PREEMPTIVE MACHINE PROTECTION SYSTEM FOR LCLS-II EXPERIMENT CONTROLS

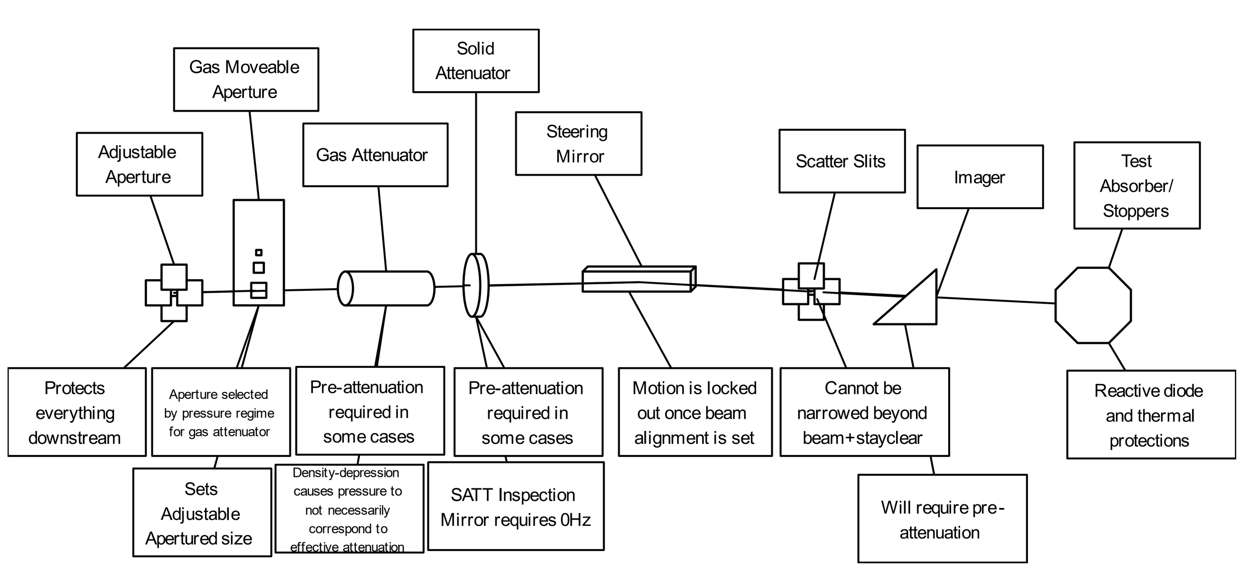
Alex Wallace (1), awallace@slac.stanford.edu, Margaret Ghaly (1), Zachary Lentz (1), Ken Lauer (1)

