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Design and Construction of Accelerator Control Systems

August 28, 2000

KEKB Controls Group

Tadahiko Katoh

Tasks of an Accelerator Control Group

- **Accelerator Control Computer System**
  - **Server Workstations and Front-end Computers**
  - **Network**
  - **I/O Interfaces**
- **Operator's Console**
- **Communication System**
- **Timing System**
- **（Safety Management System）**

Tasks (continued)

- **Software Development Environment**
  - **Tools for developing Application Programs**
- **Accelerator Database**
  - **Accelerator Components**
  - **Wiring Lists**
  - **Accelerator Parameters**
- **Education & Training for Link-Persons**

Designing Accelerator Control Systems

- Analyses of Requirements
- Restrictions and Conditions
- Basic Concepts
- System Architecture
- Cost Estimation

Requirements to the System (1)

- **Who do make requests?**
  - **Hardware Groups**
  - **Operations Group**
  - **Accelerator Physicists Group**
  - **Controls Group**
  - **Users Groups**

Requirements (2)

- **Requirements for Controlling Accelerator Hardware**
  - **Status Display of the Accelerators**
  - **Setting of Accelerator Hardware**
  - **Alarm Indication**
  - **Safe System**
    - **Radiation Safety Management**
    - **Personnel Protection**
    - **Machine Protection**
  - **Number of Points to be Controlled (KEKB= 50,000)**
  - **Data Taking Interval：0.01 Hz - 100 Hz**
  - **Number of Operations per Second: 50,000 Operations/sec.**

Requirements (3)

- **Requests from Accelerator Physicists**
  - **Take all the data that can be taken.**
  - **Store all the data that are taken for later analyses.**
  - **Record all the operations.**
  - **Close communication with the modeling software(SAD).**
  - **Analyses done by the virtual accelerator.**

Requirements (4)

- **Accelerator Controls for Physics Experiments**
  - **Automation of Process Management and Operation**
  - **Feedback System for Beam Stabilization**
  - **Adaptive Architecture for Easy Modifications of the System**
  - **Unified Management System of the Accelerator**
  - **Information Exchange between Accelerator and Physics Experiment Equipment**
  - **Operator-friendly Human Interface**
  - **Sufficiently Quick Response to Operations**
  - **Programmer-friendly Software Development Environment**

Conditions

- Limited Construction Period
- Usually, the Control System must be Ready at Least 1 Year before the Commissioning
- System Life-time must be Long Enough (More than 10 Years)
- Design a New Efficient Interfaces for Newly Developed Equipment
- Replacement of Old Control System
- Utilize Existing Equipment as much as Possible
  - Utilize Existing Equipment and Wiring
  - Use International Standard Interfaces
- Limited Man-Power

Goal in KEKB Case

- **Schedule**

– System Design	January, 1996
– Design a Part of Relational Database	August, 1996
– Finish Design of the Interface for Power Supplies, Beam Position Monitors	October, 1996
– Control System for Injection Beam Lines	July, 1997
– Install Control Equipment for other Accelerator Components	December 1997
– Start Operation of LER	May, 1998
– Start Operation of HER	September, 1998
– Commissioning of KEKB	December, 1998

Man-Power

- Researchers: 3
- Engineers: 6
- Other KEK Staffs: 5 Part-Time
- Link-Persons: 16 Application
  - Linac, BT, Magnet, RF, Monitor, Vacuum, Physics, SCC, IR
- From Company: 5 → 4

Basic Concepts

- **Standard Model of the Accelerator Control System**
  - **Hierarchical System**
  - **Open System using International Standard Interfaces**
  - **VME, VXI, GPIB, FDDI, ARCNET, CAMAC, MIL-1553B etc.**
- **Utilize Existing Software Environment**
  - **EPICS, Vsystem, etc.**
- **Use of Object-Oriented Style Methods**
  - **cdev, etc.**
- **High-speed Network**
  - **10 base T, 100 base TX, Gigabit Ethernet, FDDI, ATM, Distributed Shared-Memory Network, etc.**
- **Link-person System**

Standard Model of Accelerator Control Systems

- **Hierarchical Three-Layered System**
  - **Presentation Layer**
  - **Process Control Layer**
  - **Device Interface Layer**

