Executive Overview

To better meet Intel’s business requirements while providing our internal customers with optimal data center infrastructure capabilities and innovative business services, Intel IT has overhauled our data center strategy. Our data center transformation strategy is to run Intel data center services like a factory, affecting change in a disciplined manner and applying breakthrough technologies, solutions, and processes.

We use three key metrics to measure data center transformation success: meet growing customer demand (service-level agreements and quality of service) within constrained spending targets (cost-competitiveness) while optimally increasing the utilization of infrastructure assets (operational efficiency).

Building on previous investments and techniques, our refined data center strategy has created new business value in excess of USD 321 million from 2010 to date. Our key achievements include the following:

• We developed a system software capability called NUMA-Booster, which has delivered additional server capacity.
• We deployed more than 13,000 Intel® Solid-State Drives as “fast swap” drives, which generated a 27-percent increase in server capacity.
• Five generations of high-performance computing in our Design computing environment created a 90x capacity increase and a 64x quality improvement.
• We adopted new storage capabilities, accelerated storage refresh, and focused on increasing utilization, resulting in cost avoidance.
• We deployed more than 65,000 10 gigabit-per-second network ports.
• An integrated server and network infrastructure provided a 39-percent reduction in hardware across the enterprise.
Over the 2016–2018 time frame, we plan to extend the data center strategy to continue to transform our data center infrastructure. We will do so by using disruptive server, storage, network, and data center facility technologies that can lead to unprecedented quality-of-service levels and total cost of ownership reduction for business applications—all while continuing to improve IT operational efficiency.

Our data center transformation strategy is key for Intel IT to stay competitive, compared to public cloud services. Implementing breakthrough solutions and pursuing aggressive goals are critical factors to success in this transformation.

Background

Intel IT operates 60 data centers housing approximately 145,000 servers that underpin the computing needs of more than 105,000 employees. To support the business needs of Intel's critical business functions—Design, Office, Manufacturing, Enterprise, and Services (DOMES)—while operating our data centers as efficiently as possible, Intel IT has engaged in a multi-year evolution of our data center strategy, as outlined in Table 1.

Table 1. Intel’s Data Center Strategy is a Continuous Improvement Process

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No central strategy or ownership</td>
<td>Standardization and Cost Control</td>
<td>Foundation for Efficient Growth</td>
<td>Transform Business Capabilities</td>
<td>Focus on Resource and Energy Efficiency</td>
</tr>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>Began RISC migration</td>
<td>Formed data center team</td>
<td>Business-focused investments for DOMES</td>
<td>Holistic TCO assessment of IaaS, including facilities, server, storage, network, OS, and middleware software capabilities</td>
<td>Centralize batch computing capacity in two mega-hubs</td>
</tr>
<tr>
<td></td>
<td>Built data centers to support acquisitions</td>
<td>Began data center consolidation efforts</td>
<td>Proactive server and infrastructure refresh</td>
<td>Introduction of data center MOR to drive practically achievable performance at peak efficiency and at the lowest cost</td>
<td>Combine high-frequency servers and optimal workloads for platform pairings</td>
</tr>
<tr>
<td></td>
<td>Decentralized procurement and management</td>
<td>Completed RISC to Intel® architecture migration in Design</td>
<td>Virtualization and enterprise private cloud</td>
<td>Unit costing model to plan improvement targets and benchmark among industry peers and external cloud providers</td>
<td>Centralized management of servers and resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standardized data center designs</td>
<td>Storage optimization and IT sustainability</td>
<td>Data center pulse dashboard for comprehensive state of IaaS capacity and utilization to enable future planning and current improvements</td>
<td>Convert older wafer fabrication facilities into data centers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Custom rack design to optimize space, compute and power density</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Environmental sustainability – either free-air cooling or evaporative cooling-tower water to condition the data centers</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>State-of-the-art electrical density and distribution system</td>
</tr>
</tbody>
</table>

1 To define “data center,” Intel uses IDC’s data center size classification: “any room greater than 100 square feet that houses servers and other infrastructure components.”
Meeting Compute Environment Challenges

In the past, we focused our data center investments on improving IT infrastructure as a means to deliver a foundation for the efficient growth of Intel's business. Our primary goal was cost reduction through data center efficiency and infrastructure simplification while reducing energy consumption and our carbon dioxide footprint to improve IT sustainability.

Over the last several years, we have reduced data center energy consumption and greenhouse gas emissions, while at the same time meeting the constantly increasing demand for data center resources. We anticipate these growth rates to continue or even increase further:

- 30 to 40 percent annual growth in compute capacity requirements
- 35 to 40 percent annual growth in storage needs
- 30 to 40 percent annual growth in demand for network capacity

To address these challenges without negatively impacting service delivery, we developed and continue to rely on a number of established industry best practices in all areas of our data center investment portfolio—servers, storage, networking, and facility innovation. Since 2006, these techniques, which are described in detail later in this paper, have enabled us to realize hundreds of millions of U.S. dollars (USD) in cost savings while supporting dramatic growth.

