Minneapolis / St. Paul
Computer Measurement Group

Fall 2008 Conference

“The Green and Virtual Data Center”

October 9th, 2008
Data Center Efficiency v7
Sun Data Center Efficiency Practice

• The Data Center Efficiency (DCE) Practice is a Sun business unit dedicated to helping our customers develop and implement IT strategies and plans that lead to efficient and sustainable data centers.

• The practice focuses on strategy, planning, design, implementation, and operations of large and complex information technology and data center facility infrastructures.

• Our DCE service offerings include:
  > Data center strategy
  > Data center design/planning/construction
  > Virtualization and consolidation
  > Data center power and cooling assessment
  > Implementation of power and cooling efficiency technologies and processes
  > Data Center Management
Traditional Data Center Planning

**Step 1:** IT department decides they need blade technology which they have never used before. They analyze product and select a vendor.

**Step 2:** IT department gets pricing and submits for funding. Little or no consideration is given for facility infrastructure. Management approves funding for IT equipment.

**Step 3:** The equipment is purchased and the facilities department is notified that it is coming and the computer room must be modified to accommodate.

**Step 4:** The facilities guys look at the loads for the new equipment, are skeptical, and believe they are grossly overstated.

**Step 5:** The facilities guys do their own research and ask their counterparts in other companies and find out the loads are real.

**Step 6:** The facilities guys hire an MEP consulting engineer and assigns them the task of figuring out “how to cool this?” Compounding the technical issues is the fact that there is no budget.
Today’s Global IT Challenges

- Under-Utilized, Inefficient Systems are Limiting Business Growth
- Disaster Recovery Planning is Non-Negotiable
- Power and Cooling Constraints are Very Real Issues
- Energy Costs are Draining the Bottom Line
- Sprawling IT Infrastructure is Increasingly Hard to Manage
- Ability to Deploy New Services is Critical to Remain Competitive
Server Opex will soon Exceed Capex

Increasing Power Density is Shifting the Balance of Cost

Yearly Cost

IT Equipment Cost

IT Operating Energy Cost

2010–2015

Time

Source: IDC

IDC is the premier global provider of market intelligence, advisory services, and events for the information technology, telecommunications, and consumer technology markets. www.idc.com
Impacts of the Challenges

- A “Set it and Forget it” deployment strategy is no longer an Option.
- Coherent design and planning will include both facility and IT infrastructure.
- Tools and processes must offset the increased complexity associated with running a denser and more efficient data center.
- Planning focus will be on the efficient use of all IT resources.
- Active monitoring and capacity management will span the entire IT and facilities infrastructure.
The Power and Cooling Challenge

All power corrupts, but we need electricity.

Dan Galvin, TFTD-L@TAMU.EDU
# Power Density Continues to Rise

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Expected Watts/Equipment Sq. Ft. by 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Density Communication</td>
<td>8,000 – 10,000</td>
</tr>
<tr>
<td>Blade and Customer Compute Servers</td>
<td>4,000 – 6,000</td>
</tr>
<tr>
<td>Compute Servers =&gt; 2U</td>
<td>2,500 – 3,500</td>
</tr>
<tr>
<td>Storage Servers</td>
<td>1,500 – 1,800</td>
</tr>
<tr>
<td>Tape Storage</td>
<td>180 – 250</td>
</tr>
</tbody>
</table>

ASHREA Power Trends and Cooling Applications (TC9.9), ©2005
More Power Equals More Cooling

- Power, heat, cooling, airflow, and temperature are all inter-related.

If Power Consumption = 1 kW/hr,
Heat Production = 3,410 BTU/hr,
AC Required = 0.283 Tons,
Airflow Required = 154 CFM,
for a $\Delta T$ of 20°F @ 1 atmosphere

Note: Normal atmospheric pressure is defined as 1 atmosphere. 1 atm = 14.6956 psi = 760 torr.
Heat, Temperature and Airflow

- Under standard conditions (1 atm), heat, temperature, and airflow relate as follows:

\[
\Delta T(F) = \frac{3,412 \times kW}{1.085 \times CFM} \quad \text{or} \quad CFM = \frac{3,412 \times kW}{1.085 \times \Delta T(F)}
\]
Data Center Cooling Rule Number 1

• All the heat generated by electronic equipment (server power) has to be removed from the room.

