Control System of
the KEKB Accelerator Complex

Evolution in several aspects

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Several aspects of Evolution of the Accelerator Controls at the both KEKB and Linac

- Communication Networks
- Equipment Controllers
- Gradual Approach to EPICS
- Scripting Languages

Summary
B-factory: Electron/Positron Asymmetric Collider for CP-violation Study
~3km Dual-rings: Electron(8GeV - 1.4A) / Positron(3.5GeV - 1.8A)
KEKB and Linac

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

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

Increase of Luminosity with Crab Cavities
Increase of the Luminosity

May.2000

Apr.2003
Dual Bunch e+

Feb.2005
Continuous Injections

Now
Collision with Crab Cavities

ICALEPCS 2007, Knoxville, US.
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)
    人社局 Channel archiver, with Java viewer, and Web-based viewer
    人社局 KEKBlog, SADscript-based viewer
      人社局 Both ~400MB/day, Dynamic ADEL changes

◆ KEKB
  ❖ KEKBlog, since 1998
    人社局 Once there was a plan to replace it with Channel Archiver
      人社局 Data conversion, no much performance difference
    人社局 Only ADEL-based filter
      人社局 ~2GB/day
    人社局 SADscript-based viewer is one of the most used applications
      人社局 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
SADScript

- Accelerator Modeling Environment
  - MAD-like Environment was created during TRISTAN
  - Needs for Conditionals, Flow-controls, Data manipulations, Plot, GUI

- Mathematica-like Language
  - Not Real Symbolic Manipulation (Fast)
  - Data Processing (Fit, FFT, …), List Processing (Mathematica like)
  - EPICS CA (Synchronous and Asynchronous)
  - \( \text{CaRead/CaWrite[], CaMonitor[], etc.} \)

- Tk Widget
  - Canvas Draw and “Plot”
  - KBFrame on top of Tk
  - Greek Letters

- Relational Database
- Inter-Process Communication (Exec, Pipe, etc)
  - System[], OpenRead/Write[], BidirectionalPipe[], etc.

- Beam Operation with Full Accelerator Modeling Capability
  - Also Used for non-Accelerator Applications (Archiver viewer, Alarm handler, etc.)

- Comparable to XAL, MATLAB, but very different architecture
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)
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 modernalization
  ◆ No long Shutdown time, loosing 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