Enduring High Performance Computing (HPC) Facility Master Planning

Salishan Conference on High Speed Computing

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Enduring HPC Facility Mater Planning Beyond Energy Efficiency

HPC Sustainability Master Plan

- Benchmarking
- Computation Fluid Dynamics (CFD)
- LEED Certifications
- Leverage Existing HPC Capabilities
- Free Cooling
- Liquid Cooling Advances
- Innovative Electrical Distribution
- Facility Power Management
- HPC Facility Gap Analysis
- Sustainable HPC Modular Solutions

- HPC Sustainability Master Plan developed in 2008 to increase energy efficiency
  - Core competencies developed to improve operational efficiencies to achieve extreme scale computing
- Core competencies to date have reduced energy intensity
  - >53Mkwh and $3.5M saved annually
- HPC operational improvement achievements based to date
  - DOE FEMP 2009 Energy Award
  - B453 LEED Gold Certified 2009
  - B451 LEED Silver Certified 2011
  - Patented Sustainable Solutions 2012

Enduring HPC Facility Master Planning
Beyond Energy Efficiency: Current and Future Directions

- Recent Implementations Require More Innovation
  - Liquid Cooling Advances
  - Innovative Electrical Distribution

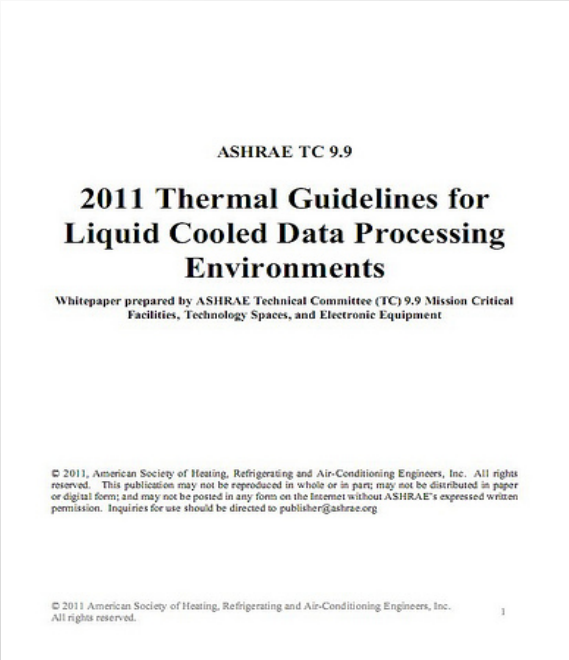
- Future Direction
  - HPC Facility Gap Analysis
  - Site-wide consolidations
  - Sustainable HPC Modular Solutions
  - Power Monitoring: System – Facility - Utility

Liquid Cooling Advances: Currently Installed with Sequoia

- 91% liquid cooled, and 9% air cooled
  - Liquid cooling inlet requirements
    - 64 F to 74F
    - New tertiary loop required
      - GPM/rack = 25 to 35 gpm
      - Stainless steel or copper specified
        - Polypropylene piping selected
        - **Total project savings: $2M**
        - Maintain B453 LEED Gold status
        - Provides efficient flow
        - Reduced heat gain and loss
        - Minimized environmental impacts
          - Ensure ISO 14001 compliance

Liquid Cooling Advances: Path Forward

- Expand the liquid cooling temperatures
  - Omit dedicated loops
  - Broaden temperature range
  - Avoid using chillers
  - Use condenser water from cooling towers
  - Vendor solutions should minimize impact on facility



ASHRAE TC 9.9

2011 Thermal Guidelines for Liquid Cooled Data Processing Environments

Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, Technology Spaces, and Electronic Equipment

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- ASHRAE TC 9.9 – 2011
  - Expands temperature ranges
  - LLNL, with other national laboratories and industrial partners, participated in the white paper

Innovative Electrical Distribution

- Sequoia electrical
  - 100 kW/rack = 9.6MW
  - (4) 480V, 3 Phase, 60A line cords/rack
    - Innovative distribution required
    - Reduced electrical distribution by 75%
    - **Total project savings: $1M**
- Future power solutions from the vendors need to minimize impacts on the facility infrastructure

Future Direction – Next Generation HPC Pushes Facility Electrical, Mechanical and Structural Infrastructure

HPC Facility Gap Analysis Strategy

Developed a strategy to access the probability of siting future extreme scale systems to meet mission by system class.

