CONSOLIDATING ORACLE DATABASE SERVERS ONTO DELL POWEREDGE R920 RUNNING ORACLE VM

Dell™ PowerEdge™ R920 server

running Oracle® VM 3.2.8 with VMs running Oracle Linux 6.5 and Oracle Database 12c

5X the workload of an older server

Used **43%** less power*

Saved **22%** on licensing fees*

*versus the power and licensing costs of the five legacy servers it would replace

As large enterprises running Oracle database make critical virtualization and consolidation decisions, they must consider many factors. The new virtualized environment must perform well, supporting the same user base as multiple legacy servers. The new solution must also offer the potential to trim costs. If you run Oracle databases on multiple older servers, you could realize substantial savings by consolidating them onto a single Dell PowerEdge R920. This powerful new server, which uses the Intel® Xeon® processor E7-4800 v2 family, can replace multiple older servers to boost performance and cut your costs for power, cooling, and licensing.

In the Principled Technologies labs, we tested a Dell PowerEdge R920 and an older server, an HP ProLiant DL385 G6, using a database workload. Our goal was to compare the performance, power, and cost of running database workloads on the older server running Oracle Linux 5 Update 10 and Oracle Database 11g Release 2, and on the Dell PowerEdge R920 running Oracle VM 3.2.8 with multiple VMs running the same database workload on Oracle Linux 6 Update 5 and Oracle Database 12c.

In our tests, the Dell PowerEdge R920 delivered five times the output of the older server we tested, meaning it could replace five of the older servers, running each of their workloads in virtual machines on Oracle VM. The Dell PowerEdge R920 also had 43 percent lower power consumption and 22 percent lower software-licensing costs than we estimated the five older servers would need. The three-year software licensing savings of $212,091 in our test environment would be multiplied many times in a larger virtualization and consolidation effort. Other benefits and savings typical of a consolidation and virtualization scenario—such as reducing administrator-to-server ratios, rack space, switches and cabling, and server maintenance costs—add to the case for a consolidation from older servers with older Oracle versions to the newest, most powerful Dell PowerEdge server virtualizing Oracle Database 12c with Oracle VM.

