Conceptual Design of the Control System for SPring-8-II

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JASRI/SPring-8

(on behalf of Control System Design Team)

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TCO205

Outline

- Introduction
  - SPring-8-II upgrade background
  - Project planning
- Transition from the present to the future
  - Control System Design
  - Equipment control for SPring-8-II
- Project schedule
- Summary

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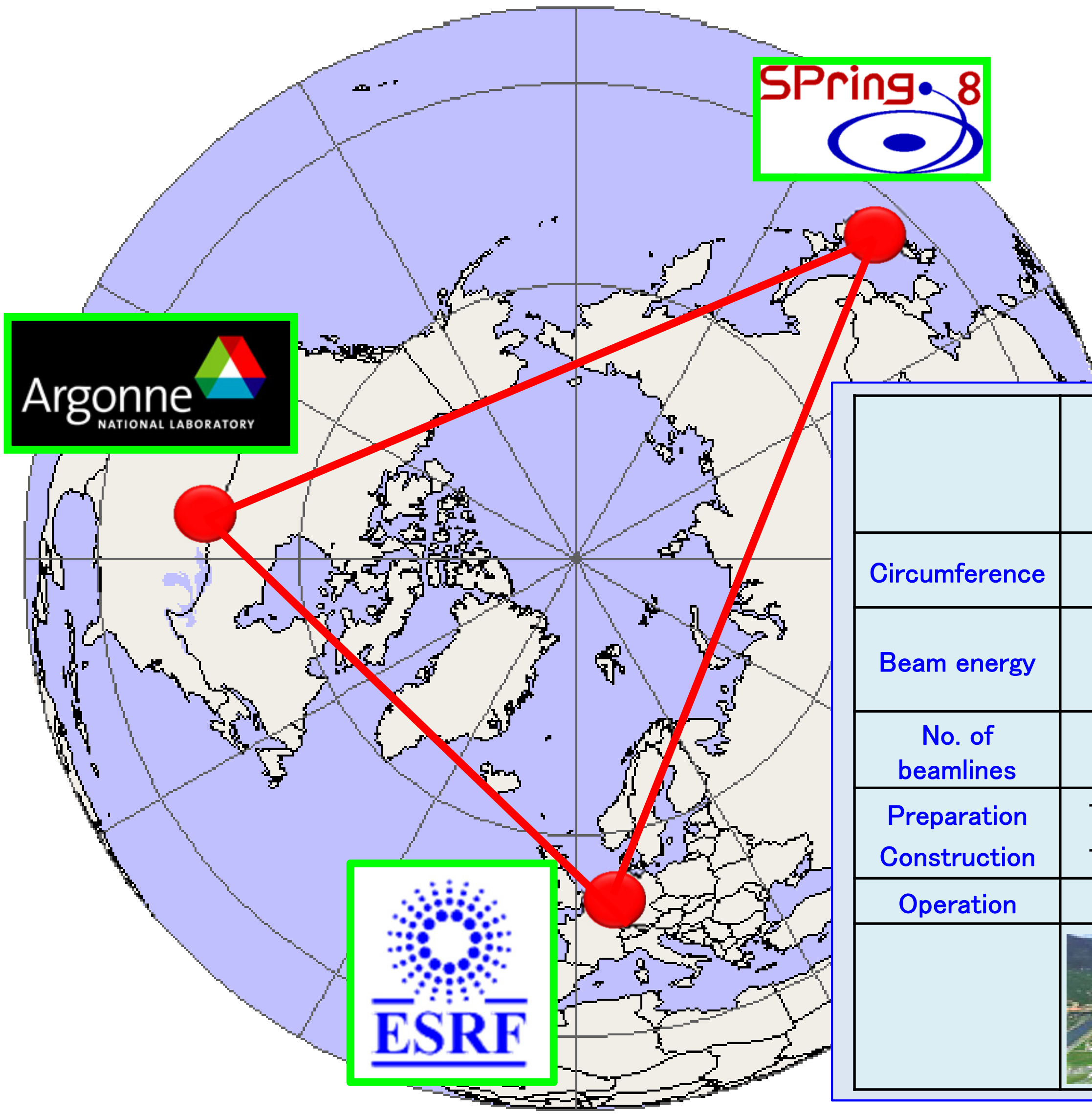
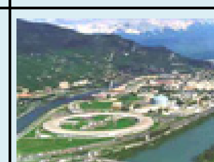
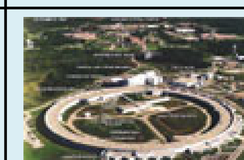
3rd Generation SR Light Sources - 1997

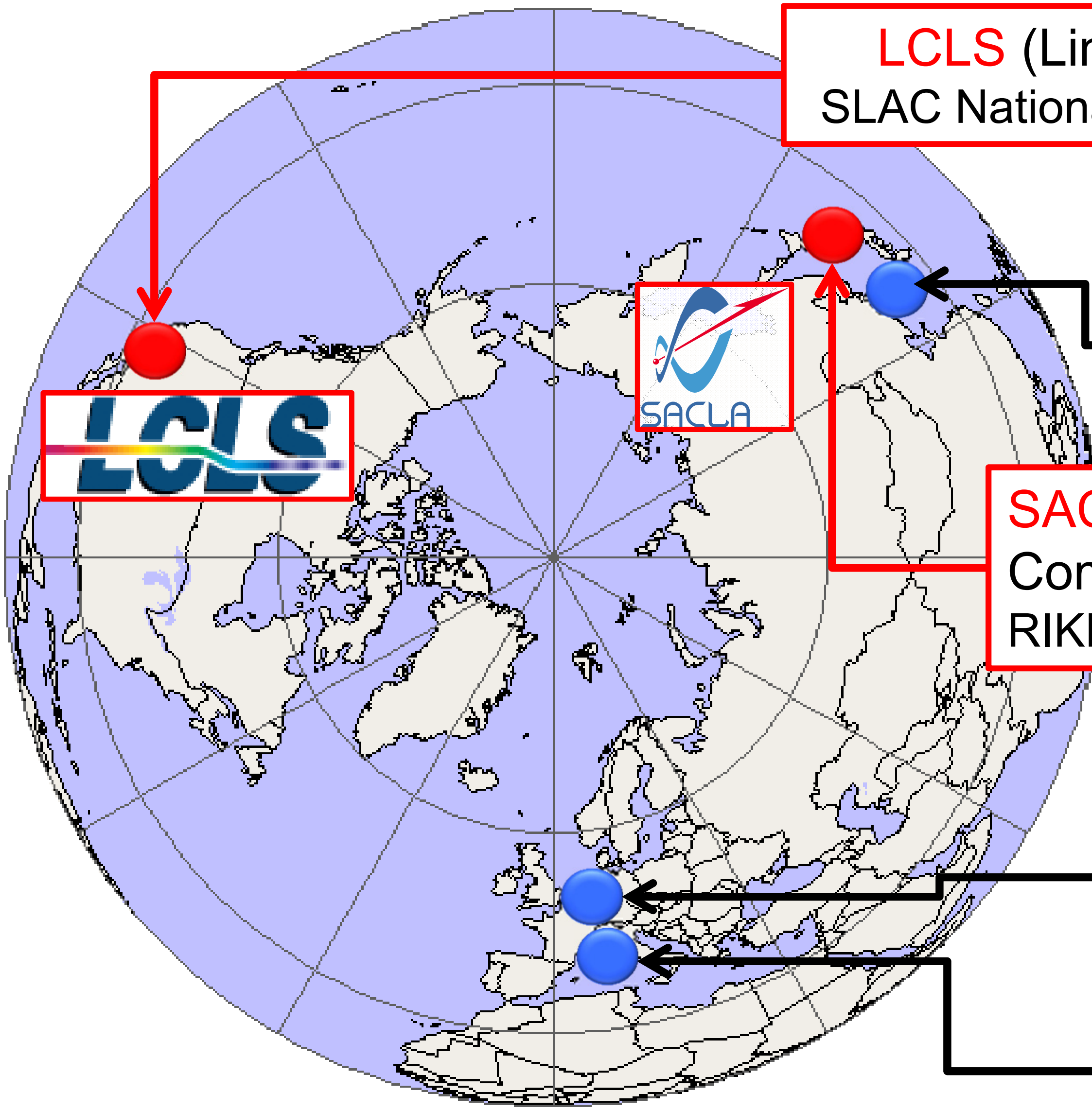


- Large light-source facilities in 1997, the year of SPring-8 inauguration.
- Seventeen years have passed, and brilliant compact (~3GeV) LS constructed in the world.

