Control System Achievement at KEKB and Upgrade Design for SuperKEKB


(Control Group, SuperKEKB Ring/Linac)

October 2011.
Earthquake in March – Thanks

◆ Thank you so much for your warm messages from all over the world.

◆ Operation will be normal soon.
KEKB Controls 1998 - 2010

◆ EPICS as Main control Software Toolkit
  ❖ Became one of de-facto standard at 1995
  ❖ Several fieldbuses were incorporated
    ✷ VME, VXI, CAMAC, ArcNet, GPIB, etc
  ❖ Reduced software design efforts much

◆ Scripting Languages for Operational Software
  ❖ SADscript/Tk, Python/Tk, Tcl/Tk used much
    ✷ Especially, SADscript as a bridge btw. Accelerator simulation, Numeric manipulation, Graphic interface and EPICS controls
  ❖ Bright new idea in the morning meeting could make the operation much advanced in the evening
    ✷ Great tool to optimize the operation
Many machine diagnostic and correction/feedback tools should be provided.

Hundred of 1% improvements will provide twice better performance, rapidness is important.
Change in Operation Modes at KEKB

**May.2000**
- Dual Bunch $e^+$

**Apr.2003**
- Continuous Injections

**Feb.2005**
- Continuous Injections

**Dec.2008**
- Crab Cavities and Simultaneous Injection

Robust controls provide a flexible and robust operation environment for daily advances.
SuperKEKB

◆ Electron-positron asymmetric collider
  ❖ Based on a decade of successful operation at KEKB

◆ Aims at 40-times higher luminosity
  ❖ $8 \times 10^{35}\text{cm}^{-2}\text{s}^{-1}$ for further flavor physics studies
  ❖ 7GeV / 2.6A electron, 4GeV / 3.6A positron
  ❖ $\beta_y^* \sim 0.3\text{mm}$, $\varepsilon_x / \varepsilon_y \sim 4\text{nm} / 9\text{pm}$, $\sigma_y \sim 50\text{nm}$, $\sigma_z \sim 6\text{mm}$
  ❖ Ante chamber, longer bend, damping ring, rf gun, etc
SuperKEKB Controls

◆ Inherit Good part of KEKB Controls
  - EPICS
  - Scripting languages
  - With simple rejuvenation of software/hardware

◆ Two Additional Concepts
1st: CA Everywhere

♚ EPICS Channel Access (CA) Everywhere

◆ Embed EPICS control software (IOC) everywhere possible
◆ Reduce efforts on protocol design, testing, etc
Transition of Architecture

1990~

- Mini Computer
- Unix
  - TCP/RPC/CA

1993~

- Mini Computer
- Unix
  - Channel Access

2005~

- Mini Computer
- OPI
  - Channel Access

- Devices
- Field Networks
  - TCP/RPC/CA

- Device Controller
- VME
  - TCP/IP

- Device Controller
- VME/IOC
  - Channel Access

- Device IOC
- IOC
  - Channel Access

CA Everywhere
Overview of controls at KEK

◆ VME + Unix (1990~)
  ✤ Standard model (later EPICS) configuration
    ✤ With several fieldbuses

◆ Every controller on IP network (1993~)
  ✤ 2-layer physical, 3-layer in logical (Linac, J-PARC)

◆ Every controller with EPICS IOC (2005~)
  ✤ Channel Access everywhere (CA Everywhere)
    ✤ Good for rapid development and smooth maintenance
    ✤ May need some consideration on network management
Embedded EPICS IOCs at (Super)KEKB

◆ Not only information server, but also the same software framework on every controller

- Rapid development and smooth maintenance
- µTCA LLRF module: Linux/FPGA (Odagiri…)
- Yokogawa PLC: Linux CPU (Odagiri…)
- Oscillo. 50Hz measurement: Windows (Satoh…)
- MPS management :Linux/FPGA (Akiyama…)
- Timing TDC: Linux/Arm (Kusano…)
- Power modulator: Linux/FPGA (Kusano…)
- Libera BPM at 50Hz: Linux/FPGA (Satoh…)
- NI cRIO : CAS/FPGA (Odagiri…)
- Many more…
Simpler PLC Usage under EPICS

