A Streamlined Architecture of LCLS-II Beam Containment System

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SLAC NATIONAL ACCELERATOR LABORATORY

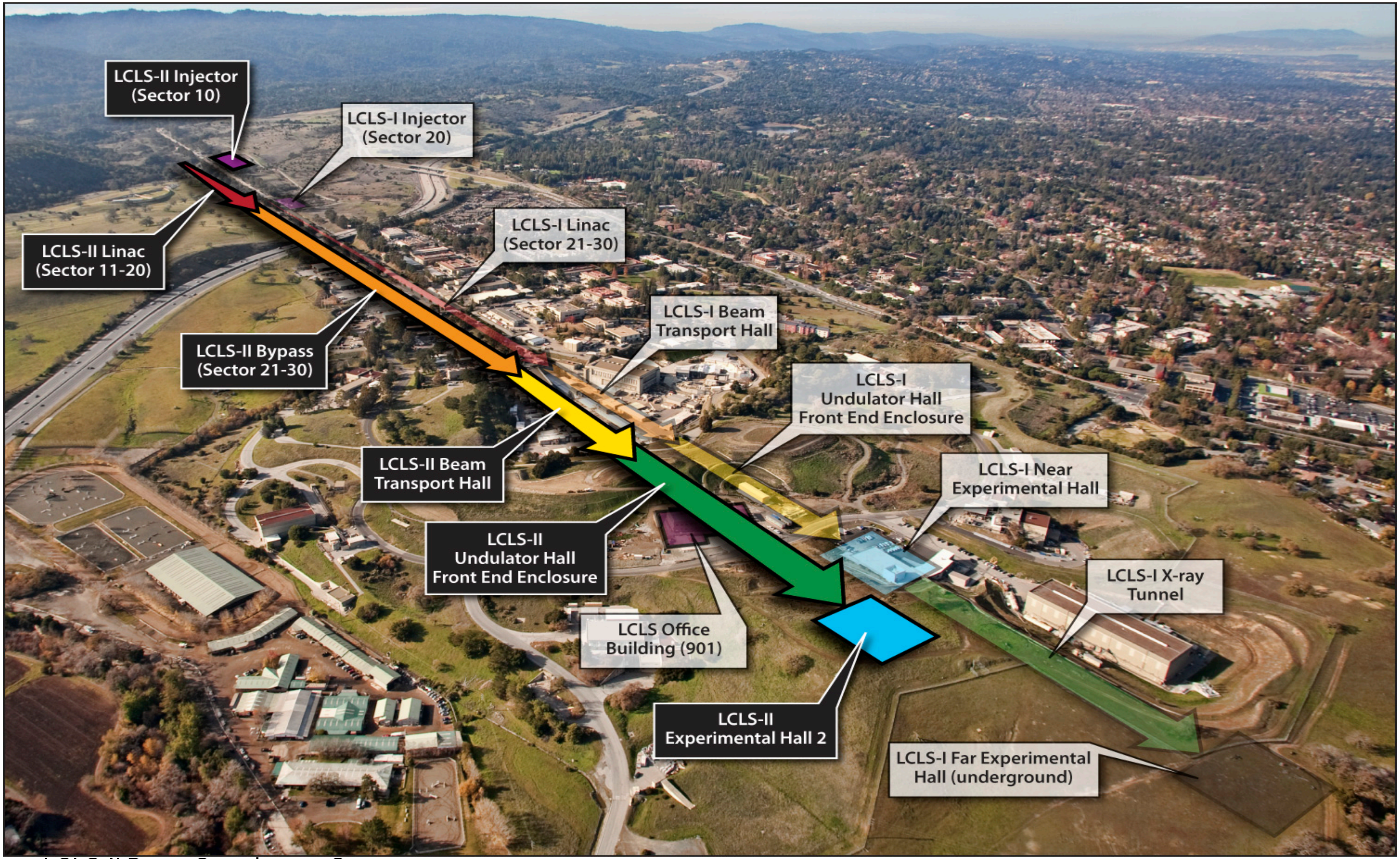
Beam Containment System (BCS) at SLAC

BCS is part of Radiation Safety System

Function: Beam confinement to the designed channel at an approved beam power to prevent unacceptable radiation levels in occupiable areas.

Keep beam operation within the safety envelope.