	ESRF (France)	SPring-8 (Japan)	APS/ANL (USA)
Circumference	844m	1,436m	1,104m
Beam energy	6 GeV	8 GeV	7 GeV
No. of beamlines	56	62	68
Preparation Construction	1986 - 1987 1988 - 1994	1987 - 1989 1991 - 1997	1986 - 1989 1989 - 1994
Operation	1994	1997	1996
			

The light sources are making significant contribution to the science producing fruitful outputs.

Two XFEL Facilities in the World - 2014



LCLS (Linac Coherent Light Source),
SLAC National Accelerator Laboratory, USA

First lasing in April 2009
Public Beam Time from Oct. 2009

PAL XFEL,
Korea

Under construction

SACLA (SPring-8 Angstrom Compact Free Electron Laser),
RIKEN SPring-8 Center, Japan

First lasing in June 2011
Public Beam Time from March 2012

European XFEL,
Germany

Under construction

SLS, XFEL,
Switzerland

Under construction

XFEL is opening a new aspect of the synchrotron radiation science

SPring-8 Site Has 3rd Generation LS and XFEL

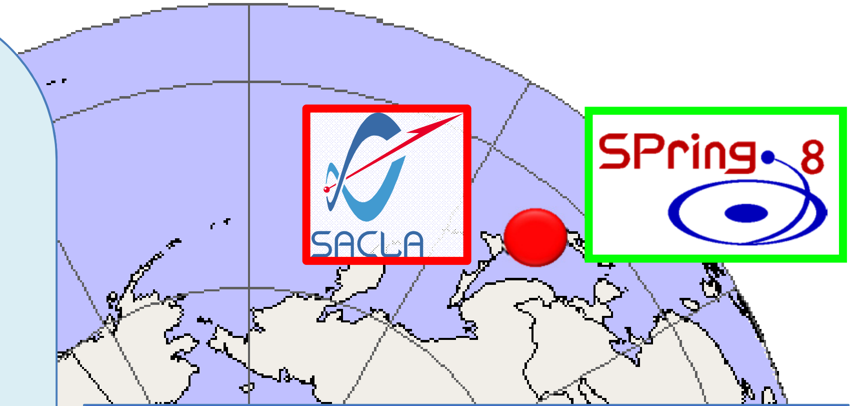
Features of SACLA/XFEL:

- Ultra short pulse= <10 fs
- High brilliance = 10^{11}/pulse
- 100% coherence = laser
- "Measure-Before-Destruction"

	SACLA	SPring-8
Phenomena	Fast, Dynamic	Slow, Static
Material	Non-crystal OK	Crystal
Sample	Destroyed	Stay, damaged

We recognize, there is a wide gap between what SPring-8 can do and what SACLA can do.

We should narrow the gap in SR perspective to see many phenomena at the atomic scale.



XFEL and SR light source facilities locate at the same site.

from CDR preface

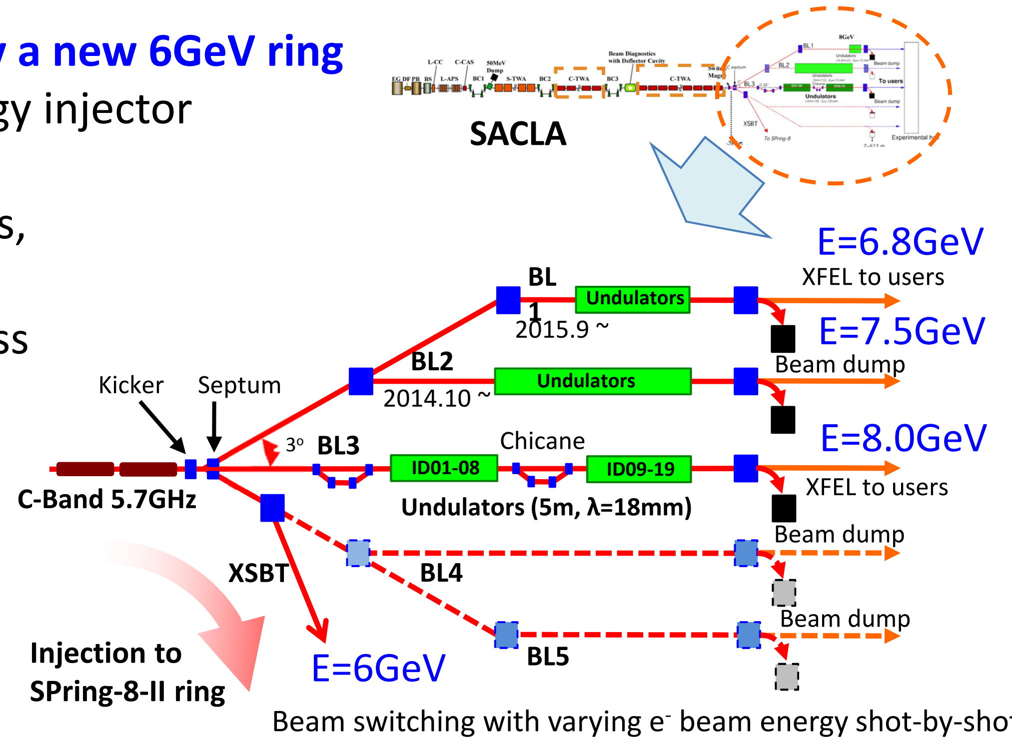
"We know how it happens, but we don't know why it happens."

We construct the basic tool to provide the answers to the many "whys" – SPring-8-II

SPring-8-II Construction Philosophy - Machine

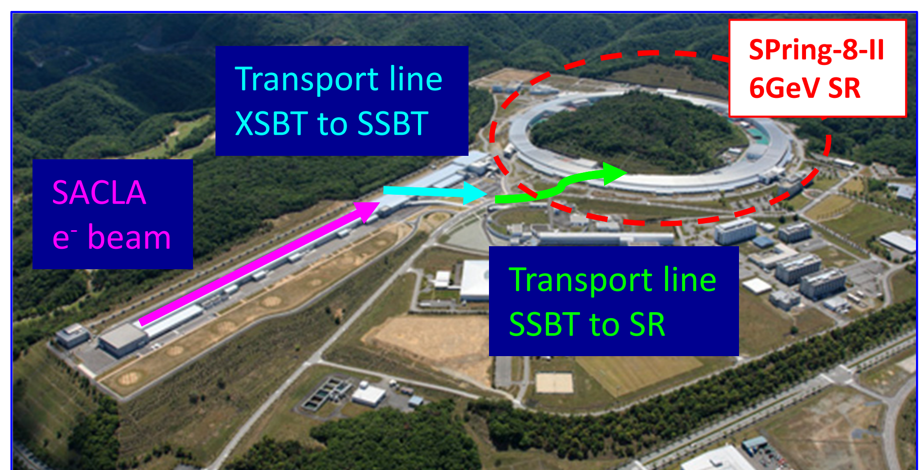
Replace the current 8GeV storage ring by a new 6GeV ring

