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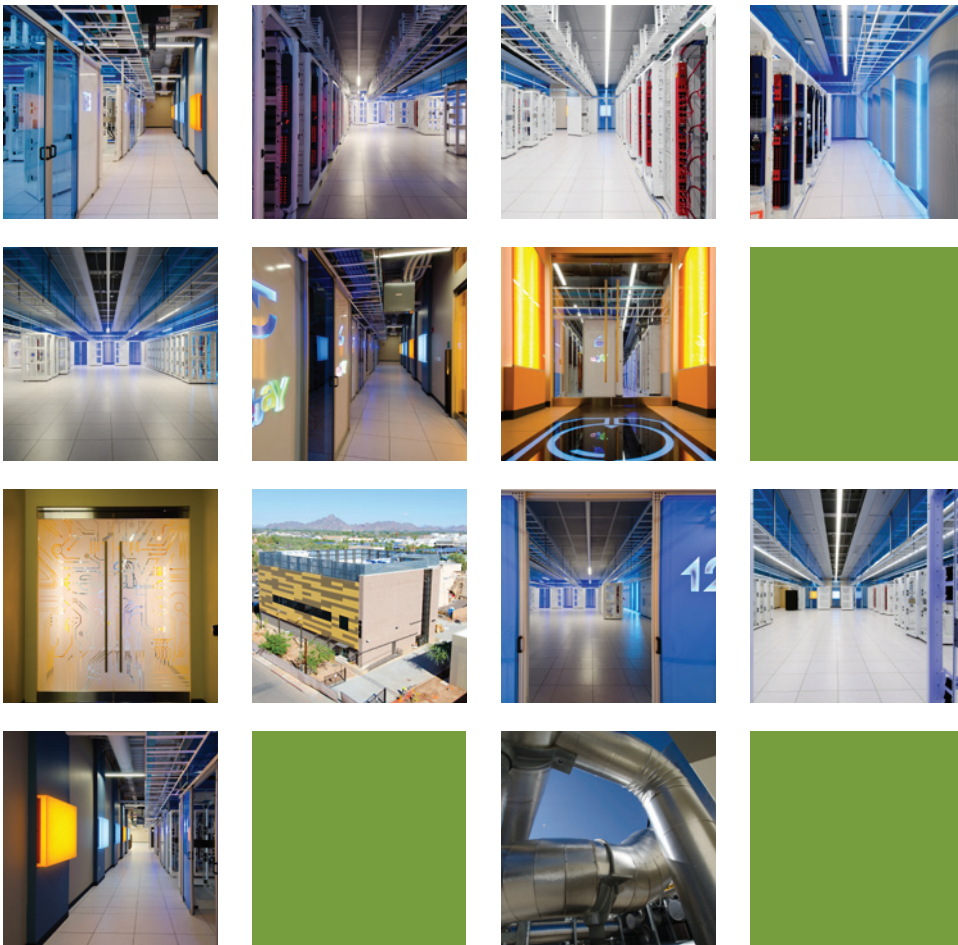
CASE STUDY

Breaking New Ground on Data Center Efficiency

How eBay's "Project Mercury" Used PUE, TCO and DCMM Best Practices to Drive the End-to-End Data Center Ecosystem

February 2012



Highlights

- Using an approach driven by metrics, and guided by The Green Grid's Data Center Maturity Model, eBay built a highly efficient data center using free cooling in the desert southwestern U.S.
- eBay designed for a site-annualized Power Usage Effectiveness (PUE™) rating of less than 1.2, and measured a partial $PUE_{L3,DC}$ in containers as low as 1.018
- Water-side economizer cooling works 100% of the time, with chillers only for backup, despite 49°C desert temperatures
- Rightsizing applications to data center space allowed 80 percent of servers to be deployed in lower-cost Uptime Institute-defined Tier II space
- Server rollout process optimized for rack-at-a-time and container-at-a-time deployments minimizes space while maximizing modularity, flexibility, and scalability
- Request for Proposal (RFP)-driven process, guided by PUE and total cost of ownership (TCO) optimized both server and data center designs that benefit not just eBay, but may also enable vendors to provide similar advantages to other customers

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Executive Summary

When eBay experienced the need to consolidate in the face of growing demand for data center space, it took a holistic, end-to-end view of the space it was using, the servers it was deploying, and how its data centers were designed and operated. This effort, internally named "Project Mercury," used advanced technical, organizational, and business techniques to create a highly efficient data center, while giving eBay's global online commerce platform lower costs, increased business agility, and room for future growth.