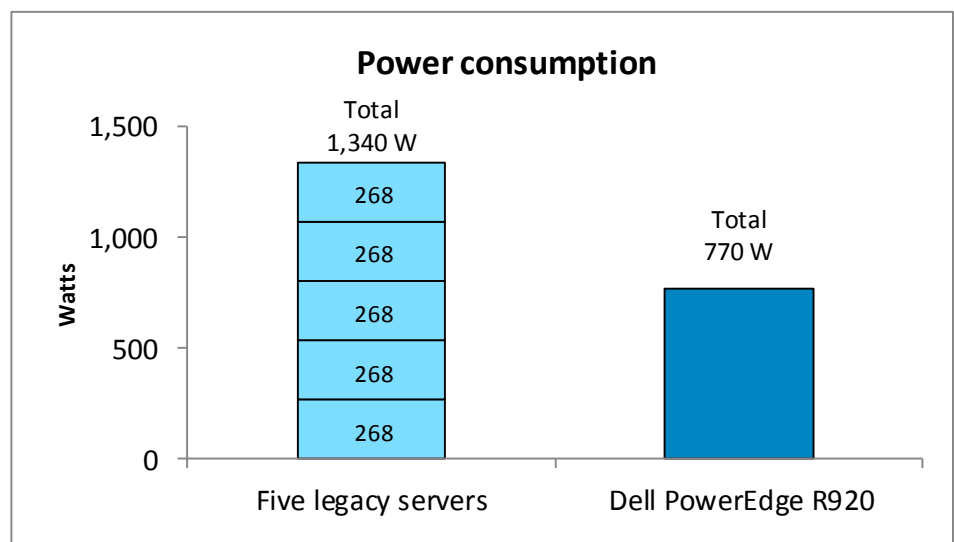# CONSOLIDATE YOUR ORACLE DATABASE SERVERS TO SAVE ON POWER AND LICENSING

Consolidating in any environment from many older servers to fewer newer servers with the latest technology in server performance and power efficiencies can add up to savings over time. To discover how many older servers a company would be able to consolidate onto the new Dell PowerEdge R920, we used a tool that measures database performance in orders per minute a solution can deliver. We ran this test on both the older physical server with Oracle Database 11*g* Release 2 and then the Dell PowerEdge R920 with five virtual machines on Oracle VM Server hypervisor. Each virtual machine ran Oracle Linux 6 Update 5 and Oracle Database 12*c*. We ran the workload with parameters to achieve approximately 70 percent CPU utilization on the older server, a critical threshold level that may push some organizations to evaluate hardware needs. We also recorded the amount of power that each solution used during testing. Finally, we analyzed the software costs and licensing that each solution would require.

We then combined the consolidation testing, the power measurements, and the licensing analysis. The testing and analysis showed that consolidating five older servers running Oracle 11*g* Release 2 to the Dell PowerEdge R920 running Oracle VM Server 3.2.8 with Oracle Database 12*c* VMs can save a company 43 percent on power and 22 percent on licensing and still maintain the same performance for end users.

Reduce power, save money

Powering and cooling a single Dell PowerEdge R920 is considerably less costly than doing so for five separate older servers. We measured the amount of power the two servers consumed as they executed the online transaction processing (OLTP) database workload.

Figure 1: A single Dell PowerEdge R920 consumed 43 percent less power than five times the power of the older server we tested. (Lower watts are better.)
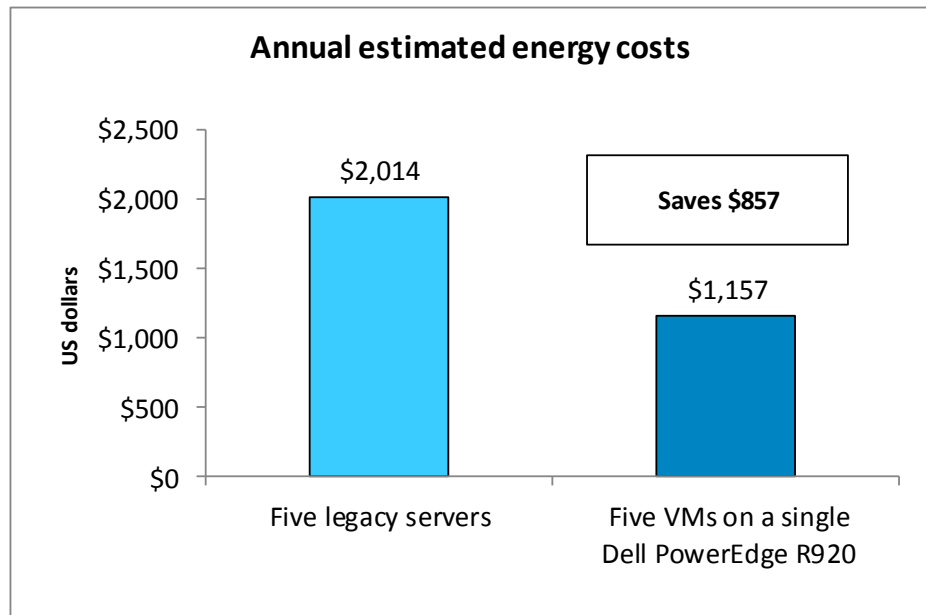

Power consumption chart showing Watts. Five legacy servers: Total 1,340 W (stacked bars of 268, 268, 268, 268, 268). Dell PowerEdge R920: Total 770 W.

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[1] Learn more at www.oracle.com/technetwork/database/multitenant/overview/index.html.

As Figure 1 shows, the single older server used 268 watts; therefore, five identically configured servers running this workload would use 1,340 watts. The Dell PowerEdge R920 used 770 watts to execute the same amount of work, 43 percent less than five older servers' total wattage.

Based on assumptions that we discuss in detail in Appendix C, this reduced power usage could translate to a savings of $857 per year in power and cooling alone (see Figure 2). In a large consolidation effort, the ongoing savings in operational expense (OPEX) of power and cooling would add up.