- SACLA C-band linac will be a full energy injector
- Reuse the existing machine tunnel,
- Retain all the undulator beamline axes,
- Electric power savings,
- Blackout period will be one year or less



Comparison of SR parameters

	SPring-8-II (New)	SPring-8 (Present)
Energy [GeV]	6	8
Beam Current [mA]	100	100
Circumference [m]	1435.4345	1435.9488
RF Frequency [MHz]	508.762	508.58
Unit Cell Structure	5Bend Achromat (w/ Long. Var.)	DoubleBend
Natural Emittance [nmrad]	0.149	6.6 (Achromat) 2.4 (Non-Achromat)
Relative Energy Spread [%]	0.093	0.109
Radiation Loss by Bending Magnets [MeV/turn]	2.98	9.12



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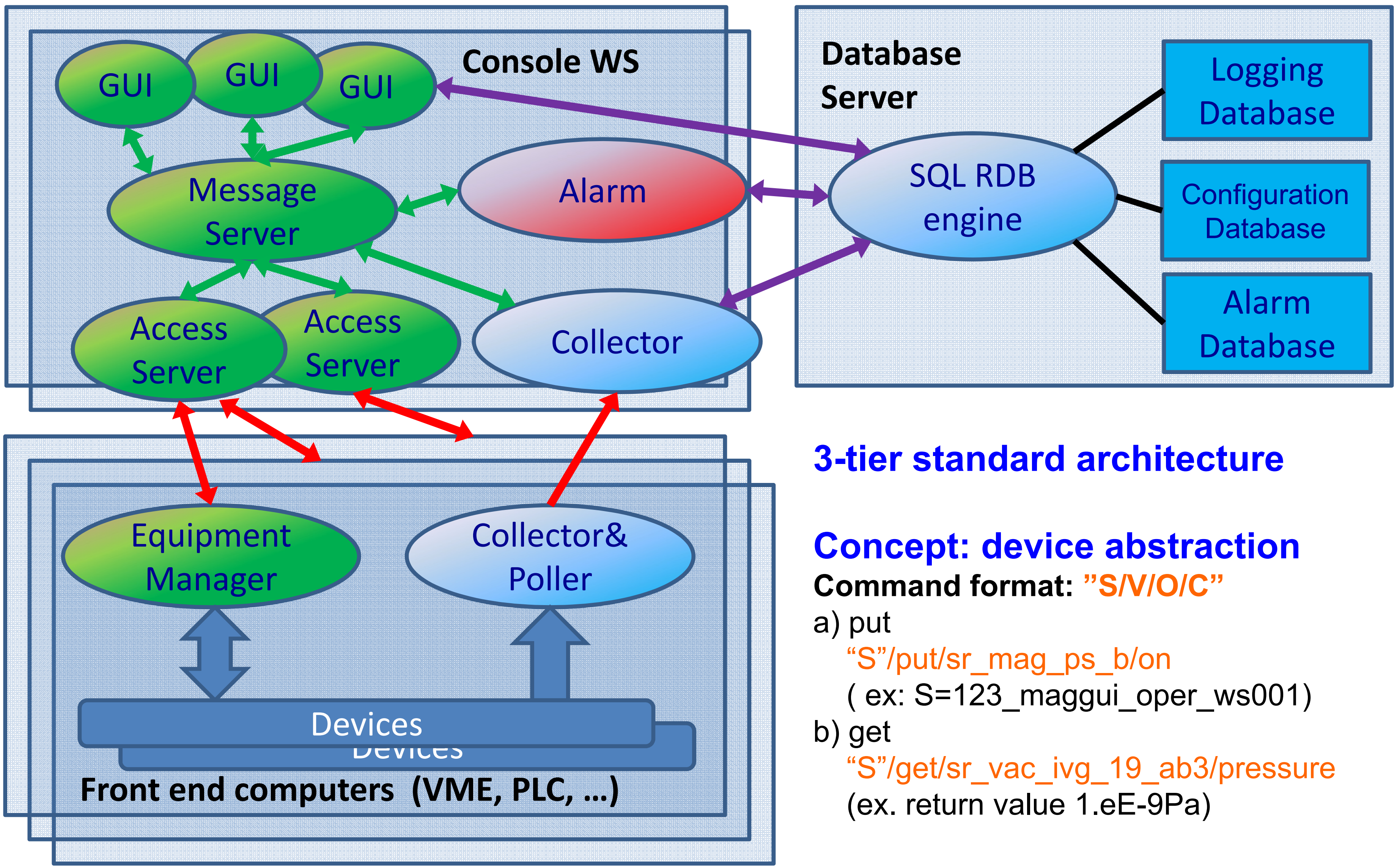
Control System Design for SPring-8-II – Software

Control system for SPring-8-II – *"Right platform in the right place"*

- Keep MADOCA framework, base of SPring-8 control
  - MADOCA got major upgrade in 2013, now MADOCA II
  - We use MADOCA II for SPring-8-II
- Not homogeneous system, but mixture of platforms
  - Think about VME future, i.e. PLC, VME, xTCA (ATCA, MTCA, *not fixed yet*)
  - Utilize state-of-the-art modern technology (AMC etc.)
- Minimize development risk
  - Use current system, if it's good enough
  - Develop new system, if demand is beyond the current level
- Keep devices with good hisory and adopt devices with potential
  - Fast control (LLRF, BPM monitor, St-mag, etc.)
    - xTCA (+VME+PLC) for LLRF
    - xTCA equipped with shared memory for BPM+St-mag
  - Slow control (Vacuum, Bending magnets, etc)
    - PLC base, we will use PLC master+intelligent slave cards.

MADOCA Software Framework (before 2013)

Middleware: SystemV IPC( ), ONC/RPC( ), SQL DB access( )



3-tier standard architecture

Concept: device abstraction

Command format: "S/V/O/C"

a) put

"S"/put/sr_mag_ps_b/on

(ex: S=123_maggui_oper_ws001)

