DCS: The MINOS Detector Control System

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The MINOS Detector Control System (DCS) implements an integrated set of hardware and software to display, control, and log data from MINOS Near and Far Detector Systems. This document provides an overview of the DCS preparatory to the Third DCS Review scheduled for January 9, 2001.

I. INTRODUCTION

The Detector Control System (DCS) controls, monitors, displays, and logs operating parameters for the MINOS near and Far Detectors. It includes or incorporates six main subsystems: the High Voltage Controller, the Rack Monitor, the Environmental Stations, the Beam Monitor, the Calibration (Flasher) System, and the Magnet (Table I). DCS also interacts with the DAQ and logs ROOT-formatted detector information to the Oracle Database via the Dispatcher. DCS is accessed via dedicated displays and user interfaces in the control room and Far Detector hall areas.

The DCS is designed as a robust, modular system comprised almost entirely of off-the-shelf, industrial control hardware and software. DCS uses established hardware and software protocols, such as OPC (Object Linking and Embedding for Process Control), Samba (Linux server software for PC networks) and ROOT TSockets (a protocol for inter-process communications). These standard interfaces permit plug-in replacement of DCS hardware and software either for upgrades during the life of the MINOS detectors or for rapid debugging.

The DCS as currently designed uses multiple dedicated processors in order to achieve modularity and reliability. Because the DCS is a real-time critical system, dedicated systems also avoid difficult-to-diagnose problems due to variable loads on processor resources by other tasks. DCS has purchased and tested a number of special-purpose processors for these applications, but concluded that general-purpose PC's are generally more flexible and cost effective. An ethernet-to-serial converter, for example, includes an internal microprocessor and costs essentially the same as a low-end PC, because the converter has a small market over which to amortize fixed costs while the PC has a large one. We are unsure how the proposed MINOS policy of no dedicated processors applies to this design, but hope this review will help clarify the issue.

II. OVERALL DESIGN

At the heart of the DCS design is the Intellution SCADA (Supervisory Control and Data Acquisition) system called iFix. iFix runs under Windows 2000 and provides the following functionalities:

1. **Data Acquisition and Control Interfaces:** iFix is able to acquire data using up to eight I/O drivers. Each can control multiple hardware devices, providing they share a similar interface. For DCS applications there is both a general driver which handles OPC servers and specific drivers for the Intelligent Instrumentation EDAS 1002 ethernet interface (built into the BiRa rack monitors) and for all FieldPoint hardware. Since these drivers are bidirectional, they are able to both acquire data and supply control information.
2. **Alarms:** iFix automatically checks its data against preset ranges in order to detect alarm conditions. Alarm settings are entered into iFix either through a spreadsheet-style display or by reading a tab-separated ASCII file. Alarm conditions trigger display changes to notify detector operators and generate email for appropriate MINOS personnel.

Main DCS Systems

System	Vendor	Model	Control	Monitor	Log
DCS MANAGER	Intellution	iFix	X	X	X
High Voltage	LeCroy	1440	X	X	X
Driver	(Custom)	C++			
Interface	Intelligent Instruments	EDAS 1025E			
Rack Monitor	BiRa	RPS-8884	X	X	X
Environmental	Oregon Scientific	WM-918	—	X	X
Beam Monitor	FNAL	SWIC	—	X	X
Calibration	(Custom)	C++	(X)	X	X
Interface	BiRa	RPS-8884			
Magnet & Coil	National Instruments	FieldPoint	(X)	X	X

TABLE I: DCS systems and interaction levels. DCS passes commands to the flashers but does not provide logical control. The magnet and coil FieldPoint system will be implemented in cooperation with the Steel Group, which is responsible for the coil current itself.

3. **GUI Interface:** iFix uses graphical programming of display objects to implement flexible visual interfaces. The DCS plans to use one dedicated computer screen that would always be visible to the detector operator. Normally, the screen will show a summary of detector operating conditions with sub-areas showing green backgrounds for each of the major detector systems. If an alarm is generated, the corresponding system area turns yellow or red in the main display, depending on its severity. System blocks also include clickable "buttons" that enable an operator to "drill-down" into specific information about a system under either normal or alarm conditions.

4. **Internal Database:** iFix maintains its own historical database of recent detector operating parameters. This database will enable displays of historical detector parameters for problem diagnosis or other studies.

5. **Programmability:** iFix is programmable using Visual Basic for Applications, a customized version of Microsoft Visual Basic. Visual Basic is an object-oriented language that has many of the features of C++ while retaining the syntax of BASIC. Despite the fact that "real" programmers may cringe at the thought, Visual Basic is currently the most popular coding language in the world. Thus there is a large knowledge pool available for commercial support, and MINOS students working on DCS will gain highly marketable programming skills.

III. HIGH VOLTAGE

The MINOS DCS High Voltage system employs LeCroy 1440 HV hardware and a custom-designed C++ controller which addresses the hardware via an RS-232 port on each mainframe. It is modelled after the MACRO [2] HV system, similar to that of MINOS [3] in size and scope. Although the 1440 system hardware is no longer manufactured, it has provided safe and reliable high voltage to MACRO for nearly a decade and continues to operate with relatively low maintenance requirements. There are, however, important points to be addressed concerning a new implementation at MINOS.