• Traditional raised floor cooling can typically handle up to 5 kW per rack. This assumes:
  > raised floor is high enough – higher than 24”
  > no obstructions – cables, trays, etc…
  > hot aisle / cold aisle equipment layout – servers front to front, back to back
Raised Floor Cooling Limitations

- Standard tiles have a limited airflow delivery capability
  - Airflow above 500 CFM is considered ‘extreme’ and requires the use of special grate tiles (typically > 40% open area)
Managing Air

• Managing air flow is inherently difficult.
• Until we move cooling to the chip level, we are going to be pushing air in some part of the equation.
• The key is managing the least amount of air and that is best done in a "contained" design
• A good design moves the initial heat transfer as close to the source as possible
• It then uses efficient and cost effective technology to move the heat off premises.
Cooling Closer to Heat Source

- Blade Designs are increasing Density, Power, and Weight per Rack
- CRAC will handle 2 – 5 kW per rack. Beyond 5 kW, CRAC becomes increasingly less efficient.
- Current planning uses 9 kW per rack as the low end of the cooling requirement
- HPC installations are currently running at 25 to 28 kW per rack
- Managing air flow is now mandatory.
  - Capture Index for In-Row and Rack Cooling
    - Open Hot Aisle – 0.80
    - Hot Aisle Containment – 0.90
    - Rack Air Containment - 0.95
Data Center Energy Productivity

• For each 1,000 Watts of electricity generated, about 450 Watts is delivered to the servers

• Of this, about 67 Watts (15%) is used to run server workloads - an overall energy productivity of about 7%

*No Power Management; EPA estimates for load levels (15%) and facilities power overhead of 50%
Server CO$_2$ in Perspective

• A single server is responsible for about the same amount of CO$_2$ as a typical automobile driven for a year.

**Server**
- 440 Watt Server
- 3,942 kWh/year
- 5.3 Tonnes CO$_2$

**Auto Travel**
- Toyota Camry
- 20,000 km/year
- 4.4 Tonnes CO$_2$

**Air Travel**
- Commercial Airliner
- Vancouver-Toronto (6 trips)
- 4.4 Tonnes CO$_2$

The EPA estimate of 5.5 Tonnes includes all cars and light trucks, driven an average of 12,000 miles/year*
Data Center CO$_2$

• Even a small or medium sized Data Center can be responsible for huge amounts of CO$_2$
  
  - 4,500 sq-ft @ 100W/sq-ft,
  - 800 servers, plus storage and networking
  - 450kW of IT load
  - 1MW of electricity
  - 5,300 Tonnes CO$_2$/year

* Assumes average of 450W per server
US Data Center CO$_2$ Emissions

- The cumulative impact of Data Centers is huge - 37 Million Metric Tonnes a year in the US alone
  > Not including PCs, Laptops, Thin-Clients, Mobile Devices, etc..!

- 61.4 Billion kWh/yr
- 7 Million kW-yr of generation capacity
  - Equivalent to 7 Million 440W Servers, or 8.4 Million Autos
- 37,000,000 Metric Tonnes CO$_2$ per year
Data Center Growth Projections

- Data Center power usage is growing fast
  - 42 Million Metric Tonnes more CO2 – (about 8 million servers)
  - $5.6 Billion in additional electricity cost (at 8 cents per kWh)
  - $20 to $80 Billion in facilities costs (at $5K to $20K/kWh of IT load)
Reducing Data Center Energy Usage

- The EPA estimates that the forecasted energy usage can be cut by up to 70% using current technology

- 100% use of energy efficient servers
- All servers use power management
- Overall 5:1 server consolidation
- 5% of servers are retired
- Overall 2.4:1 storage consolidation
- Reduced facilities overhead by 55%
Impact of Higher Utilization

@10% utilization
5x power waste
per unit of work!

@30% utilization
2x power waste!

Significant energy efficiency only above 60% Utilization!