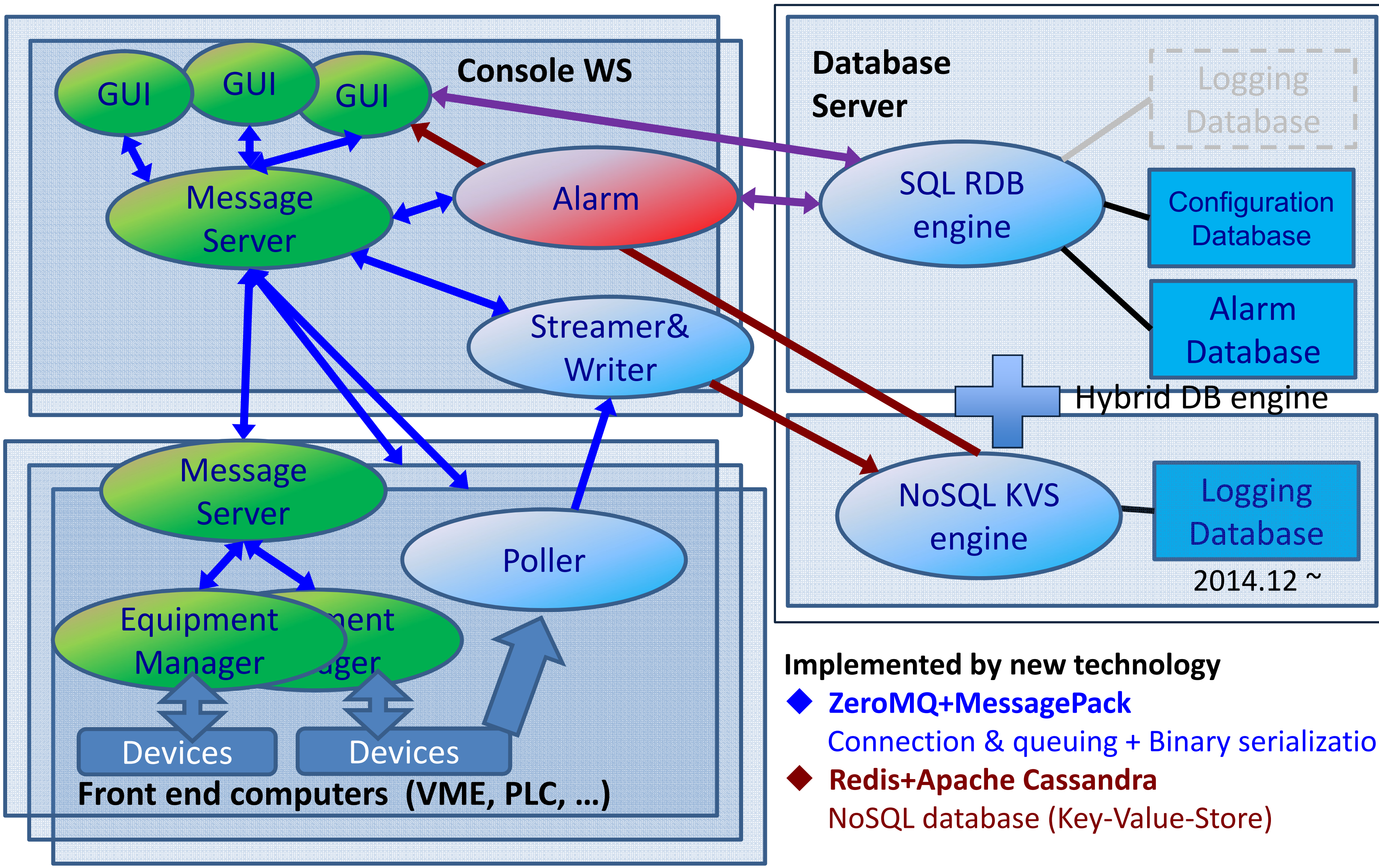
b) get

"S"/get/sr_vac_ivg_19_ab3/pressure

(ex. return value 1.eE-9Pa)

MADOCA II Software Framework (after 2013)

Middleware: ZeroMQ(↔), NoSQL DB access(↔), SQL DB access(↔)



Implemented by new technology

- **ZeroMQ+MessagePack**
  Connection & queuing + Binary serialization
- **Redis+Apache Cassandra**
  NoSQL database (Key-Value-Store)

Major Update from MADOCA to MADOCA II

MADOCA has been working well, however we updated the framework by adding new features.

→

Update to MADOCA II for the better

New features:

- **No limitation of a control message length**
  - Length is unlimited
  - Support of variable length data such as image data
- **Support of multi-OS**
  - Windows and UNIX family are supported
  - MADOCA II interface to LabVIEW provided by NI (especially for users)
- **Parallel processing is strengthened**
  - Asynchronous communication between consoles and remote CPU
  - Multiple device managing processes on remote hosts
- **Better performance is achieved**
  - Faster transaction of control messages (1.15ms for PC-VME RT)
  - Faster data logging by Redis+Apache Cassandra

MADOCA II has enough features as a keystone for SPring-8-II control.

Control System Design for SPring-8-II – Hardware

Control system for SPring-8-II – *"Right platform in the right place"*

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    xTCA (+VME+PLC) for LLRF

    xTCA equipped with shared memory for BPM+St-mag
  - Slow control (Vacuum, Bending magnets, etc)

    PLC base, we will use PLC master+intelligent slave cards.

Control System Components - 2014

- **Operator consoles**
  - SUSE Linux
- **Servers**
  - DB - Sybase, MySQL, Cassandra
  - Fiber channel NAS & NFS
  - Virtual machines on blade servers, FT-servers
- **VME systems**
  - Solaris OS on I.A. CPU
  - Shared memory network
  - Fieldbus (FL-net, Devicenet)
- **Interlock systems**
  - PLC (PPS, MPS)
- **Network switches**
  - 1Gb ~ 10Gb Ethernet
- **Subsystems**
  - LabVIEW, PoE box etc.

Machine status monitoring

Take signals from all devices in every 1 ~ 60 sec.
Keep data into On-line DB first, then
Store sampled data to Archive DB forever

of control points(SP8+XFEL)

Digital signals: 90k+230k points

Analogue signals: 22k+20k points

	Facility	No. of Unit
Computers		**332**
	Central control	40
	Beamline	165
	Network	21
	Status information	79
	XFEL	27
VME systems		**430**
	Accelerators	129
	Beamline	126
	XFEL	175
Interlock units		**812**
	Accelerators	38
	Beamline	414
	SCSS+XFEL	122
	Access control	238
Network switch		**758**
	Control LAN	337
	Public LAN	166
	Safety LAN	74
	XFEL LAN	181

SPring-8 uses the industrial standard and open software AMAP.

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SUSE Linux

◆Servers
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Fiber channel NAS & NFS
Virtual machines on blade servers, FT-servers

◆VME systems
Solaris OS on I.A. CPU
Shared memory network
Fieldbus (FL-net, Devicenet)