LLNL facilities evaluated for structural(S), electrical(E) and mechanical(M) infrastructure based on following criteria:

High	Infrastructure probability acceptable for future systems without modifications or upgrades
Medium	Infrastructure probability acceptable for future systems with minor modifications and upgrades
Low	Infrastructure probability unacceptable for future systems without significant modifications and upgrades
Fail	Infrastructure probability unacceptable for future computational and mission cannot be achieved

B-115/ B-117 HPC Facility Capability Matrix

Probability in Siting Systems

System Class	High	Med	Low	Fail
Advanced Development Systems				SEM
Commodity Systems				SEM
File Systems				SEM
Storage	EM		S	
Network/ Support Systems		EM	S	

S Structural

E Electrical

M Mechanical

- Major Limitations
  - Constructed in 1954
    - Concrete block walls
  - Major seismic deficiencies
  - No central water plant utility connections
    - Limited water delivery from B-117
  - Congested utility corridor – limited expansion
  - Failing infrastructure

No Upgrades Required	
Upgrades Required	
Upgrades Cost Intensive	
Unable to Meet Mission	

B-451/B-439 HPC Facility Capability Matrix

Probability in Siting Systems

System Class	High	Med	Low	Fail
Advanced Development Systems				SEM
Commodity Systems			SEM	SEM
File Systems			SEM	
Storage	EM	S		
Network/ Support Systems	EM	S		

S Structural

E Electrical

M Mechanical

- Limitations
  - Constructed around 1980
  - Performed a major SEM upgrade in 1997 at B-451
    - Minimal growth remaining
  - Aging infrastructure

No Upgrades Required	
Upgrades Required	
Upgrades Cost Intensive	
Unable to Meet Mission	

B-453 HPC Facility Capability Matrix

Probability in Siting Systems

System Class	High	Med	Low	Fail
Advanced Development Systems			SEM	
Commodity Systems			SEM	
File Systems	S	EM		
Storage	SEM			
Network/ Support Systems	SEM			