Conventional PLC usage with asynchronous access

If necessary, we can combine

Logics are confined in PLC, and management is easier
2nd: Dual-layer Controls

- Another layer in addition to EPICS/CA
  - Event system helps EPICS with another channel
  - Additional functionality, synchronization and speed
Dual-layer Controls

- **IOC controls via Conventional EPICS CA**
  - Above 1ms, ordered controls

- **Fast FPGA controls via SFP/Fiber**
  - 10ps ~ 100ms, 114MHz synchronous controls

![Diagram of Dual-layer Controls](image)
Fast Global Synchronous Controls

- MRF’s series-230 Event Generator / Receivers
- VME64x and VxWorks v5.5.1
- EPICS R3.14.9 with DevSup v2.4.1
- 17 event receivers up to now

- 114.24MHz event rate, 50Hz fiducials
- More than hundred 50Hz-analog/timing param.
- Multi/single-mode fiber
- Timing precision is < 10ps.
- < 1ps with external module.
Event Manipulation

**Human Operator**

Arbitrate and Generate Beam Mode Pattern (in PythonTk)
considering priorities of the ring accelerators
equalizing pulsed power supply interval
in arrays of length 2 (40ms) to 500 (10s)
each element corresponds to a 20-ms time slot and a beam mode

**Injection Programs**

Generate Events for the Next 20-ms Time Slot (in Event Generator)
reading two consecutive elements from the beam mode pattern
generate several events for the next pulse
generate preparation events for the next after next

Generate Signals based on Received Events (in Event Receiver)
generate pulsed signals as prepared in the previous time slot
program the signals (analog value, delays, etc) for the next
start to generate analog signals for the next

Flexible with script and reliable/fast with FPGA.
**One Machine, Multiple Virtual Accelerators (VAs)**

- Control/Monitor are carried dependent on a VA
  - Mostly independent between VAs
- Independent parameter set for each VA, one of the VAs is controlled at a time
  - VAs for Injections (HER (e-), LER (e+), PF, PF-AR) and Linac-only in SuperKEKB project

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**Event-based Control System**

- **PF Injection**
  - e⁻ Gun
  - e⁺ Target
  - e⁻ BT (PF: 2.5GeV, 0.1nC)

- **KEKB-LER Injection**
  - Primary e⁻ (4GeV, 10nC)
  - e⁺ Target
  - e⁺ BT (KEKB: 3.5GeV, 0.6nC)

- **KEKB-HER Injection**
  - e⁻ Gun
  - e⁺ Target
  - e⁻ BT (KEKB: 8GeV, 1.2nC)
Multiple Closed Loop Controls Overlapped

◆ Closed loops can be installed on each VA independently

◆ Tested at KEKB
Towards SuperKEKB

◆ Upgrade of controllers for each type of device
  ❖ Discussions with device groups, for aging controllers

◆ Base software components, OS, EPICS, CSS, (Scripting) Languages
  ❖ Especially EPICS Collaboration-based software

◆ Operational software
  ❖ Archiver, Archive viewer, Alarm, e-Log, etc

◆ Information sharing to offices
  ❖ More Web based application software

◆ Seminar and training

◆ IP Networking, Wireless LAN, Console Desk, etc
Accelerator Controls

◆ It’s a fan to interact with all the components of the accelerator through control hardware and software.

◆ It’s a fan to interact with all the staff members of the project in order to design and improve controls.

◆ We can contribute to the machine performance and the results even without realizing it.
Conclusion

◆ Control efforts have contacts with all activities in the particle accelerator. We are at the privileged position to enjoy it.

◆ Based on existent KEKB controls, “CA Everywhere” and “Dual-layer Controls” should be enforced.

◆ With some Phronesis (Greek: practical wisdom, ability to understand the universal truth), we believe we can achieve the target.
Thank you
Thank you