Controls and Protection Systems

Karen S. White

Controls Group Leader

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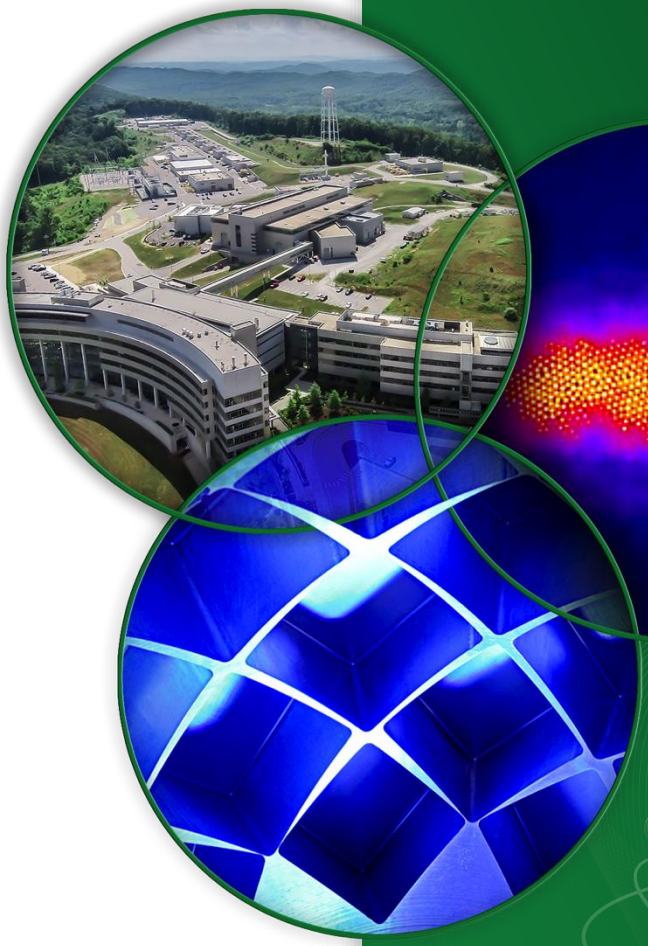


3/25/15

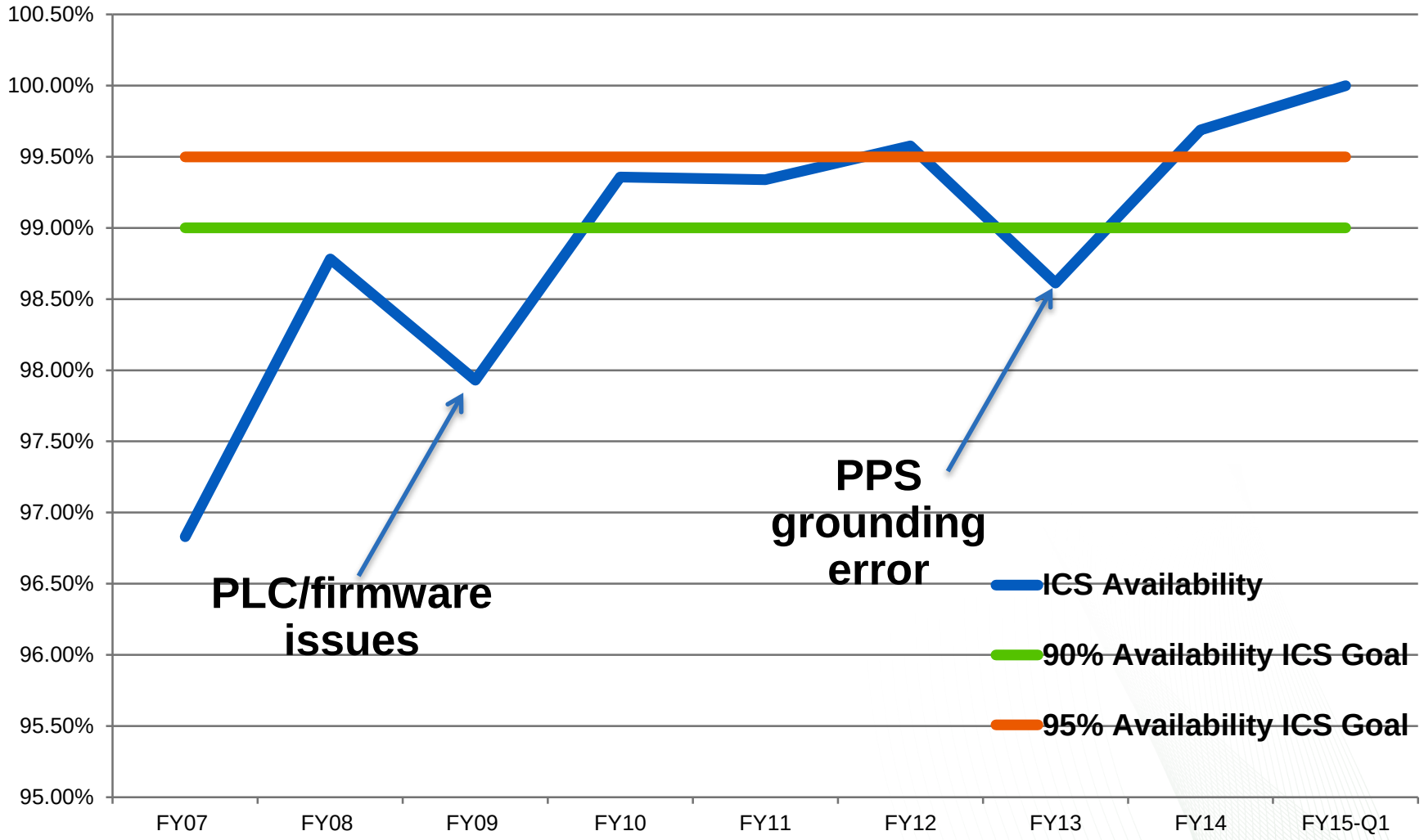
Integrated Control System Overview

- ICS Scope: Controls, Timing and Protection Systems

Accelerator	**Instruments**
Target	**Conventional Facilities**
Cryogenics	**Test Facilities**

- Large, distributed system based on the Experimental Physics and Industrial Control Systems (EPICS) toolkit and Control System Studio (CSS)
- EPICS provides a flexible, layered architecture and integrates a variety of front end platforms
- This scalable, distributed architecture allows:
  - new devices, capability, functionality to be added as needed
- Emphasis on commercial, configurable, collaborative solutions

