High Energy Photon Source (HEPS) Controls Status Report

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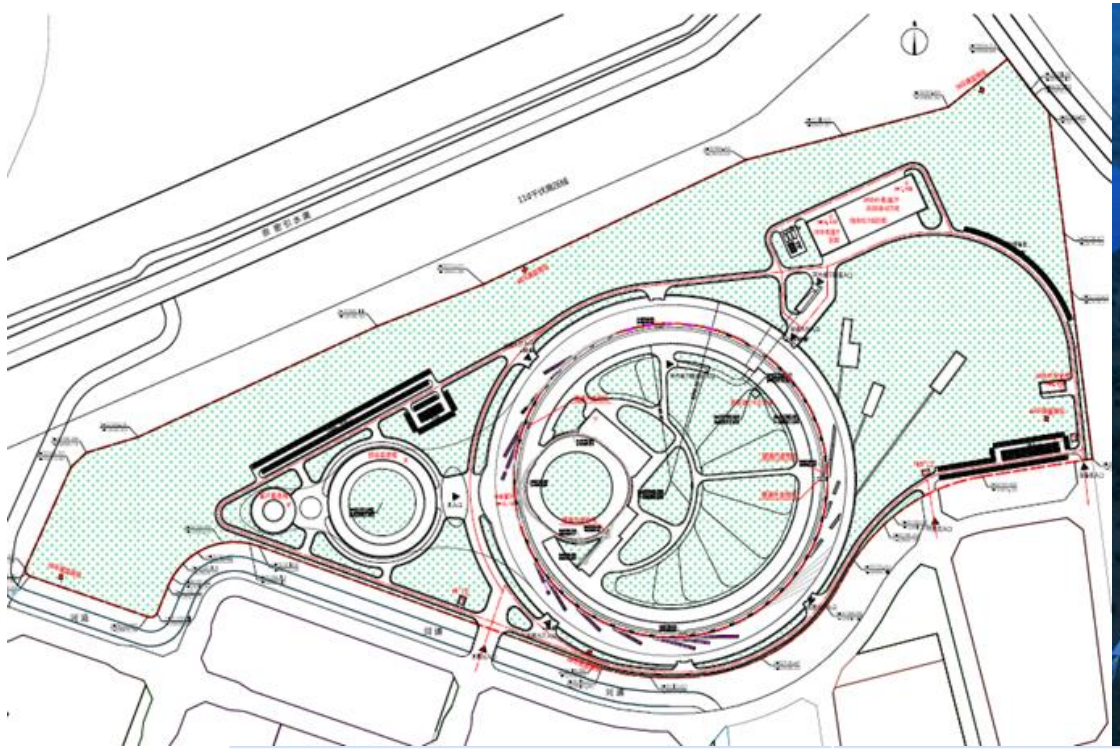
Outline

1. Introduction
2. Controls Overview
3. Control System Components
4. High-level Platforms and Applications
5. Summary

Introduction

- HEPS– 4th generation synchrotron light source, 7BA-lattice
  - 14+1 beamlines for phase 1
- Construction period – Jun. 2019 – Dec. 2025, ~US$700M

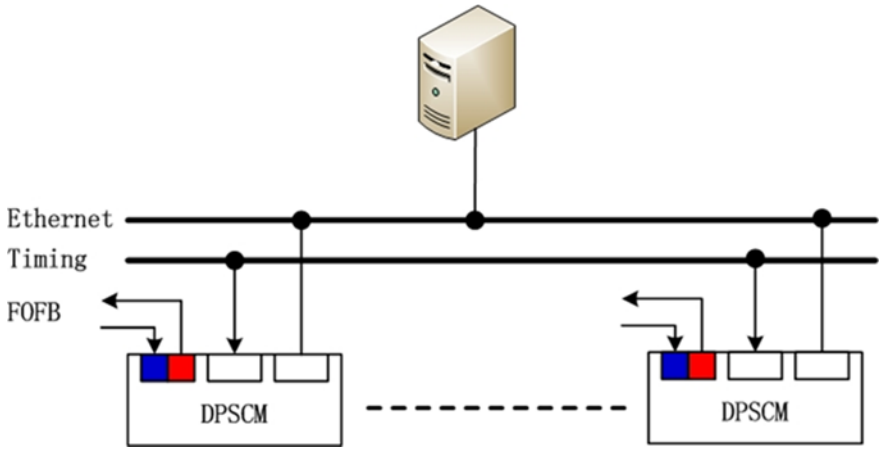


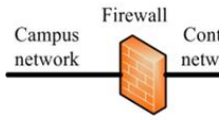
Controls Approaches

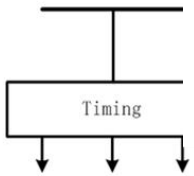
- Top-down architecture design with overall considerations
- EPICS based distributed control systems
- Industrial standard to save cost
- Expandability consideration
  - Modular design for easier upgrade and deployment
- For better construction project quality control:
  - Tracking project progress closely
- Data centric approach
- Collaboration with others