Increasing Utilization Saves More than Best Power Saving HW/SW
1 Server Watt saved equals 2.84 Watts

The Cascade Effect

1 Watt saved here

Server Component

DC-DC

AC-DC

Power Distribution

UPS

Cooling

Building Switchgear/Transformer

-1.0W

-1.18W

-1.49W

Power Distribution

and .04 W here

-1.53W

and .14 W here

-1.67W

and 1.07 W here

-2.74W

and .07 W here

-2.84W

Saves an additional .18 W here

and .31 W here

Source: EmersonLiebert, Energy Logic: Reducing Data Center Energy Consumption by Creating Savings that Cascade Across Systems, WP154-158-117 SL-24621
Measuring Data Center Efficiency

• Data Center infrastructure Efficiency (DCiE)

$$DCiE = \frac{1}{PUE} \times 100\%$$

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

• A DCiE of 100% represents maximum efficiency

• No comprehensive data in the industry related to DCiE, but early work suggests that many data centers are at 30% or less.

• With proper design, the Green Grid suggests that a DCiE of 62.5% is achievable.

• The confirmed DCiE for SCA11-1500 (APC) is 78.57%
DCiE - A Small Change a Big Difference

• US Data Center energy use is currently about 61.4 Billion kWh/yr.
• Today’s average data center operates at a DCiE of about 0.50 (50% efficient).
• This translates to 30.7 Billion kWh/yr for facilities
• Increasing DCie to an average of 0.61 would result in:
  > 6.8 Billion kWh/year reduction in facilities overhead
  > Reduction in 862 MW of electricity generation
• This is the equivalent to retiring 862,000 x 440 Watt servers, or taking 1.0 Million Toyota Camarys off the road
Eliminating Energy Inefficiencies

- Understand the economics of Data Center efficiency
- Obtain senior management support
- Develop a model of your Data Center
- Measure and benchmark your current environment
- Identify and prioritize improvement opportunities
- Execute improvements
- Sustain improvements by building energy management into your capacity and financial management practices (e.g. ITIL)
“Would you tell me, please, which way I ought to go from here?

That depends a good deal on where you want to get to,” said the Cat.

— Lewis Carroll
Modularity in Data Center Design

The Sun Blueprint
Next Generation Data Center

• Modular
• Efficient
• Flexible
• Environmentally Conscious
• Designed in Concert with the Facilities

• Incorporate Broad Based Efficiency Improvements
  > Applications mapped to specific types of processors
  > Power supplies sized to server configuration
  > Electrical distribution at higher voltages
  > Integrated management and control
  > Cooling closer to the heat source
Sun Blueprints on Data Center Efficiency

ENERGY EFFICIENT DATA CENTERS
THE ROLE OF MODULARITY IN DATA CENTER DESIGN

Dean Nelson, Michael Ryan, Serena DeVito, Ramesh KV, Petr Vlasaty, Brett Rucker, and Brian Day
Sun Global Lab & Datacenter Design Services

Sun BluePrints™ Online
Power and Cooling

• Building a data center with maximum power and cooling available from the date of commissioning is the wrong approach.

• Traditional forced air cooling works when a data center is operating at 40 W/sq. ft.

• Moving air is a large contributor to data center energy use.

• Delivering cool air to today’s high density racks through raised floor is difficult and inefficient.
The Right Power Metric

- Watts per square foot is an architectural term created for office space.
- Sun has abandoned this measure for a more accurate metric of Watts per rack.
- 2008 industry average Watts per rack is between 4 - 6 kW per rack.
- However, averages are deceiving. Today’s data center is heterogeneous and contains racks that range from less than 1kW to more than 30 kW.
Design to the Need

• Matching capacity to the temporal requirements increases efficiency.
  > Cyclical Workloads driven by time of day, month, or year
  > Frequency of Change - regularly moving servers and cabinets that have different power and cooling requirements
  > Rate of change - replacing older equipment with newer equipment; often driven by lease refresh.