Including IT and Facilities in the same organization positioned eBay to use a metrics-based approach to drive its data center design and its server procurement process. Rather than using The Green Grid's Power Usage Effectiveness (PUE™) metric as a retrospective measure of incremental efficiency improvements, it used PUE as a driving tool in its request-for-proposal (RFP) process. Because PUE is insensitive to workload, eBay also used total cost of ownership (TCO) metrics to assess servers using the total lifetime kilowatt hours (kWh) used while running eBay's workload. This metrics-based approach optimized the supply chain for lower PUE and TCO with results including the following:

- An eBay-reported average site $PUE_{L3,WC}$ of 1.35 with a best-case $PUE_{L3,HC}$ as low as 1.26 for measurements taken in January 2012 with a site load of 30–35 percent. The site reports a partial $PUE_{L3,WC}$ of 1.039, with some hourly readings of 1.018 for rooftop container systems taken in January 2012. eBay also reported partial $PUE_{L3,HC}$ as low as 1.040 with idle servers and 1.044 with servers at maximum load on a day reaching highs of 48°C.
- Server rollout optimized for both rack-at-a-time and container-at-a-time deployments that supports rapid scaling in traditional data center space or a rooftop container area
- Dense rack deployments based on a consolidated set of server designs that balance space, power, cooling, cabling and weight configurations for maximum speed, workload agility and efficiency
- Individual server models optimized for lower power consumption and the ability to vary the CPU clock frequency in order to closely profile power consumption with workload requirements
- A modular, scalable data center design that is ready to handle up to five generations of future technologies, increasing agility, density, and the overall facility lifespan
- Placed servers for different applications in the appropriate Uptime Institute-defined Tier IV[1] or Tier II locations, slashing cost in half for hosting 80 percent of eBay's applications

The approach that eBay followed sets an example of the benefits that can be achieved by implementing the lessons of The Green Grid's Data Center Maturity Model (DCMM). eBay's Project Mercury is meeting and in some cases exceeding some of the five-year horizons that the DCMM defines.

1. Tier levels are defined by The Uptime Institute, "Data Center Site Infrastructure Tier Standard: Topology," http://uptimeinstitute.com/component/docman/doc_download/5-tiers-standard-topology. The Uptime Institute, 2009.

Consolidation and Demand

With more than 100 million active users globally, eBay sold US$68 billion worth of goods in 2011, roughly $2,000 every second. As the number of registered users and number of items listed on its site increases, eBay's Global Foundation Services team continually looks for the most cost effective and flexible ways to support the rising number of transactions while providing the highest quality of service, security and reliability for its users.

In 2010, Project Mercury was conceived as a response to multiple demands at eBay: a massive data center consolidation project happening at the same time as ongoing technology refresh cycles and the single largest yearly demand to deploy new applications in eBay's more than 15-year history. The company's datacenter consolidation project was targeted to consolidate 11 data centers into three. The savings from this strategic investment are expected to not only pay for new investments across eBay's data center portfolio, it also decreased network latency, enabled long-term infrastructure scale and allowed eBay to aggressively invest in cutting-edge data center designs and server innovations.

The combined project needed to deploy tens of thousands of servers in less than six months, including 35 percent for technology refresh, more than 45 percent to power new high-performance compute clusters, and 20 percent to power massive Hadoop clusters for deep data analytics. Far from a momentary spike in demand, eBay expects the upward trend in IT demand to continue unabated. This led eBay to require new data center space to be flexible, modular, and ready to handle rapid growth in server density and be able to accommodate new cooling technologies as they emerge (including the prospect of direct-to-chip water cooling) in eBay's data centers.

Best Practices for Data Center Maturity

The Green Grid released the Data Center Maturity Model (DCMM) in March of 2011 to provide a road map for data center designers and

operators on current best practices and the path to best practices five years into the future. The Model's "Level 2" documents industry best practices, and "Level 5" serves as a target for organizations to reach in the future. eBay's Project Mercury incorporates many of the current and future best practices documented in the DCMM. This provides a real world example of how companies can save resources and money by using the Model from the beginning of design through the operations of their facilities and IT infrastructure.

Assessing its current data center portfolio, eBay determined that their existing model was unsustainable. An inventory audit showed hundreds of different hardware configurations (SKUs) were still being ordered and deployed in data centers broadly conforming to the Uptime Institute's Tier IV data center specification. Further investigation showed that 15 of these SKUs made up 80 percent of the hardware in the data centers and the majority of application servers did not require Tier IV. This overprovisioning of resiliency resulted in an infrastructure that was far more costly and complex than necessary. eBay used measures including total cost of ownership (TCO) and The Green Grid's Power Usage Effectiveness (PUE™) to highlight the inefficiency of housing servers in expensive, high resiliency space unnecessarily.