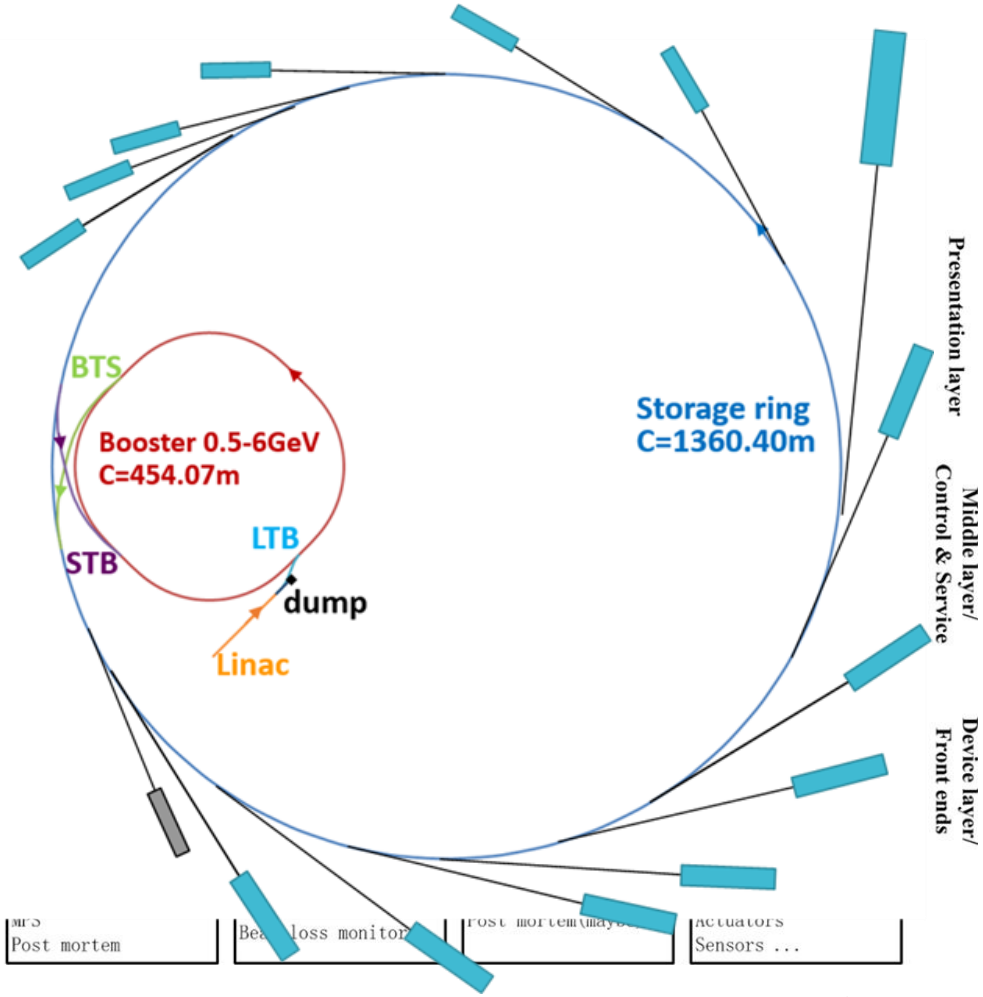
Accelerator Controls

- EPICS v3 based for now
- Standard interface to equipment
- Global Timing System
- Test bench for EPICS
- Machine Learning study







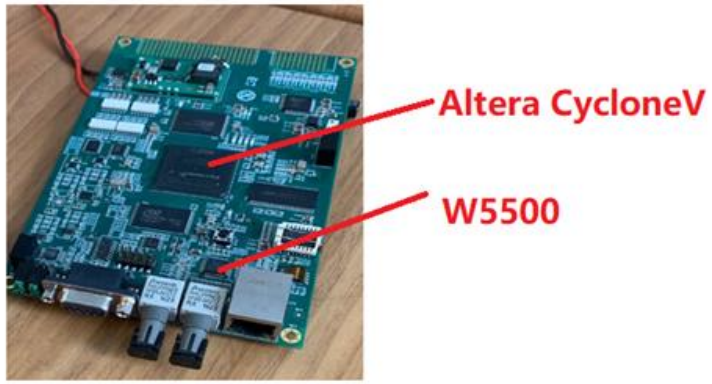


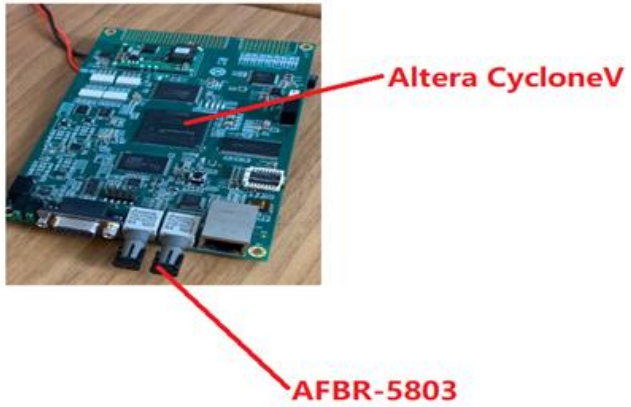
HEPS

Magnet Power Supply Control [1]

DPSCM-II Remote Control System

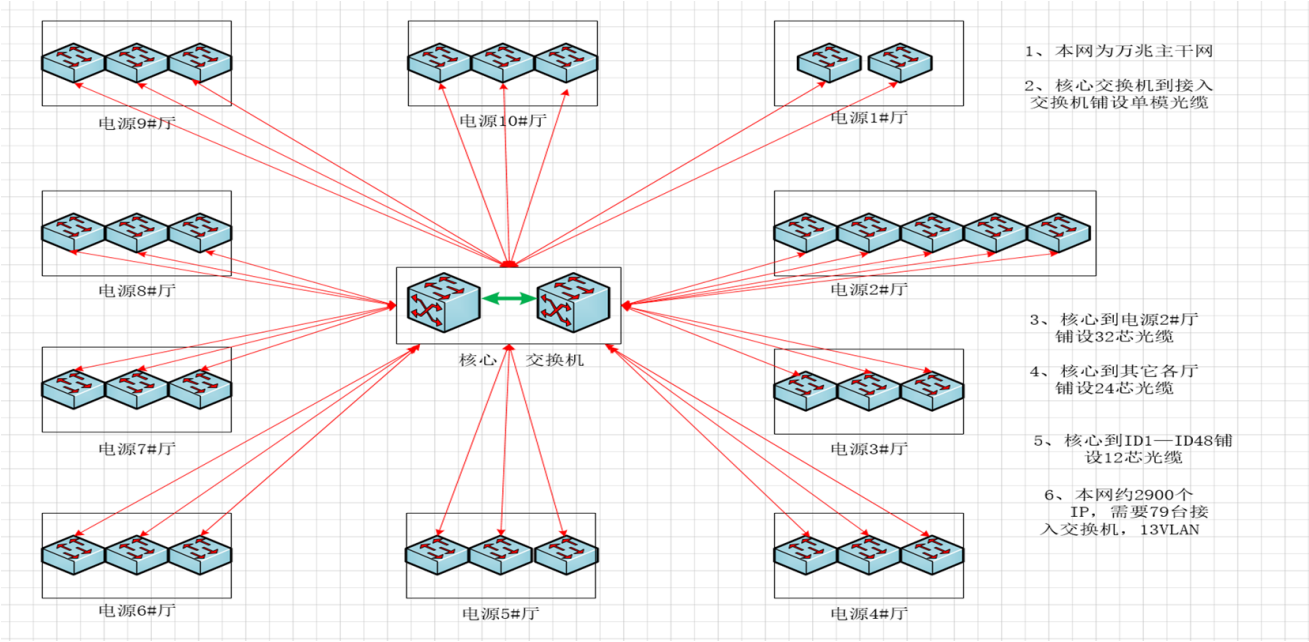
- Generic power supply and fast orbit feedback system power supply control board architecture
  - Generic power supply core architecture ： FPGA （Altera Cyclone 5 ）+ hard core Ethernet (W5500) interface
  - Fast orbit feedback system power supply ：FPGA （Altera Cyclone 5 ）+ fiber interface （AFBR-5803TZ ）





