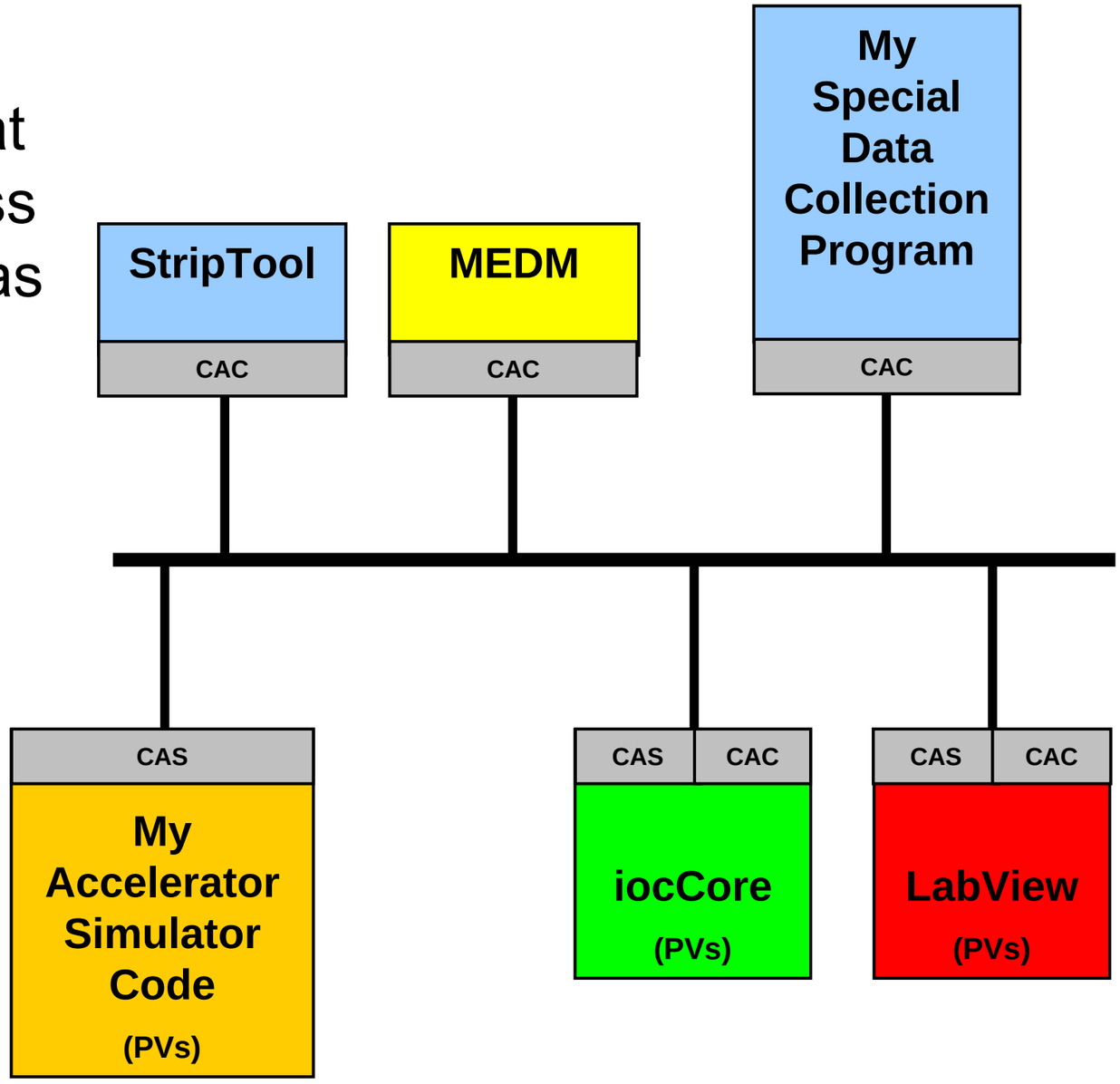
*** A** *Process Variable* **(PV) is a named piece of data.**

What is EPICS?

(Getting Started with EPICS: Introductory Session I)

Any tool/program/application that abides by the Channel Access protocol could be described as “EPICS Compliant”.

