The Decommissioning and Repurposing of the DØ Cryogenic PLC System

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Abstract

The DØ Collider Cryogenic Programmable Logic Controller (PLC) System was partially decommissioned in order to harvest parts for future experiments within Fermilab. Altogether 4 out of 12 bases located throughout the DØ Assembly Building (DAB) were deprogrammed and removed from the main Siemens PLC System. Approximately 2,000 addresses/tags were removed from the database/historical record along with their associated logic being removed from the "FasTrak PLC 505 WorkShop Suite" Programming Tool (FWPT). These tags and logic correlate to a total of approximately 13,000 words (≈832 kB or 50% of the entire PLC System) of data. The 4 bases that were removed control the Silicon Management System, the cryogenic controls in the Superconducting Solenoid and Visible Light Photon Counter, and the Insulating Vacuum Controls. The equipment will be primarily utilized within the cryogenic controls in the LArIAT, LBNE, LAPD, and MicroBooNE experiments. Altogether, Fermilab has saved an estimated $100,000+ by reusing this equipment.

1 Introduction

After the launch of CERN's Large Hadron Collider in 2009, the Tevatron's life effectively came to an end, and it was later shutdown in 2011. The DØ experiment ran for approximately 20 years and has made several discoveries alongside CDF. However, with any experiment that runs for an extended amount of time, the life-cycle of the equipment must surely be considered both before, during, and after the run. Decommissioning is a crucial step in the life-cycle proces and it can also be very beneficial to the success of other experiments throughout the lab.

In order to ensure Fermilab's continued success amongst the scientific community, emphasis must be continually placed on life-after-use of equipment. Figure 1 shows the process of an experiment from start to finish:

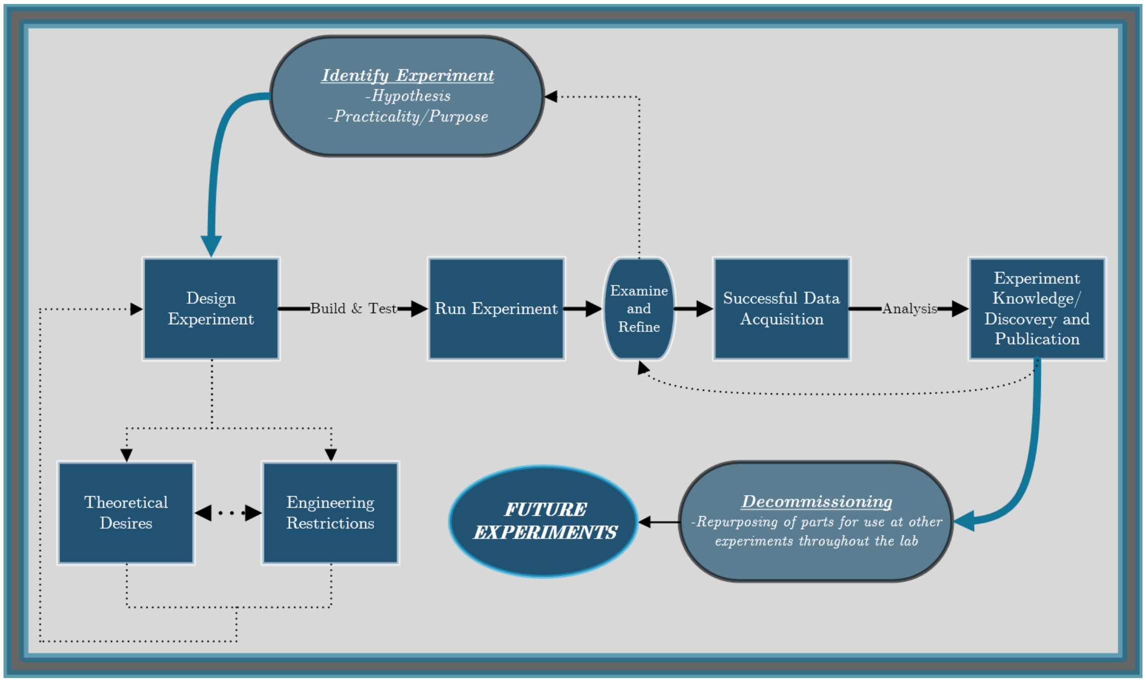


Figure 1: Life-cycle Process of Experiments

2 PLC System Overview

Cryogenics play a very important role at Fermilab, thus the demand for PLCs to control the flow and circulation of these fluids is certainly high. Rather than purchase new equipment for upcoming experiments - which would cost several tens of thousands of dollars - the Controls Group has been and will continue to carefully decommission the DØ Cryogenic PLC System for use primarily in the LArIAT, LBNE, LAPD, and MicroBooNE experiments.

The PLCs used in the DØ Cryogenic System were Siemens Simatic Series 505, which are programmed inside of the FWPT. Each PLC System contains several I/O bases that branch throughout the DAB and within each I/O base; there are as many as 16 slots available with 16 channels in each to place physical hardware connections (relay logic hardware). Each piece of relay logic hardware/software can be classified into 1 of 7 primary categories (with the address-prefix in parenthesis):

1. Analog Inputs/Outputs (WX / WY)
2. Discrete Input/Outputs (X / Y)
3. Variable-Memory (V / VF)
4. Contacts/Internal Relays (C / CR)
5. Constants (K)
6. Ladder Memory (L)
7. Special Function Memory (S)

For this project, categories 1 through 4 in the above list will be the primary concern due to the scarcity of 5 through 7. These pieces of relay logic hardware and addresses are physically located inside of the I/O Base, and the way which they operate are defined in the logic of the FWPT . The FWPT consists of 3 primary tools that control the function of these addresses. These 3 tools are:

1. — Ladder Logic —
   programming language used to construct a program dependent on the circuitry inside of the relay logic hardware. Example:

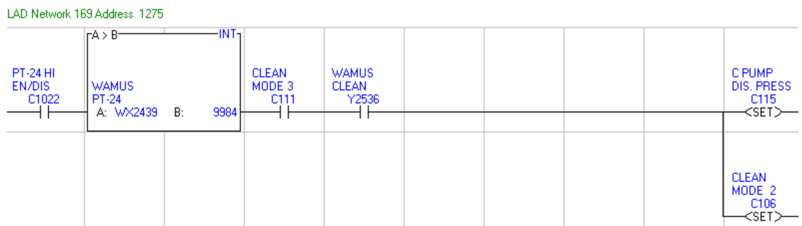


Figure 2: Fragment of Ladder Logic from FWPT

2. — Special Functions —
   custom programming language used in the FWPT, similar to Microsoft Visual Basic, used to control inputs and outputs and store variables.

3. — P.I.D. Loops —
   Proportional Integral Derivative Loops are closed loops used to control a certain input or output with a user-defined or control-defined process variable by finding the error in the set-point and the process output. A brief examination of the process and mathematics of a PID loop is displayed below in Figure 3:

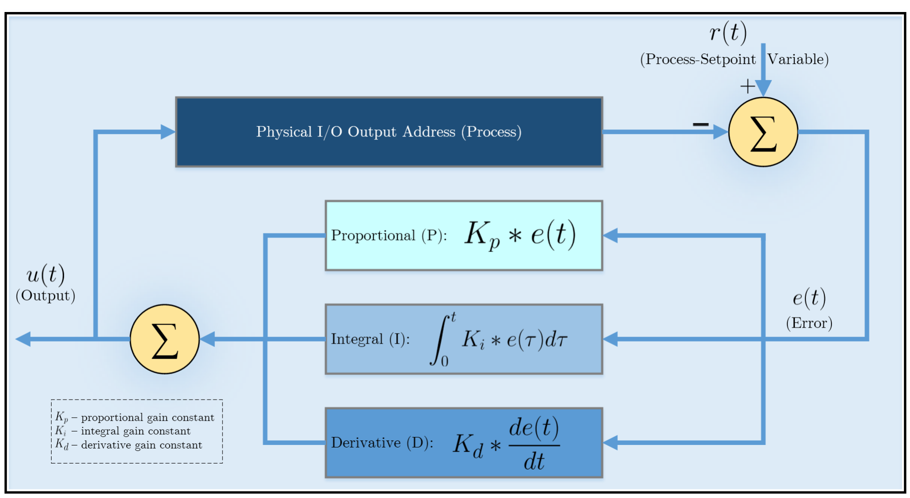


Figure 3: PID Loop

Along with being located inside of the logic, the addresses are also located within a Proficy Human Machine Interface (HMI) iFIX Database. This database contains all the current information regarding each address, displaying a read-out alongside the associated block. The iFIX Historian is used to track the progress of these individual addresses over time. Each address possesses drivers that are also displayed in the iFIX database, but also in a separate program (Driver Database). For this project, 3 types of drivers are of primary concern; Texas Instrument Ethernet (TIE), Industrial Gateway Server (IGS), and Texas Instrument Direct (TID). However, only TIE Drivers are of importance to the Cryogenic unit within the DAB.

The architecture of the PLC System is shown below in Figure 4:

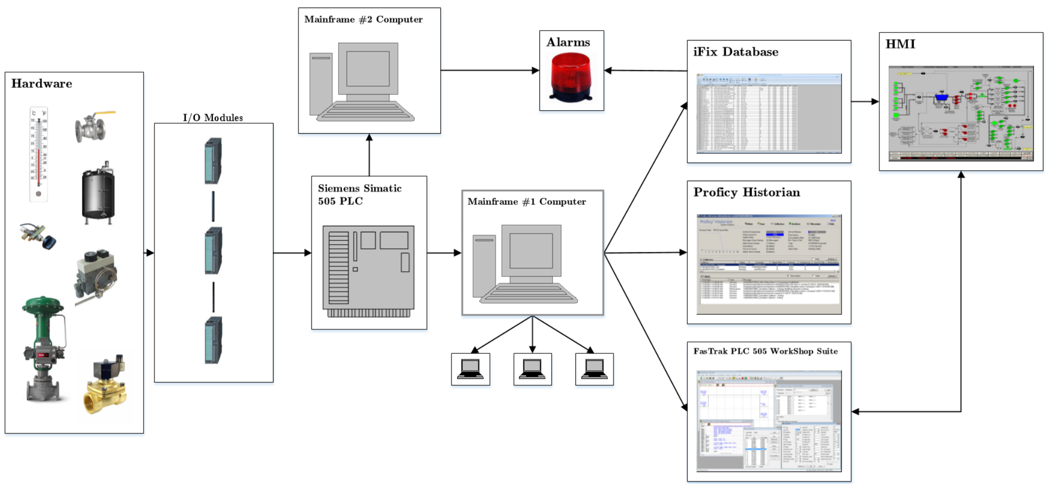


Figure 4: Architecture of PLC System in the DAB

3 Removal of Input/Output Bases

The following is a list of the subsets of the PLC that were removed:

1. Base #11 - Removed 6 / 18 / 2014
2. Base #8 - Removed 6 / 24 / 2014
3. Base #10 - Removed 7 / 7 / 2014
4. Base #7 - Removed 7 / 7 / 2014
5. ODH System - Removed 7 / 15 / 2014

Several I/O Bases are located throughout the DAB, however during the short extent of this project, only a portion of these crates were fully removed and taken elsewhere. These drawings are subsections of the above drawing, and show some of the portions of the system that were removed. The layout of the DAB Cryogenic Controls is shown in Figure 5 and the North/South side of the Control System is shown in the sequential figures as well.

