LIQUID COOLING FOR THE DATA CENTER
Controls Systems Review

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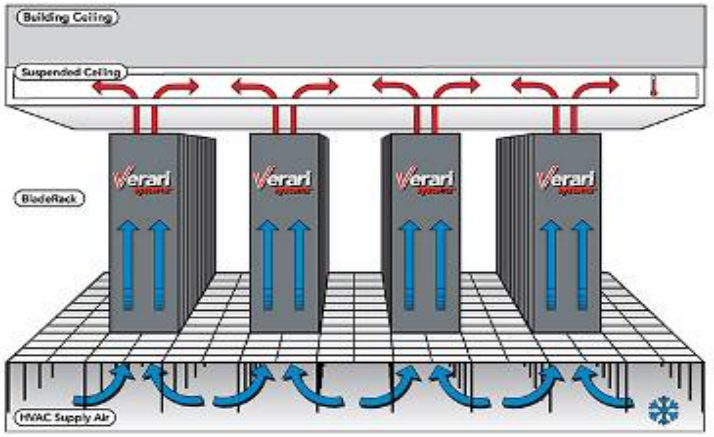
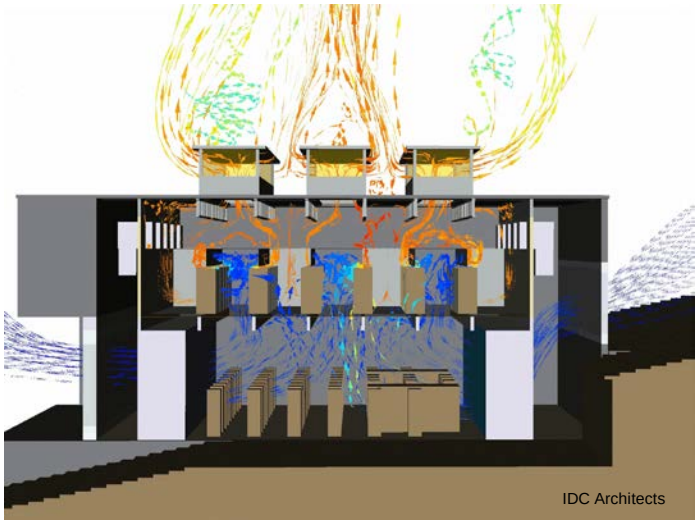
Dual & Redundant Distributed Controls
CCHP, Energy Storage, & HPC Data Center

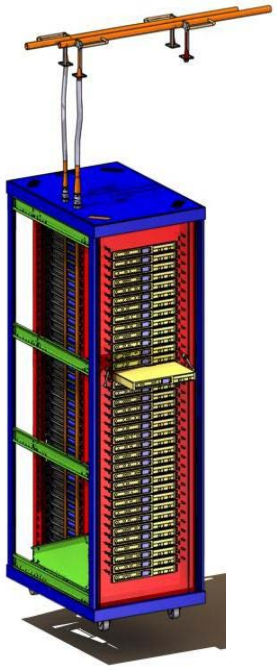
State of the Art Air Cooling Systems to 20 kW per Rack
"Row Level" Cooling
Containment Air Flow Controls & In Row Coolers

- Implement air flow controls
- Contain hot-aisle/ cold-aisle, and rack containment to control supply air temperature
- Elevate supply air temperatures per new high temperature ASHRAE guidelines
- Increase cooling equipment set points
- Free-cool more hours with air & water economizers
- Operate with very few hours of chiller and HVAC, or without chillers altogether
- Direct and indirect evaporative cooling further increase free hours
- IDEC air-to-air heat exchangers for air quality
- Use inexpensive dry coolers for hottest days
- Moving massive volumes of air that require mammoth fans and ductwork and increase the size of modules & facilities