A. HV Organization

MINOS requires four LeCroy 1440 HV mainframes per supermodule in the Far Detector, five total in the Near Detector hall, and one "test" mainframe permanently located at the Soudan laboratory. Mainframes are indexed ordinally (*i. e.,* beginning with one), consistent with the LeCroy hard-wired indexing scheme. Mainframes 1–4 serve the Far Detector first supermodule and 5–8 serve the second supermodule. MFs 9–10 provide voltage to the Near Detector, while MFs 11–13 power the Segmented Wire Ion Chamber (SWIC) beam monitors (Section IV B). There will also be a spare "test stand" mainframe (MF 14) permanently installed at the Soudan Laboratory, and an additional mainframe (MF 15) employed at the CERN test beam. Finally, while the modular design of the 1440 has in our experience made complete mainframe failure quite unlikely, spare components (low voltage power supplies, controller cards, HV cards, and fan units) will be required.

In each supermodule the lowest-numbered mainframe provides high voltage to the east (E) side of the odd planes. The second, located physically next to the first, serves the E-side even planes (of which plane zero is not instrumented). The third and fourth mainframes power the west-side (W) odd and even planes, respectively. Odd planes correspond to the "u" electronics view, running diagonally from the upper east to the lower west side, and even planes to the "v" view, running from the upper west to the lower east (Table II).

Each Far Detector supermodule includes 242 instrumented planes, 121 in each of the odd (u) and even (v) views. They are paired sequentially mod 2, or in odd-odd/even-even fashion. This produces 120 plane pairs (sixty odd and sixty even), and two unmatched planes. Each pair requires two mux boxes (for the E and W sides), with three multi-cathode (sixteen channel) photomultiplier tubes each. The pmts are also indexed ordinally, from 1 to 3. The unmatched planes still require two mux boxes each, but each has only two pmts (one with only eight pixels in use). This arrangement produces a total of $(60 + 60 + 2) \times 2$ or 244 mux boxes per supermodule, with $244 \times 3 - 4 = 728$ active HV channels.

For each mainframe there are thus sixty full and one partially occupied mux boxes, and $60 \times 3 + 1 \times 2 = 182$ active channels. The first 180 are arranged fifteen each on twelve sixteen-channel cards, yielding five single-sided plane pairs and one spare channel per card. For consistency the unmatched plane is serviced by a thirteenth HV card rather than an *ad hoc* employment of the spare channels. This underutilized card is an unavoidable but minor consequence of the fact that the number of planes is not divisible by twenty.

B. Channel Identification and Control

High voltage channels are numbered consecutively from 0 to 255 in each LeCroy 1440, sixteen per HV card slot (thirteen of sixteen slots are occupied). This "physical" or "hardware" channel number is assigned a Logical Channel ID via the local channel map and hidden from casual view. This strategy allows spare hardware channels to be swapped transparently, and provides a more physical representation of the detector for the DCS interface. Logical channel IDs include the Supermodule, Side, first Plane Number, and pmt index. Mux boxes are identified via the same scheme. Thus **1E001-1** is the **1st** (of three) photomultipliers in mux box **1E001**, which serves the **E** side of plane **001** (and plane 003) in supermodule **1**.

The HV graphical user interface would also explicitly identify both the first and the second plane of this pair and note that they present a "u" view in the electronics. This information is redundant, of course, but easy to provide and potentially useful in avoiding human error. Near Detector nomenclature follows the same scheme, replacing the supermodule designator with "N" and in accordance with Near Detector fiber/pmt allocation.

There is one important note to make regarding logical control of the HV system. Because the E and W ends of the scintillator are both instrumented, and because each mux box contains three separate photomultipliers, maintenance on a single individual pmt will in principle expose five others to ambient light. The controller program is thus organized around six-channel "groups," which serve both ends (E and W) of a plane pair. Grouped voltages are brought up and down together.

The controller itself consists of approximately 2,000 lines of C++ code, ported from the MACRO (FORTRAN) version and adapted for MINOS and a unix (Linux) environment. Because high voltage groups span the E and W sides of the detector, furthermore, the HV controller requires distributed access and is thus linked to the mainframes using both a physical serial port (RS-232) and via the network with an Intelligent Instruments EDAS 1025E ethernet/RS-232 interface.

The entire far detector could be overseen by a single HV process, but it was not considered desirable to span supermodules. In addition detector maintenance requires local control of the HV and other DCS systems, so one PC workstation is provided on each side of each supermodule (four in all for the far detector, one for the near detector). Each will support an HV controller connected directly to one LeCroy 1440 HV mainframe, and remotely to a second on the far side of the detector. This is described in Table II. These PCs will also host other DCS processes such as the environmental and rack monitor programs, and may control the magnet, calibration, or other systems consistent with the resolution of "dedicated" MINOS PC issues in this Review. With regard to software compatibility, we note that since these systems run Linux it is also possible to provide a Windows environment as a user process using VMWare. We have purchased a VMWare 2.0 license and will continue to investigate the feasibility of this approach.

The four individual HV control processes will allow local interrupt during detector maintenance, but in general will be supervised by the global iFix process. Communications between the HV control processors and the iFix SCADA system will employ the local area network (Berkeley Sockets and an OPC server process running on the same machine as iFiX). We have already successfully tested such an OPC server using a software toolkit from Northern Dynamics.

