



Experience with controls tools at J-PARC

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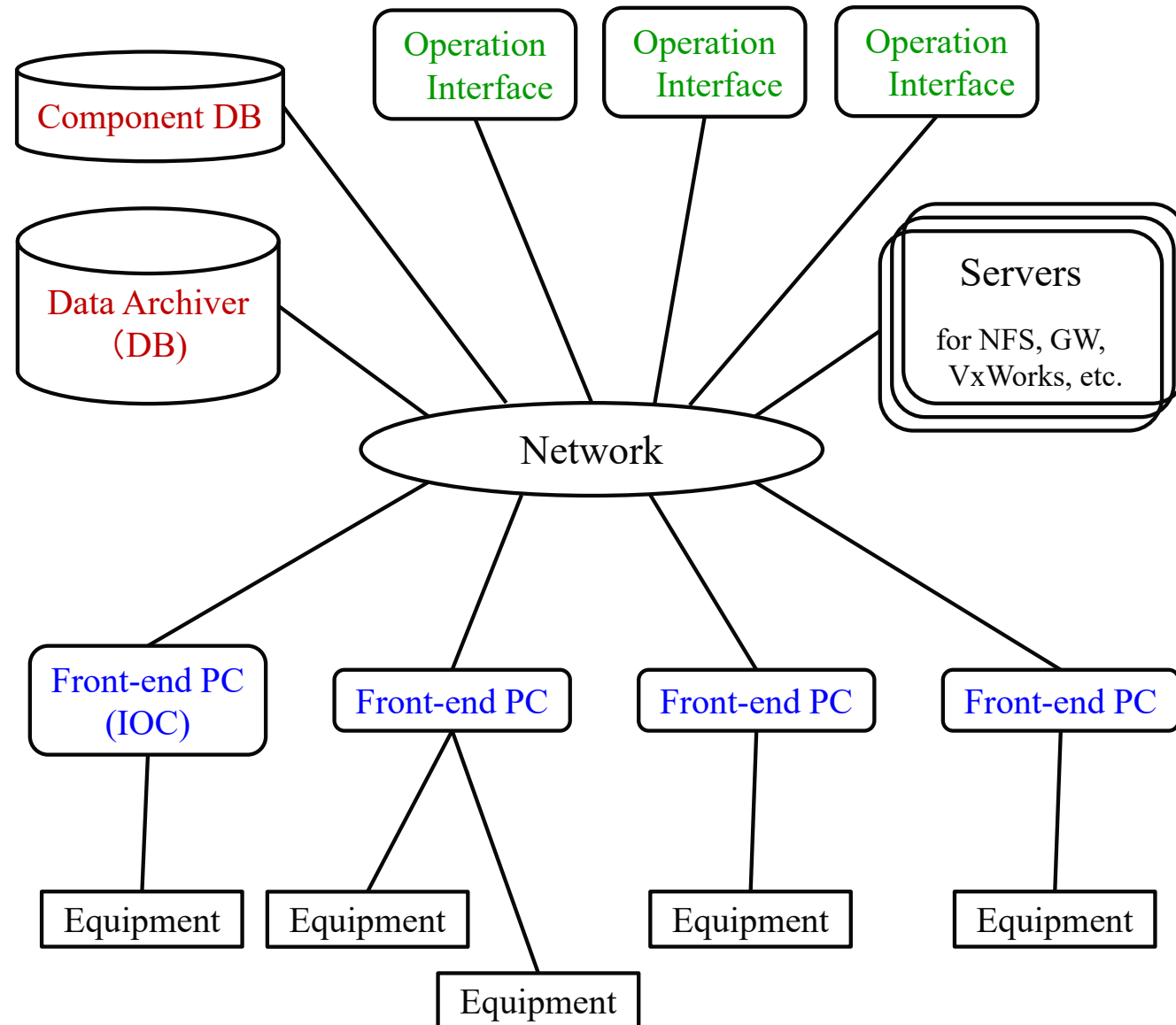


Contents

- Configuration of control system of Linac and RCS
- Database system and tools
- Operation Interface and Front-end
- Software under development
 - Operation tools
 - Equipment status monitoring system

