Outline

• DESY – an overview
• Control Systems at DESY
  – A historic view
• Cryogenic Controls
• Utility Controls
• New Technologies
• New Projects
DESY

View towards the Harbour
DESY

View towards the Airport
HERA
H1 Detector
HERA
ZEUS Detector

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Cryogenic and Utility Controls at DESY
HERA
HERMES Detector

17 March 2004
Cryogenic and Utility Controls at
DESY
HERA
HERA-B Detector
Control Systems
at DESY
1958 ~ 1998

DESY
DORIS
PETRA

HERA
HERA-e
HERA-p
PS+Quench
Cryo
Vacuum
Utility

Control Groups
MKI
PS+Quench
Cryo
Vacuum
Utility
Controls for Cryogenics

• What is to be controlled (in 1986)?
  – (HERA) Cryogenic Plant
  – Helium Distribution System in HERA Tunnel
• ... later
  – Helium Distribution for the TESLA Test Facility (TTF)
  – Cavity Test Anlage (Plant) (CTA)
HERA Cryogenic Plant
HERA Cryogenic Plant
Screw Compressors
Compressor Huts
Pressure Transducers
Valves and Limit Switches

analog
digital
HERA Magnets
Super conducting Cavities for the Electron Ring
Controls Requirements

- Reliability
- Flexibility
- Maintainability
- Self protected sub components
Reliability

Cryogenics is supposed to be like main power: It is just always ‘there’

• Provide 24/7 operation
• Redundant components:
  – Compressors
  – Cold boxes
  – Control System Components
    • Processors
    • Network
    • File Server
• Battery Backup for all major Components
Cryogenic Controls for HERA

- Existing control systems at DESY (in 1986) did not provide the necessary functionality
  - Standard I/O signals for process controls like 4-20 mA
  - Standard control functions like PID loops running @ 0.1 sec
  - NORD Computers used for machine controls were outdated
  - No resources available to add necessary functionality
  - EPICS was not available at that time – it was still called GTACS

- As a result a new control system was purchased
  - True DCS system (D/3 from GSE (currently))
  - Modular design
    - Display, Network, Font-end, I/O
DCS for Cryogenics
(DCS: Distributed Control System)

• Advantages:
  – Designed for process controls
  – Distributed databases/ programs created from a single development environment
  – Distributed access/ diagnostics
  – Display ‘everything everywhere’
  – Documentation
  – Expandability

• Disadvantages:
  – Expensive
  – Software is a black box.
    If something does not work – it is a question of ‘time and money’

• Difficult:
  – To integrate new field buses ( or even other I/O)
    Initially an inhouse solution was used. The system was not reliable and was not
    supported any more:
    -> EPICS came into play as a trouble shooter
EPICS as an Integrator

• Advantages:
  – If the DCS system is a black box, EPICS can be used to develop interfaces for new I/O types.
  – New EPICS records can be implemented to provide missing functionality.

• Since 1993 EPICS was used to:
  – Interface the DCS system to the DESY inhouse field bus called SEDAC
  – Calculate temperatures with 6th grade polynomial. Where each temperature sensor has its specific set of coefficients. (About 800 sensors in the HERA tunnel)
R-T Diagram of a PT1000 and a Cernox 1030 Temperature Sensor

 PT 1000 Sensor

 Cernox 1030 Sensor

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HERA Cryogenics
The Commercial Part

Local and Remote access
Using MS Terminal Server

OPC

Redundant PCM

26 SEDAC crates in HERA Tunnel

EPICS - VME

DMA
D/3 <-> DMA -> EPICS <-> SEDAC

MVME 162 running EPICS on VxWorks

SEDAC connection

Multibus <-> VME DMA connection

Split Crate VME
with EPICS CPU and Control Unit

Redundant Power Supply

Redundant Ethernet for D/3 System

D/3 Processor
- Intel 80486/ Multibus
VME?
Some thoughts about it...

Several boards are instelled in one VME crate.

All boards can be easily changed – without opening any chassis.

Power supplies are highly reliable. A built in diagnostic utility board allows to read out and control all parameter over the CAN fieldbus.

It is a once for ten to twenty years investment.