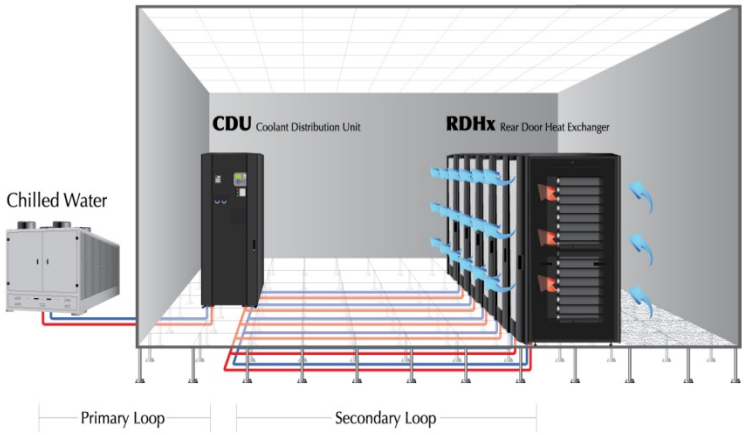




Closely Coupled Cooling for 40kW + per Rack
"Rack Level" Cooling
Rear Door Heat Exchangers



Water Cooled Overhead Supply & Return



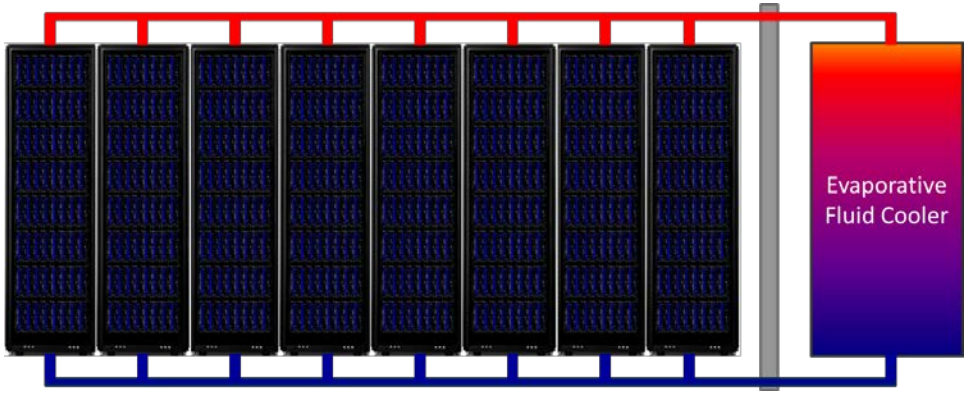
Water Cooled Underfloor Supply & Return

- Rear door cooling rated at 10, 16, 18, 20, 32 & 40 kW
- Adds rack depth and width
- Makes the rack room neutral
- NO fans –server air flow only
- NO electrical connections
- NO aisles required
- Low total fan / pump energy
- High efficiency fans (8-9x efficiency of CW w/EC fan)
- Easy access to rack components
- Piping connections –hard piped, removable, or one-shot

Data Center Air and Liquid Cooling Systems
"Processor Level" Cooling
Liquids to the Processors

Liquid Cooling System with Dialectrics

- *No water in the white space*
- *Pump supplies "cool" dielectric liquid to multiple IT racks*
- *"Hot" fluid is circulated to an evaporative fluid cooler*