Configuration of control system of Linac and RCS

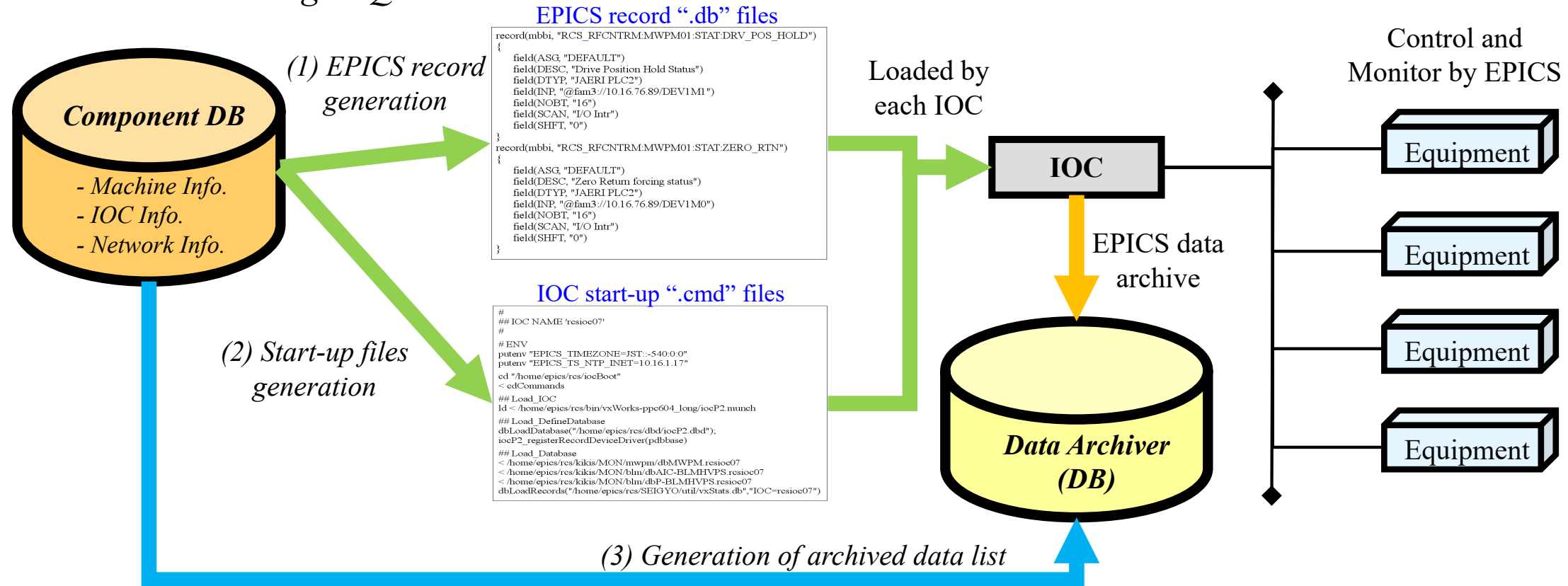
- Experimental Physics and Industrial Control System (EPICS) used in the J-PARC control system
- Network distributed control system using computers
- **Database System**
EPICS record generation and data archive
- **Operation Interface (OPI) Layer**
Consoles and displays to operate accelerator
- Network Layer
Network connecting OPI layer and front-end layer
- **Front-end Layer**
A group of computers (PC, VME) which control devices connected by field-bus



Database system and tools

Database system manages the data related EPICS.

DB : PostgreSQL



(1) EPICS record ".db" files auto-generation

EPICS record ".db" files is created using components information inserted Component DB.

To reduce workload to create EPICS record. And to reduce risk of input error by human.

(2) EPICS record start-up ".cmd" files auto-generation

Start-up files are created when EPICS record files is generated for consistency with start-up files and record files.

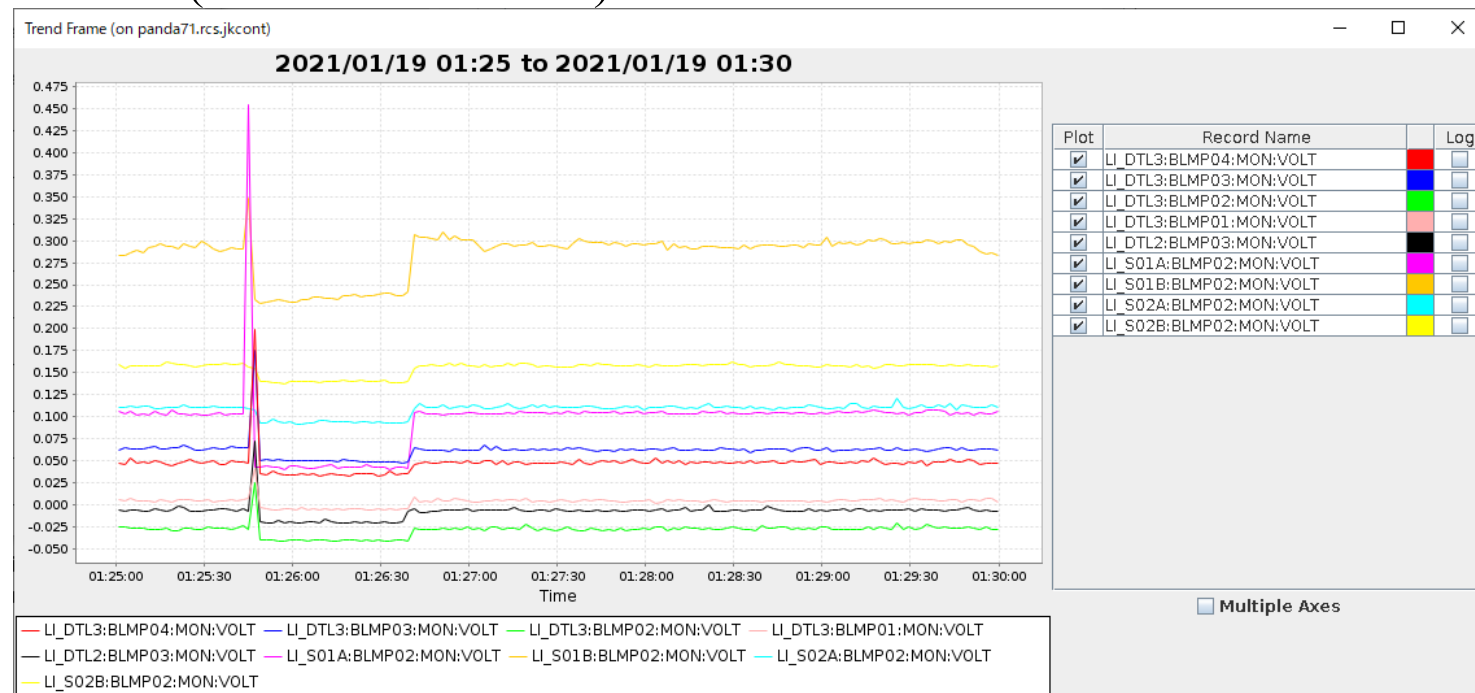
(3) Archived data list files generation

Archived data list files used by Data Archiver are generated using the data inserted Component DB.