S Structural

E Electrical

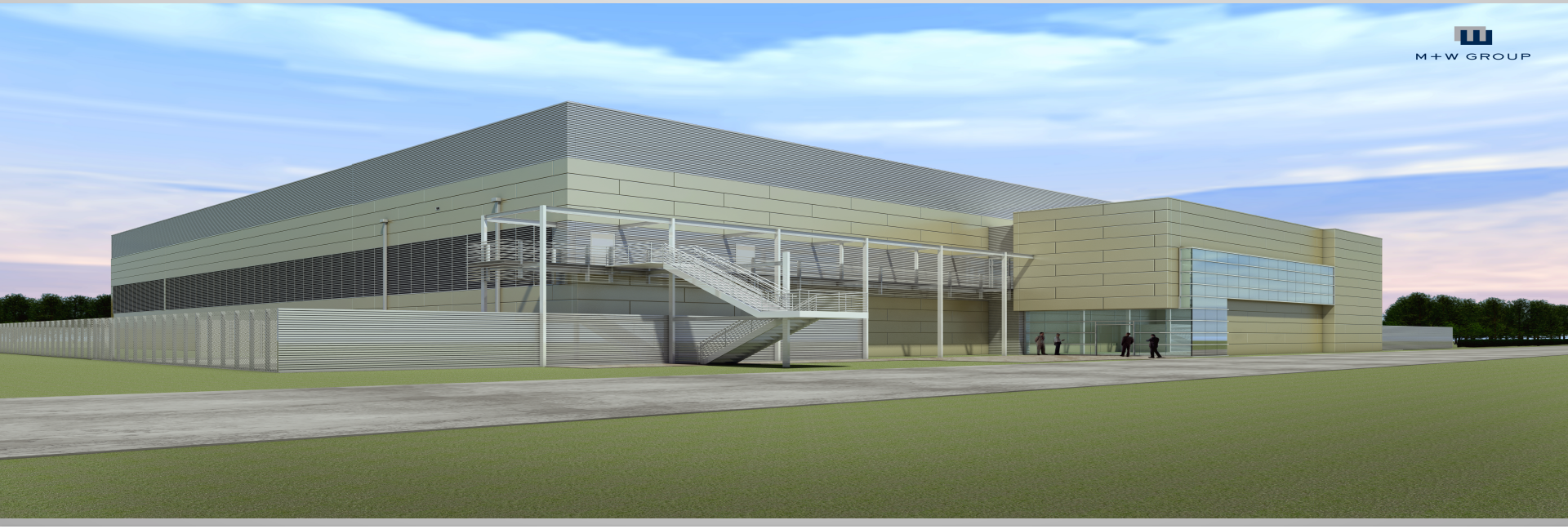
M Mechanical

- Limitations
  - Construction complete in 2004
    - Changes in local seismic requirements after construction
    - Mechanical equipment beginning to fail and show signs of needed replacement due to 24/7 operation

No Upgrades Required	
Upgrades Required	
Upgrades Cost Intensive	
Unable to Meet Mission	

HPC Facility Capability Gap Analysis: Future HPC Facility Strategy Plan

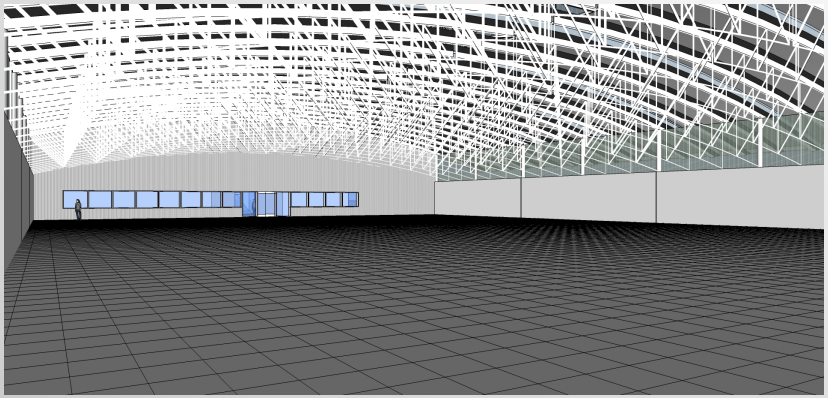
- Utilize existing facilities based on their capabilities
- Demolish or repurpose aging facilities that cannot meet mission
- Build new facilities to meet mission
  - Focus on sustainability and energy efficiency through flexibility
  - Scale footprint with the computational technology
  - Deploy innovative HPC facility design methodologies

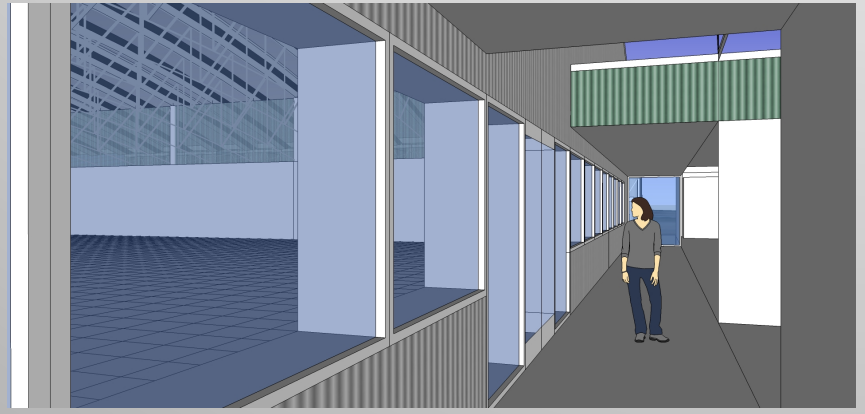


Sustainable HPC Modular Solutions: Scalable Building Concept

- Scalable building concept to meet changing HPC demands
- Design supports scalable HPC infrastructure
  - Scale power
  - Scale square footage and structure
  - Scale cooling solutions
  - Deploy facility power management system
- Minimize the use of cooling towers and chillers
- Utilize closed-loop cooling concepts with expanded liquid cooling temperature ranges
- Concept is more cost effective than containerized solutions based on detailed cost analysis