Liquid Cooled Solutions

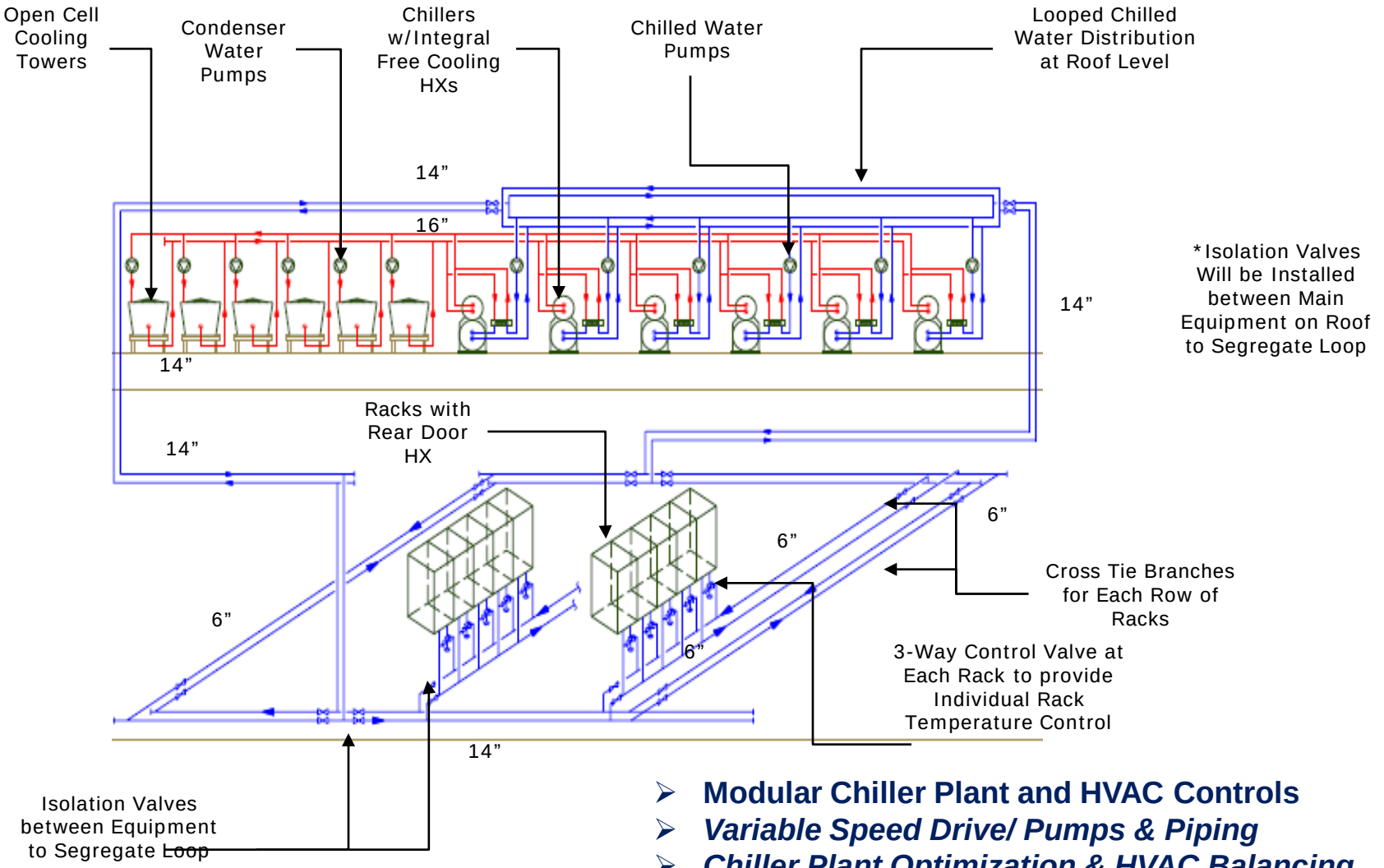
Asetek

- *Full surveillance/alarm systems monitoring temperatures, pressure, flow and leaks.*
- *Variable pump speed controls*
- *Incoming "cool" fluid can be as warm as 113°F (45°C) for some applications, per ASHRAE TC 9.9*

Water to Processors & Air to Others

- *Conduction to convection processor cooling*
- *Flow control valves to avoid leaks*
- *Waste Heat Recycling*

“Modular” Mechanical Plant & HVAC Controls-Enabled Energy Efficiencies



- **Modular Chiller Plant and HVAC Controls**
- ***Variable Speed Drive/ Pumps & Piping***
- ***Chiller Plant Optimization & HVAC Balancing***
- ***Load Variations & Performance Limitations***

No. 1 Threat to Data Center Availability

What is the No. 1 *cause of downtime* in facilities today?

Control Systems*

Potential No.1 threat to data center availability?