Data Archiver for Linac and RCS

Because, EPICS archiver did not have the performance required for data acquisition at J-PARC around 2005, we developed in-house data archiver.

- In-house data archiver for EPICS (2005~)
 - Developed by JAEA
 - Database : PostgreSQL
 - Fixed cycle of acquisition (1 ~ 10 sec)
 - Archive data defined by Component DB
 - EPICS records and archive data list are generated
 - Linac: ~ 38,000 control points, RCS: ~ 21,000 control points
 - Data stored on each archive server (for Linac and RCS)
 - Data rate:
 - Linac: 1.7 TB/year
 - RCS: 1.0 TB/year



Archived data viewer is also developed in-house by Java.

Servers for Linac and RCS

- Rackmount-servers :
 - Component DB server (EPICS records generation) : 2
 - Data archiver server (DB) : 4 + 4
 - VxWorks compiler : 2
 - NFS server : 2
 - EPICS Gateway : 5
 - Linux IOC (soft-IOC, for OSC, etc.) : ~ 20



Component DB server (DELL R320)

Operation Interface and Front-end

Operation Interface (OPI)

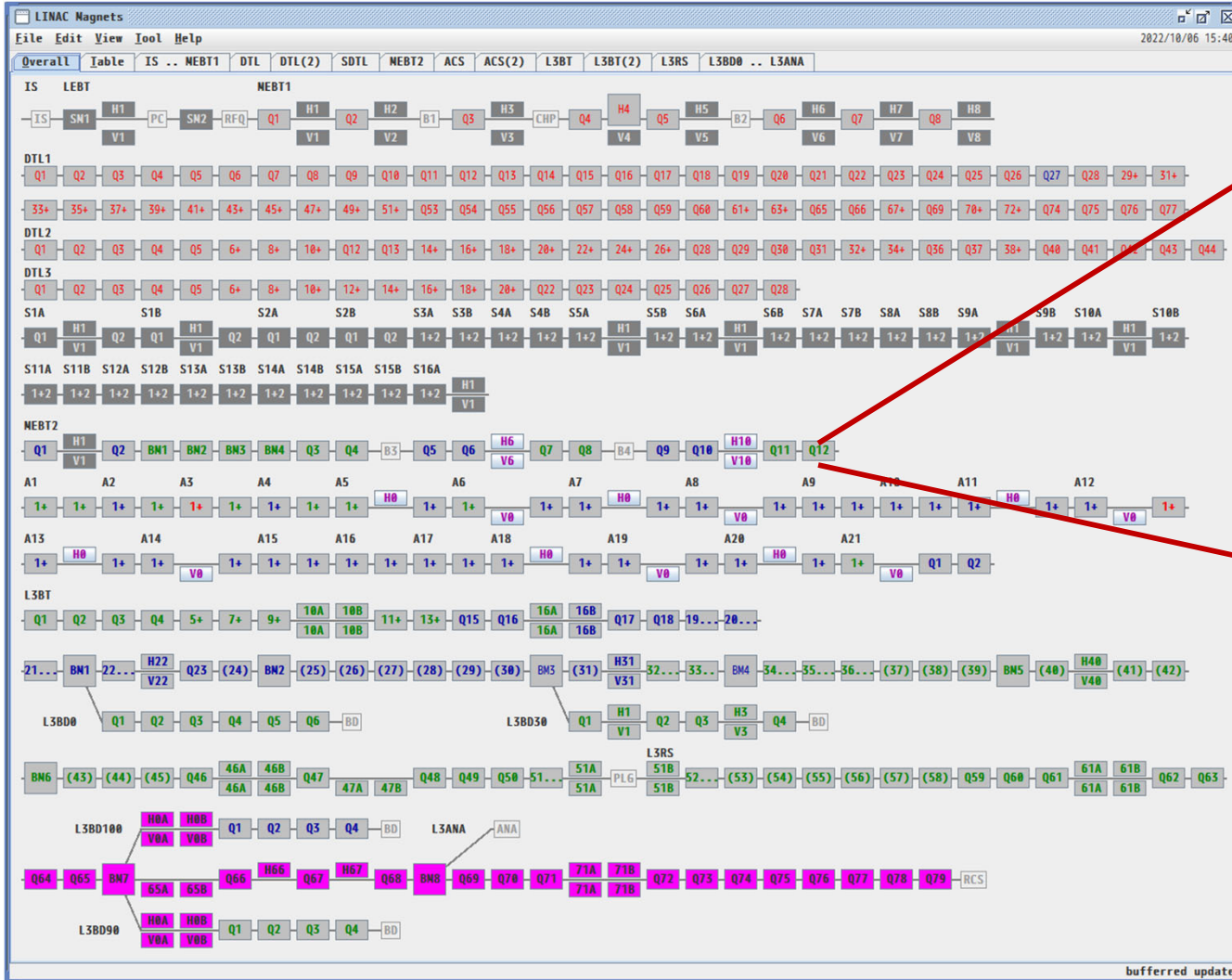
- Developed by Java and MEDM
- OPIs for simple remote monitoring and operation of equipment are created in MEDM. -> MEDM OPI
- OPIs for equipment groups are created in java. -> Java OPI
-> MEDM OPI is called (linked) from Java OPI.
- Operation logic (sequences) are implemented in java.
-> Much of the logic is implemented in Java OPIs.
(EPICS sequence record is not used)

Front-end

- VME, Linux PC (Server)
- EPICS driver is developed by JAEA (in-house).
- Supported devices :
VME (Advanet 7501, etc.), PLC (FA-M3, MELSEC, etc.),
Oscilloscope (Tektronix, Yokogawa, Rohde & Schwarz),
EMBLAN (interface network board), Refractive Memory, etc.