Between Layers, Use Standard Interfaces

Modular and Easy to Divide Functionalities

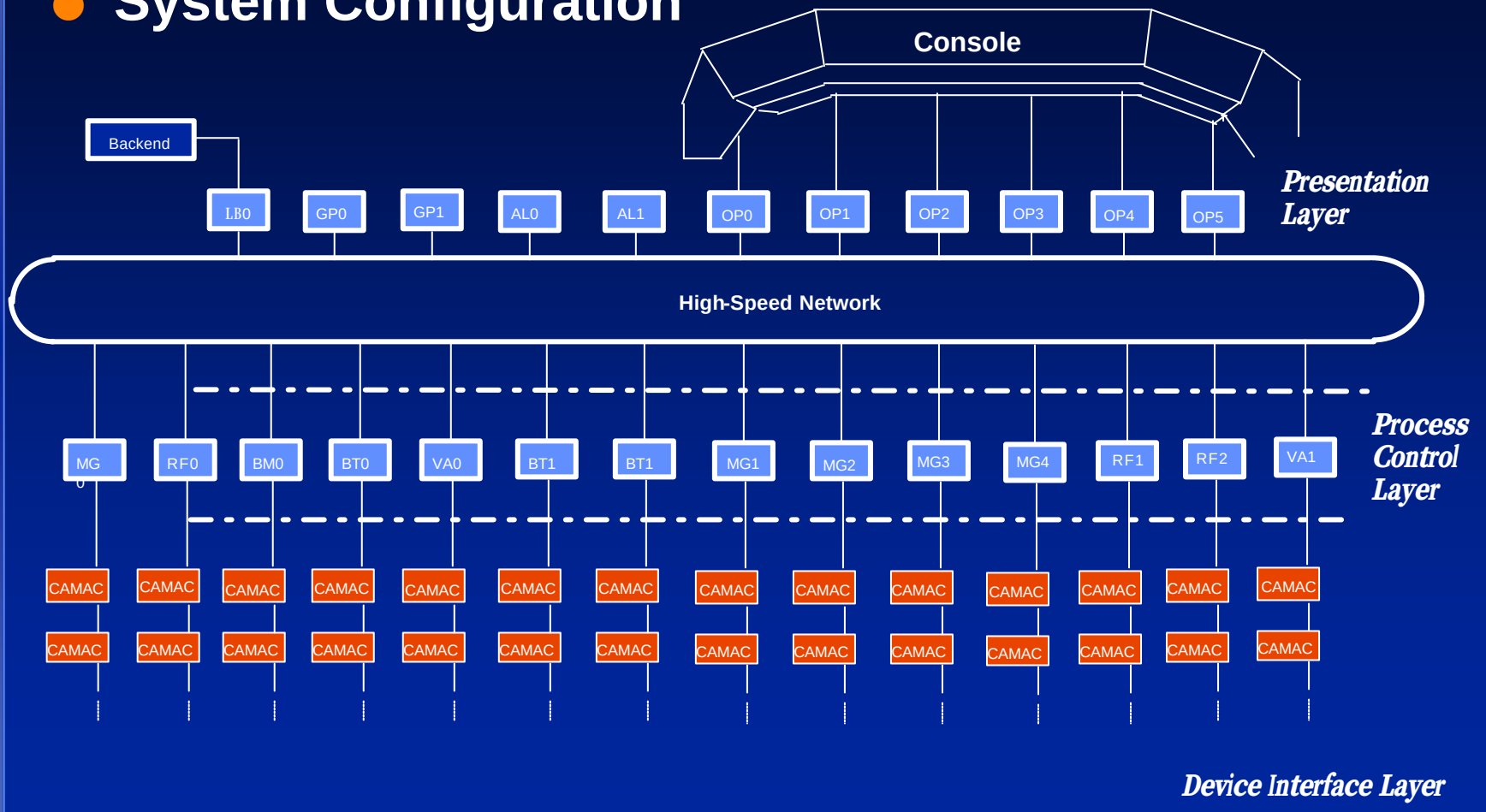
The Partial Modification of the System does not Affect Whole System

