

## ENERGY EFFICIENT DATACENTERS THE ROLE OF MODULARITY IN DATACENTER DESIGN

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## Chapter 1

# The Role of Modularity in Datacenter Design

Virtually every Information Technology (IT) organization, and the clients that they serve, have dramatically different requirements that impact their datacenter designs. Sun is no exception to this rule. As an engineering company, Sun has cross-functional organizations that manage the company's corporate infrastructure portfolio including engineering, services, sales, operations and IT. These diverse organizations each have an impact on how datacenters are designed, including the following:

- Sun's hardware development organization needs to be able to work on racks of 1 U servers one day, and then wheel in a next-generation, high-density server the next. One area may be required to power a 5 kilowatt (kW) rack and then handle a 30 kW rack hours later.
- Electronic Design Automation (EDA) and Mechanical Computer-Aided Engineering (MCAE) workloads require compute clusters built using Sun's most powerful servers. The datacenters supporting these tasks need to be able to handle a uniformly dense server configuration. These servers support a workload that demands extreme power and cooling while a simulation is running, and reduced demands when no job is active.
- Sun's software development organization has a relatively stable server configuration, with workloads and resultant cooling requirements varying as development cycles progress. In contrast to our hardware organizations, where physical systems are swapped in and out regularly, our Software organization uses the same servers and changes their configurations frequently but through software.
- Sun's Services organizations need to have two or more of every system that Sun supports, from servers to storage; from workstations to switches. They configure and reconfigure systems to test scenarios and reproduce customer environments. They have work benches for workstations next to high density cabinets.
- Sun's IT organization, which supports corporate functions, is similar to the software development organization but with more predictable workloads, standardized equipment deployments, and a lower technology refresh rate.

On the surface, the datacenters supporting these different organizations look as different as night and day: one looks like a computer hardware laboratory and another looks like a lights-out server farm. One has employees entering and leaving constantly, and another is accessed remotely and could be anywhere. One may be housed in a building, and another may be housed within an enhanced shipping container. Beneath the surface, however, our datacenters have similar underlying infrastructure including physical design, power, cooling, and connectivity.

As defined by Uptime Institute's White Paper *Tier Classifications Define Site Infrastructure Performance*, tier levels range from 1-4, with Tier 4 being the most fault tolerant.

## Choosing Modularity

When Sun's Global Lab & Datacenter Design Services (GDS) organization was created and tasked with reducing Sun's datacenter space and power requirements, we faced two diametrically opposed choices: we could design each one from scratch, or we could design a modular set of components that could be used and re-used throughout Sun's technical infrastructure spread across 1,533 rooms worldwide that range from Tier 1 to Tier 3.

The path of least resistance would be to create a customized datacenter design for the immediate business needs in each location, for the lowest possible cost. This would have involved hiring an architect in each location, then making independent, site-specific and client-specific decisions on the datacenter's key components, including power, cooling, racks, and network connectivity. This approach may provide short-term solutions that solve the customers immediate needs, but in a world where the most important requirement is to enable agility, with minimal economic and environmental impact, such a set of datacenters may limit our ability to capitalize on business opportunities.

## Defining Modular, Energy-Efficient Building Blocks

In the end, we chose a modular, pod-based design that created energy-efficient building blocks that could be duplicated easily in any size or tier level datacenter, worldwide. A pod is typically a collection of up to 24 racks with a common hot or cold aisle along with a modular set of power, cooling, and cabling components. With the pod representing a small, modular building block, we can build large datacenters by implementing a number of pods. Likewise, small datacenters can be implemented with a single pod, allowing datacenters of all sizes to benefit from modular design.

The pod design allows the different modules to be configured to best meet client requirements as the datacenter changes over time. The standard infrastructure is sized so that it can accommodate rapid change, growth, and increases in server and storage densities. Indeed, we invested 10-15 percent in piping and electrical infrastructure to "future proof" the datacenter. This allowed each datacenter to support today's requirements and adapt rapidly to increasing server densities and changing business requirements without significant up-front costs. In some cases, this small investment can have a payback in as little as 18 months — even if the anticipated changes never occur.

## Buildings Versus Containers

Sun sees a role for energy-efficient designs in both building and container-based deployments. In the case of our Bay Area consolidation project, the initial driver was to entirely vacate Sun's Newark, California campus with its corresponding datacenter

space, and leverage existing office space in Sun's Santa Clara, California campus to replicate the environment.

Since this project began, the Sun™ Modular Datacenter (Sun MD) has become available and provides many of the same benefits as our building-based designs. The Sun MD (formerly Project BlackBox) is a highly-optimized, pod-based design that happens to live inside of an enhanced shipping container — and thus it can be deployed indoors or outdoors as an independent datacenter. For many of the datacenters we designed, the building approach was the best choice given the “high touch” requirements of our Engineering organization and the need to optimize our real-estate portfolio. For datacenters that are running production workloads that require less human intervention and can be operated remotely, or are needed for temporary or transitional missions that need to be deployed in months rather than years, the Sun MD will play a big role. Sun's long-term strategy will include deploying datacenters that use a mixture of both building and container-based components.

### Cost Savings

The modular nature of the pod approach allows us to eliminate most of the custom design and re-engineering for each site, reducing costs and shrinking project times. This standardized approach allows us to recognize and correct mistakes as we discover them. This helps us to avoid the pitfalls of “doing it wrong,” which includes loss of flexibility, scalability, and ultimately a shortened life span for a facility. The additional investment in future proofing allows us to accommodate today’s requirements while making it easy to scale up or down as server densities increase and as business requirements change. This future-proof model allows us to easily add capacity without substantial capital outlay or major downtime. Modularity directly contributes to energy efficiency because we can closely match each pod’s power and cooling to the requirements of the equipment it hosts. We no longer have to increase an entire room’s cooling just to accommodate a small section of equipment. Heat removal is now focused at the source and capacity increased in smaller incremental units within the datacenter space. This allows us to use only the energy we need to power and cool our compute equipment today while enabling rapid and cost-effective expansion.

In the end, our energy-efficient, pod-based datacenters may look different on the surface, but underneath they are all built of the same modular components. Even between our building and container-based datacenters, the underlying components that contribute to efficiency are surprisingly similar. With a uniformly flexible and scalable datacenter design, our datacenters are ideally positioned to meet the needs of our core business. This highly flexible and scalable pod architecture allows us to quickly and effectively adapt to ever-changing business demands. This has become a competitive weapon for Sun, enabling products and services to be delivered faster.

## About This Article

This Sun BluePrints™ Series article discusses the benefits of modularity in Sun's energy-efficient datacenter design. The article includes the following topics:

- Chapter 2 on page 5 discusses the range of requirements that Sun's datacenters were designed to accommodate.
- Chapter 3 on page 17 provides an overview of our modular, pod-based design and how the Sun Modular Datacenter S20 represents a similar pod design.
- Chapter 4 on page 24 introduces the modular design elements, including physical design, power, cooling, and cabling.
- Chapter 5 on page 39 shows how modular design elements were implemented in Sun's datacenters worldwide, illustrating how the same components can be used to create datacenters that all look quite different.
- Chapter 6 on page 47 discusses the business benefits of the modular design and looks towards the future that the design supports.

## Chapter 2

# The Range of Datacenter Requirements

As with any company, Sun's various internal organizations place different demands on the datacenters. Some have continuous workloads; some have variable ones. Some impose higher power and cooling loads than others. Some organizations need daily access to the datacenters' equipment, while others can access it remotely. The range of requirements suggest that a good solution is flexible and modular so that, as organizational and business requirements change, our datacenters can support change without significant rework.

## Power and Cooling Requirements

Datacenter power and cooling requirements are perhaps the most important to consider, as insufficient capacity in this area can limit an organization's ability to grow and adapt to changing technology and challenging new business opportunities. If there is no headroom to grow a datacenter, a company's ability to deploy new services can be compromised, directly affecting the bottom line.

Building datacenters equipped with the maximum power and cooling capacity from day one is the wrong approach. Running the infrastructure at full capacity in anticipation of future compute loads only increases operating costs and greenhouse gas emissions, and lowers datacenter efficiency. In 2000, energy was not a major concern because datacenters were operating at 40 watts per square foot (W/ft<sup>2</sup>). Air flows to cool 2 kW racks were well within the operating range of raised floors. Random intermixing of air across the datacenter was acceptable because localized high temperatures could still be controlled. Unpredictable and non-uniform airflow under the raised floor did not pose a problem since this could be overcome by over-cooling the room with Computer Room Air Conditioner (CRAC) units. In many cases the N+1 or 2N redundant CRAC designs concealed this problem because they were already delivering more cooling than was required. Over the last few years, the compute equipment densities have surpassed the ability for raised floors to deliver adequate cooling. To compound the problem, datacenter energy usage, costs, and resultant environmental impacts have achieved much higher visibility from company executives and the public. The days of raised-floor room-level cooling are over.

Air movement in the datacenter is a large contributor to energy use. Delivering cooling for today's high-density racks is not only difficult through raised floors, it is extremely inefficient. Air mixture in the datacenter creates hot spots that are unmanageable. The unpredictable and non-uniform airflows created by raised floors must be modeled and analyzed to ensure adequate air flow to racks. Every tile in the datacenter contributes to the air flow profile of the room. If one tile changes then the air flow of the rest also change. Changes to the equipment in the datacenter require a much higher level of



analysis and maintenance to determine ways to re-distribute perforated tiles so that they are still able to deliver adequate cooling.

### Using Racks, Not Square Feet, As the Key Metric

Watts per square foot is an architectural term created to describe office space power consumption and assumes that uniform cooling. A datacenter could average 150 W/ft<sup>2</sup> but only be able to support 2 kW per rack because of how the cooling system is designed. This is equivalent to cooling only 60 W/ft<sup>2</sup>. Sun has abandoned the watts per square foot measurement for a much more accurate metric that realistically profiles datacenter loads. The metric is watts per rack. This more accurately identifies the heat load in the space and is not dependent on the room shape, square footage, or equipment.

Datacenters come in all shapes and sizes and will always have a mixture of equipment and heat loads. Measuring at a rack level rather than a room level gives the ability to control cooling at the micro level, decreasing costs and increasing efficiencies. What we have found is that the 2008 average in the industry, and our own datacenters, is between 4-6 kW per rack. This does not mean that all racks are the same — quite the contrary. It means that datacenters will have racks that range from less than 1 kW to more than 30 kW.



*Figure 1. The majority of datacenters support a mixture of high and low-density racks, just as a city skyline features skyscrapers surrounded by hundreds of small and medium-sized buildings.*

Compare this to a city skyline (Figure 1). The 20-30 kW racks would represent skyscrapers that dot the skyline. There are a smaller number of them but they are distributed throughout the city, surrounded by thousands of other small to medium-

sized buildings. These buildings represent racks that range from less than 1 kW up to 10 kW. The city average is only 5 kW, but you must be able to accommodate different load levels throughout the datacenter. It is difficult to predict the location of future high-density loads. The infrastructure needs to adapt to the IT equipment regardless of where it is placed.

The lesson is that the majority of datacenters are heterogeneous. They need to handle the base load but be able to scale up or down at every rack location to accommodate load concentrations. Every year, IT organizations replace some older equipment with newer equipment with varying degrees of density. Matching power and cooling to immediate needs with the ability to grow or shrink in any location helps to reduce time to market and decrease costs. The flexible power and cooling approach eliminates hot spots, reduces inefficiency caused by hot and cold air intermixing, and allows overall datacenter temperatures to be higher, saving more on cooling expenses.

With few exceptions, datacenters don't change from a 4 kW to a 30 kW average per rack overnight. Rack densities can be predicted based on an IT organization's planned capital outlay. The equipment lifecycle and capital depreciation practices (3-7 years) dictate how much equipment will be changed in a given year. This predictability allows datacenters to easily and cost-effectively keep pace with new power and cooling demands. Scalable, closely coupled cooling and modular power distribution helps changes to happen as business demands dictate — all without stunting or limiting a company's growth.

### Temporal Power and Cooling Requirements

Thus far, we have addressed how power and cooling requirements vary across a datacenter space, but they also vary by time. Having the capacity to match temporal requirements increases efficiency. Consider the following:

- *Cyclical Workloads.* Many workloads vary by time of day, time of the quarter, and time of the year, and some are even on 'project' time. At Sun, servers that support Sun Ray™ ultra-thin clients handle a workload that increases throughout the morning, peaks just before lunch, declines during lunch, and increases again after lunch, falling slowly during the afternoon (Figure 2). In Sun's compute clusters, power consumption increases as large High-Performance Computing (HPC) jobs are executed, falling as jobs are completed. A datacenter that can dynamically adjust its cooling system as workloads change is more efficient than one that puts out a constant level of cooling.

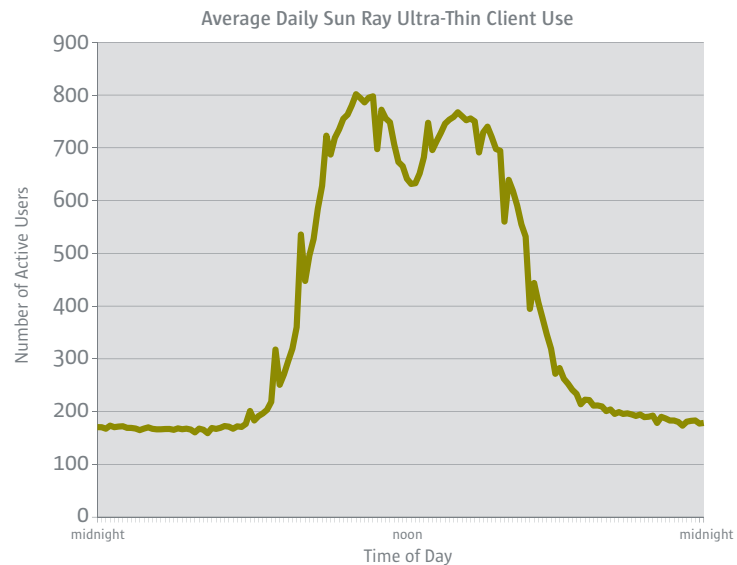


Figure 2. Cyclical workloads, such as those observed on servers supporting Sun Ray Ultra-Thin Clients, have variable power and cooling requirements.