LCLS-II Installation Overview



Beam Containment System (BCS) at SLAC

- Functions:
  - Limiting beam power
  - Detecting beam loss
  - Preventing beamline device damage

- Typical inputs/outputs:
  - Protection Ion Chamber (PIC), Long Ion Chamber (LION), Toroid
  - Timing watchdog
  - Coolant flow
  - Laser shutter, SBTC

BCS Sensors

PIC

LION

Existing BCS

BCS is in need of modernization. The existing legacy consists of:

- Custom electronics
- Vintage parts that are obsolete
- Hardware past its service life
- Limited diagnostics, lower reliability
- Needs frequent checking/testing

Challenges for New Systems

New BCS will allow for:

- Multiple beam programs: FACET, ESA, LCLS, LCLS-II
- Configuration control
- Complex interlock and bypass logic
- Relief system proof testing efforts
- Additional reliability and availability
- Simplified communication with EPICS

BCS Sub-Systems Requirements

Beam Containment Input	Shutoff Path	Shutoff Latency
PICs / LIONs	Digital Summary	< 300ms
PIC/LION Gas Pressure Interlocks	PLC	< 600ms
Average Current Monitor / Toroid Comparator	PLC	< 600ms
Laser Timing	PLC	< 600ms
Toroid Timing	PLC	< 600ms
Trigger Timing Watchdog	PLC	< 600ms
Magnet Current Interlocks (“Dual Trip Comparator”)	PLC	< 600ms
Cooling Water Flow Interlocks	PLC	< 600ms

Design Guidelines

- Regulations, policies and standards for SLAC
- Radiation Protection: Radiation Safety Systems technical basis document
- IEC 61508, ANSI/ISA 84 functional safety standards
- DOE G420.2-1 “accelerator facility safety implementation guide for DOE O420.2” acknowledges ANSI/ISA 84 (IEC 61511) as a reference standard
- Radiation physicists at SLAC are co-authors of ANSI/ HPS N43.1 “Radiation safety for the design and operation of particle accelerators”