Unsustainable Model

One of the principles of The Green Grid's DCMM is to align business needs with the most appropriate level of data center resilience and efficiency. A frank assessment of eBay's application needs, as recommended by the DCMM section 3.2.2, determined that 80 percent of the application portfolio required only Tier II reliability. By aligning these applications to the appropriate level of redundancy, eBay freed capacity in its Tier IV data centers, effectively extending their lives. Moreover, eBay also was able to augment its portfolio by adding new high-density, low-cost, and highly efficient Tier II space. Another core benefit in this new approach is that the total cost of ownership for the data centers plummeted, supported by a reduction in capital

investments and operating expenses of the new Tier II data centers by more than 50 percent. When looking at the DCMM, the right sizing of individual applications to the most appropriate level of resilience is a five-year-out best practice. By implementing this best practice now, eBay is on the leading edge when compared to most typical IT organizations.

Holistic Approach to the Compute Ecosystem

The successful implementation of Project Mercury is traced to the way in which eBay used a metrics-based approach to guide the RFP, end-to-end design, implementation, and operation of its new data center. What eBay accomplished was possible through the confluence of the company's organizational structure and the use of metrics to drive both server acquisition and data center design and operational practices (Figure 1). The design process was also end-to-end in the sense that it drove the very supply chain that provided the servers and data center itself.

Figure 1. The approach used by eBay is based on principles described in the DCMM and combines PUE and TCO metrics.

(Source: eBay image, used by permission)

Organizational Structure

By having both the Facilities and IT units under one organizational structure, eBay was able to achieve a very high level of process and communications efficiency. This best practice strategy aligns with DCMM Section 8.1.2, which dictates collaboration on energy efficiency goals throughout data center design and operation. With those who purchase servers and those who pay the power bills in the same organization, TCO of the data center and its necessary IT equipment naturally includes everything: the cost of the server, power consumption over the data center's lifetime, real estate and data center floor space depreciation, and power and cooling efficiency.

"PUE is the de facto standard driving efficiency in our data centers, and the emergence of additional metrics, including WUE and CUE, will help us drive further cost reductions while minimizing our environmental impact"

DEAN NELSON
Senior Director
eBay Global Foundation Services

PUE As a Driver

Ever since The Green Grid established the PUE metric in 2007, organizations worldwide have used it to measure the efficiency of their data centers and measure their incremental steps toward greater energy efficiency. In Project Mercury, eBay used the metric not as a retrospective measure of progress, but as an integral tool in the end-to-end process of design, construction, and operation of both brick-and-mortar and containerized data center space. Using PUE as a design driver yielded impressive results: eBay reported that the data center's overall average $PUE_{L3,WC}$ was 1.35, with some hourly readings as low as 1.26 measured for one week during January 2012, when the site was at 30–35 percent capacity. This measurement makes it one of the most efficient data centers that specifically follows the reporting guidelines of The Green Grid.

The way eBay has reported its PUE for this project is significant. eBay is one of the first sites to formally report their PUE value with full transparency around how the data was collected, processed, and reported. Using the nomenclature recommended in The Green Grid's White Paper #22, "Usage And Public Reporting Guidelines For The Green Grid's Infrastructure Metrics (PUE/DCiE)," readers can distinguish the fact that eBay's data was recorded at the IT equipment level ("L3," or "Level 3"), that the PUE number was measured over a weekly or hourly period (the 'W' or 'H' subscript), and on a continuous basis ('C' subscript, sampled at least every 15 minutes). For more information, see The Green Grid's paper or website.

TCO As a Driver

Understanding PUE, its measurement, and how it describes energy efficiency is a crucial first step in driving forward with mature data center design practices. However, PUE alone is not sufficient because the measure is workload agnostic: a data center can achieve an outstanding PUE even if its servers are acting as toasters and doing no useful work. A low PUE does not necessarily mean that the overall architecture is efficient because the absolute level of energy consumption may be higher than can be achieved with better planning and implementation activities.

One approach that eBay has tried to address this gap is through the use of Total Cost of Ownership (TCO) metrics. eBay's TCO metric factors in the cost of the server plus total cost of the energy that it will consume while running a specific workload over its lifespan. eBay has a deep understanding of the IT workloads and the influences of minute-by-minute fluctuations in these workloads. From this understanding, eBay developed a benchmark that vendors could use to provide a total-Watts-used metric in response to eBay's request for proposals (RFPs). The goal of this approach was to enable eBay to choose the most efficient compute solution by identifying the full lifecycle costs of deploying specific hardware in an optimized data center environment. Thus, the use of TCO in the end-to-end procurement process spurred innovation that benefits both vendors and their customers.