Figure 2: The Dell PowerEdge R920 Oracle VM Server 3.2.8 solution could save $857 on power and cooling over the course of a year. (Lower costs are better.)

Annual estimated energy costs

US dollars

- $2,500
- $2,000 — $2,014 (Five legacy servers)
- Saves $857
- $1,500
- $1,157 (Five VMs on a single Dell PowerEdge R920)
- $1,000
- $500
- $0

Five legacy servers | Five VMs on a single Dell PowerEdge R920

Significant licensing savings

You can see significant savings in license costs when you consolidate multiple servers running Oracle database onto one Dell PowerEdge R920 server running the same databases in VMs. In the scenario we tested, customers would save $212,091 in licensing costs over three years for Oracle Linux Premier, Oracle VM, and Oracle Database Enterprise Edition (see Figure 3). Most of the savings are for Oracle database.

This analysis includes Oracle Linux Premier support and Oracle Database Enterprise Edition support for both solutions. It includes Oracle Linux VM costs for the Dell PowerEdge R920 server to support virtualization on that server. It omits license costs for Oracle Database Enterprise Edition perpetual licenses because the existing licenses on five older servers are sufficient for either solution. See Appendix C for more details.

It would cost $23,991 less to pay for Oracle Linux Premier and Oracle VM support on the single Dell PowerEdge R920 than for the Oracle Linux Premier support on the five older servers. The remainder of the total $212,091 in software savings comes

from the $188,100 lower cost of Oracle Database Enterprise Edition on the single Dell PowerEdge R920 server vs. Oracle Database Enterprise Edition on five older servers.

Figure 3: The Dell PowerEdge R920 Oracle VM Server 3.2.8 solution could save a company $212,091 on licensing over the course of three years. (Lower costs are better.)
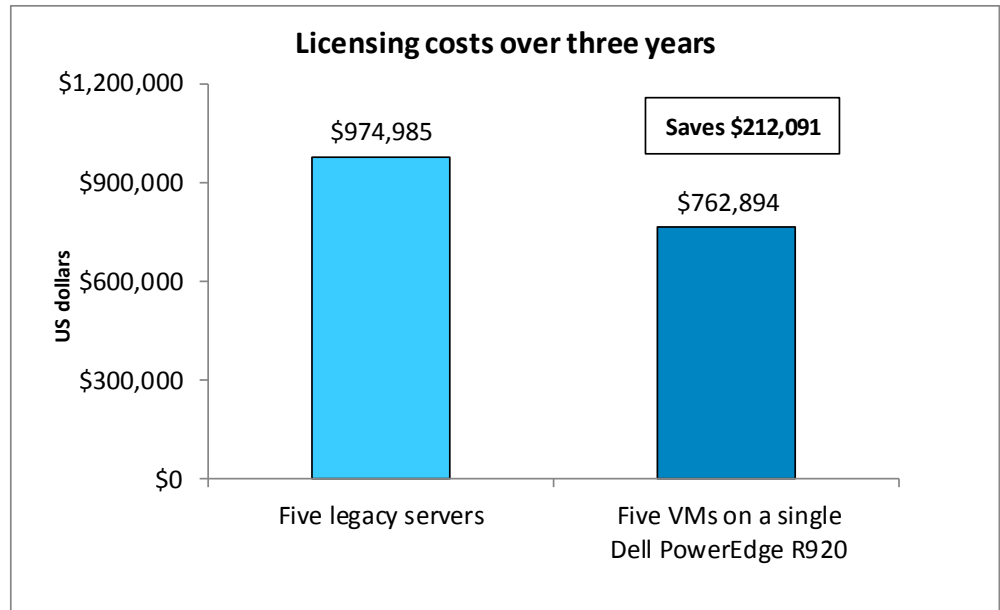
These savings for OS and database software over three years would be more than 3.5 times the hardware list cost of the Dell PowerEdge R920 server. The Dell PowerEdge R920 server we tested had a list cost of $59,221.[2]

Save in other ways

By consolidating multiple older servers onto a Dell PowerEdge R920 server, you can save on data center power and on license costs as we have shown. In addition to those key savings, you should save on other server-related capital and operating costs, such as those for hardware support, server management, data center space, and upstream cables and switches – all of which will multiply savings with with each additional consolidated server. Dropping from five physical servers to one can cut down some of these costs to roughly one-fifth. These options provide a clear cost justification for switching to a Dell PowerEdge R920 from multiple older servers.

