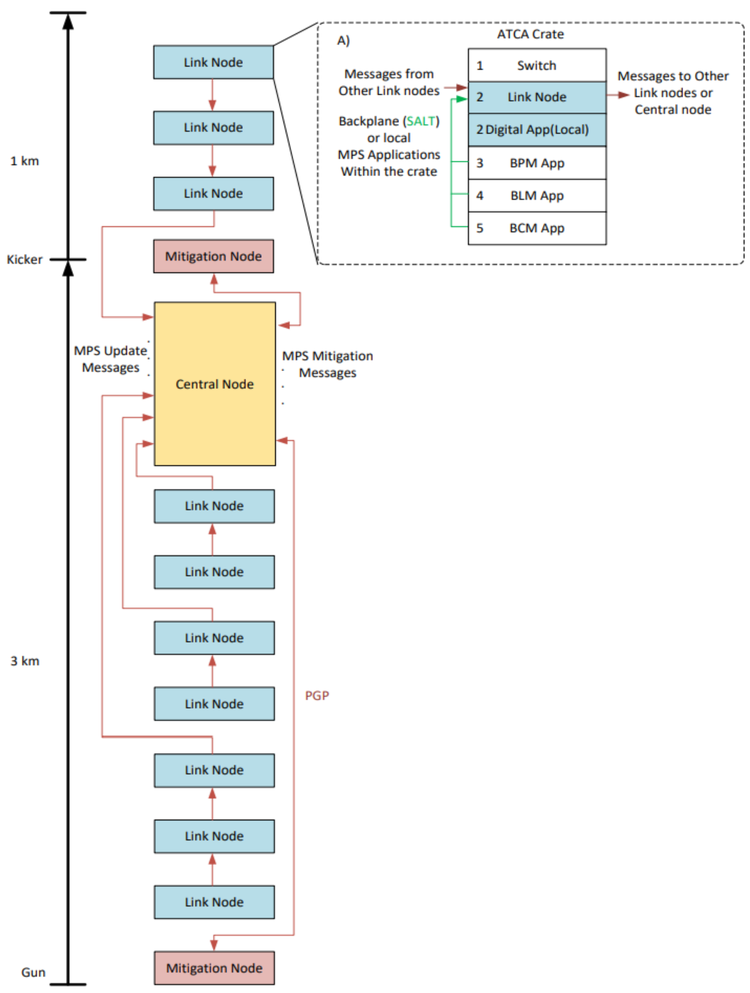
Design and Implementation of the LCLS-II Machine Protection System

J. A. Mock – jmock@slac.stanford.edu , Z. Domke, R.T. Herbst, P. Krejcik, L. Ruckman, L. Sapozhnikov
SLAC National Accelerator Laboratory, Menlo Park, California, USA.

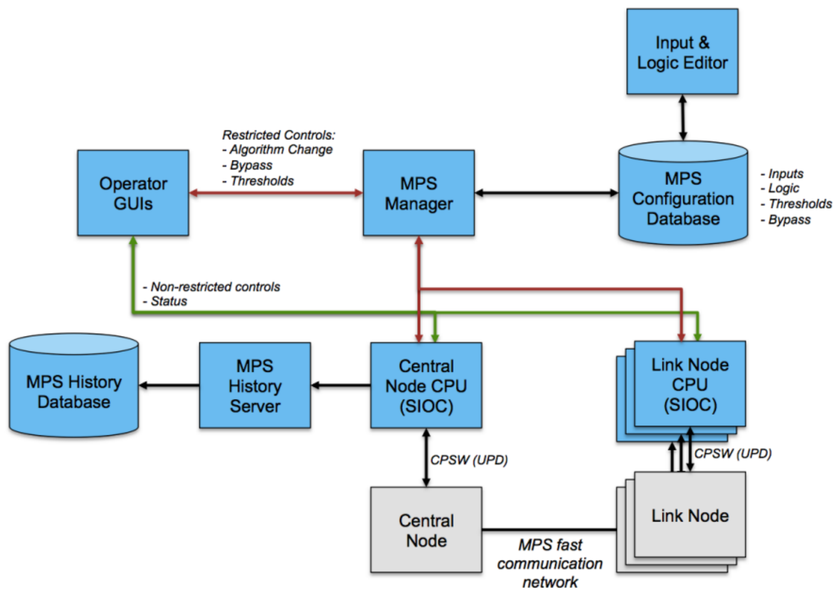
ABSTRACT
The linear accelerator complex at the SLAC National Accelerator Laboratory has been upgraded to include LCLS-II, a new linac capable of producing beam power as high as several hundred kW with CW beam rates up to 1 MHz while maintaining existing capabilities from the copper machine. Because of these high-power beams, a new Machine Protection System with a latency of less than 100 us was designed and installed to prevent damage to the machine when a fault or beam loss is detected. The overall system design of the LCLS-II MPS software including the ability to interact with the existing systems and the tools developed for the control room to provide the user operation experience is described.