Typical OPIs (1)

Java OPI for Linac power supply (PS) group



MEDM OPI for an PS

Status: **STANDBY** Remote

RUN STBY STOP Reset

Parameter: 0.0 A strobe

Monitor: 0.0 A 0.00 V

Interlock: Curr Error Outside
 Volt Error Mag. Temp. 1
 PS Fault Mag. Temp. 2
 Mag. Water Flow

for simple monitoring and control

to monitor and control so many PS

Typical OPIs (2)

Linac Status Panel (Java OPI)

Timing OPI (Java OPI)

The LINAC Status Panel (Java OPI) displays the following information:

- File Edit View Help** (Menu)
- PPS** (Pulse Position System): mode: Li+RCS+MLF, status: PPS OK, BSTP Permit.
- MPS** (Machine Protection System): target: MLF, status: MPS OK, Inhibit, IS Arc Delay.
- Accelerator**: pulse width: 385 us, repetition: 24.2 Hz, bunch (MLF|MR): 2 | 2, medium pulse: 439 | 439ns, mabiki(n/128): 128 | 128, energy @L3BT: 0.0MeV, current@MEBT1: 57.6mA.
- HV/RF** (High Voltage / Radio Frequency):
 - RFQ: B, CHOP
 - HV1: RFQ, DTL
 - HV2: S1-4
 - HV3: S5-8
 - HV4: S9-12
 - HV5: S13-16
 - HV6: B3,4
 - HV7: A1-4
 - HV8: A5-8
 - HV9: A9-12
 - HV10: A13-16
 - HV11: A17-20
 - HV12: A21 DB1,2
- Beam Path Diagram**: Shows the beam path from BEAMON through LEBT, MEBT1, DTL, SDTL, MEBT2, ACS, L3BT, and finally to RCS. Key points are marked with 0, 30, 90, and 100.

The TSTX Timing OPI (Java OPI) displays a detailed timing table with columns for various stages (S16-S22) and rows for individual beam pulses (0-34). The table contains numerical values representing timing parameters. At the bottom, there are control buttons for 'INI', 'SEQ', and 'SHIFT', along with 'Send' and 'Cancel' buttons. The status at the bottom left indicates 'TSTX device state is RUN'.

*Required array data monitoring and control.
-> Impossible to develop by MEDM.*

OPI Hardware for Linac & RCS

- Desktop PC
 - Linac: DELL Optiplex OptPlex3050, etc.
 - RCS: Lenovo ThinkCentre M720q, M75q-1, etc.
 - Linac: ~ 30 pieces, RCS: ~ 30 pieces
 - 1 screen (partially 2 screens)
 - for control and work (software development, etc.)
- Intel NUC (for applications run locally)
 - Core™ i3 (4M Cache, up to 3.60 GHz), 8 GB
 - 1 or 2 screens
 - ~ 10 pieces

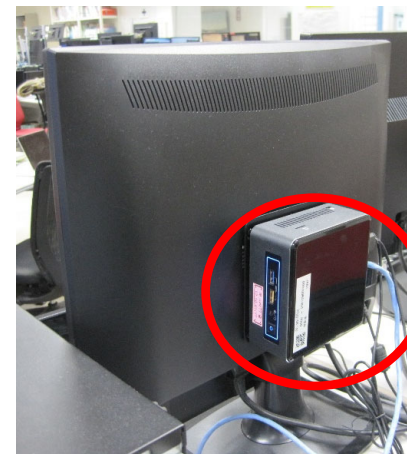
Recently, desktop PCs have been replaced by NUCs.



LI



RCS



NUC



Front-end computers (IOCs) for Linac & RCS

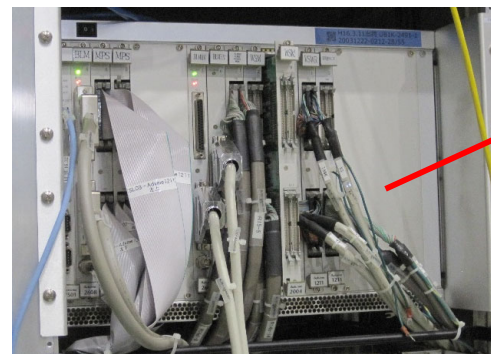
- VME
 - Advme7501: PowerPC750 (300~500 MHz) 128 MB
 - IOC for VME IO bords between power supply, MPS modules, etc.
 - IOC for PLC, EMBLAN
- Servers (Linux IOC)
 - Rack mount server (1U)
 - Soft-IOC, IOC for measuring instrument such as Oscilloscope, etc.
 - IOC for Reflective Memory of Timing system
- Small-factor fan-less micro-server (PiNON Saba-Taro)
 - Celeron J1900 (4-cores, 1.9GHz) 8GB, etc.
 - IOC for spectrometer of Ion source