- Rapid Change.** Some of Sun's environments have rack and cabinet configurations that change frequently and need to be accommodated by the datacenter's power and cooling system. In a hardware test environment, for example, engineers might bring up a rack of servers requiring 208 VAC three-phase power generating 30 kW of heat. Another day, Services organization engineers might need to work with a rack of older servers requiring 120 VAC single phase power generating only 2 kW of heat. Sun's datacenter design must be able to support rapid change between power usage levels as well as different voltages and phases.
- Rate of change.** Some datacenters evolve quickly, replacing their equipment with the latest innovations at a rapid rate. Part of our datacenter effort involved a server-replacement program that allowed us to increase density and reduce real-estate holdings at the same time. Because of the volume of refresh, the new high-density datacenter would not have a significant rate of change for at least 18 months. In other organizations and industries, however, this is not the case. In some HPC environments, most notably oil and gas reservoir modeling applications, very large compute farms are kept up to date by rotating in new racks on a monthly or quarterly schedule so that no part of the cluster is more than three years old at any point in time. These environments are the inverse of the city skyline, with most buildings being skyscrapers with a small number of smaller buildings interspersed. This serves as another extreme of datacenter requirements, highlighting the need for a design that can deliver uniform power and cooling in high-density environments.

## Equipment-Dictated Power and Cooling Requirements

A modular, flexible datacenter must be able to handle equipment and racks with physically different power and cooling configurations. Most of Sun's equipment is built with front-to-back cooling so that datacenters can be configured with alternating hot and cold aisles. Some of Sun's and other vendors' equipment uses a 'chimney' cooling model, where cold air is brought up from the floor, through the cabinet, and exhausted at the top. A datacenter's cooling strategy must be able to accommodate the different types of equipment that will be required by the business.

## Connectivity Requirements

The same requirements affecting power and cooling also places requirements on datacenter connectivity. Increasing density requires support for an ever-increasing number of cables per rack. Supporting future growth means providing headroom in cabling capacity. Different applications require different cable types to support different communication media:

- *Ethernet*. All of Sun's systems are networked, and typical configurations utilize at least two Gigabit Ethernet links. 10 Gigabit Ethernet is being deployed quickly, and the ability to use 10 Gigabit copper and fiber must be accommodated by the cabling design.
- *Fibre Channel*. Many of Sun's datacenter servers are configured with dual Fibre Channel interfaces for storage connectivity. While fiber has a smaller diameter than copper, it adds to cabling complexity because it is more fragile than copper and cannot withstand tight-radius bends.
- *InfiniBand*. Many high-performance computing environments are using InfiniBand to aggregate connectivity, increase data throughput, and decrease latency. InfiniBand cables can be large with significant restrictions on bend radius and cable length.

In previous datacenter designs, network cabling was "home run" from each server to a pair of large switches central to each datacenter. This centralized model not only uses a large amount of unnecessary copper; it also limits the ability to quickly change and reconfigure because each cable is somewhat permanently bound into a bundle that traverses a long distance and is thus difficult to change.

The ever-increasing density and rapid change of connection quantities and media demand a flexible approach to cabling. The days of running thousands of cables from racks to a centralized switching room is not only a significant waste of resources, it has become cost prohibitive. Server connectivity requirements have driven the need to relocate high port count networking switches from the centralized switching room into the pods themselves. Distributing these networking switches into the pod increased flexibility and decreased our cabling costs by almost 75 percent.

## Equipment Access Requirements

One of the challenges that we encountered in designing Sun's energy-efficient datacenters is the degree to which access requirements are important. When an initial idea of centralizing all datacenter space was proposed, requirements poured in relating to the need for various types of physical access. This eliminated complete centralization from consideration. Some organizations could operate their datacenters in a 'lights-out' fashion that would allow them to be located virtually anywhere. For other organizations, daily access was a requirement. These requirements led to the creation of the following datacenter categories:

- *Remote*. These users could access and control their equipment from a domestic or international location depending on performance requirements. The datacenter equipment does not require users and owners to have hands-on interaction outside of maintenance and administrative support. An example of remote access is organizations accessing equipment in Colorado from their offices in California.
- *Localized Remote*. These users need to control and access their equipment from within the same city or region. The organizations don't need to have frequent hands-on interaction outside of administration and maintenance, however they need more access than remote users. An example of this category is accessing equipment in Sun's Santa Clara, California datacenters from Menlo Park, California. These campuses are only 20 minutes apart.
- *Proximate*. These users need frequent hands-on interaction, for example hardware bring up, equipment fault insertion, and reconfiguration.
- *Customer Facing*. This category was created to cover rooms that require direct customer interaction, for example customer briefing centers and benchmarking facilities. These datacenters are showcases, and need to support the same kinds of equipment as the rest of Sun's datacenters, but in a more aesthetically pleasing manner.

## Choosing Between Buildings and Containers

The advent of the Sun Modular Datacenter created another option for deploying datacenter capability. A conscious choice needs to be made regarding whether to build a datacenter in a building, within containers, or a combination of both. The Sun Modular Datacenter (Sun MD) is essentially a pod design that is deployed within its own enclosure and can be located in a wide variety of indoor and outdoor settings such as a corporate campus or a remote, rugged location. The Sun MD requires power and chilled water in order to operate, and it supports both copper and fiber data connections. It can be plumbed into a building's existing chilled water system, or it can be located next to inexpensive sources of power and cooled with a modular, self-contained chiller plant. The datacenter contains eight 40U racks, seven and a half of which are available for customer equipment that can support up to 25 kW per rack.

There are several factors that point to the use of modular datacenters within Sun, and which are driving the future use of Sun MD units at Sun:

- *Where Time Is Of The Essence.* While some organizations have the luxury of constructing new building-based datacenters over a period of years, projects arise from time to time where new datacenter capacity must be deployed and equipped within a short time frame and there is no existing space to be used or modified. Using one or more Sun Modular Datacenters is a way to rapidly deploy datacenter capacity under extremely tight time requirements.
- *For temporary or transitional use.* From time to time, we have projects that completely change the way we run parts of our business. During the time that these projects are being engineered, we must run infrastructure to support the current model within existing datacenters while we build a completely new server infrastructure that will ultimately replace the existing one. In a case such as this, the Sun MD is an ideal mechanism for adding to our datacenter space for a relatively short term. Had the Sun MD been available when we vacated our Newark, California location, it could have served us during the transition between decommissioning outdated hardware in existing datacenters and moving to Santa Clara.
- *For the remote access model.* Most of the datacenters that support our engineering organizations fall into the remote, localized remote or proximate access categories described in the previous section. The Sun MD is most effective when used for applications that require less payload intervention. For example, production environments or applications providing content at the network edge where lights-out operation from a distance is feasible. The remote capability further enhances the Sun MD value by enabling us to create high-density spaces in a variety of Sun locations, including some that have lower power costs than in the San Francisco bay area.
- *For compute farms.* With the Sun MD able to cool up to 25 kW per rack, it may be a preferable way to deploy server farms used for simulation and modeling. Often these compute clusters are pushed to their limits for days or weeks at a time and then sit relatively idle between jobs. Others may require rapid deployment of additional compute capacity to augment what is currently deployed. A datacenter that can be brought online and offline, powering it on as needed, with the flexibility to rapidly add or remove compute capacity without substantial and timely investments, can decrease costs while enabling a business to quickly adapt to changes.
- *Where space is a premium.* With eight racks hosted in only 160 square feet (ft<sup>2</sup>), or 14.86 square meters (m<sup>2</sup>), the Sun MD is an option where even greater rack density is required than what we have configured in our building-based datacenters. Where the Sun MD averages 20 ft<sup>2</sup> (1.86 m<sup>2</sup>) per rack, our pods range from 26-35 ft<sup>2</sup> (2.42 - 3.25 m<sup>2</sup>) per rack.

## Living Within a Space, Power, and Cooling Envelope

All datacenters, whether in a building or container-based, are constrained by one or more of the three key variables: space, power and cooling. Some simple calculations can give a rough idea of the kind of pod-based datacenter that can be created given these three variables.

### Space

Depending on which power, cooling and racking technologies are chosen, our datacenters use between 20-35 ft<sup>2</sup> (1.86 - 3.25 m<sup>2</sup>) per rack. For purposes of calculation, we use a conservative multiplier of 35 ft<sup>2</sup> (3.25 m<sup>2</sup>) per rack to estimate building-based datacenter sizes. This includes roughly 10 ft<sup>2</sup> for the rack itself, the same amount of space for hot and cold aisles, and 15 ft<sup>2</sup> of support space for pump units, electrical rooms, UPS rooms, and CRAC/CRAH units. Dividing your available space by 35 ft<sup>2</sup> yields a budgetary number of cabinets that you can support. Less square footage can be used depending on power and cooling infrastructure choices.

### Power

A rough, budgetary rule of thumb is that a datacenter will devote half of its energy to power its IT equipment and the other half to support infrastructure. For every watt that goes to power compute equipment, another watt goes to support it. The support infrastructure includes the cooling systems, losses in power distribution, UPS inefficiencies, and lighting.

With the assumption of 50 percent of energy powering IT equipment, 5 MW of power allows 2.5 MW to be used for IT equipment including servers, storage, and networking. If the goal is to support a current use of 4 kW per rack with headroom to move to 8 kW per rack, 312 racks can be supported by this hypothetical amount of power.

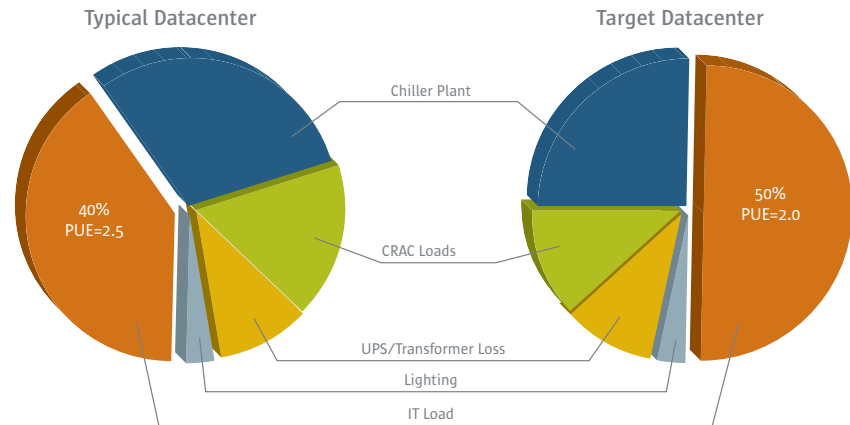
### Power Usage Effectiveness

A useful measure of datacenter efficiency is Power Usage Effectiveness (PUE), as defined by Christian Belady of The Green Grid. This measure is the simple ratio of total utility power to the datacenter's IT load:

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Load}}$$

The reciprocal of PUE is DataCenter Infrastructure Efficiency (DCiE), a metric also defined by The Green Grid. Both PUE and DCiE reflect the efficiency of the entire datacenter's power draw. A typical datacenter's PUE is 2.5, reflecting that only 40 percent of the power goes to IT equipment (Figure 3). Any reduction in total facility power due to improvements in the chilling plant, CRAC units, transformers, UPS efficiency, and lighting is reflected in a smaller numerator that brings the ratio below

2.0 (with a limit of 1.0). With a minimal amount of effort towards efficiency, a PUE of 2.0 can be achieved. This is a good rough rule of thumb for a power budget: half of the power goes to the IT equipment. We believe, however, that new datacenters should be designed to target a PUE of at least 1.6 and, as our actual measurements reveal, we have managed to surpass this goal in some of our datacenters.



*Figure 3. Without making efforts to improve energy efficiency, a typical datacenter will consume 1.5 watts of overhead for every watt delivered to its IT equipment. An efficient datacenter, as defined by the Uptime Institute, will only consume one watt of overhead.*

The calculation is as follows:

$$2.5 \text{ MW} \times 2.0 = 5 \text{ MW}$$

$$2.5 \text{ MW} \times 1.6 = 4 \text{ MW}$$

$$1 \text{ MW} = 1,000 \text{ kW}$$

$$(1,000 \text{ kW} \times 8760 \text{ hours}) \$0.08 = \$700,800$$

Consider the impact of designing to a PUE of 1.6 in our example of a datacenter with 5 MW of power available. With a 2.5 MW IT load, the entire datacenter now draws only 4 MW, a savings of 20 percent. At an average cost of 8 cents per kilowatt hour, *saving one megawatt translates to a savings of more than USD \$700,000 per year*. From another perspective, reducing your PUE gives your organization more freedom to grow without incurring the immense expense of upgrading the mechanical and electrical infrastructure. The value of this expansion capability to a business should not be underestimated.

There are several lessons in the translation of PUE to actual dollars saved:

- The lower the PUE, the shorter the payback on your investment.
- Knowing the PUE to which you are designing is more than just a best practice, it is a necessity. One prediction is that by 2012 the power costs for the equipment over its useful life will exceed the cost of the original capital investment.
- The perception that designing for efficiency equates to a larger up-front investment is inaccurate. Because of high-density loads, the capital cost of traditional designs versus modular designs have equalized. But as shown earlier in this chapter, the operating cost for a 2.5 PUE datacenter versus one having a 1.6 PUE is substantial. Companies can no longer afford to be inefficient.