System Performance - Availability



Sustaining Control System Performance

- Spares
  - Maximize use of standard hardware to minimize the number of different types of spares needed
  - Test new spares upon arrival and “green tag” to ensure operability
- Obsolescence
  - Identify hardware (primarily custom designs) at greatest risk for obsolescence issues
  - Systematically redesign and deploy new modules to stay ahead of obsolescence curve
  - Identify and phase in commercial replacements before spares are depleted

Sustaining Control System Performance

- Infrastructure – new Oracle servers
  - Significant performance improvement
  - Redundant servers in Front End in case of server room issues
- Documentation
  - Major effort underway to update and create drawings
- Staffing
  - Filled key positions (opened by retirement/departures) with high quality, experienced staff

Progress on obsolescence

- Timing System
  - Designed new timing receiver card
    - Replaces utility and trigger modules
    - Deployed for HPRF FY14/15 (15 units)
    - Deploy to LLRF FY15/16 (>100 units)
  - Designed new timing fan-outs
    - Fiber-to-Fiber fan-out 100% deployed FY14 (15 units)
    - Fiber-to-Copper fan-out 62% deployed, complete in FY15 (140/225 units)
  - New timing master running in RFTF, migrates to accelerator summer 2016

Progress on obsolescence

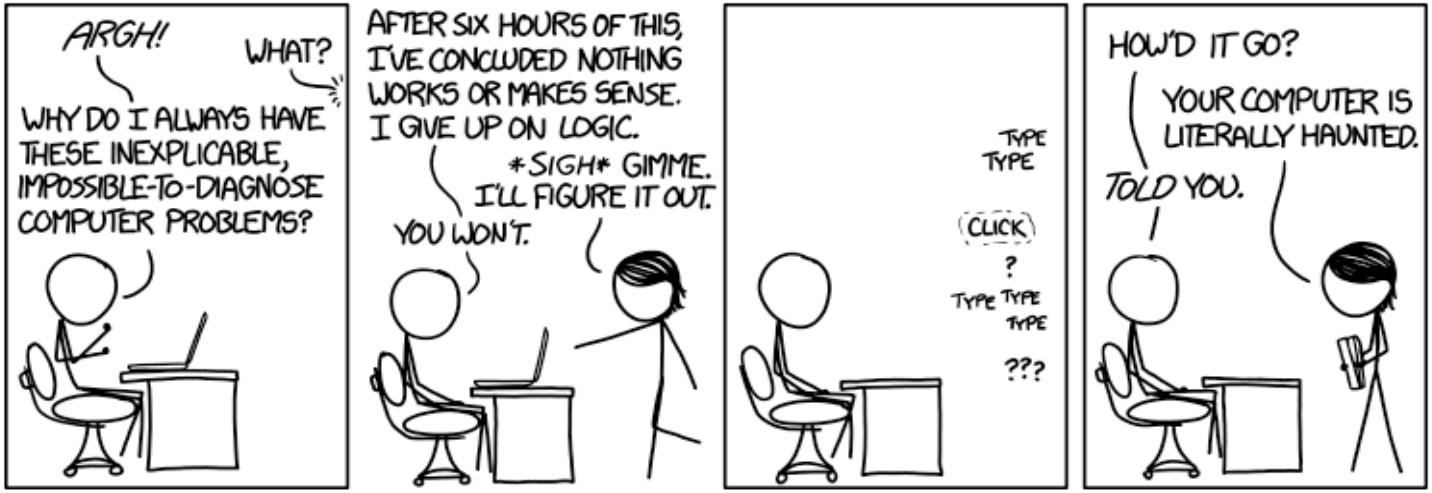
- Machine Protection System
  - Hardware near end-of-life –limited ability to repair existing platforms
  - Complex, high maintenance system
  - Design in progress FY15 (AIP-39 ~$3.3M)
- Front-end Systems
  - Standardized front end test stand and production ion source power supply controls interface, deployed to ITSF (improved reliability and maintainability
- LEBT Chopper Controller
  - Redesigned, deployed FY14

Progress on obsolescence

- Remote Handling
  - Obtained spare computer and other control components for the Remote Handling System
  - Working with Mechanical Systems Group to evaluate long term options for replacement system (future AIP)
- Vacuum – AIP-35 ($4.6M)
  - Replaces obsolete controls components: gauge controllers, ion pump controllers, PLCs
- Power Supply Interface
  - Working with Electrical Group on replacement proposal

Controls System Development

- All teams provided support to build and upgrade controls and protection systems for many customers
- Projects supported
  - Development of new test facilities
  - Improvements to infrastructure, accelerator, target, cryogenics, conventional facilities and instrument



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Controls System Development Accelerator

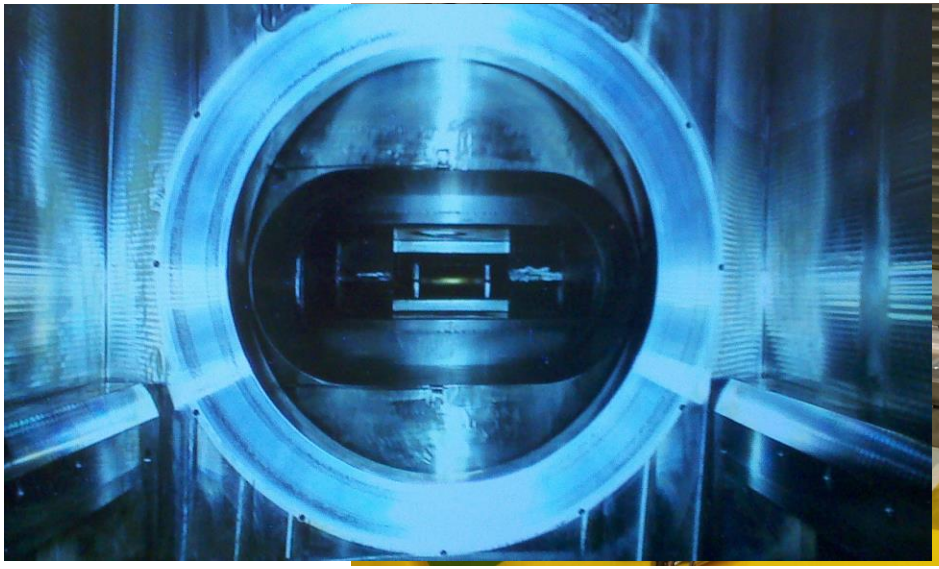
- Improving operability of secondary stripper foil mechanism
- CCR workstations migrated from 6 or 4 monitor configuration improving workstation performance while maintaining screen space