About the Dell PowerEdge R920

The PowerEdge R920 is the fastest four-socket 4U server from Dell. Designed to provide expanding scalable performance for large enterprises, it supports up to

- 96 DIMMs of memory
- 24 internal drives
- 8 Express Flash drives (with the optional PCIe backplane)
- 10 PCIe Gen3/Gen2 slots
- 12Gb/s SAS drives

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[2] Hardware price is from dell.com as of 5/9/2014.

It also offers Dual PERC option, PERC9 (H730P), Fluid Cache for SAN capability, and a number of built-in RAS features for high reliability, such as Fault Resilient Memory and Intel Run Sure technology.

The Intel Xeon processor E7 v2 family

The Dell PowerEdge R920 makes use of the new Intel Xeon processor E7 v2 family, which Intel designed to support mission-critical, high-performance workloads by adding up to 50 percent more cores/threads and 25 percent more cache to provide significant jumps in performance from previous releases. The Intel Xeon processor E7 v2 family provides up to 6TB DDR3 memory, supports up to 24 DDR3 DIMMs per socket, and supports up to 1,600MHz DDR3 speeds to improve performance and increase scalability.

The Intel Xeon processor E7 v2 family supports all the previous reliability, availability, and serviceability features of previous processor releases to support critical workloads. With Intel Run Sure technology, these processors add new RAS features, including eMCA Gen 1, MCA Recovery – Execution Path, MCA IO, and PCIe Live Error Recovery.

Supports demanding workloads

The Dell PowerEdge R920 is designed by Dell to handle extremely demanding, mission-critical workloads such as enterprise resource planning (ERP), e-commerce, large-scale virtualization, and very large databases. According to Dell, it is particularly well suited to the following workloads and environments:

- Accelerating large corporate-wide applications (ERP, CRM, Business Intelligence)
- Implementing very large traditional databases or in-memory databases
- Consolidating enterprise workloads with large-scale virtualization
- Migrating from expensive and outdated RISC hardware to a future-ready data center

About Oracle Database 12*c*

Oracle Database 12*c* has more than 500 new features and comes in three editions that feature a range of enterprise edition options to meet specific customer requirements in the areas of performance and availability, security and compliance, data warehousing and analytics, unstructured data, and manageability. Oracle Database 12*c* enables the high density of schema-based consolidation—without requiring changes to existing applications. A single, multitenant container database can now host many "pluggable databases." Consolidated databases, or databases "plugged into" the multitenant container, look and feel the same as the pre-consolidated version to applications. The new multitenant architecture can consolidate databases on clouds,

allowing businesses to manage multiple databases as one without application changes. In this study we did not use the multitenant features of Oracle Database 12*c*.

Learn more about Oracle Database 12*c* at www.oracle.com/us/corporate/features/database-12c/.

About Oracle VM 3

Oracle VM 3 is an enterprise-class server virtualization solution that includes Oracle VM Server for x86, Oracle VM Server for SPARC, and Oracle VM Manager. According to Oracle, "VM 3 reflects Oracle's strategic commitment to deliver Application Driven Virtualization—Virtualization that makes the entire enterprise software and hardware stack easier to deploy, manage, and support so IT and business can be more agile."

Learn more about Oracle VM 3 at www.oracle.com/technetwork/server-storage/vm/overview/

CONCLUSION

As our tests show, investing in the powerful new Dell PowerEdge R920 running Oracle VM Server 3.2.8 with Oracle Database 12*c* VMs achieves cost savings without compromising performance. In our testing, a single Dell PowerEdge R920 could perform five times the work of a single HP ProLiant DL385 G6 server; the costs to power and cool the Dell PowerEdge would be 43 percent less than the five servers it could replace. The three-year software licensing costs of the Dell PowerEdge R920 server would be 22 percent lower than the licensing costs for the five-server solution. These dramatic savings—which come out to $212,091 for our single test environment — could grow to millions of dollars in a larger consolidation effort.