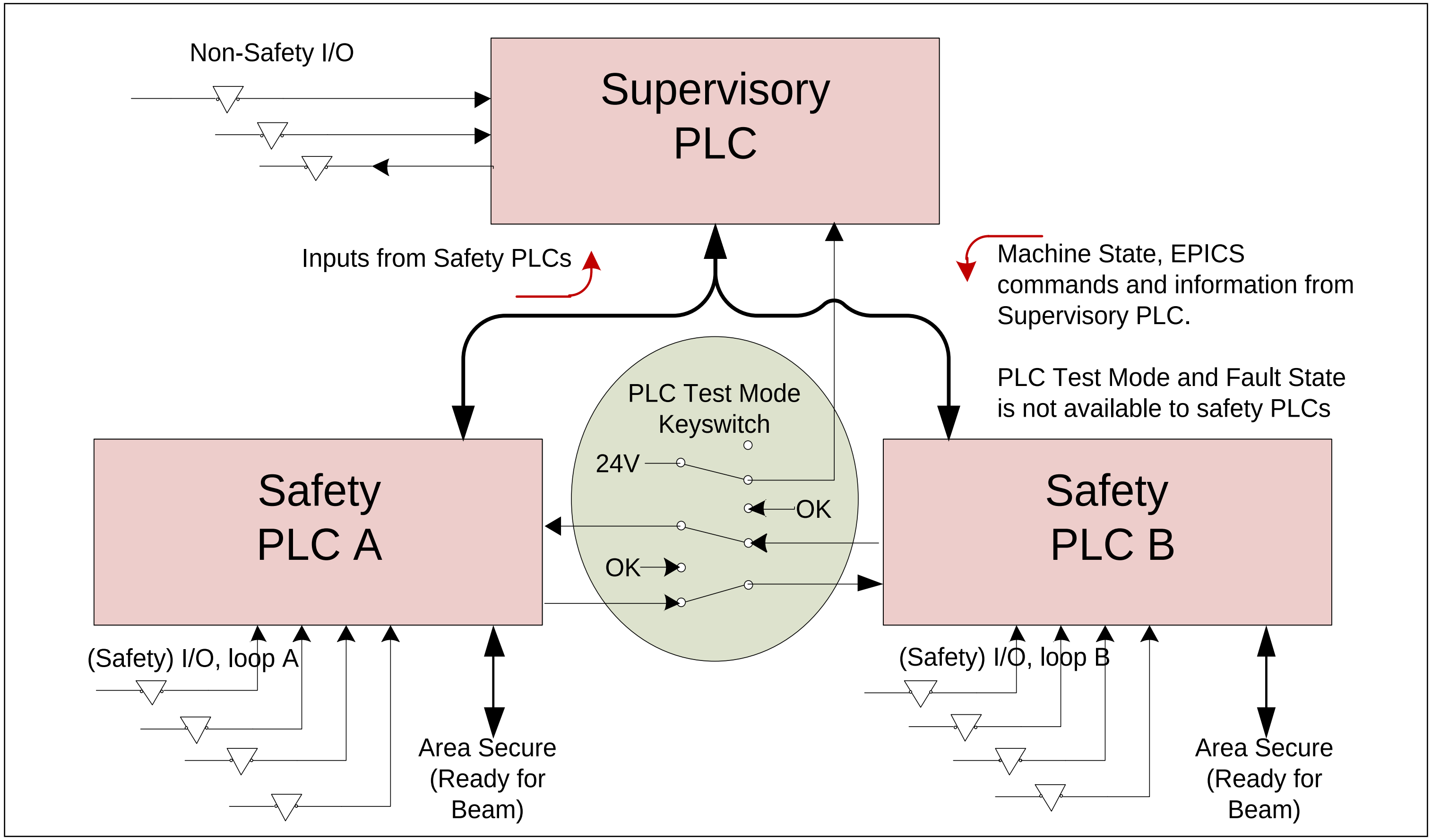
Typical SLAC Safety Systems

Personal Protection System (PPS): 3 PLC architecture

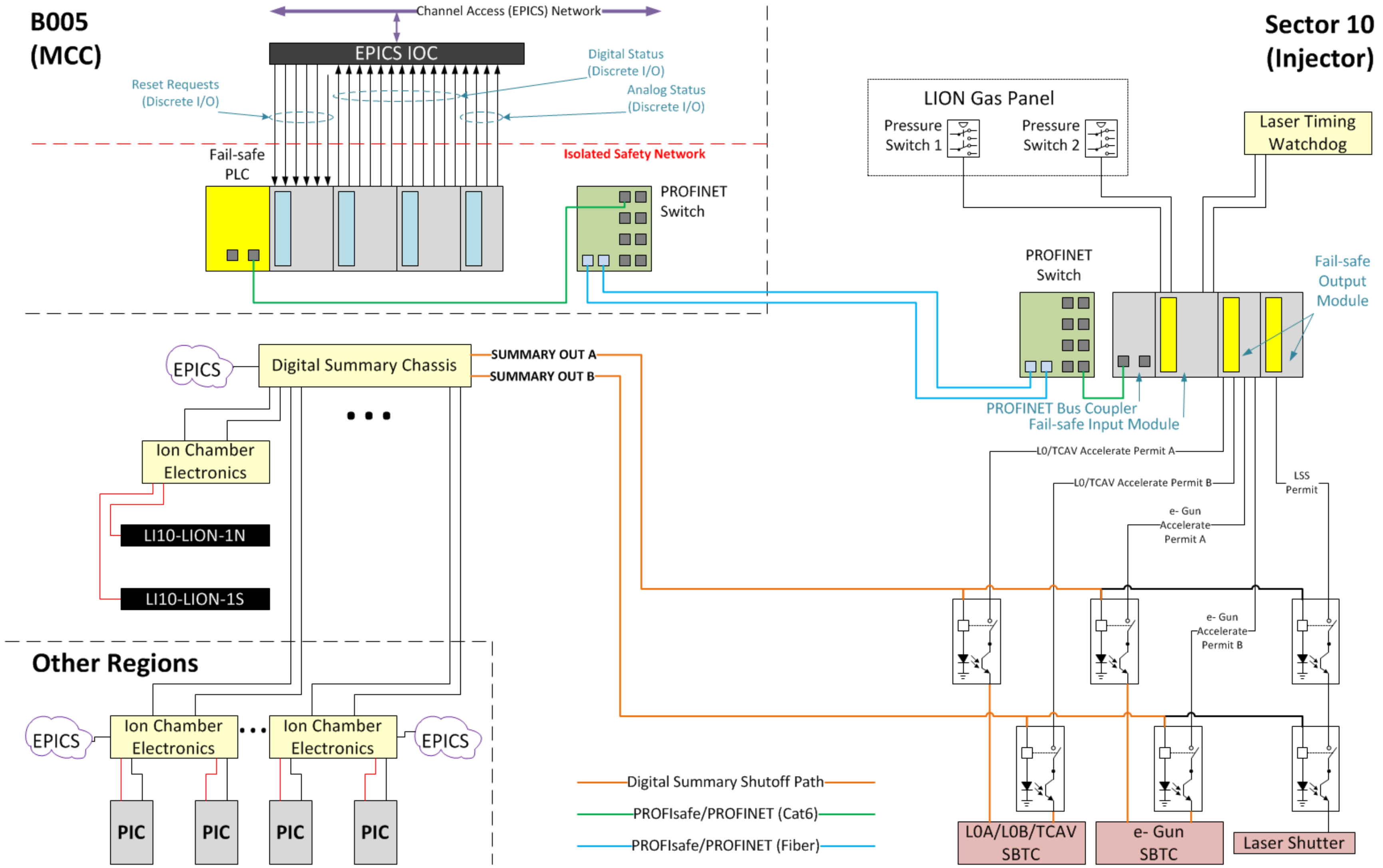
- Supervisory PLC oversees communication and non-safety functions (Access Control)