◆Interlock sys
PLC (PPS, M

◆Network swit
1Gb ~ 10Gb I

◆Subsystems
LabVIEW, Po

Device control part of the storage ring will be replaced for SPring-8-II

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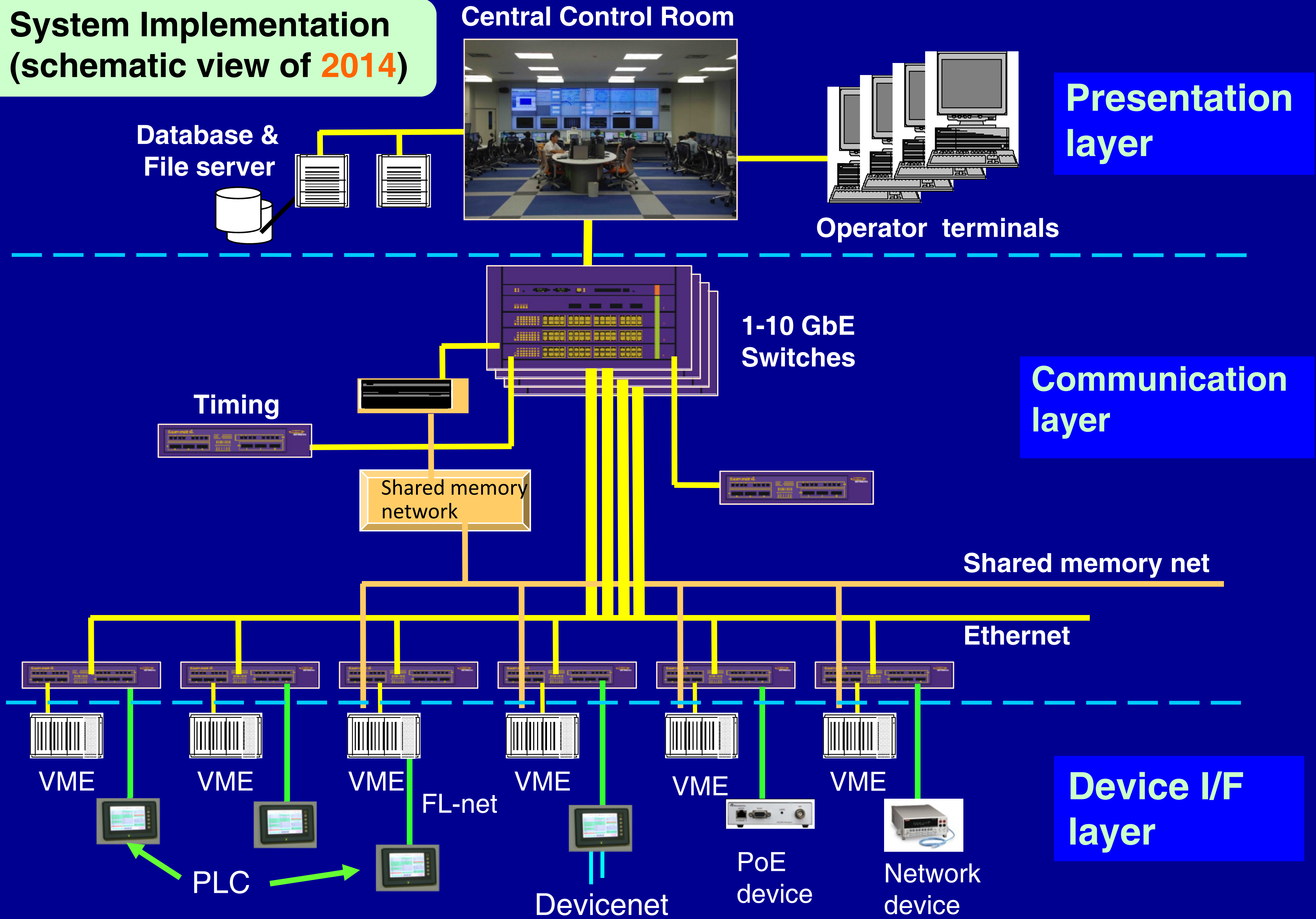
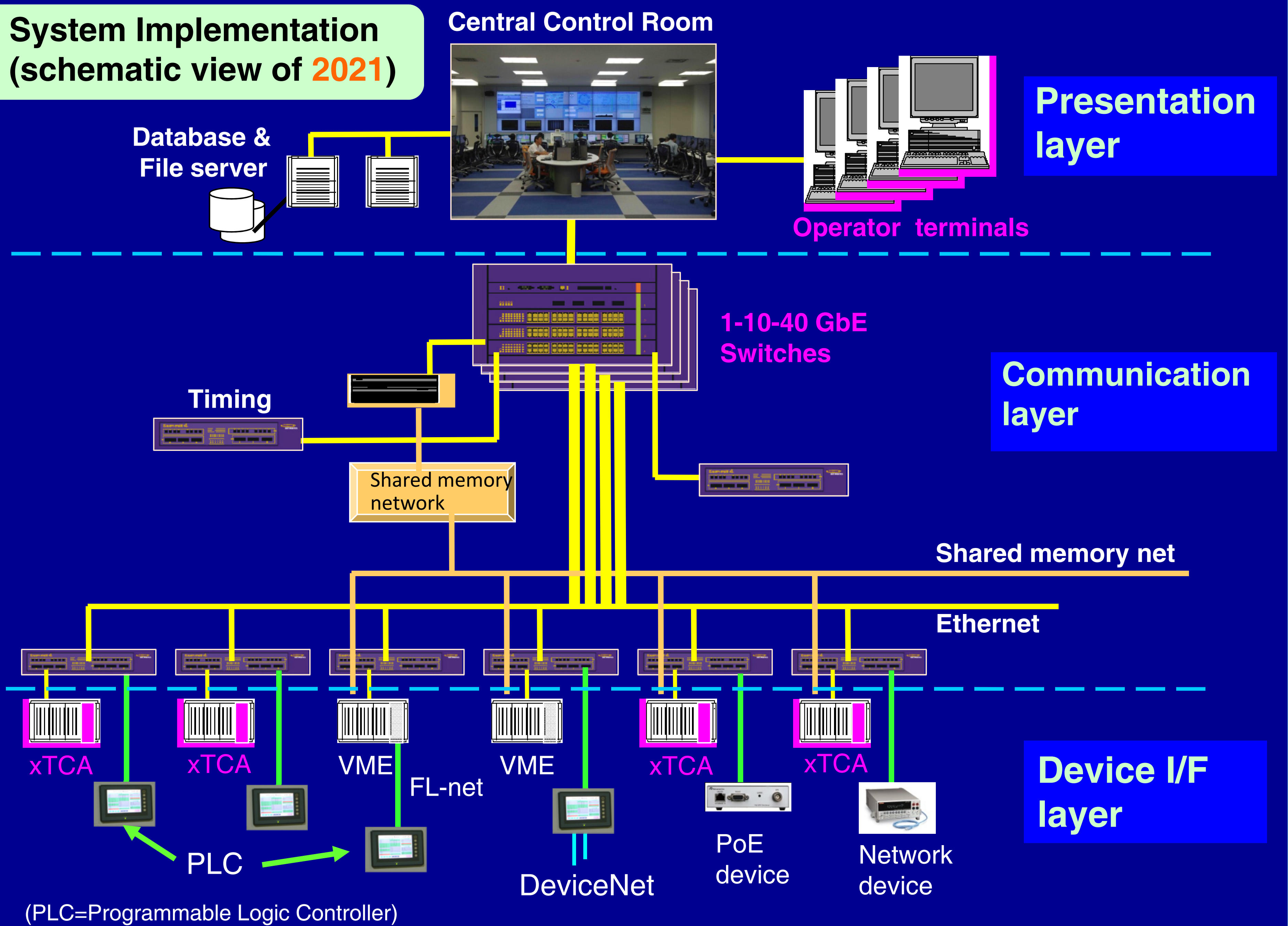
System Implementation (schematic view of 2014)



(PLC=Programmable Logic Controller)

System Implementation (schematic view of 2021)

