# eBay Inc.: A Case Study of Organizational Change Underlying Technical Infrastructure Optimization

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## Executive Summary

This work provides a case study of the organizational changes necessary at eBay Inc. to support the development and operation of efficient data center infrastructure, hardware, and software. As a part of this process, the eBay Inc. infrastructure Engineering and Operations team (responsible for the delivery of technical services including Cloud services and data center hosting) embarked on a multi-year journey to dramatically improve the efficiency of the company's technical infrastructure, and to connect infrastructure productivity to business drivers. eBay Inc.'s technical achievements in improving energy efficiency and decreasing infrastructure operations cost has been well documented elsewhere; instead this study focuses on illuminating the changes to eBay Inc.'s organizational structure and culture of the IT organization that began in 2008 and are still ongoing today. In addition to a literature review, the authors conducted in-person interviews with members of eBay Inc.'s staff within the IT organization between May and August of 2013.

## Literature Review

The first step in the study was to conduct a literature review, in order to place the study's findings in the context of wider scholarship on similar topics. While there is a fair amount of work in the technical literature on data center design and efficiency potential, the authors were able to locate very little in the management or organizational behavior literature directly relevant to the management necessary to enable the technical optimization of data center infrastructure. Nevertheless, analysis of IT-enabled organizations does exist. Further, some of the best practices in data center design utilized by eBay Inc. are reflected in the literature as well. The themes relevant to this study are briefly summarized below.

*Change agents and IT-related change management.* A broad variety of organizational behavior research has focused on implementing large-scale change within organizations. Individuals play an important role in this process. Indeed, organizational/process changes without a champion are likely to fail (Benjamin, 1993). Especially when the organizational change involves information technology, it is important that change managers act as "boundary spanners" (Balogun et al., 2005) and possess a wide variety of skills, including familiarity with company business processes and technical software expertise (Charles and Dawson, 2011). IT-enabled change often spans a variety of functions, business units, and/or geographic locations, which increases the challenge for change managers (Benjamin, 1993). Without a credible, inter-disciplinary background, a manager will find it difficult to address the needs of different stakeholder groups within the organization.

Over time, the people and skill sets needed often change as the change process continues. The people initially spearheading IT change within an organization typically have different interpersonal skills than those team members who are responsible for supporting the ongoing implementation of the new technology (Charles and Dawson, 2011).

*Communication with stakeholders.* While the technical benefits of implementing new IT systems and processes is often clear, many IT projects fail due to lack of attention to the "people" dimension. An important first step in any IT related change is to first assess the stakeholders involved and their likely motivations (Benjamin, 1993). Iveroth emphasizes that IT project success is enabled by the combination of social and material factors related to implementing IT change, and views technical change in four dimensions: "common ground, common meaning, common interest, and common behavior" (2011). These four dimensions address the necessity of aligning the psychology and behavior of stakeholders involved in the change.

Indeed, for IT organizational changes to be effective, IT executives need to develop close relationships with business unit managers, as business unit managers will drive the ultimate success or failure of the integration of the new technology into the business (Rockart, 1996). This requires a stronger emphasis on relationship management for IT executive skill sets (Loftin and Moosbruker, 1982).

*Institutionalizing change.* Lasting change and project success are correlated with the degree to which change management is institutionalized within the IT organization's policies and culture (Hammoud, 2008). There are many aspects of this process. First, and perhaps most importantly, IT organizations need to ensure that IT infrastructure is aligned with the broader goals of the business (Rockart, 1996), and take time to understand the link between the needs of the business and demand for IT services (Bishop, 2008). This can aid in the design of IT changes and facilitate acceptance of the changes by the rest of the organization.

IT executives must then go further. IT managers need to be able to communicate the value of the infrastructure they are building (Rockart, 1996), to help secure C-level buy-in as well as the support of business unit managers. This requires improving data collection procedures for data center infrastructure operations and server utilization (Bishop 2008), so that operational managers can translate IT infrastructure utilization into impacts on Key Performance Indicators across the organization (Chandra and Prasad, 2010). IT managers should also build a complimentary "soft infrastructure" to accompany hardware changes, providing a common source of information and processes to which all stakeholders can refer (Benjamin, 1993). Increasing the proximity of change agents and stakeholders can also contribute to the success of any change effort (Charles and Dawson, 2011).

It is likely that organizational change is needed as well to cement the gains of implementing new technology (Loftin and Moosbruker, 1982). Sapprasert and Høyvarde Clausen found that the rewards of reorganization and technical innovation are amplified when completed in concert (2012). The link between innovation and organizational change is reinforced by the work of Brynjolfsson, who argues that information technology actually enables innovation in business models and management techniques (2002, 2011).

*Systems design thinking.* In order to achieve the large improvements in data center infrastructure efficiency that have been achieved in recent years, data center designers have had to think outside the box. The Rocky Mountain Institute's "10xE Principles" provide a framework for holistic, integrated design processes aimed at improving energy efficiency. Under RMI's process, designers first identify the end-use of a particular product or building, and then optimize all pieces of the system simultaneously to facilitate that end-use, achieving stair-step improvements in efficiency in the process (RMI, 2010). Data center improvements in speed, scale, and cost can be achieved through combination of all data center hardware appliances into a single footprint (Bishop, 2008). Server virtualization has also been an important component of recent data center infrastructure technology leaps (Chandra and Prasad, 2010) (Kovar, 2004).