SYSTEM DESIGN
The scope of the MPS is confined exclusively to shutting off the electron beam when a fault condition occurs that can potentially damage beam line hardware. It is required to shut off the beam within 100 μs of fault detection. The system is built as a distributed set of link nodes that act as data collectors. The link nodes send data to a central node that compares the data against a pre-programmed rules table to determine a beam power permit. The permit is sent out to a mitigation device which allows or disallows the beam. A measurement is made each 1 MHz accelerator clock cycle. The link nodes and central nodes are built upon the SLAC High Performance System Common Platform (ATCA architecture) designed for LCLS-II.



The distribution of the MPS Link Nodes and Central Node

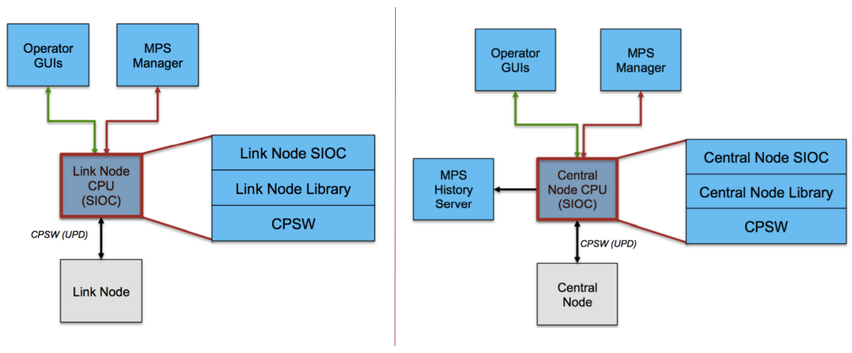
SOFTWARE ARCHITECTURE
The MPS configuration is stored in a relational database. A python representation of the database is used to import and export device and fault data as EPICS databases, central node rules tables, alarm configurations, and documentation. Additionally, GUIs and managers can load the configuration database directly with the python interface.



The MPS Software Architecture

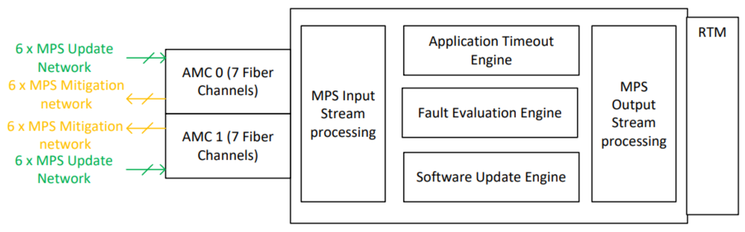
The MPS uses a low latency network to move fault data and EPICS for asynchronous control, status monitoring, and fault reporting for GUIs.

Each ATCA crate has a link node, and each link node has one IOC providing EPICS PV API for control room use. The SLAC Common platform provides a linux library for link node register access, and the link node IOC uses an Asyn driver to provide EPICS support for register access.