APPENDIX A: DETAILED SYSTEM CONFIGURATION

Figure 4 presents the detailed information for the two systems we tested.

System	Dell PowerEdge R920	HP ProLiant DL385 G6
Power supplies		
Total number	4	2
Vendor and model number	Dell 0GDPF3	HP SO6821
Wattage of each (W)	1,100	750
Cooling fans		
Total number	6	6
Vendor and model number	Nidec® UltraFlow V12C12BS1M3 J87TW-A00	Nidec Ultraflo V60E12BS147-09A032
Dimensions (h × w) of each	5" × 5"	2" × 2.5"
Volts	12	12
Amps	2.31	2.45
General		
Number of processor packages	4	2
Number of cores per processor	12	6
Number of hardware threads per core	2	1
System power management policy	Default	Default
CPU		
Vendor	Intel	AMD
Name	Xeon	Opteron™
Model number	E7-4850 v2	2435
Socket type	LGA 2011	Socket Fr6 (1207)
Core frequency (GHz)	2.30	2.60
Bus frequency	7.2 GT/s	2.4 GHz
L1 cache	32 + 32 KB (per core)	64 + 64 KB (per core)
L2 cache	256 KB (per core)	512 KB (per core)
L3 cache	24 MB	6 MB
Platform		
Vendor and model number	Dell PowerEdge R920	HP ProLiant DL385 G6
Motherboard model number	0Y4CNC	577426-001
BIOS name and version	1.0.6	A22
BIOS settings	Defaults	Defaults
Memory module(s)		
Total RAM in system (GB)	1,024	128
Vendor and model number	Hynix® HMT42GR7MFR4C	Samsung® M393T1K66AZA
Type	PC3L-12800R	PC2-5300
Speed (MHz)	1,600	667
Speed running in the system (MHz)	1,333	667
Timing/Latency (tCL-tRCD-tRP-tRASmin)	13-13-13-36	5-5-5-15
Size (GB)	16	8
Number of RAM module(s)	64	16
Chip organization	Double-sided	Double-sided

System	Dell PowerEdge R920	HP ProLiant DL385 G6
Rank	2Rx4	2Rx4
Operating system		
Name	Oracle VM Server	Oracle Linux
Build number	3.2.8	5 Update 10
File system	ext3	ext3
Kernel	2.6.39-400.214.3.el5uek	2.6.39-400.212.1.el5uek
Language	English	English
RAID controller		
Vendor and model number	Dell PERC H730P	HP
Firmware version	25.2.0.0013	6.40
Cache size	2 GB	512 MB
RAID configuration	12 × RAID1 pairs	4 × RAID1 pairs
Hard drives		
Vendor and model number	Dell ST9300653SS / ST9900805SS	EH0146FAWJB
Number of drives	22 / 2	6
Size (GB)	300 / 900	146
RPM	15K / 10K	15K
Type	SAS / SAS	SAS
Ethernet adapters		
Vendor and model number	Intel I350 Quad-port 1Gb Daughter card	HP NC382i DP Multifunction Gigabit Server Adapter
Type	PCI-e	Integrated
USB ports		
Number	4	4
Type	USB 2.0	USB 2.0

Figure 4: Configuration information for the test systems.

APPENDIX B: DETAILED TEST METHODOLOGY

The test infrastructure consisted of the following:

- Dell PowerEdge R920
- HP ProLiant DL385 G6
- A client server running a hypervisor hosting five client VMs

For storage, we utilized the onboard capabilities of each server. The DL385 was equipped with eight drive bays. We used two disks in a RAID1 for OS and logs, and six disks split up into three RAID1 pairs to be used with Oracle Automatic Storage Management (ASM) for database data files. The Dell PowerEdge R920 used 24 drives. We configured them in the following RAID groups: one RAID1 pair of 900GB drives for the hypervisor and the OS virtual disks, one RAID1 pair of 300GB drives for log virtual disks, and a RAID10 group of 20 300GB drives for database data virtual disks. For networking, we attached one NIC from each server to a Dell PowerConnect™ 5440 configured with default settings.