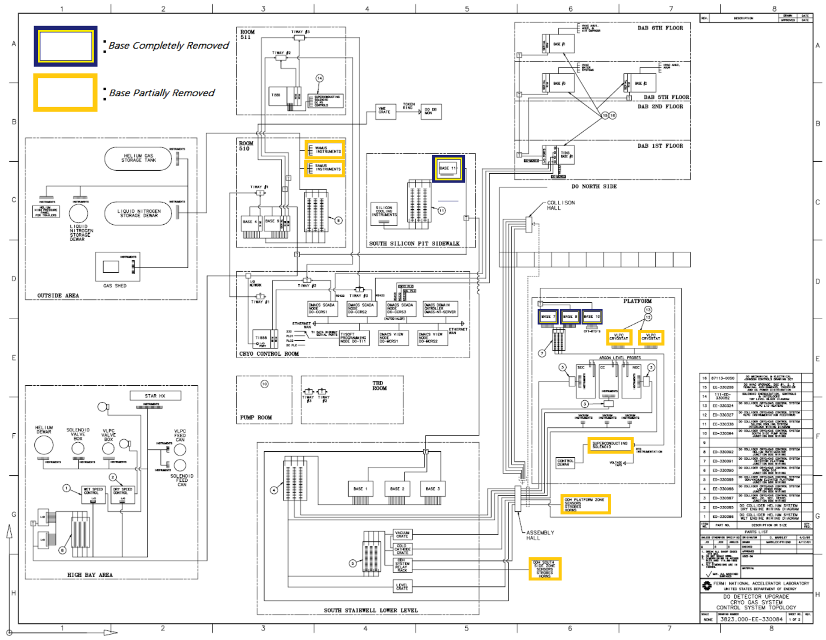
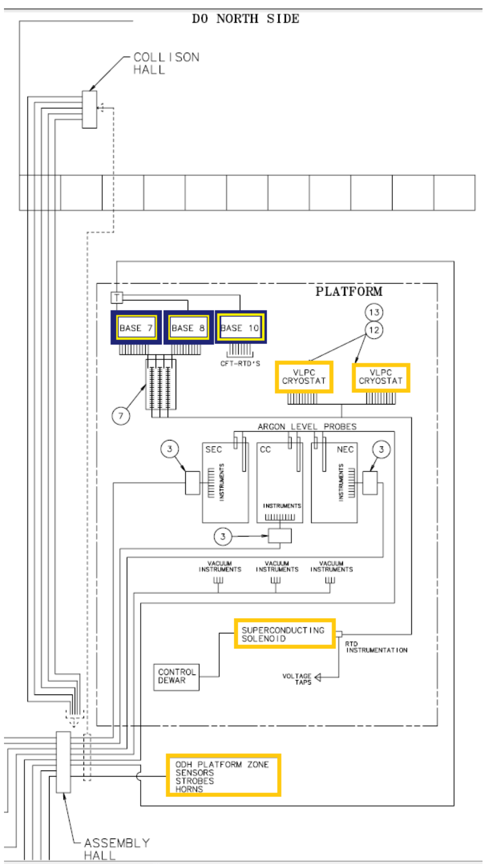
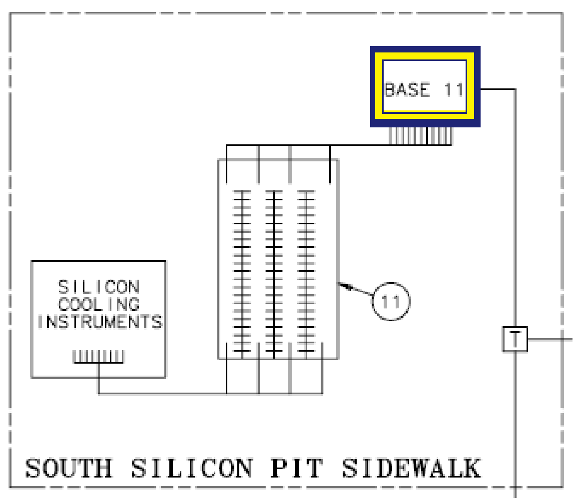


Figure 5: I/O Base Arrangement in the DAB





Base 11 was in control of the Silicon Management System. Base 7, 8, and 10 were in control of the Superconducting Solenoid Cryogenic Controls, the VLPC Cryogenic Controls, and the Insulating Vacuum Controls.

