U.S. Department of Energy, Princeton Plasma Physics Laboratory, Data Center Case Study

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SUMMARY

This case study discusses improvements to both computing systems and the supporting infrastructure at the U.S. Department of Energy Princeton Plasma Physics Laboratory (PPPL).

INTRODUCTION

Data centers are very energy intensive operations and are the focus of energy efficiency efforts across the Federal government. Older data centers that were not constructed to current energy standards face significant challenges to incorporate new computing technology and improve energy efficiency while maintaining center operations.

PPPL conducts experimental and theoretical research in the fields of plasma science and technology and fusion energy development. The computing center (PPLCC) has been the focus of engineering analysis and system improvements over several years. Various upgrades to the computing infrastructure, including regular server upgrades have expanded the center's computational capability; however there were known limitations with the existing cooling systems and associated configuration.

PPPL COMPUTING CENTER DATA SYSTEM UPGRADES

The research cluster's hot row was cloaked with top of rack curtains, sliding doors at the ends of the aisle, and ductwork to bring hot air directly into the return of the air conditioning (A/C) units. Several hardware improvements were implemented to reduce energy consumption and in some cases reduce the cooling footprint:

- A 4,800 watt SGI Altix system was replaced with a 600 watt blade system that runs jobs 12 times faster.
- Network switch frames were replaced with stackable switches that consume far less energy.
- Windows servers were consolidated into a virtualized blade environment.
- Twenty-one UNIX servers were consolidated into three high availability servers, saving ~2kW/hour.
- Two hundred dual single core servers were replaced in the research cluster with single dual core servers, saving ~$80,000 annually in reduced energy use.

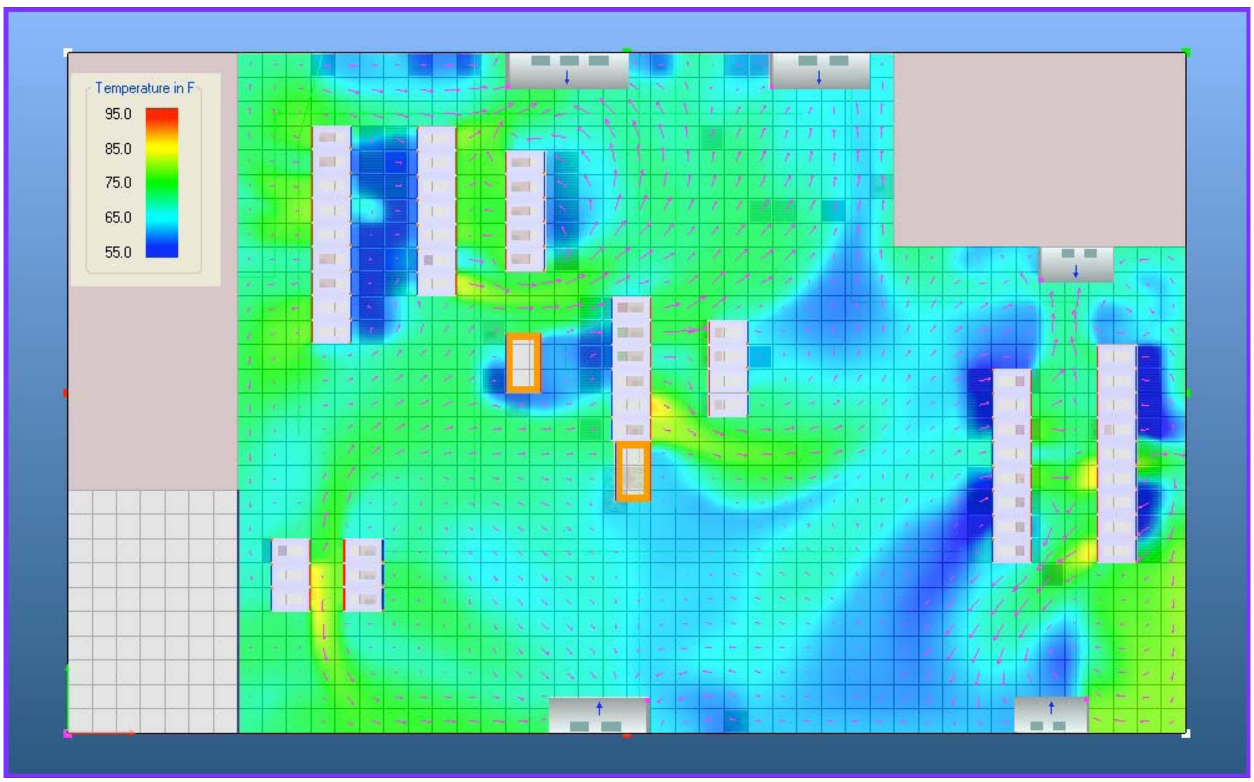
The computing group team that researched and implemented these improvements was recognized with the PPPL "Green Machine" awards at the annual Earth Day event at PPPL.