Easy to Find and Treat System Errors

Easy to Debug

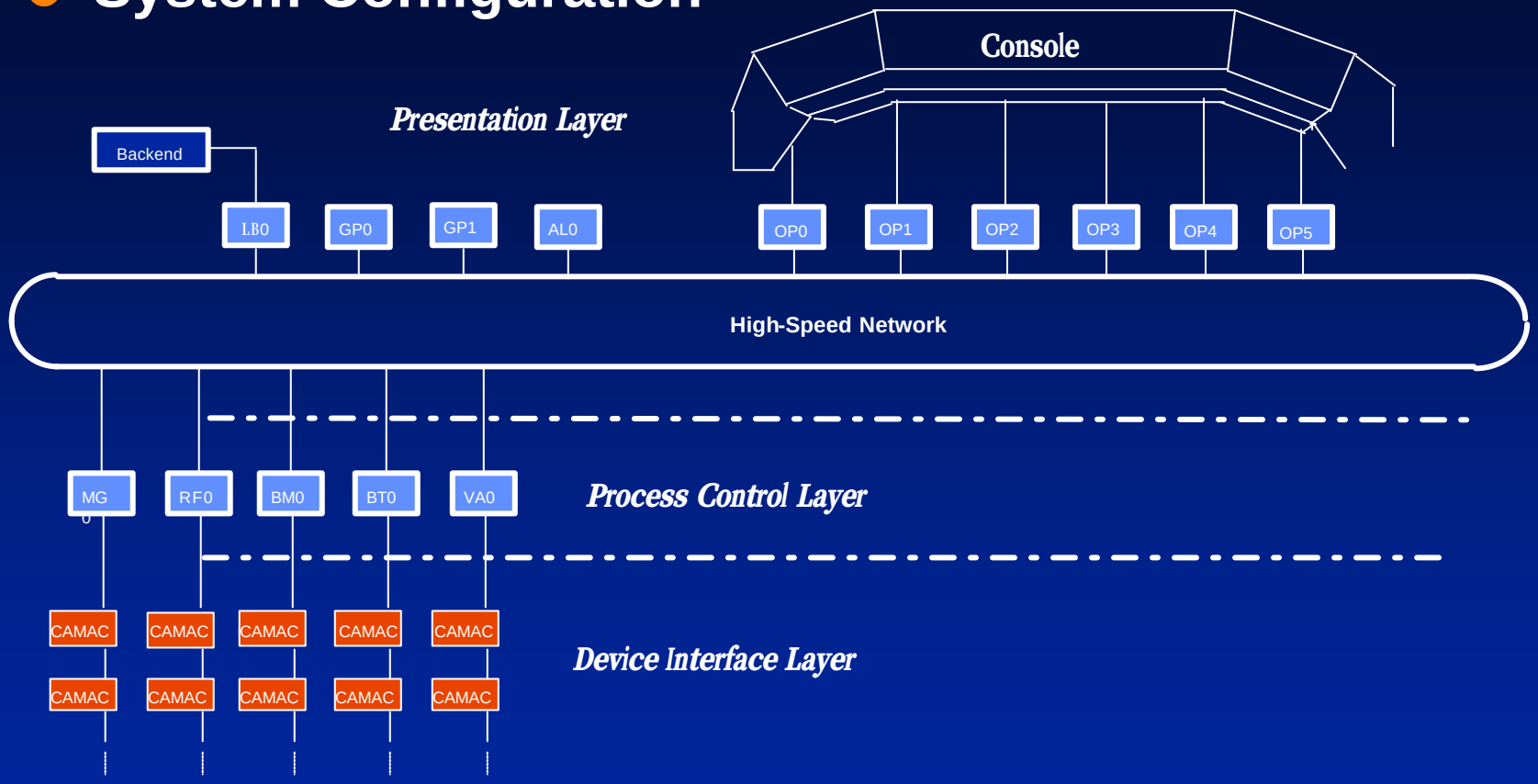
TRISTAN Control System

- **System Configuration**



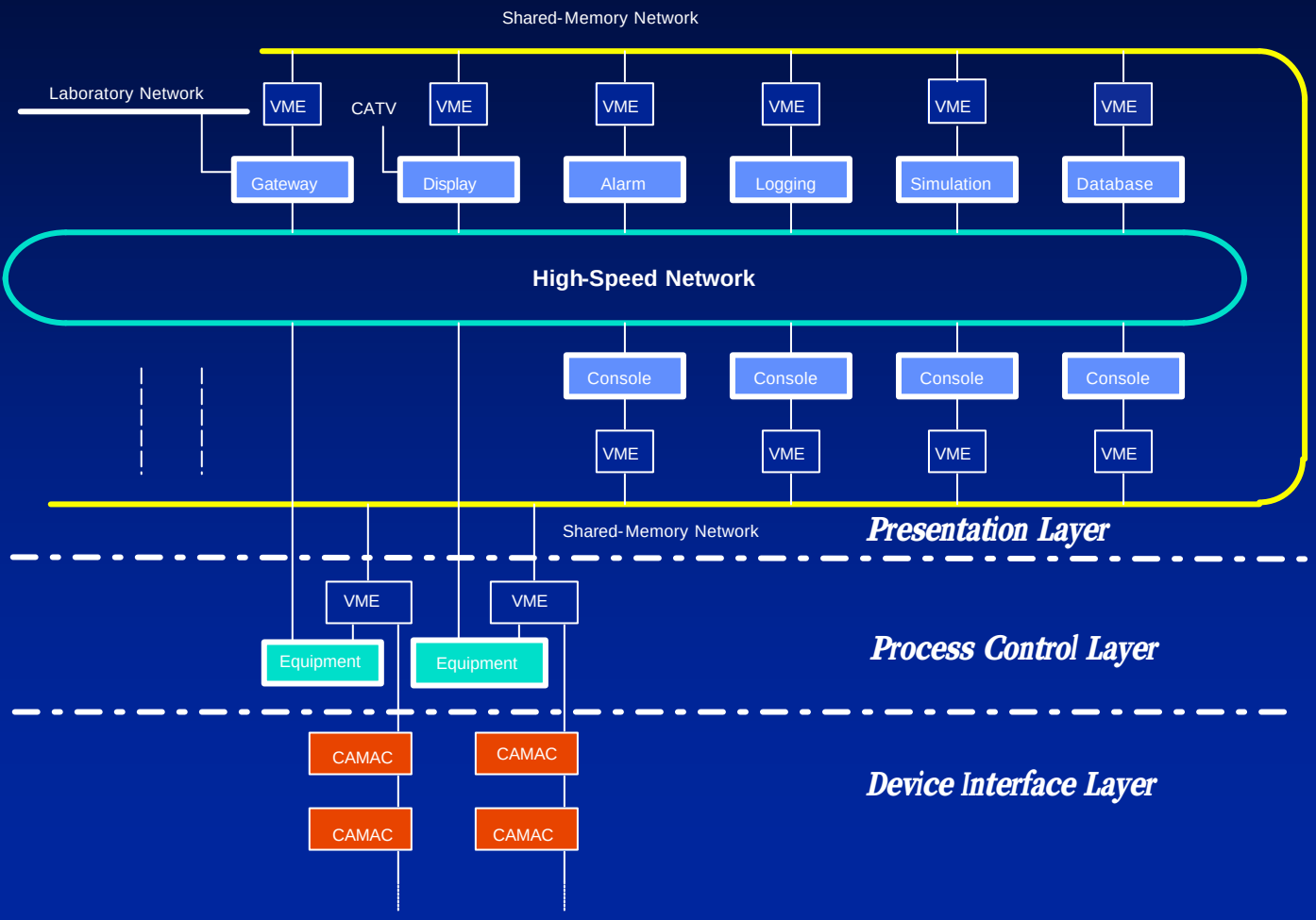