⇒ VME!!
HERA Cryogenic Control Room
PLC‘s for the Water Control System

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Cryogenic and Utility Controls at DESY
PLC‘s for Water Controls

• Advantages:
  – PLC‘s run their loaded program 'forever'
  – Many Technical Engineers know how to program PLC‘s
  – PLC‘s can be equipped with local displays
    • Useful for acceptance tests without supervisory system
  – PLC‘s provide the necessary functionality and reliability to protect sub components
EPICS for Supervisory Controls

• Advantages:
  – Make use of the DCS features in EPICS
  – Once the configuration tools have been developed:
    • Create PLC databases and EPICS databases from one source
      (Oracle database)
  – Inexpensive
  – Share developments with other control groups worldwide
    (visit KEK ;-) )
  – Bug fixes and new features do not depend on 'time and money'
    (but local manpower and/or support from EPICS community)
Cryogenic and Utility Controls at DESY

System Support by Cryogenic Controls Group

D/3
Application Configuration
Database Configuration

EPICS
Application Development
Application Configuration
Database Configuration
Driver Development

Utility Controls Group
PLC
Database Configuration

Cryogenic

Utility
Cryogenic and Utility Controls at DESY

Cryogenic and Utility Controlled/Supervised by EPICS

- Local and Remote access Using X-Windows and JoiMint
- EPICS - VME
- DIN-Rail PC
- CAN
- Profibus DP/FMS
- Siemens PLC
- Siemens TCP
- 26 SEDAC crates in HERA Tunnel
- PLC’s / distributed I/O
- Host based CA Server
- OPC

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Cryogenic and Utility Controls at DESY
IOC 'Head Count'

VME/ IP Hardware:
- Fast ADC/ DAC
- Digital I/O
- Scaler

Field buses:
- SEDAC (DESY inhouse)
- CAN
- Profibus (FMS, DP)

Ethernet Protocols (for PLC‘s):
- Siemens
- Modbus

Ethernet to other contr. Systems:
- TINE (DESY)
- DOOCS (DESY)

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<th>HW Type</th>
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<th>Anwendung</th>
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</table>

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Utility IOC‘s
D/3 and EPICS File Server

Compaq Cluster

Sun Cluster

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Cryogenic and Utility Controls at DESY
UPS
Installation at DESY with DIN-Rail PC

- CAN I/O
- DIN-Rail PC running EPICS (VxWorks)
- High prec. Temperature Measurement
Small I/O Subsystems
Mounted on DIN-Rail
Connection to EPICS via Modbus Protocol

Various I/O Modules (inexpensive)
Combined with several Fieldbus/ Ethenet Controllers
(starting from 400€ - with Ethernet controller)
Application Launcher

Tcl/Tk script
Originally written by Furukawa-san
Introduced at DESY by Kamikubota-san

Callup all Applications from ONE place
Operators do not type in anything
Dm2k Synoptic Displays
Faceplates in dm2k
Single Loop Display
Long Term Archiving
~ 10 Years

Channel Archiver
Channel Archiver
Channel Archiver
Channel Archiver
Channel Archiver

Optimized writing
Conversion into SDDS format
Long term storage with data reduction (planned)

Optimized reading

SDDS

Oracle

Other Control systems

Data Archiver Web Interface

Network API

AAPI Archive API Service

IDL

Strip History Tool

Java Viewer (plan)

Opimized correlation

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Cryogenic and Utility Controls at DESY
Archiving: Web Display
Archiving: IDL Display
Database creation

- Files created by text editors
- Macro replacement in IOC startup script 🙁
- **EPICS-ORA**
  - Oracle Forms Tool
- **VDCT**
  - For small applications
  - Create templates for EPICS-ORA

(future standard)
Performance

• 3000 – 4000 records on a 33 MHz CPU running @ 1 sec is fine
• Several 10's records running @ 0.01 sec on a 33 MHz CPU is the limit (lots of task switching)
• Today's PowerPC's provide 300MHz or more. Limitations will be given by the I/O throughput not by CPU load or memory consumption
Flexibility Provided by EPICS

• Integration of various field buses
• Embedded EPICS on small front end systems
• A rich set of tools for operations
  – Display, Alarm and Archiving tools can be used ‘out of the box’
  – The channel access library can be integrated into your favorite programming environment (like SAD at KEK)
• Built in controls functionality on the front end (IOC)
  – Complicated control loops can be easily configured
  – Additional functionality can be provided by adding new record types or writing subroutine records
Managing EPICS
Working jointly with Central Computing

• Take whatever they provide which makes our life easier. ... and saves resources!
• But! – It must be used in a way that we can disconnect from central computing without loosing fundamental functionality!
• The basis is a mutual understanding of fundamental controls requirements.
  – Some services must be always available
  – The support of dedicated controls services is sometimes easier – and fits better into the IT infrastructure - if it is provided directly by central computing.
## IT Services for Controls