EPICS can be viewed as a “toolkit” of EPICS compliant programs. One can select the appropriate tool for their need or develop their own.



Introducing the IOC

Input Output Controller

A computer running software called "*IOC Core*"

The computer can be:

- VME based, running vxWorks (only choice until Release 3.14) or RTEMS
- PC running Windows, Linux, RTEMS
- Apple Mac running OSX
- UNIX Workstation running Solaris, OSF

Usually has Input and/or Output devices attached

An EPICS control system must contain at least one Channel Access Server (usually an IOC)

An IOC loads one or more *databases*, which tell it what to do

- What Process Variables to serve
- What I/O devices to connect to
- What other Pvs to connect to
- What processing to do

IOC Database

Configuration instead of Coding

'iocCore' software loads and executes 'Records'

Example Assignment:

- Read some temperature sensor
- Open/close a valve when value is above resp. below some threshold

The Example in simplified Code

```
Sensor temp = open_device(…);

Valve valve = open_device(…);

Loop:

      if (temp.value() > 10)
      valve.open();
      else
      valve.close();

     delay(1.0);
```

What we omitted

Error checking

Code comments

Apply some smoothing to the temperature reading to filter noise.

Send current temperature and valve state to network clients (operator display).

Attach a time stamp to the data, so that network clients can see for example when the valve was last opened.

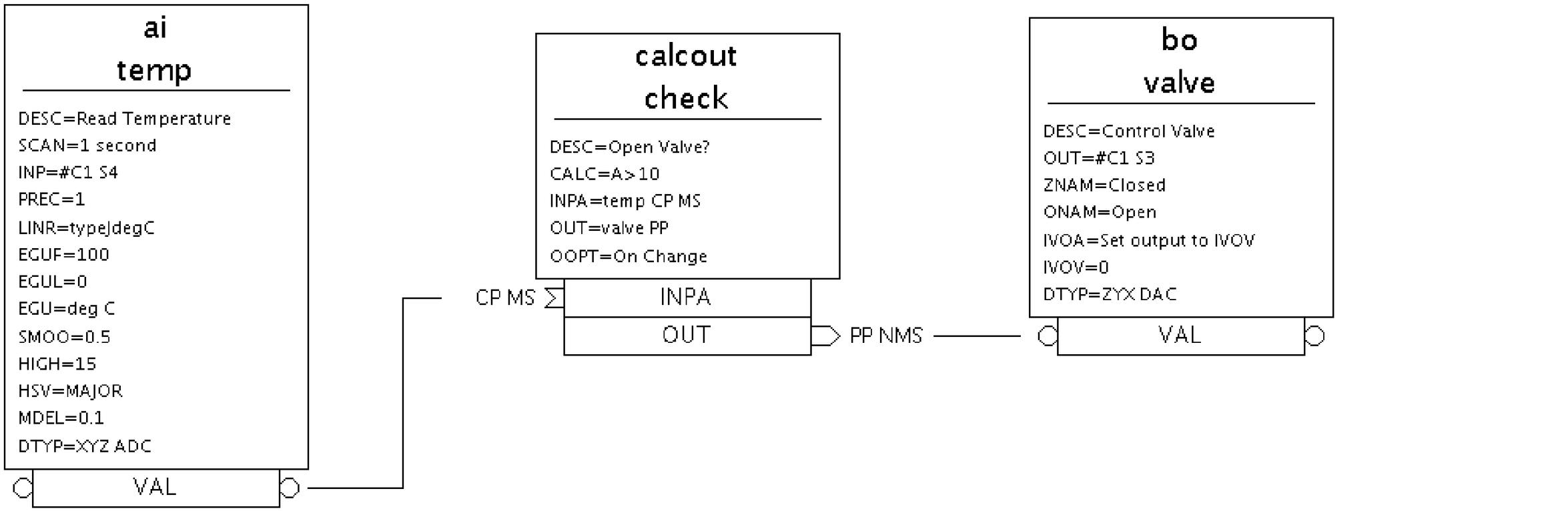
Send warnings if the temperature is close to the threshold, or an alarm when way above.

Allow runtime changes of the threshold from the remote operator interface.

Allow runtime changes to the scan rate.