*eBay Inc. in context.* This study revealed many similar themes in eBay Inc.'s IT infrastructure optimization process. Managers with credibility in both technical and business functions are helping to drive change forward at eBay Inc. The eBay Inc. team is working to create institutions and communication mechanisms (such as the Digital Service Efficiency metric and show back/charge back transfer pricing) that further ingrain the value of eBay Inc.'s technical infrastructure in the rest of the organization. Managers have also worked to align data center

infrastructure with the organization's needs, redesigning the data center infrastructure in the process; this redesign process recalls system design principles in the way it examines the relationship between infrastructure, hardware, and software, and emphasizes modular data center deployment.

**Background:**

eBay Inc. went public in September 1998. Founded by Pierre Omidyar in 1995, the company created an innovative online auction marketplace for individual buyers and sellers. The company earned revenue by charging sellers a fee to list items on the site, and by collecting a commission from any sales. eBay Inc. grew year-over-year for several years after the IPO, and acquired PayPal (a major online payments company) in 2002.

In 2008, John Donahoe was named CEO (replacing Meg Whitman). Donahoe began to refocus eBay Inc. on becoming the premiere online partner for retail brick-and-mortar stores (Mangalindan, 2013). The company's current vision is to "empower consumers to buy and sell anything, anytime, anywhere" (eBay Inc., 2013). Accordingly, over the past several years the company has put more focus on buy/sell technologies for mobile phones, expanded PayPal's presence as an offline payment option, and purchased GSI Commerce (a major e-commerce platform) in 2011 (Rao, 2011).

Since 2008, Donahoe worked to transition the company from a hot start-up (characterized by rapid and unplanned growth), to a "great and enduring company, a company that will last" (Stewart, 2012). Under Donahoe's leadership, he helped to better position the company for long-term stability and operational efficiency (R. Donaldson, personal communication, June 3, 2013).

**Growing Infrastructure Efficiency Pressure**

In its original incarnation, eBay's Global Foundation Services team functioned as a shared services vendor to other eBay Inc. business units. Individual eBay Inc. units would use the team to procure and implement custom server configurations at external data centers, paid for out of the CapEx budgets of the business unit itself (S. Das, personal communication, May 21, 2013). Starting in the mid-2000s, this system began to come under pressure due to changes in four key business drivers: cost, performance, revenue, and environmental impact.

*Cost.* By 2007, data center operating costs had grown large enough to raise interest by the CFO in developing new data center efficiencies, and momentum grew at the C-level for the company to figure out how to manage the cost moving forward (R. Jain, personal communication, May 21, 2013). The infrastructure team identified a need to get ahead of demand and determine how to keep costs under control.

*Performance.* The increase in business demand following this period put increasing pressure on the Global services team to keep up with the accelerating speed and diversity of product

deployments (and corresponding demand from eBay Inc.'s business units for infrastructure services).

*Revenue.* As a cost center, the infrastructure operations team was challenged to meet increasing need for improved infrastructure performance despite budgetary pressures of growing data center expenditures.

*Environmental Impact.* In March 2009, Greenpeace launched the "Cool IT" initiative, which was aimed at encouraging leading companies to help fight climate change (Greenpeace, 2009). One aspect of this work was scoring major companies on the dirtiness of their data center infrastructure and cloud operations. Over time, awareness increased among leading technology companies that the environmental impacts of data center infrastructure needed to be addressed and managed, from both a moral and public relations perspective (J. Rodriguez, personal communication, May 21, 2013).

**Building eBay's Own Infrastructure: Project Topaz**

In order to address the pressure of growing infrastructure cost and need for increased infrastructure reliability, eBay's infrastructure team decided to diversify its data center portfolio by developing in-house data centers. In-house data centers are generally less expensive to operate than leased ones. For eBay, the difference accounted for approximately 50% of the total cost in 2004-2005 (R. Jain, personal communication, May 21, 2013), when leased data centers were facing high demand for their services and hence had high prices.

After eBay Inc. purchased two data centers in Denver in 2004 and in Phoenix in 2006, the group decided to build a new one in Salt Lake City, Utah. The construction of the Topaz data center started in 2007; it began operating in May 2010.[1] The $287 million facility was eBay Inc.'s largest infrastructure investment to date and was expected to become a flagship data center. Topaz was awarded LEED® Gold status by the US Green Building Council.

> "We have built a fault tolerant Tier IV level data center that is 50 percent less expensive to operate than the average of all other data centers we lease today," said Dean Nelson, eBay's Senior Director of Global Data Center Strategy. "It is also 30 percent more efficient than the most efficient data center in our portfolio. At a designed PUE[2] of 1.4, it lowers both our economical and ecological costs" (Nelson, 2010).

Project Topaz was an important learning platform for eBay's Infrastructure team. It was a first step toward higher resiliency, efficiency and cost effectiveness in their infrastructure development practice. The team started internal conversations about how to connect software

[1] http://datacenterpulse.org/blogs/geekism/bullet_proof.
[2] PUE (power usage effectiveness) is equal to a data center's total power consumption (including cooling and transformer losses) divided by the power used only by computing equipment. In 2011, average PUE across the industry was reported to be approximately 1.8 (Miller.

development to the infrastructure in order to ensure that software applications utilized the infrastructure in a more efficient manner.