Aligning Data Center Investments with Business Needs

We have learned that a one-size-fits-all architecture is not the best approach for our unique business functions. After working closely with business leaders to understand their requirements, we chose to invest in vertically integrated architecture solutions that meet the specific needs of individual business functions.

Design

Design engineers run more than 55 million compute-intensive batch jobs every week. Each job can potentially take several hours to complete. In addition, interactive Design applications are sensitive to high latencies caused by hosting these applications on remote servers. We have used several approaches in our Design computing data centers to provide enough compute capacity and performance to support requirements, including high-performance computing (HPC), grid computing, clustered local workstation computing, using solid-state drives (SSDs) as fast-swap drives, single-socket servers, and a specialized algorithm that increases the performance of the heaviest Design workloads. Together, these investments enabled Design engineers to run up to 49 percent more jobs on the same compute capacity—which equates to faster design and time to market.

Because Design engineers need to access Design data frequently and quickly, we did not simply choose the least expensive storage method for this environment. Instead, we have invested in clustered and higher performance scale-out, network-attached storage (NAS) in combination with highly scalable parallel storage for our HPC needs. We use storage area networks (SANs) for specific storage needs such as databases.

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1 Intel uses grid computing for silicon design and tapeout functions. Intel's compute grid represents thousands of interconnected compute servers, accessed through clustering and job scheduling software. Additionally, Intel's tapeout environment uses an HPC approach, which optimizes all key components such as servers, storage, network, OS, applications, and monitoring capabilities cohesively for overall performance, reliability, and throughput benefits. For more information on HPC at Intel, refer to "High-Performance Computing for Silicon Design," Intel Corp., December 2015.
Manufacturing
IT systems must be available 24/7 in Intel’s manufacturing environment, so we use dedicated data centers for factories. We have invested heavily over the last few years to develop a robust business continuity plan that keeps factories running even in the case of a catastrophic data center failure. These efforts have paid off, and we have not experienced factory downtime related to data center facilities since 2009.

In our manufacturing environment, we pursue a methodical, proven infrastructure deployment approach to support high reliability and rapid implementation. This “copy-exact” approach deploys new solutions in a single factory first and, once successfully deployed, we copy that implementation across other factory environments. This approach reduces the time needed to upgrade the infrastructure that supports new process technologies—thereby accelerating time to market for Intel® products. The copy-exact methodology allows for rapid deployment of new platforms and applications throughout the manufacturing environment, enabling us to meet a 13-week infrastructure deployment goal 95 percent of the time—compared to less than 50 percent without using copy-exact methodology.

Office, Enterprise, and Services
To improve IT agility and the business velocity of our private enterprise cloud, we have implemented an on-demand self-service model, which has reduced the time to provision servers from three months to on-demand provisioning. We have achieved virtualization of 90 percent of OS instances in our Office and Enterprise environment, up from 12 percent in 2010.

In contrast to the Design environment, in the Office, Enterprise, and Services environments we rely primarily on SAN storage, with limited NAS storage for file-based data sharing.

Unique Elements of Our Data Center Strategy
Our transformational data center strategy is to run Intel data centers and all underlying infrastructure as if they were factories, with a disciplined approach to change management. By applying breakthrough technologies, solutions, and processes, we can lead the industry and keep up with the accelerating pace of Intel’s business.

We have realized hundreds of millions of USD in cost savings since 2006 by proactively refreshing our infrastructure, adopting cloud computing, updating our network, pursuing IT sustainability, and consolidating data centers. In addition, we have supported business growth and capability improvements by deploying unique solutions that benefit Intel’s critical business functions—DOMES. We have enhanced our strategy to include several new elements (as detailed in subsequent sections):

• **Key performance indicators (KPIs).** We have implemented three KPIs and have established goals for each of them:
  – Quality of service (QoS), using a tiered approach to service-level agreements (SLAs)
  – Cost efficiency
  – Effective utilization of assets and capacity
Based on improvements each year in technologies, solutions, and processes, we identify the best achievable SLA, the lowest achievable cost, and the highest achievable resource utilization. We call this combination the model of record (MOR) for that year. We set investment priorities based on these KPIs to move toward the MOR goal; each year we are getting closer to the MOR while at the same time balancing the three vectors.

- **Investment decision model.** Focusing on the MOR and comparing current data center capabilities to the best achievable KPIs enables us to prioritize our investment decisions. This approach seeks to remove the conventional improvement mindset, which focuses only on incremental improvements. Instead, we are transforming our capabilities by identifying further groundbreaking innovations—like those already used to implement our private cloud and our highly efficient silicon design computing grid.