- You can only manage that which is measured. Imagine driving your car without any gauges. You would not know there was a problem until the car stopped running. At that point, problems are usually significant and quite expensive to fix. A datacenter without metering and monitoring is the same. It must be watched and tuned.
- Using PUE as an ongoing metric in the datacenter provides real-time datacenter health monitoring. As the datacenter changes or ages the PUE may change. An increasing PUE could signal there is a problem somewhere in the datacenter that is causing it to use or waste more power.

### Cooling

The calculation is as follows:  
 $2,500 \text{ kW} / 3.5 \text{ kW/ton} = 714 \text{ tons}$

The third variable that can constrain datacenter space is the amount of available cooling capacity. In the example of a 2.5 MW IT load with a PUE of 2.0, 714 tons of cooling plant is needed in order to remove the heat generated by the IT equipment. If there isn't sufficient cooling capacity available, one of the following must happen. Less compute equipment deployed, opportunities to eliminate waste and reclaim cooling capacity must be identified and implemented, or additional cooling capacity needs to be installed.

### Calculating Sun's Santa Clara Datacenters

In Sun's Santa Clara datacenters, the goal was to reduce real-estate holdings by consolidating 202,000 ft<sup>2</sup> (18,766 m<sup>2</sup>) of existing datacenter space into less than 80,000 ft<sup>2</sup> (7,432 m<sup>2</sup>) of newly provisioned space. In our case, we had the opportunity to build a new modular, scalable power and cooling plant with an initial capacity of 9 MW with the ability to expand in steps to 21 MW.

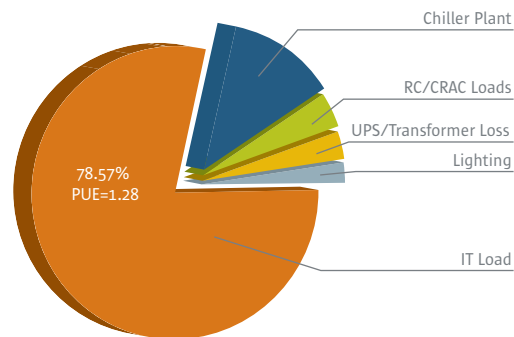
In supporting the entire technical infrastructure portfolio for Sun including IT, Services, and Engineering, GDS has a unique perspective that is applied to datacenter design. The products that will be going into our customers' datacenters in 2-3 years are already in our R&D datacenters in Santa Clara. This means we have insight into the capacity challenges our customers will face in the future. The decision to equip the plant to scale from 9 to 21 MW was based on what we know future densities will be.

Today, the Santa Clara datacenter has 32,000 ft<sup>2</sup> (2,972 m<sup>2</sup>) of localized-remote, high-density datacenter space, and 40,000 ft<sup>2</sup> (3,716 m<sup>2</sup>) of proximate low-density datacenter space spread across 14 rooms. Seven of these rooms house high-density racks, while the other seven rooms house a mixture of low-density racks and benches. The Santa Clara location houses Sun's highest-density datacenter globally. It starts at an average of 12 kW per rack and can scale to 18 kW per rack. It is the highest-density and highest-efficiency datacenter in Sun's portfolio and has reduced energy costs by half. This datacenter, like the majority of the Santa Clara datacenters, is on a slab floor.

## Efficiency in Sun's Santa Clara Software Datacenter

In 2007 Sun completed the largest real-estate consolidation in its history. We closed our Newark, California campus as well as the majority of our Sunnyvale, California campus shedding 1.8 million ft<sup>2</sup> (167,000 m<sup>2</sup>) from our real-estate portfolio. One example in this consolidation is the Software organization's datacenter, where 32,000 ft<sup>2</sup> (2,973 m<sup>2</sup>) of space distributed across 32 different rooms was consolidated into one 12,769 ft<sup>2</sup> (1,186 m<sup>2</sup>) datacenter. In the end, 405 racks were configured in this space, using an average of 31.5 ft<sup>2</sup> (2.9 m<sup>2</sup>) per rack. The initial power budget was 2 MW (out of 9 MW overall), with the ability to expand to 4 MW in the future. This design supports today's current average of 5 kW with the ability to grow to 9 kW average per rack. Keep in mind that even though the averages are 5 kW and 9 kW, racks ranging from 1 kW to 30 kW can be deployed anywhere in this datacenter.

We measured the power usage effectiveness of the Santa Clara Software organization's datacenter, and if any single number testifies to the value of our modular design approach, it is the PUE of 1.28 that we were able to achieve. By using our modular approach, which includes using a high-efficiency variable primary-loop chiller plant, close-coupled cooling, efficient transformers, and high-efficiency UPS, an astonishing 78 percent of incoming power goes to the datacenter's IT equipment.



*Figure 4. Our Santa Clara Software organization's datacenter achieved a PUE of 1.28, which translates to a savings of \$402,652 per year compared to a target datacenter built to a PUE of 2.0.*

In traditional raised floor datacenters the efficiencies worsen as densities increase. Our Pod design is efficient from day one, and remains efficient regardless of density increases.

Note that the Santa Clara datacenter is a Tier 1 facility, by choice, with only 20 percent of the equipment on UPS. Choosing Tier 1 was a corporate decision to match the datacenter with the functions that it supports. The design approach is the same for our Tier 3 datacenters with one exception: the amount of redundancy. As you increase the redundancy (to N+1 or 2N) you can lose efficiency. If you make the correct product and

design decisions that make efficiency the highest priority, you can maintain a PUE of 1.6 or less in a Tier 3 datacenter.

Consider what this means for future datacenter growth. Assume that the Santa Clara datacenter PUE average will remain constant at 1.28. When the equipment densities increase power consumption to 4 MW, the total power required will be 5.12 MW (4 MW x 1.28). If the datacenter had a PUE of 2.0, it would require a total power capacity of 8 MW (4 MW x 2). This is an increased power requirement of 2.88 MW. Using an industry average 8 cents per kilowatt hour, this equates to an annual increase of more than \$2 million per year to run the exact same equipment.

## Chapter 3

# Sun's Pod-Based Design

Sun's approach to satisfying the range of requirements discussed in the previous chapter was to use a modular, flexible, pod-based design. A pod is a small, self-contained group of racks and/or benches that optimize power, cooling and cabling efficiencies. Designing at a pod level, rather than a room level, simplifies the approach and allows the same architecture to be used in both small and large datacenters throughout Sun. Small datacenters can deploy a single pod. Larger datacenters can replicate the pod design as many times as necessary to accommodate the needed equipment. The pod design gives a standard increment by which lab and datacenter space can be scaled up and down as business cycles — including reorganizations, acquisitions, expansions, consolidations, and new product development efforts — dictate. Because each pod is independent, we can structure one pod to contain mission-critical equipment with a Tier 4 design in the same room as other pods designed to meet Tier 1 requirements. Keep in mind that to achieve true tier 4 capabilities, you would need fully redundant services behind these pods at a space and cost premium. At Sun, our business decision was to build our datacenters with infrastructure to support Tier 1-3 operation. The modular nature of the pod design allows redundancy and capacity increases — including power and cooling — to be handled at the pod itself instead of across the entire room.

A typical pod is a collection of 20-24 racks with a common hot or cold aisle along with a modular set of infrastructure to handle its own power, cooling, and cabling. The modular approach allows pods to be reconfigured and adapted to different uses without having to design each one from scratch or completely reconfigure a datacenter every time its space is repurposed. The pod design can be replicated by ordering from standard parts lists for its various components, making it easy to deploy the same infrastructure — and incorporate lessons learned — without the expense of custom designs in each location.

Integral to our building-based pod design is the additional budget of 10-15 percent for larger mechanical and electrical support infrastructure to future-proof the space. This choice enables future capacity increases in power, cooling and connectivity. Some of the costs include increasing chilled water piping and electrical conduit sizes as well as planning square footage and taps for additional components such as transformers, chillers, UPS, and in-room cooling units.

These components may not be required today, but they allow a pod's power consumption to increase or its components to be replaced without significant interruption of datacenter operations. The modular pod design supports a level of flexibility that the datacenter needs to have in order to maintain a competitive edge while reducing operating costs and extending the equipment lifecycle. A datacenter

built with the pod design can support a 2 kW rack of equipment with single-phase 120 VAC today, and a 30 kW rack of equipment with 208 VAC three-phase power tomorrow with a simple change or addition of modular components.

## Modular Components

Sun's pod-based design uses a set of modular components that are discussed in detail in the following chapters:

- *Physical design.* A pod takes on one of two basic appearances based on the spot-cooling strategy that is used: racks are organized in a hot-aisle/cold-aisle configuration with closely coupled overhead or in-row cooling and heat isolation that includes hot or cold aisle containment.
- *Power distribution.* A busway distributes power from above or below depending on whether a raised floor is used. Different power requirements can be accommodated by plugging in different 'cans' that supply the appropriate voltages, provide a circuit breaker, and feed power to the rack. The busway is hot pluggable, and the pod's power configuration can be easily changed in a matter of minutes without risking damage to other equipment.
- *Cooling.* The pod design uses in-row or overhead cooling to cool the equipment and neutralize heat at the source. Room air conditioning is used to meet code requirements for habitable space, provide humidity control and air filtration, as well as low density base cooling to pods in some instances.
- *Connectivity.* The pod design allows short cable length and in-pod switching equipment, saving copper, decreasing costs and increasing flexibility. Patch panels are installed above or below each rack, depending on whether the datacenter is on a raised floor or slab.

The Sun Modular Datacenter is an example of a completely self-contained pod, with integrated high-efficiency cooling, power infrastructure, and a capacity of eight racks, seven and a half of which are available for payload. The Sun MD is like our building-based datacenters in that it is built from a set of modular components. As with our pods, a Sun MD can be replicated over and over to build datacenters of virtually any scale. Both designs are based on neutralizing heat created by the IT equipment at its source, leading to much lower power usage than traditional CRAC-based designs.

Unlike our building-based designs, all of the decisions on physical design, power distribution, and cooling inside the modular datacenter are already defined for the customer. The only decision left is what type of equipment (or payload) you will deploy inside. Unlike building-based designs the Sun MD has the ability to operate in warehouses, outside locations, or remote locations with no buildings at all.

## Pod Examples

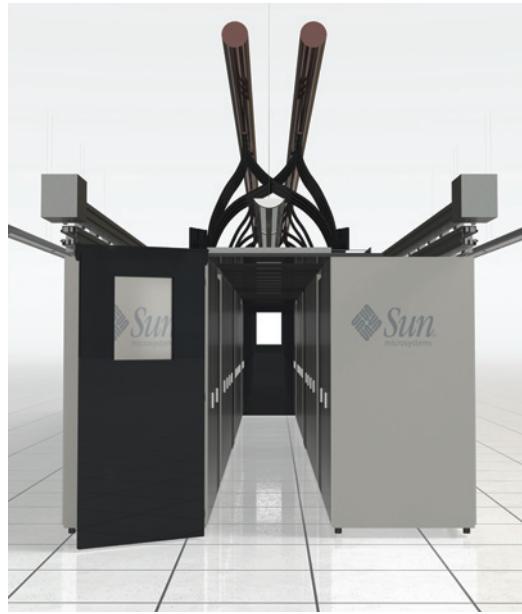
Architectural models of our pod design show how different datacenters can look based on the choice of which pod modules to deploy. The examples show the pods on slabs and raised floors, but the design can accommodate both environments equally well. Also included is an example of a pod based on a Sun Modular Datacenter.

## Hot-Aisle Containment and In-Row Cooling

Figures 5 and 6 illustrate a pod configured with a contained hot aisle and APC InRow cooling units. Consider them as rooms inside of rooms. The pod's hot aisle is contained with an overhead floating ceiling and access doors on each end. Overhead is the hot-pluggable power busway and patch panels to meet each rack's communication needs. Distributed between racks are APC InRow RC cooling units that use variable-speed fans to move hot air out of the hot aisle through water-cooled heat exchangers. These units sense the actual load and adjust their fan speeds automatically, significantly reducing power costs and maximizing efficiency. Since this roof approach contains the hot aisle at the rear of the racks, and cooling units are interspersed within them, this design is optimized for equipment requiring front-to-back cooling. Chimney-based racks and equipment require a customized containment design to work with this approach. This design does not require a large amount of overhead space, allowing virtually any office space to be converted into a datacenter with this set of modules. It also allows for easy replacement of entire racks since the roofing systems is suspended from the ceiling rather than mounted to the cabinets.



*Figure 5. An architect's rendering of a pod that uses hot-aisle containment and APC InRow cooling systems on a slab or raised floor.*



*Figure 6. View of the hot aisle showing the overhead roof and doors at each end of the aisle.*

### Overhead Cooling for High Spot Loads

Figures 7 and 8 illustrate a pod that uses the same overhead power busway and communication infrastructure as the previous example. This example uses overhead Liebert XDV cooling modules to provide closely coupled cooling for all racks, neutralizing heat at its source. These units hot-plug into preconfigured overhead refrigerant lines, allowing them to be installed and removed as cooling requirements change. This type of pod is excellent for rapidly changing environments where cabinets are rolled in and out and intermix front-to-back and chimney cooling models.

The approach starts with XDV cooling modules in every other overhead location. Cooling capacity can be doubled by adding additional XDV cooling modules to complete the first row. Cooling capacity can be doubled again by adding a second row of XDV cooling modules overhead, with the end state shown in Figure 8. Another major advantage of this approach is the savings in square footage. Because no in-pod floor space is required for cooling devices, you can deploy more equipment into the same space. One disadvantage of these units is the required overhead space to install the supporting pipe work. This may limit your ability to deploy in low-ceiling locations.

Even without hot-aisle containment, XDV cooling modules reduce the random intermixing of cold and warm air, allowing the cooling infrastructure to neutralize heat at the source. The datacenters we deployed using this cooling model initially did not use containment, however the development of a transparent, fire-retardant draping system illustrated in Figure 7 allows us to achieve higher efficiencies by minimizing or eliminating the mixture of hot and cold air.

