Single board computers for EPICS IOC and its reliability at RIKEN RIBF

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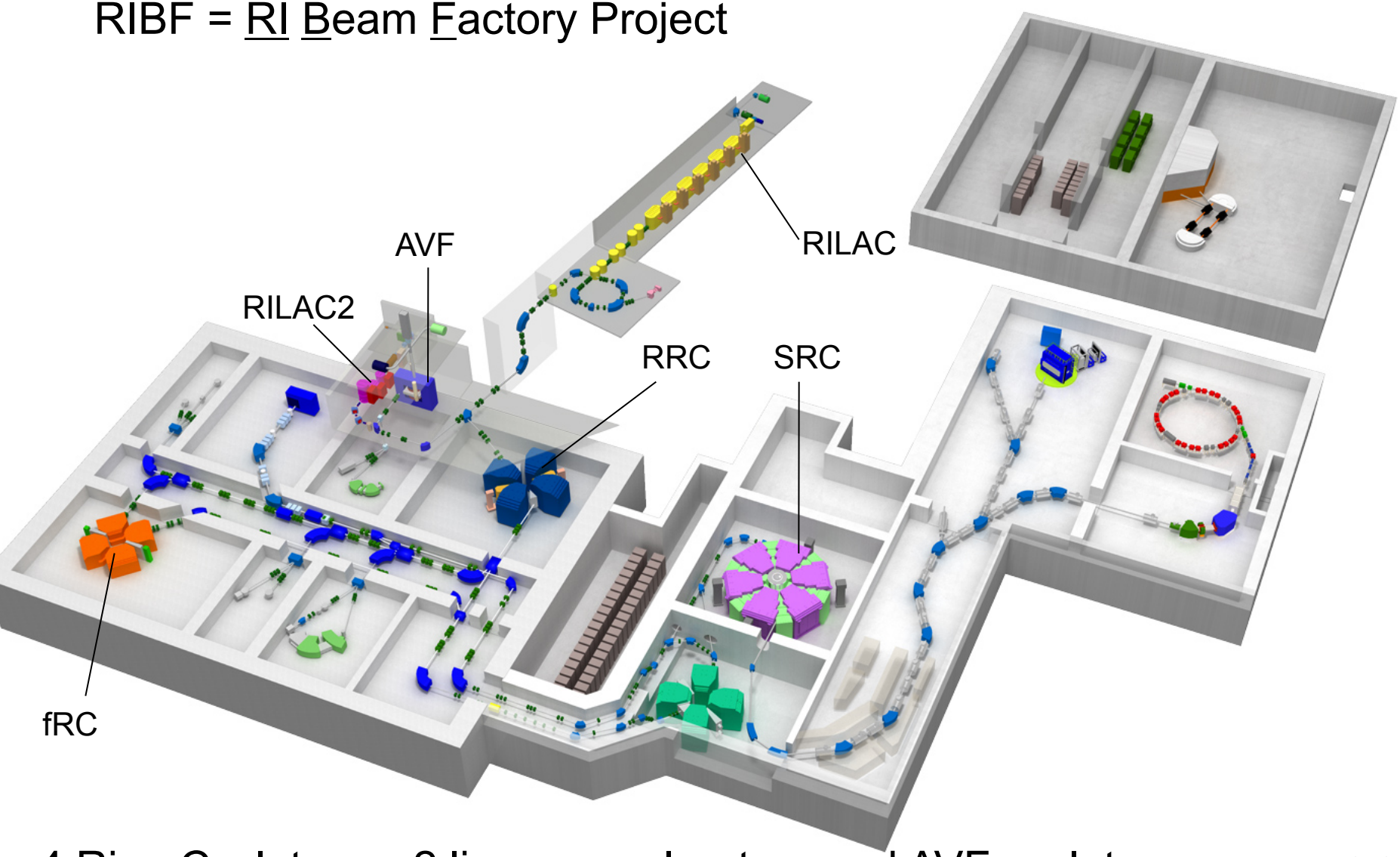
Outline