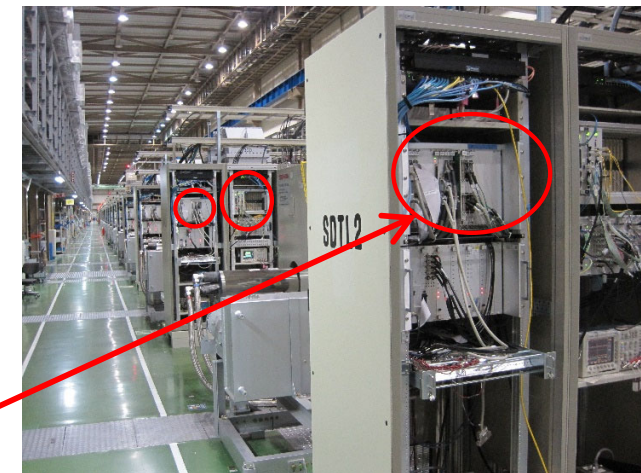
IOCs for
measuring instrument



PiNON Saba-Taro



VME



Software under development (OPI tools)

Background :

- At the beginning of J-PARC operation, it was unclear what software tools would be required.
- Now, it is considered that the required applications have been almost fixed.
- It is difficult to maintain the original system in terms of cost and manpower.

Under consideration :

- Develop OPI with EPICS CSS, basically.
- About functions that cannot be supported by CSS, those will be developed by Java and C language.
- Replace Data Archiver (in-house) with Archiver Appliance.

Replacement of OPI and Data Archiver for some systems have been started from 2021.

Typical OPI by CSS (Gas-sheet beam monitor)

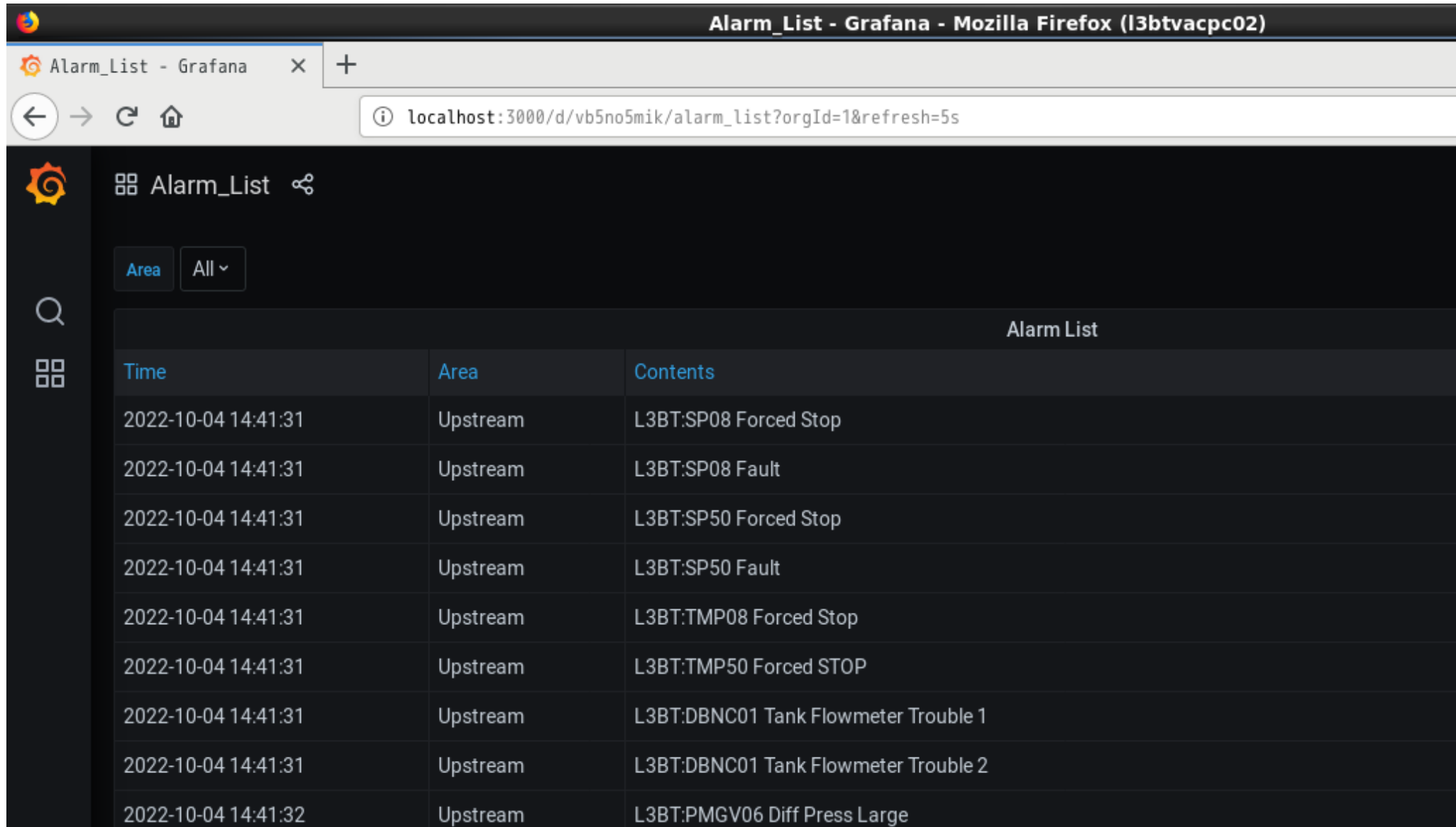
The screenshot displays the CS-Studio OPI for the J-PARC Linac Gas-sheet Beam Monitor. The interface is divided into several functional areas:

- Auto/Manual Control:** Includes buttons for CONTROL, LOCAL, and REMOTE. Below these are MASTER INTERLOCK MODE, INTERLOCK, and MAINTA.
- Alarm State:** Shows 'ALARM' in a red box and 'MPS' in a red box. A 'RESET' button is located below.
- MPS State:** Shows 'MPS' in a red box and 'Vacuum Setting' below it.
- Status Information:** A legend box on the bottom left defines the following states:
 - STOP / CLOSE / DOWN (Green background)
 - STANDBY / ACC / BRK / MOVING / DEGAS (Yellow background)
 - RUN / OPEN (Red background)
 - FAULT (Pink background)
 - Status Error (Grey background)
- Process Diagram:** A complex schematic showing the gas injection system. Key components include:
 - Gas Injection Chamber:** The central component with associated valves (GASIN MV01, GASIN LV01, GASIN VV01, GASIN SV01) and gauges (GASIN PIG01: 0.92E0, GASIN PIG02: 0.90E0).
 - High Voltage Monitors (MC HV01-5):** Five monitors with values of 1 V, 2 V, 1 V, 2 V, and 2 V.
 - Beam Line (BL) and L3BT Components:** Various gauges and valves along the beam line, such as BL BAG01 (2.6E-7), BL L3BT:BAG08B (1.0E-7), and L3BT_BLGV12A (GM:GV01).
 - Diaphragm (DIFF) and Turbopumps (TMP):** Components like DIFF MV01, DIFF DSP01, and MC TMP01 (38.1 K).
 - Other Sensors:** MC BAG01 (4.1E-7), MC TM01 (38.1 K), MC PIG01 (0.35E0), and BL PIG01 (0.32E0).

Typical Alarm List OPI (Vacuum system)

Software Information :

PostgreSQL 9.6, Alarm Server 4.5.0, grafana 7.2.0



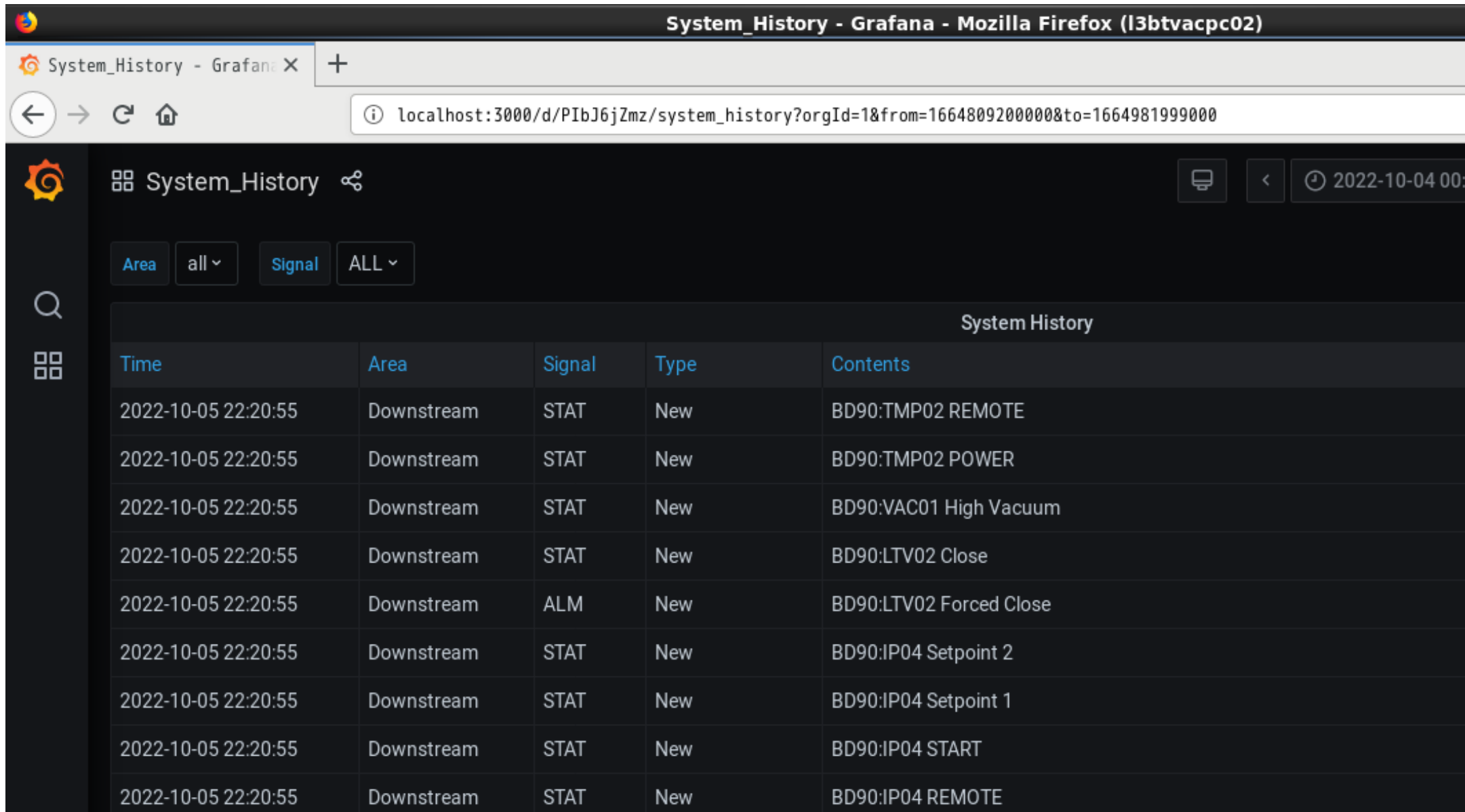
The screenshot shows a web browser window with the title "Alarm_List - Grafana - Mozilla Firefox (l3btvacpc02)". The browser address bar shows the URL "localhost:3000/d/vb5no5mik/alarm_list?orgId=1&refresh=5s". The Grafana interface displays a table titled "Alarm List" with the following data:

Time	Area	Contents
2022-10-04 14:41:31	Upstream	L3BT:SP08 Forced Stop
2022-10-04 14:41:31	Upstream	L3BT:SP08 Fault
2022-10-04 14:41:31	Upstream	L3BT:SP50 Forced Stop
2022-10-04 14:41:31	Upstream	L3BT:SP50 Fault
2022-10-04 14:41:31	Upstream	L3BT:TMP08 Forced Stop
2022-10-04 14:41:31	Upstream	L3BT:TMP50 Forced STOP
2022-10-04 14:41:31	Upstream	L3BT:DBNC01 Tank Flowmeter Trouble 1
2022-10-04 14:41:31	Upstream	L3BT:DBNC01 Tank Flowmeter Trouble 2
2022-10-04 14:41:32	Upstream	L3BT:PMGV06 Diff Press Large

Typical System History OPI (Vacuum system)

Software Information :

PostgreSQL 9.6, Alarm Server 4.5.0, grafana 7.2.0



The screenshot shows the Grafana System History interface. The browser title is "System_History - Grafana - Mozilla Firefox (l3btvacpc02)". The URL is "localhost:3000/d/PIbJ6jZmz/system_history?orgId=1&from=1664809200000&to=1664981999000". The interface includes a search bar, a sidebar with navigation icons, and a table of system history events. The table has columns for Time, Area, Signal, Type, and Contents. The events listed are:

Time	Area	Signal	Type	Contents
2022-10-05 22:20:55	Downstream	STAT	New	BD90:TMP02 REMOTE
2022-10-05 22:20:55	Downstream	STAT	New	BD90:TMP02 POWER
2022-10-05 22:20:55	Downstream	STAT	New	BD90:VAC01 High Vacuum
2022-10-05 22:20:55	Downstream	STAT	New	BD90:LTV02 Close
2022-10-05 22:20:55	Downstream	ALM	New	BD90:LTV02 Forced Close
2022-10-05 22:20:55	Downstream	STAT	New	BD90:IP04 Setpoint 2
2022-10-05 22:20:55	Downstream	STAT	New	BD90:IP04 Setpoint 1
2022-10-05 22:20:55	Downstream	STAT	New	BD90:IP04 START
2022-10-05 22:20:55	Downstream	STAT	New	BD90:IP04 REMOTE

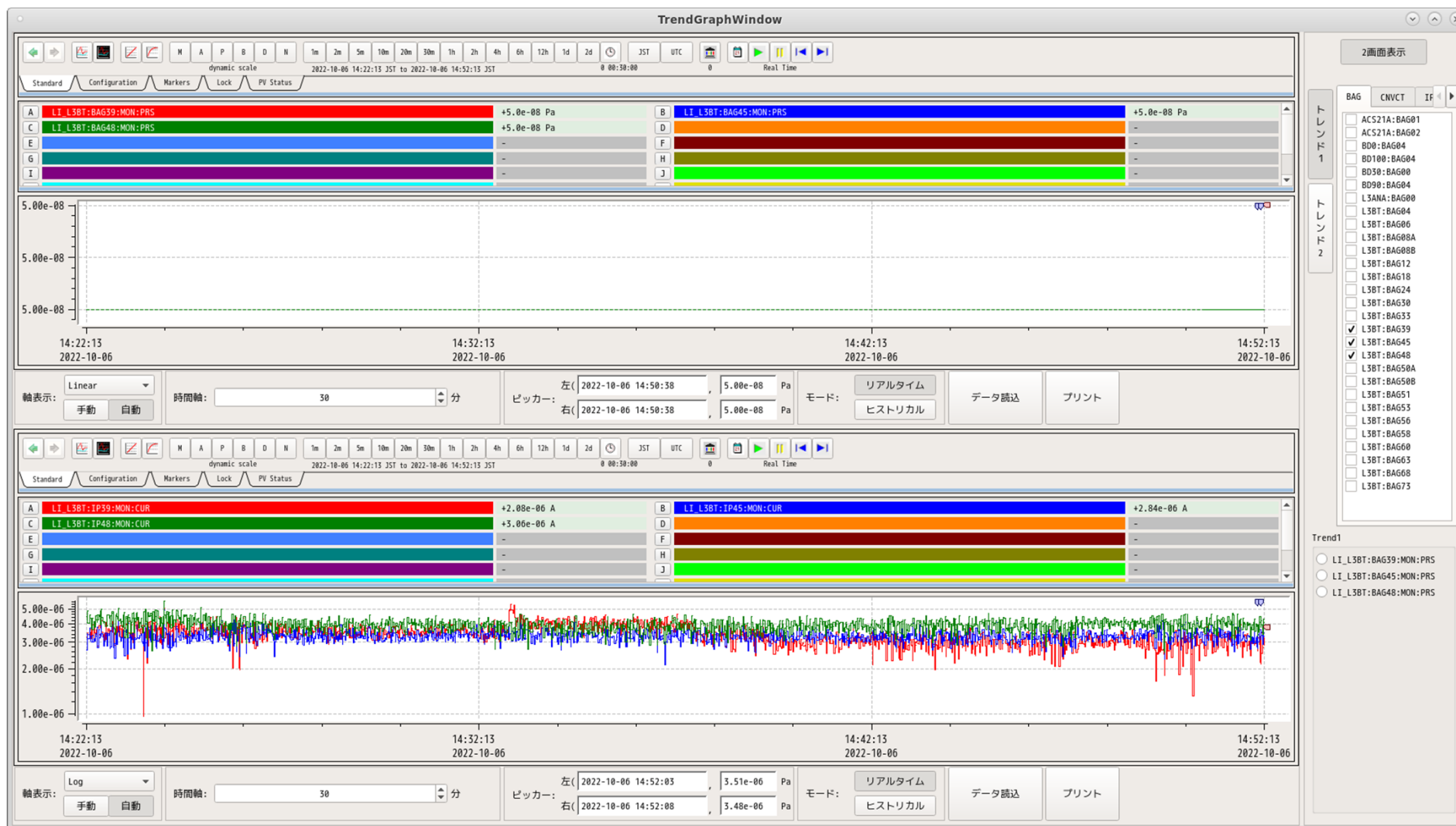
Typical Trend Graph OPI (Vacuum system)