* Lawrence Berkeley National Labs identified controls and control systems as the number 1 cause of HVAC systems problems as cited by the National Building Controls Information Program in a study called "Building Energy Use and Control Problems: Defining the Connection" revised May, 2002

HPC Power & Cooling
Critical Availability

Availability – time a system is performing its proper function

Four Tier Classification for DCA

Uptime Institute™

Tier Class	Design Features	Percentage Uptime	Annual Allowable Downtime Hours
I	Single path for power and cooling, no redundancy	99.67%	28.75
II	Single path for power and cooling, with redundancy	99.75%	22
III	Multiple path for power and cooling, only one active path, with redundancy	99.98%	1.5
IV	Multiple path for power and cooling, only one active path, with redundancy, fault tolerant	99.99%	0.75

Dual & Redundant Equipment "and/or" Controls

Data Center Control Systems Summary

Direct Digital Control (DDC)

- Relatively low level of "critical" reliability
- Typical application in commercial and light industrial HVAC and "comfort" applications
- Pros
  - *Low cost*
  - *Established / Familiar*
- Cons – proprietary (protocols, structures are manufacturer-specific), low availability

Programmable Logic Controllers (PLC)

- Higher level of "critical" redundancy
- Typical application in industrial mfg. applications (Industrial HVAC, Chilled Water Plants, CHP)
- Pros
  - Moderate cost
  - Easy configuration, "Open" development
  - Modular scalability & inter-operability;
  - Tier II, III and IV availability
- Cons
  - Require skilled operations/maintenance staff
  - Moderately more expensive

Distributed Control Systems (DCS)

- Most often used in high availability, high level of "critical" reliability
- Typical applications (Power gen plants, highly analog applications, Oil and Gas, Nuclear, Mission Critical Facilities etc)
- Pros – Highly available (system), reliable and robust – extremely fault tolerant, scalability Tier IV availability
- Cons – require skilled/ knowledgeable maintenance staff, Higher capitalization costs,

Key Differences – PLC & DCS vs. DDC

- System Architecture and Existing Software
- Redundancy Features
- Overall System Performance
- IEC 61131.xx Programming Features
- Controllers
- Field Instrumentation
- Final Control Devices
- Maintenance & Services Contracts

Distributed Digital Control

Solution for Commercial Applications

“Commercial Grade” DDC
Direct Digital Control

- *No standard programming interface.*
  - *Programming ranges from high end graphical function block interface to low end text programming in a “Basic” programming language-like format*
- *Less comprehensive math functions*
- *Comparatively slow communications*
  - *less than 100k baud with remote controllers and sub-controllers*
- *Proprietary or non-standard implementations of TCP/IP protocols*
- *Analog modules generally 10 and 12 bit A/D resolution*
- *Component MTBF more frequent than industrial grade system components*
- *Screen refreshes generally longer, can be tens of seconds*
  - *Generally attributed to slower network communications and slower program scan times*
- *Scan time can be 3 to 30 seconds or longer as opposed to “milliseconds” for a PLC in a similar application*

Reasons for Widespread Installation Base of DDC

- **Most Legacy Data Centers use a DDC system typical of Building Automation Systems**
  - *Commercial AE's who design data centers are not aware of the differences, so they specify what they know*
  - *Data center stakeholders want to keep the CapEx costs as low as possible with little regard for the computing process*
  - *This is in contrast to other mission critical process facilities such as pharmaceutical, bio research labs and semiconductor facilities*
- **PLC and DCS systems generally cost more than DDC or BAS systems**
  - *Cost differences typically range from*
    - *1.25 – 1.5 to 1 for PLC's*
    - *Up to 2 to 1 DCS's*
  - *Integrator plays a key role*