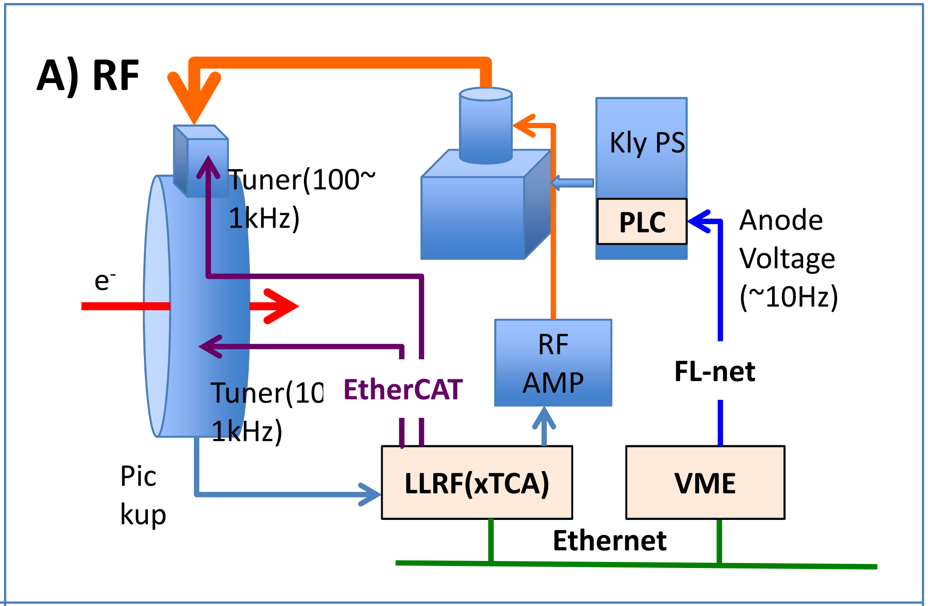


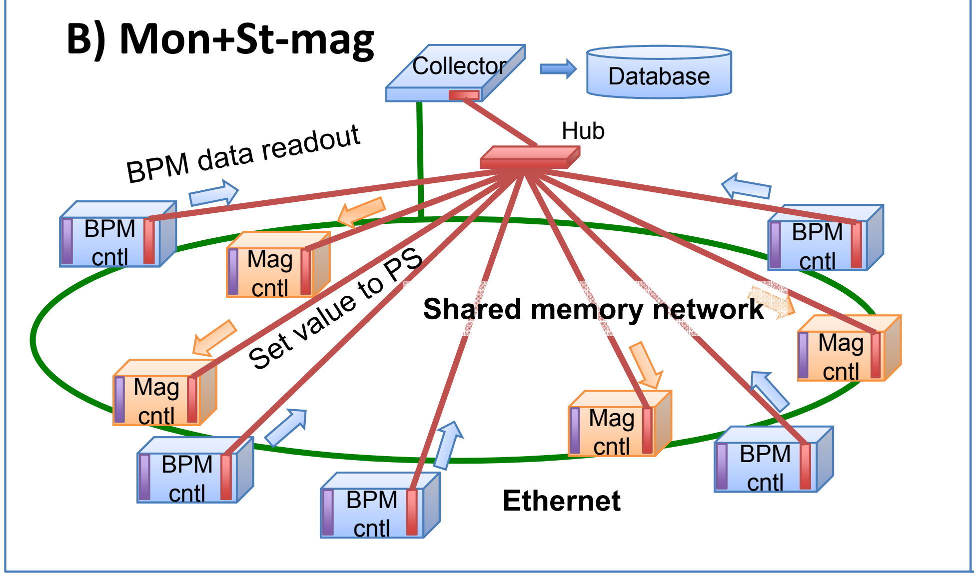
Examples of Each Equipment Control

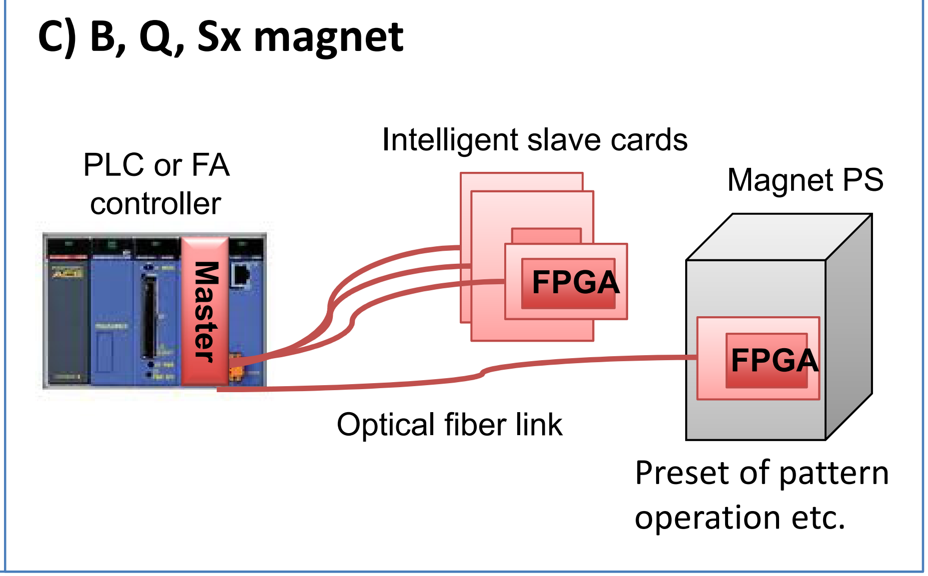
Case A) : RF
Mixture platform such as fast control (xTCA) for LLRF and slow control (VME+PLC) high-power RF.

Case B) : Mon+St-mag
Fast control for monitor readout and St-magnet PS using shared memory network > 100Hz.

Case C) : Main mags
Slow control is good enough for B, Q, Sx-magnet PS by PLC master and intelligent slave cards.



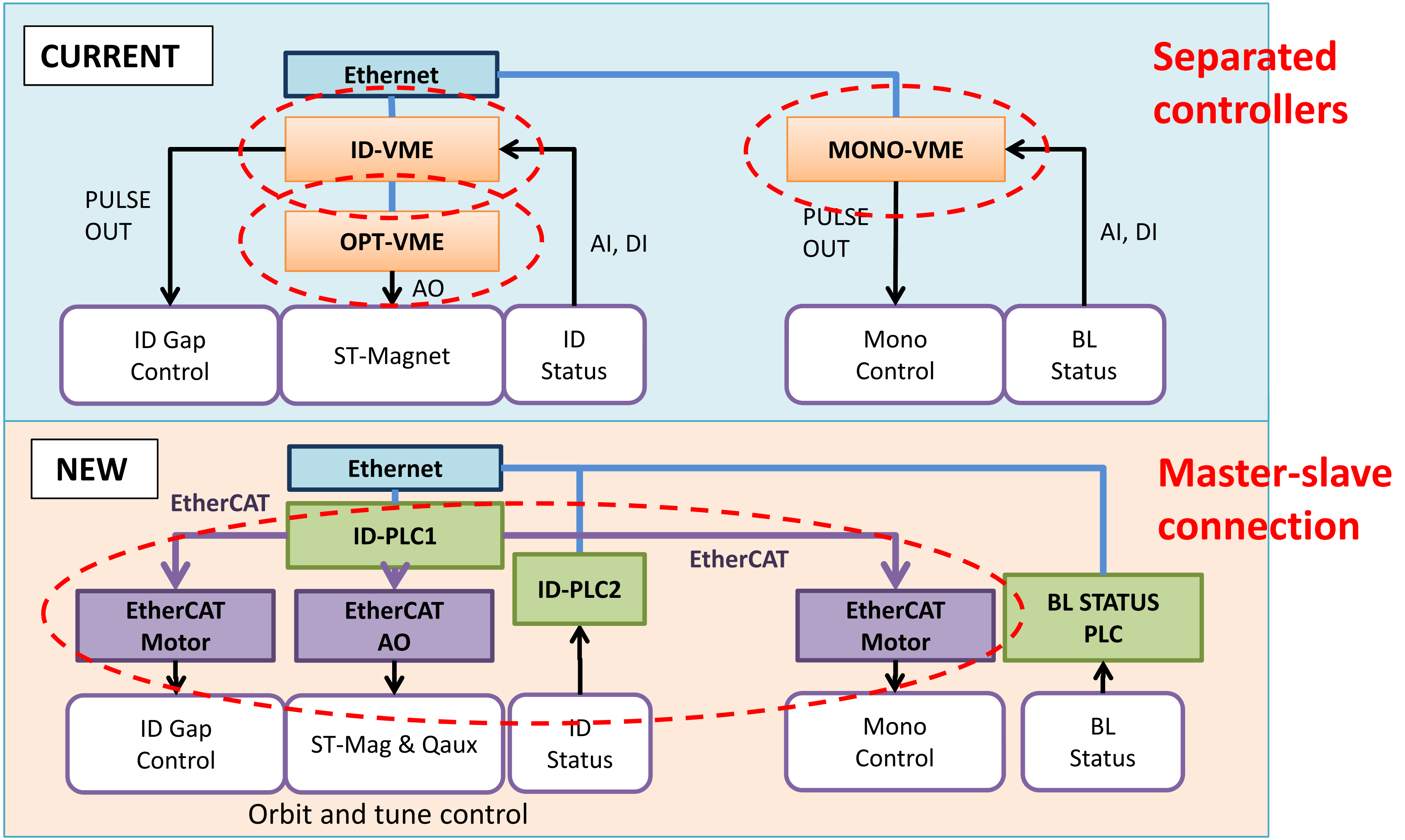




Beamline control system – *plan*

- Separated control
- Software based cooperation
  - communication overhead

- Better cooperative operation
- Better real-time performance
- Cost effective of maintenance