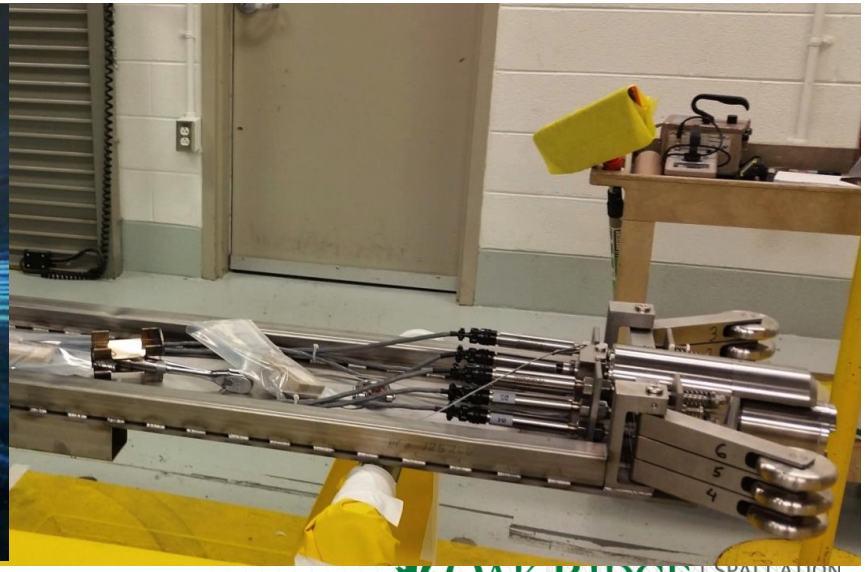
Controls System Development Accelerator

- Upgrading HPRF IOCs due to high load
- DTL and CCL RCCS
  - Flow transmitter upgrades
  - All electronics removed from tunnel
- HVCM Oil Skid Prototype – new controls developed and will be used in final solution

Controls System Development Target

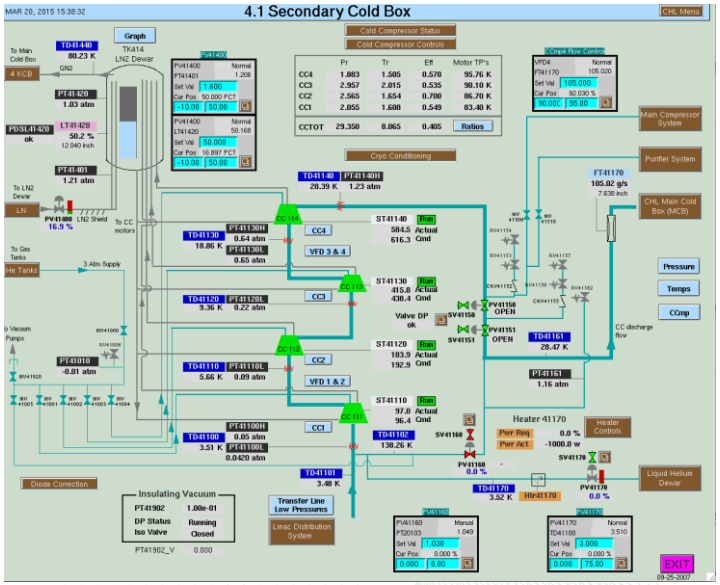
- Designed improvements for mercury leak detection circuit
- Upgraded target shutter drive pump skid controls
- Designed and built measurement/data acquisition system for Inner Reflector Plug Tool





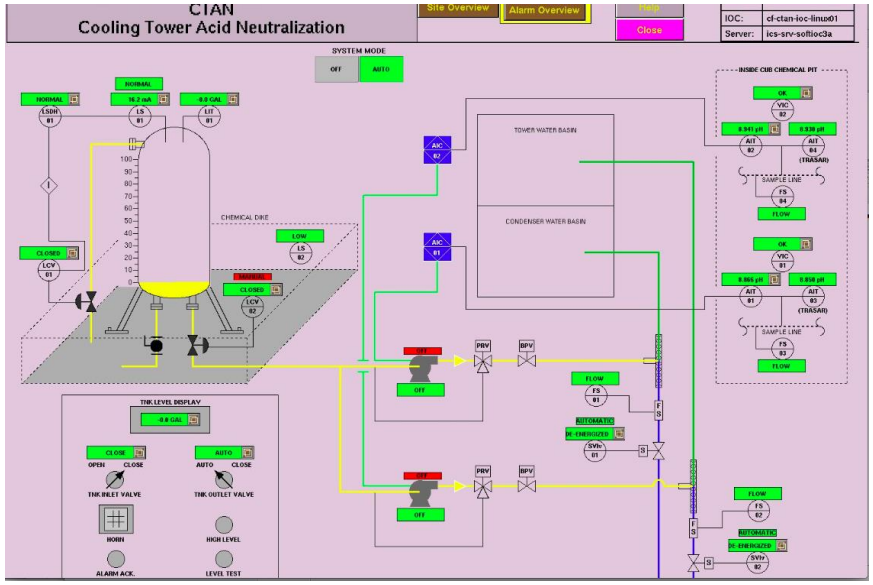
Controls System Development Cryogenics

- Worked closely with Cryogenics Group to improve CHL and SCL controls
  - Tuned control loops to provide more stable primary return pressure from the cryomodules => more stable beam
  - Investigation and correction of problems with 2K cold box variable frequency drive
  - Investigation and correction of problems with 2K cold box magnetic bearing system