Programmable Logic Controller

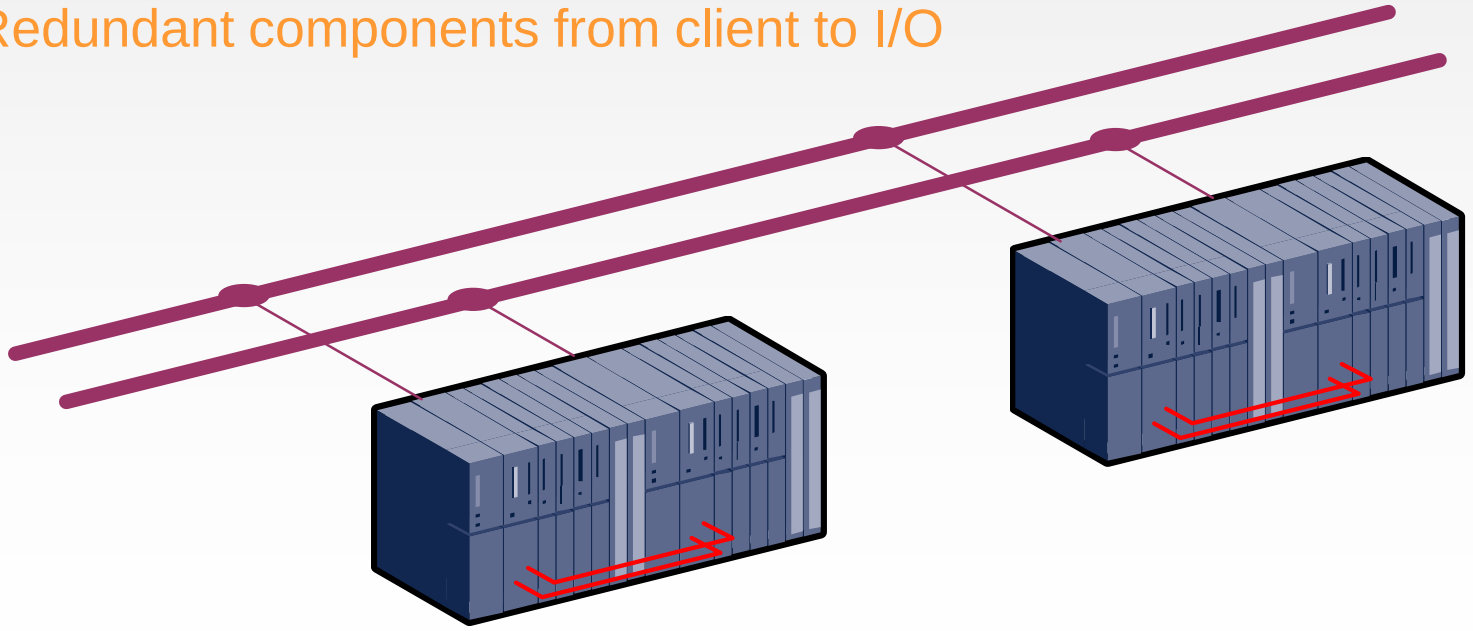
PLC – Fault Tolerant & Scalable

“Industrial Grade” & Fault Tolerant PLC Programmable Logic Control

- **Avoidance of control system single point of failures**
  - *This is attained primarily through a redundant configurations of networks and control hardware*
- **Fault-tolerance is required in the following functions:**
  - *CHWST Control*
  - *CHWF Control*
  - *White Space Dry Bulb Temperature Control*
  - *White Space Dew-point Control*
  - *NO SINGLE POINT OF FAILURE*