C. Status and Budget

As of this Review, the HV code is substantially complete. In its present form it can operate a single LeCroy Mainframe using the direct RS-232 port, and can be run either locally (via the keyboard) or over the ethernet

MINOS High Voltage Mainframe Distribution

MF	Location	Planes	View	PC	Link
1	Far SM1	E-Odd	u	DCS1	RS-232
3		W-Odd	u		ethernet
2	Far SM1	E-Even	v	DCS2	RS-232
4		W-Even	v		ethernet
5	Far SM2	E-Odd	u	DCS3	RS-232
7		W-Odd	u		ethernet
6	Far SM2	E-Even	v	DCS4	RS-232
8		W-Even	v		ethernet
9	Near	E-All	u/v	DCS5	RS-232
10		W-All	u/v		ethernet
11	Near	SWIC-1	—	DCS5	ethernet
12		SWIC-2	—		ethernet
13		SWIC-3	—		ethernet
14	Test Stand	—	—	DCS6	RS-232
15	CERN Beam	All	u/v	DCS6	RS-232

TABLE II: HV Mainframes by location and service area. Odd planes in the far detector correspond to a "u" electronics view, even to"v." PC processor allocation is described in section III B.

(via Berkeley Sockets). The HV hardware has been identified, and LeCroy 1440 mainframes are already in place at Macalester College and Texas A&M. Additional mainframes and high voltage cards are available as needed for construction, as coordinated by the Texas A&M University group. TAMU is also responsible for delivery of HV cables to the Soudan Laboratory and Near Detector sites. The HV system required for the CERN test beam is fully operational, and DCS will support this effort with on-site personnel during installation and first data collection in August 2001, and with troubleshooting consultation by email and telephone during the remainder of the CERN test beam period.

Since the high voltage (HV) controller employs existing hardware obtained from Fermilab Prep and the HV cables themselves will be produced by the scintillator group, there are few DCS-accountable HV costs. They cover the controller PCs and associated networking hardware:

- Controller Processors: 800 MHz Pentium IV or equivalent running Linux and VMWare).
  Cost: $9,000 (6 @ $1,500, including software and interface cards.
- Ethernet-to-serial (RS-232)interfaces: Intelligent Instruments EDAS 1025E.
  Cost $3,600 (6 @ $600, including mounts and RS-232/ethernet cables).
- Total DCS Outlay for HV control: **$12,600 (ESTIMATE)**.

Immediate remaining HV tasks include integration of the 1025E ethernet/RS-232 interface, allowing a single HV process to control distributed mainframes and simultaneous direct and ethernet communications. Software drivers for the 1025E already exist and the channel-grouping structure is built into the code, so these tasks are expected to be straightforward. The 1440 hardware must also be slightly modified for use with the SWIC beam monitor as described in Section IV B. Lastly the HV/Oracle Database communication protocol must be established, but at the HV end this requires only writing the logical/physical channel map and prompting the DCS-DAQ communicator (Section IX) to translate it to ROOT form and notify the Dispatcher (Section X).

More significant work remains in the area of iFix and high voltage integration. While the strictly HV end of this task is nearly complete and commercial drivers exist for the remaining links, seamless iFix administration of the HV and other DCS processes is nontrivial. Global integration and communications are expected to occupy much of our effort in the coming months, not only for the HV controller but for the entire DCS system.

IV. RACK MONITORING

The DCS group is charged with monitoring the state of the experimental electronics in the racks at the detectors. Three general tasks will be accomplished:

1. **Safety:** Immediately shut down AC power when a potential danger such as fire or leaking water is present.

2. **Monitor:** Record conditions which might affect the electronics performance such as crate voltages and temperatures, and periodically log the resulting data. Warning or Alarm conditions on any of the parameters of concern will be detected by the iFix SCADA system, generating an alarm indication on the DCS monitor screen and in the detector log file transmitted to both the DCS and Oracle databases (Section X).

3. **Communications:** Provide primary or secondary communication links via standard hardware ports.

The heart of the rack monitor is the BiRa RPS-8884, a 1U rack-mounted module that performs most of the functions the DCS system needs, and which communicates with the DCS control computer over a standard ethernet link. Software drivers to control this device exist in the iFix environment (see Sec. II). An overview of the generic device can be found at:

`http://www.bira.com/cat/rps.htm`,

while final details of the specific MINOS system will be determined in cooperation with BiRa systems. The following sections describe the several functionalities of the BiRa monitor and how those functions will be used in the MINOS DCS.

A. Safety and Emergency Power Shutdown

In accordance with safety regulations, unattended electronics racks with AC power have the ability to shut themselves off in event of a fire or other dangerous circumstance. For our purposes, this self-shutdown will extend to other alarm conditions that could lead to damage to the electronics, such as large power fluctuations, water leaks (in water cooled racks), or high temperature caused by cooling failures or electronics overheating. Any of the alarm conditions discussed below will cause the AC power to the rack to be cut. This will also trigger a DCS alarm.

Power cutoff is accomplished by a relay box (also from BiRa) controlled by the RPS unit. We emphasize that this emergency power shut-off function is hardware-driven and is not dependent on DCS software. The iFix SCADA system will, however, also produce a software alarm requesting operator interaction, which is required to re-start a tripped rack. The following can generate warnings or alarms (both are logged, with the latter cutting rack power):

- RPS-8884 “Fenwal CPD7051” ionization smoke detectors installed near the top of each rack. Alarm and power cutoff.

- AC power surges, internally monitored by the AC relay box itself. Alarm and power cutoff.

- VME crate DC backplane voltages (connections to post connectors on the 9U VME crate with crimped ring terminal wires). Both warning and alarm threshold are preset by resistor selection during RPS-8884 installation.

- Cooling air flow temperature. Warning at 40°C for the input, or an input/output difference of 20°C. Alarm and power cutoff at 50°C for the input, or an input/output difference of 30°C. A warning is also generated if the output air reaches 100% relative humidity.