PPPL COMPUTING CENTER COOLING SYSTEM MODIFICATIONS

The PPPL data center for the facility was constructed in the 1970's to support large-scale experimental data collection and computational plasma physics research requirements. The computing technology and infrastructure have evolved over the many years to keep pace with the computing industry and the computational needs for the laboratory. The center became limited with computing expansion in the 1990's initially due to space limitations and then in the past 3-4 years due to cooling capability for the systems. Recent developments in server technology have increased the speed and reduced the physical size of the servers while significantly increasing the computing capacity. The installation of new server clusters to support expanded computational needs increased the cooling needs for the center. The heat load became too great for the existing cooling systems, resulting in a high-temperature emergency shutdown in April 2010. This event precipitated expedited efforts to improve the center's cooling capability to ensure continued operational capability.

Additionally, Executive Orders 13514 and 13423 have established aggressive goals to reduce overall energy consumption. For data centers this is not only applicable to the cooling needs of the electronics but also to the building envelope and electrical energy consumption of the servers and computers.

PPLCC consists of five computer room air conditioning (CRAC) units that supply cold air to the room through an 18" under-floor plenum. This cooling system includes one 30-ton unit and two units each of 15-ton and 10-ton capacity.



Air Flow Short Circuiting

The room is separated in to rows labeled A through J, with I and J being the most densely clustered rows supporting theory and computational research. Other servers support data analysis, business computing and administrative functions. The room was historically operated to maintain a room temperature of 67°F with little detailed evaluation of airflows. Internal server temperatures using this method routinely were in the low to mid 40°C range with a 48°C alarm temperature that would shut the servers down. In April 2010, during high usage of the computational cluster, server temperatures exceeded 48°C and the cluster shut itself down stopping theoretical work. The chart below, representing a total of 65 tons of cooling capacity, list the operating conditions of the units at the time of the failure.

Unit	Percent Load
AC-1 = 10 Tons	100%
AC-2 = 10 Tons	100%
AC-3 = 15 Tons	100%
AC-4 = 15 Tons	100%
AC-5 = 30 Tons	50%

PPPL's Facilities Division installed a Hot Isle Containment System in rows I and J of the center to direct the exhaust air from these servers back to the AC units and reduce hot/cold air mixing in the room. Additionally they installed floor diffusers in the floor vents to lower the exit velocity of the cooled air so it would no longer bypass the equipment racks.

The raised floor tile was also retrofitted to reduce leakage of air from beneath the tiles to the room. This was performed in stages to allow functionality of the cooling. The tiles were very old and exact replacements were not available. Therefore the tiles were refurbished by an outside contractor. The asbestos-containing floor tile was abated and replaced with vinyl tile, new seals were installed and the metal frame was replaced.

Installation of Hot Isle Containment

RESULTS

Implementation of the above actions enabled PPPL to raise the ambient temperature in the room from 67ºF to 74ºF while maintaining appropriate cooling for critical computer equipment. The combined actions provided significant immediate energy savings by reducing cooling load on the existing chillers. In July 2010, the average daytime high temperature was 92ºF. An evaluation of chiller loads during these operating conditions revealed a significant reduction in cooling from the 65 tons noted for April 2010 to only 37.5 tons in July 2010. This represents a 42% reduction from the original cooling load of 65 tons.

Unit	Percent Load
AC-1 = 10 Tons	50%
AC-2 = 10 Tons	100%
AC-3 =15 Tons	50%
AC-4 = 15 Tons	50%
AC-5 =30 Tons	25%

In addition to the hot isle containment systems the computer division has set up internal monitoring systems for the most critical servers. Since the systems were installed the average running temperature of these monitored servers dropped 7^{o}C while raising the room temperature 8ºF and reduced the loading on the CRAC units

LESSONS LEARNED AND NEXT STEPS

The old practice of cooling a room in order to cool equipment is flawed. Data centers are now one of the most energy intensive classifications of buildings rivaled only by hospitals on a cost per square foot basis. The better method for cooling servers and other computer hardware is to focus cooling directly to the equipment. Sizing and design of the ducting combined with air flow zones termed hot and cold aisles contributed to reducing overall plant size and thereby reducing energy costs.

The energy efficiency measures presented here are only a first step toward improving the center's energy efficiency. Funding limitations will require a multi-year effort to fully implement the recommendations of the engineering study. A three phase plan has been developed to address re-configuration of the air flow to the server isles; replacement of existing chillers with variable speed chillers; enhancement of daylighting in the center to reduce lighting energy use; and installation of an R-30 roof with vegetative covering.

REFERENCES

For more information about the Department of Energy Fusion Energy Research, please see the Princeton Plasma Physics Laboratory web site at http://www.pppl.gov.

Information regarding Sustainability at PPPL is available online from Princeton Plasma Physics Laboratory, at: http://www.pppl.gov/sustainable.cfm.

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