1. SLAC National Accelerator Laboratory, USA.

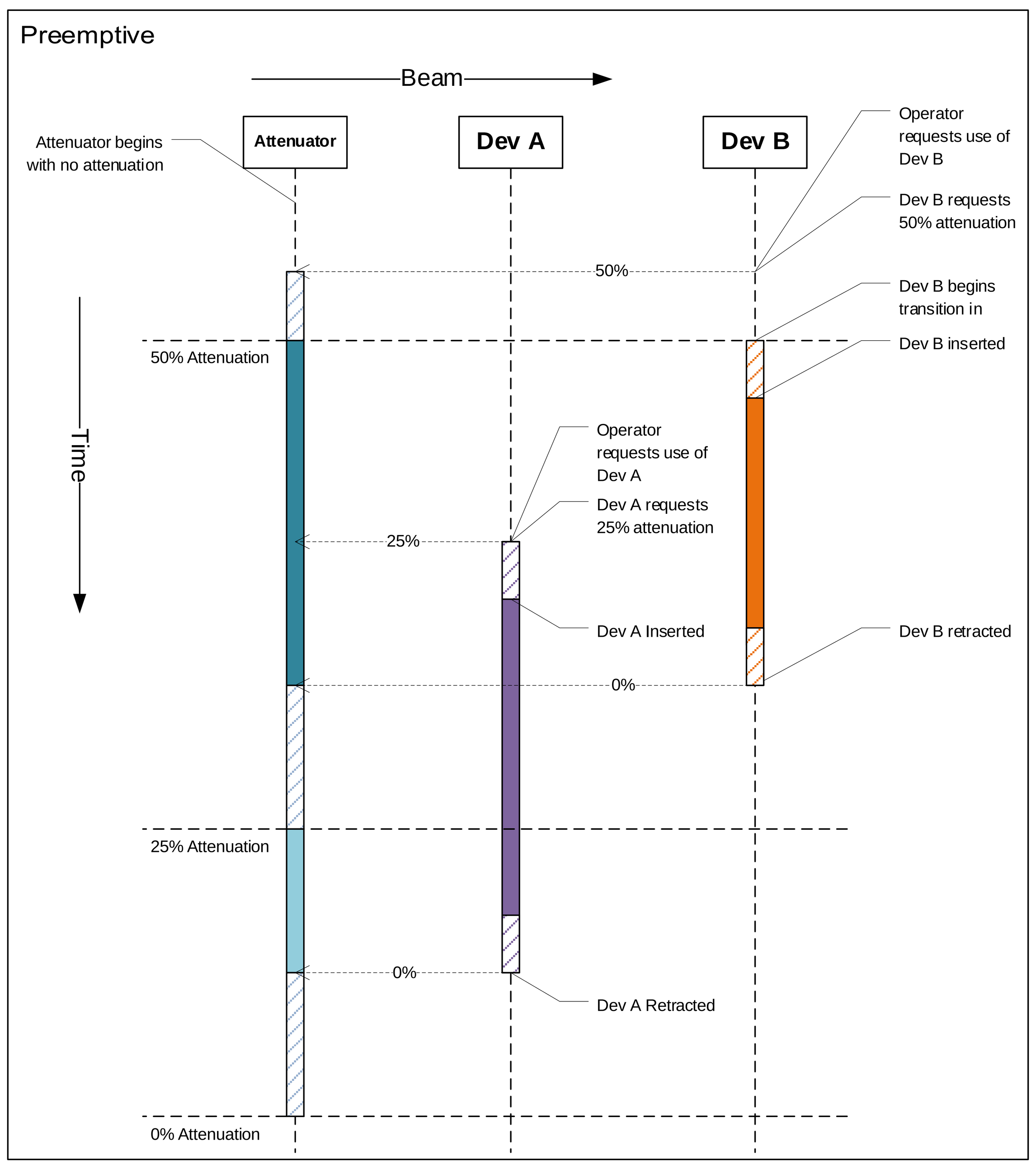
SLAC NATIONAL ACCELERATOR LABORATORY | U.S. DEPARTMENT OF ENERGY | Stanford University

UNPRECEDENTED POWER IN THE LCLS-II BEAM REQUIRES A DIFFERENT MACHINE PROTECTION STRATEGY

LCLS-II beam is destined to be orders of magnitude more intense than its predecessor and operate at up to 1MHz (1-10KHz for most science applications today). The accelerator MPS was upgraded to preserve undulator magnets and other accelerator systems from beam-loss damage, while the MPS for the experiment areas was upgraded to preserve x-ray optics and diagnostics.



The preemptive concept of the Photon Machine Protection System. This diagram illustrates the way beam transmission is automatically arbitrated between two devices with different absorption and damage thresholds. The PMPS keeps both devices safe, and permits as many photons as possible.