Control System for AR

- **System Configuration**

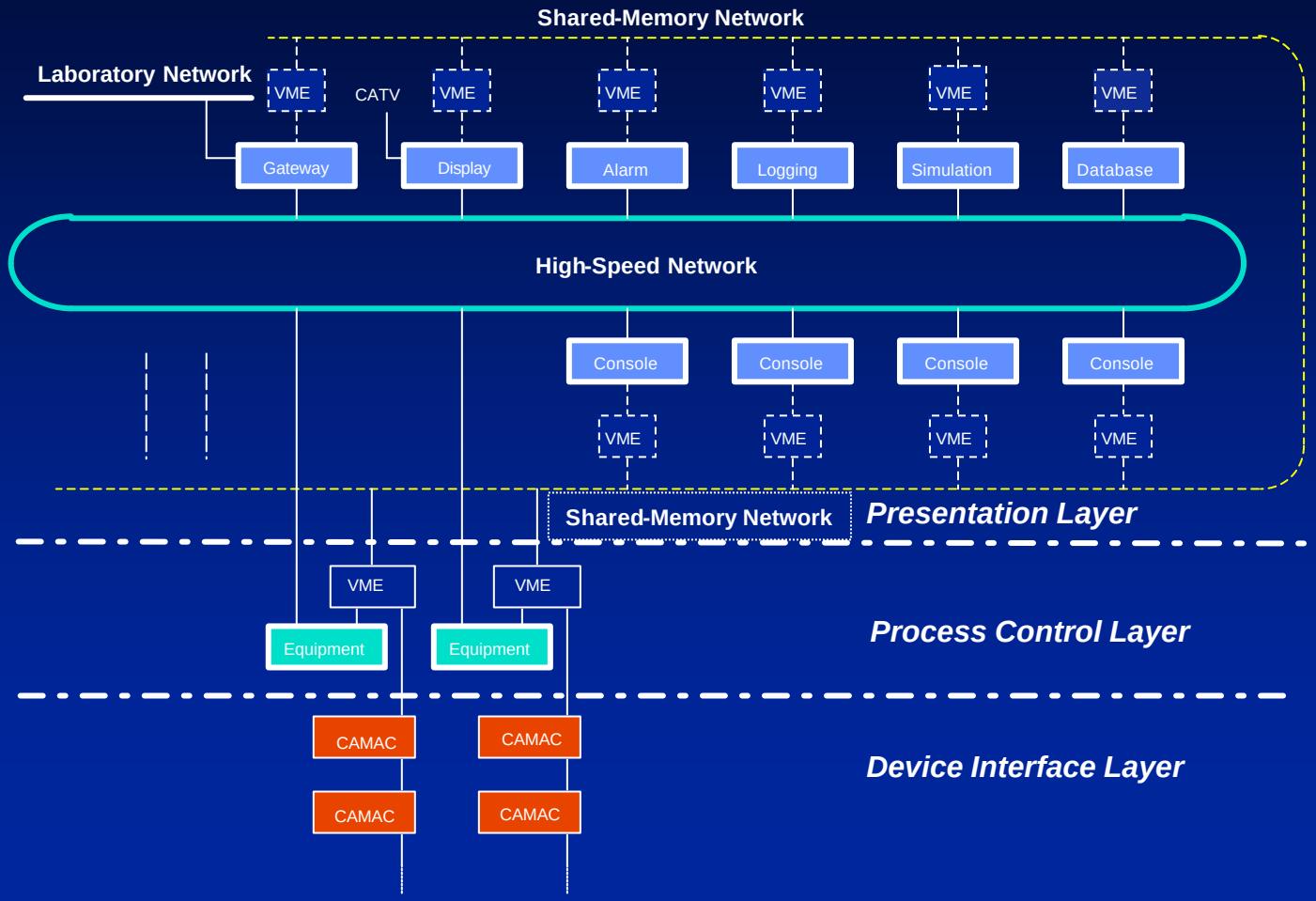


After the Removal of the MR Control Equipment

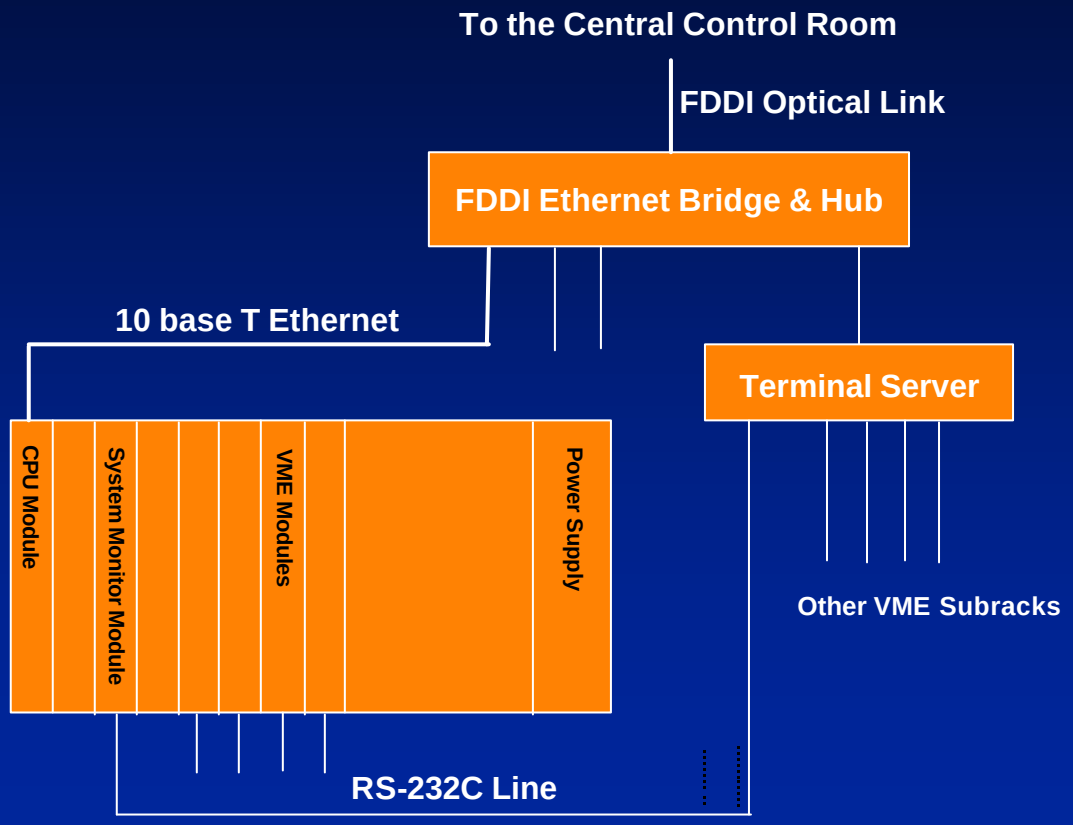
System Configuration (1)