- Overview of RIBF
- Control system for RIBF
- PC Engines ALIX as EPICS IOC
  - Interface for maintenance
  - Shared file system
  - System load
- Future plan
- Summary

Overview of RIBF

RIBF = RI Beam Factory Project

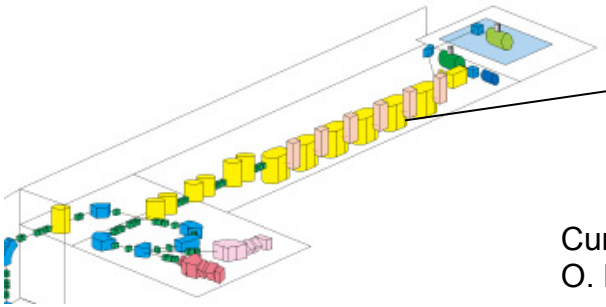


4 Ring Cyclotrons, 2 linear accelerators and AVF cyclotron.

Overview of RIBF

- Variable heavy ion beams have been provided for experiments.
- RIBF mode(RILAC2+RRC+fRC+IRC,SRC) have been provided
  * 238U, 124Xe, 48Ca, 70Zn beam = 345MeV/u.
- RILAC stand-alone mode have been provided
  * 50Ti, 51V, 48Ca, 27Al, 40Ar, 70Zn, 24Mg, and 22Ne beam < 6.6 MeV/u.

New chemical element Nihonium with symbol **Nh** and atomic number **113**, were discovered in RILAC of RIBF project.



RIKEN Linear Accelerator (RILAC)

Current status
O. Kamigaito, et al. Proc. of IPAC2016, Busan, Korea, P. 1281

Control System for RIBF

RIBF control system is based on EPICS.

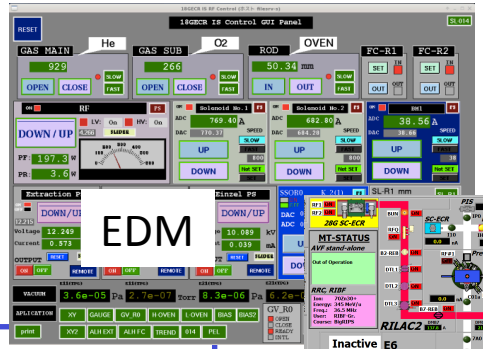
It covers

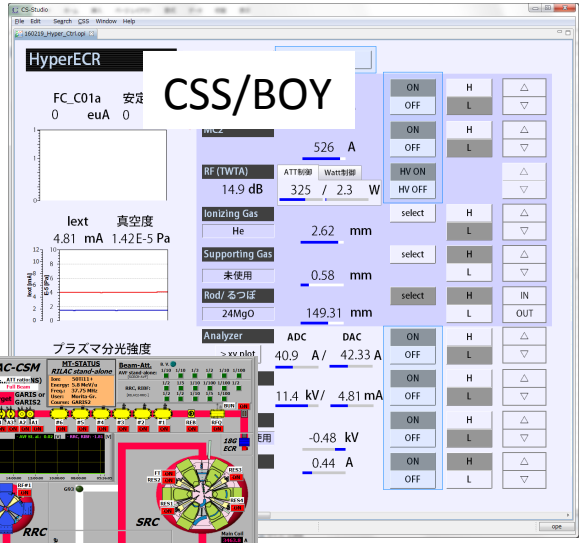
* Magnet Control
* Beam Diagnostics
* ECR Ion Source Control
* Vacuum Control
* Beam Interlock System