- BiRa 1U 19” rack-mounted parallel-plane screen mesh conductivity sensor/leak detectors installed beneath the Near Detector (water cooled) front-end electronics crate. Alarm and power cutoff.

- “GEMS RFO-2500” series RotorFlow (water flow) sensors. Warning at 3.5 gallons per minute (gpm) and alarm/power cutoff at 2.5 gpm.

- An LM35 water temperature sensor mounted inline, inside a copper block secured to the water inlet pipe. Warning at 20°C and alarm/power cutoff at 30°C.

The RPS main chassis obtains AC power from the line at a point before the AC relay box, so that it can continue to function even after rack power has been tripped. Continued power is required to read out the condition that caused the trip and remotely re-enabled power, although our intention is at least initially not to permit the latter. Even should power completely fail, the RPS unit will remember its alarm and warning status for up to a day without power, so its history can be retrieved even after systemic failure.

B. Electronics Monitoring

Many of the quantities relevant to electronics monitoring have already been described above in Section IV A. Alarm and warning events will be logged to the MINOS data stream and audiovisual warnings displayed on the DCS main status machine in the control room. Analog quantities such as DC voltages and temperatures will be periodically read out and logged to the data stream as well. The time between such readouts is determined by the DCS control software, at a period appropriate to the time scale over which changes actually occur during testing of the system.

Additional monitoring of the 9U VME crate status can be accomplished through a serial link to the Weiner power supply's RS-232 port, and one of the two RPS-8884 serial ports could be dedicated to this purpose. This interface is normally part of the CaenNET interface, which we do not employ, but if the communication protocol is available from Weiner it could provide essentially cost-free DCS redundancy.

In addition to the rack power, cooling, and VME backplanes, the Power Distribution Box ("PDB") must also be monitored. This box supplies two voltages, +5V and -5V, each of which must be monitored in a differential fashion with respect to its own "return" line rather than local ground. The PDB temperature must also be monitored as the box employs its own air cooling system. The allowable parameter ranges of voltage and temperature are currently under discussion, but warnings will be set if the yet-to-be-determined thresholds are crossed, and both parameters will be periodically logged.

The last monitor item is the VME cooling fans, which can raise a warning but not an alarm (that is, fan failure alone cannot shut off power). While catastrophic air flow failure should eventually be detected by the air temperature sensors mentioned above, the FNAL-built fan trays are also provided with a single two-terminal MOSFET output which indicates the failure of one or more fans in the tray. The switch is normally closed, and when open raises a DCS warning indicating that repairs should be made. The LED flasher box is not directly monitored by the DCS, but does communicate via the RPS-8884's RS-485 serial port (see below and Section VII).

C. Communications

In addition to its safety and monitoring functions, the RPS-8884 provides convenient communications access to the electronics it monitors. Two uses for this system are planned. First, a warm reboot signal independent of the normal VME communications chain is desired. This covers the case of a VME crate "locking up" in such a way that it cannot be recovered using normal protocol. For this purpose the RPS-8884, already connected to the VME backplane to monitor voltages, will also connect to the System Reset line. Should the DAQ make a request to DCS, this line can be set low, causing the VME processors to reboot. Second, the RPS-8884's second serial port (an RS-485 connection) in combination with the built-in EDAS ethernet to serial converter will provide the communications channel needed for the calibration PC to control the LED flasher boxes (Section VII).

D. Budget

The rack monitoring equipment needed is somewhat different for the different flavors of racks present in the MINOS experiment. There are three types:

1. Far Detector ("FD")
2. Near Detector Frontend ("FE")
3. Near Detector Master ("Master")

The FD racks contain a 9U VME crate, a power distribution box ("PDB"), and the calibration flasher box. The FE crates contain two water-cooled 6U VME crates, two Alner boxes, and a FieldPoint monitor. The Master crates are the same as the FD crates, except only a fraction of them contain a flasher box. Table III lists the rack monitoring items needed for the FD racks and Table IV for the FE racks. The Master racks are the same as the FD racks. Table V shows the total numbers needed.

E. Status

The status of the rack monitoring sub-system has progressed rapidly from a general concept to a concrete plan. System requirements have been established and matched with hardware which can perform the required tasks. Some

Item	Cost	#	Total Cost
RPS-8884	$1,950	1	$1,950
VME DC cable	25	1	25
Smoke Det. cable	20	1	20
Airflow Temp. inlet cable	35	1	35
Airflow Temp/Humidity outlet cable	35	1	35
AC Relay Coil/Rackpower cable	60	1	60
Inlet Air Temp. board	135	1	135
Outlet Air Temp./Humidty board	160	1	160
Smoke Det. Unit	150	1	150
115V AC Relay Box	220	1	220
Total (one rack):			$2,790

TABLE III: A Far Detector or Near Detector Master Rack

Item	Cost	#	Total Cost
RPS-8884	$1,950	1	$1,950
VME cable	25	2	50
Smoke Det. cable	20	1	20
AC Relay Coil/Rackpower cable	60	1	60
Water Flow Sensor	120	1(?)	120
Water Temp. Sensor Block	25	1(?)	25
Water Temp. Sensor	5	1(?)	5
1U Mesh Leak Detector	170	1(?)	170
Smoke Det. Unit	150	1	150
115V AC Relay Box	220	1	220
Total (one rack):			$2,770

TABLE IV: A Near Detector Frontend Rack. Do we need two leak detectors (one under each 6U crate) or will one (under both) do? Same for the water flow and temperature - are they plumbed serially so one will do?