A question that is commonly asked while deconfiguring each particular base may be "Why not unplug and reuse every base within the Cryogenic PLC System?". As easy as it sounds, this is not a viable option to the Controls Group. Not every single address/channel/module is currently being used at this point in time. There are still systems currently in use inside of the Cryogenic PLC System throughout the DAB. Therefore, the PLC must be thoroughly examined prior to removal.

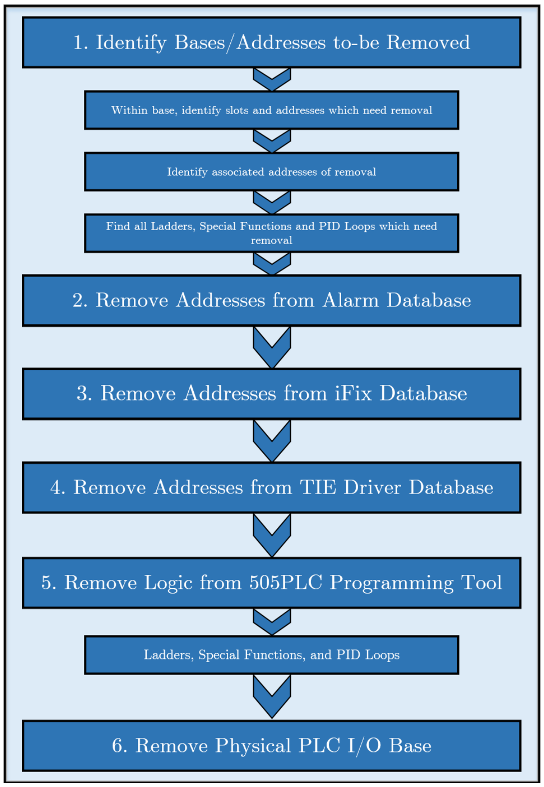


Figure 6: Removal Process

Prior to the bases being physically removed, the addresses within each slot of the base must be identified to ensure that no errors are thrown post-removal. Along with each address being removed, the associated addresses that are utilizing the original address must also be removed. This is to eliminate unnecessary memory usage on the PLC.

The alarm database is used is used to relay important information about sensitive equipment to employees and notify them when problems exist. It is necessary that the alarm database be removed first prior to the other database removals, because if not properly handled, it will throw alarms. This alarm database typically contains the least amount of addresses. However, the iFix database contains the most and tends to be the most time consuming.

Once all the steps are completed in the proper order, then the physical removal of the I/O base may begin for usage elsewhere.

4 Conclusion

By decomissioning particular I/O Bases in the PLC System throughout the DAB, it will save the expenses of other experiments throughout the Lab. The estimated potential savings can be calculated by assuming the average cost per I/O Base being \$25,000/unit (not including the partially removed modules and labor costs). Without considering labor costs and other miscellaneous expenses, the raw estimated potential savings is shown below in Table 1.

Although 832 kB seems like a relatively low amount of memory compared to today's standards, this is almost half of the total memory available in the PLC System (1856 kB). Also, even when considering the savings of repurposing of equipment, one must also consider the lifetime of the PLC System Hardware. The Siemens 505 series PLC luckily has a shelf-life of roughly 30 years, with a maturity of 20 years. In comparison, the 500 Series, also made by Siemens, has been discontinued and are no longer in production, but there are still modules in use at Fermilab.

I/O Base	Addresses Freed	Total Memory Freed (kB)	Potential Savings
7	517	346	≈$25,000
8	379	149	≈$25,000
10	52	18	≈$25,000
11	300	115	≈$25,000
ODH (Partial)	83	24	—
MISC	455	180	—
TOTAL	**≈1980**	**832**	**≈$100,000**

Table 1: Potential Savings Table

Overall, the decommissioning and repurposing of the DØ Cryogenic PLC System has brought several benefits to both Fermilab and the U.S. Department of Energy from a financial perspective. In an era that emphasizes reuse and environmentally friendly alternatives, this approach seems to be the most pragmatic.

5 Acknowledgments

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