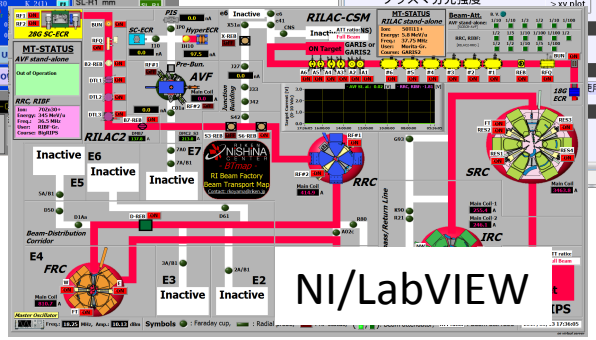
Other services

* Operational Log system (Web)
* Data archive system (PostgreSQL)
* Management system (like IRMIS)
* Alarm system (CSS/Beast)

Operator Interface







Stand Alone Control System

- RF Control (Only monitor via EPICS)
- Radiation Management System

Control System for RIBF

Number of all EPICS IOCs are 63 in 2017. The classification is ….

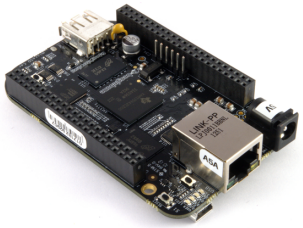
* Yokogawa FAM3-based F3RP61 Linux IOCs (Embedded) × 17
* vxWorks IOCs (Embedded) × 7
* CAMAC-based embedded IOCs × 6
* x86 PC-based IOCs × 2
* Single board computer-based Linux IOCs (Soft IOC) ×30

Single board computer

* Nowadays, various kind of single board computers are utilized as EPICS IOCs.

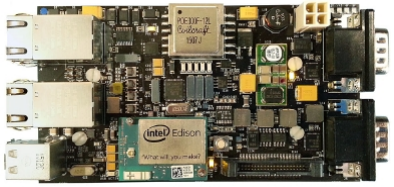
For examples)

Beagle Borne Black [1]
Raspberry Pi (Banana Pi) [2]
Intel Edison [3]



https://beagleboard.org/black

https://www.raspberrypi.org/



* Original photo is References [3]

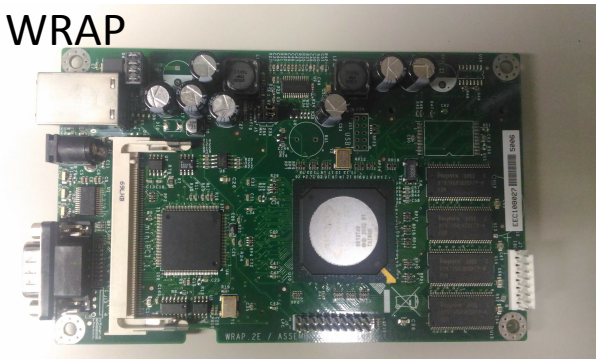
For RIBF control system, PC Engines ALIX series is adopted.

[1] Takashi Obina et al., Proc. PASJ2014, Aomori, Japan, P. 210.
[2] Y. S. Cheng et al., Proc. IPAC2016, Busan, Korea, P. 4122.
[3] D. Pedretti et al., Proc. ICALEPCS2015, Melbourne, Australia, P. 673.

PC Engines ALIX as EPICS IOC

For RIKEN RIBF, PC Engines WRAP (Wireless Router Application Platform) had already used since 2006 [4].
In 2007, it's replaced with ALIX, which is next-generation model of WRAP.