Rack	# Installed	# Test Stands	Total Cost
FD	16	8	$44,640
FE	27	2	$74,790
Master	8	2	$22,320
Subtotal:			141,750+
less 10% volume discount			-14,175
Total:			$127,575

TABLE V: The numbers of racks needed. Test stands are assumed not to need monitoring and are not included in the total price, but listed for completeness.

details do remain to be mapped out, such as the particular VME backplane and PDB temperature thresholds, but the overall design is largely complete.

The first real test of the rack monitor system will occur later this January, when a prototype RPS-8884 will be delivered to UMD for testing. In addition to verifying the functionality of all the individual components, this will allow the larger task of software integration to begin. Enabling RPS/iFix and DAQ/FLasher communication will be the major immediate areas of effort. To assist with these tasks additional resources have been procured from the University of Minnesota to hire an undergraduate Physics major, Eric Hall. Eric begins work this semester at UMD with Alec Habig, with RS-8884 hardware testing and software development as his primary assignment. The DCS goal is to produce a complete prototype rack monitoring system for the calibration detector by August 2001.

V. ENVIRONMENTAL MONITORING

The MINOS Detector Control System is also responsible for the measurement, storage, and display of the environmental parameters capable of influencing the operation of the experiment. Our efforts in this area have been concentrated on the measurement of "weather" conditions in the detector areas, including ambient temperature, humidity, air pressure, and radon concentration.

Standard atmospheric measurements will be performed by means of the Oregon Scientific WM-918 Electronic Weather Station, a collection of instruments capable of monitoring the air temperature, relative humidity, barometric pressure, and wind speed and direction. These components are coupled to a monitor which in turn communicates with a PC via RS-232.

Atmospheric conditions might be an important factor affecting the underground concentrations of radon, especially in the Far Detector cavern. Radon is a naturally occurring radioactive gas generated by the radioactive decay of heavy elements in the soil. Because the radon concentration in confined spaces can be elevated with respect to the levels present in the outside air, particularly in underground work areas such as mines, DCS will continuously monitor the radon concentration in all detector areas.

For this purpose the Aware RM-80 Radon Monitor has been purchased. This device also communicates with a Personal Computer via an RS-232 port, sending an interrupt via the Ring Indicator Line each time a particle is detected. The device can also be directly controlled by means of Visual Basic. Currently we are investigating various schemes of incorporating this type of Radon Monitor into DCS, among which is the National Instruments FieldPoint FP-CTR-502 counter module. FieldPoint/iFix communications have already been demonstrated, and FieldPoint stations are already incorporated into DCS planning, allowing Radon measurements to take place via the existing local area network.

Lastly, detector temperature must also be monitored. For this purpose we are investigating Omega thermocouples which can be read out via the FieldPoint FP-TC-120 thermocouple input module. In the the muon alcoves containing the Near Detector beam monitoring chambers pressure in addition to temperature measurements will be necessary, which can also be accomplished with a FieldPoint station. Field point hardware in this area will also be used for the beam monitor electronics low voltage power supplies, as described below (Section VI).

VI. BEAM MONITORING

At the present time the Beam Monitoring Group plans to monitor only the muon beam at the downstream end of the MINOS decay pipe, south of the Near Detector hall. DCS plans for control and readout of this system could, however, be extended with little change to accommodate a future hadron monitoring system.

Fig. 1 shows the physical layout of the muon monitoring system and associated electronics, including three Segmented Ion Wire Chambers (SWICs) located in separate alcoves downstream of the beam absorber. The SWIC readout electronics is a standard unit provided by the FNAL accelerator division for accessing data from 96-channel SWIC detectors.

SWIC readout is controlled by an accelerator division VAX operated via remote terminal or telnet. SWIC operating modes will be switched to collect data on pedestals, beam spills, and between-spill calibration sources, accomplished by way of the VAX through the use of an internal sequencer and dual port memory built into the SWIC electronics. The VAX communicates with the SWIC via ethernet and a VME crate located at the monitoring chambers (Fig. 2). One centrally located crate will serve all three SWIC devices (Fig. 1).

In this scheme it should not be necessary for the DCS Group to provide any additional control for the SWIC electronics, but readout is of course required. The plan is to use the same model applied to Beam Monitoring Group test beam runs, in which a Visual Basic program on a PC requests data from an accelerator division server using sockets. The server in turn acquires the requested data from the VME crate and delivers it to the PC.

One can use SWIC beam monitor data to calculate moments for the muon distribution, perhaps up to the 5th moment. Their time evolution will be recorded by the iFix controller. After some experience has been gained with beam behavior, iFix can in principle be used to set alarm and warning signals for variations in the moments, at which point muon beam monitoring would become largely automatic. Data acquired by the DCS from the beam monitoring ionization chambers will be stored in the iFix database and passed via Dispatcher to the Oracle Database.

Periodically the Beam Monitoring Group will test chamber gas purity by running voltage plateau curves. The SWIC HV will employ the standard MINOS controller (Section III), noting only that the LeCroy 1444 module must be modified according to LeCroy Application Note AN-48 in order to accommodate the 0–500 V range of the chambers. While the procedure is straightforward, AN-48 describes a silicon microstrip application and satisfactory performance for the SWIC devices must be demonstrated or other commercial supplies will be used.

