High Performance Computing with High Efficiency

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A new high performance supercomputer center for scientific computing in Berkeley, California

High Performance Computing (HPC) center on first floor
- 32,000 square feet computer room
- 7.5 MW initial total power requirement, expanding to 17 MW

Offices on second and third floors

Mechanical space below HPC, chiller plant adjacent

Total gross square feet 126,000

2012 occupancy?
Computational Research and Theory (CRT) Facility
Computational Research and Theory (CRT) Facility rendering
Supercomputer systems power
Historical change in supercomputer intensity
Site: 12 MW; 77 GWh; 2,132k GSf
CRT building: 17 MW; 150 GWh; 32k computer room

Effect of CRT: peak power x 2.4
annual electricity x 2.9
CRT Project objectives

Major Project Objectives

- Leading HPC capability
- Model of energy efficiency
- Maximum flexibility for future systems
  - Computer systems layout
  - Air and/or liquid cooling
  - Front to back or bottom to top airflow
- Energy efficient infrastructure
  - DCiE 0.83 or higher based on annual energy
  - Efficient system design
  - Use of waste heat

$$DCiE = \frac{IT \text{ energy}}{Total \text{ energy}}$$
**DCiE design goal**

DCiE higher than any benchmarked centers = 0.83

*Source: LBNL*
Many generations of high performance computers over several decades
High computing load densities: 20 – 30 kW/rack
Potential mix of air, liquid, or hybrid cooling
Potentially different temperature and humidity requirements for different computer systems and other IT equipment
Budget: must be life cycle cost effective
Design advantages for efficiency

- Minimal requirements for Uninterruptible Power Supplies (UPS) since work involves only scientific computing
- Mild climate suitable for economizer cooling
- Ability to use full ASHRAE TC 9.9 range of recommended temperature and expanded humidity range
- Integrated Architectural - MEP design
Design features

- Flexibility for air or liquid cooling
- Large efficient air handlers
- Integrated modular design
- Liquid cooling capability
- Part load modulation

- Environmental conditions
- Air side economizers and evaporative cooling
- Integrated water side economizer
- Air management
- Power distribution
- Use of heat recovery
Flexibility for air or liquid cooling

- Advanced HPC systems pushing limits of air cooling
- Systems could be built that:
  - Continue to be air cooled
  - Have liquid cooled cabinets removing some or all of the heat
  - Have liquid cooling to the processors
  - Use combination of refrigerant and liquid
  - Others?
- Network or storage equipment may continue air cooling even if servers require liquid
Large efficient air handlers

Applying sound HVAC engineering to air movement:

- Efficient fans and motors
- Low system pressure drop/ face velocity
- Variable speed
- Modular layout
- Effective air management

### Design Pressure Drops Across Major HVAC Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Initial Pressure Drop (in. w.g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Air Louvers</td>
<td>0.15</td>
</tr>
<tr>
<td>Outside Air Dampers</td>
<td>0.20</td>
</tr>
<tr>
<td>Filters</td>
<td>0.35</td>
</tr>
<tr>
<td>Direct Evap. Media Pad</td>
<td>0.25</td>
</tr>
<tr>
<td>Chilled Water Coil</td>
<td>0.25</td>
</tr>
<tr>
<td>Ductwork+Plenum+Outlets</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.5</strong></td>
</tr>
</tbody>
</table>
Modular design

Building and system modular build out

- Add as you go
- Build only what you need
- Space to add systems later

A building information model (BIM) was developed
Modular cooling plant

- Large headers sized for efficient operation for future loads - even higher efficiency in the interim
- All pumps, fans, and compressors are variable speed
- Unequal chiller sizes for better turn-down and load matching
- Optimal control for maximum overall plant COP at any load and outdoor condition
- Space for additional chillers and towers for future loads
- Headers, valves and caps for modularity and future flexibility allow additions without shutting down
Liquid cooling capability

Use of chilled water or treated water connected to cooling tower through heat exchanger

- 4 pipe system allows all of one or the other - or mixing
- Blanked off for future addition
- Space for piping provided
- Reset for efficient operation
Part load operation

HPC systems operate fully loaded however systems will be added and removed over the life of the facility varying the cooling requirements significantly

- Modular
- Variable speed everything
  - tower fans
  - chilled water pumps
  - condensing water pumps
  - chiller
  - exhaust fans
  - main air handler fans
- Controls
Environmental conditions

Design Conditions:
- Summer 100F DB/ 65 MWB; Winter 37.5F (99.5% Oakland ASHRAE)
Environmental conditions

CRT design guidelines: 60 to 75F DB; 30-60% RH
### Environmental conditions – operating modes for air cooling

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Number of Hours Per Year</th>
<th>Percent of Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix of outside and return air</td>
<td>8200 hours</td>
<td>93%</td>
</tr>
<tr>
<td>Direct evaporative cooling</td>
<td>45</td>
<td>0.5 %</td>
</tr>
<tr>
<td>Direct evaporative cooling and chilled water coil</td>
<td>38</td>
<td>0.4%</td>
</tr>
<tr>
<td>Chilled water coil</td>
<td>510</td>
<td>6%</td>
</tr>
</tbody>
</table>
Air economizer and evaporative cooling

- Direct evaporative cooler doubles as humidifier
  - Uses sensible heat from equipment
- Humidity allowed to float within recommended range
- Evaporative cooler has more pressure drop but lower life cycle cost relative to spray nozzles or ultrasonic humidifier
Water side economizer

Integrated Water-Side Economizer (WSE)

Evaporator
Condenser
Evaporator
Condenser

Pumps with Variable Speed Drives
Heat Exchanger in series with Chillers on CHW Side
**Air management**

- **Isolation of hot and/or cold aisles on the HPC floor**
  - minimize mixing and recirculation
  - CFD model to predict air pressures for consistent air flow

- **Divisible space under and above raised floor**
  - allows for different environmental conditions for different computing systems
Heat recovery

- Hot air or water will be available
- Warm enough to preheat air in CRT and nearby laboratory and office buildings
- Enough heat available to eliminate all space heating energy usage in these buildings
- Interconnection also used for heating water to CRT (at start-up)
480 volts to the racks
- Minimizes conversion loss

Minimal UPS (under 10% coverage)
- Selection of delta-conversion or double-conversion with bypass to minimize losses

No need for redundant power supplies
Predicted HPC Performance

- DCiE of 0.90-0.95 based on annual energy
- DCiE of 0.83-0.90 based on peak power
- No credit taken for heat recovery