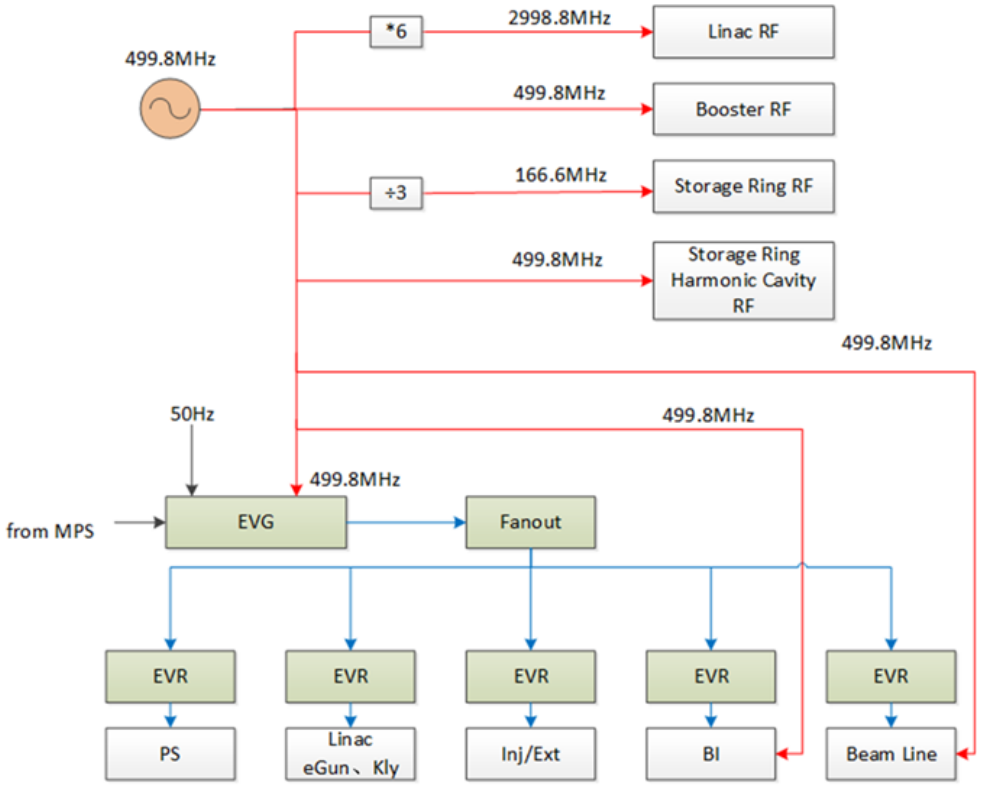
Magnet Power Supply Control [2]

- Over 2800 power supplies!
- 42-53 IOCs (8U servers, each with 16 PS), 238 embedded MOXA DA720 (2U, each with 14 PS)
  - Distributed
  - Redundancy
  - Geographically Networked
  - Cost considered
- Testing with EPICS 3.14.12



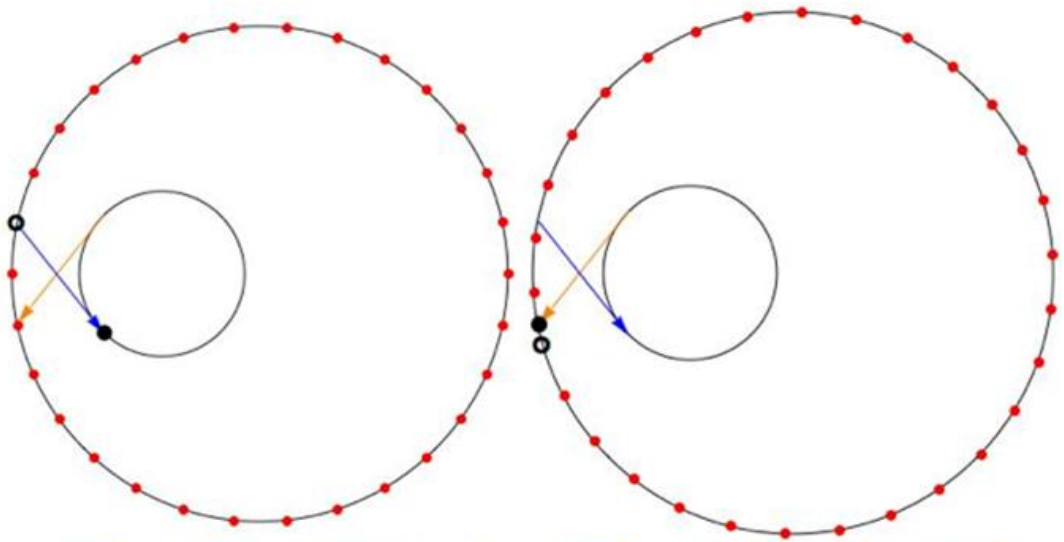
Global Timing System [1]

- Provide timing for accelerator systems, beamlines and experiments
  - ➢including clock, trigger and timestamp
- Less than 1 ps RMS jitter RF CLK signal distributed to linac, booster and storage ring RF and BPM system
- Event based trigger distribution system. Accuracy need to reach 20ps