Below, we outline the steps we took to setup each server under test and execute the benchmark.

Oracle Linux 5 Update 10 and Oracle Database 11*g* Release 2

We configured the older server with a two-disk RAID 10 running Oracle Linux 5 Update 10 with Oracle Database 11g Release 2. Below are the detailed steps we used to configure the software.

Installing Oracle Linux 5 Update 10

1. Insert the Oracle Linux 5 Update 10 x86_64 install DVD, and boot the server.
2. On the CD Found screen, select Skip, and press Enter.
3. On the first Oracle Linux 5 screen, click Next.
4. On the Installation Language screen, select English, and click Next.
5. On the Installation keyboard screen, select U.S → English, and click Next
6. On the Installation Number pop-up screen, either enter the subscription number or select Skip, then click OK.
7. On the Warning pop-up screen, click Yes to initialize the boot disk.
8. On the disk-partitioning screen, verify that the correct drive is checked, and click Next.
9. On the Warning pop-up screen, click Yes to remove any previous Linux partitions and data on the installation drive.
10. On the Network Devices screen, click Edit to configure the NICs.
11. On the Edit Interface pop-up screen, select IPv4 and Manual configuration, enter the server's IP address and Prefix, and click OK.
12. Back on the Network Devices screen, enter the server's hostname and the IP addresses for its Gateway and DNS server. Click Next.
13. On the Time zone screen, select the time zone, and click Next.
14. On the Administrator Password screen, enter the root password twice, and click Next.
15. On the software-package screen, keep the defaults, and click Next.
16. On the next screen, click Next to partition the drive and begin OS installation.
17. When the install completes, click Reboot.
18. On the Welcome screen, click Forward.
19. One License Agreement screen, select Yes, and click Forward.
20. On the Firewall screen, select Disabled, and click Forward.
21. On the Warning pop-up screen, click Yes.

22. On the SELinux screen, select Disabled, and click Forward.

23. On the Warning pop-up screen, click Yes.

24. On the Kdump screen, keep the defaults, and click Forward.

25. On the Date and Time screen, check the defaults, and click Forward.

26. On the Software Updates screen, choose the option for the subscription status, and click Forward.

27. On the Create User screen, enter the user id, password, and name, and click Forward.

28. On the Sound Card screen, click Forward.

29. On the Additional CDs screen, click Finish to reboot the server.

30. Log into the server as root.

Initial configuration tasks

Complete the following steps to provide the base functionality that Oracle Database requires. We performed all of these tasks as root.

1. Disable firewall services. In the command line (as root), type:
   ```
   # service iptables stop
   # chkconfig iptables off
   # service ip6tables stop
   # chkconfig ip6tables off
   ```

2. Modify the /etc/hosts file to include the IP address of the system and the hostname.

3. Install the following packages:
   ```
   # yum install oracle-validated
   # yum install oracleasm-support
   # passwd oracle
   ```

4. Create the /u01 directory for Oracle inventory and software and give it to the Oracle user:
   ```
   mkdir -p /u01/app/oracle
   chown -R oracle:oinstall /u01
   chmod -R 775 /u01
   ```

5. Add the following lines to /etc/sysctl.conf for huge pages configuration:
   ```
   vm.nr_hugepages=57344
   vm.hugetlb_shm_group = 54321
   ```

6. Prepare the data RAID groups for oraclasm:
   ```
   # fdisk /dev/cciss/c0d1
   # fdisk /dev/cciss/c0d2
   # fidsk /dev/cciss/c0d3
   ```

7. Create two logical volumes with the free space on the OS drives:
   ```
   # lvcreate -n redo01 -L 20G VolGroup00
   # lvcreate -n redo02 -L 20G VolGroup00
   ```

8. Create 3 ASM disks using the oracleasm command:
   ```
   # oracleasm configure -i
   # oracleasm init
   # oracleasm createdisk DATA1 /dev/cciss/c0d1p1
   # oracleasm createdisk DATA2 /dev/cciss/c0d1p2
   # oracleasm createdisk DATA3 /dev/cciss/c0d1p3
   # oracleasm createdisk redo01 /dev/mapper/VolGroup00-redo01
   ```

```
# oracleasm createdisk redo02 /dev/mapper/VolGroup00-redo02
# oracleasm scandisks
# oracleasm listdisks
```