Data Browser in CSS could not support the requested functions such as graph scale control, etc.

-> Developed using Qt (used at other facilities).

Software Information :

Archiver Appliance 2018.Nov Release, MySQL 5.7.24, Qt 5.3.2



Equipment status monitoring system (Soft MPS)

To eliminate accidents caused by human error, such as operation errors.

Monitoring OPI (RCS Collimator)

Monitored value Threshold

ILK Status

DeviceName	SetVal	RbVal	RB_LO	RB_HI	MonVal	MON_LO	MON_HI	BaseVal	BASE_LO	BASE_HI	FIX_LO	FIX_HI	ILK	MON	RB	BASE	FIX	MASK	M
RCS_C02:H0COL01:MON:1ST_POS	0.00				18.46	0.00	0.00						Red	Green					
RCS_C02:H0COL01:MON:2ND_POS	0.00				8.83	0.00	0.00						Red	Green					
RCS_C02:H0COL01:MON:3RD_POS	0.00				13.12	0.00	0.00						Red	Green					
RCS_C02:H0COL01:MON:4TH_POS	0.00				1.54	0.00	0.00						Red	Green					

DeviceName	SetVal	RbVal	RB_LO	RB_HI	MonVal	MON_LO	MON_HI	BaseVal	BASE_LO	BASE_HI	FIX_LO	FIX_HI	ILK	MON	RB	BASE	FIX	MASK	M
RCS_S02:CLLMTCTRL02:MON:VOLT01					291.00			292.00	290.00	294.00									
RCS_S02:CLLMTCTRL02:MON:VOLT02					391.00			392.00	390.00	394.00									
RCS_S02:CLLMTCTRL02:MON:VOLT03					324.00			324.00	322.00	326.00									
RCS_S02:CLLMTCTRL02:MON:VOLT04					331.00			331.00	329.00	333.00									
RCS_C02:RNGCOL01:MON:1ST_TARGET_POS	5.95				5.95	4.95	6.95												

DeviceName	SetVal	RbVal	RB_LO	RB_HI	MonVal	MON_LO	MON_HI	BaseVal	BASE_LO	BASE_HI	FIX_LO	FIX_HI	ILK	MON	RB	BASE	FIX	MASK	M
RCS_S02:CLLMTCTRL02:MON:VOLT05					405.00			375.00	373.00	377.00			Yellow			Green			
RCS_S02:CLLMTCTRL02:MON:VOLT06					565.00			566.00	564.00	568.00			Yellow			Green			
RCS_S02:CLLMTCTRL02:MON:VOLT07					400.00			369.00	367.00	371.00			Yellow			Green			
RCS_S02:CLLMTCTRL02:MON:VOLT08					463.00			462.00	460.00	464.00			Yellow			Green			
RCS_C02:RNGCOL02:MON:1ST_TARGET_POS	13.12				13.12	12.12	14.12												

- Monitor the equipment status based on EPICS monitored values (PV values) and threshold.
- This system logic part is developed in C language.
 - > Same status can be displayed in all OPI.
- Threshold can be set for each operation
 - > Threshold can be generate from a snapshot value.
- Errors of initial parameter setting can be avoided.
- Currently, under operation test (parameters are being adjusted)
 - > Goal is to run as Soft MPS.

Summary

- In the beginning of J-PARC operation (around 2005), the OPI tool and Data Archive tool of EPICS could not support the requirements of J-PARC.
 - > Therefore, we developed them in-house at JAEA.
- Database system automatically generates EPICS record db files, IOC startup files, and the archiver data lists for Data Archiver from equipment information.
- OPI was developed by Java and MEDM.
 - Java: for the implementation of sequences and OPI with a lot of information.
 - MEDM: for simple operations.
- Currently, the requirements for the control system are almost fixed.
 - > We have started to consider the functions implementable in the EPICS tool and to replace JAVA with CSS, etc.

Thank you for your attention