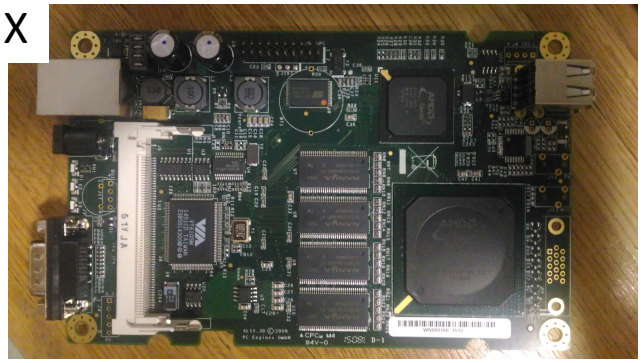
WRAP



CPU AMD Geode SC1100 233MHz
RAM 128MB

1 year

ALIX



CPU AMD Geode LX 500MHz
RAM 256MB

The characteristics of ALIX board are

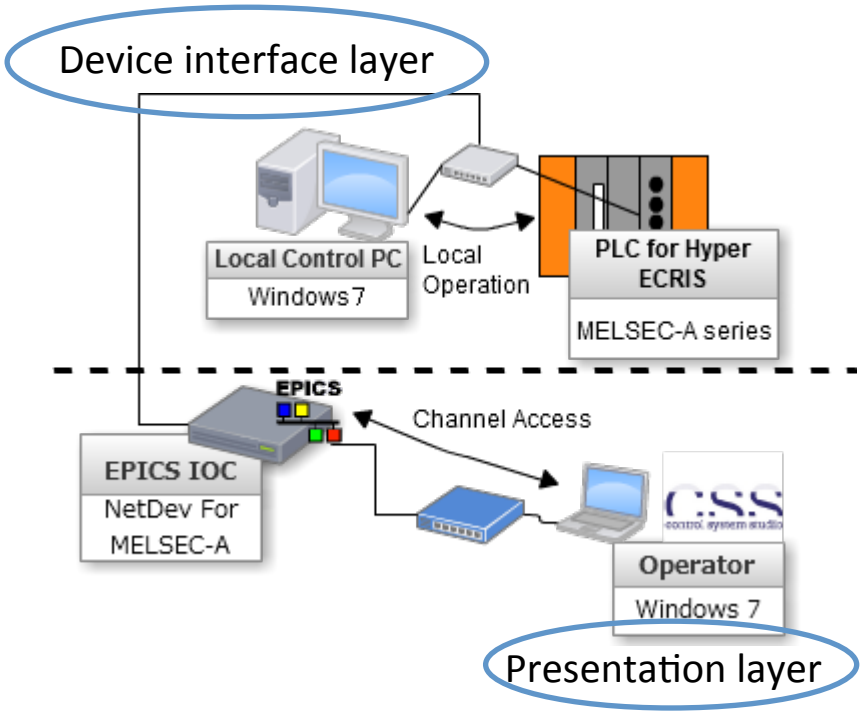
* Very low-cost (about 120US$)
* Low-performance and low power consumption
* Fan less and hard disk less (Compact Flash is used)
* x86 platform (No cross-compile environment)
* Running IOC automatically after booting

[4] A. Uchiyama et al., Proc. ICALEPCS2007, Knoxville, Tennessee, USA. P. 334.

PC Engines ALIX as EPICS IOC

Lineup of several types of ALIX board.

ALIX is available without system change, even the layers are separated by Ethernet network.



Actually, this is utilized for electron cyclotron resonance ion source control system[5] in injection into the AVF cyclotron.

[5] Makoto Nishimura et al., Proc. PASJ2014, Aomori, Japan, P. 660.

PC Engines ALIX as EPICS IOC

Purpose of adopting ALIX IOC is for introducing of…

* Easy maintenance system
* High durability system

Because it's difficult to implement many PC-based IOCs without hardware troubles for long term.


In many cases, power supply, hard disk and fan will cause hardware troubles.

So, ALIX is suitable for EPICS IOC from the view point of reliability.

Actually, no hardware trouble about ALIX for 10 years !!

PC Engines ALIX as EPICS IOC

No hardware trouble about ALIX for 10 years, however …

* 2 AC adapters was broken 8 years later from the implementation.

Therefore,

* All AC adapters should be changed in maintenance periodically (5 years ?).

PC Engines ALIX as EPICS IOC

Using a method of Linux from Scratch (LFS), minimized Linux for running EPICS IOC is constructed.

* For compensate for the low performance. (500MHz single core, 256MB memory)
* LFS is to build own Linux from kernel source and the necessary packages.
* Packages :

  Linux kernel, glibc, BusyBox, Apache, bash, telnetd, NTP, PHP, libncurses, libreadline, libstdc++,and etc.