- Safety Chain A/B PLCs independently handle safety tasks
  - DeviceNet, ProfiBus, ProfiSafe, etc. communication
  - Independent programmers to prevent programming error

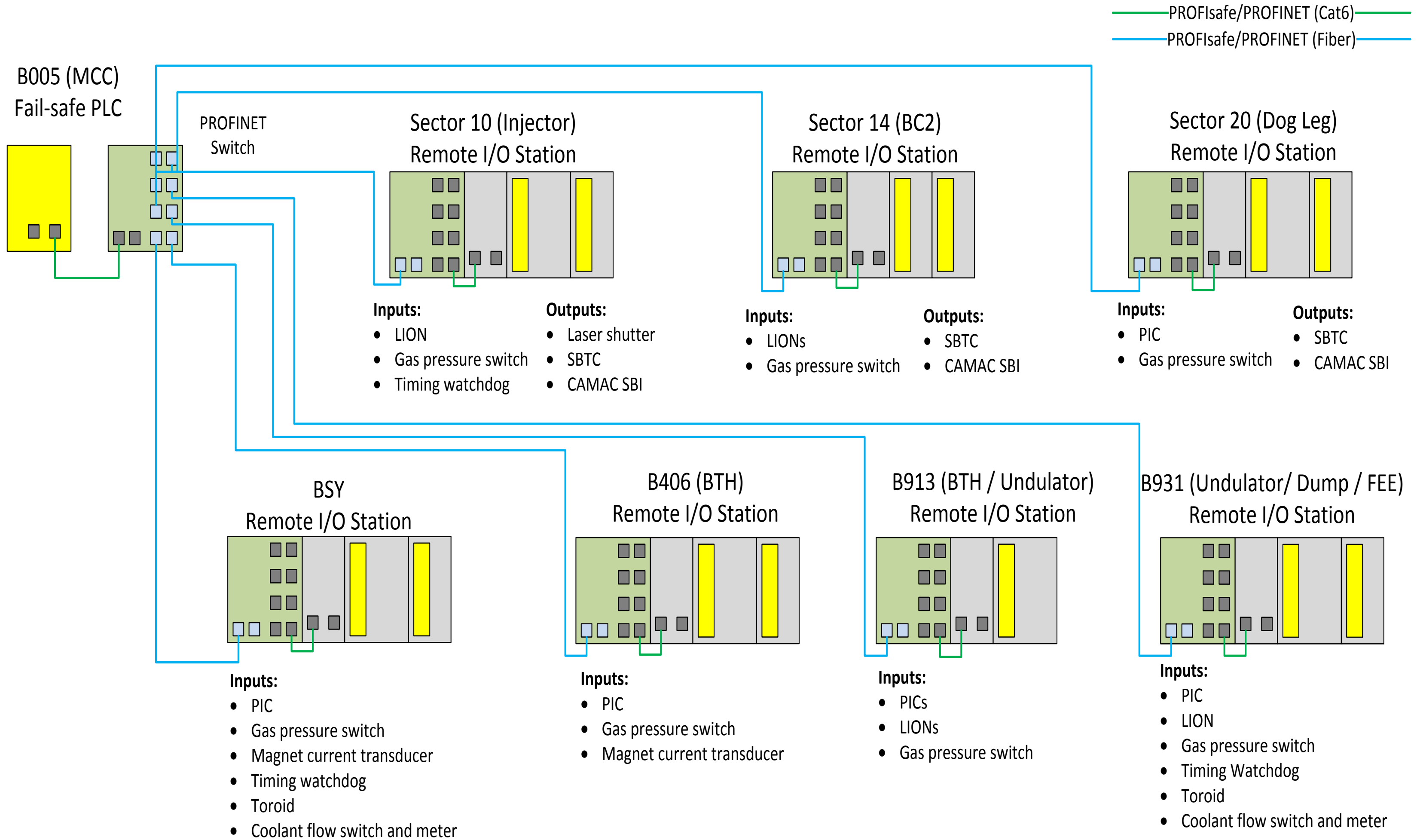
Typical SLAC Safety System



New BCS Architecture



Distributed Architecture



Similarities and Differences wrt to SLAC PPS

SIMILARITIES

- Dual Input (field sensors redundancy);
- Safety System Design;
- Cyber Security;
- Software Configuration Control;
- Project QA;
- Standard & Safety I/O Networking;
- Manufacturer;
- Training.