Sustainable HPC Modular Solutions: Design Features





- Leverage existing complex successes
  - Clear, unencumbered space
  - Scalable mechanical and electrical infrastructure
- LEED Gold Certification Goal
  - Advance liquid cooling options
  - Deploy free cooling
  - Cool roof
  - Scalable electrical distribution
  - Accommodate increased weights
  - Decrease space impediments
- Initial build out
  - 3 to 6MW in 6,000 SF
- Total build out capability
  - 15MW in 24,000 SF

Future Computing Planning to Include LLNL Utility Distribution: Electric Utility Example

- Evaluating LLNL site load flow is crucial for electrical distribution expansion
  - Modeling current distribution
  - Performing event analysis
  - Performing predictive modeling
- Evaluating instantaneous and historical electrical site data
  - MW – MVAR - MWh
  - Amps – Voltage - Power Factor
- Evaluating LLNL site load flow is crucial for future HPC and Big Data
  - Develop future HPC facility sites based on power availability – Build in the right location

LLNL FY12 Data Center Consolidation Goals

- Reduce footprint, water usage and energy intensity site wide
- Standardize LLNS computing support model to “One Lab”
- Address recent FY2012 DOE Sustainability Guidance
  - Data Center > 500SF and > 1 server
  - Fully meter by FY15 all enduring data centers
  - Obtain a LLNL site wide weighted average Power Usage Effectiveness (PUE) of 1.4 by FY15
    - Consolidation to provide cost avoidance to achieve guidance

PUE	Level of Efficiency
3.0	Very Inefficient
2.5	Inefficient
2.0	Average
1.5	Efficient
1.2	Very Efficient