Goals and Constraints

The goals and constraints driving Project Mercury were not efficiency for efficiency's sake—they were to accomplish several of eBay's business goals for its new data center space. eBay's business objectives included:

- **Highest compute performance.** High compute performance allows more processing power with fewer servers in less space, therefore saving on total data center area, power, and cooling while also optimizing supply chain costs. For eBay, a larger number of lower power-consuming commodity servers would not meet its requirements because it would require more space and power to house the equipment. Low-density equipment required nearly twice the number of servers to do the same work, significantly increasing capital investments and operating expenses when considering the entire ecosystem in which the equipment operates. With a three-year refresh cycle, eBay can stay on the leading edge by aligning compute performance, density and operating expense.
- **Flexibility.** The three-year refresh cycle means that the data center must be built to accommodate rapid deployments and rapid change

at both rack and container levels. For the open-floor data center space, a "rack-and-roll" model was developed to allow entire racks of equipment to be replaced in a matter of minutes. The data center design includes the potential of doubling the power and cooling capacity with each rack replacement without major construction. The data center would also need to be capable of handling regular installation and replacement of entire containerized data centers on the rooftop area. Both rack and container deployments must be able to accommodate new cooling technologies as they emerge.

- **Forward-thinking design.** As referenced in The Green Grid's DCMM, for the investment in a new data center to pay off, the data center should be able to support four to five new generations of equipment as they are rolled into production. For eBay, this means that the data center would need to have the built-in ability to scale racks and containers to triple the initial power capacity over the life span of the data center. To illustrate, this requirement is equivalent to having a central plant that could scale from 4 MW to 12 MW, and rack density that can scale from an average of 4 kW to 40 kW of power and cooling per rack. eBay also required the ability to support three generations of spot-cooling technologies. At the server level, the data center needed to handle a doubling of density in each generation.
- **Cost effectiveness.** By augmenting the data center portfolio with high-efficiency Tier II capacity, the total operating cost per megawatt would be significantly reduced.

Data Center Results

The Project Mercury data center was designed with 1300 square meters of usable Tier II IT space. The data center needed to have two levels: one open raised-floor area for rack-and-roll deployments, and a second rooftop infrastructure capable of supporting up to twelve, 12-meter long containers. The building would be fortified to support over one million pounds of weight with an initial capacity of 4 MW of IT power and cooling and the ability to scale to 12 MW over time.

With these rough parameters established, eBay began Project Mercury by initiating two parallel processes: one for server procurement and one for data center design. The philosophy was based on the idea that the PUE and TCO metrics would be integral to the RFP process and would help to drive the supply chain to deliver the most cost-effective and energy-efficient infrastructure for eBay. This approach again illustrates eBay using current and future best practices from the DCMM by incorporating TCO in decisions involving both IT procurement and facility design.

Server Procurement

For its server purchases, eBay issued RFPs that incorporated three key focus areas for the project: holistic total cost of ownership, volume packaging and delivery, and future technology implementations. The RFP process was designed so that open competition could fuel technological advancements, leading to the achievement of eBay's business objectives: a lower TCO, and reduced energy consumption. By using a competitive RFP process with industry vendors, eBay was able to achieve similar efficiencies and optimizations compared to organizations building their own white-box solutions. eBay considers its vendor engineering teams as extensions of its own, with open competition between them stimulating innovation.

Simplifying Server Types

The process of reducing the number of SKUs began with an internal assessment of server requirements. After an extensive asset audit and workload performance requirement evaluation, eBay found that it could reduce the diversity of its server population. eBay was able to consolidate 15 primary server SKUs down to only two server types: those systems suitable for its high-performance computing deployments, and those systems suitable for supporting big data applications. As described in Section 5.2 of the DCMM, reducing the number of server types simplifies the number of moving parts in the data center, increases workload portability, and increases agility through more rapid deployment. From the

vendor perspective, responding to specific requirements in eBay's RFP by fine-tuning server designs was more feasible for a small number of SKUs. The process enabled a high degree of optimization for the two server types, resulting in highly efficient products in eBay's data centers, and arming the vendors with better products to sell to the rest of the industry.

Updated Search Engine

The first RFP eBay issued was for high-performance servers to support a new compute-intensive workload. This RFP was designed to encourage server suppliers to meet the specifications eBay laid out based for the total cost to procure and operate a server. This included server cost depreciation and total kilowatt hours projected to be consumed over three years running eBay's standard workload. After an intense process with more than 50 participants, eBay's selection was based on the vendor's unit cost and ability to fine tune its server components to consume the smallest wattage possible while executing the eBay-specified workload modeled over three years. This resulted in a holistic TCO that assessed the real cost of operating the server over its useful life.

