

## J-PARC CONTROL TOWARD FUTURE RELIABLE OPERATION

N. Kamikubota<sup>#</sup>, N. Yamamoto, H. Nakagawa, S. Yamada, K.C. Sato, T. Katoh, J. Odagiri  
KEK / J-PARC, Tokai-mura, Ibaraki, Japan

N. Kikuzawa, Y. Kato, M. Kawase, Y. Ito, T. Suzuki, T. Ishiyama, S. Fukuta, H. Yoshikawa,  
H. Sakaki, H. Sako, H. Takahashi

JAEA / J-PARC, Tokai-mura, Ibaraki, Japan

S. Yoshida, M. Takagi, S. Motohashi, T. Iitsuka

Kanto Information Service (KIS), Tsuchiura, Ibaraki, Japan

H. Nemoto, ACMOS Inc., Tokai-mura, Ibaraki, Japan

D. Takahashi, Mitsubishi Electric System & Service Co. Ltd., Tsukuba, Ibaraki, Japan

### Abstract

The J-PARC accelerator complex comprises proton LINAC, 3-GeV RCS, and 30-GeV MR. The J-PARC is a joint project between JAEA and KEK. Two control systems, one for LINAC and RCS and another for MR, were developed by two institutes. Both control systems use the EPICS toolkit, thus, inter-operation between two systems is possible. After the first beam in 2006, beam commissioning and operation have been successful.

The current status of J-PARC control structure is given. Components are introduced and reviewed with reliability issues: A plan to develop new GUI applications for operators is given.

### INTRODUCTION

A high-intensity proton accelerator complex, J-PARC (Japan Proton Accelerator Research Complex), consists of three accelerators: a) 180-MeV LINAC (energy upgrade to 400 MeV is underway), b) 3-GeV RCS (Rapid Cycling Synchrotron), and 30-GeV MR (Main Ring). J-PARC is a joint project between two institutes: JAEA in Tokai-mura and KEK in Tsukuba.

The construction of J-PARC facilities started in 2002 in Tokai-mura. The first proton beam to LINAC was in 2006, followed by RCS (MR) in 2007 (2008), respectively. In March, 2011, we have achieved stable beam operation at the power of 220 kW for neutron productions, and of 140 kW for neutrino productions.

In the very early phase of the project, a decision was made that JAEA is in charge of LINAC and RCS, and KEK is of MR. Discussions on J-PARC controls were also made around 2001. As a result, we decided to have two independent control groups. However we had some agreements: a) both use the EPICS toolkit, b) three accelerators must be controlled from a single control room, c) have single personnel protection system (PPS), and so on. Even after the beam operation started, we still keep two control groups.

The above history has made our control structure very difficult to understand. In the past, general design views of J-PARC controls were reported in [1,2]. System and infrastructure of JAEA was given in [3]. Control

overview was presented in [4]. In this report, our control structure is reviewed, with discussions on reliability issues.

## CONTROL SYSTEMS OVERVIEW

### Components Overview

A brief summary of control components is given in Fig. 1. It is apparent that JAEA (LINAC and RCS) and KEK (MR) have different policies.

Accelerator	OPI Application Basic High-Lvl.	IOC(VME) OS,H/W	Drivers
Linac	Java +MEDM	XAL /JCE	VxWorks PowerPC - VME I/O Modules - TeraDev for PLC
RCS	Java +MEDM	SAD	VxWorks PowerPC - VME I/O Modules - TeraDev for PLC
MR	MEDM or EDM	SAD Python ROOT	Linux Intel-based (+PLC/F3RP 61-Linux) - Network devices - NetDev for PLC - WE7000 drivers

Figure 1: Overview of control components at J-PARC.

### OPI (GUI) Applications

JAEA has developed stand-alone Java applications for basic GUI applications. In the early phase, JCA libraries, which handle Java to EPICS connections, had small bug. JAEA modified the library to avoid problems [5]. For high-level applications used in beam commissioning studies, XAL was introduced from SNS [6]. Later JCE, simulating SAD script using Java [5], was developed and used by JAEA[7].

KEK introduced MEDM and EDM as basic GUI tools. SAD script, Python script, and ROOT, were used for high-level applications.

The key idea of JAEA is that Java should be the primary platform for all applications. In addition, JAEA developed tools by themselves, except for XAL. However, rack of rapid development tool allowed some MEDM applications in LINAC and RCS.

In turn, KEK introduced EPICS standard tools, based on experiences of KEKB controls. This selection saved start-up man-powers, and enabled rapid developments of GUI applications for MR. Up to now, number of applications registered to the MR launcher is about 270.