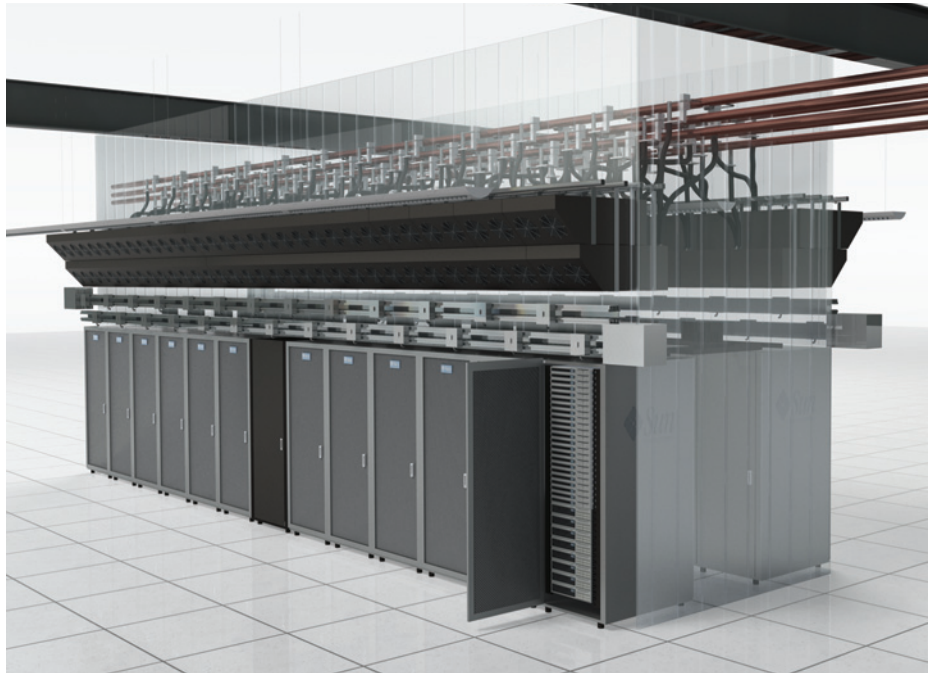


Figure 7. Architect rendering of a pod using Liebert XDV overhead spot-cooling modules and a transparent drape above the racks and at the ends of the hot aisle.

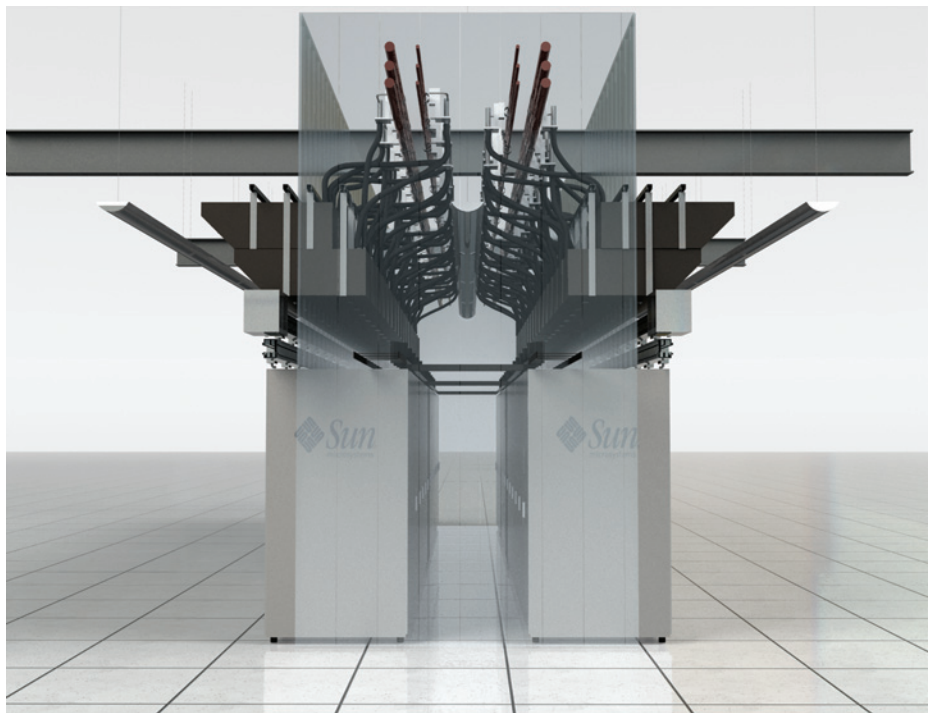


Figure 8. Hot aisle view illustrating the relative positions of the Liebert XDV cooling modules, refrigerant plumbing, the electrical busway, and the cabling system.



## A Self-Contained Pod — the Sun Modular Datacenter

The Sun Modular Datacenter S20 is a high-density, energy-efficient, self-contained datacenter that is configured in an enhanced 20-foot shipping container (Figure 9). Like our building-based pods, it is engineered to minimize energy and space requirements while maximizing compute density and operating efficiency. Whereas our building-based pods took up to 12 months to deploy because of the building retrofits that were required, the Sun MD can be deployed in a much shorter time frame — sometimes in a matter of weeks if permits can be obtained. This allows customers to deploy and scale their compute capacity quickly, when and where it is needed. Using the ISO standard shipping container size allows the Sun MD to be handled by standard equipment and shipped via air, cargo ship, and truck.



Figure 9. The Sun Modular Datacenter S20 is a pod that is built in an enhanced 20-foot shipping container. The datacenter is self sufficient except for power, chilled water, and networking connections.

Figure 10. One cooling module accompanies each rack, with temperature-controlled fans modulating speed across five different zones.

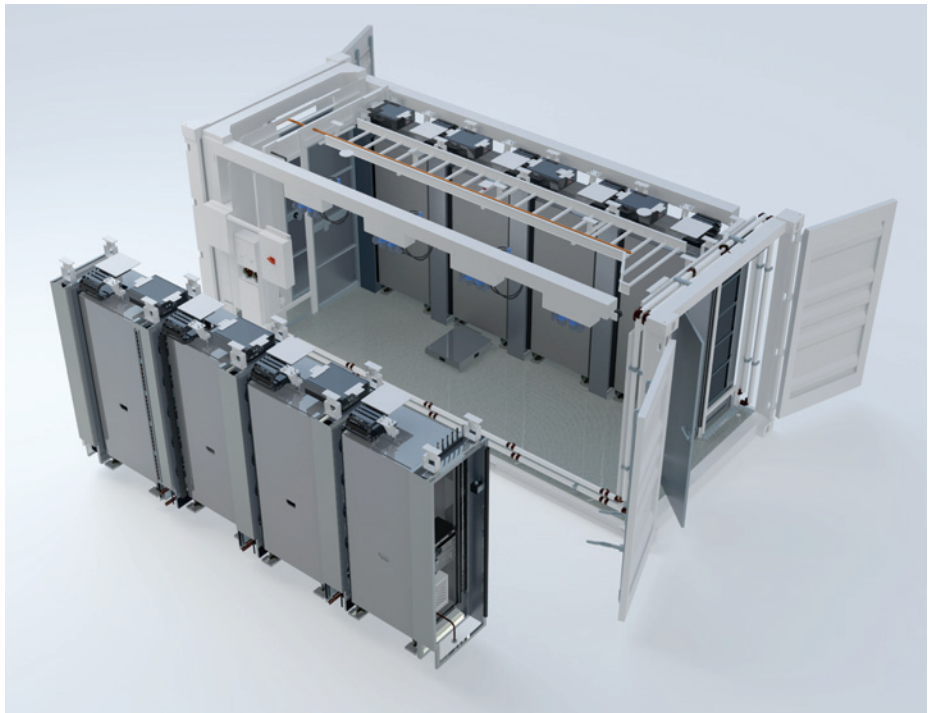


The Sun MD is self sufficient except for the need to provide chilled water, power, and network connections to the unit's external connections. Internally, the Sun MD contains the following modular elements (Figure 11):

- Eight high-density, 40 U racks capable of supporting 25 kW of equipment per rack. Each rack is shock mounted, and slides out into the central service aisle for maintenance. One of the racks is reserved for switching equipment and the internal environmental monitoring system. Sun MD racks are designed for rack-mount, front-to-back cooled equipment and it does not accommodate chimney-cooled cabinets.
- Circular airflow design that uses a closed-loop water-based cooling system with one cooling module per rack to neutralize heat at the source before passing the air onto the next rack in the loop. The Sun MD cooling modules have temperature-controlled fans that adjust airflow independently for each of five zones per cooling module (Figure 10). Like the APC InRow RC cooling modules, the Sun MD uses dynamic temperature-controlled fans to help to reduce power consumption. Sun's own

measurements of Sun MD cooling efficiency point to over 40 percent improvement over traditional raised floor datacenter designs using CRAC units.

- Redundant electrical system that powers each rack from two separate, customer-configured breaker panels housed within the Sun MD.
- Cabling system that supports rack movement in and out of the cooling system loop, with connectivity to the internal switching equipment and on to the configurable external copper and fiber network ports.
- Internal environmental monitoring and fire suppression system.



*Figure 11. The Sun Modular Datacenter S20 incorporates eight racks that participate in a circular airflow. Air reaching one end of the datacenter crosses to the other side through an internal vestibule that serves as an air plenum.*

The Sun Modular Datacenter S20 includes 280 rack units of space for servers. If populated with 280 Sun SPARC® Enterprise T5140 servers, the Sun MD would support 4,480 processor cores and 35,840 compute threads. If populated with Sun Fire™ X4500 servers, the modular datacenter could support up to 3 petabytes of storage. The Sun<sup>SM</sup> Customer Ready program can pre-configure Sun MD payloads to customer specifications, or they install equipment from Sun or other vendors themselves.

## Chapter 4

# Modular Design Elements

The most important characteristic of the pod design is that it is modular, with design elements that can be swapped in and out depending on the organization's requirements. Modularity allows datacenters to be built quickly, and scaled up and down as needed. It allows proven designs to be repeated easily, incorporating lessons learned over time, helping to increase agility while reducing risk. This chapter discusses the modular nature of each of the pod design's main elements. Future Sun BluePrints Series articles will go into further depth on each of these components.

## Physical Design Issues

Physical design characteristics to support the pod design include handling the increasing weight load that comes with increasing density, the choice of slab or raised floor configurations, rack sizes, and future proofing that supports later growth without down time.

## Sun Modular Datacenter Requirements

The considerations for deploying a Sun Modular Datacenter are mostly physical design ones, as the datacenter's interior systems usually come fully configured. The Sun MD can be located on a flat, self-draining surface, such as a concrete slab, or on four posts capable of supporting up to 8,500 lbs (3,856 kg) each. The site should be designed to provide safe and sheltered access to each end of the container, and flexible connections should be provided for chilled water, power, and networking. At our Santa Clara campus, where we are planning to deploy several Sun MD units, we are developing a modular chilled water and power distribution system that will allow us to scale by plugging in new Sun Modular Datacenters without disrupting any other datacenters or Sun MD units.

## Structural Requirements

Rack loads are starting to reach 3,000 lbs (1,361 kg). In some cases we have used steel to reinforce existing floors above ground level to accommodate the anticipated load. In cases where we have the flexibility, we have chosen to place datacenters onto the ground-floor slab.

## Raised Floor or Slab

The pod design works equally well in both raised-floor and slab environments, allowing practically any space that can handle the structural load to be turned into a datacenter. Historically, raised floors have been the datacenter cooling standard. They've also been included in the Uptime Institute's definition of tier levels. Raised floors tend to have unpredictable and complicated airflow characteristics, however. These traits cause non-

uniform airflow across the datacenter and are very difficult to optimize, leading to hot spots that are difficult to control. The complicated airflow characteristics also make it very difficult to reconfigure airflow to handle high-density racks without creating other cooling problems as a side effect. Designers may attempt to mitigate this issue by raising floor heights. This can support up to 5 kW per rack of cooling inefficiently, but it is a game of diminishing returns as densities continue to increase beyond what raised floors can handle on their own.

In contrast, our approach integrates cooling into the pod so that each pod is self-sufficient from a cooling perspective, making it irrelevant whether the pod is positioned on a floor or a slab. We do have room-level cooling in our datacenters to handle the following needs:

- Eliminate heat from solar gain, people, and lighting — anything that is not an IT load.
- Control humidity to within a range of 30-60 percent relative humidity. In the overhead cooling approach, we must keep the dew point below 50 degrees Fahrenheit (10 degrees Centigrade) so that the XDV cooling modules can operate at capacity.
- Filter particulates from the air.
- Provide fresh air and ventilation to the space as required by code so that the space can be occupied by people.

We have used raised floors in customer-facing datacenters where appearance is important. We have used them in pre-existing datacenters, and locations where the client organizations have insisted on them and when a competitor's product cannot operate without them. Given the expense, vertical space and inefficiencies of raised floor we prefer to build our datacenters on slab.

## Racks

For the pod's physical design, Sun has standardized on 42 U racks with a mixture of 24 and 30-inch widths depending on cable densities. The use of standard racks is, as with other components, optional. In some datacenters, rack-mount servers are mounted relatively permanently in fixed racks. In other datacenters, where the rate of change is high, cabinets and servers are wheeled in and out, replacing the use of fixed racks. The key is that the pods accommodate racks of different dimensions.

## Future Proofing

One of the choices we have made in our datacenter consolidation project is to add infrastructure today that supports tomorrow's growth. Our future-proof approach adds 10-15 percent to mechanical and electrical costs for larger support infrastructure. Some of the costs include increasing chilled water piping and electrical conduit sizes as well

as planning square footage and taps for additional components such as transformers, chillers, UPS, and in-room cooling units.

This cost enables future capacity increases in power, cooling and connectivity. The estimate is that we will be saving 75 percent on future expansion costs due to the investment that allows additional modules, such as chillers and transformers, to be added easily. Consider that no additional pipe work or major construction needs to be done to expand. Future proofing not only saves cost over the long term: it also saves vacating or idling a datacenter while upgrades are made, helping to increase the datacenter's effectiveness to the company as well as helping to reduce product development time.

