Control System of the KEKB Accelerator Complex

Evolution in several aspects

Kazuro Furukawa, KEK

KEKB Control Group
Linac Control Group
Mt. Tsukuba

J-PARC

KEKB

KEKB Complex

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KEKB and Linac Accelerator

KEKB and Linac

◆ KEKB B-factory: Electron/Positron Asymmetric Collider for CP-violation Study
  ~3km Dual-rings: Electron (8 GeV - 1.4A) / Positron (3.5 GeV - 1.8A)
  ✧ Stable and Robust Operation
  ✧ Many Active Operation Parameters
  ✧ Importance of Controls

◆ Linac:
  ~600m, 50Hz
  8 GeV 2nC Electron, 3.5 GeV 1.2nC Positron
  ✧ Beam switchings for PF and PF-AR rings

Increase of Luminosity with Crab Cavities
KEKB and Linac Control Systems

◆ Linac
  ❖ Controls Upgrade (1990~) 1993
    ☰ De-facto (and International) Standards, IP-only Networks
  ❖ No long Shutdown for KEKB upgrade
    ☰ 3.5-times Energy increase, 10-times current increase
  ❖ Division changed at the end of Upgrade
  ❖ Three indirect User Facilities (KEKB, PF, PF-AR)
  ❖ Fewer resources

◆ KEKB
  ❖ 5-year Shutdown after TRISTAN 1994-1998
    ☰ Precision requirements were much different for KEKB
  ❖ Complete transition of Controls
    ☰ from Nodal at TRISTAN to EPICS+SAD at KEKB
  ❖ Basically Single-user (Belle)
Communication Network at Linac

◆ Fiber-optic Networks (1982~)
  ▶ Because of High-power modulators for rf systems
  ▶ ~30 Loops to connect many equipment controllers
    ▶ However, the fiber-optic Technology was not mature enough yet
      ◆ Often Failed and Loop Topology made it difficult to identify the trouble

◆ All IP network (1993~)
  ▶ Still all Fiber-optic
    ▶ Faster Ethernet enables shorter packets and less failures
  ▶ Inherited at J-PARC Controls as well

◆ Gradual Transition of Technologies
  ▶ From FDDI + 10Base-FL to 1000Base-LX + 100Base-Fx

◆ Redundancy (1996~)
  ▶ At more than 40 Ethernet links
  ▶ Helped continuous operation in spite of a failure at night
    ◆ Redundant Transceivers, then Rapid Spanning-tree and HSRP/VRRP
Communication Network at KEKB

◆ TRISTAN
  ◆ Token Ring and CAMAC Serial highways
    - Token ring between mini-computers
    - CAMAC serial highways to equipment controllers

◆ KEKB
  ◆ IP Network for EPICS
    - FDDI+10BaseT to GbE+100Base-Tx
      - Sometimes unnecessary excess broadcast
  ◆ ARCNet for equipment controllers
    - More than 200 network segments
  ◆ MXI-2 for VXI-based frames
    - 20 segments
  ◆ Keep some CAMAC Serial highways
    - About 50 Crates
Equipment Controllers at Linac

◆ 1982~(1997) (1st generation)
  ❖ 300 microprocessor-based controllers
    ▪ Linked together with home-grown fiber-optic network

◆ 1993~now (upgrade of controls)
  ❖ 150 PLCs (programmable logic controller)
    ▪ Linked via only Fiber-optic Ethernet/IP
      ✷ Control communication with servers and program development

◆ 1995~now (upgrade for KEKB)
  ❖ 30 VXI for rf measurement
  ❖ 5 VME / 10 CAMAC for Timing
  ❖ 20 VME for Beam monitors

◆ 2006~ (upgrade of BPM readout)
  ❖ 24 Oscilloscopes with WindowsXP IOC for 100 BPMs
    ▪ 10Gs/s, 50Hz acquisition, local processing with 20 calibration parameter/BPM
Equipment Controllers at KEKB

**TRISTAN**

- Mostly CAMAC
  - Equipment group responsibility: CAMAC module and outside

**KEKB**

- 100 VME/IOC without Analog processing
- 200 VXI/MXI mainframes for 900 BPMs
- 50 CAMAC crates are kept for rf and vacuum
- ARCNet boards for Magnet ps. settings, and others
- GPIB for Magnet ps. readback, and others
- PLCs for Magnet interlocks, and others
EPICS Transition at Linac