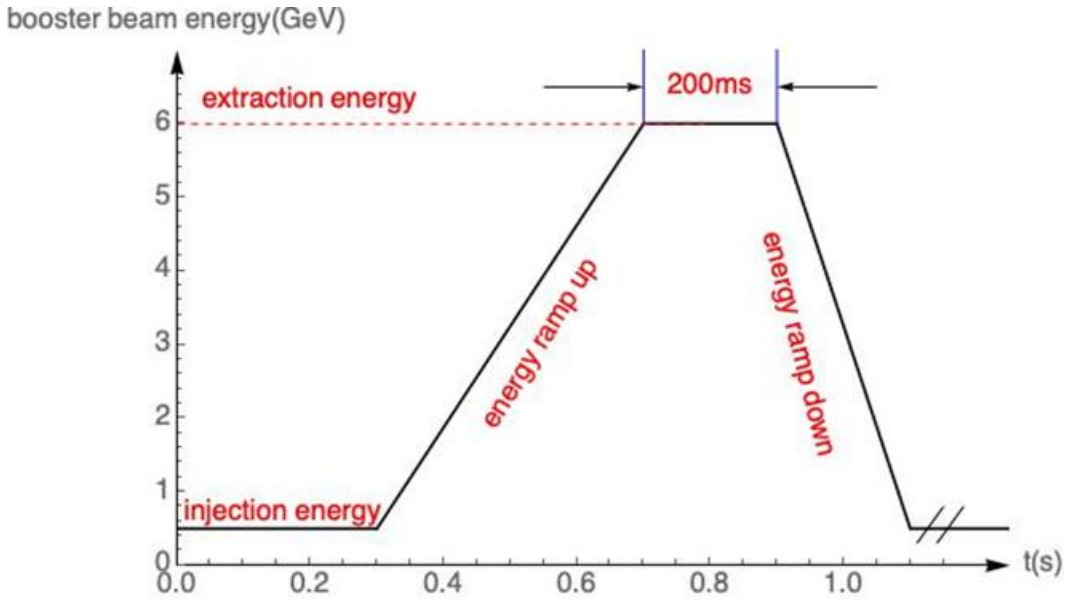


Global Timing System [2]

- 2 operating modes and complexed Injection & Extraction
  - high brightness mode: 680 bunches @200 mA: 1.33 nC/bunch, 6 ns bunch spacing
  - high bunch charge mode: 63 bunches @ 200 mA: 14.4 nC/bunch, 72 ns spacing

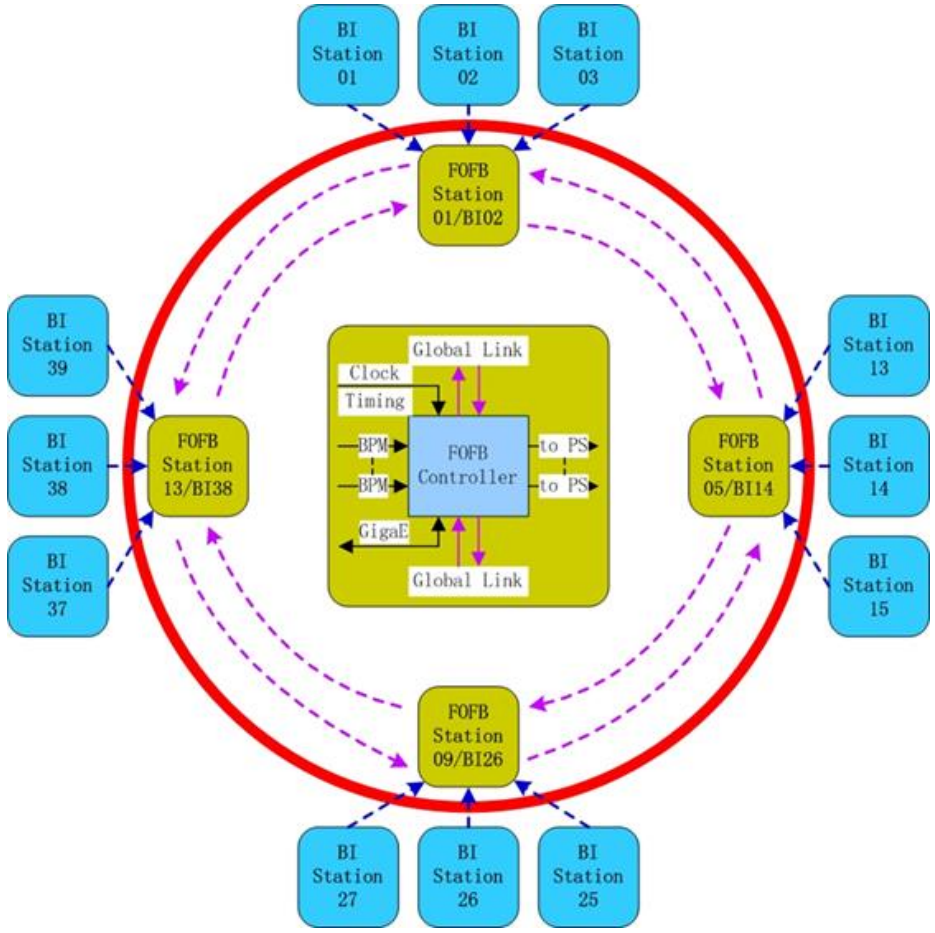


sSTB + sI2EB + NB * circB + sBTS == NS * circS + sE2IS,



Fast Orbit Feedback (FOFB)

- 300 Hz – 1 kHz bandwidth
- 576 BPMs, 192 horizonal/vertical correctors
- 16 FOFB nodes
  - Each as star topology
  - 16 connected as ring topology
- FPGA for fast computation
- Gigabit Transceiver for data communication



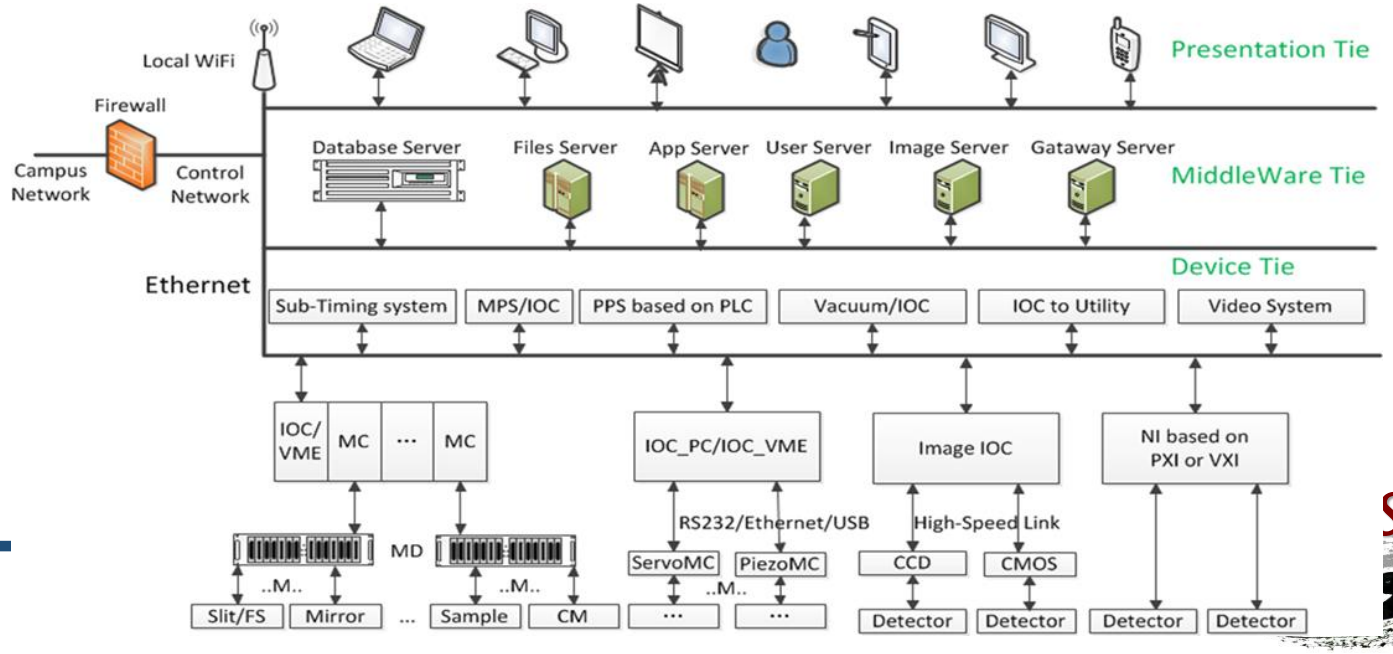
Beamline Controls [1]