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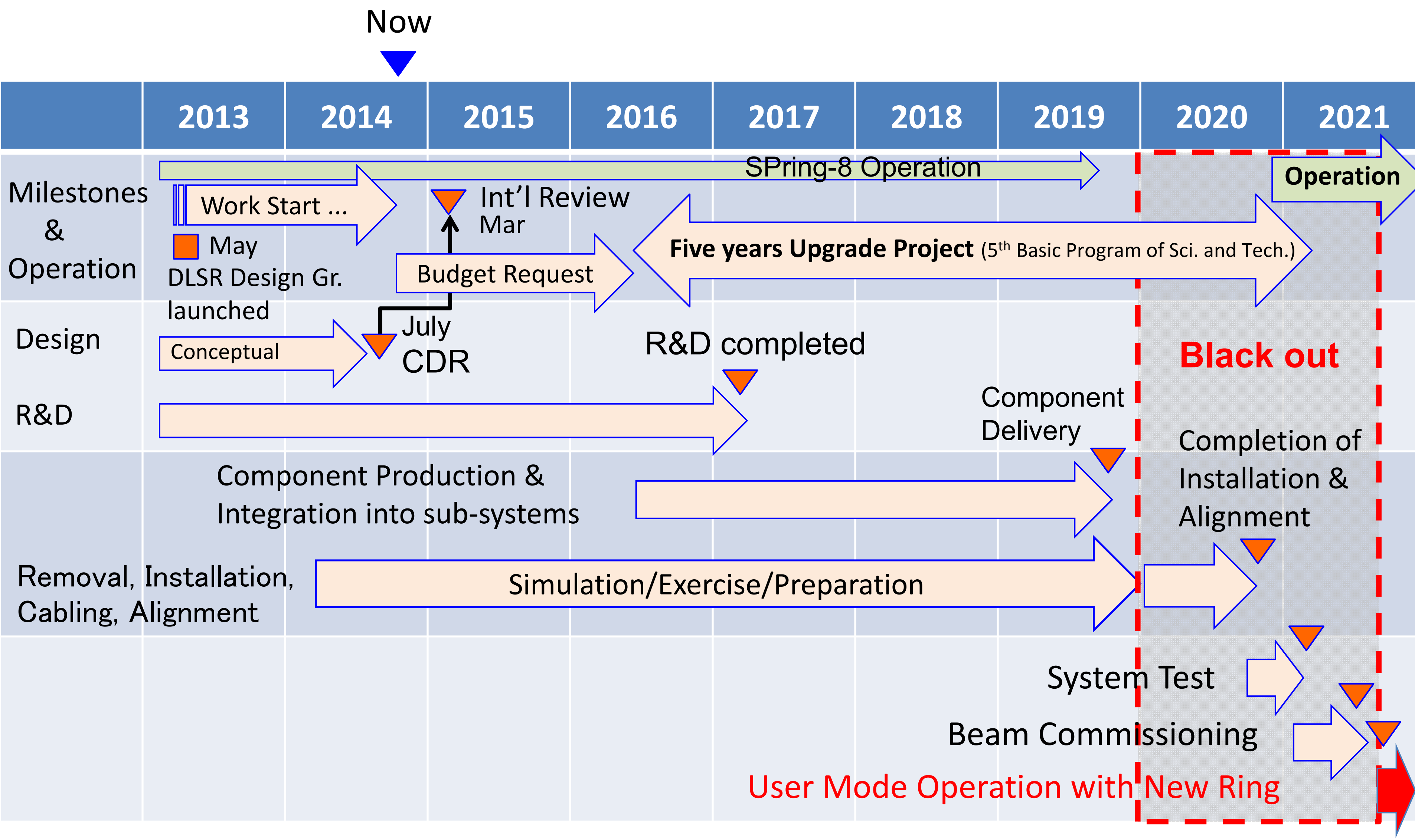
Tentative Project Schedule - *not authorized yet*



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Summary

- **Replace the current 8GeV storage ring by a new 6GeV ring to provide the answers to many *"whys"*.**
- **We use MADOCA II for SPring-8-II control**
- **Choose control equipment on the bases of *"Right platform in the right place"*.**
- **Keep devices with good records and use devices with potential considering towards the future**
- **We have a plan to start the commissioning of SPring-8-II in the early 2020s.**

SPring-8-II CDR is available on the web http://rsc.riken.jp/

Appendix

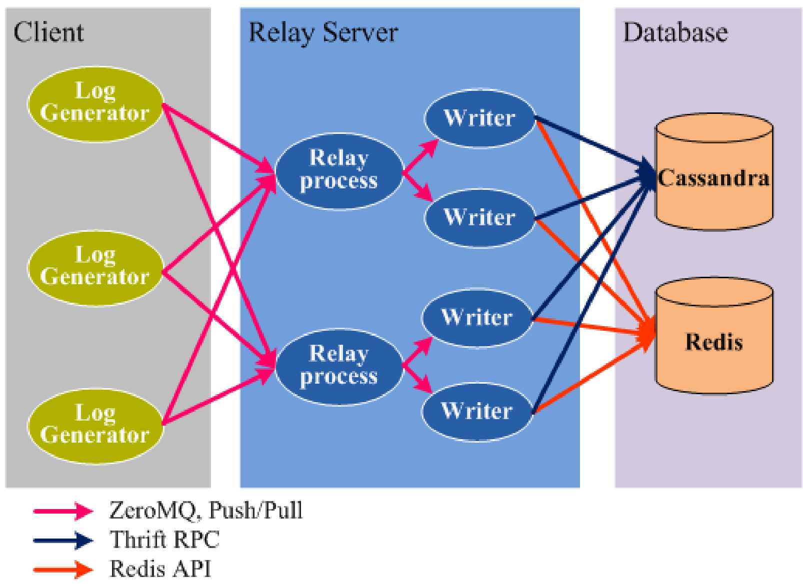


Figure 3: System architecture.

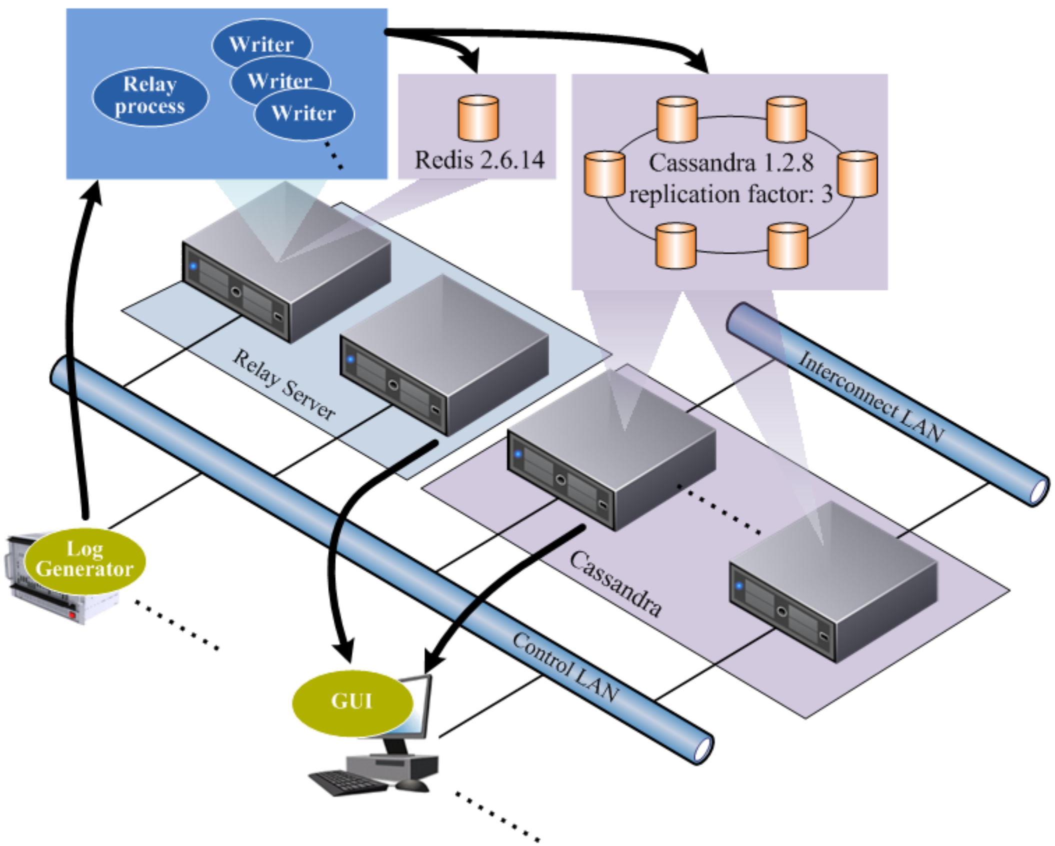


Figure 5: System structure. Arrows show the data flow.