The following six aspects of infrastructure design became central for eBay Inc.:

- Standardization: consolidation of hardware purchases into a small number of consumable stock-keeping units (SKUs)[3];
- Density: highly dense, but optimized hardware/server rack SKU configurations—each rack is designed to optimize capacity utilization of power, cooling, monitoring, network, compute and storage elements to achieve the highest transactional performance and cost performance per rack;
- Resiliency: ability of servers and the network to recover quickly and continue operating after power outages or other disasters, fault-tolerance;
- Redundancy: effective power and system back-up;
- Efficiency: maximizing power efficiency (e.g. minimizing PUE) as well as IT Load efficiency (server, storage and network utilization);
- Cost effectiveness: focus on total cost of ownership (TCO) which includes all infrastructure capital expenditure and operating expenses applied to the lifetime cost of an asset.

**Dean Nelson Arrives at eBay Inc.**

The consolidation of responsibility for the Facilities and IT expenses under one VP in 2009 was a key organizational improvement that helped align investment and budgeting decisions and develop the above goals for eBay Inc.'s infrastructure. This consolidation was also an important precondition for Dean Nelson to join the company.

Nelson began his career as an engineer at Sun Microsystems in 1989. As he rose through Sun's ranks in following years, he gained experience with software, hardware, and physical infrastructure development, eventually becoming Senior Director. In his last position, he moved from engineering to the Real Estate team, experiencing firsthand the efficiency benefits of aligning real estate purchases and infrastructure design with the hardware that would be placed in the building, and in turn aligning the hardware with the software applications that would be implemented through it.

After consulting with the eBay Inc. team in the early stages of Project Topaz throughout 2007 and 2008, Nelson became more interested in joining eBay Inc. once he learned that Facilities and Hardware were brought under one VP. "It meant that we could make some meaningful decisions and have the authority to implement them," said Nelson (personal communication, May 21, 2013). Since CapEx and OpEx budgetary responsibility for all infrastructure was under one VP, incentives were aligned to make decisions based on the total power consumption of data center buildings and hardware (e.g. the Total Cost of Ownership or TCO).

[3] SKU (Stock Keeping Unit) is discrete hardware components packaged into a custom configuration

Nelson joined eBay Inc. in September 2009 as Senior Director of Global Data Center Strategy, Architecture and Operations. Building on his past experience, Dean's goal was to connect eBay Inc.'s infrastructure productivity to the drivers of the business. The capability to trace infrastructure utilization and management to its impact on Key Performance Indicators had the potential to align individuals throughout eBay Inc.'s organization on building a more efficient infrastructure system that delivered more useful work per unit of consumption.

In order to achieve higher efficiency in data center infrastructure and operations, eBay undertook two parallel but interlocking processes: *technical and organizational optimization*. Technical optimization required the simultaneous optimization of data center facilities, hardware, and software. At the same time, changes in eBay Inc.'s IT organizational structure were needed to drive cultural change with respect to building a more efficient infrastructure system in order to take full advantage of newly implemented technologies.

**Driving Technical Optimization**

Technical Optimization was a very important goal on the way to increasing infrastructure efficiency. Since eBay Inc.'s technical achievements are not the focus of this study and have been well documented elsewhere (The Green Grid, 2012[4]), what follows is a brief summary.

Continuing the strategy to invest in its own data centers, and motivated by a projected increase in demand for data center infrastructure from a new eBay search product and data analytics, eBay Inc. launched project Mercury in 2010. The goal of the project was to construct a highly efficient and dense data center in Phoenix, Arizona, to augment the data center eBay Inc. had built in 2006. Metrics such as PUE and TCO were the driving assessment tools in the design process.

Organizational changes, described in the next section, supported optimization of engineering and procurement for the sake of lower PUE and TCO. The major technology optimization results of the project can be divided into three categories: efficiency, collaboration with vendors, and cleaner energy.

*Efficiency*. With a goal to minimize PUE, the eBay Inc. Foundation Services team wanted to develop a high-density data center that achieved better performance using less space. High-density data centers can deploy more efficient water and air management systems (operating at elevated temperatures, including hot water cooling), and use modularity in rack design (e.g., server containers on the roof) to allow for more flexibility, faster deployment and higher density. Project Mercury was also constructed with the ability to scale from 4 to 40 kW per rack, which ensures that several generations of data center hardware can replace the existing hardware while maintaining the same physical infrastructure over time (The Green Grid, 2012).

[4] http://www.thegreengrid.org/~/media/Case%20Studies/CS3-Breaking_New_Ground_on_Data_Center_Efficiency.pdf?lang=en

Beyond eBay Inc.'s innovation in facilities design, eBay Inc. also standardized types of servers used. The team realized that only two main server SKUs could substitute for the majority of other types (approximately 90 types) used before (S. Das, personal communication, May 21, 2013). Consolidation of server SKUs significantly contributed to the efficiency of the Mercury project.

*Collaboration with vendors*. As a result of standardization of server SKUs, the infrastructure team was able to develop a more efficient supply chain management organization. It was also able to collaborate closely with infrastructure suppliers in order to develop the best custom server configurations for eBay Inc.'s needs.