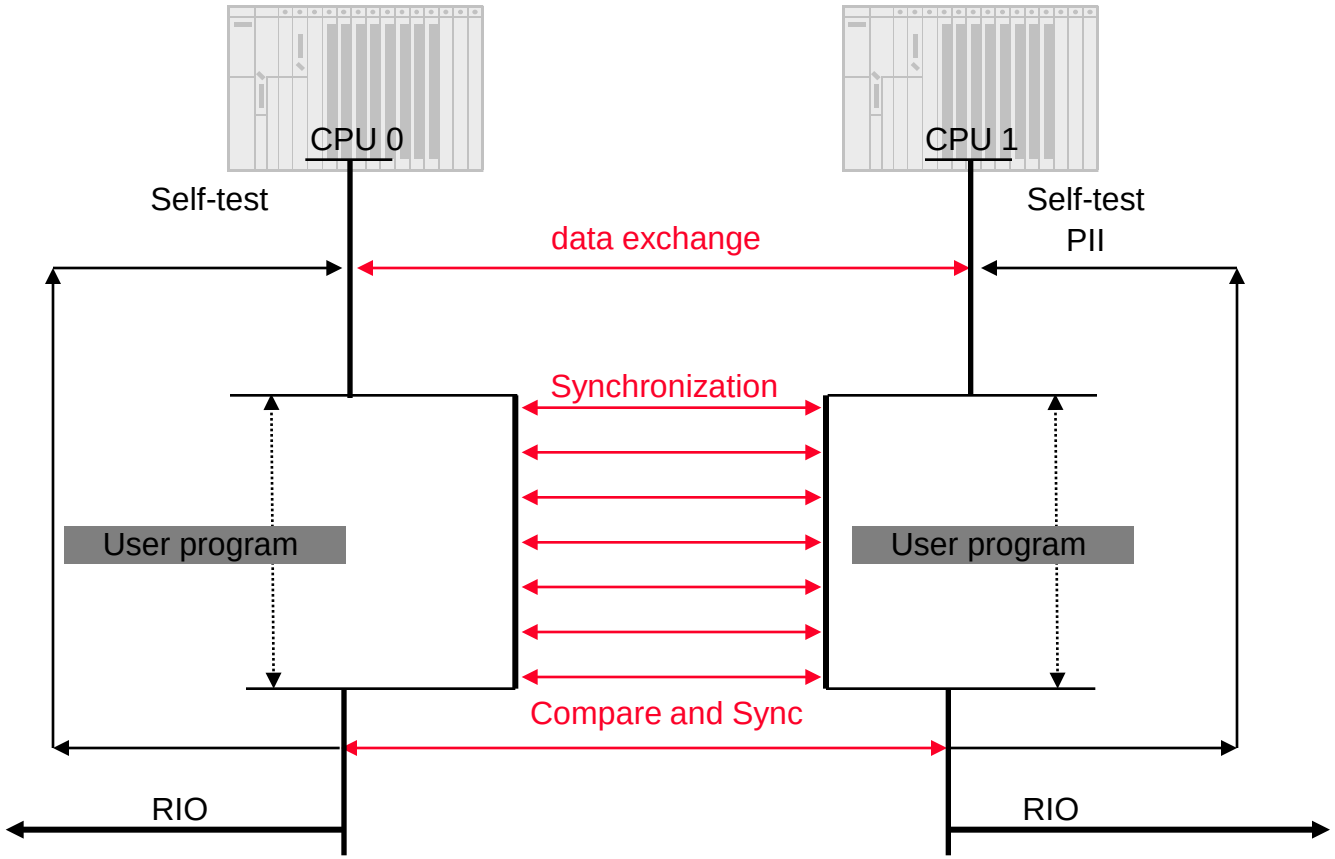
Redundant Communication Principle

- Redundant communication is attained through redundant connections, which are then used when a problem occurs.
- Redundant connections can be created from redundant CPU's to
  - *Other CPU's (one- or two-channel)*
  - *HMI Servers*
- Redundant components from client to I/O