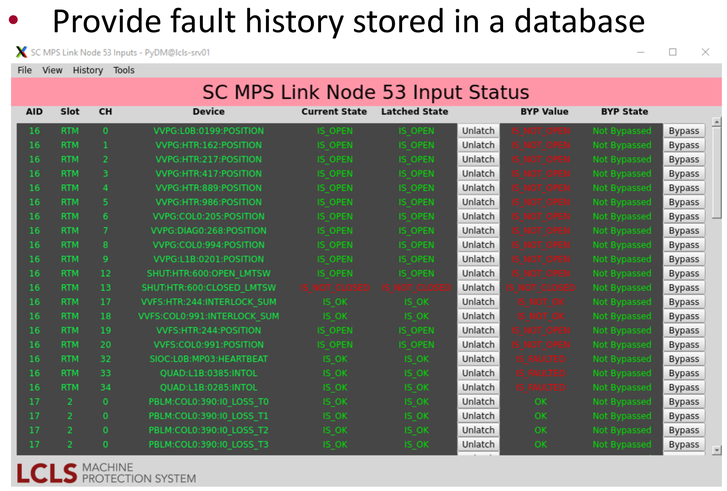
The link node and central node software stacks

The central node also utilizes the linux library and Asyn driver for EPICS access to asynchronous register access. The central node firmware evaluates fast fault rules, but more complicated logic tables are evaluated in the central node software. Data are exchanged between the firmware and software at a 360 Hz update rate. Within this 2.2 ms window, the central node software evaluates complex rules and sends a permit back to the firmware to be included in the processing

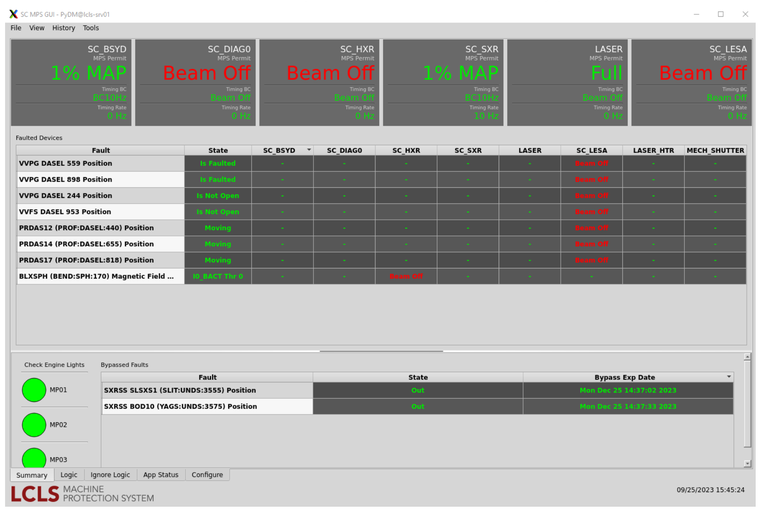


The central node evaluation engines

CONTROL ROOM TOOLS
MPS provides a suite of control room tools for
- Monitoring the health of the link nodes
- Monitoring the health of the central nodes
- Providing current, latched, and bypass status of all inputs
- Providing the ability to apply fault bypasses, adjust thresholds, and load rules tables
- Provide an interactive GUI that shows the current permit state and all fault states. Also provides searchable interface to logic tables to see their inputs, status, and additional information
- Provide fault history stored in a database



A GUI that shows inputs current and bypass status



Searchable interactive GUI that shows current permit states

The GUIs are written in python and take full advantage of the python interface to the MPS Configuration Database. The searchable GUI, for example, can build all the information about fault inputs, states, beam destinations, beam power, etc. from a single relational database ID, so the system only must publish the relevant ID in a PV. The GUI will reconstruct the rest of the information. This reduces the PV access in the central node Asyn driver and reduces overall network traffic.

RESULTS
The LCLS-II Machine Protection System was designed to protect the new high power linear accelerator at SLAC. It was installed and successfully supported beam operation allowing the LCLS-II project to be successful. It shuts off the electron beam within 70 μs of fault detection and the operator GUIs indicate why.

ACKNOWLEDGEMENTS
Use of the Linac Coherent Light Source (LCLS), SLAC National Accelerator Laboratory, is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-76SF00515.