Power In

Total Facility Power

Switchgear
UPS
Cooling Towers
Chillers
Air Handlers

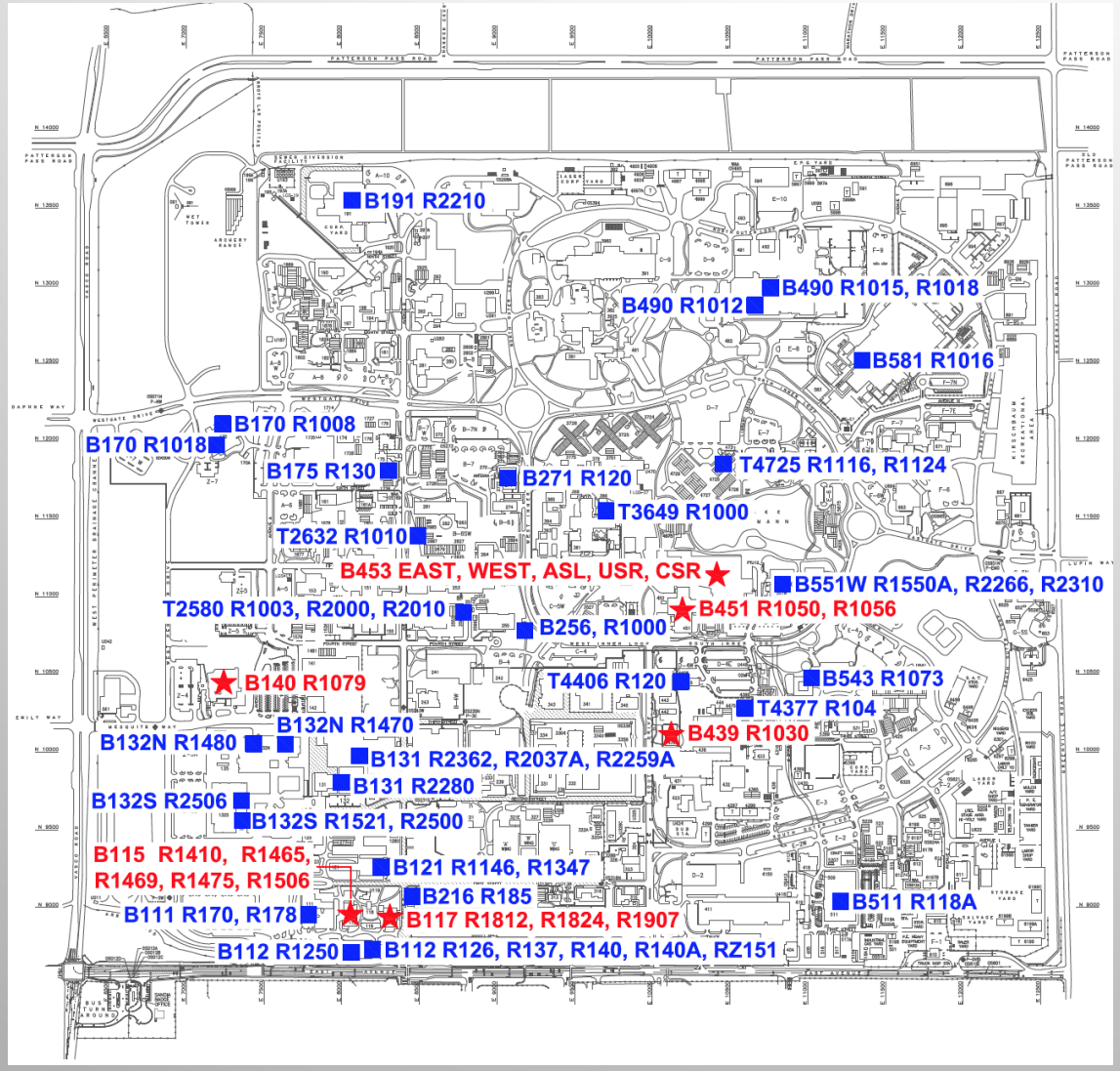
Power Out

Total IT Equipment Power

Servers
Networks
Storage

PUE = Total Facility Power / IT Equipment Power

Data Center Population FY12



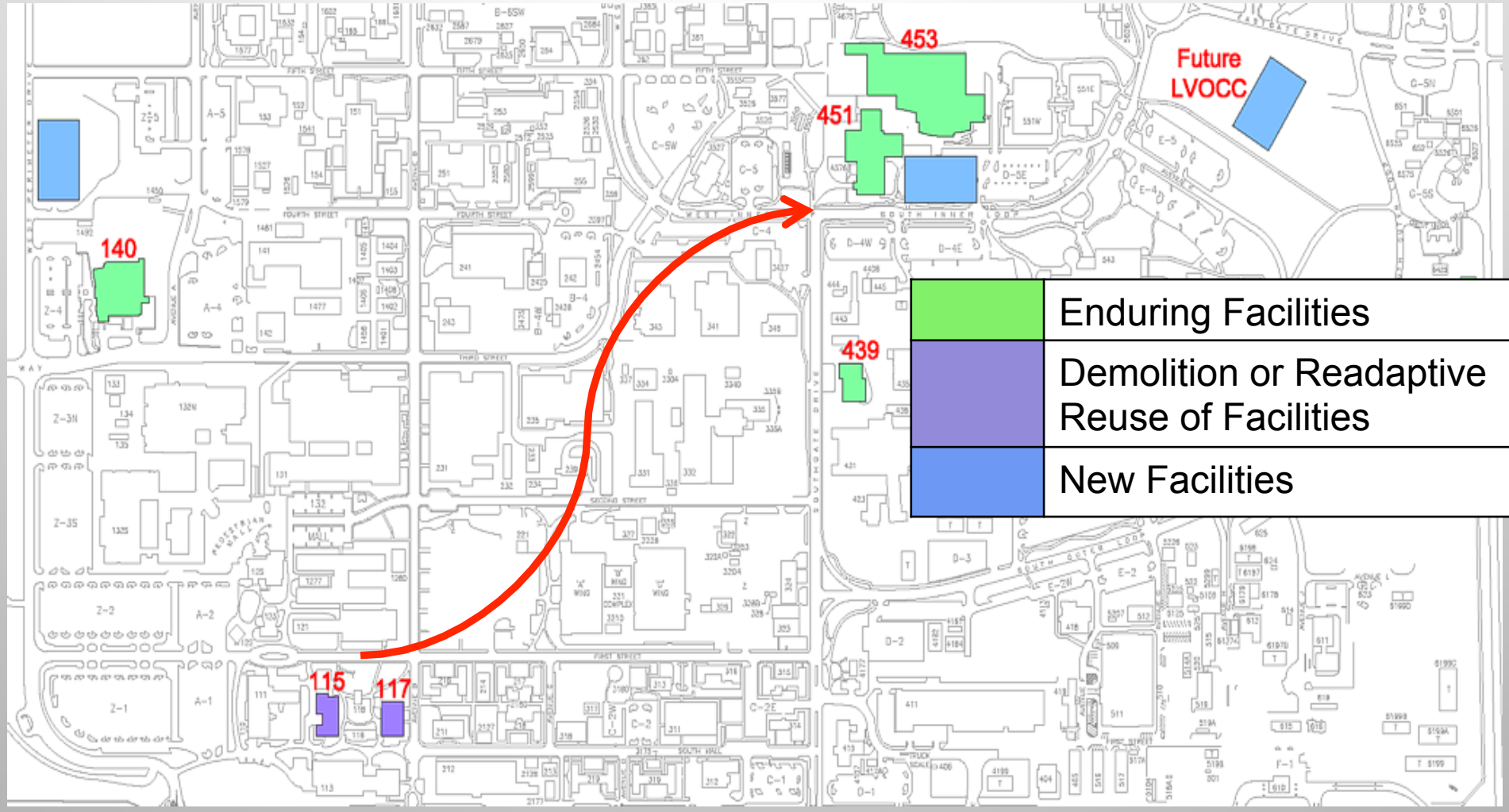
- 61 rooms site wide
- Spread across 29 facilities
- High Performance Computing (HPC)
  - 13 rooms
- Big Data Computing
  - 4 rooms
- Enterprise Computing
  - 44 rooms