Supporting Big Data

The second public RFP was for servers to support new Hadoop clusters. The vendor selected for this RFP had fine-tuned its servers and container solutions to improve the total wattage consumed from what was reported in the first RFP response. The vendor's engineering teams increased efficiency through improved airflow, lower-voltage DIMMs, low-load server BIOS optimization, and improved CPU heat sinks. The result was energy savings of up to 16 percent at full load and 41 percent while idle, a highly significant improvement that could benefit not just eBay, but other customers of the optimized product.

Profiling Energy Use to Workload

While improvements in server energy efficiency came from the bottom up as vendors optimized their servers to perform against eBay's RFP, other

innovations came from the top down as specific RFP requirements. One of the innovative elements of the RFP required hooks to allow eBay software to dynamically change the server CPU clock frequency so that it could slow down a server (and reduce its energy consumption) when workload conditions permit, and ramp up the frequency for a rapid response to workload demands (Figure 2). This opens the door for future software to balance physical infrastructure capacity with workload. This virtual gas pedal will match server performance with demand by increasing or decreasing clock frequency, further lowering total wattage consumption. This strategy is aligned with the DCMM's Section 5.3, which recognizes the need to understand workload energy consumption.

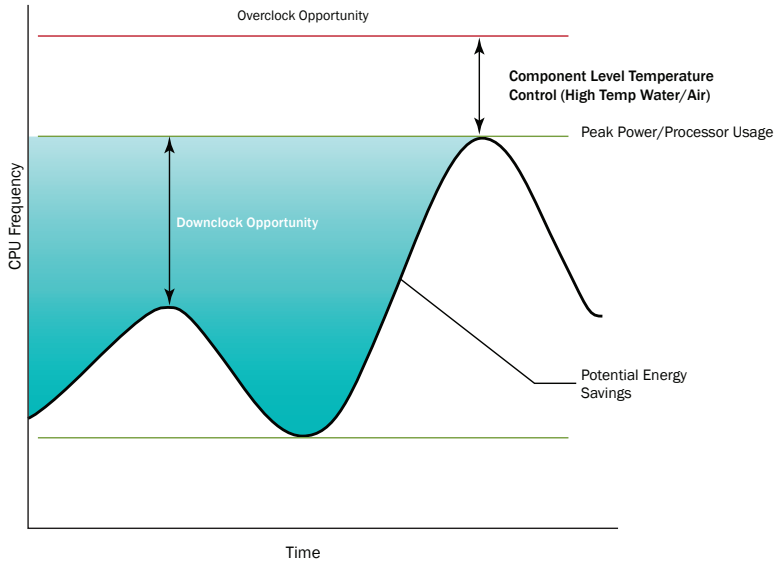

Figure 2. eBay can adjust CPU frequency based on varying load, increasing energy savings in low utilization periods, and overclocking for peak demand. (Source: eBay diagram, used by permission)

Managing Packaging Density

Greater data center packaging density reduces the use of costly data center area, increases business agility by allowing more servers to be

deployed at once, and increases data center cooling efficiency. The DCMM's Section 1.3 recommends that companies align rack power sizing with typical uses. The server RFPs that eBay issued clearly aligned with this recommendation, and they are designed to support two different deployment models:

- **Fewer than 1,000 servers.** When the business requirements drive a deployment of one to 1,000 servers, the need is fulfilled with rack-and-roll deployments. This deployment unit has all power and network cabling infrastructure preconfigured and tested by the server manufacturer in custom eBay-specified racks. The rack-and-roll deployment model allows server racks to be moved quickly from the loading dock and into position in the data center, reducing hardware deployment times from months to minutes

  eBay nicknamed the racks they use in the data center "sidewinder," because of the extra room on each side of the server space. The sidewinder racks that eBay sources from two manufacturers are optimized for size, power, cabling, weight and cooling. These racks are 76 cm wide, 122 cm deep, and 48 RU high supporting either 48 or 96-server configurations depending on their form factor (Figure 3). Network-enabled, modular power distribution units (PDUs) support capacities from 5 to 50 kW based on configuration. A top-of-rack switching model is used where the network access switches are actually mounted vertically in any of six 2-RU slots on either side of the stack of servers. These racks are capable of supporting up to 1,600 kg of rolling load and support in-row or passive rear-door cooling technologies. This configuration tightly aligns supporting infrastructure components without sacrificing any server space.