*Cleaner power generation.* Though project Mercury didn't involve any investment into cleaner energy, Project Quicksilver, constructed to augment project Topaz in Utah (deployed in September, 2013) utilizes Bloom Energy fuel cells that generate 6 megawatts of power at the site. Typically, fuel cells are used for backup power, but fuel cells can also provide cleaner and more reliable power (relative to the grid). Thus, eBay Inc. has chosen to use Bloom Energy's fuel cells as the primary source of energy to increase data center availability and resiliency (Lesser, 2012).

As of June 2013, eBay Inc. operates eight primary data center buildings in three different regions (Figure 1): four data centers are located in Phoenix, Arizona, including project Mercury, two data centers are in Salt Lake City, Utah (Project Topaz and a new project Quicksilver coming online in 2013) and one leased partner facility (switch) is located in Las Vegas, Nevada. There are also several other data centers in California and Colorado, but eBay Inc. currently intends to consolidate the equipment in those facilities in the Arizona, Utah, and Nevada locations. EU expansion is also underway.

**Driving Developer Agility and Clockspeed for Innovation**

While infrastructure efficiency and optimizations were necessary to drive the costs down. In 2010, Debashis Saha, Director of Platform & Systems Engineering, led the teams that delivered the core platforms that powered eBay's application. Under his leadership, eBay's Platform team looked at all aspects that slowed development and business delivery and undertook a massive project in modularizing the platform components, simplifying development processes, improving development tools and architecting the platform on top of modern open-source off-the shelf software components.


*Figure 1. eBay Inc. Data Center Portfolio as of September 2013*[5]

Debashis and the team soon recognized that providing platform agility is only part of the problem. To bring true agility, eBay Inc. needed to look at all aspects of how platforms and infrastructure are consumed by the product development teams. This would mean understanding end-to-end processes and technologies in platform and infrastructure stack,. Around the same time, JC Martin, who joined eBay Inc. as the Cloud Infrastructure Architect, embarked on a journey with Debashis's team to standardize Cloud Architecture patterns and principles forming the blueprint for eBay Inc.'s private Cloud and converged site infrastructure. The fundamental tenet of this architecture was to simplify infrastructure design, automate operational processes and standardize infrastructure deployment to enable a shared infrastructure (Wolpe, 2013) offering differentiated multi-tenant logical environments using server and network virtualization.

**Driving Organizational Alignment**

The technology change leading the company to cutting-edge innovation in data center design could not be achieved without corresponding changes in the organization in the 2009 – 2012 time frame. Before 2009 the primary goal of infrastructure improvement was "to drive the cost down" (P. Santana, personal communication, June 5, 2013), while after the Topaz project the primary goal became the "alignment of organization" in order to drive efficiency up.

Alignment of organization of the infrastructure team was achieved through consolidation of several teams and their incentives to optimize investment decisions, implementation of lean

[5] California and Colorado locations will consolidate to primary sites; EU expansion is underway

processes, standardization of technologies used, and introduction of data driven approaches to improve efficiency and asset utilization. The transformation was led from the top down and was supported by middle management, in both the hardware and software teams. The process is still ongoing.

A key factor in unlocking the efficiency potential of the eBay's new approach to data center design and hardware procurement was the partnership of eBay's Cloud Engineering Team, which came under the leadership of one VP, as did the Global Foundation Services in 2012. Under Debashis Saha, the Cloud team developed the software services and portal that eBay product developers now use to request data center infrastructure. The Cloud software provisions the majority of resources hosted in the physical data center, and provides a ubiquitous virtual layer of compute instances that powers eBay's eCommerce engine. The software also optimizes the placement and utilization of the physical and virtual servers for all compute and storage resources.

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| | 2008 | 2013 |
|---|---|---|
| **IT load, kW** | 11,461 | 31,279 |
| **Total load, incl. facilities, kW** | 22,922 | 46,919 |
| **PUE, kWh total / kWh IT load** | 2.0 | 1.5 |

*Table 1. Data center power consumption and PUE at eBay Inc. (P. Santana, personal communication, June 5, 2013). Note: PUE measures the efficiency of all eBay Inc.'s data center locations.*

The results of the reorganization effort can be measured by, for example, average PUE. It has decreased to 1.5 from 2 in the last 5 years (Table 1), ending in 2013. This is all the more impressive when one considers that the total infrastructure electricity load more than doubled in the same time frame; further, this infrastructure helped enable approximately $175 billion in global commerce in 2012 across all of eBay Inc.'s divisions (eBay Marketplaces, PayPal, Enterprise, etc.). The following overview of the organizational changes highlights the milestones and the corresponding benefits of the organizational transition that led to such results (See Exhibit 2 for a complete timeline of organizational changes).

**Consolidation of Facilities and IT Hardware groups under one VP (2009).** This step was key for eBay Inc. to achieve its goal of bringing data center infrastructure and management in-house. As Paul Santana, the Director of Data Center Operations, stated: "Unique to eBay, our operations group has been already running all decisions regarding data center infrastructure since the company launch, while in most companies, data centers are managed by the real estate group" (personal communication, June 5, 2013). Consolidation of Facilities and Hardware within such an organization allowed "alignment of

demand for three key deliverables: data center infrastructure, space, and disaster recovery."[6] As a result of the consolidation, capital expenditure decisions were centralized leading to improvement in data center design and server procurement process.