- 14 Beamlines+1 testing beamline

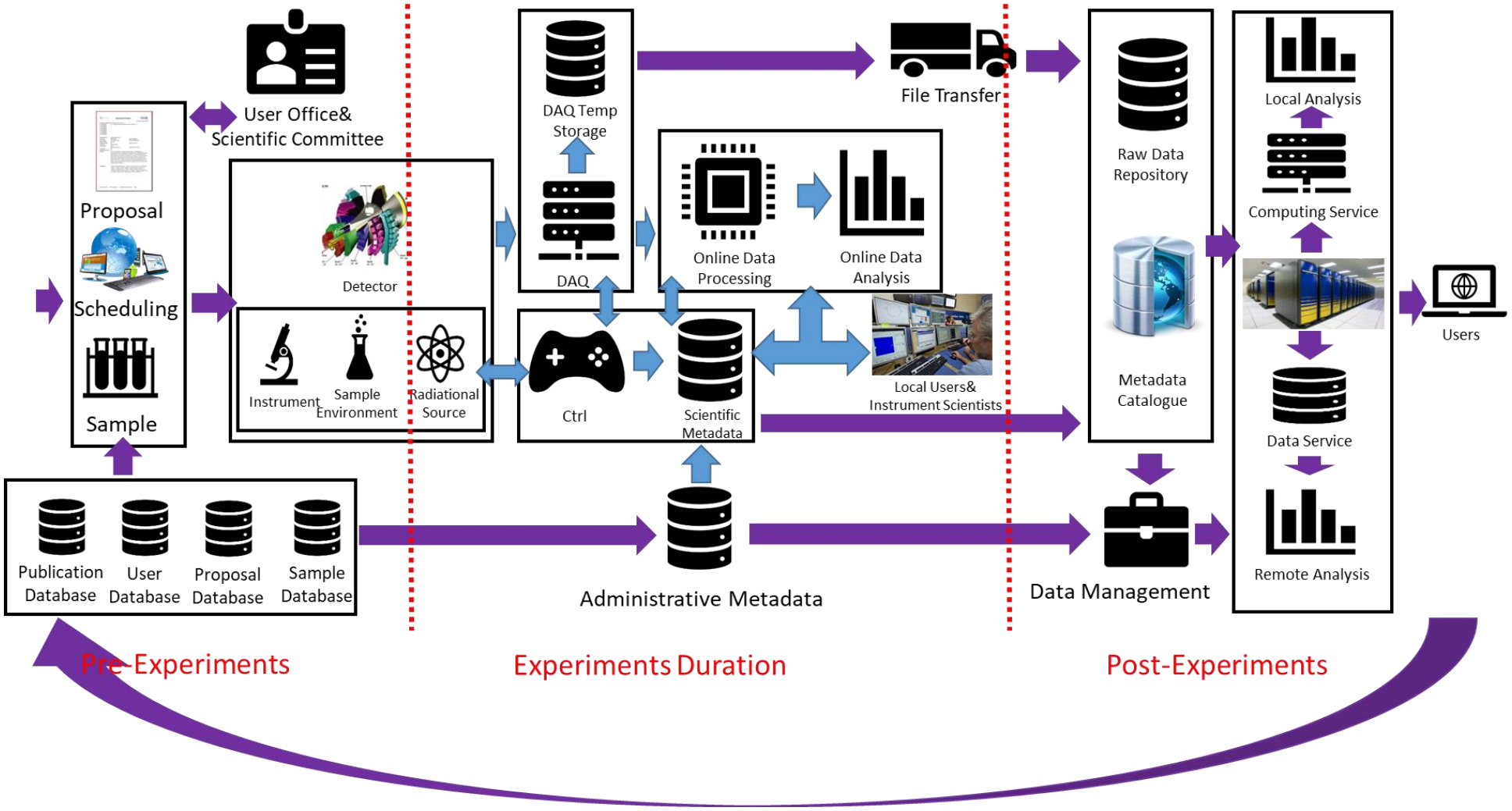
No.	Beamline
1	Engineering Materials Beamline
2	Hard X-ray NAnoprobe Multimodal Imaging (NAMI) Beamline
3	Structural Dynamics Beamline（SDB）
4	Hard X-ray Coherent Scattering Beamline
5	Hard X-ray High Energy Resolution Spectroscopy (HX-HERS) Beamline
6	High Pressure Beamline
7	Hard X-Ray Imaging Beamline
8	X-ray Absorption Spectroscopy Beamline
9	Low-Dimension Structure Probe (LODISP) Beamline
10	Microfocusing X-ray Protein Crystallography Beamline
11	Pink Beam SAXS
12	High Resolution Nanoscale Electronic Structure Spectroscopy (high-NESS)
13	Transmission X-ray Microscope Beamline
14	Tender X-ray beamline

Beamline Controls [2]

- EPICS based, possibly v7
- Trying to standardize equipment
- Designing data flow architecture, Integrating with scientific computing
  - Common data format, e.g. HDF5
  - Data preprocessing
  - Online analysis
  - Smart control w/ IoT