- **Unit-costing financial model.** By identifying metrics for improvements in each DOMES area, we can benchmark ourselves and further prioritize our investments.

We believe our new approach to data center costing and investment evaluation, along with a continued focus on meeting business needs, has stimulated a bolder approach to continuous innovation. Our efforts have improved the quality, velocity, and efficiency of Intel IT’s business services, creating a sustained competitive advantage for Intel’s business. For details, see “Results: Building on the Past, Building for the Future.”

### Defining Key Performance Indicators and Goals

The KPIs provide a means to measure the effectiveness of data center investments. Because the service output for each business function is different, we evaluate each business function separately. In our data center investment decisions, we seek to balance and meet all business requirements while optimizing the KPIs.

#### Quality of Service

We use a tiered approach to SLAs, tailored to each business function’s sensitivity to performance, uptime, mean time to repair (MTTR), and cost. Our goal for this KPI is to meet specific performance-to-SLA requirements for defined tiering levels. For example, for our most mission-critical applications, we aim for a higher performance to SLA than for second-tier applications, which are less critical. The end goal and true measure of IT QoS is zero business impact from IT issues.
Effective Resource Utilization
Our refined data center strategy represents a dramatic shift in how we view resource utilization. Historically, we measured utilization of IT assets—compute, storage, network, and facilities—by simply determining how busy or loaded an asset was. For example, if a server was working at peak capacity 90 percent of the time, we considered it 90-percent utilized. If 80 percent of available storage was allocated, we considered that 80-percent utilization.

In contrast, we now focus on the actual output of an asset—that is, effective utilization. For example, if Intel’s design engineers start one million design jobs—thereby keeping the servers very busy—but a third of those jobs terminate before completion because there was not enough storage available, that is low effective utilization of compute capacity—only 66 percent. Or, if a customer consumes only 4 GB of a 10-GB storage allocation, the remaining 6 GB is essentially wasted storage—even though it is allocated—and does not represent effective utilization of this asset. Our goal for the effective utilization KPI is to achieve 80 percent effective utilization of all IT assets.

Cost per Service Unit
As shown in Table 2, different business functions have a different service unit that we can measure. This unit represents the capacity we enable for our business users.

Our goal for this KPI is to achieve a 10-percent improvement in data center cost efficiency every year. This goal does not necessarily mean we will spend less each year, but rather that we will get more for each dollar we spend. For example, we may spend less for the same number of service units, or we may spend the same amount but get more service output.

Stimulating Bold Innovation through a New Investment Model
Building on a time-tested methodology that has proven successful in Intel’s manufacturing environment over multiple process technology generations, we adopted a new data center investment decision model that compares current data center capabilities to a “best achievable model” that guides us to make investments with the highest impact.

Previously, Intel data center planning teams looked at existing capabilities and funding to establish a plan of record. This plan drove incremental improvements in our existing capabilities; our goal was to minimize total cost of ownership (TCO) and deliver positive return on investment (ROI).

In contrast, the MOR ignores the constraints imposed by what we have today. Instead, it identifies the minimum amount of resources we should ideally have to support business objectives—thereby establishing an optimal state with available technology.

<table>
<thead>
<tr>
<th>Function</th>
<th>Service Unit</th>
</tr>
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<tbody>
<tr>
<td>Design</td>
<td>Cost per EDA-MIPS</td>
</tr>
<tr>
<td>Office, Enterprise, and</td>
<td>Cost per OS instance</td>
</tr>
<tr>
<td>Services</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Cost per integrated factory compute environment</td>
</tr>
</tbody>
</table>
By setting a standard of maximum achievable performance, the new model enables us to:

- Determine which investments will have the highest ROI.
- Identify the benefits of using disruptive infrastructure technologies and breakthrough approaches that deliver more optimal data center solutions across all aspects of our infrastructure.
- Make data center location decisions, including identifying potential data centers to consolidate, upgrade, or close.

The new model focuses limited available resources in specific areas for maximum holistic gain.

As shown in Figure 1, because technology is always changing, peak performance also changes—the maximum achievable performance keeps on getting better through innovation. We know that resource constraints make it impossible to ever actually achieve the standard set by the new investment model—although our HPC environment comes very close to that goal. However, the model enables us to identify gaps between where we are and where we would like to be. We can then identify the biggest gaps in capability to prioritize our budget allocation toward the highest value investments first.

Implementing a New Unit-Cost Financial Model

We evolved our financial model from project- and component-based accounting to a more holistic unit-costing model. For example, we previously used a “break/fix” approach to data center retrofits. We would upgrade a data center facility or a portion of the facility in isolation, looking only at the project costs and the expected ROI of that investment, with no holistic view as to the impact of service unit output. In contrast, today we focus on TCO per service unit—using the entire data center cost stack per unit of service delivered. This cost stack includes all cost elements associated with delivering business services and now considers the worldwide view of all data centers in the assessment of our investments.