Figure 1: The write throughput when the access load is increased. Hardware specifications of a node are Xeon 2.93 GHz, 8 GB RAM, 64 bit Centos 6.2. Cassandra is version 1.0.5. Data size per row is 20 bytes, and a client inserts 1,000 rows at once.

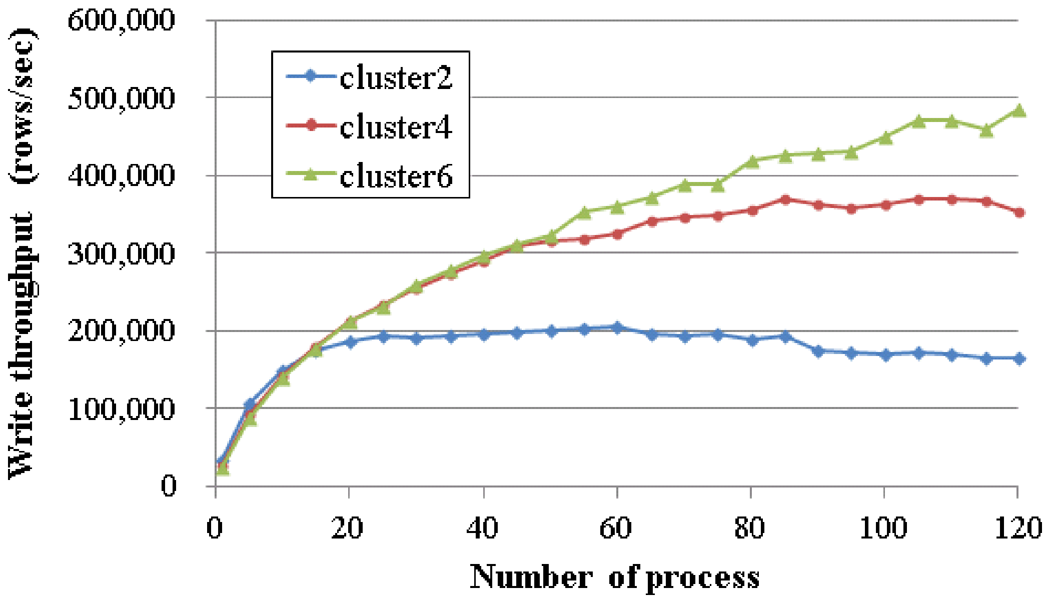
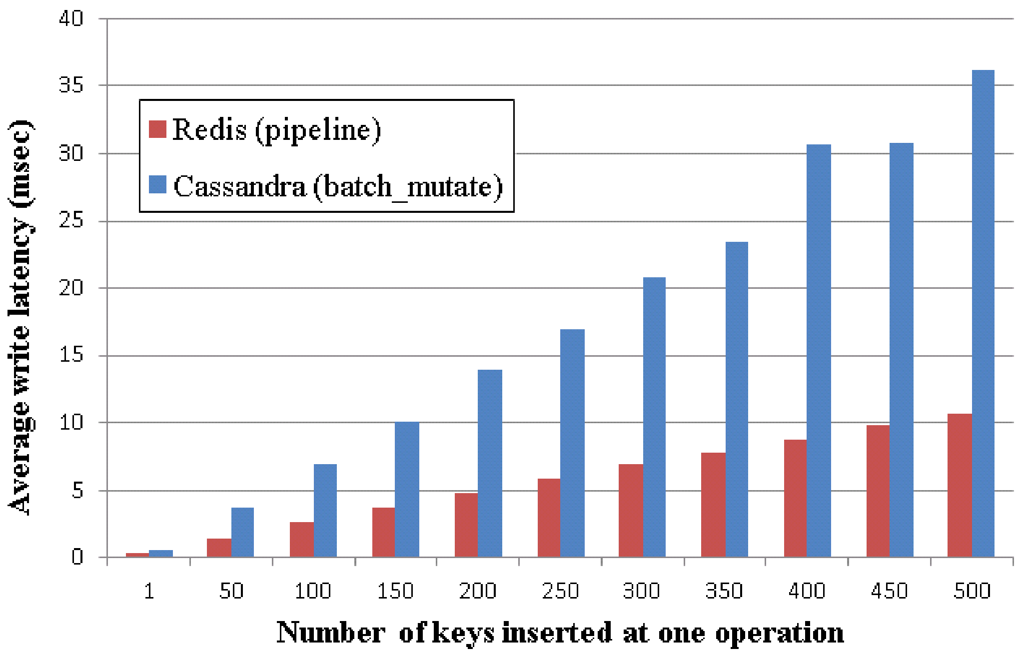


Figure 2: The write latency of Redis compared to Cassandra, where low latency is better. Testing conditions of Cassandra are the same as Fig. 1.



Introduction

Current System

- **Relational database management system (RDBMS)**
  - Time-series data
  - Stable operation for 16 years

RDBMS is not always the best one for data logging.

New System

- **NoSQL (Not only SQL) database**

*NoSQL is defined as a new type database management system that is non-relational.

New System Features

Scaling-out

The system can easily grow the performance by adding more low-cost servers.

Flexible Data Format

The system supports various data type such as integers, reals, strings, arrays and maps.

High Reliability

There was no single point of failure (noSPOF).

Low Latency Access

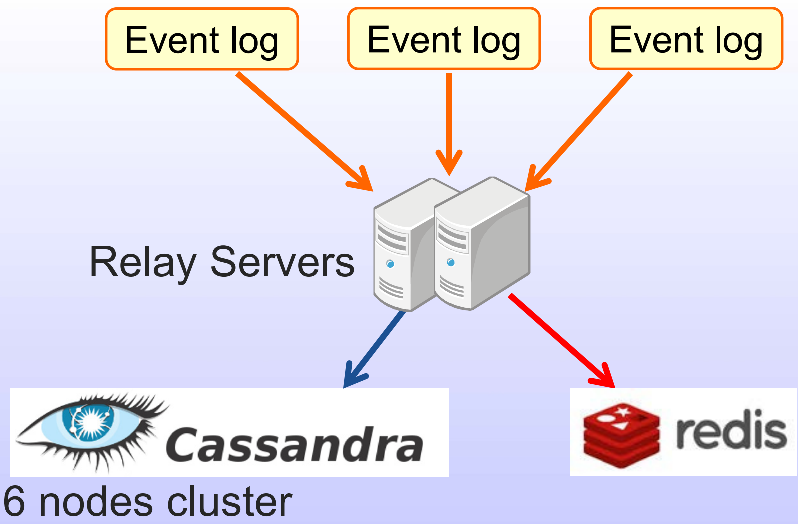
Users can take the latest data in microseconds order.

New System

NoSQL Database

- **Apache Cassandra**
  - Distributed database without SPOF
  - Excellent fit for time-series data
  - Perpetual archive
- **Redis**
  - In-memory key-value store
  - Real time data cache

System Overview



Long-term Test

- The system had been inserted 50,000 messages/sec for 3 months.

  => No data loss during the test even when the server was forced a shutdown.

High reliability and stability

Poster ID : TUPPC012