- **More than 1,000 servers.** When business requirements drive a deployment of more than 1,000 servers, the economics shift from favoring the rack-and-roll model to containerized data centers. These deployment units allow server manufacturers to

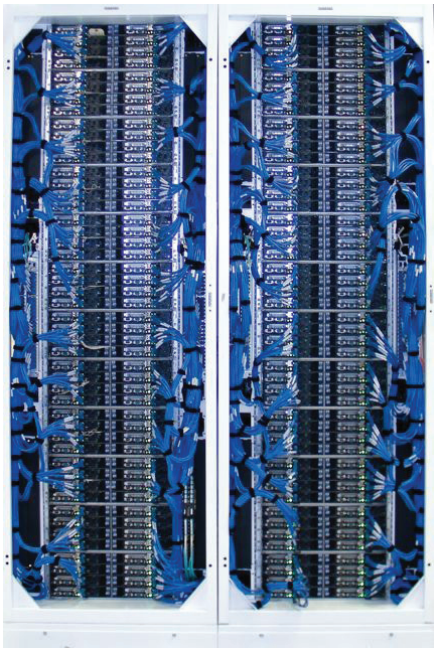

Figure 3. Preconfigured, eBay-standard racks are deployed in units of 48 or 96 servers.

closely couple their server innovations with the power and cooling infrastructure that optimizes both TCO and PUE. From eBay's perspective, containerized data centers support an even more efficient deployment model. The entire server complex can be moved to the data center roof space in one step, with modular power, cooling, and network connections made in a highly optimized, self-contained data center environment.

All three data center modules shown in Figure 4 were deployed in less than one day, with one container holding 1,500 servers lifted from the truck to the rooftop in 22 minutes. The data center containers were sourced from two vendors and utilized completely different cooling designs, showing the flexibility of the building to support different cooling technologies. There is space for eight additional modules on the 700 square meter area, bringing the total roof capacity to 6 MW of IT load.

Figure 4. 4,920 servers were deployed in containerized data centers to support eBay's new search engine and its Hadoop clusters. (Source: eBay photo, used by permission)

Data Center Design

In parallel with the server procurement process, eBay issued an RFP for its data center design that gave rough parameters for its construction. While TCO factors heavily in the design, the primary goals for the data center included free cooling year round, driving eBay's design PUE of 1.2 with rack densities up to 40 kW per rack. Achieving such a low PUE in a hot, desert location in the United States virtually dictates out-of-the-box thinking on the part of the winning vendor.

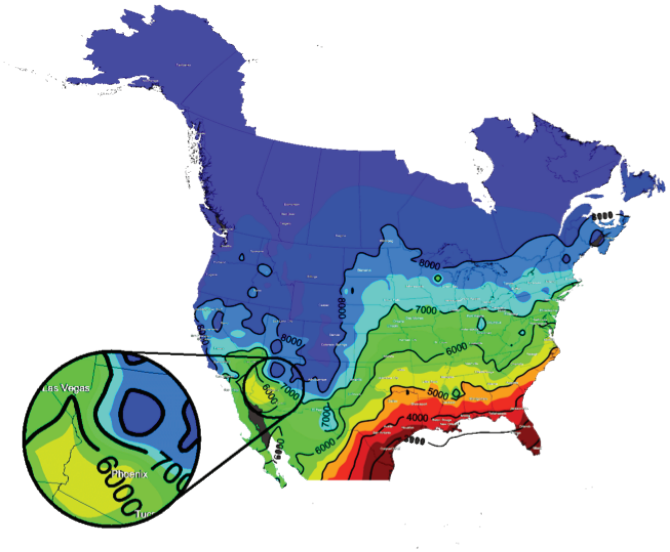

Figure 5. Phoenix lies in an arid desert, with summer temperatures peaking at 49ºC, yet has an estimated 6,000 hours of free-air cooling available per year; tower water can be delivered at 31ºC all year without using chillers..

Data Center Design Requirements

- **Multi-tier space.** The data center campus is a multi-Tier environment and high-availability applications are placed in the Tier IV space. Project Mercury is designed as Tier II redundant capacity components space with a single path of UPS power. A second power path comes direct from the utility connection with no UPS backup. The Tier II topology of this space implies scheduled downtime events for maintenance and capacity upgrades, however

the Project Mercury design included concurrently maintainable Tier II infrastructure. This meant that eBay would be able to conduct maintenance on the mechanical, electrical, and plumbing infrastructure without requiring the IT equipment to be powered off. Without the alignment of resiliency requirements between facilities and IT, this would not have been possible.