Within the pod, we have configured the cooling system so that it can be upgraded without interrupting service. For rooms using APC InRow RC units, chilled water lines are stubbed with future valves so that twice the current number of in-row cooling units can be supported. Where refrigerant lines are used, positions for a cooling unit are stubbed out at every rack position, and in some cases the lines are plumbed for two units per rack position. Communication infrastructure is also in place for expansion, with additional ports, rack locations, and patch-panel locations above each rack or in pod IDFs for future use.

Outside of the datacenter itself, our Santa Clara location's electrical yard has concrete pads poured and piping in place to support two additional 1,000 ton chillers and cooling towers. Pads are in place for two more phases of electrical infrastructure expansion that can take us to 21 MW in capacity. Complementing the power is an additional pad for future generator capacity. All of the site power infrastructure and cooling piping has been pre-sized to accommodate an end state of 21 MW.

## Modular Power Distribution

Most datacenters are designed with the hope of having a 10-15 year life span. With most equipment refresh cycles running from 2-5 years, datacenters should be built to support 2-4 complete replacement cycles over their lifetimes. This is a particular challenge when it comes to power distribution within the datacenter.

According to Sun's historical data, a high-density rack in the year 2000 imposed a 2 kW heat load. In 2002, a 42 U rack full of 1 U servers demanded 6 kW. The increased density of blade systems broke the 20 kW barrier in early 2006. In 2008, we are seeing some deployments sustaining an average load of 28 kW per cabinet. Moore's law will continue to push these rack levels ever higher as worldwide Internet use grows and infrastructure expands to accommodate it. These numbers reflect the 'skyscrapers' in our city skyline analogy. Before the real-estate consolidation project, our datacenters were inconsistently designed and usually at or exceeding power, space, or cooling capacities. The new datacenters were designed to support an average range of 5-12 kW

per rack, with the ability to grow to an average range of 9-18 kW per rack. These rack loads are averaged, however all of our locations are capable of housing loads from 1 to 30 kW.

The challenge with power distribution is being able to accommodate an overall increase in power consumption over time, be able to power the ‘skyscrapers’ even when their location is not known beforehand, and to be able to accommodate the server churn that causes high variability in power demand per rack.

### The Problem with PDUs

The traditional power-distribution model is to use Power Distribution Units (PDUs) located on the datacenter floor. These units are usually “breaker panels in a box” from the UPS with individually sized cables (‘whips’), or hard-wired connections in wireways routed to smaller PDUs in the racks either overhead or under a raised floor (Figure 12). In some cases they may transform the higher UPS voltage to lower voltages used by the IT equipment. There are several disadvantages to this approach that affect how easily and rapidly a datacenter can accommodate change:

- PDUs take up valuable datacenter floor space.
- Adding or changing whips means changing circuit breakers, which opens and exposes internal components of the PDU, increasing the risk to any equipment to which the PDU supplies power. This increases the risk of unexpected down time.
- “Home runs” of cable for each rack wastes copper.
- PDUs typically have limited circuit breaker positions. As datacenters change, availability of available breaker positions can become a problem.
- The risk and hassle of removing an unused whip from overhead cable trays or from beneath raised floors is so great that often cables are abandoned in place. In traditional raised floor datacenter designs where air is being supplied from underneath the floor, these runs can lead to cooling inefficiency because abandoned whips create additional obstructions in the raised floor plenum.

We elected to use large, distributed PDUs for the Santa Clara Services datacenter, a choice that we now view as a limiting factor in that datacenter’s modularity. (See “Santa Clara Services Organization Datacenter” on page 40.)

*Figure 12. Using PDUs can result in an unmanageable snarl of cables. Pictured are whips running from a PDU to an overhead cable tray.*



*Figure 13. Modular busways provide flexible, adaptable power distribution that is monitored and can be changed rapidly.*



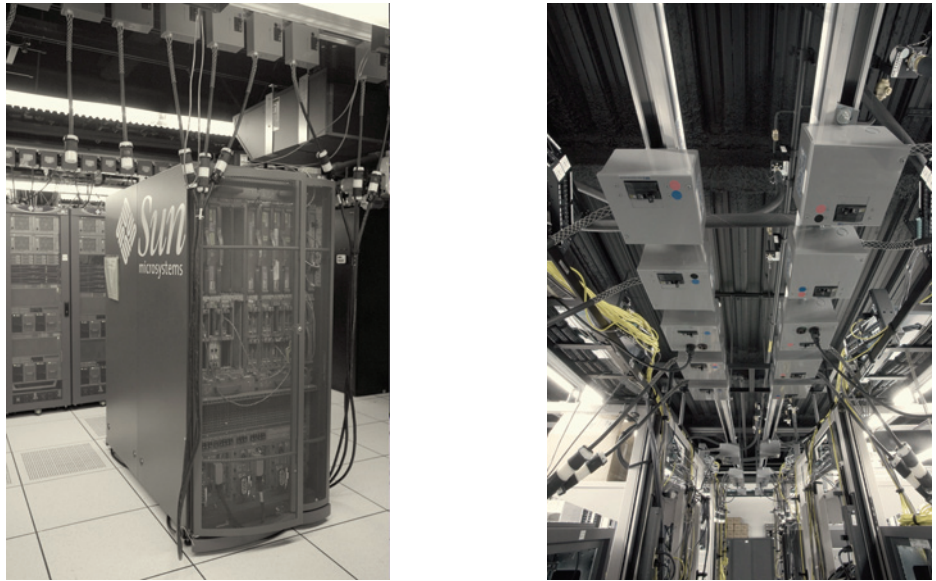
## The Benefits of Modular Busway

Our pod design removes all transformers and power distribution units from the datacenter floor. Instead, we use a hot-pluggable overhead busway to distribute power to each rack. We use one busway above each row of racks, two busways per pod. We use four busways per pod when dual (redundant) utility feeds are required for mission-critical datacenters requiring Tier 2 and 3 availability.

It should be noted that there are a number of modular busway manufacturers today and we have no doubt there will be more in the future. Relying on a single source is a potential risk for availability of product and response time from the vendor. For our current datacenter deployments, we have standardized on Universal Electric's Starline Track Busway and deployed a combination of 225A and 400A busways to distribute power from the last stage of transformers to the server racks. In a typical U.S. datacenter, the busways deliver 208 VAC three-phase and 120 VAC single-phase power to the racks. The busway uses hot-pluggable power outlets or 'cans' that include one or more circuit breakers and whips that drop down to the rack or cabinet (Figure 13). Each busway is equipped with a power-metering device that provides real-time power data. We also monitor individual rack power consumption through metered rack power strips. As Figure 14 illustrates, the busway allows intermixing of 120V single-phase and 208V three-phase power feeds. Figure 15 illustrates how the Busway is effective for rapidly changing datacenter environments.



*Figure 14. The Starline busway supports an intermixing of 120V, single-phase up to 208V, 100A, three-phase power feeds. In this example, a 60A three-phase can is being plugged in beside a 120V can.*



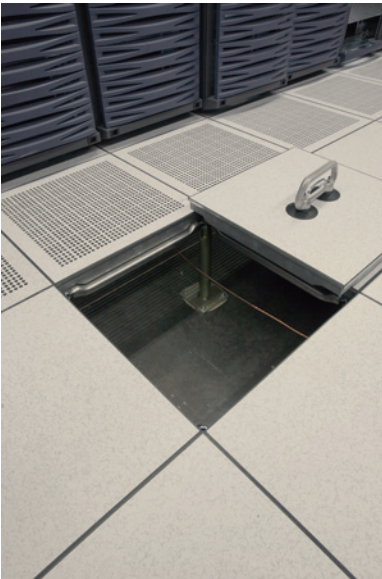
*Figure 15. The Starline busway provides flexible power delivery for environments with cabinets moving in and out (left), and above racks (right).*

The Starline busway is a vast improvement over PDUs for the following reasons:

- The busway requires no datacenter floor space, helping to increase overall density.
- Adding or changing busway cans takes only minutes.
- Power reconfiguration is non-disruptive: cans can be added or removed on a live busway.
- Shorter copper runs save copper use by approximately 15 percent on initial install.
- Cables never need to be abandoned in place.
- Future copper needs are also significantly reduced due to the ability to re-use, or re-deploy, busway cans to different locations rather than adding more dedicated circuits.
- The busway supports all densities, high & low, as well as increased power density over time.
- The cost of installing traditional power distribution versus busway to high-density equipment has become equal.



*Figure 16. Traditional raised floor datacenter cooling used perforated tiles to direct cold air to racks and can be pressed to cool 4-6 kW per rack but with a dramatic loss of efficiency and increase in cost.*



## Modular Spot Cooling

Historically, datacenters have been cooled by CRAC units placed along the walls, feeding cold air underneath a raised floor that serves as a plenum. Perforated floor tiles provide control over where the cold air is delivered to racks, as illustrated in Figure 16. When used with raised floors, cooling by CRAC or CRAH units is effective to densities of approximately 2 kW per rack. Because of ever increasing densities, raised floors have needed to cool 4-6 kW per rack. But that requires higher raised floors and larger cold aisles. Even at 2 kW per rack densities, this technique becomes inefficient and unpredictable as floor tile airflow becomes a factor, and the ability to adequately pressurize the raised floor and create a uniform air flow pattern underneath the raised floor space becomes critical.

To make up for non-uniform cooling, datacenter operators usually reduce the overall datacenter temperature in order to overcome the random intermixing of hot and cold air. This approach wastes energy by creating cold datacenters and hot spots that can decrease equipment life. It also creates demand fighting between CRAC units, increasing the dehumidification and re-humidification processes. In lightly loaded areas the CRAC units can go into heating mode due to low air return temperatures in the datacenter space. In many cases datacenter managers have even been known to add additional CRAC units to overcome hot spots in the datacenter, further contributing to this waste of energy. Many of these CRAC units would not have been needed if mixing was not occurring. Some case studies have shown that up to 60 percent of the air flowing around a datacenter cooled this way is doing no work. This equates to wasted fan power and energy being used to accomplish no useful work.

## Self-Contained, Closely Coupled Cooling

The pod design does not require any room-level cooling to remove heat from server racks. Room-level cooling equipment is installed to handle the heat load created by the room itself, such as building loads, lighting, people, and for controlling humidity and particulates. All equipment cooling is performed through close-coupled in-row or overhead cooling devices. This greatly increases cooling efficiency while greatly reducing energy use by the cooling system.

The challenge is how to handle increasing overall loads and eliminate hot spots created by the 'skyscraper' racks using up to 30 kW each. Our solution is to use either in-row or overhead spot cooling to neutralize heat at the source.

Closely coupling the cooling to the racks creates a very predictable air flow model. This eliminates hot spots in the datacenter and allows the overall datacenter temperature to be raised because the cooling system no longer has to over-compensate for the worst-case scenario. System efficiency is increased because cooling is closely matched to IT equipment air flow requirements dynamically throughout the datacenter. The higher datacenter temperature that this approach facilitates also increases the

temperature differential between the air crossing over the cooling coils and the cooling medium running through them (chilled water or refrigerant). This further increases the heat removal capabilities of the cooling coils by increasing heat removal efficiency. Now the entire system does not have to work as hard to cool the equipment.

In both of the cooling designs we have used, we have future proofed the datacenter by installing the plumbing needed to scale the cooling to deliver the maximum expected capacity over time. In both our chilled water and refrigerant-based approaches, additional spot-cooling units can be installed quickly and inexpensively using plumbing taps already in place.

### In-Row Cooling with Hot-Aisle Containment

For environments that use equipment with front-to-back cooling, we have used a modified version American Power Conversion's InRow Cooling with hot-aisle containment. This model uses two key elements:

- *APC InfraStruXure InRow RC Cooling Module.* These units are interspersed between racks and use temperature-controlled, variable-speed fans to move air from the hot aisle across a chilled water-based heat exchanger back out to the main datacenter floor. Each InRow RC Cooling Module is rated to up to 30kW depending on the required temperature differential.
- *Hot-Aisle Containment System.* This mechanism completely contains the hot aisle with an overhead roof that includes an integrated ladder racking system that supports decoupled networking cabling connections and equipment. The system has doors that close off each end of the hot aisle, and it requires blanking panels to block airflow through unused rack positions. This approach supports the heterogeneous nature of datacenters, enabling you to cool a combination of high and low rack loads as efficiently as possible.

The key benefit of this approach is that variable-speed fans use only as much power, and deliver only as much cooling capacity, as the pod needs. Airflow delivered to the hot aisle by servers can be closely matched to the airflow of the InRow RC modules. Intermixing of hot and cold air is minimized by blocking unused rack positions, and datacenter temperatures can be raised, increasing the differential between room air and the water circulating through the cooling coils — all of which increases efficiency.

Figure 17 illustrates a pod using in-row cooling and hot-aisle containment. Figure 18 shows the hot aisle and the ceiling tiles and the APC InRow RC cooling modules placed between racks.



*Figure 17. Pods cooled with hot-aisle containment and in-row cooling have an unmistakable appearance.*

Although the in-row approach takes floor space for the cooling modules, these pods can be placed in virtually any office space without needing high ceilings. In our Santa Clara datacenters, we future proofed by installing one InRow RC cooling module and one empty unit in each position where one was required today. The example in Figure 18 allows capacity to increase from our current 5 kW per rack average to a 9 kW per rack average by replacing a an empty InRow RC acting as a blanking panel with an active one.



*Figure 18. The hot aisle is contained with ceiling tiles and doors at the ends of the pods (left). Two InRow RC units were installed where one was required, providing expansion capacity (right).*

One of the highest-density installations of this approach is the Texas Advanced Computing Center (TACC) Ranger system, a compute cluster that includes 82 Sun Constellation systems with 63,000 cores and 1.7 petabytes of storage on Sun Fire X4500 servers. This installation is currently managing to power and cool a sustained average of 28.5 kW per rack.