• Physically different power and cooling requirements. Front to back cooling versus chimney.
Living within the Envelope

• Space
  > How much should you plan on using? (20 - 35 sq. ft. per rack)
    > Rack = 10 sq ft
    > Access = 5 - 10 sq ft
    > Mech/Elec/Other = 15 sq ft

• Efficiency
  > PUE - Total Facility Power divided by Power going to IT
  > A PUE of 2.5 means that only 40% of the power into the data center is going to the compute infrastructure.
  > The lower the PUE the shorter the investment pay back period

• Cooling Capacity
  > 2.5 mW IT load with a PUE of 2.0 requires 714 Tons of cooling plant.
Living within the Envelope

• Floor Loading
  > Rack weight increased with compute density
  > Today’s blade racks can weigh as much as 2400 lbs and are rapidly moving into the 3000 lb range
  > Floors often have to be reinforced.

• Raised Floor or Slab
  > Raised floors tend to have complex and unpredictable airflow characteristics.

• Cooling
  > Eliminate heat gain from people, solar, lighting
  > Control humidity within the range of 30 - 60 percent
  > Filter air
  > Fresh air as required by code.

• Wider racks to accommodate increasing cable densities.
Sun’s Approach to Data Center Design

- Scalable, repeatable, modular architecture (PODS)
  - Vendor independent
  - Slab or raised floor
  - Modular, right-sized power and cooling
  - Simplified, flexible cabling and plumbing
- Real-time energy monitoring
- Scale cost with use
- Easy to build and expand

Entering a New Age of Engineered Data Centers
Modular Building Blocks

- POD Based Design
- Up to 24 Racks with a common hot/cold aisle
- Modular power, cooling, and cabling components
- Size is variable
- Tier of Service is variable
- Data center within a data center
- Eliminates most of the custom design cost
- Avoids cost of “sizing it wrong.”
The Sun POD Design

- Small, self-contained group of racks (generally 20 - 24) that optimize power, cooling, and cabling.
- Design at the pod level, rather than room level, simplifies the approach.
- The same architecture can be used in both small and large data centers.
- Integral to our building design in the pod architecture is a 10 - 15% larger MEP support infrastructure to future-proof the space.
The Sun POD Design

• Physical layout is hot aisle/cold aisle with either:
  > Spot overhead cooling
  > In row hot aisle containment

• Power distribution uses a busway that runs either above the pod or below the floor.

• Equipment cooling is in-row or overhead as close to the heat source as possible. Room air conditioning is provided to meet code for habitable space, humidity, and air filtration.

• Connectivity allows short cable lengths with in-pod switching and patch panels either above or below each rack.
Spotlight: Sun Engineering Data Center

- 72,000 SF Datacenter
- 9MW scalable to 21MW
- Largest Liebert/APC installs
- Shed 1.8M Square Feet
- 15 Buildings to 2
- 152 Data Centers to 14
- Completed in 12 months
- $1.2M Utility Rebates
- $250k Innovation Award
- 39% more efficient than ASHRAE std (.489 kW/ton)
- Reduced OPEX 30%

Delivered: Modular, scalable, future-proof and highly efficient in 63% less space. Under budget & on schedule.
Sun's DCiE Achievement

A DCiE of 78.57% translates into energy savings of $402,652 per year when compared to a more traditional data center built with a DCiE of 50% (PUE of 2.0).
Pod Hot Aisle
APC in Row Cooling Units
Capacity of up to 30 kW Per Unit
Liebert XD
Liebert Pumping Unit and XDV Capacity of 8 to 10 kW per Unit
StarLine Bus Power Distribution
Structured Cabling Solution
Isometric View of Computer Lab—
All services and components were coordinated in this three-dimensional model of the space.

Sun Burlington Campus Lab
Conceptual Design
European High Performance Computing Center
Virtual Server Planning

• Heterogeneous versus Homogeneous
• Utilization targets - What is the point of diminishing returns?
• Where are the constraining factors that have nothing to do with capacity
  > Security - Firewalls, DMZs, etc.
  > Networks and Subnets - as in every department needs their own…
  > Physically separate storage infrastructures
Managing the Virtualized Infrastructure

- Capacity Planning
- Engineering and Provisioning
- Problem and Incident Management
- Availability Management
- Change and Release Management
- Financial (Capex and Opex)
- Infrastructure Management
  - Design
  - Procurement
  - Deployment
Virtual Capacity Management

- **Capacity Planning and Deployment** - Adding to the base of hardware capacity available to the enterprise.

