Energy Feedback Systems at KEKB Injector Linac

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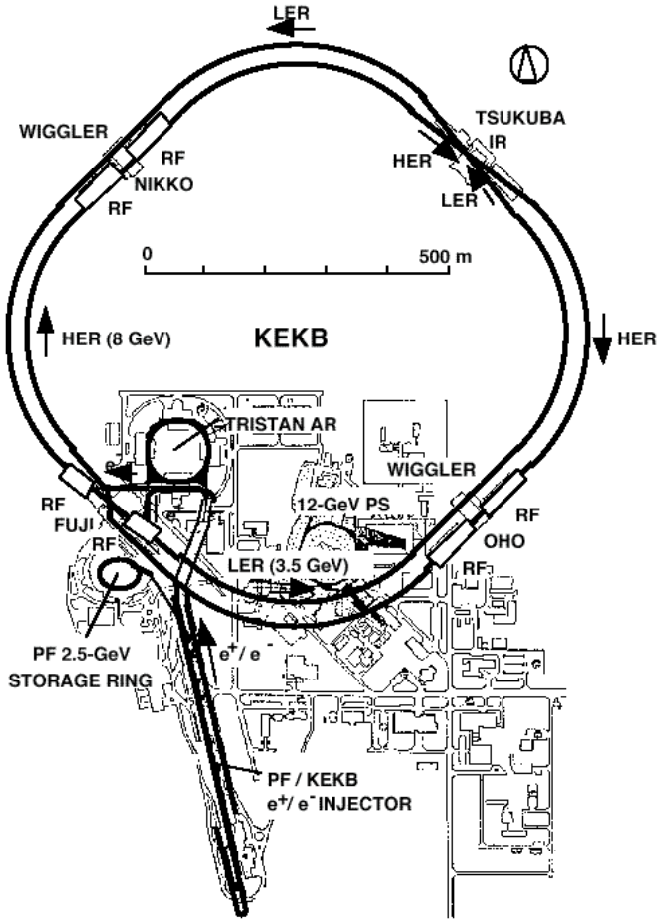
KEKB Linac Commissioning Group
Electron Linac Control Group

Introduction, KEKB Linac

- Stable and Robust Operation of Linac for Higher Experiment Efficiency
- Many Active Operation Parameters at Microwave Systems, etc.
- Frequent Switching between

KEKB e^-	8GeV 1.2nC Single Bunch
KEKB e^+,	3.5GeV 0.64nC Single
	(Primary e^- 10nC)
PF e^-	2.5GeV 0.3nC Multibunch
AR-PF e^-	2.5GeV 0.5nC Multibunch



Linac Beam Parameters & Stability

- Precise Tuning of the Beam Parameters
  energy, orbit, emittance, energy spread,
  bunch profile, bunch charge, beam timing
- Each Component of Linac was Designed to Satisfy
  Predefined Values
- Simultaneous Fluctuation of
  Electric Power or Temperature
- Interim Failure of Linac Equipment
- KEKB Luminosity Degradation
- Linac/Ring Equipment may be Damaged

Beam Parameter Fluctuation & Stabilization

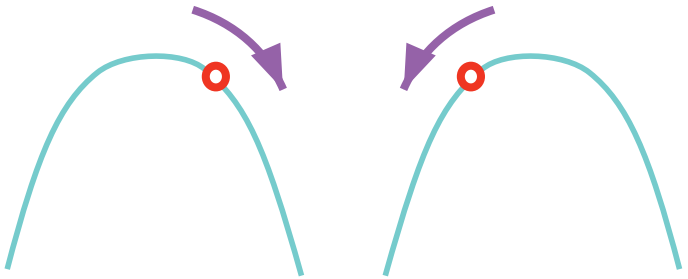
- If certain Instability was Observed
  We have to Hunt the Source
  to Fix the Problem (if possible) or to Form a Closed Loop
- To Find the Source, Correlation Analysis
  and Singular Value Decomposition (SVD)
- Often the Source is Attributed to the Linac Injector Section
  where Many Devices Reside
- Feedback Loop without Resolving the Real Source
  Choosing certain Pair of Monitor & Tuner, Still Effective
- (Instead of Simple Feedback, Sophisticated Method like
  Downhill Simplex or Global Orbit Correction
  But Important Defects may be Hidden)

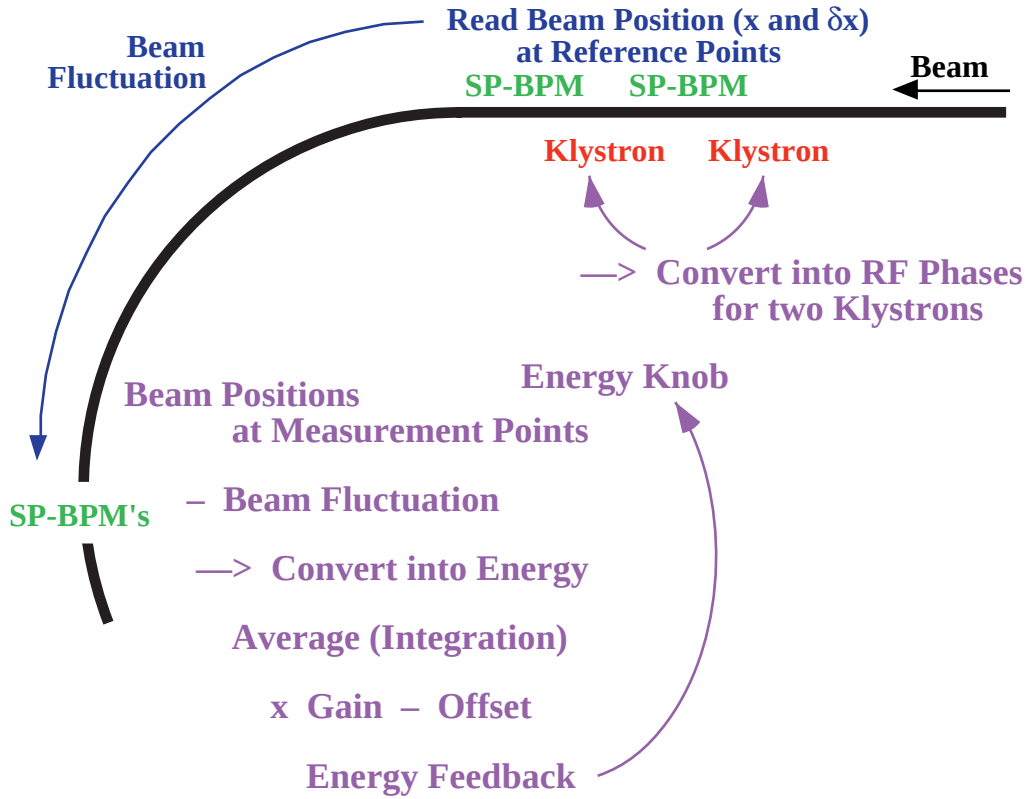
Beam Monitors

- Computer Readable Beam Instrumentation
  - Strip-line type Beam Position Monitors (BPM)
  - Streak Cameras for Beam Bunch Profile
  - Wire Scanners for Transverse Beam Profile
- To Find the Beam Energy
  - BPM Readout where Dispersion is Large
- Noise: External Electric Noise mainly from Klystrons
  - Integration; Resolution, Frequency, Dispersion
- Noise: Beam Orbit Fluctuation (Betatron Oscillation)
  - Can be Derived from Orbit at Straight Section