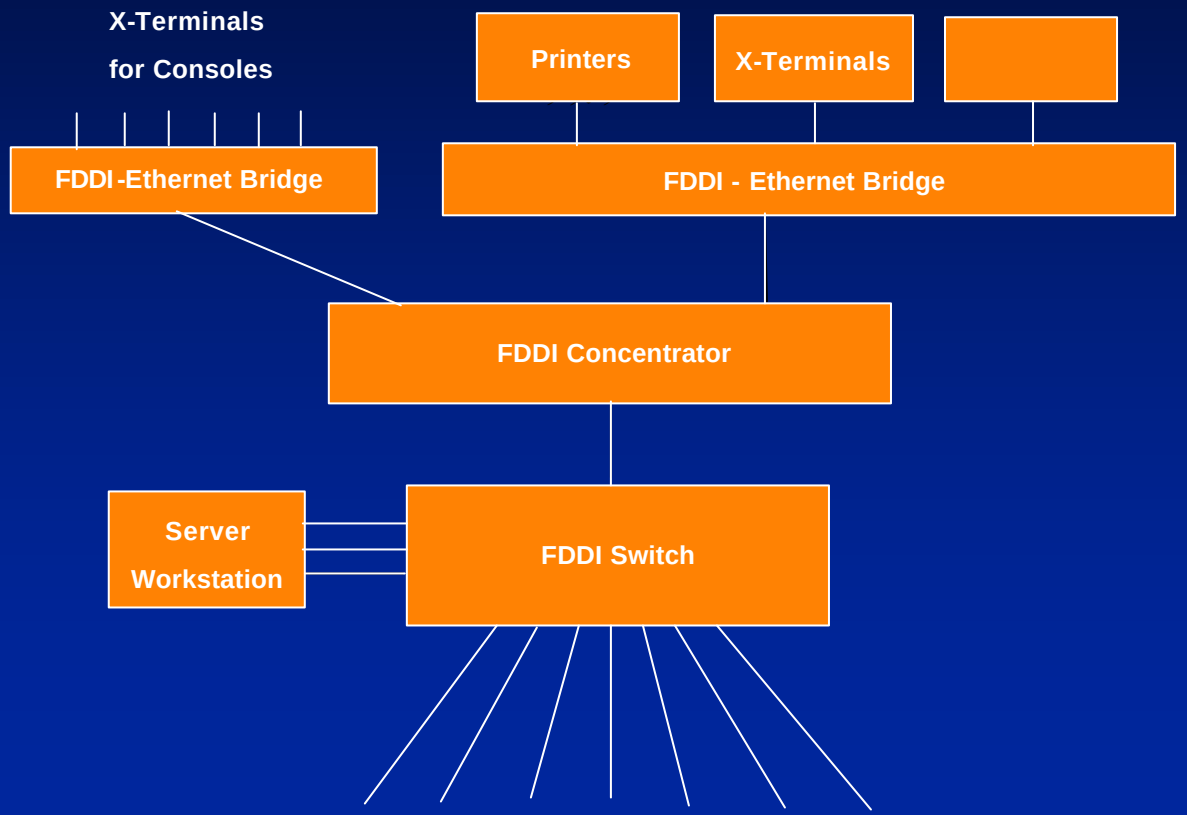
System Configuration (2)



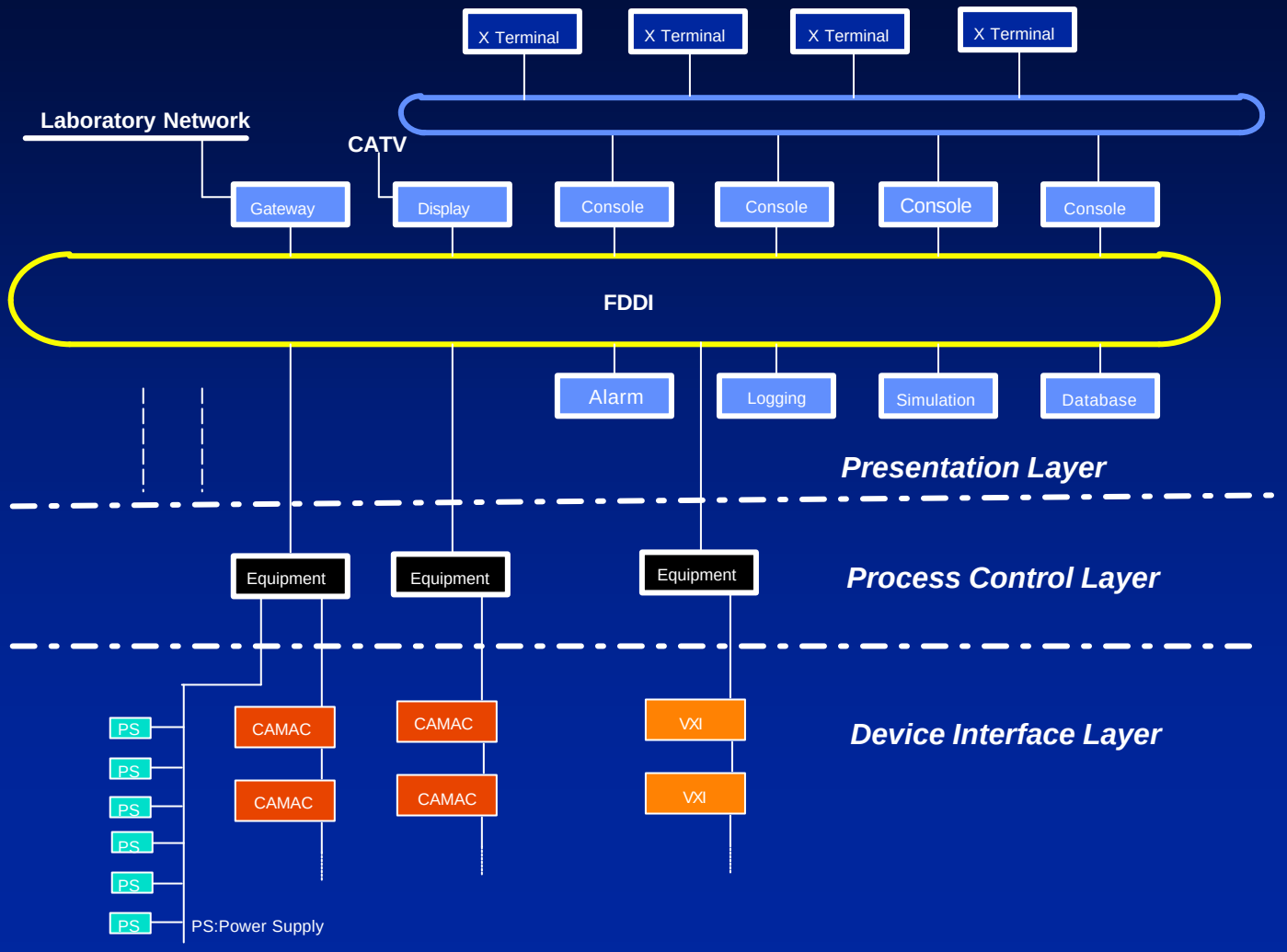
System Configuration (IOC)