- **High density.** The data center would have to support high density in both its conventional rack space as well as its containerized data center area. The team found that when 96 servers were installed into a single rack with two 28 kW PDUs and four 48-port Gigabit Ethernet switches, fewer racks, switches, and PDUs were necessary. The cooling system also extracts heat from dense racks more efficiently, and less data center space is needed, slowing the rate of data center expansion and extending the new data center's lifespan.
- **Modular and future proof.** The data center must be modular so that it can evolve through four to five generations of technology refresh. To optimize the environment, compute capacity should be deployed in "whole rack" or "whole container" increments. The power system must scale from 4 MW on day one to 12 MW over the data center's lifespan. The cooling system must scale by expanding capacity a module at a time. Each rack position must be prepared to scale up to 40 kW of power and cooling over time.
- **Low PUE.** As stated above, the design PUE needed to be less than 1.2, which virtually dictates a cooling system that pushes the envelope of possible technologies.

Hot Water Cooling Throughout

To maximize flexibility and modularity, the facility was designed with two parallel water cooling systems so that racks and containers could tap into one or both cooling loops depending on their requirements (Figure 6).

- **Traditional cooling loop.** A traditional cooling system consisting of modular chiller units was designed to circulate 13°C water throughout all of the data center space.

- **Hot water cooling loop.** A separate cooling loop was designed to use cooling tower water exchanged through a water-side economizer to deliver 30°C hot water cooling to container and rack positions. 30°C is the worst-case scenario on the hottest day of the year based on 50 years of weather data. The cooling system and the servers can use hot water cooling for the entire year by

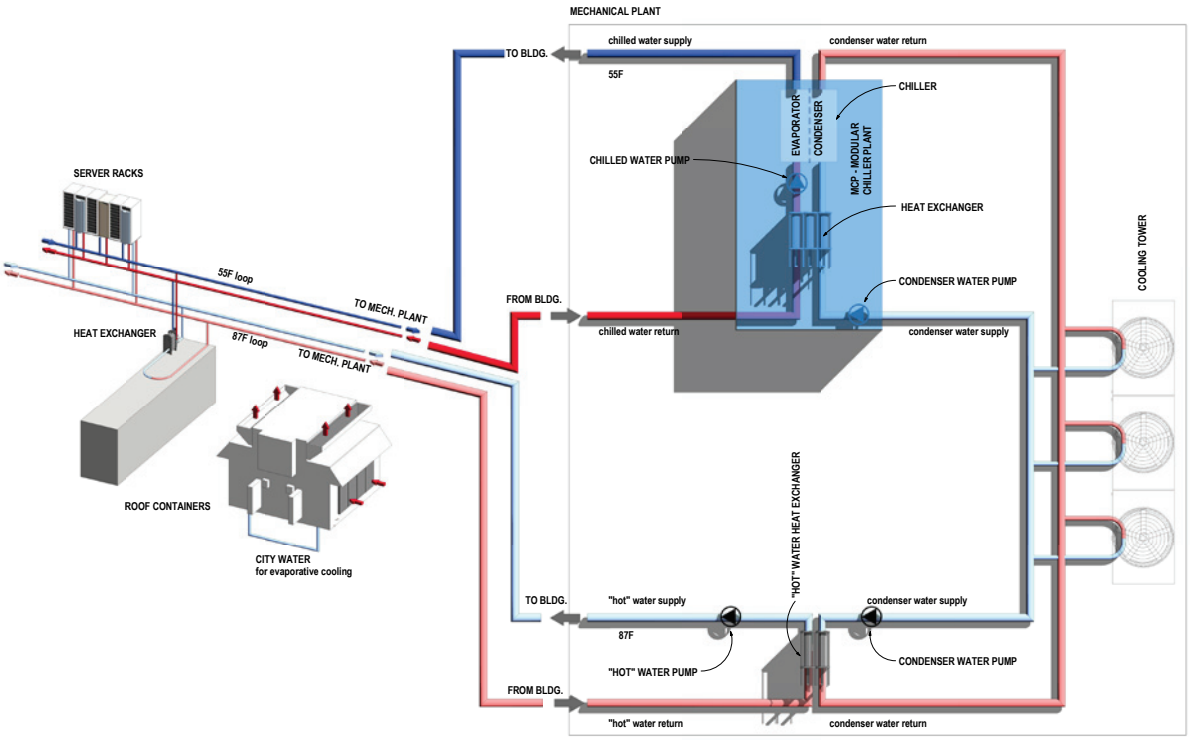

Figure 6. The Project Mercury data center is designed with two cooling loops for maximum flexibility and efficiency; efficiency of the chilled water loop can be increased by pre-cooling with the hot water loop. (Source: eBay, used by permission)

designing both to accommodate a water temperature maximum of 30°C and a maximum data center inlet temperature up to 36°C. Server manufacturers tuned their equipment in response the server RFP to align with this goal.