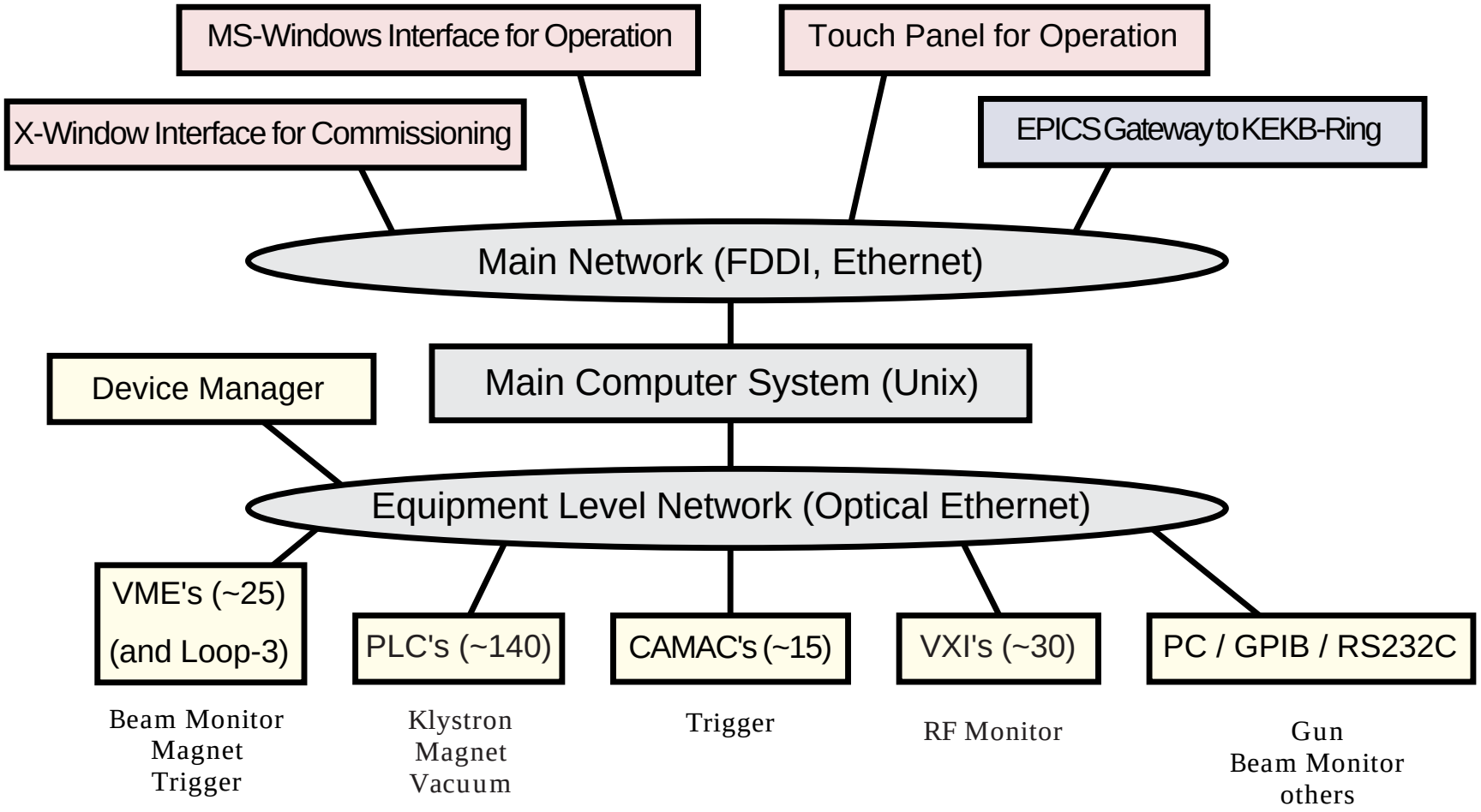
Beam Energy Tuner & Feedback

- Energy Tuner — Energy (Software) Knob
  Microwave Phases at two Adjacent Klystrons
  (Voltage may change both Phase and Amplitude)



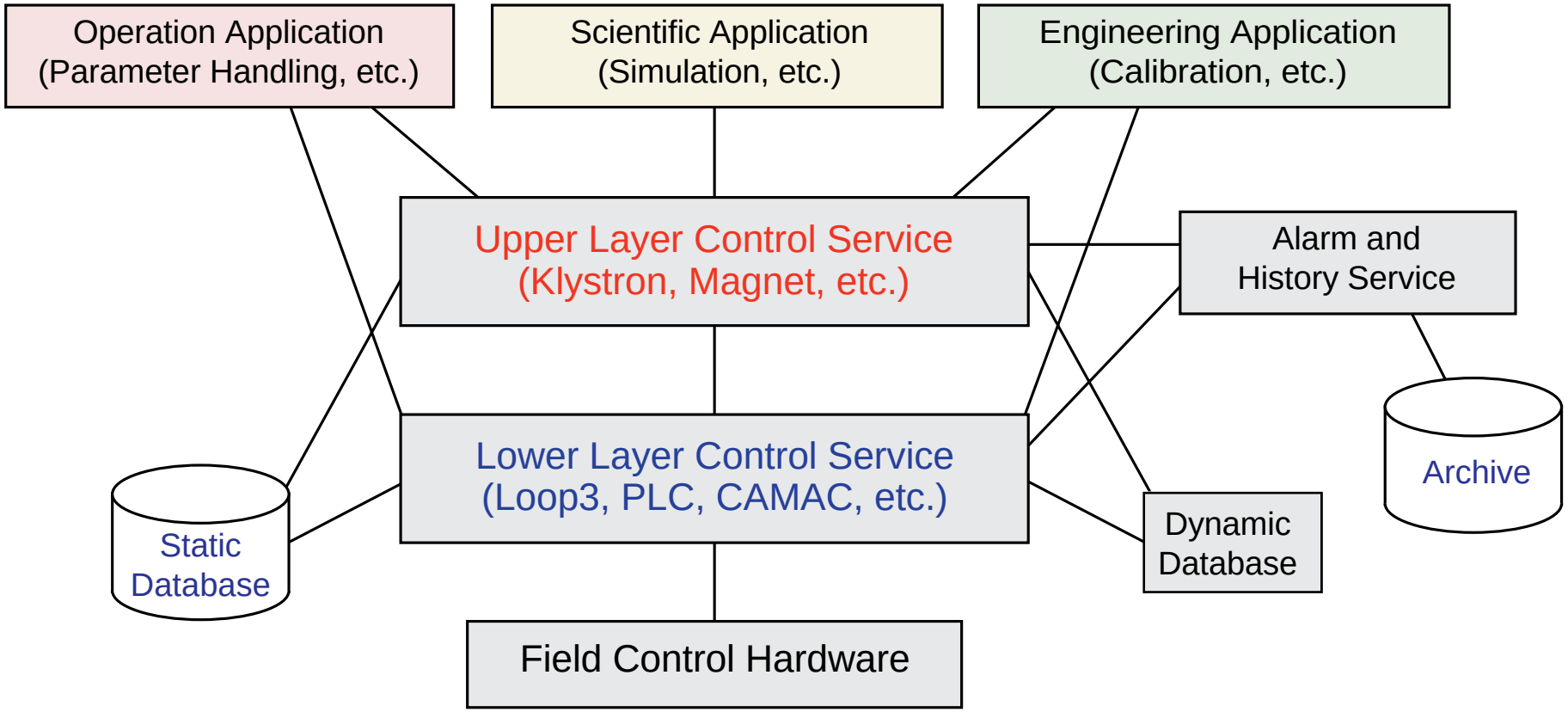


Physical Configuration of KEKB 8-GeV Linac Control System



There are many kinds of local controllers, but, they all communicate through UDP/RPC over switched optical Ethernet segments.

Logical Configuration



Each lower layer software supports corresponding field controllers. Upper layer software hide differences between controllers and serves accelerator equipment controls to clients. While UDP-based RPC protocol is used at lower layer, upper layer make use of TCP-based one.

Software Architecture

- Client to Linac Control System via RPC
  Written in Tcl Script Language to Maximize Flexibility
  Employing Tk Widget to Enable Runtime Configuration
- 1) Check Condition: Beam Operation Mode, Beam Charge
- 2) Determine Monitor Value:
  Limit, Integration, Betatron Isolation, Post-process(Tcl)
- 3) Calculate Feedback: Conversion, Gain, Frequency, Dead-band
- 4) Tune: Pre-process(Tcl), Limit, Control thru Energy Knob
- 0) Controls: Flow Control, Error Check, Graph, Log,
  Remote Control (Tcl/Tk send) from other Applications
  (ex. global orbit correction, status viewer)

Other Feedback Loops

- Simple Orbit Feedback

  Monitor: Weighed Average of BPM's

  over 1 Betatron Wavelength based on Steering Response

  Tuner: Two Steerings with 90-degree phase advance

  (Difficult to Predict Orbit Because of Wake Fields)