Maybe allow runtime changes to the device address?

This IOC 'Database' does all that



At first glance, this might look much worse than the code, but…

- that was simplified code.
- there's no way the full source code for the above would fit on one screen.
- after learning more about the database (~2 days), this becomes much more readable than somebody else's custom code for the same functionality.

How fast is EPICS?

Can be fast or slow, it depends how you use it!

Use the correct tool for the job; Database, sequencer, custom code (ioc) or custom code (client)

Ultimately speed depends upon hardware

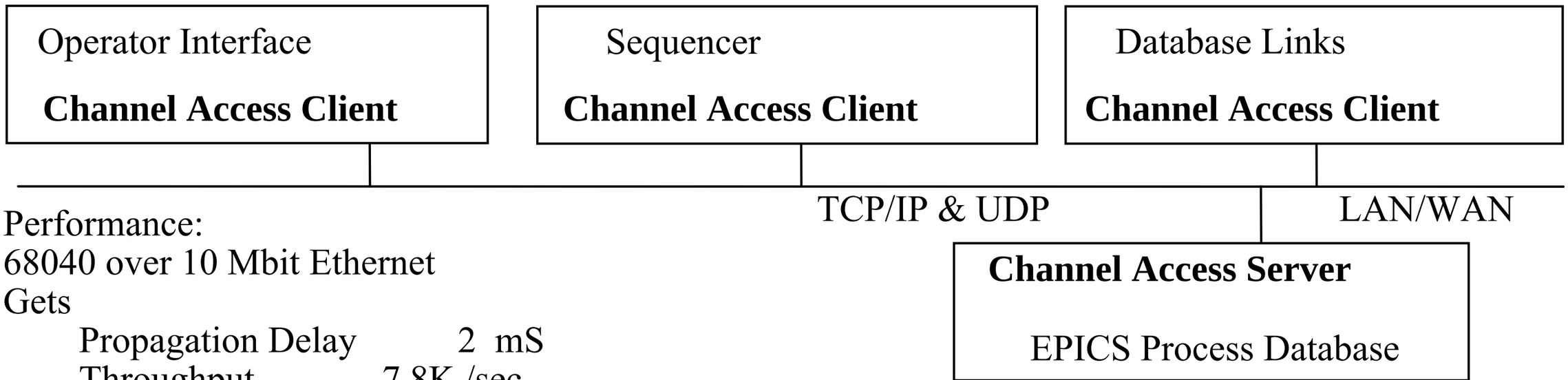
Some benchmarks*:

Machine	OS	CPU	Speed	Rec/sec	%CPU
MVME167	**vxWorks**	**68040**	**33MHz**	**3,000**	**25**
MVME 2306	**vxWorks**	**PPC604**	**300MHz**	**20,000**	**20**
MVME5100	**vxWorks**	**PPC750**	**450MHz**	**100,000**	**25**
PC	**Linux**	**PII**	**233MHz**	**10,000**	**27**
PC	**Linux**	**P4**	**2.4GHz**	**100,000**	**18**

* Extrapolated from benchmark figures courtesy of Steve Hunt (PSI) and L.Hoff, (BNL)

- **Database design and periodic scanning effect *apparent* system speed**

IOC Core: Channel Access Services



Performance:
68040 over 10 Mbit Ethernet
Gets
- Propagation Delay 2 mS
- Throughput 7.8K /sec

Puts
- Propagation Delay 1 mS
- Throughput 17K /sec

Monitors
- Propagation Delay Dependent
- Throughput 15K / sec
- (Typically 10% channels have monitors)
- (memory use in IOC - 2 Meg / 60 connections)
- (30% network load for 15K monitors / second)

Increase bandwidth with Routers, Bridges, Higher speed networks and EPICS gateway

The Learning Curve for EPICS is difficult

Installing EPICS

Setting up the application environment to automatically build databases

Setting up the IOC to boot from the workstation

Installing the new drivers

Knowledge of how to debug the application - is needed by everyone

Learning to use the process database

Choosing and learning which client tools to use

This learning curve can be eased by receiving training from other laboratories, having one of your employees work and train at an EPICS site, or reading the documents and using the software support document to determine the collaboration member supporting your platform.