★ HPC/Big Data

■ Enterprise

Big Data?

Future Master Facilities Plan



Power Monitoring Challenges

- Power monitoring is critical but challenging to implement
  - Numerous data streams
  - Need to aggregate data into single source and analyze on common system
  - Determining what data is significant
  - Unable to correlate events from various sources
    - Different timestamps and formats

Power Monitoring - Centralized system of real time data from the rack to the entire site

Create an operational, event, and real-time data management infrastructure of all external and internal data sources

Data Sources

Rack, Equipment, Metering, Building Management, Utility

Interfaces

Hundreds of Real Time Data Streams

Manage

Gather and Evaluate Large Amounts of Data

Analyze

Convert Real Time Data

Notify

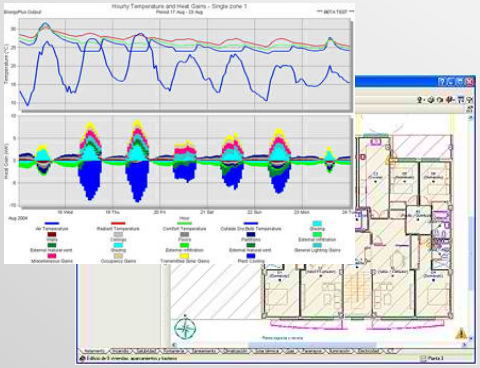
Centralized Event Notification

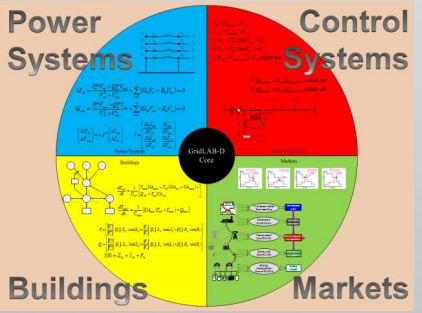
Visualize

View Data and Reports

Goal = Lower power utilization and achieve Exascale

HPC Opportunities for Power Monitoring





- Developed projects in modeling/analytics to improve facility efficiency, reliability and scalability
  - Currently working with HPC Data Analytics and Computational Mathematics Groups
  - Coorelate real time events and troubleshoot operational issues
  - Installing additional utility grade PMUs on the LLNL system (facility level to utility level) for predictive trending
    - Ties to CES-21
- GridLab-D: electricity power flow modeling to improve reliability, load shedding, etc.

Future Challenges for Power Monitoring

- Future Issues:
  - Power Usage
    - Larger block loads
  - Power Forecasting with Utilities
    - Sequoia Energy Swing
    - Forecasting Hourly
      - Working with WAPA to explore opportunities to improve forecasting transfer of data
  - Power Demand Response with Utilities

Questions

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