Controls System Development
Conventional Facilities

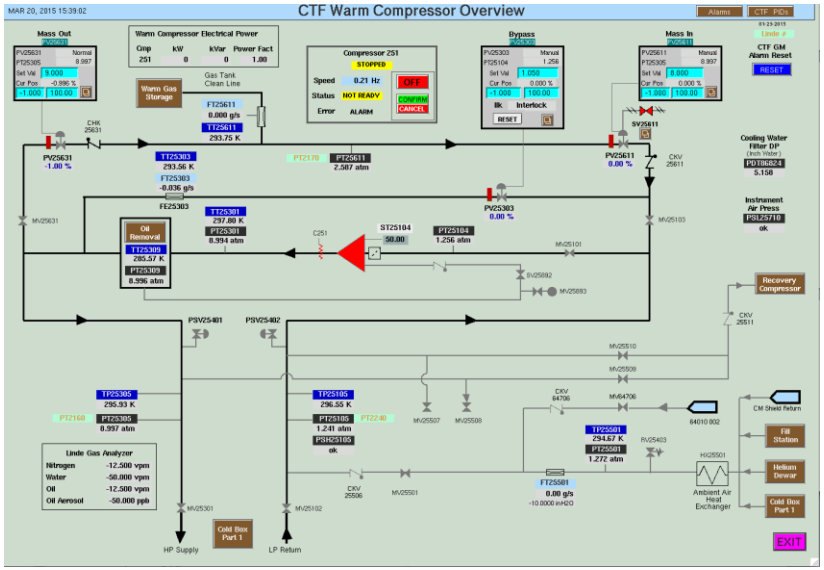
- KL01-KL05 HVAC Upgrade
- Beam Diagnostics Room HVAC Upgrade
- HEBT DI Water Upgrade – integrated new VFDs and additional instrumentation



- Cooling Tower Acid Neutralization System
- Beam Diagnostics Room HVAC upgrade

Controls System Development Test Facilities

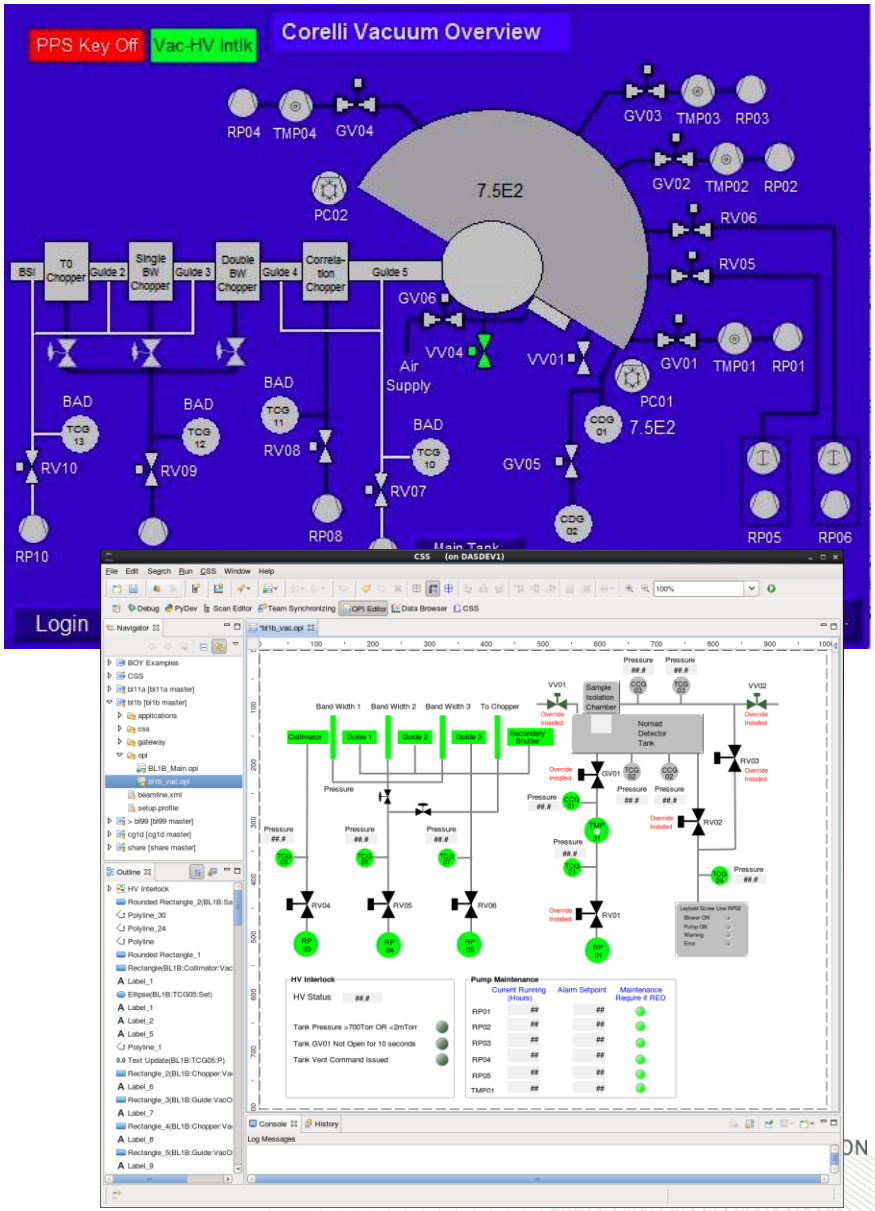
- Spare RFQ – Timing, MPS, PPS, Vacuum, subsystem controls
- Upgraded RFTF cryogenic controls to support horizontal test apparatus, vertical test apparatus and medium beta cryomodule



- Cryogenic Test Facility – developed controls for compressor, cold box, and helium dewar controls