<sup>#</sup>norihiko.kamikubota@kek.jp

### IO Controller and Signal Front-end

Both groups selected VME-bus computer as a default IO controller. JAEA selected a Power-PC based CPU board with real-time operating system (vxWorks). There are about 120 (30) pieces of CPU boards for LINAC (RCS), respectively. Standard IO boards of VME-bus are used to handle signal cables. In addition, pieces of Yokogawa PLC (Programmable Logic Controller) with ladder logic were introduced as local controllers of various power-supplies.

In KEK, an Intel-based CPU board and Linux operating system were selected. They are used as disk-less Linux computers. KEK enhanced to use network-based devices, such as Yokogawa PLC and WE7000 measuring station [8,9]. In 2011, we have about 90 pieces of CPU boards for MR, however, 60 of 90 CPU boards do not have any IO boards (see Fig. 2).

In 2008, a new CPU module for Yokogawa PLC (F3RP61-2L) appeared. It can be a Linux-based IO controller with PLC IO modules [10]. In 2011, there are about 30 pieces in MR.

Selections by JAEA were traditionally safe for 25Hz machines. This is because decision was made around 2002. Before the decision by KEK in 2007, we had much discussion whether we chose the same operating system (vxWorks) as JAEA or not. Finally KEK selected Linux. Use of Linux allows easy maintenance and customization of control software. It is worth noting that MR is a slow-cycle machine (a few seconds), thus, real-time features of vxWorks are not needed.

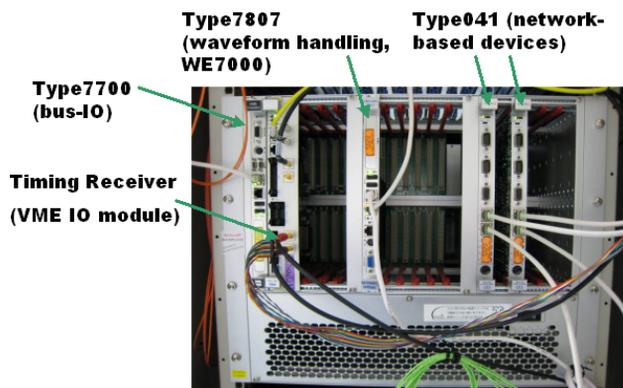


Figure 2: Typical IO Controllers for MR.

### Network System

Network system for J-PARC accelerators was introduced around 2004 by JAEA. The system has intelligent core loops to ensure high redundancy [3]. Later in 2006, KEK joined to use the system together. In 2011, we have 80 edge switches for LINAC, 24 for RCS, and 5 for MR. The bandwidth between buildings has been 1 Gbps, partly upgraded to 10Gbps in the summer, 2011.

The network system is logically divided into sub-networks (vlan), which correspond to accelerators (LINAC, RCS, MR) and other facilities. Thus, most of network traffics are localized within single sub-network.

For EPICS protocol, we put a few gateways (CA gateway) to enable communication between sub-networks.

Basic services of TCP/IP networks (DNS, NTP) are managed by JAEA, while user authentication service (LDAP) is by KEK. A web server has been operated by KEK to indicate accelerator status and information.

### Computers and Storage Disks

JAEA has used rack-mount servers for disk storage. In 2011, total amount is around 16 TB. Standard desktop PCs, running RHEL, have been used as operator's consoles as well as platforms to run control applications.

KEK started to use a dedicated disk storage system and blade-type servers in 2007. In 2011, total amount of disks is around 20 TB, and more than 20 pieces of blade-type servers, running Scientific Linux, are used in operation. Control applications run on blade-type servers, while GUI screens are displayed on thin client terminals [11].

### RDB (Relational Database) and Data Archive

Both JAEA and KEK have been using PostgreSQL RDB engines. JAEA has used RDB features for: a) automatic generation of configuration files for EPICS IO Controllers, and b) handling operation parameters (for example, timing-signal settings [12]). In addition, data archive system has been developed using RDB [13].

KEK has used RDB for backup purposes. Databases for a) IP addresses and EPICS record names in MR, b) copies of GUI screens on operator consoles, have been managed using RDB. One can search them through Web-based interfaces. For data archive, channel archiver, a standard tool of EPICS, was introduced and has been used since the beginning of MR beam commissioning [14].

## ISSUE FOR RELIABLE OPERATION

### Control Room

In J-PARC, all accelerators (LI, RCS, and MR) are controlled from a single control room. We have arranged console desks to form a rectangular shape, in order to force people stay inside (Fig. 3). Two workspaces and one meeting desk are nearby. This structure encourages tight communication between operators, a shift leader, and commissioning staff. In addition, people from experimental facilities (MLF, HD, NU in Fig. 2) can stay in the control room for communication. We believe that this idea is essential to improve reliability.