- **Capacity Provisioning** - Creating virtual servers based on requirements developed in the engineering process.

- **Capacity Engineering** - Developing the specific requirements from either actual data of a source environment or planning data from a user.

- **Performance Monitoring and Management** - Monitoring performance of CPU, Memory, Fiber Channel, and Network and adding capacity or moving virtual servers as required.
Capacity Planning and Deployment

- Virtualization implicitly assumes that a base of virtual capacity is always available and that new hardware capacity is added in advance of the need to deploy virtual servers.

- In its most robust form, virtualization fully supports a capacity on demand model.

- Hardware capacity can take the form of additional boards in a large enterprise class server frame, entirely new enterprise class servers, multiple mid-range servers, or blade servers and storage and network.
Capacity Planning and Deployment

- Monitor overall utilization for the installed base of virtual capacity.
- Develop and maintain a forecast of virtual server demand based on new applications, existing applications targeted for virtual servers, and growth on current virtual servers.
- Develop a hardware capacity plan for Q+2 and Q+3 that accommodates the forecasted demand for virtual capacity.
- Produce reports on current utilization, available capacity, and forecasted additions to capacity for the virtual server base.
- Plan, manage, and implement the deployment of new capacity.
- Maintain current Bills of Material for the hardware supporting virtualization.
- Determine the type utilization data that will be reported by the agents running on the servers.
- Collect and maintain utilization data in the Capacity Management Database.
Capacity Provisioning

- Unlike traditional servers, a virtual server will often be created within an operating environment that is already in production.
- As such, the provisioning process demands a different set of steps than a standalone server.
- For example:
  - The creation of a virtual server will likely require a change order.
  - The virtual server’s access to hardware resources should probably be restricted while the application is being deployed, tested and staged.
  - Provisioning will likely be completed by operations as a change order.
Capacity Engineering

• Capacity Engineering involves the planning, allocation, and effective utilization of the installed base of virtual capacity.

• It includes the assessment of the virtual capacity required by new applications and the performance evaluation of existing applications moving to a virtual server platform.

• Capacity Engineering is also responsible for tracking the changes in utilization of deployed virtual servers.
Capacity Engineering Tasks

- Produce utilization reports for all virtual server platforms.
- Collect data and maintaining an inventory of available virtual server capacity.
- Validate and maintain a virtual server application sizing tool.
- Estimate the virtual server capacity required for new applications by translating application performance into workloads levied on the virtual server components.
- Collect performance data for existing applications scheduled to move to a virtual server, and estimating the virtual server capacity required on the target platform.
- Evaluate the performance of an application on a test/quality assurance virtual server in advance of the deployment to a production server.
- Actively participate in the resolution of performance problems on virtual servers.
- Maintain the virtual server configuration database.
Performance Monitoring and Management

- Traditional low average server utilization obviated the need to actively monitor and manage performance.
- Performance related problems have been handled as they have arisen. With virtualization, the monitoring and management of performance will be a ongoing responsibility.
- Virtualization will drive up hardware utilization and the shared resources used by the virtual servers will have to be continuously monitored.
- Shared resources include CPU, memory, disk I/O, and Network I/O.
- To achieve this, monitoring agents on the servers will need to be configured to generate data that can track performance at the virtual server level
- Performance related incidents will need to be tracked and handled
Performance Monitoring and Management Tasks

- Record, analyze, and report performance data for virtual servers.
- Tune virtual servers and underlying hardware to optimize performance to insure they meet SLAs.
- Establish performance profiles and thresholds for alerts generated by performance monitoring agents.
- Add or move hardware or virtual resources as needed to address incident related issues.
Performance Management (Operations)

- Performance management involves the identification and isolation of performance problems. This includes both reactive (incident related) and proactive activities.