**Start of Project Mercury (started in 2010, deployed in 2011).** Project Mercury, also described above in the Technology Innovation section, used advanced technological, organizational, and business techniques to create a highly efficient data center in Phoenix (The Green Grid, 2012). Mercury was eBay Inc.'s first data center "designed around the principle of density" (P. Santana, personal communication, June 5, 2013), one of eBay Inc.'s main principles for technological requirements developed during the Topaz project. High-density deployments at Mercury featured a revised strategy of operating data centers at elevated temperatures, including hot water cooling, and deployment of server containers on the roof of the center (Miller, 2012). From an organizational standpoint, Project Mercury was also a platform for improving the operational practices of the Global Foundation Services team.

**Formation of the Cloud Engineering Team (October 2010).** As product developers around the organization were demanding more agility from operations in delivering data center infrastructure (D. Saha, personal communication, August 1, 2013), there were multiple efforts underway to automate eBay Inc.'s infrastructure and operations, the teams still operated in relative isolation from the Platform teams. In 2010 Debashis Saha, head of eBay's Platform Engineering and primarily focused on platform frameworks and developer tools, started to focus on automation across both platforms and infrastructure components to deliver end to end automation, full self-service and cloud-enabled infrastructure and "application pools" for eBay developers. The Cloud Engineering team, under Debashis was formed to address this problem by developing eBay's internal private Cloud (Stratus) to be used for virtualizing and automating server/application provisioning. Note that at this time, the Cloud Engineering Team still reported to a different VP from the Global Foundation Services Team.

**Project for consolidation of server SKUs (Spring 2011).** Jeremy Rodriguez and his team (brought on board by Dean Nelson) formed and led a "virtual team" (P. Santana, personal communication, June 5, 2013) of hardware and software engineers that set a goal to greatly improve the server procurement process. In early 2011, this team started a project to consolidate server SKUs ordered by eBay Inc. business units for use in data centers and cut this number from approximately 90 SKUs down to 2 (S. Das, personal communication, May 21, 2013). At that time, eBay Inc. was about to purchase close to 10,000 servers for its multiple sources (tech refreshes, search, big data) The consolidation initiative used those projects to calculate "total cost of ownership for density" (P. Santana, personal communication, June 5, 2013).

[6] Disaster recovery (DR) is the process, policies and procedures that are related to preparing for recovery or continuation of technology infrastructure which are vital to an organization after a natural or human-induced disaster (Abram, 2012)

Server SKU consolidation created considerable benefits for eBay Inc. First, together with the platform engineering team (a software engineering team), the Global Foundation Services team showed a significant potential in cutting cost and improving efficiency by focusing on the two most used types of servers. This in turn allowed deployment of modular server units and stronger collaboration with server vendors to create the highly dense, customized infrastructure purchased for Mercury (mainly, Dell and HP). Second, the virtual team led by Jeremy Rodriguez became a real team (called the Hardware Engineering Team—see discussion below), therefore institutionalizing the process of coordinating hardware with software needs. Finally, the collaboration between software and hardware engineers had a cultural impact on the eBay Inc. infrastructure group, an organization accustomed to a cultural divide between the operations organization and software developers. Rodriguez noted that the culture started to change as the teams began a transition from an "over the wall" mindset to a more collaborative relationships (personal communication, May 21, 2013).

**Creation of the Hardware Engineering Team (Fall 2011)**. Transition from a "virtual" to a "real" Hardware Engineering Team based on consolidation of server SKUs institutionalized and simplified forecasting, planning, and budgeting processes for hardware procurement and provisioning. Prior to the server SKUs consolidation project, most engineering teams had their own budget; after the consolidation project and the foundation of the Hardware Engineering Team, eBay Inc. transitioned to a budgeting system where all server CapEx was concentrated in Global Foundation Services. The Hardware Engineering team then became responsible for developing a product development road map in consultation with the Cloud Engineering team and the eBay Inc. Systems Lab, collecting infrastructure/server requests from all of eBay Inc.'s product development teams, and translating that demand into procurement and provisioning.

Internally, this change has been seen as a transition from a "sit-down restaurant style" type of sourcing with long lead times to create custom server configurations to a "buffet style" system where product developers have access to standard server configurations on demand (S. Das, personal communication, May 21, 2013; P. Santana, personal communication, June 5, 2013). Such centralization has the advantages of faster fulfillment and "warm cache" capability. However, demand forecasting difficulty (and hence, budgeting) for the Foundation Services team. Some of the projects that followed were begun to cope with these challenges.

**Creation of the Supply Chain Management Organization (Fall 2011)**. After getting "true control of the budget" under the Hardware Engineering Team, supply chain management was centralized under a corresponding team led by Sudip Das. Optimization of the supply chain organization and purchasing servers in bulk gave eBay Inc. leverage in vendor relationships, including the ability to demand precise performance per watt expectations (per the Hardware Engineering Team), cost of ownership metrics from vendors, negotiate cost savings through bulk pricing, and influence order lead times. Such a group was

"required for scalability" going forward (P. Santana, personal communication, June 5, 2013). The standardization of SKUs also allowed Das and his team to apply classic inventory management techniques to approach the ideal of maintaining "warm cache" of servers, ready to be deployed as soon as a product development team requested them.