In summary, it appears that it will be possible to read out and control the beam monitoring equipment remotely. This will require three ethernet interfaces at each chamber location: one for the VME processor, one for the high voltage 1025E RS-232/ethernet converters, and one for the FieldPoint temperature and voltage controllers. Finally, some of the control for the SWIC readout is encoded with the accelerator clock signal, requiring a 900 foot RG-8 cable from the Near Detector area to deliver an adequate copy.

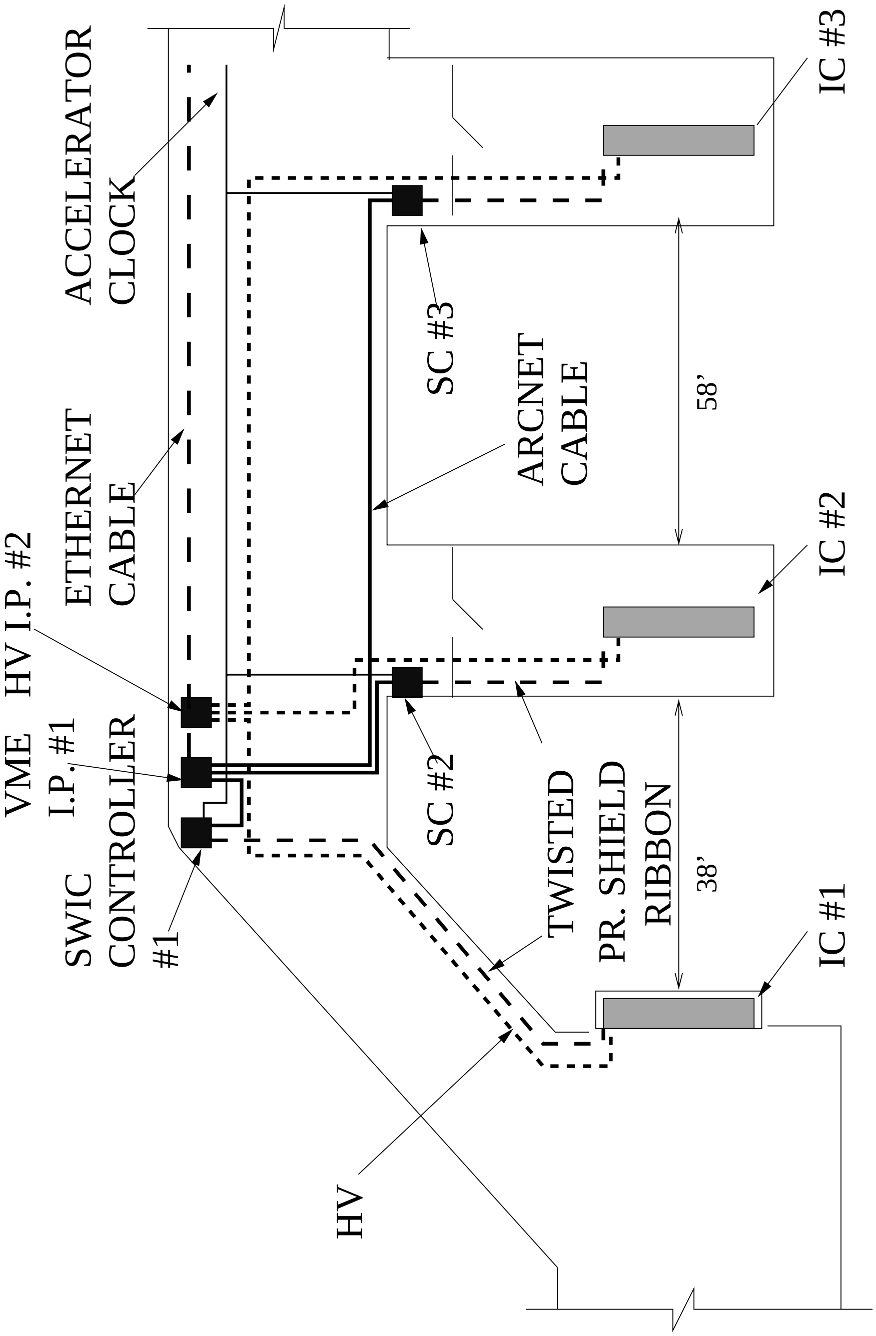

FIG. 1: Schematic layout of the beam absorber area and the muon alcoves. Cable runs are indicated for the three SWIC controllers.