The system is designed to deliver spot cooling throughout, without any traditional CRAC units. In the data center space, both cooling loops were plumbed to every potential rack position underneath a two-meter-high raised floor. Likewise, both systems were plumbed to the rooftop container area. In practice, eBay has found that its modular chiller units (MCUs) were not needed for primary cooling. Their function changed to act as trimmers that eBay can use if the temperatures are unseasonably hot or the workload is too high for any period. With hot water cooling as the primary system, eBay has been successful with free cooling year round.

The traditional data center space was equipped for flexibility to accommodate rack power changes. Initially, eBay designed the data center for using in-row cooling systems to provide up to 70 kW of cooling for groups of racks using hot water, chilled water, or a combination of both using three-way valves. As individual racks reach densities of 28 kW, they can be equipped with a passive rear door for spot cooling of the single rack. When passive doors are added, in-row cooling systems can be removed, freeing up more space for compute racks. The expectation is that as racks reach 40 kW of density, direct-to-chip cooling can be used to handle even this highest density with the hot water loop. If densities increase further, weather conditions become too hot, or overclocking yields better than expected results, three-way valves at each cooling position can be switched to use either chilled water or hot water.

The containerized data centers were fitted with a plate-type heat exchanger that allows the hot water system temperature to be trimmed by running chilled water through the heat exchanger in the event that water temperatures could not be maintained on the hottest 50°C days. Experience has shown that the chillers are not needed unless the temperatures exceed the maximum recorded over the last 50 years of weather data.

The Green Grid's DCMM dedicates an entire section of the model to cooling systems. The contribution of cooling systems to overall PUE, including the reduced dependence on mechanical cooling, and the wider temperature

and humidity ranges are all part of the DCMM's best practice model. In this area, eBay has exceeded even some of the five-year best practices.

Engineered Efficiency: Containerized Data Centers

Containerized data centers' heat loads are typically closer to their cooling systems, require smaller volumes of air, and are designed to tolerate wider extremes of temperature and humidity. The Project Mercury data center was designed with a 700 square meter rooftop facility to house containerized data centers, further helping to reduce TCO with average PUE less than the traditional data center space. The containers were designed to withstand direct exposure to the 50ºC summertime heat while using adiabatic cooling or hot water for cooling. One of the most impressive parts of this installation was the container housing eBay's new high-performance compute deployment. The container utilizes adiabatic cooling and supports 26 kW per rack, achieving a $pPUE_{L3,HC}$ as low as 1.046 with an outside air temperature of 48ºC. This containerized data center contributed significantly to the data center's overall efficiency and is expected continue to drive down overall site PUE as more containers are deployed.

Competition between multiple vendors promises to increase data center efficiency more than traditional brick-and-mortar designs because of the degree to which efficiency can be engineered to match the heat load. The Project Mercury data center is poised to benefit from rapid advances in efficiency with its large and flexible space combined with its standard three-year technology refresh cycle.

For more information from The Green Grid on containerized and modular data center facilities, please refer to The Green Grid white paper #40, "Deploying And Using Containerized/Modular Data Center Facilities."

Conclusion

Faced with the challenge of data center consolidation combined with the need to deploy tens of thousands of new servers in less than six months, eBay responded with Project Mercury, a holistic, end-to-end effort that resulted in a highly efficient data center. The publicly reported best-case site $PUE_{L3,HC}$ of 1.26 at 30–35 percent site load, and container $pPUE_{L3,HC}$ values as low as 1.018 in January 2012, and 1.046 in August 2011, are significant achievements—especially given that the data center is located in one of the hottest desert locations in the United States.

eBay is one of the first data center owners to report PUE values in compliance with The Green Grid's recommendations. Adopting strict measurement protocols for PUE increases both measurement accuracy and precision, providing the highest levels of engineering confidence in the results.

Project Mercury was a success because eBay began with its IT and facilities organizations aligned from the beginning. Parallel server and data center RFP processes that used PUE and TCO metrics to motivate optimizations in the server supply chain, coupled with a modular, scalable and forward-thinking data center design amplified this success. The approach used by eBay, as aligned with The Green Grid's Data Center Maturity Model, further testifies to the value of rightsizing data center spaces. By using metrics to guide design and purchase decisions, and projecting several generations of technology into the future in order to achieve a longer data center lifespan and drive an end-to-end compute ecosystem.

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