9. Edit bash profiles to set up user environments:

```
# vim /home/oracle/.bash_profile

        # Oracle Settings
        export TMP=/tmp
        export TMPDIR=$TMP
        export ORACLE_HOSTNAME=orcl.localdomain
        export ORACLE_BASE=/u01/app/oracle
        export GRID_HOME=$ORACLE_BASE/product/11.2.0/grid
        export DB_HOME=$ORACLE_BASE/product/11.2.0/dbhome_1
        export ORACLE_HOME=$DB_HOME
        export ORACLE_SID=orcl
        export ORACLE_TERM=xterm
        export BASE_PATH=/usr/sbin:$PATH
        export PATH=$ORACLE_HOME/bin:$BASE_PATH
        export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
        export
        CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
        alias grid_env='. /home/oracle/grid_env'
        alias db_env='. /home/oracle/db_env'

# vim /home/oracle/grid_env

        export ORACLE_SID=+ASM1
        export ORACLE_HOME=$GRID_HOME
        export PATH=$ORACLE_HOME/bin:$BASE_PATH
        export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
        export
        CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib

# vim /home/oracle/db_env

        export ORACLE_SID=orcl
        export ORACLE_HOME=$DB_HOME
        export PATH=$ORACLE_HOME/bin:$BASE_PATH
        export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
        export
        CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
```

Installing Oracle Grid Infrastructure 11g Release 2

We downloaded Oracle Database and Oracle Grid Infrastructure from
www.oracle.com/technetwork/database/enterprise-edition/downloads/112010-linx8664soft-100572.html. The
following tasks were performed by the Oracle user.

1. Unzip linux.x64_11gR2_grid.zip
2. Open a terminal in the unzipped Grid directory.
3. Set the Oracle hostname and Oracle base values by entering the following commands (Note: Replace
   `hostname` with the actual hostname):
   ```
   ORACLE_HOSTNAME=hostname
   ORACLE_BASE=/u01/app/oracle
   ```
4. To start the installer, type `./runInstaller`
5. In the Select Installation Option screen, select Install and Configure Grid Infrastructure for a Standalone Server,
   and click Next.
6. Choose the language, and click Next.
7. In the Create ASM Disk Group screen, choose the Disk Group Name, change redundancy to External, and change
   the discovery path to the directory set by the oracleasm command.
8. After you've changed the discovery path, select only those LUNs that you are planning to use for the database,
   and click Next.
9. In the Specify ASM Password screen, write the passwords for the ASM users, and click Next.
10. In the Privileged Operating System Groups screen, leave the defaults, and click Next.
10. Leave the default installation, and click Next.
12. Leave the default inventory location, and click Next.
13. In the Prerequisite Checks screen, make sure that there are no errors outside of missing packages. If there are
    any errors, click Fix & Check Again.
15. In the Summary screen, verify that everything is correct, and click Finish to install Oracle Grid Infrastructure.
16. At one point during the installation, the installation prompts you to execute two configuration scripts as root.
    Follow the instructions to run the scripts.
17. After you have run the root scripts, go back to the Execute Configuration Scripts window, and click OK to finish
    the installation.
18. At the Finish screen, click Close.

Installing Oracle Database 11g Release 2

1. Unzip linux.x64_11gR2_database_1_of_2.zip and linux.x64_11gR2_database_2_of_2.zip.
2. Open a terminal to the unzipped database directory.
3. Set the Oracle hostname and Oracle base values by entering the following commands (Note: Replace
   `hostname` with the actual hostname):
   ```
   ORACLE_HOSTNAME=hostname
   ORACLE_BASE=/u01/app/oracle
   ```
4. To start the installer, type `./runInstaller`
5. In the Configure Security Updates screen, uncheck I wish to receive security updates via My Oracle Support, and
   click Next.
6. If you receive a warning about the email address not being specified, click Yes to continue.
7. In the Select Installation Option screen, select Create and configure a database, and click Next.