As shown in Figure 2, there are six major categories of cost to consider: network, headcount, servers, facilities, OS and management, and storage and backup and recovery. By adding these costs and then dividing by the total number of appropriate service units for the environment, we arrive at a cost per service unit.

Service-based unit costing enables us to benchmark ourselves and prioritize data center investments. Determining service-based unit costs also allows us to measure and compare the performance of individual data centers to each other, identifying which are underperforming and giving us the tools to decide whether to upgrade or consolidate underperforming data centers.
To show how the new unit-based costing model works, Figure 3 compares Design cost data and Office, Enterprise, and Services cost data. The headcount category accounts for a greater percentage of total cost in Office, Enterprise, and Services than it does in Design; in contrast, servers are more of a cost factor in Design than they are in Office, Enterprise, and Services. Knowing our exact unit cost in each environment, as well as the breakdown of that cost, enables us to develop optimized solutions for each environment that will have the greatest effect on cost efficiency and ROI.

Results: Building on the Past, Building for the Future

This section provides details on some of the improvements and cost savings our data center strategy has enabled over the years. We are building on the success we have already achieved through our data center initiatives over the last decade. Therefore, some of the results shown here are cumulative; others have been achieved over the last three years and are a direct result of our new MOR strategy. Our refined data center strategy will enable us to support the growth of Intel’s customers, products, and acquisitions, as well as enhance the quality, velocity, and efficiency of the services we offer to Intel business groups.

Cumulative Results from 2003 to 2015

During the last decade, we have dramatically improved performance and reduced costs for our data centers (Table 3).

Data Center-Wide Improvements

We have improved the performance and cost efficiency of our data centers as a whole.

Smaller Total Data Center Footprint

Figure 4 shows how we have consolidated our data center facilities during the past 10 years. We have reduced the total square footage by 27 percent and reduced the number of data center facilities from 152 to 60. See “Continued Data Center Consolidation” for a discussion of how the MOR strategy has directly enabled some of these achievements.

Improved Overall Storage Practices

A significant focus on effective utilization in our Design environment has enabled us to improve resource utilization from below 45 percent to more than 60 percent—our goal is to reach 65 percent.

We have applied several storage techniques to enhance storage efficiency and reduce costs:

- **Tiered storage.** A five-tier approach to storage has helped us increase effective utilization of storage resources, improve our performance...
to SLAs, and reduce the TCO for Design storage. The tiers of Design storage are based on performance, capacity, and cost. Tier-1 servers have the highest performance and the least storage capacity. Tier-2 servers offer medium performance but greater storage capacity. Tier-3 servers provide lower performance but emphasize capacity, while Tier-4 and Tier-5 servers have the highest capacity but are used for low-frequency access and read-only archive data. We started updating our strategy in 2015 to consolidate the tier offerings down to three while improving our ability to meet the quality, SLA and cost targets.

- **Scale-out storage.** We are making a strategic shift from a fragmented scale-up storage model to a pooled scale-out storage model. Scale-out storage better supports on-demand requests for performance and capacity. In addition, scale-out storage enables transparent data migration capabilities and increases the effective utilization of space freed by the use of efficiency technologies such as deduplication and compression.

- **Storage refresh cycle.** To improve performance and reduce cost, we are implementing a four-year storage refresh cycle. This accelerated refresh cycle enables us to take advantage of servers with better performance and more efficient energy use, thereby reducing both capital and expense costs. For example, a more energy-efficient server can reduce data center power usage; a more powerful server that replaces several older servers can reduce our data center footprint.

- **Data deduplication.** The introduction of new storage to support company growth and our commitment to a four-year refresh are enabling us to use the latest generation of Intel® Xeon® processors. These processors provide us with the processing power to handle data deduplication on our primary storage servers—freeing greater than 5 petabytes of capacity, which we are making available for our users.

**Improved Overall Network Practices**

To accommodate the increasing demands that data center growth places on Intel's network, Intel IT converted our data center network architecture from multiple 100 megabits per second and 1 gigabit Ethernet (GbE) connections to 10GbE connections. The older, slower connections no longer supported Intel's growing business requirements. The conversion to 10GbE started in 2010; we currently have deployed more than 65,000 10GbE ports. Our new 10GbE data center fabric design accommodates our current annual 40-percent network capacity growth (see Figure 5). We expect it will also meet increasing network demand in the future.

In addition to increasing the network capacity, we have also increased the effective utilization of network ports over the last six years, from 40 percent to 62 percent (see Figure 6). Higher utilization means we do not have to purchase additional ports to meet network capacity demand growth.