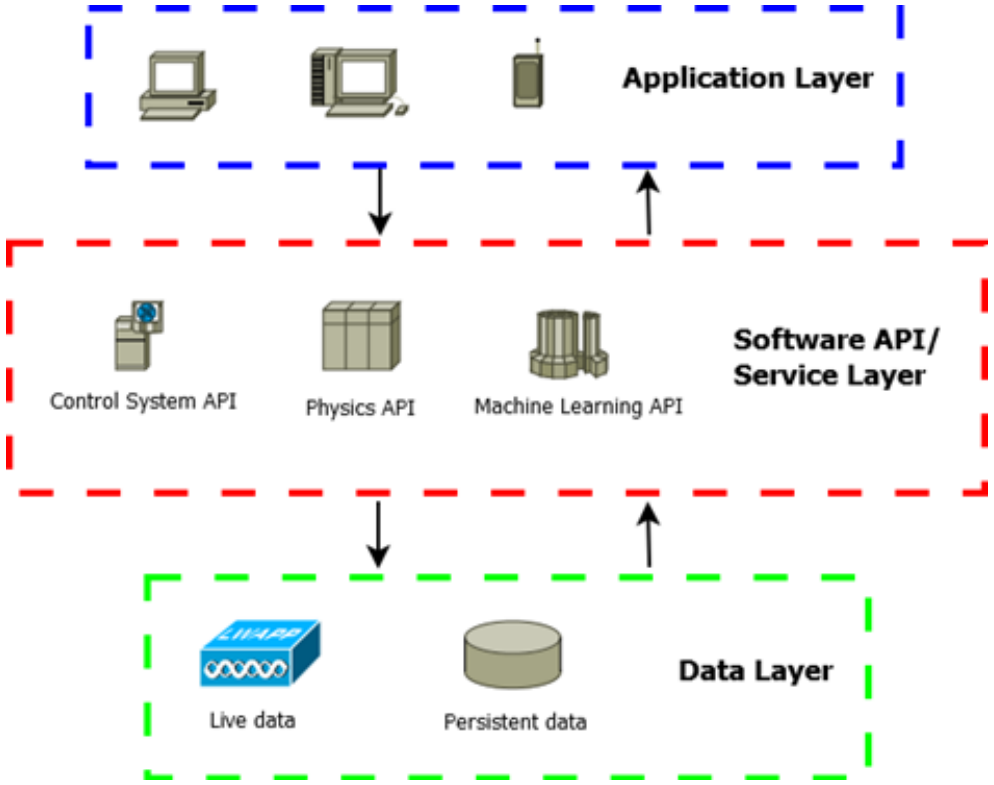


HEPS User Facility Software Architecture



High-level Application Platforms [1]

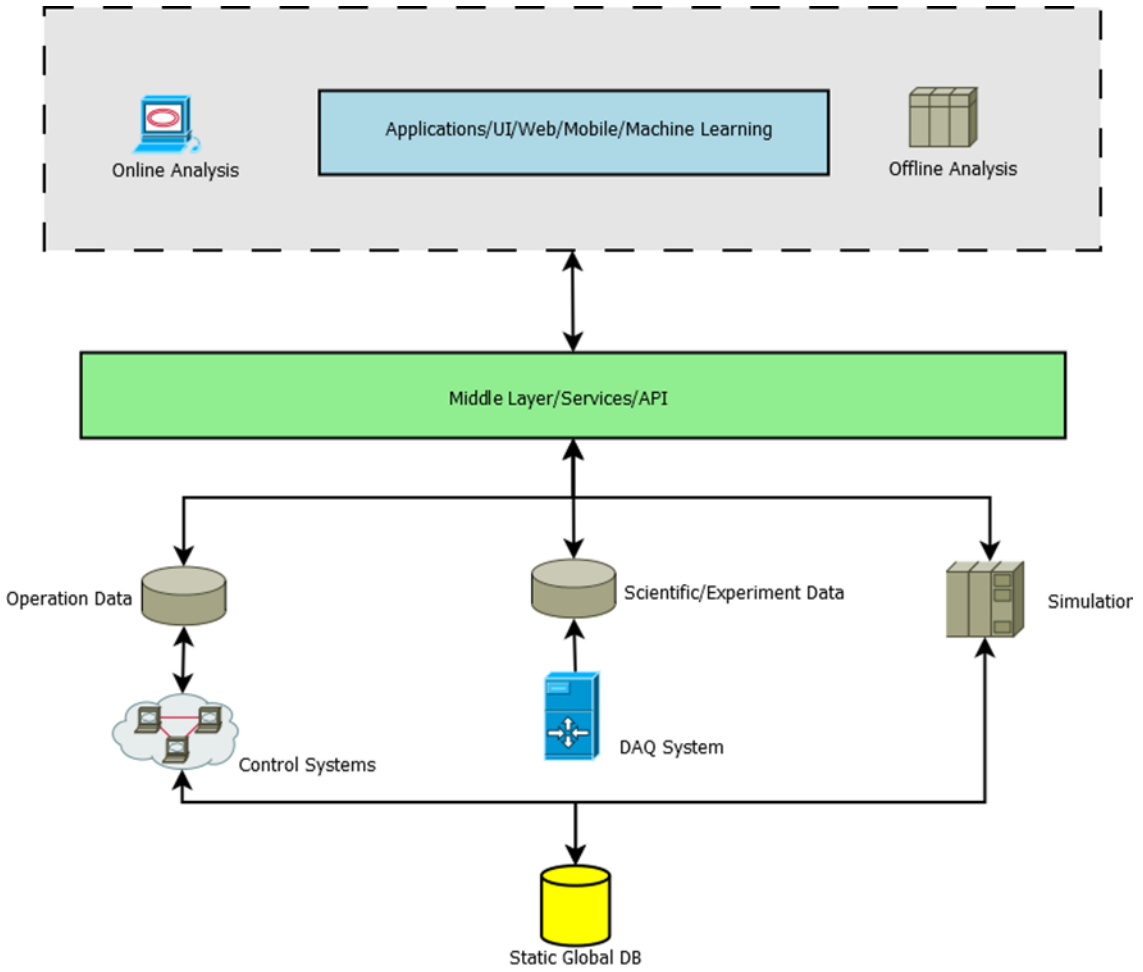
- Code reusability
- Physics applications
  - Open XAL, AP Toolbox
- General-purpose applications
  - CS-Studio
- Machine learning applications
  - Scikit-Learn, TensorFlow
- Python, MATLAB support
  - Quick prototyping
  - Flexible controls/apps
- Mobile apps support



High-level Application Platforms [2]