- Simple Device Feedback

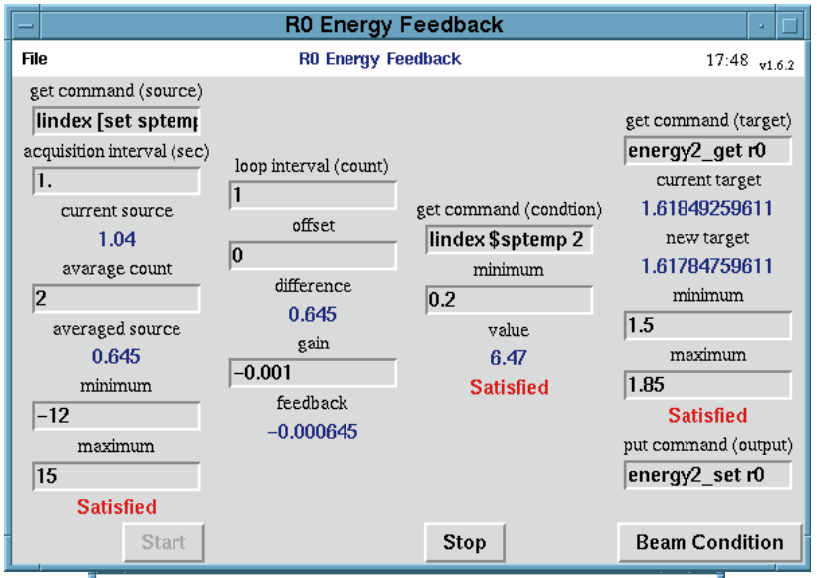
  As a Quick Fix

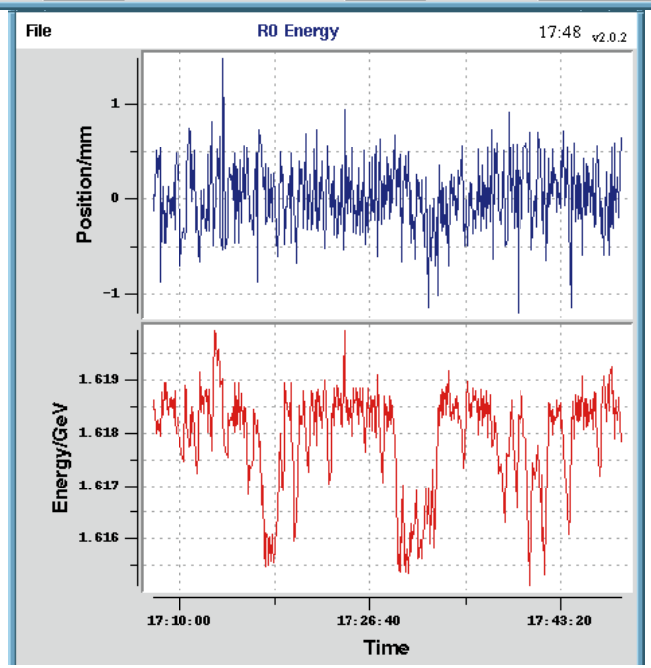
  Voltage of two Guns

  Amplitude and Phase of two Sub-Harmonic Bunchers (SHB)

Example

- Any Parameters can be Changed at Any Time
- Runtime Debugger to Test Internal Variable / Routine





Linac Feedback Status

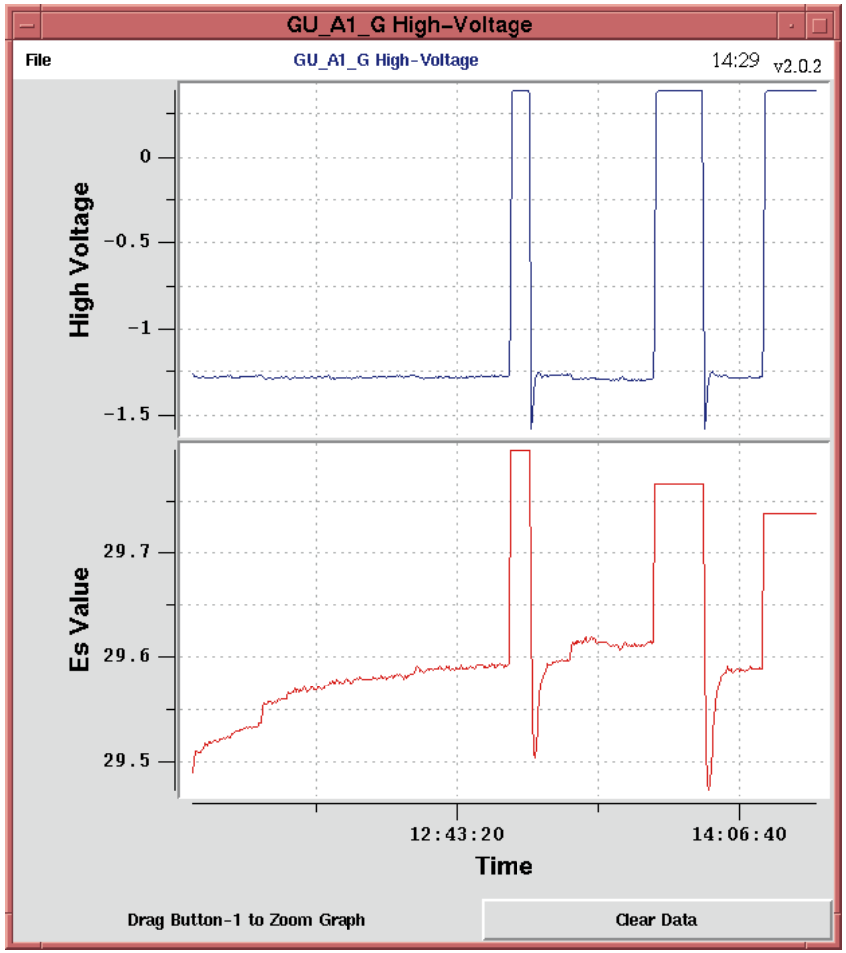
File — Linac Feedback Status — 10:35 v1.1.2

(sorry, but Information below can be False)

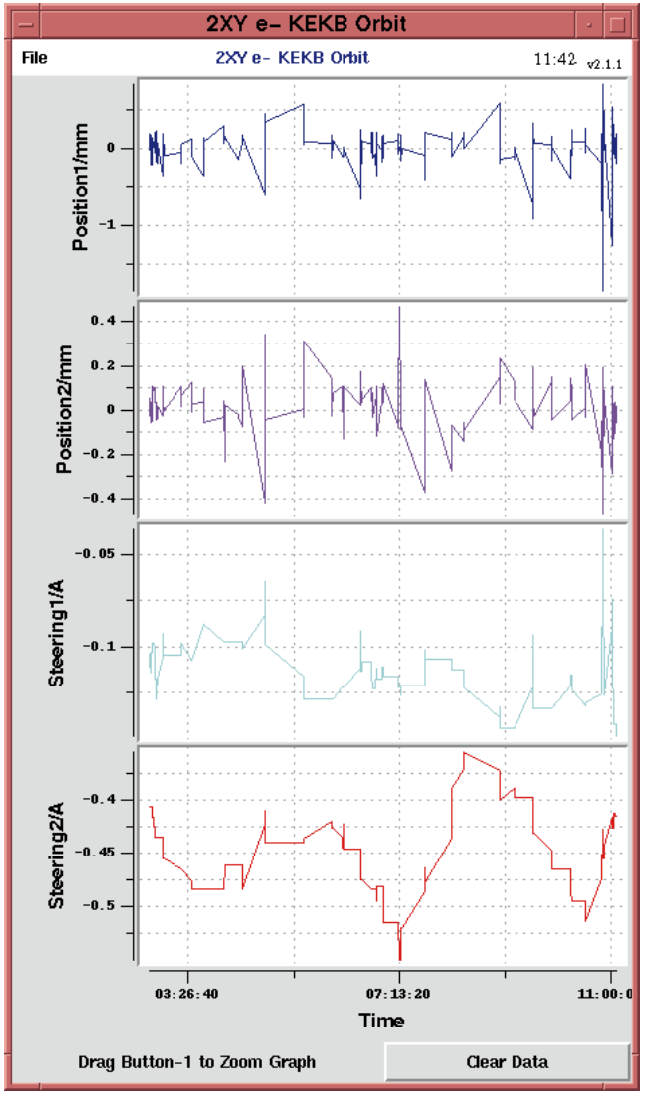
Title	Name	Display	Hostname	Start	Status1	Status2	Status3	LastGet	LastPut
Energy BCS	tkfb-bcs	xp400d2:0	lychee.kek.jp	Start	Beam onA Denied	Satisfied		08:54:23	08:54:24
GU_A1_G HV	tkfb-guna1	xp217c:0	grape.kek.jp	Start	Satisfied	Satisfied		10:24:35	10:24:45
Energy KEKB e-	tkfb-kbe	xp400g2:0	lychee.kek.jp	Start	Beam onA Denied	---		09:43:01	09:42:53
Energy KEKB e+ 61	tkfb-kbp #2	xp400g2:0	lychee.kek.jp	Start	Beam onA Denied	Satisfied		08:54:21	08:54:22
Energy KEKB e+ BT	tkfb-kbpbt	xp400g2:0	plum.kek.jp	Start	Beam onA Denied	Satisfied		08:54:24	08:54:27
Orbit 1XY KEKB e+	tkfb-orbit1XYpk #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	Satisfied		08:54:24	08:54:34
Orbit 5X KEKB e-	tkfb-orbit2 #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:57	09:42:55
Orbit 2XY KEKB e-	tkfb-orbit2XYek #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:54	09:42:42
Orbit 5X KEKB e+	tkfb-orbit2p #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		08:54:25	08:54:13
Orbit 5Y KEKB e-	tkfb-orbit5Yek #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:58	09:42:35
Orbit A1X KEKB	tkfb-orbitA #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:55	09:42:32
Orbit A1Y KEKB	tkfb-orbitA2 #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:50	09:42:38
Orbit BX KEKB	tkfb-orbitBX #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:58	09:42:56
Orbit BY KEKB	tkfb-orbitBY #2	xp400d2:0	plum.kek.jp	Start	Beam onA Denied	---		09:42:50	09:42:38
Energy R0	tkfb-r0	xp400d2:0	lychee.kek.jp	Start	Beam onA Denied	---		09:43:00	09:42:55
SH_A1_S1 Power	tkfb-shb1	xp217c:0	grape.kek.jp	Start	Satisfied	Satisfied		10:24:47	10:24:37
SH_A1_S8 Power	tkfb-shb2	xp217c:0	grape.kek.jp	Start	Satisfied	Satisfied		10:24:29	10:24:39
SH_A1_S8 Phase e-	tkfb-shb2ph	xp217c:0	grape.kek.jp	Start	Beam onA Denied	Satisfied		09:43:01	09:43:09
SH_A1_S8 Phase e+	tkfb-shb2php	xp217c:0	grape.kek.jp	Start	Beam onA Denied	Satisfied		08:54:12	08:54:20