**Figure 5.** Implementing 10 gigabit Ethernet (GbE) data center fabric design accommodates current capacity growth as well as meets increasing network demand in the future.

**Figure 6.** We have continued to increase effective utilization of our network.
We are also focusing on improving data center stability. In the past, we used a large installation of layer 2-based technology. We are now migrating to a layer 3-based network. This new architecture is enabling us to use all available bandwidth on primary and secondary paths at the same time. Therefore, we are able to use our network capacity more effectively. We are also able to eliminate the spanning-tree protocol within our data centers; this protocol does not scale well for large networks. Because the Internet uses layer 3-based, scalable architecture, using this concept within Intel’s data center will make our data center network more scalable and resilient. Also, we are using other technologies such as overlay, multi-chassis link aggregation (MLAG), and tunneling to extend layer 2 across data centers, over the layer-3 topology.

As shown in Figure 7, we tend to adopt higher-speed network technology almost as soon as it is available in the market. We started adoption of 40GbE in data centers in 2015 and we expect to adopt 100GbE technology within some data center environments by the end of 2016/2017, to keep pace with network demand.

In 2015 we also made two key architecture changes within Design data centers to reduce the oversubscription through the infrastructure and shift from chassis-based switches to fixed form factor switches for better cost and upgrade efficiency. Over the next three years we will reduce the oversubscription from 8:1 to 6:1 on the compute side and 8:1 to 3:1 on file server side. Over the same time period we plan to transition Design data centers by 70 percent using fixed form factor switches in a modular design.

**Improvements in the Design Environment**

Because silicon chip design represents a significant portion of Intel’s business, we have applied our data center strategy to several aspects of Design computing.

**More Efficient Design Compute and Storage**

One of the major challenges in our Design environment is that server and storage growth is occurring at a high rate. Compute demand is growing 30 to 40 percent year over year, while storage capacity demand is increasing 35 to 40 percent annually (see Figure 8).

We expect the number of cores to continue to increase. We plan to measure data center performance based on number of cores, number of racks, power consumed, and the extent to which we meet the meaningful indicator of performance per system (MIPS) demand.

**5th Generation of HPC**

Designing Intel® microprocessors is compute intensive. Tapeout is a final step in silicon design, and its computation demand is growing exponentially for each generation of silicon process technology. Intel IT adopted HPC to address this large computational scale and realized significant improvements in computing performance, reliability, and cost.
As shown in Figure 9, our HPC solution has enabled a 90x growth in Design compute capacity from 2005 to 2015. We are now using the 5th generation of our HPC solution and will continue to develop new HPC generations as Intel process technology advances. The figure also shows our commitment to quality. Through a disciplined approach to change management (basically running our data centers as if they are factories), we have reduced the number of compute issues that impact tapeout by 64x.

**Increased Design Throughput Using NUMA-Booster**

Overall data center optimization includes more than simply looking at server performance and facility efficiency. Application performance and workload optimization can also be contributing factors. We developed a system software capability called NUMA-Booster, which automatically and transparently intercepts our Design workloads and performs workload scheduling better than the default OS scheduling capability. This is implemented on all our two-socket servers.

We have achieved the following specific results without any system downtime or end-user impact:

- **Performance.** Our tests showed up to a 17-percent improvement in design performance (see Figure 10).

- **Data center space and procurement costs.** We have deployed NUMA-Booster on approximately 30,000 servers, thereby reducing the footprint needed to meet demand by 3,296 servers (representing 68 racks of data center space).

- **Carbon footprint.** These 3,296 servers represent a savings of approximately 11.83 million kWh annually, which equals about 7,014 metric tons of CO$_2$.

We expect to reap even greater results from NUMA-Booster as we retire older servers and deploy newer multicore servers with NUMA-Booster capability.

**Register Transfer Logic (RTL) Performance with NUMA-Booster**

**Table: Intel® Tapeout Computing Metrics**

<table>
<thead>
<tr>
<th></th>
<th>Pre-HPC</th>
<th>HPC-1 (45nm)</th>
<th>HPC-2 (32nm)</th>
<th>HPC-3 (22nm)</th>
<th>HPC-4 (14nm)</th>
<th>HPC-5 (10nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compute issues</td>
<td>32.2</td>
<td>5.4</td>
<td>3.8</td>
<td>13.20</td>
<td>20.58</td>
<td>29.87</td>
</tr>
<tr>
<td>impacting tapeout</td>
<td>1.00x</td>
<td>3.99x</td>
<td>2.9</td>
<td>1.3</td>
<td>1.6</td>
<td>3.8</td>
</tr>
<tr>
<td>per 1,000 masks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tapeout processing</td>
<td>13.20x</td>
<td>4.09x</td>
<td>2.9</td>
<td>1.3</td>
<td>1.6</td>
<td>3.8</td>
</tr>
<tr>
<td>capacity CPU hours</td>
<td>51.87x</td>
<td>40.94x</td>
<td>29.87</td>
<td>20.58</td>
<td>17.32</td>
<td>13.20</td>
</tr>
<tr>
<td>per day</td>
<td>90.21x</td>
<td>51.87x</td>
<td>40.94x</td>
<td>29.87</td>
<td>20.58</td>
<td>13.20</td>
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**Figure 9.** Our high-performance computing (HPC) solution, combined with disciplined change management, has steadily increased compute capacity and improved quality of service.
Increased Design Throughput Using Intel® Solid-State Drives as Fast-Swap Drives