- Data Layer
- Middle Layer
- Applications

Data processing for ML Platform



ML Platform General Ideas

Machine Learning in Python

Scikit-learn/TensorFlow

- Simple and efficient tool for data mining & data analysis
- Built on NumPy, SciPy, and matplotlib
- Open source, commercially usable - BSD license

Machine Learning in MATLAB

MATLAB Machine Learning Toolbox

Data Handling

Data Sources

- EPICS live data
- TXT/Excel Files
- EPICS Channel Archiver
- EPISC Archiver Appliance
- Other data sources (e.g. PVLogger)

Output Data Format

- Pandas DataFrame
- TXT/Excel Files
- Other format: HDFS

Code Snippet

```
pvnames=['BIBPM:R1OBPM02:XPOS','BIBPM:R1OBPM03:XPOS','BIBPM:R1OBPM04:XPOS]
#also can load pvnames from files
engine=LoadData.getKey(server_addr,pvnames)
data=LoadData.getFormatChanArch(server_addr,engine,pvnames,start_time='11/30/2018
14:15:00',end_time='11/30/2018 14:16:00',merge_type='outer',interpolation_type='linear',
fillna_type=None,how=0)
```

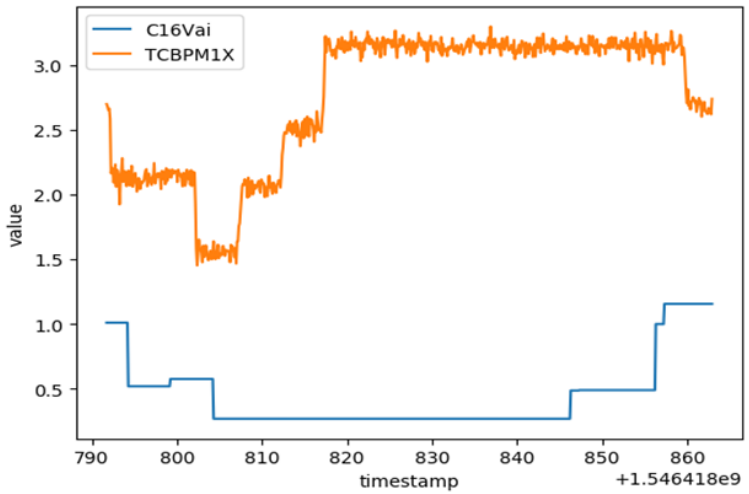
Machine Learning at Work

A test for BEPC-II timestamp correction

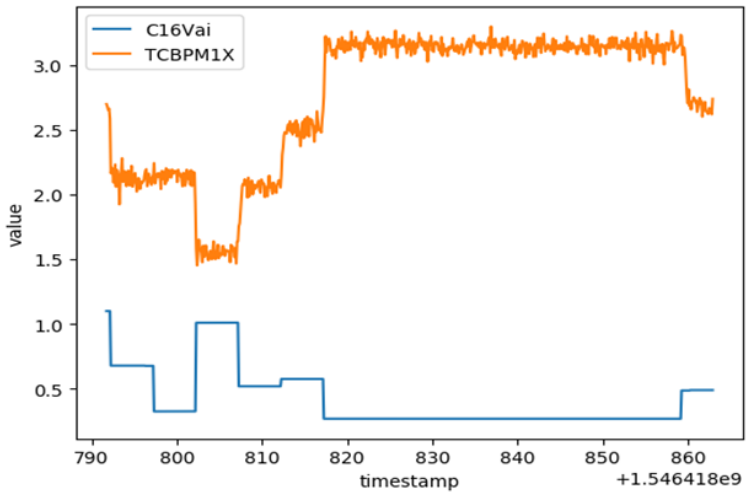
- Correlation function $R = [1 - \int \zeta (h(f_1(t + dt)) - f_2(t))]$
- Objective function $\arg\max R(dt)$

f1(t)&f2(t) : The relation between 'value' and 'timestamp' of two systems(such as correctors with BPM).
h(): Projection of one group of value to another.
ζ(): Integral coefficient. (Remove interference and noise. Keep normalization)