- The typical process steps include:
  > **Detection.** Ideally this is done with a level of automation that generates alerts based on performance thresholds.
  > **Notification.** Notification should be automated two or more notification methods and two or more parties on the notification list.
  > **Confirmation.** Once notified, operations will generally perform some additional tests to confirm that a problem exists.
  > **Isolation.** Following verification of the problem, the next step is to isolate the cause of the performance problem.
  > **Resolution.** Once the performance problem has been isolated, an action plan is developed for resolution. Often that plan has two parts.
    > The first involves steps to immediately remediate the problem.
    > The second part of the resolution may involve a longer term remediation activity
  > **Service Verification.** Once the problem has been resolved, operations must verify that the service has been restored to the service levels specified in the SLA.
Thinking about CPU Capacity

<table>
<thead>
<tr>
<th>Total CPU Capacity in the Virtual Server</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allocated Capacity</strong></td>
</tr>
<tr>
<td>Production</td>
</tr>
<tr>
<td>Staged</td>
</tr>
<tr>
<td>Reserved</td>
</tr>
<tr>
<td><strong>Unallocated Capacity</strong></td>
</tr>
<tr>
<td>Available</td>
</tr>
<tr>
<td>Head Room</td>
</tr>
</tbody>
</table>

- **Allocate Capacity**: Production, Staged, Reserved
- **Unallocated Capacity**: Available, Head Room
Allocated and Unallocated Capacity

• Allocated Capacity
  > **Production** – Capacity allocated to production servers. Initially this capacity is estimated but once an application is promoted to production, the capacity allocated to production is based on aggregate actual performance data for the virtual servers zone.
  > **Staged** – Allocated capacity based on engineering estimates that can be confirmed as the application is moved through the steps leading to conversion.
  > **Reserved** – This capacity is assigned during the initial engineering planning process. Capacity requirements are only estimates.
  > **Failover Reserve** – While this capacity is not required unless there is a failure of a virtual server running on another hardware platform, it needs to be accounted for in the allocated capacity. The engineered capacity requirement of the source server is the value used in determining the amount of capacity in reserve.

• Unallocated Capacity
  > **Available** – Can be used for new virtual server requirements
  > **Head Room** – Amount of capacity that is held in reserve
Normalizing Resources (CPU)

- Because of different CPUs, mapping a source server to a target environment requires some form of normalization.
- One CPU normalization measure available from Sun is Application Measured Performance (AMP) values.
- The AMP metric was developed by Sun as an alternative way of characterizing the performance of servers on industry and ISV benchmarks.
- It uses results from a variety of such benchmarks to create an average metric of the server performance across several classes of workload: OLTP, DSS and Business Logic.
- It provides a way to normalize CPU performance across Sun compute platforms.
- It does not normalize competitive computing environments.
## Sample Application Measured Performance (AMP) Values

<table>
<thead>
<tr>
<th>Server Model</th>
<th>CPU Count</th>
<th>CPU Type</th>
<th>CPU Speed</th>
<th>AMP* (Typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V440</td>
<td>4</td>
<td>US-IIIi</td>
<td>1600</td>
<td>262</td>
</tr>
<tr>
<td>V440</td>
<td>4</td>
<td>US-IIIi</td>
<td>1280</td>
<td>210</td>
</tr>
<tr>
<td>V440</td>
<td>4</td>
<td>US-IIIi</td>
<td>1000</td>
<td>172</td>
</tr>
<tr>
<td>V490</td>
<td>4</td>
<td>US-IV+</td>
<td>1500</td>
<td>726</td>
</tr>
<tr>
<td>V480</td>
<td>4</td>
<td>US-III</td>
<td>1200</td>
<td>235</td>
</tr>
<tr>
<td>V480</td>
<td>4</td>
<td>US-III</td>
<td>1050</td>
<td>218</td>
</tr>
<tr>
<td>V480</td>
<td>2</td>
<td>US-III</td>
<td>1050</td>
<td>110</td>
</tr>
</tbody>
</table>

*Application Measured Performance values for a *typical* application load*
**AMP Mapping Example**