DIFFERENCES

- One PLC performing safety and non-safety functions;

- One single programmer.

Why a different architecture

Safety systems standards are in transition

- Avoid over-engineering
- Safety system standards are evolving

Machinery Safeguarding

EN954 → ISO 13849 ↘

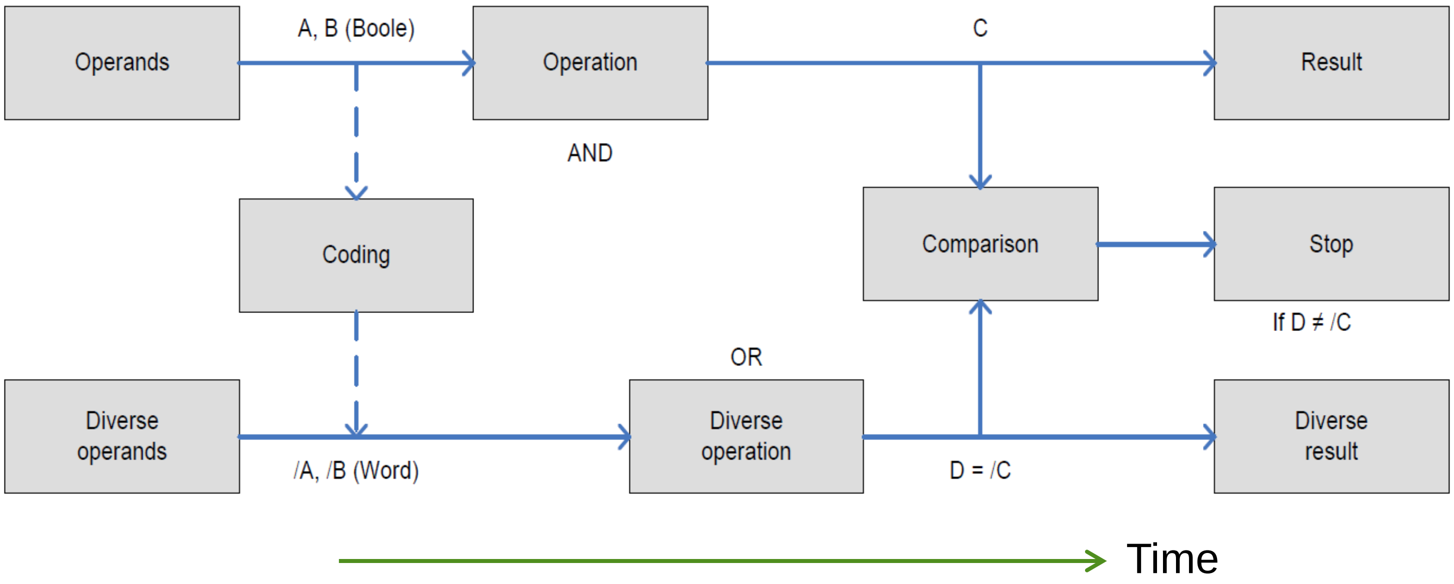
IEC 61508 → IEC 62061 ↗ ISO/IEC 17305

Process Industry: Safety Instrumented System

IEC 61508 → IEC 61511 (ANSI/ISA 84)

Logic Solver Internal Redundancy

Time Redundancy/Diversity instead of Structural redundancy



Single programmer

- Limited variability language programming (IEC 61508)
- Supported by the newer edition of IEC 61511

Benefits

Safety PLCs replace legacy hardware (Shut-off Chassis, Digital Summary Chassis, and VME Crate):

- Employ Commercial Off The Shelf (COTS) PLCs and industrial I/O products for lower system service life costs;
- Expand system level diagnostics to reduce machine down time;
- Scalability for duplication to other facilities;
- Modularity to easily add BCS sensor coverage;
- Streamlined certification;

Conclusion

- New BCS is being designed for LCLS-II
- System's streamlined architecture different from PPS
- Design philosophy: performance based approach
- Build consensus with stakeholders