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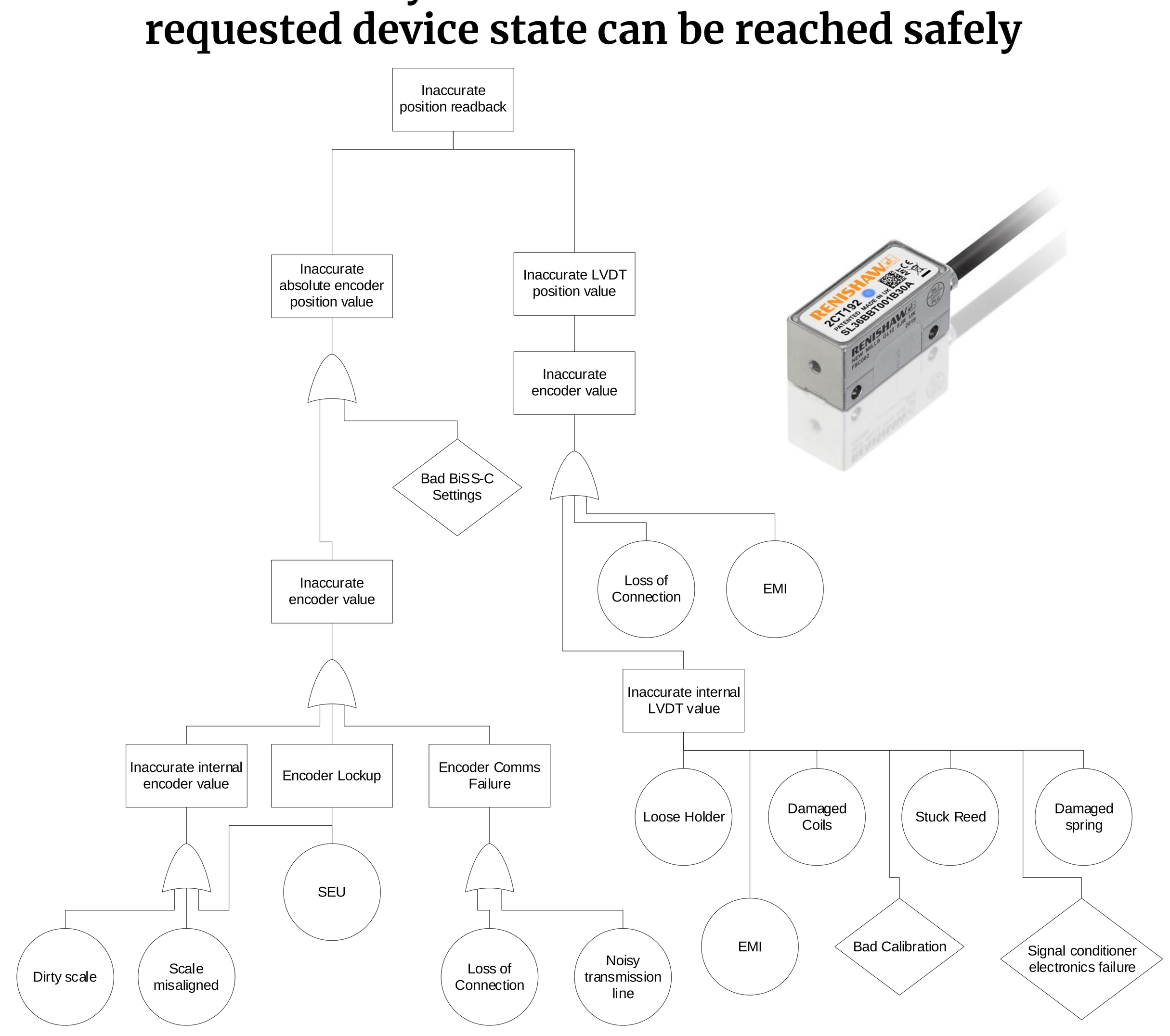
DESIGNED FOR FLEXIBILITY, OPEN-ENDEDNESS, AND PROTECTION OF HIGH-IMPACT COMPONENTS