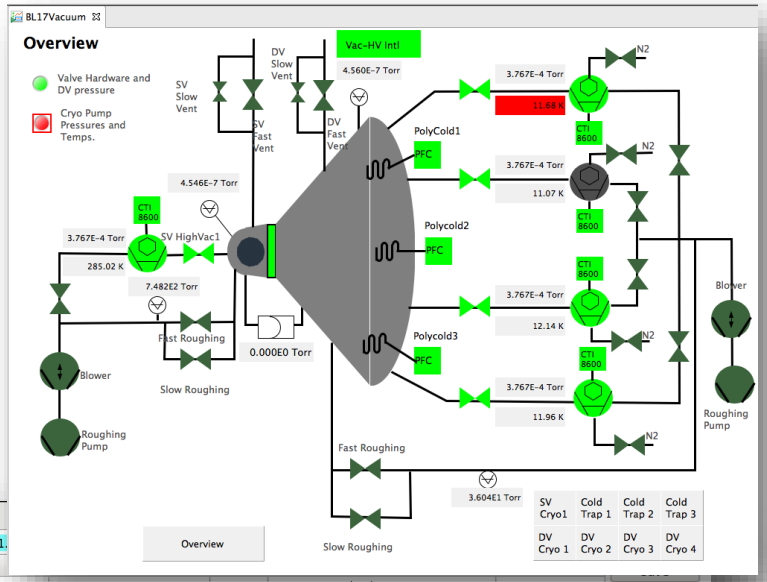
Controls System Development Instruments

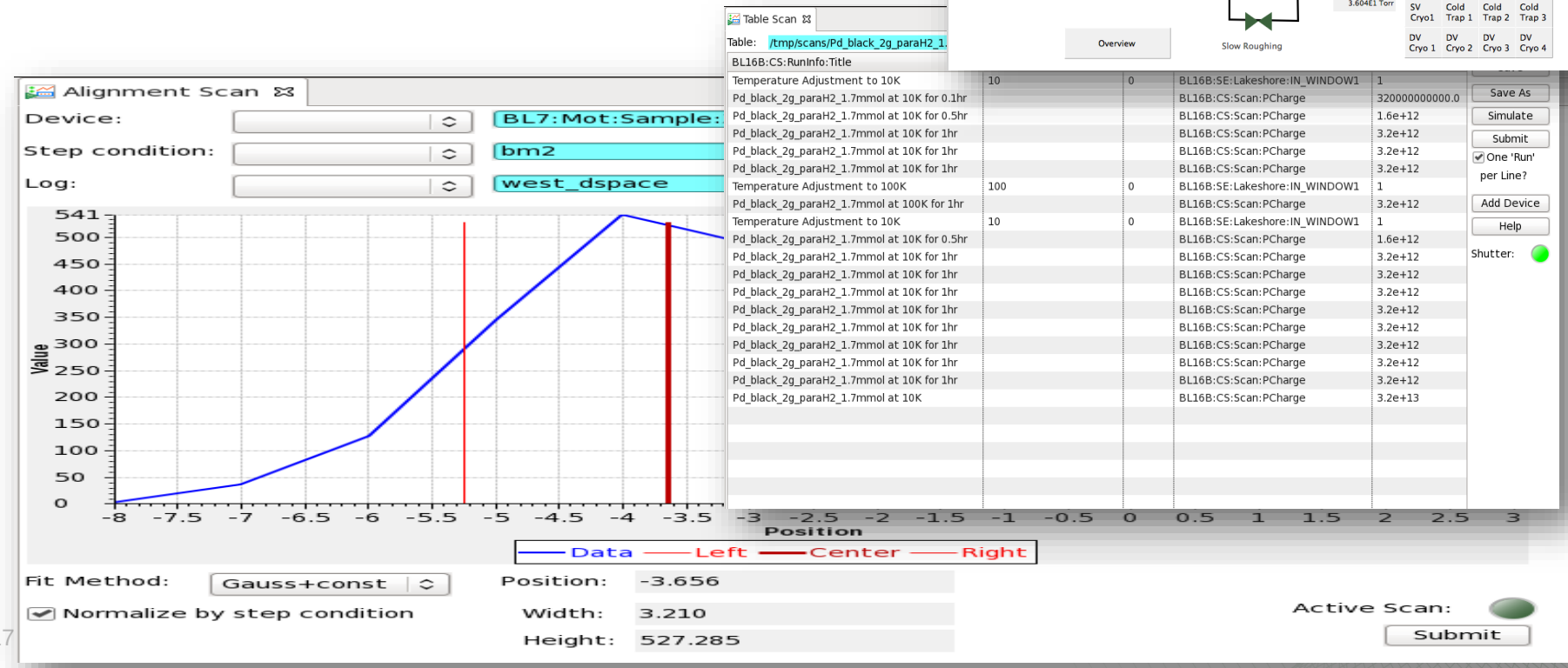
- New construction
  - Corelli (IPPS, Vacuum, HVAC, EPICS controls, system tools)
  - USANS (IPPS, Vacuum, HVAC, EPICS controls, system tools)
- Upgrades
  - BASIS, Sequoia – Vacuum Controls Upgrades
  - Vision, Vulcan – EPICS controls



Controls System Development

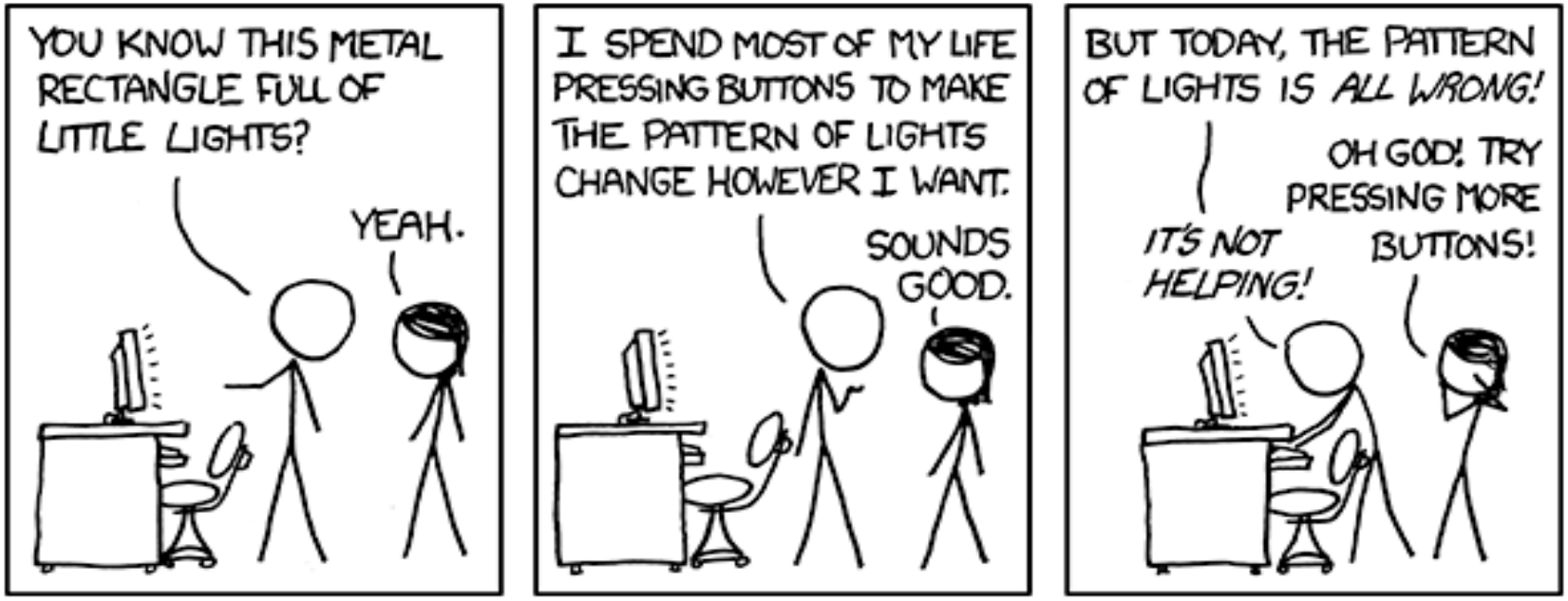
- Tools
  - New CS-Studio tools developed to support instrument and experiment operations