EPICS software

* Base(R3.14), AsynDriver, StreamDevice, NetDev, AutoSave, Sequencer
* EPICS software is stored into shared file system.

ALIX IOCs manage over 400 network-based devices.

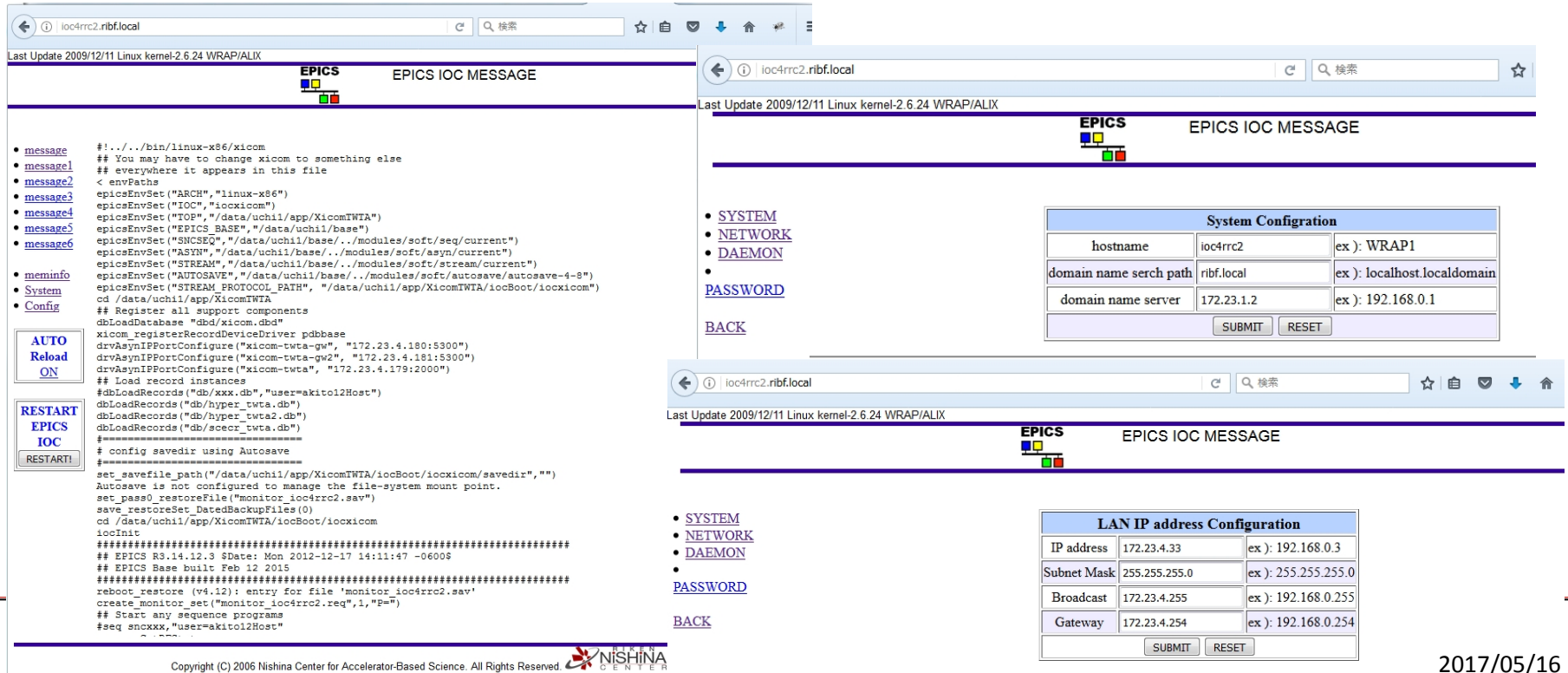
* Programmable Logic Controller : (Yokogawa, MELSEC, OMRON)
* N-DIM (Original designed by RIKEN Nishina Center)
* Other network-based devices (RF amplifier, Data Logger, and etc)

Interface for maintenance

For maintenance, simple Web application like commercially network router is implemented.