Last Update: Aug 03 10:24:49 — Update

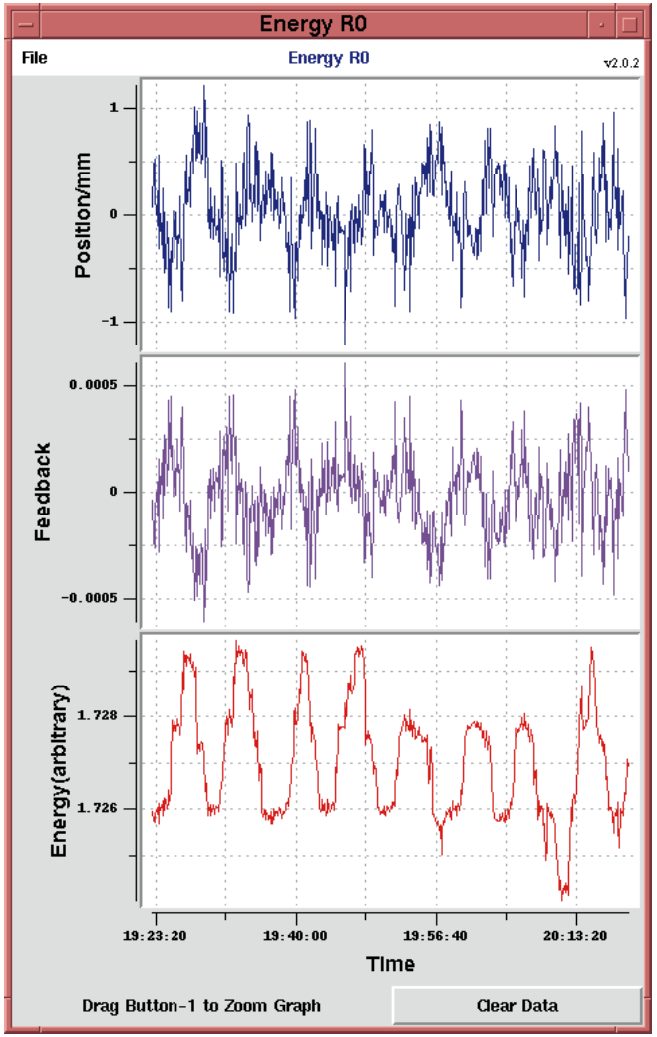
- Gun Voltage Change
  after Power-on
  which was not Expected in the Design



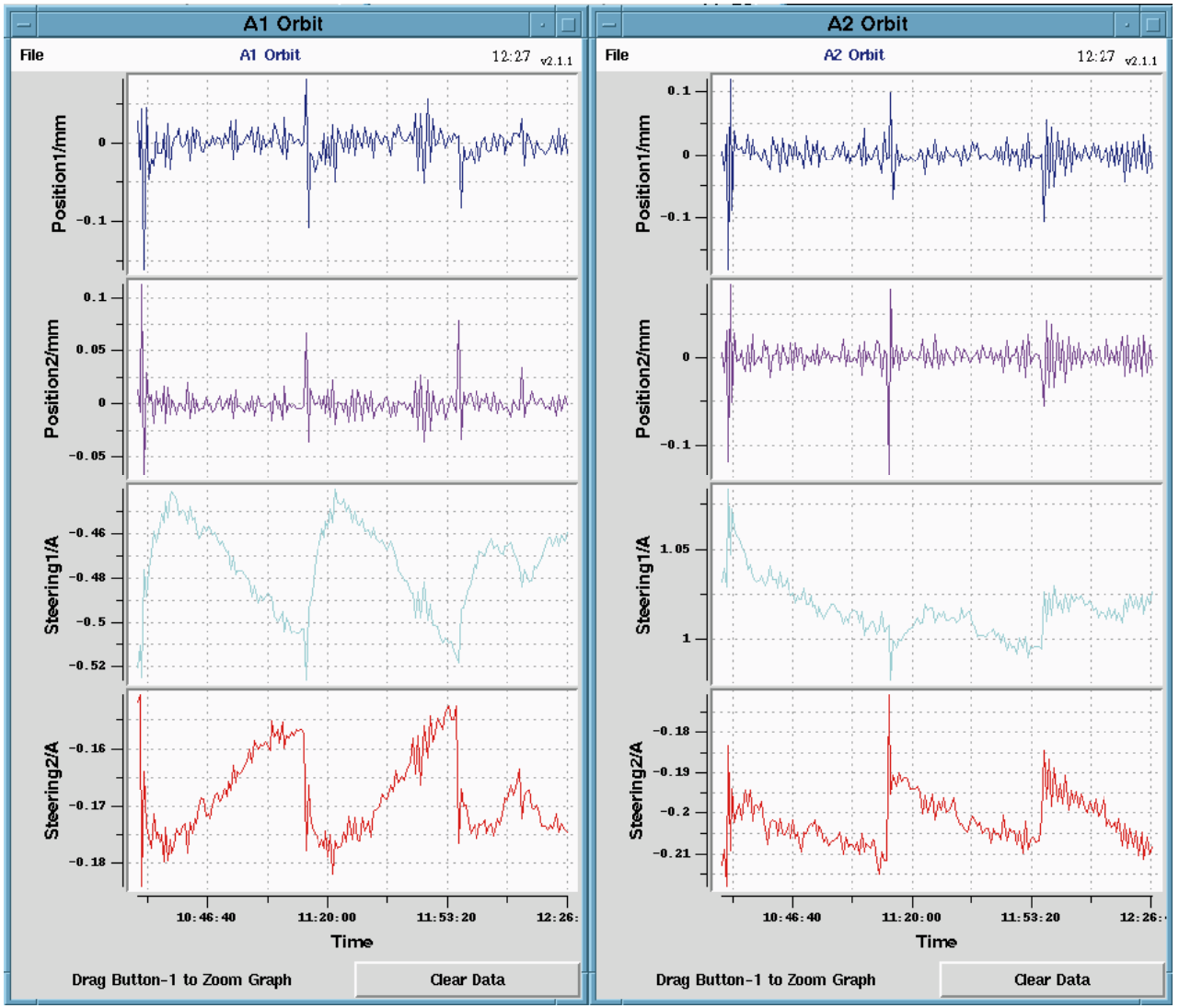
- Orbit Daily Change,
  Peaks at 6 o'clock,
  Later Attributed to SB_C