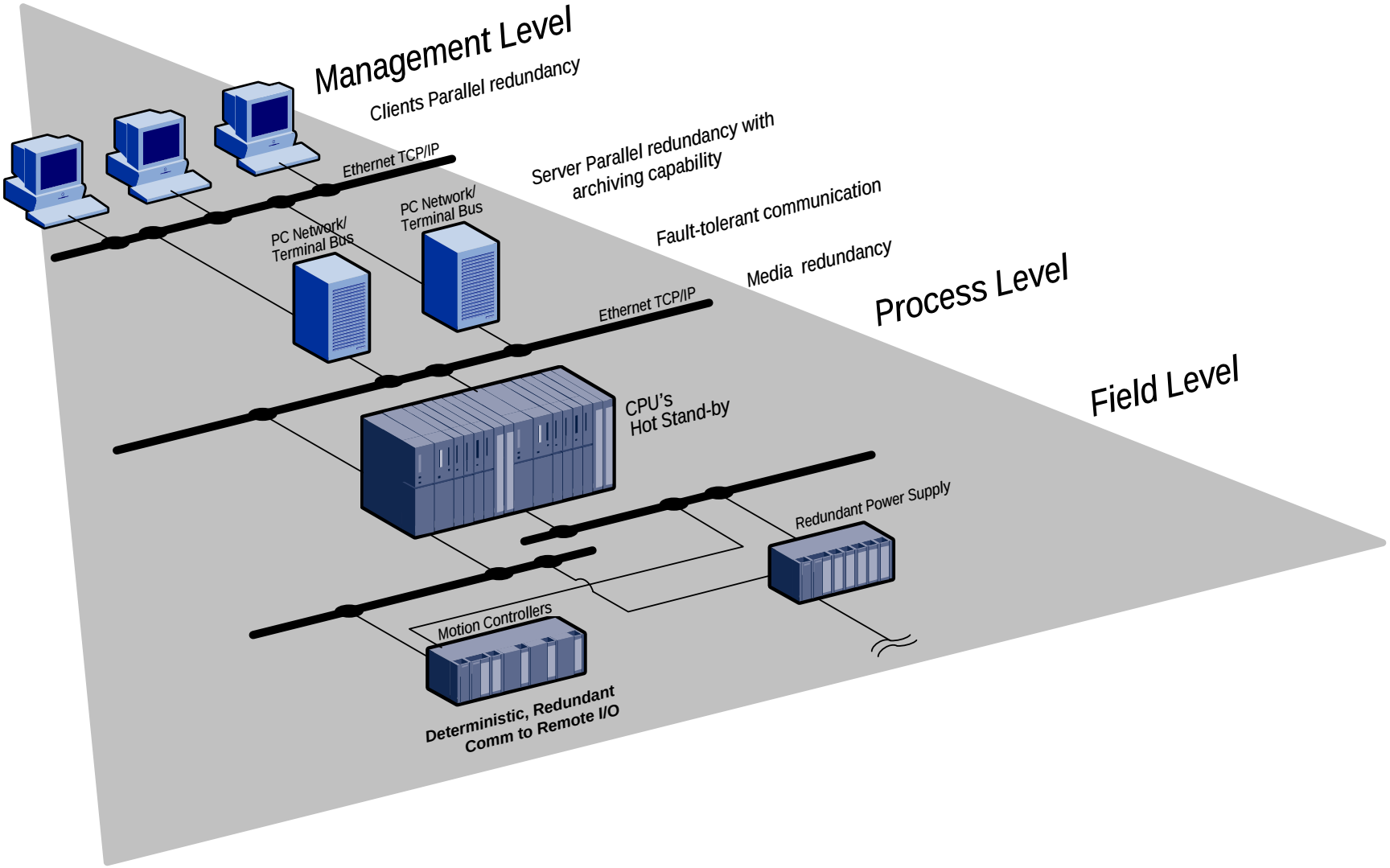


Automatic Event Synchronization

- Each CPU Executes the Program Simultaneously…
- Instantaneous fail over to redundant device