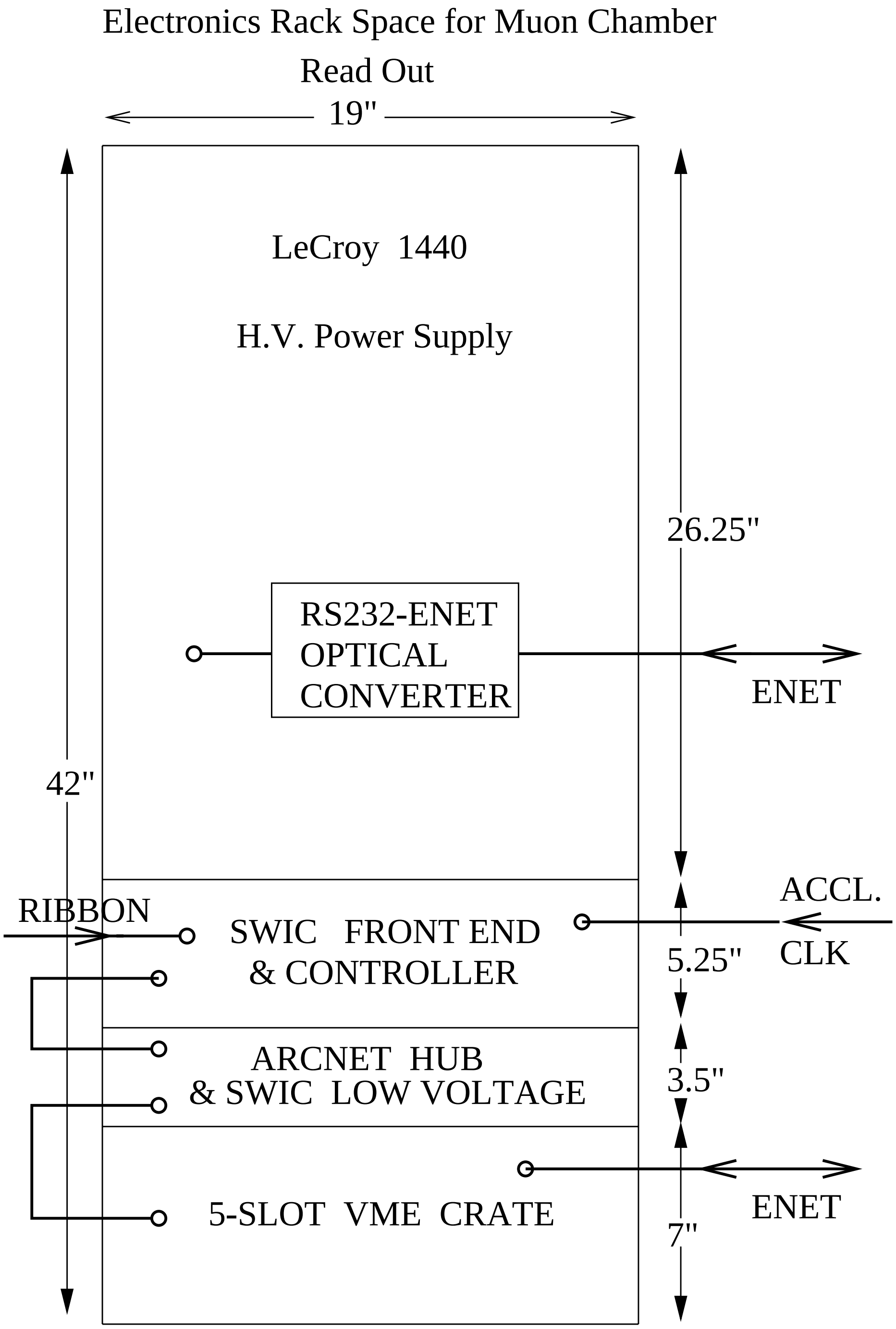

FIG. 2: Essential components in the primary readout rack for the muon monitoring chambers. Two other racks will not contain the HV supply and the VME crate. They will have a low voltage power supply in the position of the ARCNET hub.

A. Primary Beam Monitoring

Some end-of-spill information relating to the primary beam may be of interest to MINOS analysis. These data are collected by the accelerator division and made available to the DCS group through sockets and the server described above. The iFix database will be used to archive and display them. Alarm functions would presumably be supplied by the accelerator division, but they could also be implemented in the DCS iFix environment. A preliminary list of potentially relevant beam monitor items is given in Table VI.

VII. CALIBRATION

The DCS system will provide the Calibration system with the means to control the LED flasher boxes and to log data such as the LED on/off states. This will be accomplished through the RPS-8884 rack monitor's RS-485 port, taking advantage of the RPS's secondary communications ability (Sec. IV C). The calibration control PC will access this serial port through the built-in EDAS ethernet-to-serial converter, and control the flasher box as if they had a direct serial connection to their control PC.

For each LED event, the calibration PC will present the DCS logging daemon (Sec. IX) with a ROOT object containing information about which LEDs fired and at what time. This object will be logged by the DCS iFix manager and delivered to the Oracle Data Base via the Dispatcher. Hardware monitoring of the flasher boxes themselves will not be conducted—they are self-contained with respect to both power and cooling, their functionality is non-critical, and flasher power failure should be self-evident.

VIII. DETECTOR MAGNETIZATION

Both SM1 and SM2 coil current supplies are equipped with remote readout and remote control capabilities. The current will be monitored using the power supplies' internal power transducers, and each toroid will be instrumented with thermal sensors, resistance bridges (to monitor for small changes in the resistance of the coil), and interlocks to detect possible hot spots in the event of local mechanical or electrical failure. The supplies' control and monitoring systems will be interfaced to the DCS using National Instruments FieldPoint hardware and built-in iFix communication protocol.

Signals from the outputs of the various monitoring channels associated with the coils (itemized below) are split and routed to the DCS, the coil monitor PCs, the induction monitor PC's, and also delivered directly to the power supply hard interlocks. Signals are read out via Fieldpoint, for which standard iFix drivers have already been successfully exercised.

Control of the coil currents will be executed in hardware and monitored by the DCS. Transfer of sparcified induction data will proceed via files on network-mounted disks. The only substantial source of communication between the DCS and magnetics PCs is change of condition commands and status feedback (e.g. degauss SM1, ramp down, ramp to standard operating conditions, set current in SM N to i). The details of this interface have yet to be addressed, but it is similar to the light injection and HV subsystems in its software and hardware requirements. DCS monitor channels are (preliminarily) summarized in Table VII.