- 7-min-Period Energy Change, Later Attributed to Air Conditioner at KL_A1



- 40-min Period Orbit Change, Later Attributed to SHB



Discussions

- GUI Improvement to Avoid Human Errors
- Betatron Orbit Isolation is not Mature Enough
  Need more Study on Beam Optics with Wake Field
- 50-Hz BPM Readout (instead of 1-Hz)
  at least to Make Numerical Integration Better
  to Suppress Frequency Component Above 1Hz
  (50-Hz Phase Shifter is under Development)
- Not only Energy Center Value but also Energy Spread
  Improved Software for Wire Scanners
  Not Linear but Quadratic: Optimization Feedback

Conclusions

- Suppress Energy Fluctuation to a Half or a Third
- Installed at 6 Locations and Used Routinely
  for 4 Beam Operation Modes
- The Same Software was Applied to
  12 Orbit and 6 Equipment Feedback Systems
- Is Possible to Install and Modify quickly
  with the Script Language Tcl/Tk
- Helps not Only Routine Operation
  but also the Beam Commissioning Greatly
  Primitive but Indispensable even to Carry Study

Linac Control System Overview

- Rejuvenation in 1993
  with a New Equipment-Oriented Design
- Unix, VME, TCP/IP,
  International and de-facto Standards
- Old Field Controllers Kept Running
- Redundant Unix Servers
- Layered Software to Serve Equipment Services
- Homemade RPC Protocol at both Internal / External
- No Strict Standard for Field Controllers
  but Diskless and UDP at Least
- Upper Layer Software Hides Lower Layer Differences
- Memory-Resident Hashed Database
  and Cached Field Information

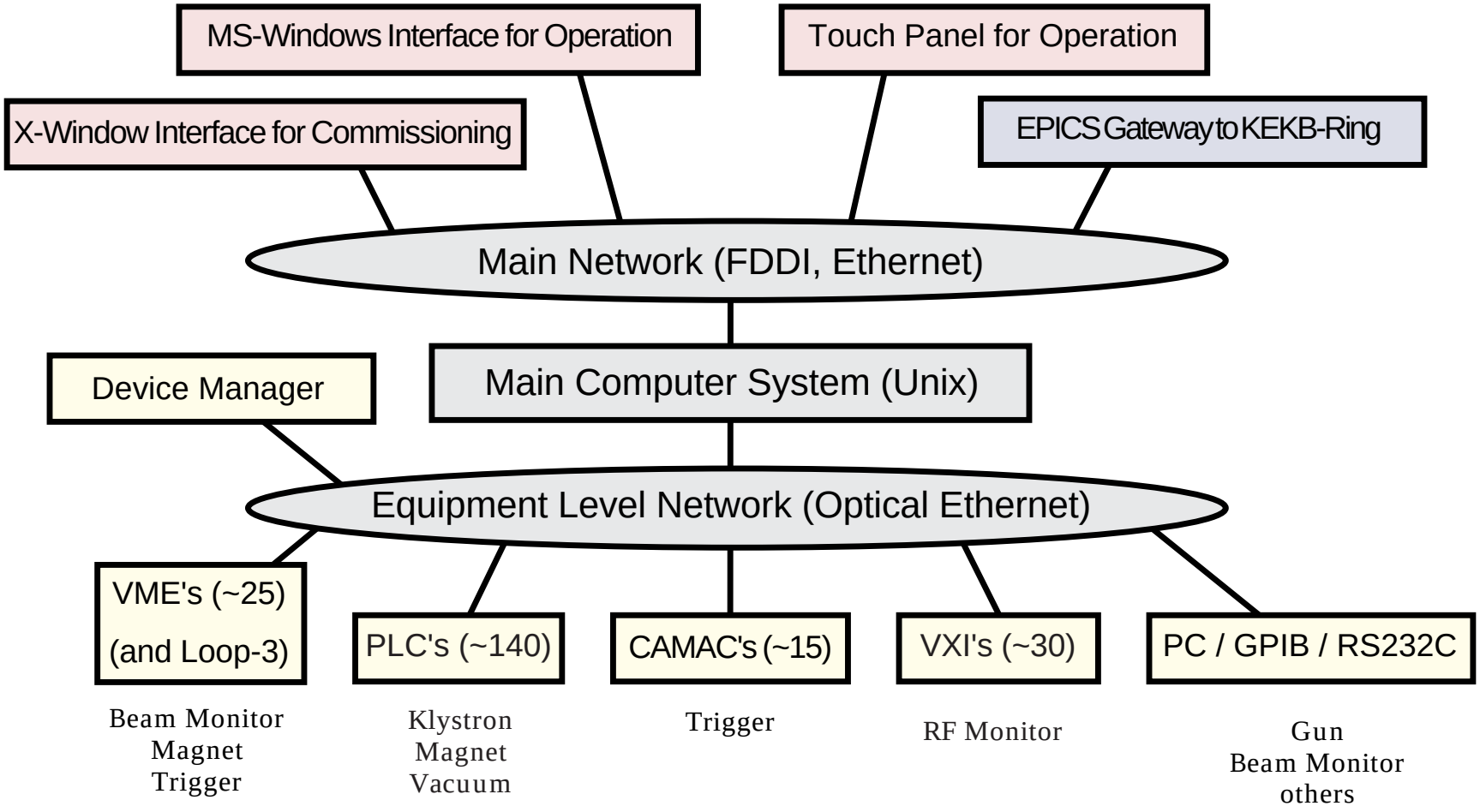
Control Network System

- FDDI and 100Base-Tx / 10Base-T Ethernet at Center (about 100 computers / controllers)
- 10Base-FL (Optical) Ethernet at Fields to Avoid Klystron Noises
- About 200 10Base-FL Field Controllers
- Layered Switches and Repeaters in Star topology
- Redundant Configuration at Central Network and Upper Field Network

Layered Configuration in Control Systems

- No Resources to Replace all Field Systems
- At least two Layers to Manage each Components of Hardware and Software
- Must Survive Long Term in spite of Technology Advance (already 15 years and maybe 10 years more)
- Layered Architecture with well-defined Interface is Necessary

Physical Configuration of KEKB 8-GeV Linac Control System



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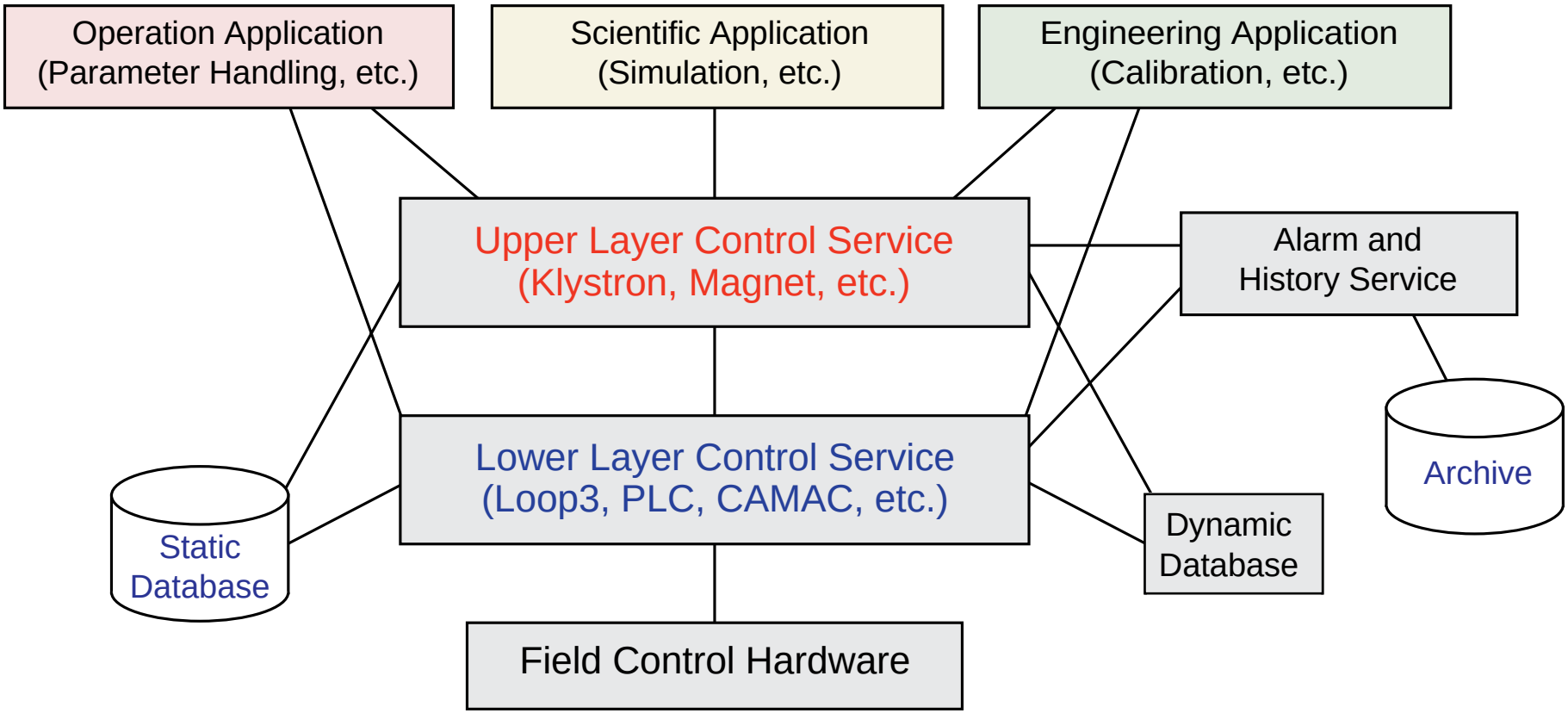