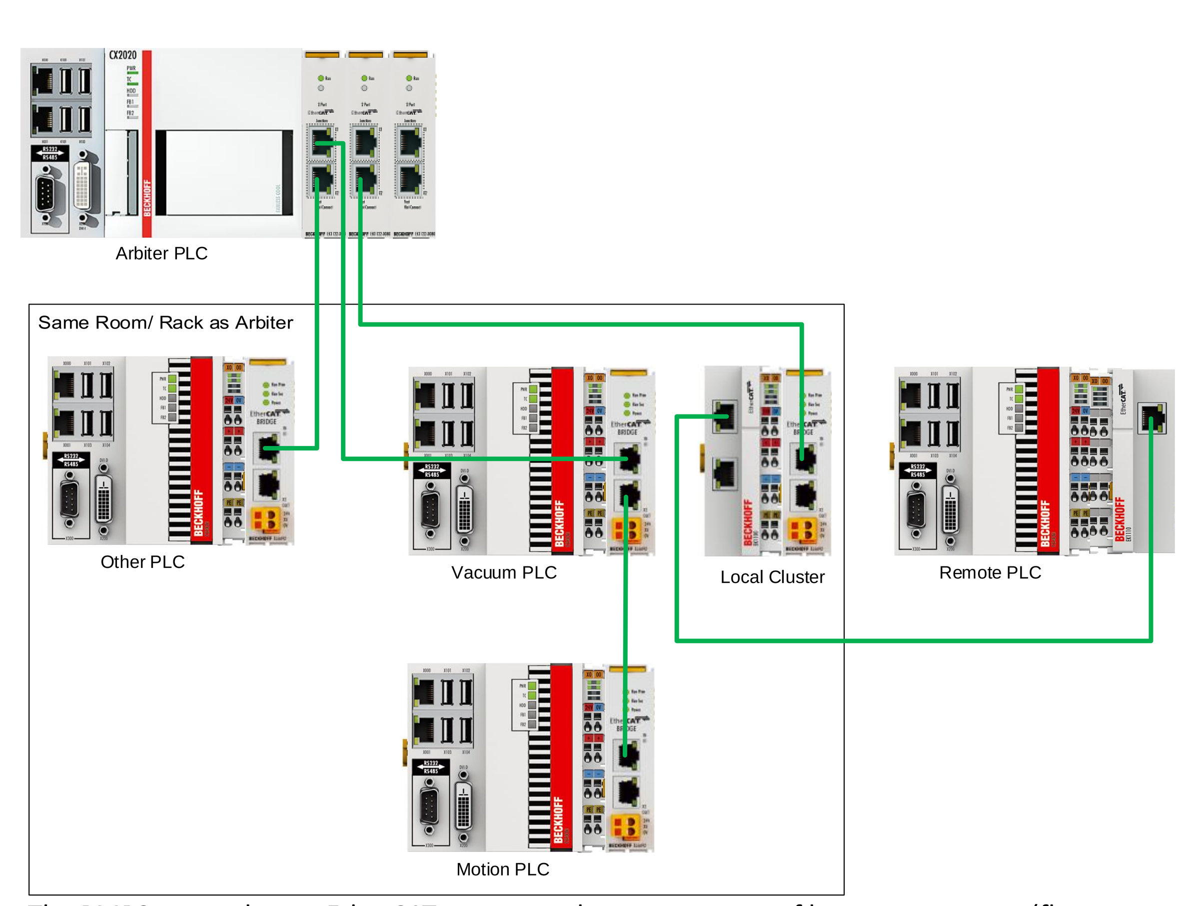
Damage thresholds, modes of operation were subject to change during commissioning and operation. Beam aberration due to thermal deformation of x-ray optics adds more complexity to operations.