Central Control Room



System Configuration (3)



Presentation Layer

- **Operator's Console**
  - UNIX Server Workstation
  - X Window, Windows NT, etc.
- **Relational Database**
  - ORACLE, Sybase, Informix, …
- **Alarm Indication/Logging**
- **Data Logging**
- **Data Display**
  - Web-TV, CATV Network, …
- **Simulation**
  - SAD Program
- **High-speed Network**
  - Gigabit Ethernet, 100 base TX, FDDI, ATM, 10 base T, …
- **Gateway to External Networks**

Process Control Layer

- **Standard Interfaces**
  - **VME, VXI, Compact PCI, ISA, PCI**
- **Computers**
  - **VMEbus Board-Computer**
  - **Compact PCI Board-Computer**
  - **PCs using ISA or PCI**
  - **Workstation**
- **Operating Systems**
  - **VxWorks, Windows NT, etc.**
- **Data I/O Interfaces**
  - **Fieldbuses: GPIB, CANbus, Profibus, WorldFIP, ARCNET**
  - **CAMAC Serial Highway, MIL-1553B, RS-232C**

Device Interface Layer

- **Standard Interfaces**
  - **GPIB**
  - **ARCNET**
  - **RS-232C**
  - **CAMAC**
  - **MIL-1553B**
  - **CANbus**
  - **WorldFIP**
  - **Profibus**
  - **etc.**

  - *** Suitable for Analog Interfaces?**

Evaluation at KEK

- **Software Environment**
  - EPICS — February 1995 (adopted)
  - Vsystem — February 1995 (rejected)
  - NODAL — (not evaluated)
- **Graphical User Interface**
  - X Window — (being used)
  - Windows NT — (being used)
- **Relational Database**
  - ORACLE — Installed and adopted
  - SYBASE — Installed but not adopted

Hardware Comparison at KEK

- **CAMAC vs. Other Fieldbuses**
  - CAMAC — Very long experiences (TRISTAN) but old
  - GPIB — A lot of equipment in the market
  - ARCNET — Experienced suppliers in Japan
  - CANbus, etc. — Not enough experience in Japan
- **VME vs. Compact PCI, ISA, PCI, …**
  - VME — Enough experience(since 1983 at KEK PS) but for digital signals, not analog signals
  - Compact PCI — Under development (still)
  - ISA, PCI — Cheap but not reliable enough
- **CPU (MC68k, Power PC, vs. Intel x86)**
  - MC68k — Suitable for VMEbus
  - Power PC — Was not delivered yet, currently O.K., but there are problems still
  - Intel x86 — Not suitable for VMEbus, not so many

Cost Estimation

- **VME vs. PCs**
  - **Long-term Expenses**
  - **Cost for Maintenance**
- **Use of Filedbuses**
  - **Can buy Proper Equipment with the Minimum Cost (Competition)**
  - **Can Choose among Many Candidates**
- **Software**
  - **VxWorks: Well-supported and Stable but expensive**
  - **Linux: Inexpensive but requires experts**
  - **Windows NT: Easy to Use but So Heavy**