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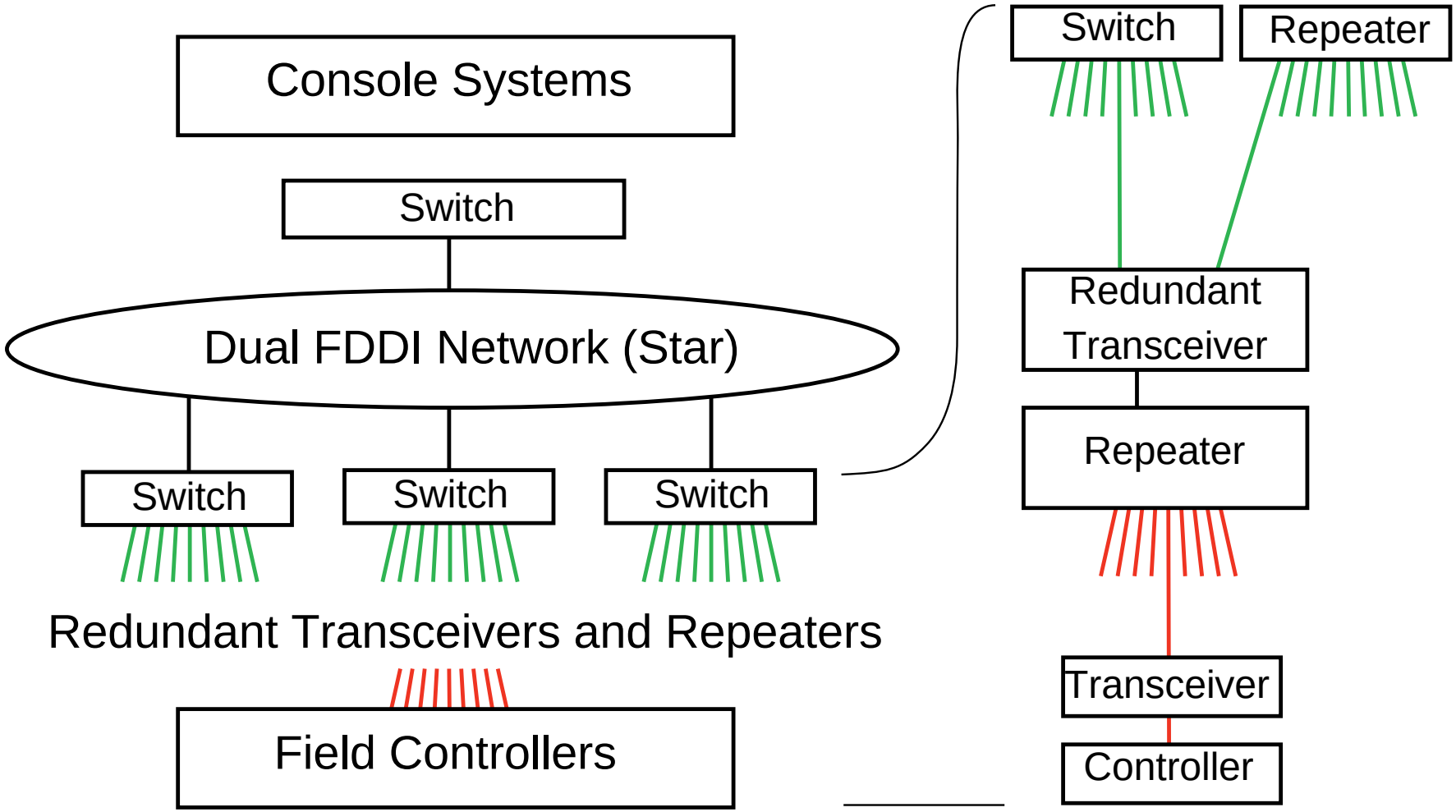
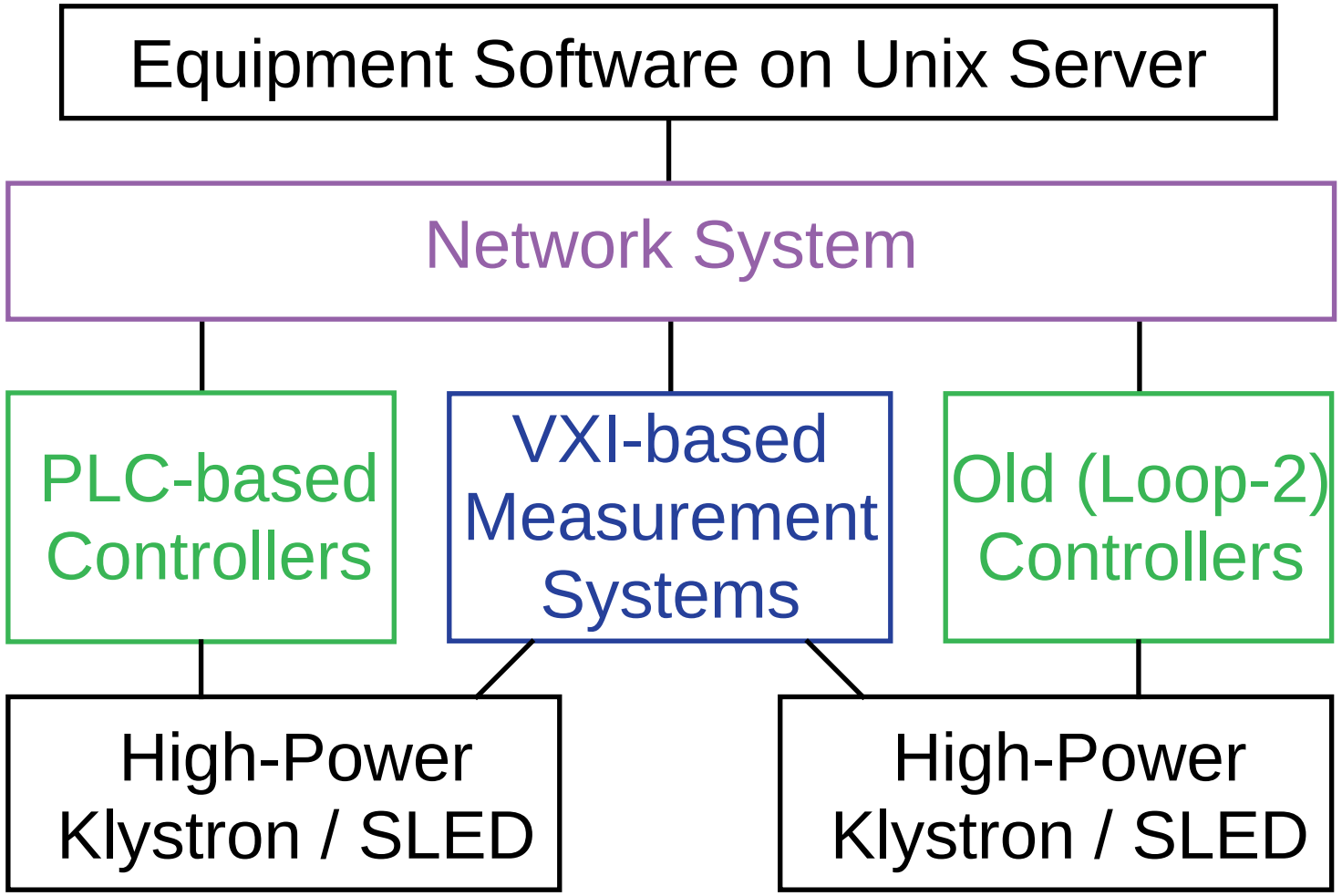
Network Configuration of Linac Controls