Synchronization of the field monitoring system, the current settings, and the current measurements is an important component of the magnetic calibration process. This problem is solved by having all signals and controls run though the magnetics (coil and induction) PCs. Readout is separated by side and supermodule in the far detector, with Fieldpoint stations located on the lower-deck south-west end of SM1 and the lower-deck north-west end of SM2. Noting that the question of dedicated DCS and magnet PC use is to be addressed within this Review, readout PCs are planned on the mid-level decks, three on the east and one on the west, all connected to the DCS LAN.

While this (preliminary) section describes the Far Detector, most coil and magnet systems information applies to the Near Detector as well. Little progress has, however, been made in detailed design of this system. We hope to address it during Spring 2000 on the Near and Far Detector coil prototypes, which we expect to be operational by the end of Winter.

IX. DAQ-DCS COMMUNICATIONS

Due to the separation of the data acquisition system and the detector control system, a communication path between them must be developed. This is further complicated by the fact that the DAQ and DCS exist on separate operating systems, but a satisfactory network-based communication layer has been developed.

Item	**Words**
Last 2 Beam Position Monitors (BPM's; $x + y$)	$2 + 2$
OTR (Optical Transition Radiation) monitors	2×400
Muon beam monitor chambers	3×96
Low energy beam Budal monitor	1
If higher energy beam targets	(+1)
Left/Right thermocouple monitors (for beam wander; need a few minutes for equilibrium)	$1 + 1$
Horn currents, timing, microphone	$4 + 4 + 4$
Hall probe and B-field pickup	2
Target pile temp	1
Hadronic Hose currents, timing	$4 + 4$
Absorber temps (8 Al & 1 steel water cooled; 3–5 steel, not water cooled.	$8 + 1 + m$
Water flow meter, temp, level	3
Cooling air temp' in, out	$1 + 1$
Decay pipe vacuum, temp	$1 + 1$
Exhaust stack monitor for air activation	1
Beam loss monitors	$+n$
Word Count	**\$1135+**

TABLE VI: Preliminary Beam Monitor items.

Magnet Power Controls

Signal ID	**Type**	**Activation**
Current Setting	Analog	0–10 VDC
Forward/Reverse	Contact	SPDT
DC On	Contact	NO mont
DC Off	Contact	NC mont
Remote Reset	Contact	NO mont
Contact Spares (3)	Contact	

Magnet Power Monitors

Signal ID	**Type**	**Activation**
Output V	Analog	0–10 VDC
Output I	Analog	0–10 VDC
Analog Spares (2)	Analog	0–10 VDC
Forward	Contact	
Reverse	Contact	
Interlock Ready	Contact	
DC On	Contact	
Contact Spares (3)	Contact	

Coil Temperature Monitors

Signal ID	**Type**	**Activation**
T/C Temp 1–10	Analog	TBD
Klixon over Temp Sum	Contact	NC
T/C over Temp Sum	Contact	NC

TABLE VII: DCS magnet and coil signals by type and source (PRELIMINARY). NO/NC = normally open/closed.

Two principle network protocols are supported on most modern operating systems: TCPIP and UDP. The TCPIP protocol guarantees delivery but requires a "server" and "client" relationship via a "socket". UDP, conversely, guarantees nothing but allows for "broadcast" communication which is not available in the TCPIP protocol. As reliability is a concern as well as security, we have chosen TCPIP as the DAQ/DCS. In this protocol it is possible to manage many "client-server" connections with a simple socket manager; one expects, however, that most connections will be determined in advance and that an adaptive socket manager is not required.

Currently, DAQ-DCS communication is conceived with two type of notification objects: "commands" and "messages." Command objects notify of changes of state in the detector, such as a new run start, while message objects represent notification from monitoring processes regarding the quality of the data.

Message objects will be displayed and appropriate action determined by a (human) DCS operator. Command objects, on the other hand, may require an automated action such as recording the start time and generating appropriate database links for a new run. Several similar appropriate command objects are expected, but in each case the role of DCS is to provide a service to the DAQ. DCS can provide warnings and messages for DAQ, but it has no ability to control or influence the acquisition of data.

A prototype DAQ-DCS communication system has been developed using TSockets as implemented in the ROOT [1] C++ program library. ROOT was chosen because of its flexibility, platform independence and in order to limit the number of system software dependencies. Communication via the ROOT interface has been prototyped using a ROOT object which indicates the type of notification and a short string which contains the message itself. In addition, GUI interfaces have been developed using ROOT GUI classes for displaying message types and for further developing the DAQ-DCS interface.

One important attribute of the system is flexibility in receiving non-ROOT messages (simple strings). This is elegantly handled by ROOT because such messages can be identified either as a ROOT object or as a simple string type. Communication acknowledgement is also provided, yielding a quick confirmation for the sender that a message has been received.

X. DCS-ORACLE DATABASE INTERFACE

Although DCS will maintain its own historical record of detector operating parameters in the iFix internal database, it will also transmit an archival abstract of detector operating parameters to the main MINOS Oracle Database. This will be sent as an ASCII file through a ROOT TSocket. Each hour, the DCS will produce a summary table listing the current values of all relevant operating parameters for both the Near and Far Detectors, with a date-time stamp encoded in the filename and provided internally within the text. Between hourly files DCS will produce “incremental” files, also date-time coded by filename, consisting of one-line entries for each parameter change and alarm condition noted by the iFix SCADA system. It will thus be possible to reconstruct the detector state at any time from a combination of one hourly “snapshot” and the following “incremental” file.

REFERENCES

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[3] D. S. Ayres, *Nucl. Phys. Proc. Suppl.* **59**, 297 (1997).