Typical PLC System Architecture



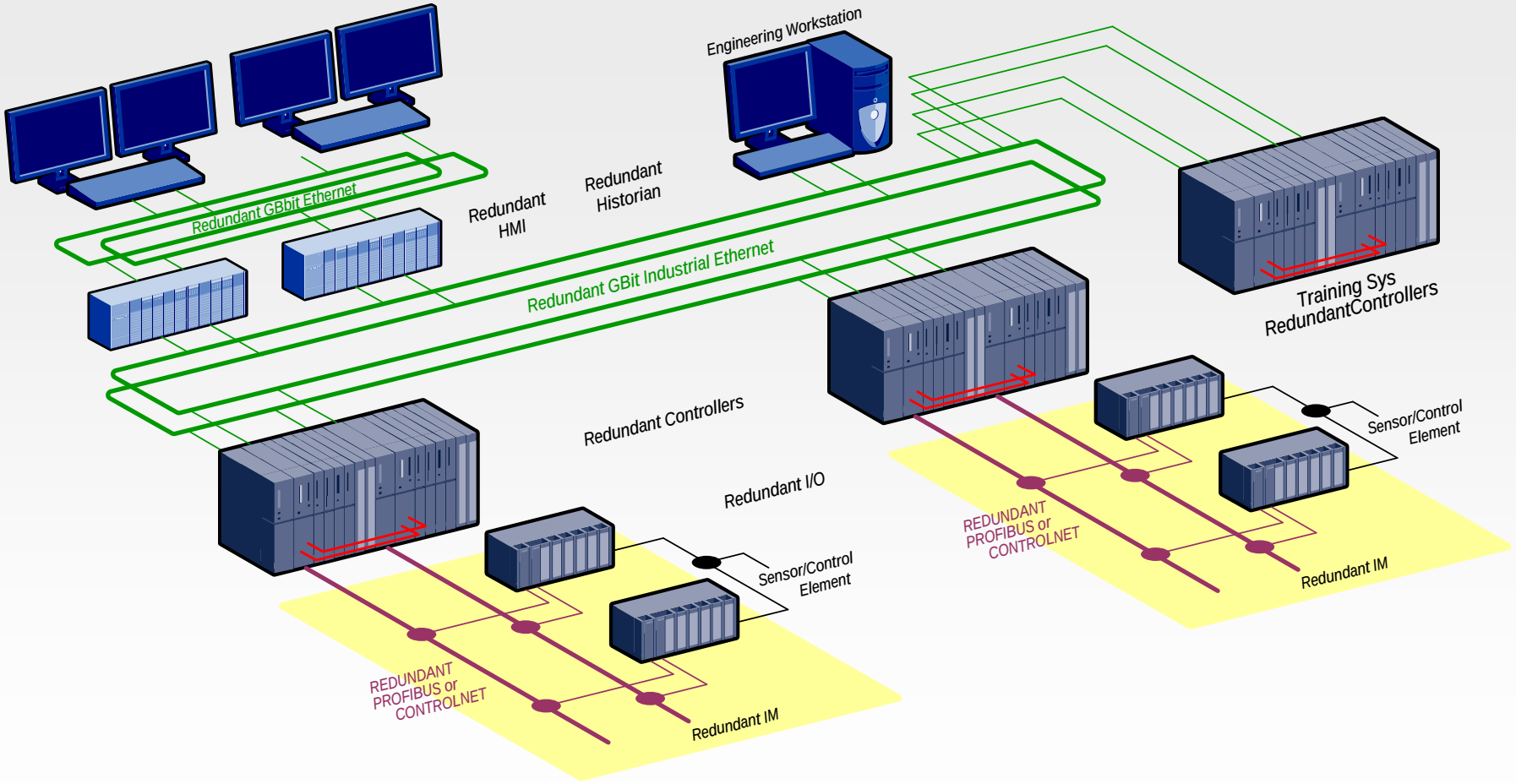
Distributed Control System, DCS

DCS – Mission Critical & Fault-Tolerant

“Process Grade” DCS
Distributed Control System

- **Most often used in high availability, high level of “critical” reliability applications for precise process control**
- **Software and Hardware engineered together providing highly integrated platform solutions; system enhancements can take up to a year in pre-release & QC testing**
- **Typical applications**
  - *Power Generation*
  - *Oil and Gas*
  - *Nuclear*
  - *Life Safety*
- **Pros –**
  - *Highly available & stable implementations, reliable and robust*
  - *Extremely fault tolerant*
  - *Scalable*
- **Cons –**
  - *Capital costs*
  - *Company staff skills sets*
  - *Complex configuration*

Typical DCS - Control System Architecture



Summary

So what's the Big Deal?

- PLC and DCS-based systems and architectures were designed specifically for high-reliability, robust, industrial applications
- Technology has been proven over the course of 30 years in the most demanding environments in industry
- Within a single technology platform, able to scale from DCS to redundant PLC to simplex PLC – offers owners significant flexibility
- Little to no difference in system interfaces (HMI's) in form, fit, look, and feel
- Improved scalability and integration capabilities to incorporate additional functionality
- Non-proprietary protocols and development environments
- Reduced total cost of ownership
- Access to all global PLC and DCS products and resources
- Personnel and company management & control of the change management process
- Company controls personnel capable of programming, services & maintenance support
- Mission critical functionality

Qs & As

Thank you SC'14 and EEHPCWG

EEHPCWG Controls Standards Committee

weekly telephone conferences

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