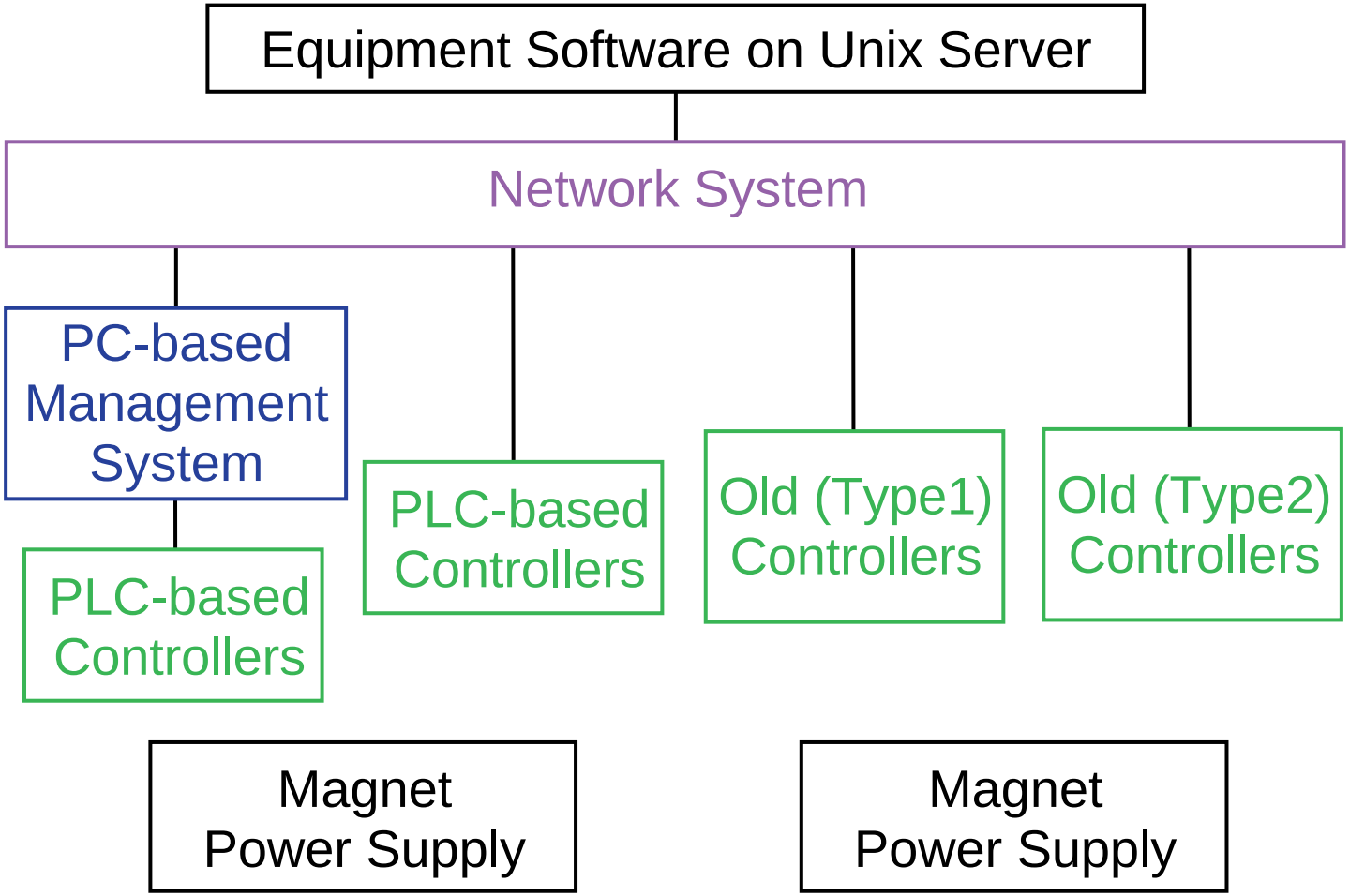
33 field network stations are connected with central switches on FDDI through redundant 10Base-FL Ethernet. Each station is connected to 4 to 10 field controllers. All connections at fields use 10Base-FL because of the klystron noises. Network traffic at important points are monitored via SNMP.

Layered Configuration of RF Controls



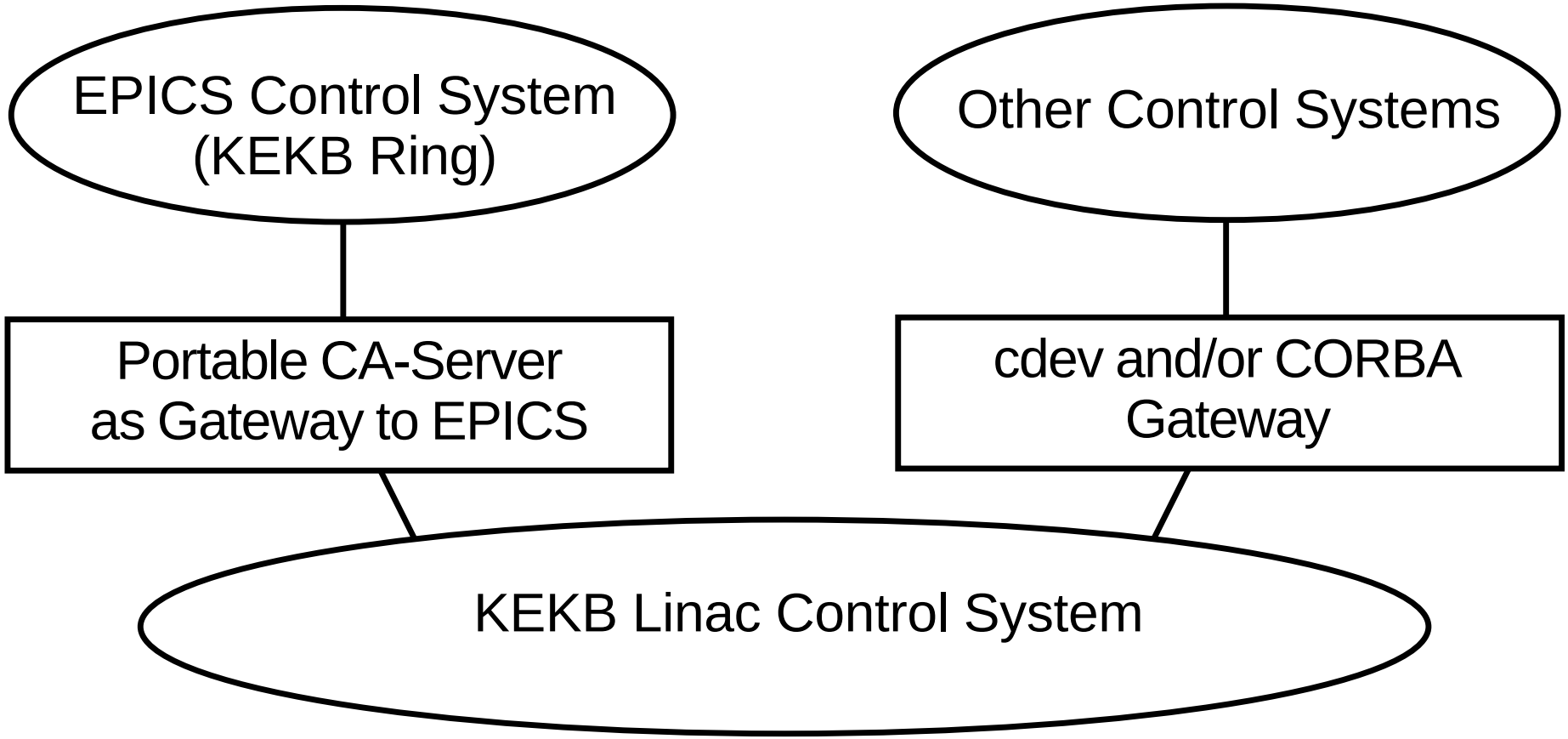
About 30 new controllers (PLC-based), 40 old (microcomputer-based) controllers and 30 VXI-based measurement systems are connected with the central control software, which is designed to hide local differences.