<table>
<thead>
<tr>
<th>IT Service</th>
<th>Local Control Group</th>
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<tr>
<td>General (office) support</td>
<td>Services dedicated to controls</td>
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<td>Wide Area Network</td>
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<td>VPN</td>
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<td>Mail</td>
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<td>2nd DNS Server</td>
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<td>YP</td>
<td>2nd YP Server</td>
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<td>X-Fonts</td>
<td>2nd X-Fonts Server</td>
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<td>Windows Domain</td>
<td>2nd Domain Controller</td>
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<td>Windows Home Direct.</td>
<td>Local user on machines</td>
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<tr>
<td>Unix – AFS user</td>
<td>Windows Cluster + RAID</td>
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<tr>
<td>AFS Home Directories</td>
<td>Local user on machines</td>
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<td>VLAN (QIP)</td>
<td>Sun Cluster + RAID</td>
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<td>Network</td>
<td>Router configuration</td>
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<td>Compatible Components selected in close contact with IT</td>
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</table>

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Cryogenic and Utility Controls at DESY
Network Pitfalls: Spanning Tree (Cisco Bug)

Problems:
- VLAN separation not working – multiple loops cause heavy network load.

In both cases:
- D/3: DCOM service lost connection
- EPICS: Many CA connections lost -> causing even more traffic -> avalanche!!!

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Cryogenic and Utility Controls at DESY
Network Pitfalls: Spanning Tree Calculation Load

Problems:
1. Core Switches busy due to PVSTP calculations (for more than 130 VLANs). As a result: Local switch/router is not available for long time (minutes)
   - No connection to DNS server -> X-Terminals, telnet, NFS-mounts ...
   - No connection between control systems/segments
   - No new VLAN connections
Solution

Central Computing did their homework:
• Change algorithm to 'Multiple Spanning Tree' (MST bzw. 802.1s)
• Install new software to avoid bug
• Central Computing installed a new Switch with routing module for the controls group
• As a result:
  – Local Routing (independent from Core Switch)
  – But: not VLAN possible any more (only static)
  – Better separation of office/controls traffic
Network Solution: Dedicated Switch for Controls

IT Supported
Supported by Controls Group
Switch with routing module configure without all the fancy features.
EPICS Network

EPICS Name Server

EPICS Gateways

Console

Switch

Switch + Router controls

Switch

Switch

Switch

Switch

Switch

Switch

Switch

Cryogenic PLC Network

Utility PLC Network

PLC

EPICS IOC

Windows 2nd Domain Controller

DNS/X-Fonts/YP

PLC Integrated over common network

EPICS IOC Access by Name Sever

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Cryogenic and Utility Controls at DESY
EPICS Access

Switch

Switch + Router controls

DNS/ X-Fonts/ YP

Switch

EPICS IOC

Access by Name Server

EPICS IOC Access by Name Sever

Windows 2nd Domain Controller

CORE

CORE

CORE

CORE

Console: Access via Gateways

VPN

FireWall

Switch

EPICS

Name Server

EPICS Gateways

Console

Cryogenic PLC Network

Utility PLC Network

PLC

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EPICS Network
Using Terminal Server

Access Console

Switch

Switch + Router controls

DNS/ X-Fonts/ YP

Windows 2nd Domain Controller

Terminal Server
On the same network as the IOC / PLC

Cryogenic PLC Network

EPICS IOC

Utility PLC Network

Switch

Term.S.

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Cryogenic and Utility Controls at DESY
Network Summary

• Today's networks provide a rich set of functionalities
  – Not all of them are (yet) designed for 24/7 controls operations
  – Many of them will find their way into the controls domain

• Working together with the central networking group helped us to save resources and to implement stable controls networks.
  – This might be DESY specific

• Working in extended EPICS broadcast domains increases the sensitivity for any kind of distortions.
  – Splitting EPICS networks into several broadcast domains can be achieved and supported by using gateways and name servers
EPICS Reliability

Since we started with EPICS in 1993
Many things changed in EPICS
– Many bug fixes from version 3.11 to 3.13.8
– Ridged CVS control for the core software
– Core software reduced to the ‘real’ core

• New version of VxWorks
  – Changes in the IP-Kernel

• New application software
  – Make it simple, efficient and reliable
  – Example: IOC running since 2001
Dm2k System Status
New Technologies

• Using Web-Services
  – Servlets running in a Tomcat engine
  – Example:
    • Electronic Logbook
    • Web-based channel access get (and put)
    • Accessing the Oracle database (instead of Oracle Forms)

• Using Java in general
  – Database creation: VDCT
  – Display tool: JoiMint
  – ... more to come!
Electronic Logbook

Search in Logbook: MKS-2.KRYO

From: 05-03-04 09:57:12 To: 08-03-04 12:57:12

KRYO: 2004-03-05 10:19:23.0 Verstopfter Filter Waermetauscher
designer
Klassisches Beispiel:

Dieses Bild zeigt die sich ein Waermetauscher (auch Filter) ueber die Zeit
verstopft. Die Analy森werte (Stickstoff und Sauerstoff) waren ueben den gleichen
Zeitraum immer kleiner 2 vps.
JoiMint
Java Operator Interface and Management Integration Toolkit