Recommendations from AAC 2013

- There were no recommendations for Controls or Protection Systems from the 2013 AAC



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Controls Strategy for STS

- The ICS can be extended to meet the needs of STS
- Hardware and software will be added for new devices
- Important to stay on track replacing obsolete components to ensure we can duplicate proven systems

Challenges

- MPS “Silent Failure” resolved
  - An IC could fail undetected, letting the MPS grant permission to operate despite active fault condition
  - Caused by a fundamental design flaw in the original hardware which prevented the fault condition from being reported to MPS Master
  - Weekly MPS surveillance was conducted until this problem was fixed by a firmware update
  - Modifications deployed during summer FY14
- PPS grounding error
  - Discovered in the accelerator PPS system in July 2013
  - Kelly Mahoney will discuss response to this problem and long-term plans for Protection Systems, next talk

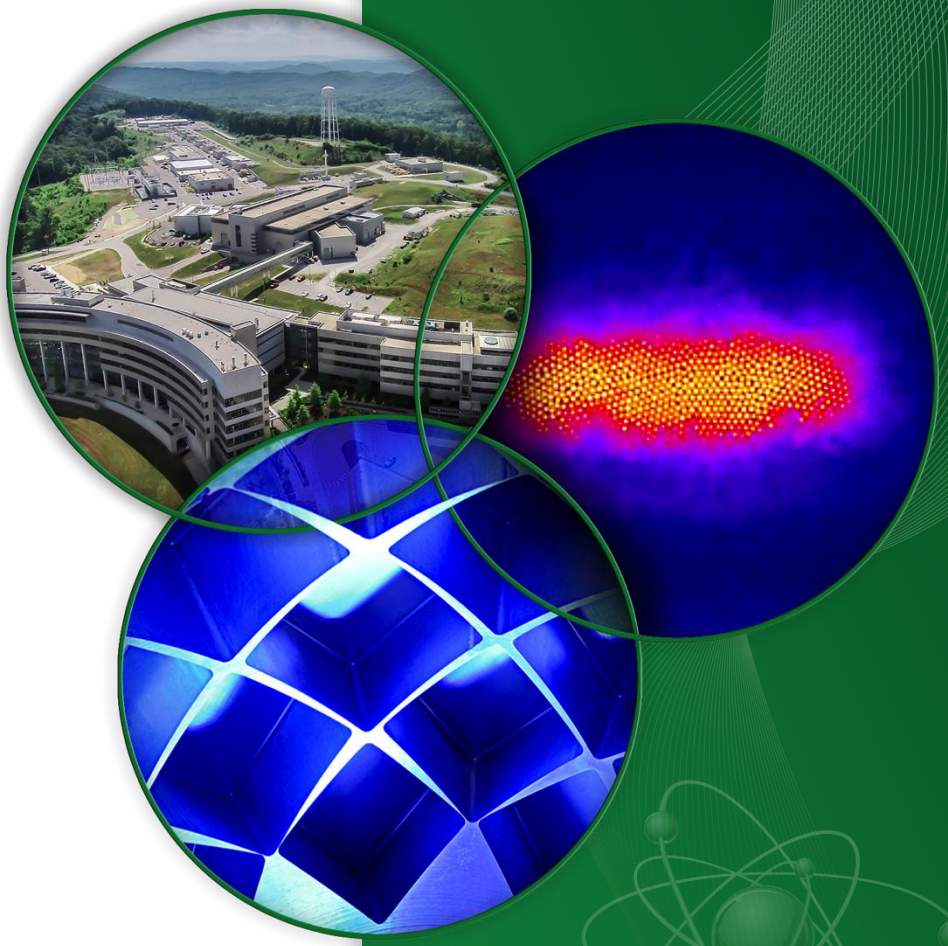
Summary

- Controls and Protection Systems performance is good, meets availability goals
- Supporting many improvement projects
- Important to continue efforts to update obsolete components
- The ICS is extensible for the STS project
- Investments in Protection Systems are necessary to improve processes

Controls – Protection Systems

Kelly Mahoney

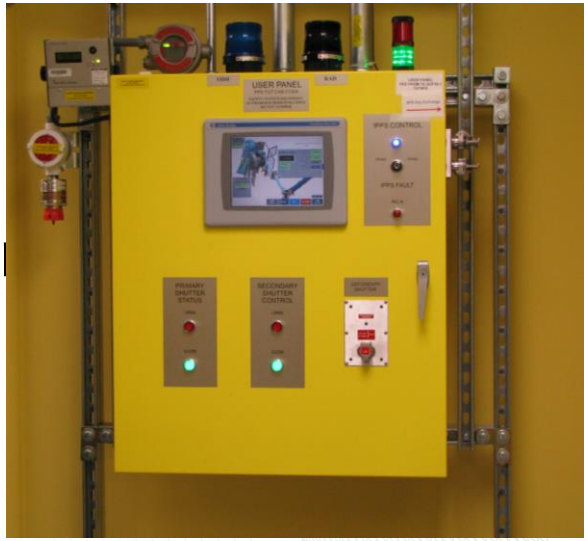
Protection Systems Team Leader



Controls - Protection Systems

Responsibilities

- Accelerator, Target, and Instrument access controls and interlocks – Personnel Protection Systems (PPS)
- Target Protection System (TPS)
- Test facility access controls and interlocks
- Environmental Monitoring Systems
  - Oxygen
  - Prompt Radiation
  - Target Bay Access Differential Pressu
  - Central Stack Flow/Radiation
  - Instrument Toxic/Explosive Gas



Major Protection System Equipment Locations

Protection Systems for Sustainability and SNS Mission Support

- Aligned with SNS goals of high availability at high power, high quality science output
- Updating training and mentorships
- Validating the protection systems' configuration basis
- Revising documentation; addressing obsolescence
- Updating system ownership relationships
- Analyzing failure modes and statistics