Layered Configuration of Magnet Power Supply Controls



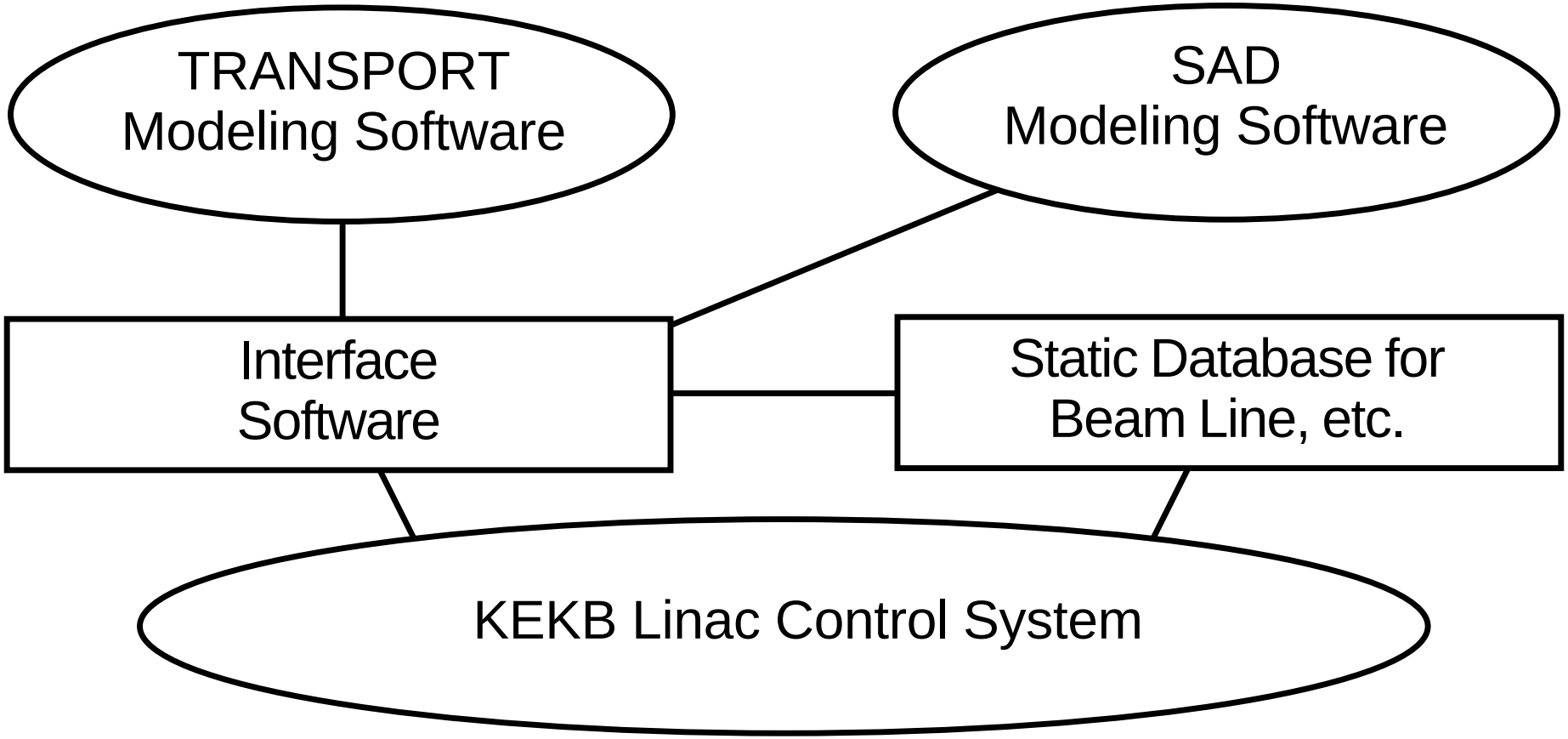
There are 4 types of local controllers for magnet power supply controls. Its central control software is designed to hide those differences.

Interoperability with other Control Systems



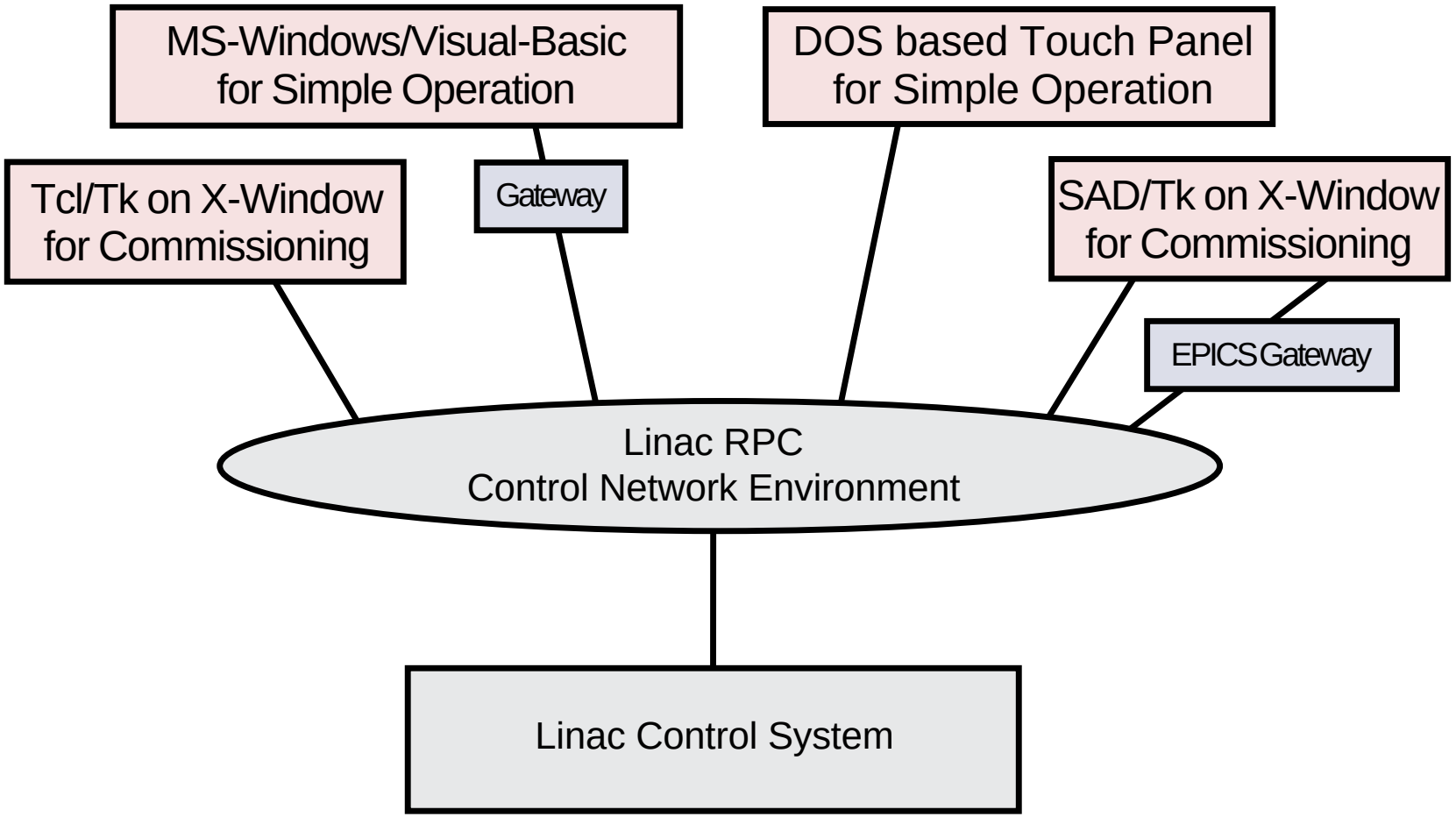
Layers which are planned on top of the linac control system. Portable CA-Server is being installed. These layers will expand the linac control system and increase the interoperability.

Online Accelerator Modeling on Top of Control Systems



An interface layer is provided to enable online accelerator modeling. Currently two software packages are mainly used. It is a kind of the operator interface, but with large specific database.

Accelerator Control Applications at KEKB 8-GeV Linac



Script languages are utilized for graphical operator interfaces, while client codes for Linac remote procedure calls are written in C. The Linac is operated from the KEKB main control room, although the Linac control room is still active mainly for Photon Factory injection. (SAD is an accelerator designing software developed at KEK, which now has its own script language and X-Window interface through Tk.)

Conclusions

- Software resources can be shared easily between Unix control system and Windows consoles with small modification, and they provide good performances.
- Shared libraries (DLL) could be built to generate links to languages other than C/C++ like Visual-Basic or Tcl, etc. That part was not tested much yet.
- This scheme provides an interim solution without any loss.