## Overhead Spot Cooling

Some of our datacenters have a mixture of front-to-back and chimney-based cooling that is not suitable for the standard in-row approach. In these spaces we were also unable to sacrifice the floor space required by the InRow RC units.

In these situations, we have used Liebert XD (X-treme Density) overhead cooling systems using the following components:

- *Liebert XDV Vertical Top Cooling Module.* These units are refrigerant-based cooling units that are suspended from the ceiling and tapped into hot-pluggable refrigerant lines. They draw air from the hot aisle and return cool air to the front of racks. These units are as wide as a single 24-inch (600 mm) rack, allowing cooling capacities up to 10 kW per unit. In some locations we have double stacked these units to achieve 20 kW of cooling per rack.

The close coupling of cooling capacity to individual racks helps with ‘skyscraper’ cooling. The units’ overhead configuration allows them to be independent of racks, which can be changed and replaced underneath without affecting the cooling modules. The cooling modules deployed in Sun’s Santa Clara datacenter has manual switches for the fans, but our Broomfield, Colorado project is scheduled to be the first recipient of new intelligent XD units with integrated fans to match heat loads and increase overall efficiency.

- *Liebert XD Piping.* The cooling modules are supplied with refrigerant through quick-connect fittings. Flexible piping comes pre-charged with refrigerant, and the quick-connection fittings make it easy to change configurations and add, move or reduce capacity (Figure 19). Due to the nature of the design, the XD systems require more overhead space to supply the required pipe work for the XDV units. These units usually require a minimum 12-foot ceiling to accommodate all infrastructure.
- *Peripheral Equipment.* The Liebert system uses the Liebert XDP Pumping Unit. These devices condense the refrigerant back to its liquid phase without using a compressive cycle. The refrigerant in the loop is pumped to the XDV modules as a liquid which partially or completely converts to a gas when extracting heat from the air. The extent to which the state change is complete depends on heat load being handled by the XDV module. The vapor and liquid mixture then flows back to the pumping unit where the heat is transferred to the chilled water loop and the vapor condenses back into a liquid. Another benefit of this system is that if there is a leak, the refrigerant will turn gaseous on exposure to air. No liquid will escape into your datacenters. To

ensure life safety in the event of a leak, however, oxygen sensors in the room are usually required by code. The XDP units can be placed on the datacenter floor or in an adjacent room.

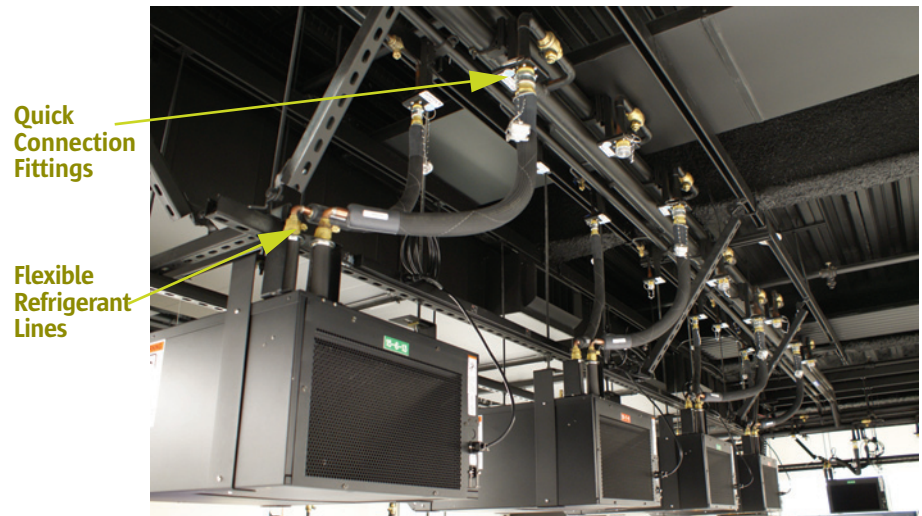


Figure 19. In this view from the hot aisle, overhead Liebert XDV top-cooling modules use fixed copper refrigerant lines and quick-connection fittings. Note that only half of the quick-connection fittings are currently used.

Figure 20. Overhead Liebert XDV top-cooling modules can be used in open environments.



Figure 20 illustrates the use of Liebert XDV top cooling modules in the Services organization datacenter where the racks are variable and open, and where configurations must be changed easily. Figure 19 points out the fixed Liebert XD piping along with the flexible lines supplying refrigerant lines to the XDV units themselves.

The benefits of the overhead cooling approach include the following:

- Supports both front to back and chimney-based systems with intake on the XDV units that can be positioned in the back or the bottom respectively
- Scalability up to 20 kW per rack average by stacking two units vertically above each rack
- Overhead configuration that enables mobility and does not require floor space
- Close coupling of cooling with high-power racks
- Easy to install and move cooling units to where the heat is generated
- No liquid is released in the datacenter if there is a leak

### The Future of Datacenter Cooling

A quick glance at the section “Power Usage Effectiveness” on page 12 serves as a reminder that the energy cost of cooling a datacenter is second only to the cost of powering the IT equipment itself. The increased attention on energy efficiency, combined with the limitations and inefficiencies of raised floor approaches for

increasing densities, as well as skyrocketing costs, is leading to rapid innovation in the area of datacenter cooling.

We have developed close relationships with APC and Liebert during our worldwide datacenter consolidation project, and both of these companies have responded to our needs with improvements to their products. For example, APC has refined their hot-aisle containment system based on our experience and is working to accommodate chimney-based systems. Liebert has introduced refinements in their overhead spot-cooling solutions. These innovations and many more will continue to drive efficiency into the datacenter.

### **Chilled Water Versus Refrigerant**

Most medium to large-sized datacenters use a chilled water system to deliver cooling capacity to the datacenter perimeter. The choice of running chilled water at least to the datacenter perimeter is a compelling one. Water (or a mixture of water and glycol) has sufficient density for efficient heat transfer. It can be cooled using a standard chilling plant such as the one we have built for our Santa Clara datacenters. It can be chilled using outside air as we have done in one of our Menlo Park datacenters (see “Sun Solution Center” on page 41). There is also a project that is outfitting large container ships as collocation datacenters that use ocean water for cooling and could house more than 4,000 racks below deck and potentially 300 Sun Modular Datacenters on the deck.

There is significant debate, however, regarding whether to extend the chilled-water system onto the datacenter floor. Ironically, water has been in datacenters from the beginning. Mainframes have required water piped to them. Water-based fire-suppression systems are used to protect many datacenters, including many of our own. Facilities engineers tend not to be concerned about water extended into the datacenter. Among IT engineers, the perception is that this should never be done.

Water extended to the datacenter floor is simply an engineering problem. As with any engineering effort the good designs will prevail. Flexible pipes, double sleeving, isolation valves, leak sensors, and a solid building management system helps to minimize risk. Today, organizations can choose to extend the chilled-water loop directly to localized cooling units in pods, or they can use the chilled-water loop to condense refrigerant that is circulated throughout the pods instead.

Despite the fact that both water and refrigerant piping is pressure tested before a pod is commissioned, some organizations have a strong preference for or against water circulating in close proximity to computing equipment. We have used both chilled water and refrigerant in our datacenters, even on slab, and we have not had any outages or problems related to water leaks.

Because each organization has its preferences, we expect to see cross-pollination between refrigerant and chilled water innovations. For example, the success of APC’s

InRow RC solution has drawn at least one vendor into offering a similar, refrigerant-based approach. Over time, we expect to see an equivalent set of options for both chilled water and refrigerant, leaving the choice up to individual datacenters.

### Close-Coupled Cooling Innovations

The closer the heat-removal mechanism can be tied to the heat source the more efficiently that it can remove heat from the datacenter. We expect to see market movement towards a richer set of close-coupled cooling techniques as well as approaches that more precisely target their cooling capacity.

- *Pod-level cooling.* The closely-coupled cooling solutions we have deployed so far have been at the pod level using products from both APC and Liebert. APC was the first to provide this type of highly efficient solution in the market before datacenter efficiency became a focus. Like APC, Liebert has introduced an increasing number of products to directly assist in pod-style spot cooling. In addition to its XDV cooling modules, Liebert offers an XDO Overhead Top Cooling Module that draws hot air from above two rows of racks and directs chilled air into the cold aisle. Liebert also offers an XDH Horizontal Cooling module that operates like the APC In-Row RC units except that it uses refrigerant instead of water.

We deployed the XDO solution in our Guillemont Park datacenter (“Guillemont Park Campus, UK” on page 42). In a drive for even higher efficiency, Liebert has integrated controls that can vary fan speeds in their XD cooling modules. To continue the drive for low implementation and operating costs, we have created new designs using draping systems to contain either the hot or cold aisle in conjunction with both APC and Liebert cooling equipment.

- *Rack-level cooling.* Some innovations move cooling to the racks themselves, neutralizing heat before it can leave the cabinet. Sun Modular Datacenters are cooled by an active, water-cooled system that neutralizes heat as it leaves the rack. Other passive rear-door heat exchanger attach to the back of a standard 42 U rack and use server fan pressure to push air through the heat exchanger. We would be surprised not to see similar, refrigerant-based products in the future. Likewise, we would expect to see rack-level cooling systems designed to work directly with specific equipment so that a rack that consumes even 50 kW or more could return air to the datacenter at its ambient temperature.
- *Direct CPU cooling.* The most focused closely coupled cooling system would chill server CPUs directly. These solutions may become necessary as densities are pushed higher and CPU die temperatures continue to rise. There are at least two issues to this approach, however. Each server must have a direct connection to the chilled water or refrigerant system, raising the number of connections that can fail, and complicating maintenance. Direct CPU cooling removes heat from the CPU, but it does not remove heat generated from disk drives, memory, adapter cards, and other

electronics — so it must be augmented by technology to remove heat from the rest of the rack, pod, or datacenter.

- *Free cooling.* Many organizations are working on ways to eliminate chillers and in-room cooling units all together. Utilizing free-cooling techniques such as air-side or water-side economizers and exploring the ability to use higher temperature water in datacenters will continue to drive innovation in this area. While there is no single answer to this challenge, there are many products that are likely to be introduced in the coming years.

## Modular Cabling Design

Increasing density in datacenter racks means more cables to support the increased bandwidth requirements that arise from having greater processing power in a smaller space. Many servers require connections to multiple Ethernet, Fibre Channel, console, and out-of-band management ports, bringing the number of cables possible in a 42 U rack full of 1 U servers to more than 300. A blade server using InfiniBand and 10 Gigabit Ethernet connectivity can require as many cables as an entire rack of 1 U servers.

Traditional datacenter designs use a centralized cabling model, with network and system management connections each making a home run to a centralized access-layer switch in an Intermediate Distribution Frame (IDF). This approach results in a static cabling configuration that is difficult to change or to expand. It wastes significant amounts of copper, and requires more effort to work around large cable bundles.

Our cabling design puts IDF switches directly into each pod. This makes the pod relatively self-sufficient, with shorter cables running from above each rack position to the distributed network edge devices. Uplinks connect each pod to aggregation-layer switches. In the case of Ethernet, we use multiple 10 Gigabit Ethernet links to connect each pod's switches to the next layer of switches in the datacenter.

In order to support the rapid change that datacenters require, each rack position has access to an overhead patch panel that connects the rack's equipment into the pod's wiring infrastructure (Figure 21). This makes it simple, for example, to roll out a rack of 1 U servers that use a large number of cables and roll in a cabinet that requires a small number of cables without leaving an entire wiring harness of unused cables hanging down above the racks. Our best practice is to populate half of each rack's overhead patch panel with cables running to pod-based switches, leaving room to double the patch panel's capacity or add switches to be shared between racks in the future.





*Figure 21. Patch panels above each rack position support a wide range of connectivity requirement while providing room for future expansion.*

### Cabling Best Practices

Some of the best practices that support the pod's modularity include:

- Make the additional up-front investment in 10 Gigabit Ethernet connectivity using both fiber and copper capability.
- Maintain the shortest cabling distance between switches and devices. Short cabling in the pod design saves up to 50 percent of the copper required by centralized configurations. Shorter cable lengths also make it easier to deploy 10 Gigabit Ethernet, where cable lengths are more limited than for Gigabit Ethernet.
- Configure switches in two pod IDF's, making each pod a relatively self-sufficient, room inside a room.
- Install patch panels at half capacity, leaving room for future expansion.
- Distribute cable management systems to the pod's overhead patch panels or in cabinets, depending on the density. This includes cables for console ports and KVMs.
- Use standardized cables that do not present performance or compatibility issues.
- Make cabling locations independent of the racks, so that no cables from overhead or under-floor bundles actually terminate in racks. Use patch cables to connect from patch panels to equipment in racks themselves.
- Consider distributing smaller edge switches into the racks to limit the amount of termination that needs to be done.

## Chapter 5

# The Modular Pod Design At Work

One of the best ways to communicate the solutions that we have implemented worldwide — and the lessons we have learned in the process — is through a guided tour of several of the pod-based datacenters we have deployed, including one use of the Sun Modular Datacenter.

## Santa Clara Software Organization Datacenter

Our datacenter supporting Sun’s Software organization is a dramatic illustration of how different a datacenter can look using the various modular techniques we have discussed in this paper (Figure 22). Because the Software organization primarily uses equipment with front-to-back cooling, we were able to use hot-aisle containment and in-row cooling.

“The new datacenter design has enabled our operations teams to focus on service performance, system utilization, and support excellence instead of system recovery, capacity constraints, and operational costs. This, in turn, supports our product development strategies by facilitating faster provisioning and deployment of new hardware and software systems.

When facility design supports value-creating IT functions, the business benefits. With the modular datacenter, the pace of innovation, product development, and customer delivery all have increased, along with operations employee productivity.”