◆ Home-grown RPC at Linac (1990~/1993~)
  ❖ Bad timing but no choice because of end of old mini-computer support
◆ No real transition to EPICS yet at Linac
  ❖ There are middleware and applications
◆ LynxOS Transition was developed (1994~1996)
  ❖ To cover both RPC and EPICS with pthread, posix
    ▷ Mostly working, Failed to get funding for Hardware/Software upgrade
◆ Gateways to EPICS in several ways
  ❖ Software-only IOC and Gateway (Clients to both RPC/CA)
  ❖ Soft-IOC with device support to Linac RPC (2002~)
◆ Real IOCs are increasing
  ❖ PLC(rf,vacuum,magnet) and Linux, Oscilloscope(bpm) with Windows, VME(llrf and timing)
  ❖ RPC servers read EPICS IOCs, EPICS gateways read RPC servers
EPICS Transition at KEKB

◆ Some candidates discussed after Nodal at TRISTAN
  ❖ RPC/CORBA based control design
  ❖ Reflective memory (hardware shared memory) design

◆ No other choice than EPICS for KEKB
  ❖ No man-power for control system software
  ❖ The choice at SSC
  ❖ International collaboration was attractive
Archiver/Logger

◆ Linac
  ❖ Several archivers with different filters and stored in ascii
  ❖ Replaced with two EPICS archivers (2002)
    ✧ Channel archiver, with Java viewer, and Web-based viewer
    ✧ KEKBlog, SADscript-based viewer
      ✤ Both ~400MB/day, Dynamic ADEL changes

◆ KEKB
  ❖ KEKBlog, since 1998
    ✧ Once there was a plan to replace it with Channel Archiver
      ✤ Data conversion, no much performance difference
    ✧ Only ADEL-based filter
      ✤ ~2GB/day
    ✧ SADscript-based viewer is one of the most used applications
      ✤ With Data analysis capability, easy manipulations
Scripting Languages

◆ Heavy use because of rapid prototyping

◆ Linac

❖ (1992~) Tcl/Tk as Test tools on Unix
❖ (1997~) Tcl/Tk as Main Operator Programming Tool
❖ (Now) Mixture of Tcl/Tk, SADscript/Tk, Python/Tk
  ✴ SADscript has most accelerator design capability
    ♦ Covers many features like MATLAB, Mathematica, XAL, MAD

◆ KEKB

✴ (Nodal interpreter and Fortran covered everything at TRISTAN)
❖ Python covers many areas which is not covered by medm
❖ SADscript is used by operators and physicists everyday
  ✴ Realization of novel ideas in hours
    ♦ Only some ideas are effective, so rapid prototyping is important
Virtual Accelerator in SADscript

◆ For Example in KEKB
  - most Beam Optics Condition is maintained in the Optics Panel
  - Other Panels Manipulate Parameters
  - Communicating with the Optics Panel

(Oide, Koiso, Ohnishi et al)

Tune Measurement/Changer

Optics Panels
Near Future

◆ SADscript
  ❖ Will be maintained, but should look more at XAL - CSS
◆ EPICS
  ❖ Still many hopes waiting to be realized
◆ More integration between control systems
◆ PLC usage
  ❖ IEC61131-3 Standards
◆ FPGA usage
  ❖ More embedded controllers / instrumentations
◆ More reliability considerations
  ❖ Testing environments, Surveillance, Redundancy, etc.
◆ More operation side developments

Linac and KEKB groups will share the tasks
Summary

◆ Linac had slow and gradual modernization
  ❖ No long Shutdown time, losing good timing
◆ KEKB made big transition at the Construction
  ❖ 5-year Shutdown, Big help from EPICS community
  ❖ Runs without much modification ever since
◆ Control system design needed a balance between many aspects
  ❖ Large and Small group differences
◆ EPICS and Scripting Languages brought a success to the both KEKB and Linac Beam Operations
◆ Linac and KEKB groups are ready to share more tasks for the future
Thank you
Thank you
KEKB Control System (Hardware)

◆ GbE Fiber Optic Networks
  ❖ Single Broadcast Domain
  ❖ Central Control Room and 26 Local Control Rooms

◆ VME/IOC
  ❖ ~100 VME/IOC mostly with PowerPC CPU

◆ Field bus
  ❖ ~200 VXI thru MXI for BPM Instrumentations
  ❖ ~50 CAMAC for rf and Vacuum (inherited from TRISTAN)
  ❖ ~200 ArcNet network segments for Magnet Power Supplies, and other field Controllers
  ❖ GPIB for Instrumentations, RS232C, Modbus+ for PLCs

◆ Host Computers
  ❖ HP-UX/PA-Risc, Linux/x86 Controls Server
  ❖ 3 Tru64/Alpha with TruCluster
  ❖ Several Linux
  ❖ Many MacOSX
  ❖ (Solaris/Sparc for VxWorks)
KEKB Control System (Software)