Start JoiMint from eLogbook transferring configuration data of recorded event

JoiMint reads configuration of display and gets actual data from event recorder (@ DESY)

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Cryogenic and Utility Controls
DESY
New Projects

• PETRA-III
  – Complete change of the previous PETRA-II injector for HERA into a Synchrotron Light Source

• XFEL
  – Free-electron laser that operates according to the SASE principle (self-amplified spontaneous emission)
**XFEL - Facts**

1. Free-electron laser that operates according to the SASE principle (self-amplified spontaneous emission)
2. Total length of the facility: approx. 3.3 km
3. Accelerator tunnel: approx. 2 km
4. Depth underground: 6 - 15 m
5. Experimental hall: 10 experimental stations at 5 beamlines, floor area approx. 3000 m²
6. Scope for expansion: Second experimental hall with an additional 10 experimental stations
7. Wavelength of X-ray radiation: 6 to 0.085 nanometers (nm) corresponding to electron energies of 10 to 20 billion electron volts (GeV)
8. Length of radiation pulses: below 100 femtoseconds (fs)
9. Total costs of the XFEL project: 684 million Euro, based on the price level of the year 2000
10. Location: The tunnel of the linear accelerator will begin on the DESY site and run in the north-western direction. The experimental hall is situated in the town of Schenefeld, in the distance of 15 minutes by car from DESY.
TTF-2/ VUV-FEL/ XFEL/ TESLA - Module
Undulators
Location
Average Brilliance

The diagram illustrates the relationship between the average brilliance and energy for various types of synchrotrons and free-electron lasers. The brilliance is plotted on a logarithmic scale, with TTF (seeded), XFEL, SASE FELs, PETRA III, X-ray Undulator, VUV-Undulator, DORIS III, PETRA II, Wiggler, Ablenkmagnet, and Cu Kα curves shown. The energy is also plotted on a logarithmic scale. The diagram highlights the 1st, 2nd, and 3rd generation synchrotrons and their energy levels.
XFEL Applications:
Analyse Chemical Reactions (Femto-Chemics)
Control Systems

Several 'work packages' have been defined

• Machine Controls
• Cryogenic – with controls
• Utility – with controls
• ... many others

The following has a high probability:
• Machine controls: DOOCS
• Cryogenic/Utility controls: EPICS
DOOCS
Distributed Object Oriented Control System

Distributed System
Server Name Data Base
Device Definitions on Server
Archiving in all Servers
Based on RPC
Multiple Protocols
Variable Data Objects
Access Control
C++
Rich Library
Runs on: Solaris/LINUX/(Windows)
DOOCS — RPC Sequence
(DOOCS) - RPC / Channel Access

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Cryogenic and Utility Controls at DESY
XFEL Controls Demands

- A user facility with high demands for 99.8% efficiency
  - The control system may not fail
  - Possible scenarios:
    - Hot stand by (seamless switch of IOC’s)
    - Cold stand by (switching ‘on demand’; i.e. for maintenance)
  - Biggest problem: Find radiation hard electronics for the tunnel
    - Distributed redundancy in cold stand by may help
    - Most sensors and actuators contain electronics nowadays.
Principle Layout of the Control System
EPICS wishlist

IOC:

• Online Add and Delete (Records/ Objects)
• Dynamically change:
  – The addresses (keeping the same device)
  – The device type
• Bumpless Reboot:
  – I.e.: Support for Flash-EPROM
  – Important/ complicated: Save internal Record-States -> digital Logic
• Synchronize Time using NTP
• Soft Reboot
• Java VM on the IOC?
  – SNL could be written in Java
• Redundancy Concepts built into EPICS core
EPICS wishlist

Applications

• EPICS Name Service
• Access from all applications to Name Service
• Common 'EPICS look and feel' for all applications
• Support for IEC 61131 programming standard (PLC)
• VDCT:
  – Add records on IOC with command from VDCT
  – Different display of data flow and process flow
Forming a Collaboration With SACLAY

The DESY Cryogenic Control Group and the SACLAY/CEA Controls group have expressed their interest to work jointly on the XFEL controls. (To be confirmed by the directorates)

• Collaborative Tools must be evaluated in order to set up the common ground for the project.

• Requirements for such a tool must be specified
Conclusions

• The experience over the last 10 years of using EPICS for controls is very promising.
• EPICS has reached a maturity which can easily compete with industrial systems.
• The EPICS collaboration is a reliable partner.
• The ongoing effort to improve the product – namely in the EPICS-2010 initiative - is the key for the future.
• We are looking forward to use EPICS in our projects to come.
Questions?