By using Web application, we can handle …

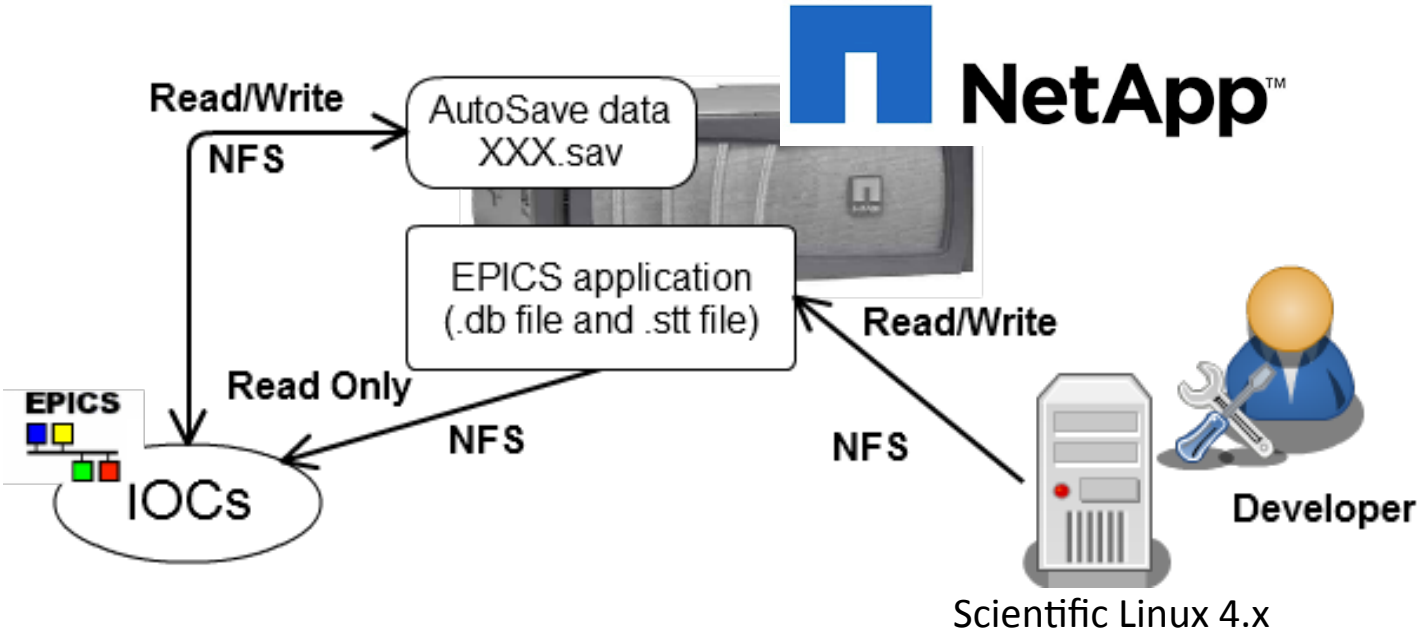
* Restarting IOC (authentication is needed).
* Configuration of IP address, hostname, DNS, and etc (authentication is needed).
* Watching the running IOC process on the terminal (startup script).



Shared file system

As shared file system, NetApp FAS2240 (NAS) with redundancy is utilized.