**Consolidation of Platform, Infrastructure, and Engineering (PIE) under one VP (Sri Shivananda, Spring 2012)**. Consolidation of facilities, hardware, and platform software teams into PIE has been the "fastest move toward organizational alignment" (P. Santana, personal communication, June 5, 2013). Operational excellence is the core of this transition. Stratus (eBay Cloud), Project Linnaeus and the Digital Service Efficiency initiative (discussed below) have been the headline projects further contributing to organizational alignment.

As a major component of this consolidation, the Cloud Engineering team (that automated the provisioning and management of servers) and Infrastructure Operations teams (that operated and managed the servers) were combined to create a unified Cloud Engineering & Operations team under the leadership of Debashis Saha. This team and Global Foundation Services under Dean Nelson, now reported to the same VP of PIE and were jointly responsible for delivering highly efficient and agile infrastructure to all teams that needed infrastructure resources at eBay Inc. This solidified the position of the Cloud as the software and management layer fulfilling self-service on-demand infrastructure requests from product developers, by automating the provisioning of computing resources hosted in the physical data centers. In a significant process and paradigm shift, product developers interacted with the software stack, instead of dealing with hardware and procurement teams. As a result, the Cloud Engineering Team became Global Foundation Services' primary "client". The Cloud team now provisioned the servers, operated the Cloud and the instances managed by the Cloud. The Cloud team also assumed responsibility for optimizing server utilization, which was accomplished through Stratus APIs. Stratus was now eBay's fully functional and centrally managed private Cloud, automating server provisioning and server virtualization. This was the tipping point in creating "Infrastructure on Demand" for eBay Inc. product developers, which led to gains in productivity due to faster delivery of infrastructure resources.

**Cloud Engineering aligns with Global Foundation Services to deliver Infrastructure On-Demand (Fall 2012).** Building on the promise of more efficiency through the virtualization of infrastructure requests, and taking advantage of the opportunity created by the SKU consolidation project, Debashis and Dean realized that the true power of the infrastructure will come from providing a seamless layer of physical infrastructure that can be logically managed and utilized by a software plane. Debashis increased collaboration between Cloud Engineering and Global Foundation services to ensure strong alignment between development of the Cloud and procurement and provisioning of server hardware.

**Project Linnaeus (Winter 2012)**. Project Linnaeus is a cross functional team consisting of GFS and Cloud Engineering leaders with cooperation from all other platform teams. It is a

great example of the success of the PIE consolidation. With a goal "to optimize the asset inventory and allocation data" (P. Santana, personal communication, June 5, 2013), the team implemented a program to continuously identify and assign the correct state to assets (e.g. server is faulty, server is serving traffic, server is in a cache, etc.). As a result, the Project Linnaeus team discovered unused and orphaned assets that led to millions of dollars in cost avoidance, decreasing overall eBay server count. The next step in this program, which is currently underway, is to increase the asset utilization by functional group. Project Linnaeus is one of the knobs being turned to drive the overall productivity of the eBay system, or engine. This engine is being measured by eBay's new Digital Service Efficiency metric.

**Development of Digital Service Efficiency (DSE) (2010-13).** Dean Nelson and his team began the development of the DSE in 2010, releasing the concept to the public in early 2013. The belief is DSE is the next step to align the organization to achieve optimal infrastructure system performance. DSE is a "miles per gallon" measurement of technical infrastructure that "makes an end-to-end connection between what customers do and the fundamental business metrics, including cost, performance, environmental impact, and revenue" (eBay, March 2013). In other words, DSE provides a detailed metric that measures efficiency of infrastructure utilization using an understanding of capacity ownership, operational processes and business metrics. The DSE metric of cost per transaction (URL), for example, shows how the company is doing relative to its past performance and how different product development groups vary in terms of their consumption of IT capacity as this relates to subsequent business results.

Since DSE measures how the overall system performs regardless of how it is designed or operated, the different constituents of those designs and operations will need to adjust accordingly. Facilities, hardware, and software designs coupled with process optimizations are "knobs"[7] that can fine-tune the overall performance of eBay's infrastructure system. Eventually, the vision is that the individuals in each functional group will have a responsibility to the overall performance and efficiency of how eBay's customers "drive" their engine, as measured by DSE.

In order to develop the DSE metric, a special team was formed with members from the Global Foundation Services team, Results Reporting, and the Sustainability office. After months of data analysis, including the interim results of Project Linnaeus, and joint meetings with operations support teams, Cloud development teams and platform developers, who were already a part of the PIE structure under Sri Shivananda, the team released its first DSE results[8] in the beginning of 2013.

[7] More specific examples of "knobs" include data center efficiency implementations, hardware SKU selections, supply chain optimization, software tuning, asset allocation cleanup, and many more.
[8] http://dse.eBay Inc..com/

DSE tracks infrastructure productivity to corporate level KPI metrics. It is a top level tracking mechanism to look back on quarterly performance of aggregated technical and organizational changes versus a leading indicator to help direct the effectiveness of internal projects. Like any cultural change, adoption and use of the metric will take time, especially at lower levels in the organization. Currently, a key win for the DSE metric is that a standardized, holistic measurement capable of trending performance quarter over quarter and year over year regardless of technology, process, business or leadership changes, will show the results of eBay Inc.'s business decisions. The "DSE team has the necessary data to generate DSE visibility at a business unit and functional group level. Now they need to figure out the reporting mechanism, put the logic in place to aggregate it and automate the calculations" (S. Das, personal communication, May 21, 2013); in other words, the goal is to calculate and track DSE metrics for the business unit or even product level to hold groups accountable for the results of their infrastructure and software implementations in terms of cost, performance, environmental impact and revenue per URL. When this level of tracking and reporting is achieved, it will change DSE from a "look-back" on quarterly performance to a prospective analysis tool for assessing the business value of new strategic initiatives.