KEKB Console

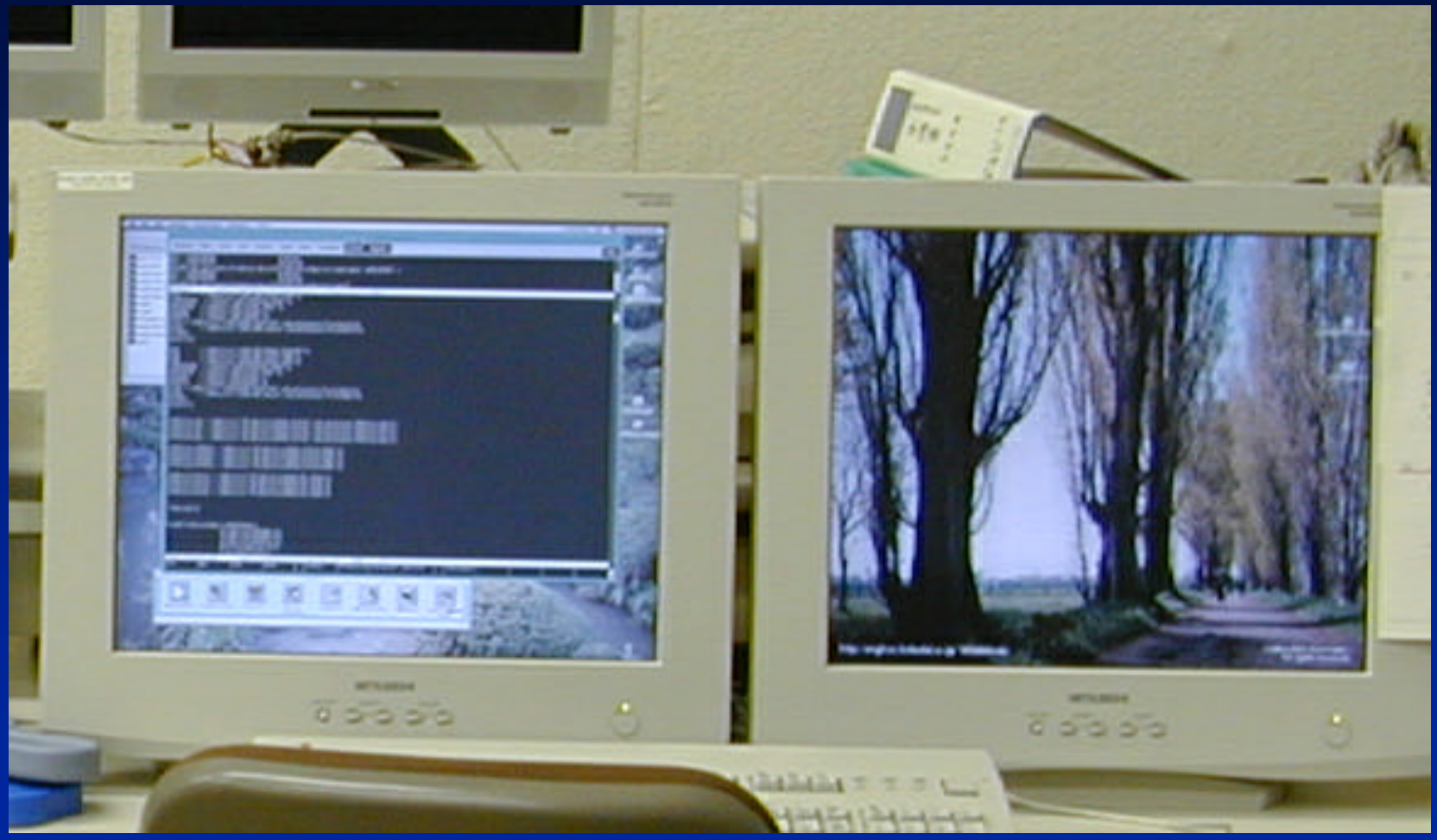
Old Console for AR

CRT Displays

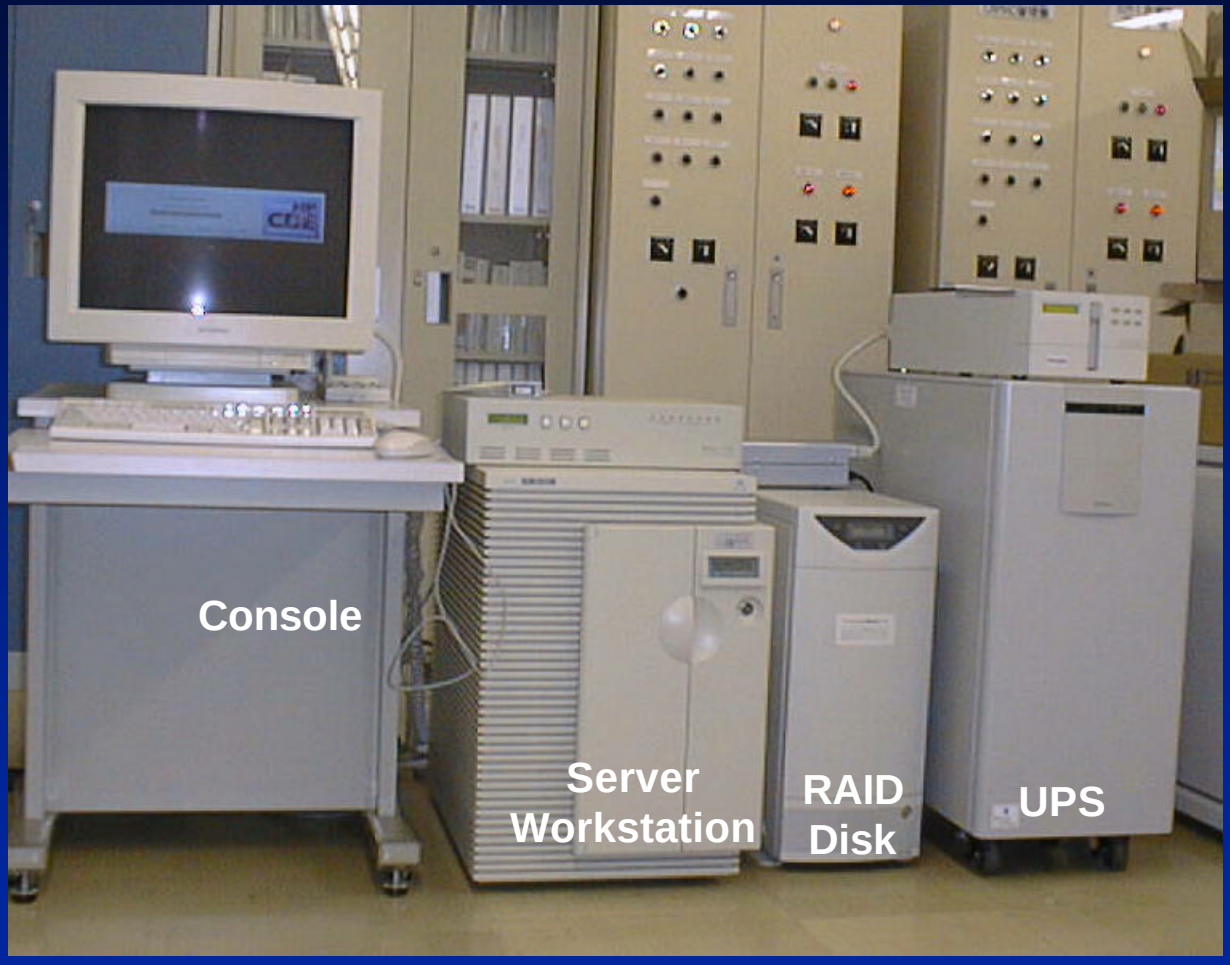
Reflections from the Screen

Lighting of the CCR