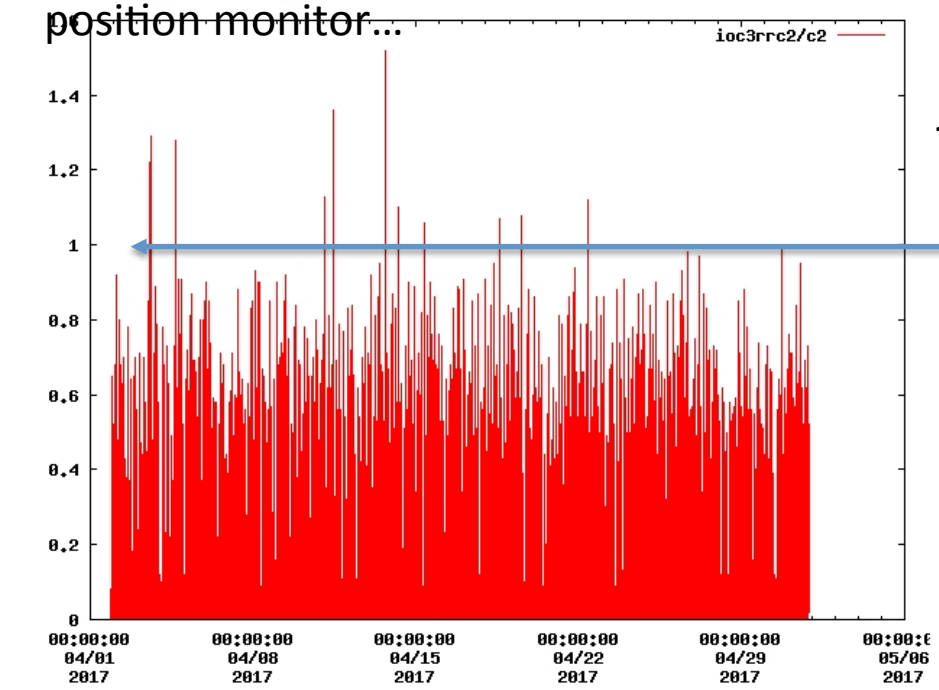
* For development, the program is compiled on other Linux server (SC4.X), and it's shared with ALIX board.
* ALIX has read-only local file system (CF), so AutoSave data is stored into NAS.



System load

Low-cost and low-performance board, but enough

* The system load average is recorded by MySQL-based logger system.
* For example, 47 network-based devices are managed by one ALIX IOC, for beam position monitor…