Input data

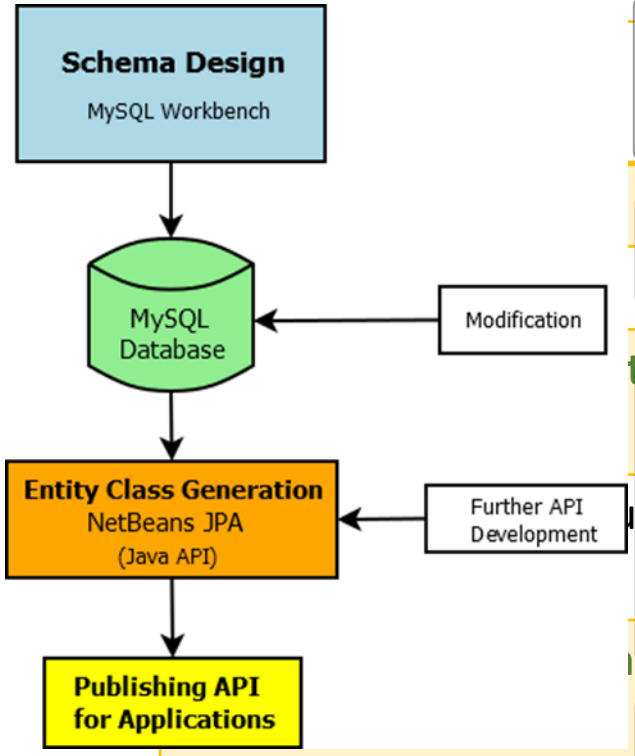


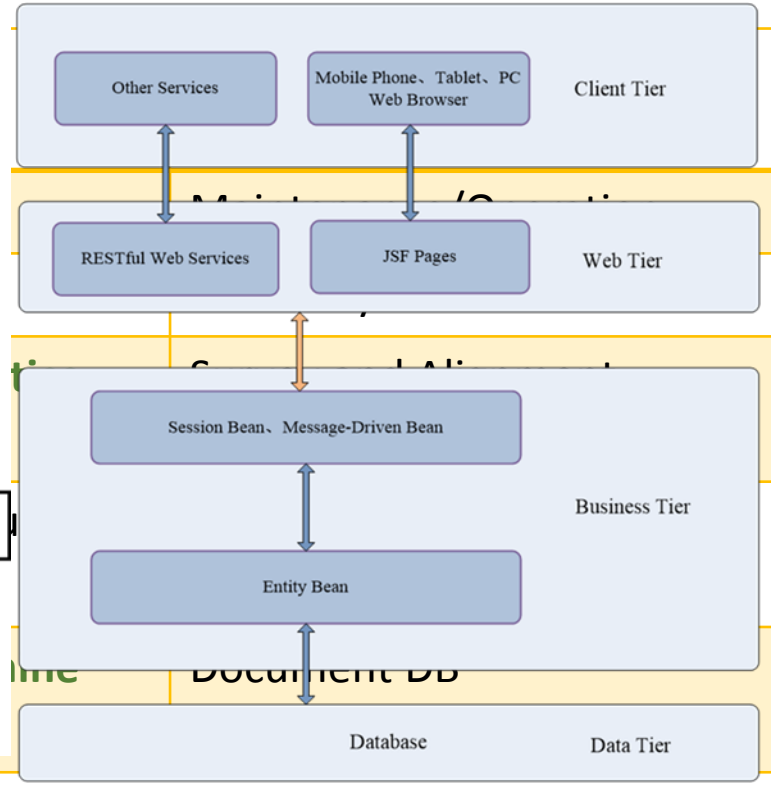
return

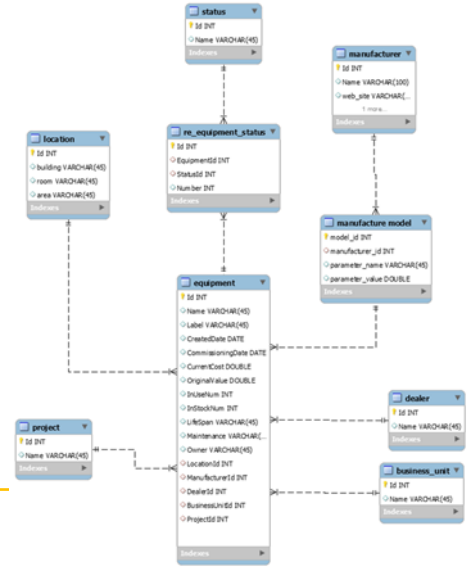


Databases

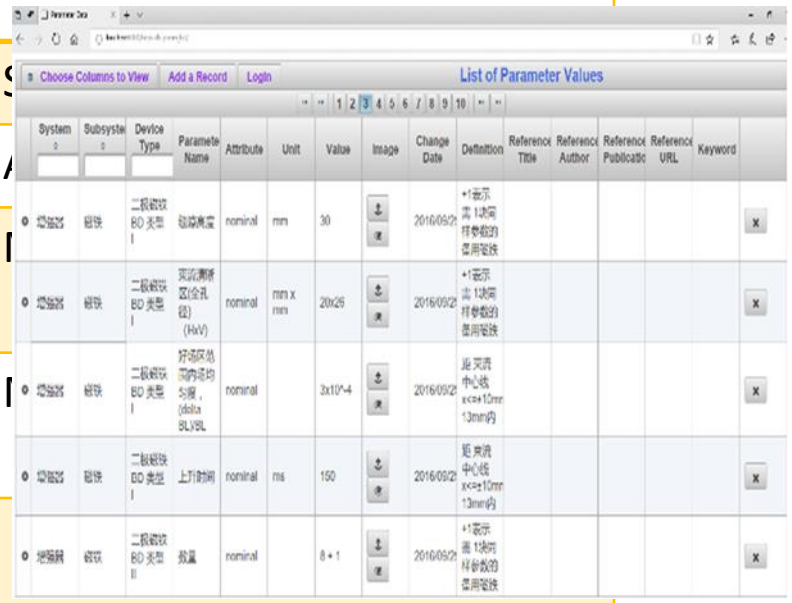
- 17 database domains in plan
- MySQL or Microsoft SharePoint/SQL







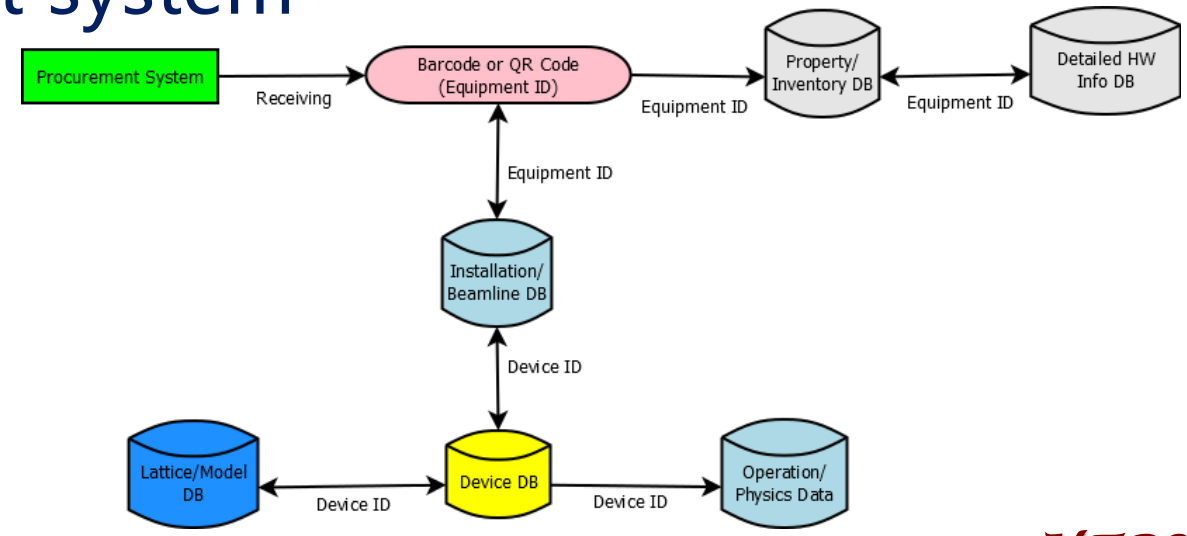
Cable



HEPS

Project Control

- Procurement, Equipment
- Issue Tracking System, Maintenance, Operation Logbook…
- Work Breakdown Structure (WBS) for project management
  - Cost and schedule control/monitoring
- SharePoint based document system
  - Project Web site
  - Work flow control
  - Document and data sharing



Summary

- HEPS Control Systems have initial design
- Overall consideration, modularized implementation
- Integration with project business sector
- Data centric approach
- Tough challenge for large amount of devices being controlled, large data sizes, control precision and speed
- Software platforms for applications
- Collaborations are welcome

Thank you for your help and support!