Functional requirements:

- Protect devices from damage by the beam
- Limit impact on operations
  - Try not to fault/ turn off the beam
  - Deliver as many photons as possible
  - Report why the beam is being limited
  - Report why a device ignored a request
  - **Automatically condition the beam so a requested device state can be reached safely**



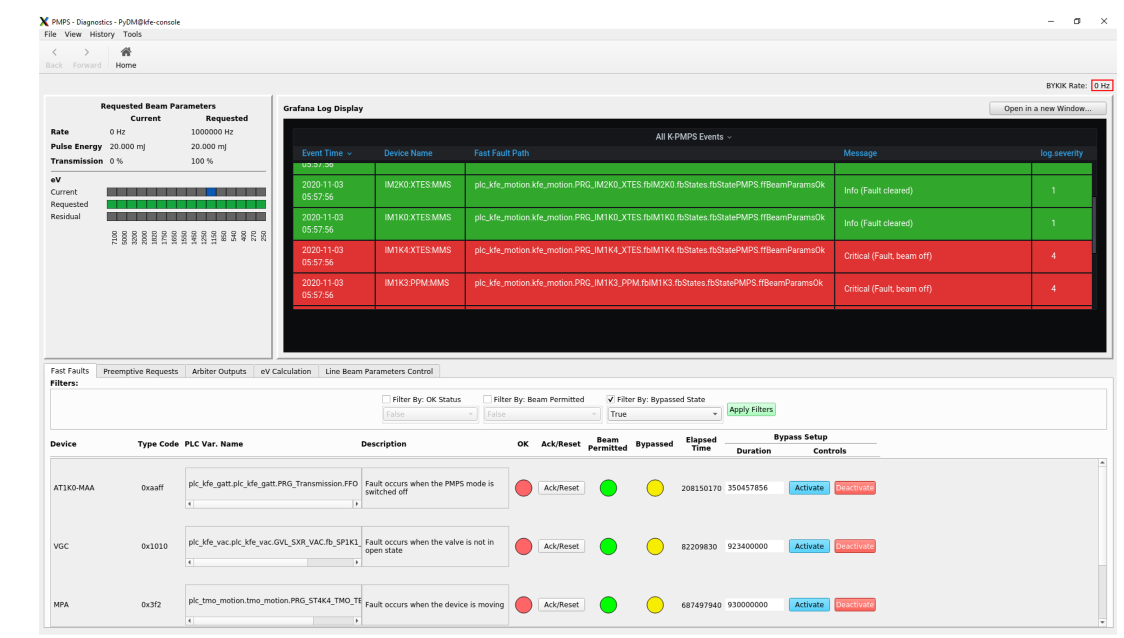
Absolute encoding is required for PMPS integration. This is an example FMEA for encoders.



The PMPS network uses EtherCAT to convey the current state of beam parameters (fluence, wavelengths, rate, etc.), and the requested beam parameters for each subsystem. The Arbiter PLC summarizes the beam parameter state for the entire beamline. There is one arbiter per XFEL source. The network is easily extendable so additional subsystems can be added as LCLS grows.