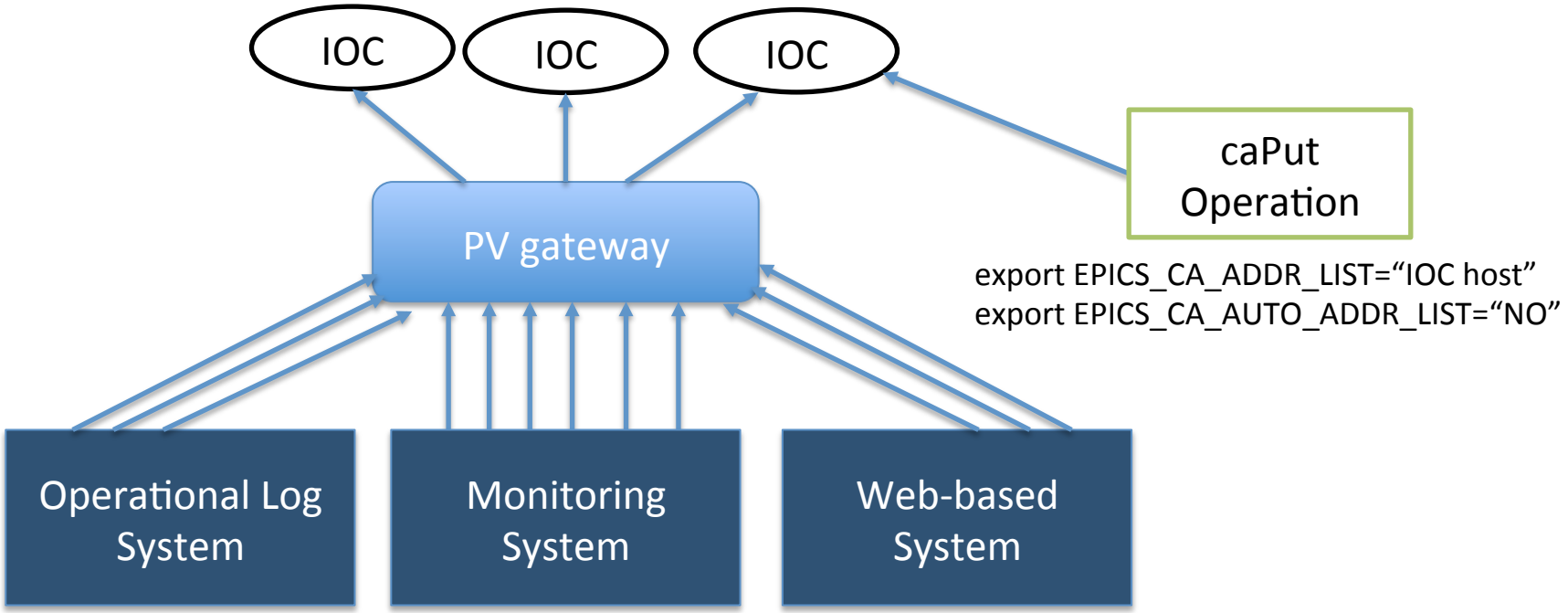


The load average for one month is more or less than 1.0.

System load

Measures against system load

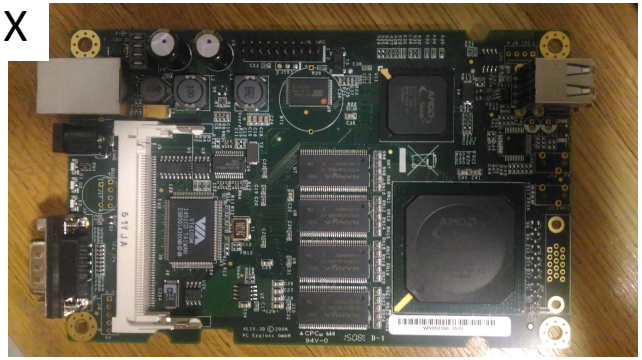
* In case of RIBF operation, caPut access is not increased drastically.
* PV gateway is installed as a CA proxy for monitoring system.



Future plan

We can buy the next-generation single board computer of ALIX.

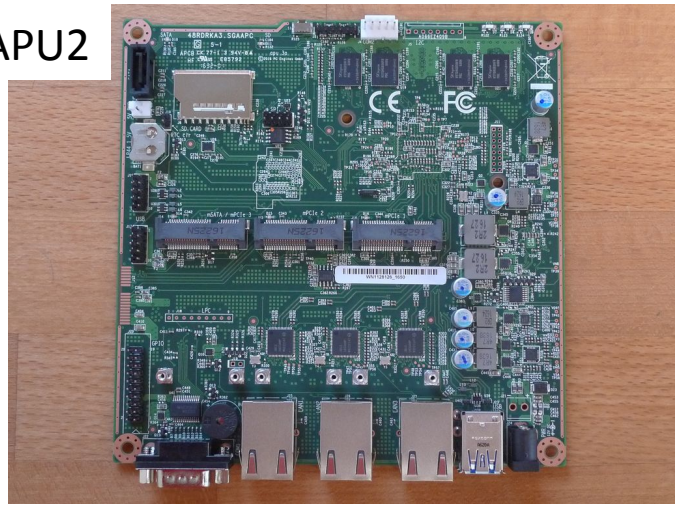
ALIX



CPU AMD Geode LX 500MHz
RAM 256MB

10 years

APU2



CPU AMD Geode Embedded GX-412TC, 1GHz Quad Core
RAM 2GB or 4GB

* Original photo is https://www.pcengines.ch/apu3a4.htm

* From the hardware specification of APU2, the distribution (CentOS, Ubuntu, etc) will be used instead of minimized Linux using LFS.

Summary

* In RIBF control system, PC Engines ALIX, which is a single board computer is utilized as EPICS IOC for network-based devices. (vs Virtual IOC ?)

* 30 ALIX IOCs manages about 400 network devices.

* For 10 years, ALIX single board computer didn't has hardware trouble.

Thank you for your attention