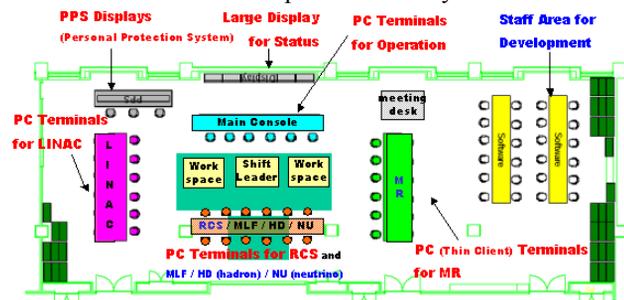


Figure 3: Schematic view of control room for J-PARC.

## Safety System (PPS)

The safety is fundamental for high power proton machines like J-PARC. The PPS is to protect personnel from the radiation and other hazards caused by accelerator operations. In order to avoid confusions originated from different policies of JAEA and KEK, we assigned a single person for design and construction for whole of the PPS.

The PPS must be highly reliable and fail-safe. The system was developed using PLC with ladder logic, but no usual computer with operating system. Moreover, we asked two companies to develop PLC ladder logic independently. Thus, having two PLC-based sequences makes the PPS system extremely redundant. More detailed description of PPS is given in [15].

## United Sub-Systems

Some sub-systems were introduced for LINAC and RCS by JAEA first, later KEK disagree to extend it to MR, but developed a different system with a link to the JAEA system. The examples of “united” sub-systems are: a) MPS (Machine Protection System) and b) timing system.

The MPS for LINAC and RCS was developed by JAEA [3]. The system has a simple tree-type topology. Because the MPS system for MR was requested to have links to downstream experimental facilities, more complicated logic scheme was needed. As a result, KEK developed a new MPS using FPGA-based logic controllers [16].

The studies of timing system for J-PARC were made in very early phase. NIM modules for signal distribution to all buildings and VME-bus timing IO modules were developed in 2002-2003 by JAEA [3,17]. However, software strategy by JAEA was designed only for 25Hz machines. As a result, KEK decided to use the same hardware (NIM and VME modules) to link to the JAEA timing system, but developed another software framework to fit slow machine cycle of MR (a few seconds) [18].

## Electric Logbook

An electric logbook, Zlog, was developed using RDB and Python script by KEKB [19]. We decided to use Zlog for all J-PARC accelerators since early phase of its operation. Operators are responsible to insert machine events. One can watch at them remotely by a Web interface.

Since Zlog is RDB-based, it has advanced features as: a) search entries to search for past events, b) automatic generation of machine study report, c) recalling a shift summary, and so on. In addition, automatic insertion mechanism of machine faults has been developed. It has been in evaluation in operation.

## PLAN FOR NEW GUI FOR OPERATORS

Up to now, we already experienced three-year beam operation for experimental facilities. However, operation experience shows that two control systems often make

operators distressed. For example, different GUI look-and-feels, separated MPS screens, independent data archive systems, and so on. In addition, we do not have an alarm system, which informs pre-critical events of devices before a severe fault. Moreover, many of GUI applications for MR were developed for accelerator experts, not for operators. A miss-operation by operator would cause a serious machine stop.

Considering demands of further power upgrade and longer beam delivery times in the future, we need a new GUI system for operators. We, two control groups, have started to discuss to develop common GUI screens of status and alarms, and an interface to connect to both data archive systems. Recently we have interested in CSS (Control-System Studio) [20], which has been widely introduced in EPICS-based control systems. An idea is that we add a CSS layer over existing control systems. As shown in Fig. 4, the CSS layer will contain: a) new GUI applications common for all three accelerators, b) a single alarm system for all three accelerators, and c) an archive viewer for two different archive systems.

In the summer, 2011, we succeeded to introduce CSS package with helps of CSS experts [21]. Three components of CSS (GUI, Alarm, Archive viewer) worked well. Evaluation and development will start soon.

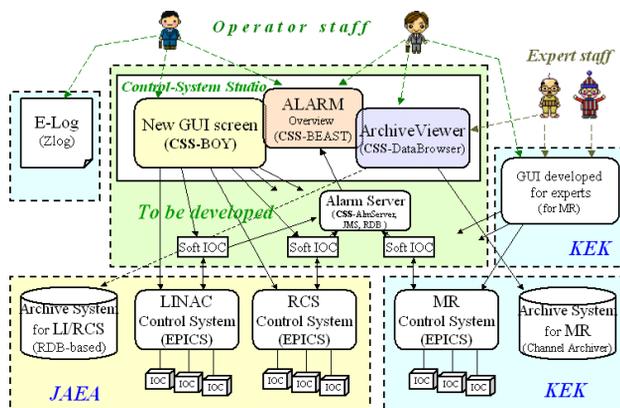


Figure 4: Relations of CSS layer and control systems.

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