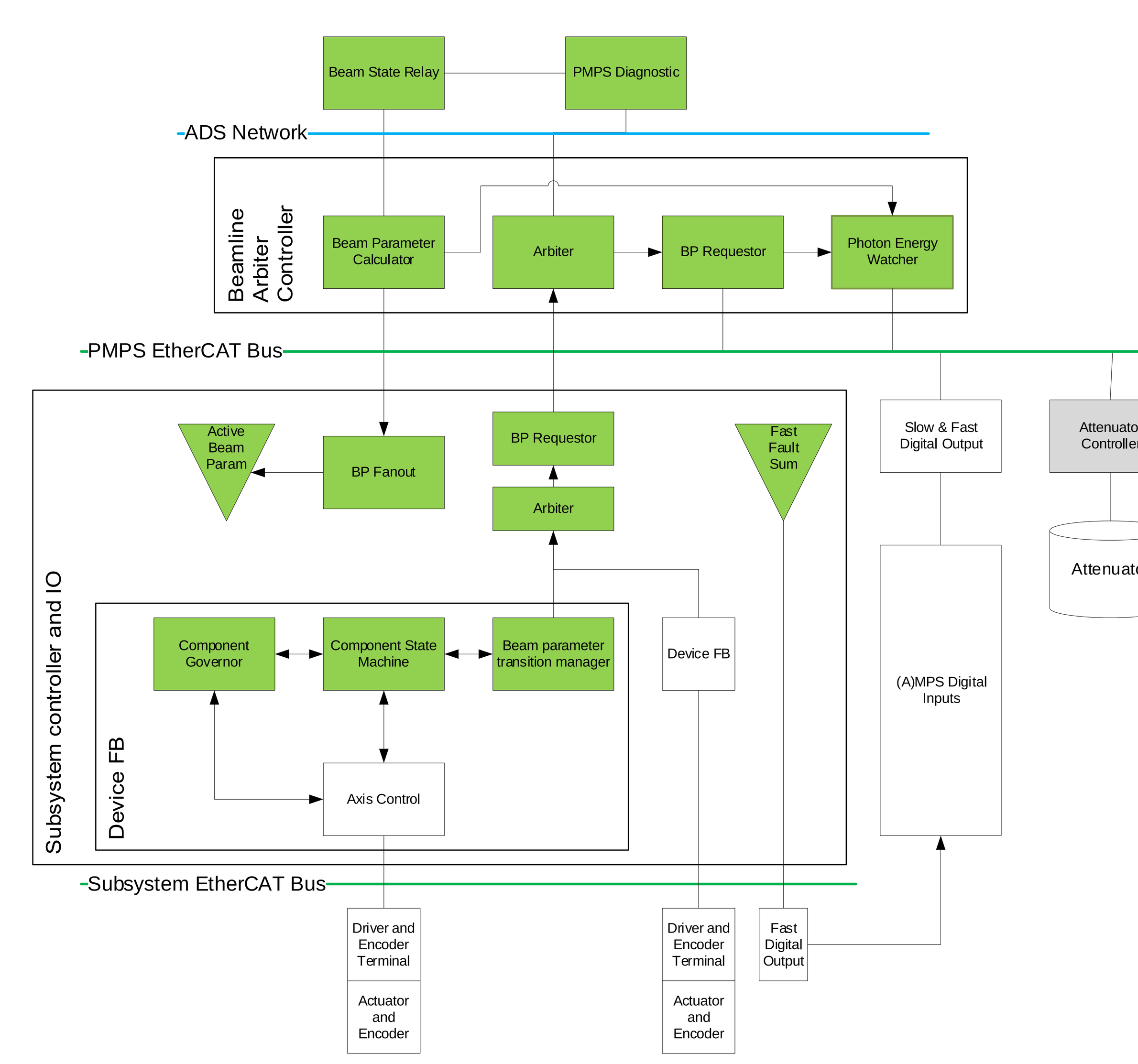
BECKHOFF PLCS AND COMMON LIBRARY FRAMEWORKS EMPOWER THE CONTROL SYSTEM ENGINEERING TEAM

The PMPS was built to be used and deployed by the entire control system team with the core framework supported by a small team of experts. Beamline operators set thresholds and bypasses.



The original PMPS diagnostic leverages PyDM functionality enabling observability. The ECS Centralized Logging System showing PMPS related messages is displayed through a Grafana dashboard embedded directly in the diagnostic.

TcUnit, a unit-testing framework for TwinCAT, is used for a test suite for PMPS software components. The suite ensures the core PMPS functionality is preserved, and system ownership transfer is enabled.



PMPS software components are highlighted in green. Beamline devices with MPS requirements dynamically submit their required beam conditions or parameters (BP) to their local arbiter pool which then summarizes and registers a request with a higher-level arbiter until the arbiter for the beamline applies the request to accelerator and other beamline elements. Independent software components provide a simple fault pathway for responding to abnormal conditions by turning the beam off.

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REFERENCES

Lcls-twincat-pmps: https://github.com/pcdshub/lcls-twincat-pmps
TcUnit: https://github.com/tcunit/TcUnit
LCLS-II MPS: https://ibic2023.vrws.de/papers/tu3i01.pdf