<table>
<thead>
<tr>
<th>Global Zone Type</th>
<th>CPUs</th>
<th>Speed</th>
<th>AMPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS008A 25K Domain</td>
<td>16</td>
<td>1.8Ghz</td>
<td>2990</td>
</tr>
<tr>
<td>Cores: 32</td>
<td>AMPS/core: 93.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source Server or Application</th>
<th>IPR**</th>
<th>Application</th>
<th>Source Server Type</th>
<th>Base AMPs* for Source Server</th>
<th>Estimated Sever Utilization</th>
<th>Util. Basis**</th>
<th>Estimated AMPs</th>
<th>Assumed Annual Growth Rate (%)</th>
<th>Assumed Server Life in Years</th>
<th>Target Server Name</th>
<th>Required AMPs</th>
<th>Equivalent Cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>eContract</td>
<td>Web</td>
<td>280/1.2/2</td>
<td>113</td>
<td>55%</td>
<td>E</td>
<td>62.15</td>
<td>10.00%</td>
<td>2</td>
<td>cls008 a ectd01</td>
<td>75.20</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>eContract</td>
<td>App</td>
<td>480/1.2/4</td>
<td>224</td>
<td>55%</td>
<td>E</td>
<td>123.20</td>
<td>10.00%</td>
<td>2</td>
<td>cls008 a ectd02</td>
<td>149.07</td>
<td>1.60</td>
<td></td>
</tr>
</tbody>
</table>

| Application x New App | 480/1.2/4 | 224 | 55% | E | 123.20 | 10.00% | 2 | cls008 a dlrd04 | 149.07 | 1.60 |
| Application x New App | 480/1.2/4 | 224 | 55% | E | 123.20 | 10.00% | 2 | cls008 a dlrd06 | 149.07 | 1.60 |
| CLDLR18 x Web/IHS | 280/1.2/2 | 113 | 10% | P | 11.30 | 10.00% | 2 | cls008 a dlrd01 | 13.67 | 0.15 |
| CLDLR19 x Web | 280/1.2/2 | 113 | 50% | P | 56.50 | 10.00% | 2 | cls008 a dlrd02 | 68.37 | 0.73 |
| CLDLR20 x Model | 480/1.2/4 | 224 | 15% | A | 33.60 | 10.00% | 2 | cls008 a dlrd03 | 40.66 | 0.44 |
| CLDLR22 x App | 480/1.2/4 | 224 | 65% | P | 145.60 | 10.00% | 2 | cls008 a dlrd05 | 176.18 | 1.89 |
| CLDLR24 x App | 480/1.2/4 | 224 | 40% | P | 89.60 | 10.00% | 2 | cls008 a dlrd07 | 108.42 | 1.16 |
| CLDLR25 x DB | 480/1.2/4 | 224 | 90% | P | 201.60 | 10.00% | 2 | cls008 a dlrd08 | 243.94 | 2.61 |
| CLDLR27 x Vignette | 480/1.2/4 | 224 | 0% | E | 0.00 | 10.00% | 2 | cls008 a dlrd09 | 0.00 | 0.00 |
| CLDLR28 x Web Arch | 480/1.2/4 | 224 | 40% | A | 89.60 | 10.00% | 2 | cls008 a dlrd10 | 108.42 | 1.16 |
| CLDLR29 x Vignette | 480/1.2/4 | 224 | 0% | E | 0.00 | 10.00% | 2 | cls008 a dlrd11 | 0.00 | 0.00 |
| CLDLR30 x FC Appl | 480/1.2/4 | 224 | 35% | A | 78.40 | 10.00% | 2 | cls008 a dlrd12 | 94.86 | 1.02 |

| **Current Production AMPs:** | 700.00 |
| **Totals:** | 1376.92 | 14.74 |

* An AMP is Application Measure Performance and values are based on typical AMPs

** Key:
- E - Estimated Utilization
- P - Estimate based on peak utilization
- A - Estimate based on average utilization
- x - Confirmed In IPR

** Assumptions:
- AMP requirements for the new applications provided by planning
- Utilization on existing servers is provided by planning
- Growth percentage applied at end of 12 month period

Net Available: 913.08
Precent Allocated: 69.46%
Form Version: 5.0
Actual Performance of the Virtual Servers
Thank you

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