Diann Olden  
VP, Global Product Development  
Software Business Unit



*Figure 22. The Santa Clara Software datacenter has 18 pods based on in-row cooling and hot-aisle containment.*

The datacenter is made up of 18 pods of 22 racks each, with 9 additional racks on the perimeter. Each pod uses a floating, overhead ceiling with doors at both ends of the hot aisle. All empty rack positions have blanking panels to prevent hot air recirculation. Each pod is installed with eight APC InRow RC units. Five are operational, and three are blanked off, ready to accommodate future expansion. This cooling system supports an average of 5 kW per rack today, with the ability to support an average of up to 9 kW per rack in the future.

One of the advantages of the in-row solution is that the cooling fans provide intelligent cooling that is matched to the airflow and the heat produced by the pod’s equipment.

The closer that this match can be made, the more efficient the datacenter. With the APC InRow RC units, all of the pod's fan speeds are tied together, producing even airflow from the hot to the cold aisle. This design was successful in achieving a PUE of 1.28 cutting our energy consumption in half. This is the highest-efficiency datacenter in our portfolio.

### Santa Clara Services Organization Datacenter

Our Santa Clara Services Organization's datacenter stands in stark contrast to the uniformity and relatively uniform nature of the Software organization's datacenter (Figure 23). In order to be able to re-create customer environments, this datacenter contains one or more of every Sun product, from first release to end of service life. The equipment ranges from desktop workstations to chimney-cooled servers. The Services organization needs to be able to configure and reconfigure these systems in order to re-create customer problems. This enables the engineering groups to investigate and fix any related bugs.

“Due to the nature of our services support delivery operation, our datacenter contains multiples of almost every server and storage product Sun has produced in the past seven-plus years. We continuously add products as they are introduced into the market. The flexibility of the datacenter pod design with its modular cooling, power, and networking, gives us the ability to arrange, configure, and add equipment as business demands. In our business this happens on a daily basis.”

Tracey Kyono  
Serviceability and Readiness Director  
Global Customer Services



*Figure 23. The Services organization datacenter required a high degree of flexibility, with lab benches and racks. This was an ideal application of the Liebert XDV cooling modules.*

To support a rapidly-changing environment of racks, chimney-cooled servers, and lab benches with workstations, we used Liebert XDV cooling modules placed as necessary to provide uniform cooling and eliminate hot spots. The view of an aisle in this datacenter shows how the cooling infrastructure is independent of the computing infrastructure, supporting rapid change.

We built this datacenter before it was clear to us how much PDUs limit flexibility. This datacenter was built with a PDU for every aisle, and whips running from the PDU to

each rack position. This datacenter provided us with an illustration of the mass of cables that result from the use of PDUs, in particular the photo shown in Figure 12.

## Sun Solution Center

“The Sun Solution Center in Menlo Park, California allows our customers to test products in a real-world setting before they buy. The pod design that was used for this center allows us to rapidly deploy any product configuration in support of our customers’ needs. The modularity of the power and cooling makes changes simple and showcases how to deploy next-generation equipment. The center not only enables our agility, it lowers Sun's operational costs because of the efficiencies of the design.

The pod design gives our customers a holistic view into the datacenter ecosystem. Our server and storage products, coupled with this highly adaptable environment, gives a clear path to brutal efficiency and solidifies Sun's thought leadership around eco-centric datacenters.”

Graham Steven  
Senior Director  
Sun Solution Center

The Sun Solution Center in Menlo Park, California is an example of where we have used a raised access floor for the sole purpose of making the datacenter as neat and clean looking as possible given the fact that it is adjacent to our executive briefing center (Figure 24). For easier customer access, we designed this datacenter with larger hot aisles and a total of four pods. Our pods support a mixture of front-to-back cooled racks and chimney-cooled racks.



Figure 24. The Sun Solution Center in Menlo Park, California is designed to have a neat and clean appearance using the same modular design combined with a raised floor for power and connectivity access.

*Figure 25. View of modular busway and cabling infrastructure beneath the raised floor in our customer briefing center. Note the raised floor tile cutout at the top of the photo.*



*Figure 26. The Dolphin water treatment solution virtually eliminated the use of chemicals while substantially reducing water use.*



No cold air is circulated under the floor. We have placed the modular busway and the cabling infrastructure underneath the floor with access through cutouts in the floor tiles. This makes access to power and cabling both easy and unobtrusive (Figure 25). Refrigerant plumbing is overhead and flexible lines allow easy connectivity to the cooling modules as was illustrated in Figure 19 on page 34.

The Sun Solution Center is cooled entirely with Liebert XDV cooling modules and was designed to fit within the building power constraints. The datacenter has a capacity of 5 kW per rack average and can scale to 9 kW per rack average. Like all our datacenters, it can accommodate a mixture of equipment including cooling for racks up to 30kW. To increase cooling efficiency, we have installed a water-side economizer on the roof (Figure 27). When outside air temperatures are low enough, this unit chills water using outside air rather than using the more expensive electric chilled water system. Two VFD-controlled CRAC units installed in the room provide air filtration and humidity control.

A water treatment solution from Dolphin was also installed. This pulsed-power water treatment system virtually eliminated chemical costs, reduced maintenance costs on the tower and chillers, and significantly reduced water usage by allowing it to be reused many times. (Figure 26). In addition to the numerous environmental benefits, this system paid for itself in four months just by chemical cost reduction.



*Figure 27. A water-side economizer uses outside air to directly chill the cooling system's water when outside air temperatures are sufficiently low.*

## Guillemont Park Campus, UK

At our Guillemont Park campus in the U.K, we built another customer-facing datacenter with six 22-rack pods. (Figure 28). The datacenter has a combination of front-to-back cooled racks and chimney-cooled cabinets, making overhead cooling the best option. The Liebert XDO cooling modules used in this datacenter draw air from above the racks

and blow chilled air down into the cold aisle. They have twice the cooling capacity of individual XDV modules, however since these are running on 50 Hz power, their 20 kW cooling capacity is de-rated to 18 kW because of slower fan speeds. The datacenter is built to handle an average of 5 kW per rack today and grow to up to 9 kW per rack in the future. Based what we learned from this project, we have moved away from XDO modules and standardized on XDV modules. The XDO modules are larger and more difficult to install and maintain. Because of this, we had to install all ten XDO units when we built the datacenter instead of installing them as the demand increased.

“The Pod design has been so successful in driving down operational costs that it's become the building block for our entire datacenter consolidation strategy. Without it, we'd have increasing datacenter space at Sun instead of accomplishing this massive consolidation.

We've been able to scale the Pod design as needed and repeat it in a number of locations. In each case, we've been able to deliver dramatic savings in square footage and energy. In the Guillemont Park datacenter, we were able to cut our real estate by more than half and our energy consumption by 70 percent”

Bob Worrall  
Chief Information Officer  
Sun Microsystems.



*Figure 28. A customer-facing datacenter at our Guillemont Park campus in Blackwater, U.K. uses a combination of ambient cooling using a raised floor and Liebert XDO cooling modules that are positioned over the cold aisle.*

Because this datacenter was one of the first we built with the pod architecture, there were many lessons learned. We used a raised floor for base-level cooling with busway and cabling installed under floor. We used CRAC units to deliver an additional 2 kW per rack of cooling while providing humidity control and air filtration. The under floor busbar system enables power modules to be installed by an electrician. While it is not as flexible as the busway used in our other datacenters, it provides similar functionality.

The biggest lesson learned in this project was around cabling. It was built with cabling home run from every rack to a Main Distribution Frame (MDF). Because of server density, it required 960 copper and 960 fiber pairs per pod and required the raised floor height to be increased by six inches to ensure proper air flow. This substantially increased cabling costs and added complexities to overhead designs. The results of this project led to the current pod design that distributes IDFs to each pod decreasing cabling costs by more than 50 percent.

“The implementation of the new datacenter was essential for targeted growth in our Prague Engineering Center. The flexible pod design helped decrease the time to bring new groups on board by more than 30 percent. Also, shared infrastructure such as cooling, UPS, tape libraries and networking presented another substantial saving, around 15 percent in capital investment and 8 percent head count when compared to traditional design and operations.

In addition, the datacenter became an important tool for our sales force. Customers definitely prefer to see Sun's products in real production environments.”

Pavel Suk  
Director  
Prague Engineering Site

## Prague, Czech Republic

Our Prague datacenter is an example of how we have managed to work within the existing limits placed on us by the building (Figure 29). This datacenter uses a six-inch raised floor for weight distribution and piping runs, but not for forced-air cooling. The site was limited to a total of 750 kW. We installed 108 racks in a total of 6 pods, achieving the highest square-footage density of all of our datacenters — an average of 26 ft<sup>2</sup> per rack. This datacenter is entirely cooled by Liebert XDV cooling modules, with Liebert Mini-Mate cooling systems used for humidity control and air filtration. This was the first and largest XD installation in the EMEA (Europe, Middle East and Africa) region. This project used fixed pipe work rather than flex piping to the cooling modules. We have since standardized on modular, flexible connections to simplify the deployment of new XDV modules.



*Figure 29. Our Prague datacenter was built to operate within the constraints of the building. It achieves the highest square footage density of all of our datacenters, with an average of only 26 ft<sup>2</sup> per rack.*

## Bangalore, India

As with Prague, our Bangalore datacenter presented the challenge of working within the power, space and cooling constraints of an existing office building and within the constraints of existing equipment. No servers were replaced during the move to the updated space and, despite this fact, we were still able to reduce our space consumption by slightly more than half while reducing our power use by 17 percent.

This datacenter used hot-aisle containment with APC InRow RC cooling (Figure 30). This was one of the first projects completed, and its configuration shows how we have slightly modified our designs over time.

“The pod architecture is the cynosure of our datacenter design in Sun. We were constrained by a leased building which was capped on space, power and cooling, yet we had to accommodate rapid growth in R&D requirements. The pod design not only helped us address our immediate growth requirement — it also enabled future growth by reducing space by 51 percent and power by 17 percent.

The datacenter was awarded PC Quest magazine's Best IT Implementation of the year, beating out 250 competitors. In addition, it has spurred weekly tours with customers interested in how Sun has implemented high density in a geography challenged region with power instability. The economic benefits, availability, scalability and repeatability of this design has helped the India Engineering Center thrive.”

KNR  
Site Director  
India Engineering Center  
Software Business Unit

- We used APC racks and a fixed ceiling over the hot aisle since the floating roof design was not yet available. Today we use a floating ceiling with a drape between the ceiling and the racks, allowing us easier access to network cables and the ability to easily change entire rack positions. In the future, we are moving to a containment system that uses material originally designed for the clean room industry which extends to the ceiling and eliminates the need for a roof.
- We used APC PDUs with power cabling also overhead in the cable ladders because Starline busway was unavailable in India at that time.

This datacenter was built on the ground floor of an existing office building with 20-foot ceilings. A false ceiling was installed for aesthetics, and an additional layer was added to the concrete floor to strengthen it for our rack loads. Because of the frequent power outages at this site, an average of four per day, we had to built it to Tier 3 standards.



*Figure 30. Our Bangalore datacenter was built to operate within the constraints of leased office building space. It uses hot-aisle containment, and fits within the office building's standard ceiling height.*

## Louisville, Colorado: Sun Modular Datacenter

Our organization maintains two Sun Modular Datacenter S20 containers at our Louisville, Colorado location for use by the Sun MD Engineering team. These modular datacenters serve as test beds that can be used to reproduce proposed customer scenarios and test them before they are deployed in the field. Given the need to frequently change payloads in these datacenters, we installed them in warehouse space as illustrated in Figure 31.





*Figure 31. Two Sun Modular Datacenter S20 containers used for testing at our Louisville, Colorado facility were installed in three weeks.*

The plan for this test bed is to move it a few miles away to our Broomfield campus when the consolidation of our Louisville facility is finalized. Because of this, we created a modular cooling subsystem on a separate skid that can be moved with the datacenters themselves:

- The system uses a 500 kVA transformer to convert the building's 480V three-phase power to 208V three phase. The transformer provides sufficient capacity to power two 600A panels in the Sun MD units. A set of switch gear allows us to use this power to energize both panels in a single Sun MD unit, or one panel in each of the two containers. These different scenarios are used depending on whether or not we are simulating redundant feeds.
- The skid contains a heat exchanger and pumping system that transfers heat from a separate chilled water loop used for the Sun MD units and the building's chilled water system. We use a separate loop for the Sun MD units to test the containers with different payloads and different water-to-glycol ratios to simulate exact customer environments.

Once the skid and power designs were complete, local building permits obtained, and the specialized heat exchanger brought on site, the Sun MD units were installed in approximately three weeks. Although we planned to put the systems in an unconditioned garage space, we instead used inside building space when it became available. With the modular design of the Sun MD's supporting infrastructure, we plan a straightforward move to the Broomfield, Colorado site.

Additional Sun MD installations in our Santa Clara datacenter are currently in process. As with Louisville, they will quickly tap into existing chilled water, UPS, and generator infrastructure once permits are received.

## Chapter 6

# Summary

The last thing that a datacenter design should do is get in the way of a company's ability to conduct business. Traditional datacenter designs can do just that. Cooling via raised floors and perimeter CRAC units limit the ability to increase density and achieve energy efficiency. Power distribution units and under-floor whips limit flexibility and require downtime for reconfiguration. Home-run, under-floor cabling makes growth difficult, impacts cooling and raises costs.