Protection Systems for Sustainability and SNS Mission Support

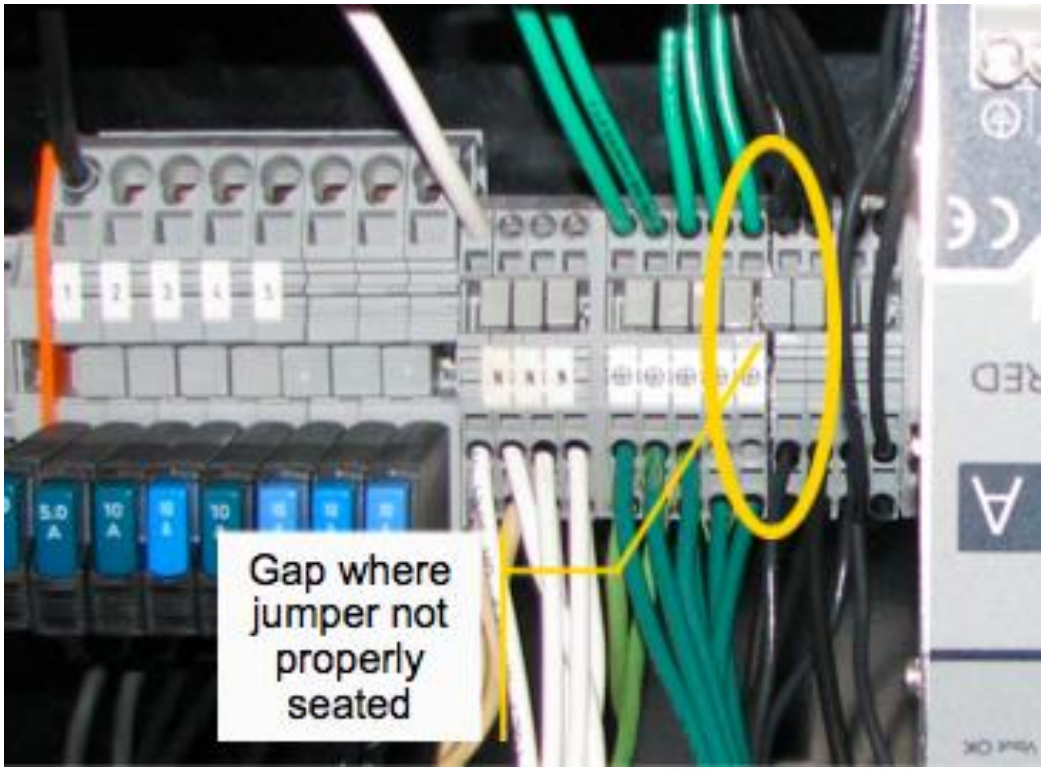
- Simplifying Protection System Infrastructure
  - Consolidate PPS architectures and equipment
  - Improved post-maintenance testing – better result in less time
  - Reducing types of equipment interlocked by PPS; e.g. low voltage magnets
- Updating Protection Systems Business Processes
  - Defined PST Mission, Vision, Goals
  - Updating work processes
  - Revising how data management tools can better support work processes
  - Creating and tracking metrics
  - Using CMMI for benchmark

July 2013 Accelerator PPS Grounding Error

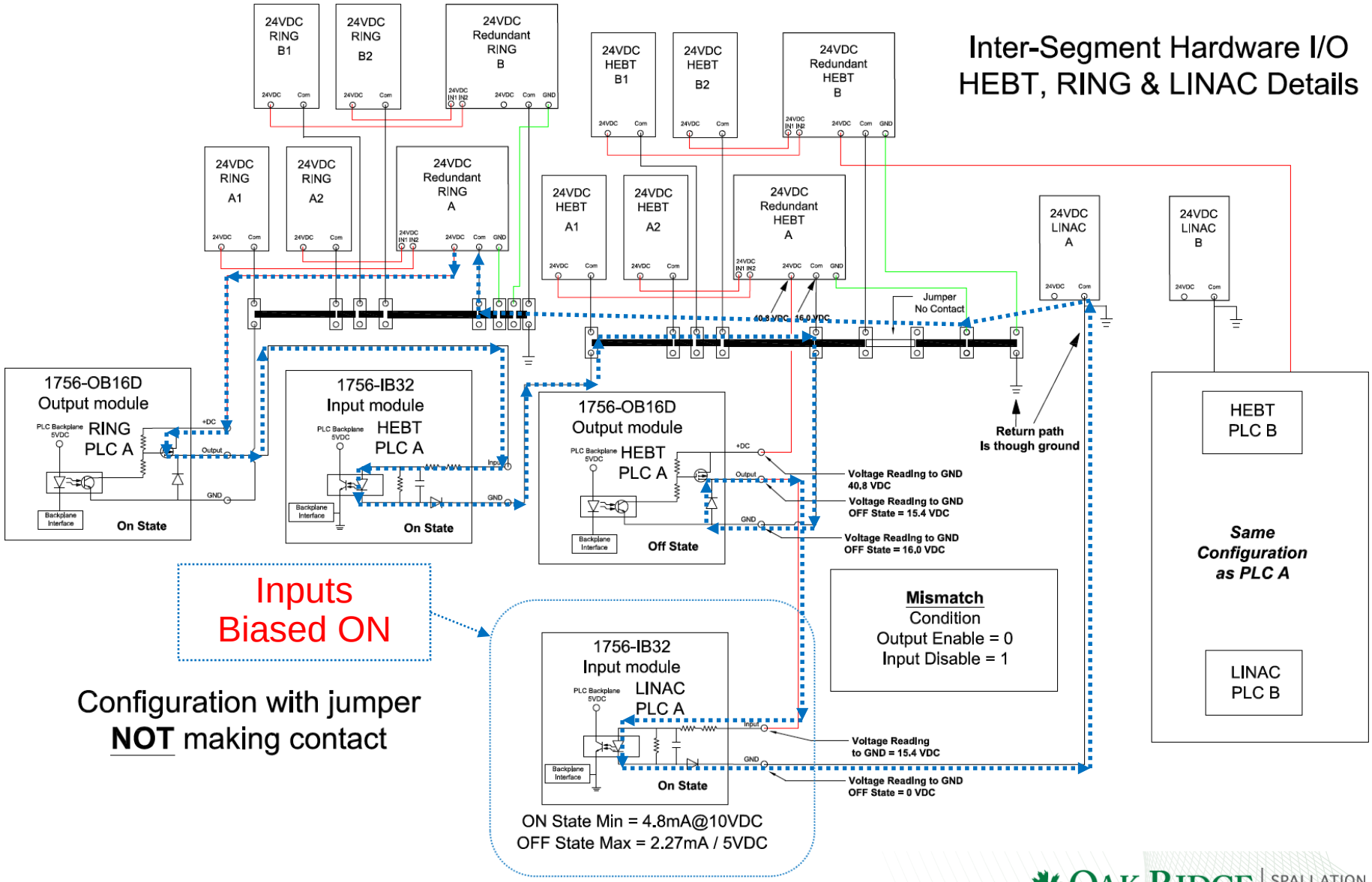
- April 2014 - Modification to add redundant power supplies to increase availability
  - Inter-segment handshaking not tested as part of installation QA or post modification tests
- Error found July 31, 2013 during annual certification testing
  - Under certain conditions, PPS would not have shut off the front end for a downstream fault
  - Common mode error affected both of the redundant chains
  - Unintended result of modification to PPS systems to add redundant power supplies
  - Beam Operations halted until mitigating measures in place
  - Failure mode identified and replicated on bench
    - Very complicated failure mode