As we mentioned in the Literature review, in order to be effective, it is key for IT executives to align incentives with business unit managers (Rockart, 1996). DSE is a good example of how IT and business executives can use data-driven approach to start the conversation.

There are two distinct ultimate goals of DSE for eBay:

- **Provide information to product developers about the infrastructure costs of their programming/operating decisions.** This system is internally called a show-back/charge-back. "Show-back is a reporting mechanism to expose the costs of infrastructure to the consumers of that infrastructure, i.e. the business unit managers" (R. Donaldson, personal communication, June 3, 2013). Eventually the show-back will become a true charge-back to the business units, to cover eBay Inc. Inc. infrastructure costs. Under this system, less efficient business units will pay more, more efficient business units will pay less. DSE is the next level linking those costs to the other business level efficiency and productivity KPIs – URLs per kWh, cost per URL, $CO_2e$ per URL and ultimately revenue per URL;
- **Behavioral and cultural change in the organization.** "DSE frees [eBay Inc.] from the cost center mindset" (S. Das, personal communication, May 21, 2013). Once the DSE is implemented and adopted at all levels of the organization, the productivity of the infrastructure will continuously improve. DSE will help business unit managers reach into their respective organizations to gain operational and cost efficiencies and hold their teams accountable for efficiency and productivity.

In the first quarter of 2013, eBay released the 2012 DSE baseline numbers. Shortly after, the VP of PIE, Sri Shivananda, drove deeper data analysis for the Q1 2013 Year over

Year results release. His intimate knowledge of overall architecture (including platform and infrastructure layers) coupled with improvements in data collection and reporting systems were instrumental in fine-tuning the data gathering and analysis process to produce solid results. With this improvement in data analysis, Shivananda then had the data in hand to launch strategic initiatives like halting server orders in Q2 to force an increase in utilization. This executive level engagement is important to amplify the effectiveness and impact of DSE throughout eBay.

**The Future of eBay Inc.'s Infrastructure Optimization Efforts**

eBay Inc. has achieved a great deal of innovation in the past five years, but more work lies ahead to complete the transition of shared infrastructure from a corporate cost center to full incorporation into each business unit's operating expenditures.

The following three steps will be important for eBay Inc. in the near future:

1. *Continue to improve data collection and server utilization measurement procedures.* Project Linnaeus will reconcile historic records of server ownership while the capacity team institutes transparent and fair procedures to measure infrastructure utilization going forward. This will uncover further efficiency potential by both empowering product developers to utilize their dedicated resources more effectively and holding them accountable for those decisions.

2. *Utilize cultural transition to add efficient infrastructure utilization to software/product design goals.* Although the C-suite supports the effort to integrate infrastructure, hardware, and software design, this support should continue to be communicated to the business unit teams in order to realize the value of these efforts.

3. *Incorporate infrastructure productivity measurements into incentive/cost structure to further behavioral change.* eBay Inc. is working to complete development of the show-back in order to transition it to a full charge-back (i.e. internal transfer price for infrastructure services charged to each business unit). The advent of the show-back will give insight into the inefficiencies of infrastructure consumption by leader, team and individuals, subsequently motivating them to drive more efficiency. Aspects of DSE could also be incorporated into individual and/or business unit level KPIs so that performance, or productivity, is tied explicitly to efficiency (Democratization of DSE).

**Key Recommendations for Other Companies**

eBay Inc.'s experience with infrastructure optimization provides an important model for other companies looking to facilitate similar efficiency gains, cost decreases, and performance improvements.

***Find a champion.*** After eBay Inc. consolidated Facilities and IT expenses under one VP prior to 2009, committed individuals with the vision to connect infrastructure management to business

KPIs and the ability to communicate were able to champion this vision to others throughout the organization to achieve results. Over past five years, the drive to improve efficiency and overall productivity has remained constant. Dean Nelson's Global Foundation Services team has led infrastructure improvements that resulted in a 54% reduction in the cost per megawatt over 4 years. Under Debashis' leadership, eBay Inc.'s Stratus Cloud serves 90% of site traffic today and the time to provision servers and application pools have dropped from months to minutes over the same period. Cloud Development and Operations Engineering teams have set an example of how adopting a "DevOps" culture can drive significant business agility. The development of the DSE metric took this to a new level, providing visibility into the overall performance of the eBay.com system that was understandable and actionable by the top executives in the company.

***Secure the support of the C-Suite.*** eBay Inc.'s efficiency achievements in technical infrastructure deployment may not have been possible without the evolution of the "business model" of eBay Inc.'s infrastructure operations team and the development of the cloud layer to speed server provisioning, increase productivity and optimize capacity usage; in turn, the implementation of these changes would not have been possible without C-Suite buy-in. In eBay Inc.'s case, the effort to optimize the company's technical infrastructure dovetailed neatly with CEO Donahoe's interest in building company operations and processes towards a goal of mature, stable growth over time.