◆ EPICS 3.13.1 and 3.14.6,8
◆ VxWorks 5.3.1 mainly, and 5.5.1
  ❖ Hope to upgrade EPICS/VxWorks Shortly
◆ IOC Development
  ❖ CapFast, (VDCT) Perl, SADscript for Database Configuration
  ❖ Oracle as a backend Database Management
    ✷ Migration towards Postgresql
◆ Operational Application Development
  ❖ MEDM(DM2k) for Startup
  ❖ Python/Tk for Equipment Controls
  ❖ SADScript/Tk for Beam Operation, etc
Linac; History and Design Concept

History

- 1989-1992: Design of the next system
- 1993-1997: Installation and expansion for KEKB

Design Concept

- Use of International and/or de-facto Standards
- Use of Optical IP Networks for every Device controllers
  - No new field Networks, only IP Network (inherited by J-PARC as well)
- Both of above should make future upgrade easier
- (EPICS was not available widely at that time)
Linac; Physical Structure

◆ Multi-tier, Multi-hardware, Multi-client, …

Diagram:
- X-Window Interface for Operation
- Touch Panel Interface
- MS-Windows Interface
- EPICS Gateway to KEKB-Ring

Central Network (Gb-Ethernet)
- Device Manager
- Main Computer Systems (Unix)
- Interface to other Facilities

Equipment Level Network (Optical Ethernet)
- VME's (~30): Beam Monitor Timing etc.
- PLC's (~150): RF Magnet Vacuum
- CAMAC's (~15): Timing
- VXI's (~30): RF Monitor
- PC / GPIB / RS232C: Gun Beam Monitor others
Linac; Software Architecture

◆ Base control software structure for Multi-platform
  ❖ any Unix, OS9, LynxOS (Realtime), VMS, DOS, Windows, MacOS
  ❖ TCP - UDP General Communication Library
  ❖ Shared-Memory, Semaphore Library
  ❖ Simple Home-grown RPC (Remote Procedure Call) Library
  ❖ Memory-resident Hash Database Library

◆ Control Server software
  ❖ Lower-layer servers (UDP-RPC) for control hardware
  ❖ Upper-layer server (TCP-RPC) for accelerator equipment
  ❖ Read-only Information on Distributed Shared Memory
  ❖ Works redundantly on multiple servers

◆ Client Applications
  ❖ Established applications in C language with RPC
  ❖ Many of the beam operation software in scripting language,
    ✧ Tcl/Tk
    ✧ SADscript/Tk
Network with only IP/Ethernet

◆ The policy chosen when we upgrade Linac in 1993
  ❖ Make network management simpler
    ✤ Faster switches, routing, network-booting, etc.
  ❖ Avoid Hardware failure and analysis effort with old field network
    ✤ Home-grown field networks need much dedicated man-power
  ❖ Cost for optical Ethernet went down at around 1995
    ✤ Linac has high-power modulator stations, noise source
  ❖ Nowadays many facilities have this policy with GbE
    ✤ J-PARC controls basically followed this
  ❖ More and more intelligent network devices
    ✤ ex. Oscilloscopes with Windows/3GHz-Pentium built-in
    ✤ Even EPICS IOC, MATLAB, or others can be embedded
  ❖ Network components can be replaced one-by-one
  ❖ Security consideration will be more and more important
EPICS

◆ Now is a kind standard, but …
◆ Object-oriented design support
  ❖ Naming scheme, and/or design of new record
  ❖ More software-engineering support favored
    ☳ Several different efforts to provide better environment
      ♦ Java IOC (M. Kraimer), Control system studio (M. Clausen), Data access (R. Lange)
◆ Security mechanisms
  ❖ User, Host-based protection available
  ❖ More security
    ☳ Dynamic controls of security
    ☳ Access logging
◆ Dynamic configuration of database
  ❖ Dynamic creation / loading of records
  ❖ Dynamic removal of records
    ☳ Maybe some part of the codes can be shared with redundant-IOC project
Magnet Controls

◆ It is typical controls and still many things to do

◆ Many magnets and many power supplies
  ☐ No one-to-one correspondence
  ☑ Which hardware interface to use

◆ Procedures
  ☑ Interlock status, on/off, analog with some precision, etc
  ☑ Energy, kick - field - current conversions
    ☐ How to represent those conversion curves
  ☑ Timing synchronous operation
    ☐ for tune change, orbit correction, etc.
  ☑ Standardization
Phronesis

◆ Aristotle’s view of wisdom.
◆ Contrary to Sophia; the ability to understand the universal truth
◆ Phronesis is the ability to find a way to achieve an overall goodness
Thank you