July 2013 Accelerator PPS Grounding Error

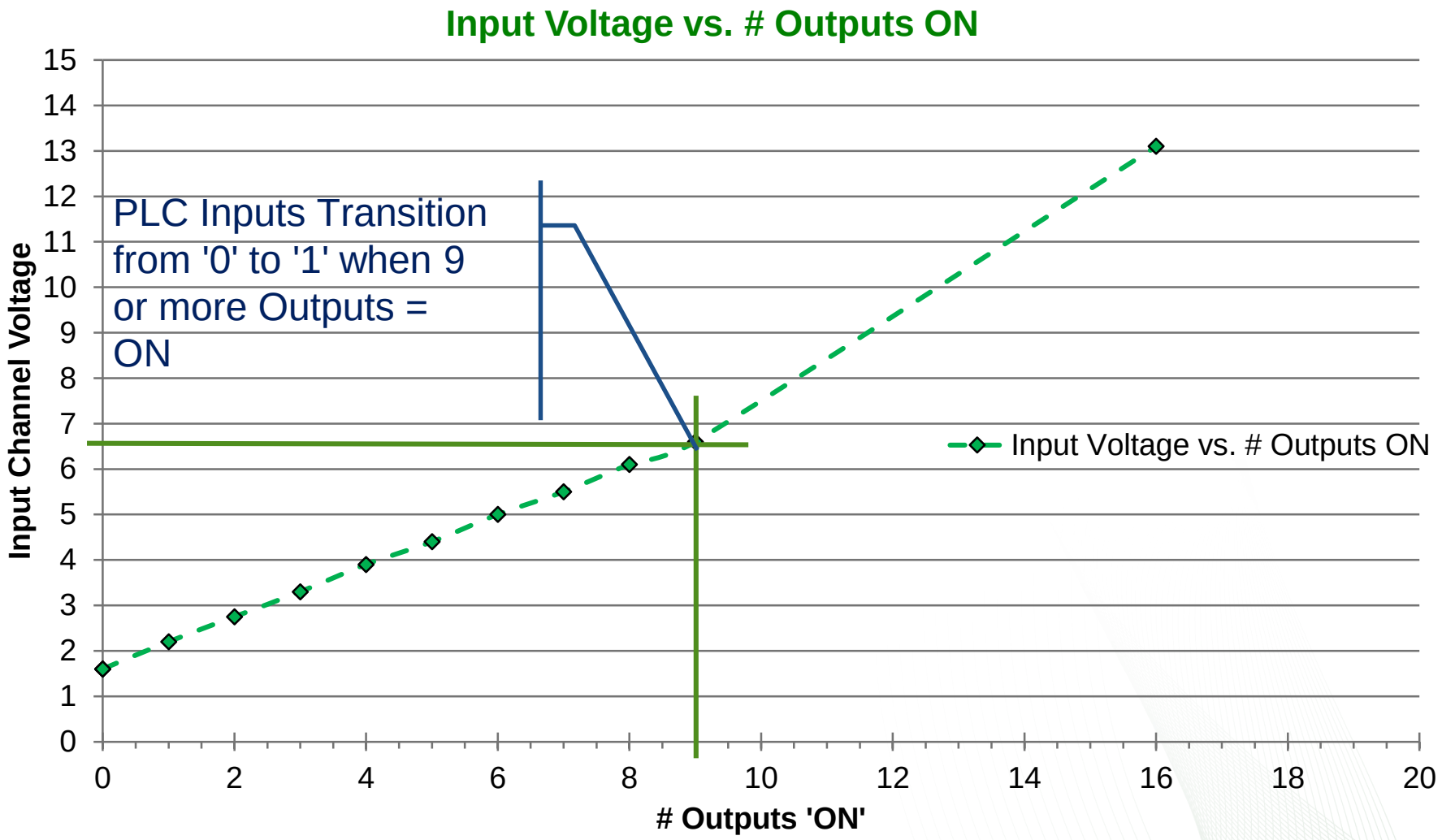
- Power supply modification required a common ground between A and B divisions
- Improperly installed jumper floated Linac PPS ground, creating a sneak circuit
- Sneak circuit defeated segment to segment handshaking if enough PLC outputs were ON



Sneak Circuit Biases Inputs



Sneak Circuit – Outputs Bias Inputs



PPS Grounding Error – Recovery

- August 2013 – January 2014 – Administrative Controls:
  - Weekly testing of segment to segment handshake
  - Extent of condition finds no similar common mode error vulnerability
  - HAZOP identifies areas for improvement
  - Sept. 2014 Independent External Review of Configuration Management of Credited Controls

PPS Grounding Error – Recovery

- January 2014 Engineering Controls Phase I:
  - External design review
  - Added continuous self-test function to inter-segment communication
  - Re-routed grounds to minimize impact of an open ground connection
- July 2015 Engineering Controls Phase II:
  - Reverting back to isolated power/ground for PPS
  - Building duplicate set of control room racks to ensure adequate time for testing
- Forward
  - Implementation of areas for continuous improvement

Summary

- Protection Systems are aligned with sustainable high availability, high power SNS operations
- Improving Protection System work and technical processes
- ORPS corrective actions for PPS error complete
  - Now addressing continuous improvement