Datacenter designs that facilitate — rather than limit — growth, density, flexibility and rapid change can be a company's competitive weapon. At Sun, our modular, pod-based datacenters can turn on a dime whenever business directions change, from accommodating new equipment in our pods to expanding our rack footprint by deploying additional Sun Modular Datacenters. We can accommodate growth and increases in density because three key datacenter functions — power, cooling, and cabling — are prepared from day one to support an overall doubling in each area. The pod-based design is an enabler, rather than a barrier, to business growth whether it is through an increase in demand, server replacement, merger, acquisition, reorganization, or other business activity. Our pod-based design has the flexibility to support gradual or rapid change to match the pace of the engineering and IT environments at Sun. We can roll in a new product that has five times the cooling requirement as the rest of a datacenter's racks, integrate it into the pod's network, and provide three-phase power to it without requiring major retrofits or requiring downtime for the entire pod. We have successfully transformed tasks that ordinarily take months into ones that take only minutes. This flexibility accelerates time to market by helping to shorten product development cycles and corporate infrastructure redeployment. These designs have helped support the agility and pace of Sun's Engineering and IT organizations while reducing real-estate expenses and keeping them more predictable.

## Looking Toward the Future

This Sun BluePrints Series article has focused on the importance of modularity in datacenter design. Through a guided tour of datacenters, we have shown how our repeatable, modular design principles have built datacenters meeting a wide range of client needs — from high-profile, customer-facing environments to datacenters that are really laboratories. All of them support rapidly-changing sets of equipment and configurations.

We have already reaped the benefits of modularity in the business advantage that it brings. Our modular design incorporates future-proofing features that allow us to support new generations of equipment as they arrive on the loading dock or are tested

by our engineering organizations. How far into the future can these datacenters support our growth?

- *Generations of equipment.* We have generally designed our pods to support the doubling of density that occurred in moving into the datacenters in the first place, followed by a doubling of power, cooling, and cabling expected to arrive over time. This allows us to support the next generation of equipment as it is phased in.
- *Increases in density.* The pod-based design is ready for increases in density, and changes in power distribution including three-phase supply. The future may hold cooling systems integrated directly into racks — and the chilled water or refrigerant lines already running to our pods can be adapted to these purposes readily.
- *Future 30 kW cabinets.* The foundation of our modular approach is to plan for the base power and cooling load that we have today, and plan to double the average load in the future. Just as a city has thousands of 10-story buildings and a much smaller number of skyscrapers, a datacenter is likely to have hundreds of 5 kW racks and a few 30 kW racks as newer, more dense designs come to market. Our modular design is ready to handle these requirements today, and the overall doubling that happens over a longer period of time.

Extreme datacenters don't require extreme designs. They require a flexible, modular set of components that can be deployed and re-deployed with ease, and they require planning for future expansion. We expect that the future proofing that we have integrated into our pod-based design will pay off handsomely in terms of the ability to non-disruptively scale our datacenters as client requirements increase over time. The growth of datacenter densities will continue. For companies to be able to adopt new technologies that give them a competitive edge, they must have the agility to deal with change. Sun's modular approach not only enables this agility, it significantly contributes to the economic and ecological viability of our company. We are not only delivering for our shareholders by making long-term economic decisions in our datacenter investments, we are doing our part to optimize our datacenters to lower ecological impacts by ensuring brutal efficiencies.

## About the Authors

### Dean Nelson

Dean is the Senior Director of Global Lab & Datacenter Design Services (GDS) in the Workplace Resources business unit of Sun Microsystems. The GDS organization bridges the gap between Facilities and IT/Engineering and is currently managing more than USD \$250 million in datacenter design and construction activity. The GDS work supports the Act portion of Sun's Eco Strategy, and was showcased at Sun's Eco Launch in August 2007.

Dean has been in the technology industry for 19 years, of which 16 have been with Sun. He spent four years in Sun manufacturing in roles ranging from component-level debug to managing quality. This included helping the drive to achieve Sun's ISO 9002 certification. Dean joined the Sun engineering community in 1993. He led systems and network administration support for some of Sun's largest and most complex R&D lab environments.

Dean left Sun in 2000 to join a networking startup company called Allegro Networks. At Allegro, he built a world-class QA team, state of the art R&D lab environments, and a fully integrated automation system.

In 2003, Dean returned to Sun joining the newly formed N1™ Software organization. He orchestrated the integration of Terraspring and Center Run R&D labs and the merger of the Sun™ Cluster Engineering organization into the N1 organization. In mid 2003, Dean took over management of all the N1 organization's R&D labs and datacenters, build engineering, automation, and capital budget responsibilities worldwide.

In 2004, Dean became a leading member of the Global Lab & Datacenter Design Services (GDS) team tasked with creating a strategy to standardize Sun's multi-billion dollar technical infrastructure portfolio. He was the architect of the GDS operating model and lead design engineer for lab and datacenter projects worldwide. In 2006, he became the GDS Director. Since taking over the group, Dean has delivered the GDS strategy, executing the largest technical infrastructure consolidation in Sun's history that revolutionized datacenter design. Dean holds numerous industry technical and business board positions including VP of the AFCOM Northern California Chapter. Dean has been featured in *Contrarian Minds*, a focus on the engineers, scientists and dreamers of Sun Microsystems. Dean lives in northern California with his wife and daughter.

### Michael Ryan

Mike Ryan is a Senior Staff Engineer in Sun's Global Lab & Datacenter Design Services organization. Mike graduated from San Jose State University with a degree in mechanical engineering. He is a licensed professional mechanical engineer and has been involved in the design, construction, and operation of mission-critical facilities for the past 18 years. His experience spans numerous industries such as gas turbine co-generation, semi-conductor manufacturing, and mission-critical datacenters. For the last seven years he has focused on the design and operation of mechanical and electrical infrastructure systems supporting high-availability datacenters. Mike joined Sun as a Staff Engineer for the GDS organization in March of 2006. Mike is the primary author of the GDS physical standards and was the lead design engineer for the Santa Clara, California datacenter project, one of the largest and most complex in Sun's history. Mike's design work supports the Act portion of Sun's Eco strategy, and was showcased at Sun's Eco Launch in August 2007.

Mike is a member of ASHRAE (American Society of Heating, Refrigeration, and Air-conditioning Engineers) and ASME (American Society of Mechanical Engineers). He also participates in the Critical Facilities Round Table group and the AFCOM Northern California Chapter.

### Serena Devito

Serena DeVito is a Datacenter Design Engineer in Sun's Global Lab & Datacenter Design Services organization. Serena joined Sun over ten years ago and has spent the bulk of her career as a system administrator within the IT organization where she designed, deployed, and supported critical infrastructure for the company. She then moved to the Software organization and managed the beta testing project for the Sun Cluster product group. Serena acted in a customer capacity running early releases of Sun Cluster software on production home directory clusters with over one hundred active users as well as clustered web services. Serena identified, documented, and filed bugs while supporting one of Sun's largest and complex engineering lab environments.

Serena has been a core member of the GDS team since 2004. In December 2005 she joined the GDS organization to drive lab and datacenter consolidation projects world-wide. Along with building numerous labs and datacenters in America, Serena was the technical lead and customer engagement engineer on the Santa Clara, California datacenter consolidation project, one of the largest and most complex datacenter consolidations in Sun's history.

Serena is a graduate of the University of Adelaide (Australia) with a Bachelors of Architectural Studies and a focus in Computer-Aided Design. She is a Sun Certified Solaris Administrator for the Solaris™ 7, 8 and 9 Operating Systems. She also loves traveling and riding horses.

### Ramesh KV

Ramesh has been in the technology industry for over 13 years and has held a variety of technical & managerial roles since joining Sun in 2001.

Ramesh began his career as a customer support engineer at Kumdev computers, where his clients included companies in the manufacturing, pharmaceuticals, telecom and IT industries. He later joined SAS (now know as SASKEN) as a Systems Engineer, where he supported the NORTEL infrastructure. He then moved on to TATA Elxsi as a Design and Development Specialist, where he was involved in various key infrastructure projects.

Ramesh spent the initial years at Sun working for the RPE organization as Global Lab Manager, where he drove the global lab model and designed, deployed, and supported critical infrastructure across USA, EMEA & India. In early 2006, Ramesh moved into the role of IT/ Lab Council head for the India Engineering Centre (IEC) reporting to the site VP as well as the Global Lab & Datacenter Services (GDS) lead for the APAC region. In this role Ramesh led the physical and technical design for the Bangalore, India

Datacenter consolidation project and supported all APAC lab and datacenter projects. In 2007 Ramesh became a Regional Work Place Manager (RWPM) covering Asia South and India in addition to his GDS responsibilities. In this role he has been responsible for all workplace resources activities across Asia South & India, including portfolio management, real estate services & facilities management. Ramesh has been a critical member of the GDS technology team since 2004 and has designed multiple labs and datacenters across Asia Pacific. Ramesh is the recipient of a research disclosure on “Web Based Multi OS Installation,” PC Quest IT Implementation project of the year award in 2007 and has received 12 internal awards globally including Sun's leadership award in 2005 and 2007. Ramesh lives in Bangalore, India with his wife and daughter.

### **Petr Vlasaty**

Petr has been working in the IT industry for more than 12 years. His experience that started as an implementation engineer and project coordinator in 1996 has grown into a variety of people, project, process and service management areas of datacenter operations and technical support services. Petr worked for ANECT to define and develop the System Support and Maintenance department responsible for systems implementations and support for key customers including the Czech Ministry of Finance, Commercial Bank, and others. Petr formed a 12-person team that defined internal and external processes, established contracts, and represented support services to customers. In November 2004, Petr joined the Sun Software organization as R&D Datacenter Manager and Team Lead for the Prague Datacenter Management Team. Petr designed and implemented two internal datacenter projects in Prague in partnership with the GDS team. He applied the GDS processes and standards for the new Prague datacenter expansion that was completed in June 2006. Due to Petr's outstanding performance in Prague, he was assigned as the technical lead for the Louisville, Colorado consolidation project in August of 2006. He spent four months in Colorado developing the very detailed and complex plan. Petr joined the GDS organization full time in January of 2007. He is responsible for the Europe, Middle-East and Africa (EMEA) region and continues to act as technical lead for the Colorado datacenter consolidation project, the largest and most complex in Sun's history.

Petr is a Staff Engineer, Datacenter Architect, and the GDS Technical Infrastructure Lead for the EMEA region. He loves sports like mountain hiking (year round, especially winter) and rock climbing. Petr lives with his wife Vera and 10 month-old son Erik in Prague, Czech Republic.

Petr is a CCSE (Check Point Certified Security Engineer), CCSA (Check Point Certified Security Administrator) and SCSA (Sun Certified Solaris Administrator).

### **Brett Rucker**

Brett Rucker is a Staff Engineer in Sun's Global Lab & Datacenter Design Services organization where he focuses on physical environment issues. Brett has been in the

Corporate Engineering, Construction and Management business for 25 Years. A Graduate of the University of Colorado, Boulder, and a licensed Professional Engineer, Brett began his career with Ball Aerospace Systems Division, a rich opportunity that gave him complete design and management responsibility for all construction projects. He supervised products including building additions, clean rooms, X-Ray rooms, datacenters, laboratories, anechoic chambers, secure areas, gallium arsenide facilities, high elevation satellite dish structural mounts, RF shielded rooms, and office, conference, and customer show areas. Highlights of Brett's time at Ball include design and construction of large secured program area in 7-days to support critical Corp. project, stick build design and construction of MAMA Lab Clean Room facility for 1/3 market cost (still in operation today with one of Ball's premier products), metal finish Area with a \$30,000 per year energy savings in 1992 base, and creation of the Facility Engineering Program at Ball Aerospace which grew to take over Ball corporate facilities.

In 1992, Brett joined a newly forming engineering group at StorageTek to address facility backlog and project issues. Brett and his team created corporate building specifications, drawing standards, and quickly eliminated all backlog. Brett drove the high tech areas, and HVAC infrastructure as well as general projects. He represented StorageTek on refrigerant conversion and reported on this project at an ASHRAE function. Brett became manager of the New Project Management Group in 2000 directing projects at headquarters and in the field. His responsibilities soon included StorageTek's energy management program, which deployed processes and delivered high-quality, low-cost projects with consistent high metrics with limited staff support. This group lead all project designs, construction and project budgets. The energy management group delivered ISO Certification, installed monitoring systems, metrics, monthly log and issue reviews, best payback energy projects and commodity contracts that beat the market consistently. Brett joined Sun's GDS team in 2006 as a design engineer and is the physical design lead for the largest and most complex datacenter consolidation in Sun's history, the StorageTek move from Louisville, to Broomfield, Colorado.

Brett is a member of ASHRAE, AEE and is active in developing youth programs and coaching his daughter's competitive fast-pitch team with great support from his wife and two daughters.

### **Brian Day**

Brian day is a Senior Program Manager in Sun's Global Lab & Datacenter Design Services organization. Brian has been working in the technology industry for over 10 years, of which more than five have been with Sun. He spent over two years in Sun's Systems group, developing automation programs for server, storage, and software QA functions. This work included testing, configuring, and administering some of Sun's largest systems at the time, including the Sun Enterprise™ 10000 and 6500 servers, and Sun StorEdge™ D1000 storage device. Brian then served in a similar role for iPlanet™

software, developing server side Java™ technology-based tools that automated core team processes (ticketing system, equipment tracking, on-call notification).

Brian left Sun in 2000 to pursue his MBA full time. He then joined Adobe Systems in 2001 as a Program Manager, leading the development of several Digital Imaging plugins for Adobe Acrobat. In 2003 he took over full time program management of the Photoshop Elements product, releasing an all new version (3.0) in the fall of 2004. This included the coordination of all key product teams (engineering, QA, marketing, localization, documentation) and ensuring a successful release for the critical holiday shopping season. Brian returned to Sun in early 2005 to program manage the GDS initiative. As Senior Program Manager & Chief of Staff for GDS, Brian is responsible for first engagement with new customers, ensuring world-wide GDS projects are resourced, deliverable expectations are set, and commitments honored. Brian's work in GDS has significantly contributed to Sun's modular design and the teams success. Brian holds a Bachelor of Science in Computer Science and a Masters of Business Administration.

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## References

More information on Sun's energy-efficient datacenters can be found at:  
<http://www.sun.com/eco>.

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