Silicon chip design engineers at Intel face the challenge of integrating more features into ever-shrinking silicon chips, resulting in more complex designs. The increasing design complexity creates large electronic design automation workloads that have considerable memory and compute requirements. We typically run the workloads on servers that need to be configured to meet these requirements in the most cost-effective way.

In Intel IT tests with large silicon design workloads, substituting lower-cost Intel® Solid-State Drives (Intel® SSD) for part of a server’s physical memory resulted in a 1.63x performance-normalized cost advantage. Using SSDs as fast-swap drives increased the Design throughput of more than 13,000 servers by 27 percent.

Optimizing Servers to Meet Increasing Compute Demand

To achieve continually faster time-to-market improvements, given the ever-growing complexities in Intel® silicon design, Intel IT provides a global framework for parallel hardware and software design of numerous System on a Chip platforms and IP blocks.

Matching single-socket servers and highly scalable server configurations in our data centers yields 25- to 30-percent faster product design and architecture validation processes. By leveraging a global scheduling mechanism pooling compute capacity of over 120,000 servers at multiple sites around the world, our design hub provides scalable capacity and delivers optimal memory and compute capability in a shorter amount of time.

More Efficient Office and Enterprise Compute and Storage

Similar to our Design environment, the compute and storage demands in our Office and Enterprise environment are also growing quickly. Nevertheless, as shown in Figure 11, we continue to meet that demand while maintaining the number of physical servers over the last three years. From 2009 to 2015, we achieved an approximate 6.1x increase in the number of virtual machines (VMs). We also greatly increased average VM density per physical server—from 11 VMs in 2009 to 26 VMs in 2015 due to improved server platforms.
Results from 2010 to 2015

As part of our 10-year cumulative efforts to improve data center efficiency and reduce costs, our innovative and transformational data center MOR strategy and execution over the last five years has resulted in over USD 321 million in business value.

Here is a summary of the efficiency improvements and cost savings we have achieved in the Design environment from 2010 through 2015:

- **Design computing.** Intel IT innovations in the Design computing data center include the NUMA-Booster solution (17-percent higher performance); Intel SSDs (27-percent higher capacity at lower cost); faster servers (35-percent higher performance); and procurement efficiency. Together, these innovations have resulted in USD 241 million in savings.

- **Design storage.** We have implemented Design computing data center storage efficiency improvements by adopting new technology capabilities and increasing utilization—generating USD 37 million in savings.

- **Design network.** The adoption of a multi-vendor strategy for our Design computing data center network, combined with a focus on reduction of expensive maintenance costs associated with older equipment, generated USD 13.32 million in savings.

In addition to the contributions to the Design-specific environment, our new investment model has enabled us to identify other actionable gaps between the best achievable performance and our current plan. These actions include the following:

- Continuing to consolidate data centers
- Reducing unit cost for both the Design and Office and Enterprise environments
- Extending our use of blade servers in the Office, Enterprise, and Services environments

**Continued Data Center Consolidation**

We used our new investment model to look at the number of data centers we have and the number we should have. The new investment model identified opportunities to reduce the number of Intel data centers by as much as 35 percent, using techniques such as the following:

- Close, retrofit, or reclassify data centers and improve efficiency.
- Co-locate local infrastructure with Design and Manufacturing data centers or provide services from a server closet.
- Manage local infrastructure sites remotely.
- Improve facility power efficiency through strategic investments.

We have targeted 32 inefficient data centers, eliminating 61,770 square feet of data center space and converting 23,609 square feet of data center space to low-cost infrastructure rooms, saving Intel USD 25.45 million annually.
Reduced Unit Cost for the Design Environment

Figure 12 details how our budget has remained relatively flat (left side of the figure) while unit growth (middle section of the figure) has continued to rise in both the Design and Office and Enterprise environments. Our investment model has enabled us to reduce unit costs in both environments (right side of the figure)—reducing Design unit cost by 79 percent and Office and Enterprise unit cost by 74 percent. Figure 13 shows the same 79 percent unit cost reduction in Design and 74 percent unit cost reduction in Office and Enterprise by relational pie charts.