***Map infrastructure utilization to the business.*** Development of the Cloud layer to collect and organize the data on infrastructure consumption and utilization was a difficult process for eBay Inc. that continues to be refined today—but it was and remains key to the company's infrastructure optimization efforts. While eBay Inc. faces many data collection challenges, the process itself helped to develop common goals and provided an initial forum for collaboration between the infrastructure, hardware, and software teams of the organization.

Further, the mapping procedure is essential in order to hold product development and operations teams accountable for their use of company resources. Without accurate information about how servers are currently being used, it is difficult to communicate the consequences of operational decisions and software design decisions to business unit managers and provide incentives to move infrastructure utilization metrics in the right direction.

***Win the hearts and minds of the rank and file.*** In addition to the executive office, achieving and sustaining improvements in infrastructure efficiency requires the buy-in of all members of the organization. In eBay Inc.'s case, the Global Foundation Services team can only take efficiency so far. Once a data center is consistently able to achieve a PUE close to one, then the only major avenue left is to attack the "one" itself, by reducing the energy required for the code running on the servers to complete its computation (J. Rodriguez, personal communication, May 21, 2013). This requires a partnership between the Foundation team and Cloud Engineering Team to build an infrastructure system that enables developers to use resources more efficiently. It also requires the commitment of business unit managers to build more efficient

products. An internal education campaign around these key pillars would be helpful to encourage this commitment.

***Optimize all pieces of the system simultaneously.*** Amory Lovins of the Rocky Mountain Institute wrote that "Optimizing components in isolation tends to pessimize the whole system--and hence the bottom line." One key secret of eBay Inc.'s success was its goal to simultaneously optimize data center facilities, hardware, and the cloud layer. Making sure that the hardware was aligned with the needs of platform/cloud developers, and that hardware could be deployed and cooled efficiently in data center facilities led to rapid infrastructure efficiency improvement and cost reductions.

**Conclusion**

The eBay Inc. journey from a "hot start-up" to a mature company has been accompanied by the transformative change of the internal infrastructure organization. The authors conducted 11 interviews with team members of the Platform, Infrastructure and Engineering team at eBay Inc. to understand what drove the change in the data center infrastructure, what factors defined success, how the organizational culture of the internal infrastructure evolved following the changes, and what steps are key to institutionalize the processes focusing on efficiency in the future. In order to develop highly efficient data centers to support the growth of its business, eBay Inc. consolidated its data center portfolio, invested in technology innovation and aligned its internal infrastructure teams and processes in the organization towards efficiency and business drivers. The key success factors are committed leaders driving the transformation, support of the executive team, individual accountability to infrastructure efficiency, constant communication and collaboration throughout all layers of the organization, and alignment of the technical infrastructure with business value.

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**Exhibit 1: Interview Subjects/Dates**

- Dean Nelson – VP, Global Foundation Services. *Interviewed May 21, 2013 and June 3, 2013.*
- Debashis Saha – Senior Director, Compute & Data Infrastructure. *Interviewed August 1, 2013*
- Rohini Jain – Marketplaces Technology Finance Lead. *Interviewed May 21, 2013.*
- Paul Santana – Director, Data Center Operations. *Interviewed June 5, 2013.*
- Richard Donaldson – Director, Global Managed Services. *Interviewed June 3, 2013.*
- Jeremy Rodriguez – Senior Manager, Hardware Engineering. *Interviewed May 21, 2013.*
- Serena DeVito – Advanced Data Center Engineer. *Interviewed May 21, 2013.*
- Sudip Das – Senior Manager, Asset Supply Management. *Interviewed May 21, 3013.*
- Randall Newcomb – Manager, Infrastructure Analytics. *Interviewed May 20, 2013.*
- Kyle Richardson – Business Systems Analyst. *Interviewed May 20, 2013.*

**Exhibit 2. Organizational Transition Timeline**

| | |
|---|---|
| **2009** | • Facilities and Hardware brought under one VP. Power bill and CapEx control centralized<br>• Dean Nelson hired to head Data Center operations |
| **2010** | • Project Topaz (launched in 2007) commissioned: focus on resiliency and efficiency<br>• Start of the Project Mercury: Focus on dense modular data center design to enable uber-efficiency; PUE and TCO a focus of the RFP process<br>• Cloud Engineering Team is formed<br>• Formal development of DSE initiated |
| **2011** | • Consolidation of server SKUs from ~90 to 2, development of modular/flexible server units<br>• Cloud engineering increases collaboration with Hardware Engineering; Cloud team developed the software services and portal that eBay Inc. product developers now use to request data center infrastructure<br>• Hardware Engineering Team formed<br>• Supply Chain Management Organization formed (under Sudip Das)<br>• Data center operations transition from "sit-down" (customized servers) to "buffet" (with access to standard server configurations) style service |
| **2012** | • Platform, Infrastructure, and Engineering consolidated under one VP, Sri Shivananda<br>• Increased collaboration between Cloud Engineering and Global Foundation services to ensure strong alignment between development of the Cloud and procurement and provisioning of server hardware<br>• Development of DSE, base-lining begins<br>• Project Linnaeus initiated to clean up data/server ownership<br>• Development of show back/charge back begins with Richard Donaldson |
| **2013** | • External DSE release, goals for 2013 announced<br>• Second external DSE release, Q1 2013 results, re-baseline of historic data<br>• Third external DSE release, Q2 2013 results, exceeding 10% net gain goal two quarters early |

**Exhibit 3. Organizational Chart**