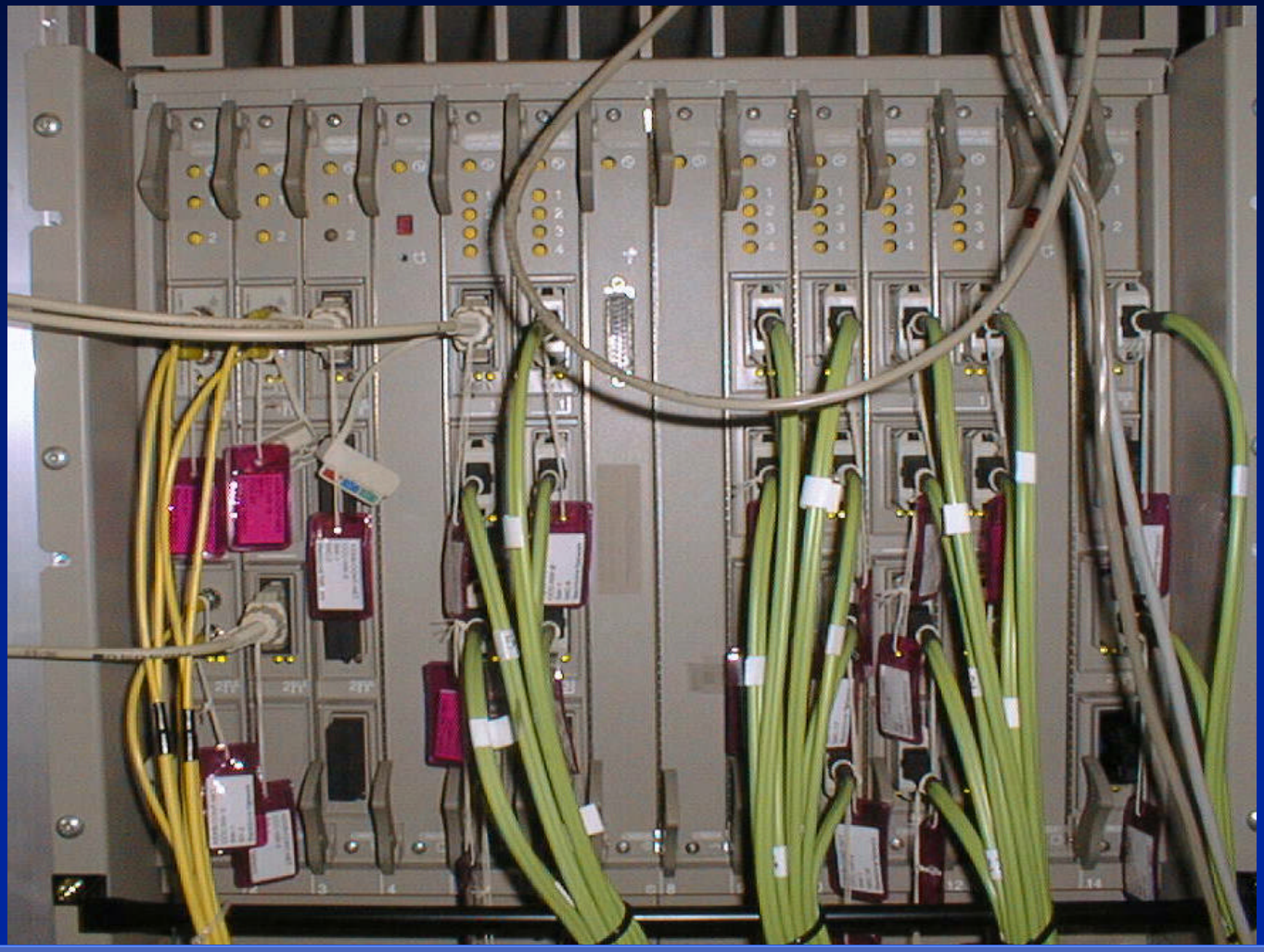
New Liquid Crystal Displays



Server Workstation



FDDI GIGA Switch



Plasma Displays and LCDs

Linac Control Console

LCD Monitors and LCD TV Monitors

Multi-Screen TV Display