![Figure 12](image-url)

**Data Center Strategy Summary**

![Data Center Strategy Summary](image-url)

**Change in Total IT Costs**

![Change in Total IT Costs](image-url)

Figure 12. Our new strategy has enabled us to meet increasing growth and reduce unit cost without increasing our budget.

Figure 13. The pie charts reflect how our total IT costs have changed with the new data center strategy.
Reduced TCO with Blade Server Technology

As shown in Figure 14, our new investment model has shown us that moving from rack-mount servers to blade servers can reduce TCO in our cloud computing environment by about 39 percent. This reduction results from reduced port, network, and cable costs. For example, a group of 16 blade servers compared to 16 rack-mount servers requires only 8 Ethernet interfaces instead of 128, and only four Fibre Channel interfaces instead of 32. Deploying a newer generation of blade-server technology with converged network fabric within the blade chassis (labeled “Gen-2” in Figure 14) allowed us to reduce the cost even further.

Based on this data, we are actively deploying blade servers to support further virtualization efforts in the Office, Enterprise, and Services environments.

Summary of Data Center Best Practices

Over the last decade, we have made many strategic investments and developed solutions to make our data centers more efficient and better serve the needs of Intel’s business. We are now applying our MOR approach across our entire infrastructure stack—compute, storage, networking, and facilities. Table 4, on the next page, provides a summary of the best practices we have developed and the business value they have generated.

Plans for 2016 and Beyond

Our data center strategy is a continuous improvement process—we are always striving to close the gap between current achievements and the best possible scenario. To that end, we plan to explore the following areas and apply our MOR approach to them.

- **Embrace disruptive servers.** Deploy ultra-dense, power-optimized server nodes to reduce data center space and power consumption for computing needs.
- **Adopt standards-based storage.** Use industry-standard hardware and software for scale-up and scale-out storage, to take advantage of the latest hardware more quickly—enabling higher throughput.
- **Drive network efficiency.** Continue to drive LAN utilization toward 75 percent and pursue top-of-rack architecture to support ultra-high density data center designs. Implement 40GbE and 100GbE where appropriate and cost effective, in order to meet network capacity demands.
- **Increase facilities efficiency.** Use techniques such as higher ambient temperature for specific data center locations to take advantage of newer equipment specifications, which will reduce cooling needs.

Figure 14. Blade servers with integrated network/data fabrics have reduced our virtualized environment infrastructure costs by 39 percent.
Table 4. Intel IT Data Center Best Practices and Business Value

<table>
<thead>
<tr>
<th>BEST PRACTICE</th>
<th>BUSINESS VALUE</th>
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<tbody>
<tr>
<td><strong>Compute (Servers)</strong></td>
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<tr>
<td>Migrate applications from RISC to Intel® architecture(^i)</td>
<td>• Enabled significant savings and IT efficiencies</td>
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<td>• Allowed us to realize the benefits of industry-standard OSs and hardware</td>
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<td>Adopt cloud computing</td>
<td>• Virtualized more than 90 percent of Office and Enterprise servers</td>
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<td>• Reduced the time it takes to provision a server from 90 days to on-demand provisioning</td>
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<tr>
<td>Regularly refresh servers using the latest generations of Intel® Xeon® processors</td>
<td>• Virtualization ratios of up to 60:1</td>
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<td>• Reduced Design environment energy consumption by 10 percent annually between 2008 and 2013</td>
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<tr>
<td></td>
<td>• ~10x increase in performance between 2005 and 2015</td>
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<tr>
<td>Deploy high-performance computing(^i)</td>
<td>• 90x increase in capacity, with a 64x increase in stability</td>
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<td>• Saved USD 44.72 million net present value with HPC-1</td>
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<td>Enhance server performance through software optimization</td>
<td>• Increased Design job throughput up to 49 percent</td>
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<td></td>
<td>• Delivered USD 241 million from 2010 to 2015 from various optimizations including NUMA-Booster, fast-swap based on Intel® Solid-State Drives, and high-frequency servers and optimal workload to platform pairing</td>
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<tr>
<td><strong>Storage</strong></td>
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<tr>
<td>Refresh and modernize storage using the latest generations of Intel Xeon processors</td>
<td>• Take advantage of new technology to increase storage capacity, quality, velocity, and efficiency at a lower cost</td>
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<td>• More than twice the I/O throughput than older systems</td>
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<td></td>
<td>• Reduced our data center storage hardware footprint by more than 50 percent in 2011-2012</td>
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<td></td>
<td>• Reduced backup infrastructure cost due to greater sharing of resources</td>
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<td>• Tiered backup solutions to optimize backup costs and improve reliability</td>
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<tr>
<td>Right-size storage solutions using a tiered model(^iii)</td>
<td>• Provide storage resources based on business needs: performance, reliability, capacity, and cost</td>
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<td>• Better management of storage costs while still enabling easy access to necessary data</td>
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<td></td>
<td>• Transition to scale-out storage to reduce operational complexity in tiering data</td>
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<td>• Automated policy-based data migration between tiers</td>
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<tr>
<td>Continuously monitor and reclaim disk space consumed by aged data</td>
<td>• More than USD 1 million in capital expenditure avoidance in 2011</td>
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<tr>
<td>Implement thin provisioning and deduplication for storage resources</td>
<td>• Helps control costs and increase resource utilization without adversely affecting performance</td>
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<td>• Increased storage effective utilization in Design from 46 percent in 2011 to 60 percent in 2015</td>
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<tr>
<td><strong>Network</strong></td>
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<tr>
<td>Upgrade the data center LAN network architecture to 10 gigabit Ethernet(^iv)</td>
<td>• Increased data center network bandwidth by 400 percent over three years, enabling us to respond faster to business needs and accommodate growth</td>
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<td>• Increased the network utilization from 40 percent to 62 percent between 2010 to 2015</td>
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<td>• Eliminated spanning tree with multi-chassis link aggregation (MLAG) and Layer 3 protocol</td>
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<td>• Reduced network complexity due to fewer network interface cards (NICs) and LAN ports</td>
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<td>• Reduced network cost in our virtualized environment by 18 to 25 percent</td>
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<td>Open the data center network to multiple suppliers</td>
<td>• Generated more than USD 60 million in cost avoidance over five years with new network technology</td>
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<td><strong>Facilities</strong></td>
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<tr>
<td>Increase cooling efficiency</td>
<td>• Saved close to 16 million kilowatt-hours over 18 months, which is equivalent to reducing our carbon dioxide emissions by 6,800 metric tons</td>
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<td>Use a tiered approach to redundancy, availability, and physical hardening</td>
<td>• Better matching of data center redundancy and availability features to business requirements</td>
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<td>• Reduced wasted power by more than 7 percent by eliminating redundant power distribution systems within a data center</td>
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<td>Retrofit and consolidate data centers using a modular design</td>
<td>• Retrofitted old wafer fabrication plant to high-density, high-efficiency data center modules with industry-leading PUE of 1.06</td>
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<td>• Utilized free-air cooling and environmentally efficient evaporative cooling for maximum energy efficiency</td>
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<td>• Avoided significant capital expenditures by not equipping the entire facility with generators</td>
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<td></td>
<td>• Quickly respond to changing data center needs with minimal effort and cost</td>
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\(^i\) For more information see "Migrating Mission-Critical Environments to Intel® Architecture."
\(^ii\) For more information see "High-Performance Computing for Silicon Design."
\(^iii\) For more information see "Implementing Cloud Storage Metrics to Improve IT Efficiency and Capacity Management."
\(^iv\) For more information see "Upgrading Data Center Network Architecture to 10 Gigabit Ethernet."
Conclusion

To provide a foundation for continuous innovation that will improve the quality, velocity, and efficiency of Intel IT’s business services, we have refined our data center strategy, building on the practices established over the last decade. Our refined data center strategy has created new business value in excess of USD 321 million from 2010 to date. The data center transformation strategy (Figure 15) is a key for Intel IT to stay competitive.

Key achievements include the following:

- We developed a system software capability called NUMA-Booster, which has saved millions while delivering additional server capacity.
- We deployed more than 13,000 Intel SSDs as fast-swap drives, which increased server capacity by 27 percent.
- Five generations of HPC in our design computing environment created a 90x capacity increase and a 64x quality improvement.
- We adopted new storage capabilities, accelerated storage refresh, and focused on increasing utilization, resulting in additional storage capacity.
- We deployed more than 60,000 10GbE network ports, saving millions in cost avoidance.
- An integrated server and network infrastructure provided a 39-percent reduction in hardware across the enterprise.

Figure 15. Maximizing the business value of Intel's data center infrastructure requires continued business-driven innovation in the areas of compute, storage, network, and facilities.
We have achieved these results by running Intel data centers like a factory, implementing change in a disciplined manner and applying breakthrough technologies, solutions, and processes. Transformational elements of our data center strategy include the following:

- **A focus on three primary KPIs.** These metrics enable us to measure the success of data center transformation: Meet growing customer demand (SLAs and QoS) within constrained spending targets (remaining cost-competitive) while optimally increasing infrastructure asset utilization (asset efficiency).

- **Stimulating bolder innovation by changing our investment model.** Comparing our current capabilities to a “best achievable model” encourages us to strive for innovation that will transform our infrastructure at a faster rate than if we sought only incremental change.

- **New unit-costing financial model.** This model enables us to better assess our data center TCO based on the business capabilities our infrastructure is supporting. The model measures the cost of a unit of service output and enables us to compare investments and make informed trade-off decisions across business functions—thereby maximizing ROI and business value.

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