8. In the System Class screen, select Server Class, and click Next.
9. In the Node Selection screen, select Single instance database installation, and click Next.
10. In the Select Install Type screen, select Advanced install, and click Next.
11. Select the language, and click Next.
12. In the Select Database Edition screen, select Enterprise Edition, and click Next.
13. In the Specify Installation Location screen, accept the defaults, and click Next.
14. In the Select Configuration Type screen, select General Purpose / Transaction Processing, and click Next.
15. Name the global database and SID, and click Next.
16. In the Specify Configuration Options screen, uncheck Enable Automatic Memory Management, and click Next.
17. In the Specify Management Options screen, select Use Database Control for database management, and click Next.
18. In the Specify Database Storage Options screen, select Automatic Storage Management, type the password for the ASMSNMP user, and click Next.
19. In the Specify recovery Options screen, select Enable automated backups, and click Next.
20. In the Select ASM Disk Group screen, select the database Disk Group, and click Next.
21. In the Specify Schema Passwords screen, type the passwords for the accounts, and click Next.
22. In the Privileged Operating System Groups screen, accept the default groups, and click Next.
23. In the Prerequisite Checks screen, make sure that there are no errors outside of missing packages. If there are any errors, click Fix & Check Again.
24. There will be errors with the Packages, as Oracle Database checks for i386 libraries instead of the backwards-compatible i686 libraries. Verify that the only missing libraries are i386 libraries, click the Ignore All checkbox, and click Next.
25. In the Summary screen, verify that everything is correct, and click Finish.
26. When the database has been created, the Database Configuration Assistant will alert you. Click OK to continue.
27. At the end of the installation, the installation prompts you to execute a configuration script as root. Follow the instructions to run the script.

For details on the specific Oracle database configuration, see Appendix D.

Backing up and restoring the database

To back up the database, do the following:

1. Log into the server as the oracle user.
2. Log into RMAN.
   ```
   # rman target /
   ```
3. Once in the RMAN console, run the following:
   ```
   SHUTDOWN IMMEDIATE;
   STARTUP FORCE DBA;
   SHUTDOWN IMMEDIATE;
   STARTUP MOUNT;
   CONFIGURE DEVICE TYPE DISK PARALLELISM 12;
   BACKUP AS COMPRESSED BACKUPSET SECTION SIZE 1G DATABASE TAG
   'BACKUP_DS2_100GB';
   ALTER DATABASE OPEN;
   ```

To restore the database, do the following:

1. Log into the server as the oracle user.

2. Log into RMAN.
   # rman target /
3. Once in the RMAN console, run the following:
   ```
   SHUTDOWN ABORT;
   STARTUP MOUNT;
   CONFIGURE DEVICE TYPE DISK PARALLELISM 12;
   RESTORE DATABASE FROM TAG 'BACKUP_DS2_100GB';
   RECOVER DATABASE FROM TAG 'BACKUP_DS2_100GB';
   ALTER DATABASE OPEN RESETLOGS;
   ```

Oracle VM Manager 3.2.8 and Oracle VM Server 3.2.8

We configured a separate server running Oracle VM Manager 3.2.8. We then configured the Dell PowerEdge R920 with Oracle VM Server 3.2.8 and used the separate management server to manage our virtual environment. Below are the detailed steps we took to configure the software on each server.

Installing Oracle VM Manager 3.2.8

On a separate server, we configured a basic install Oracle Linux 6 Update 5 to host our Oracle VM Manager software. We used the following steps to install and configure the Oracle VM Manager software.

1. Ensure that the management and hypervisor server hostnames are entered in the /etc/hosts file.
2. Install TightVNC from YUM.
3. Mount the Oracle VM Manager install disk.
4. Navigate to the mounted folder, and run createOracle.sh.
5. Turn off iptables.
6. To begin the installer, run runInstaller.sh.
7. When prompted, select 1 for the Simple install.
8. Enter the desired password for the new users.
9. Select 1 to continue the installation.
10. Once the installation is complete, open a web browser on a client system, and navigate to the Oracle VM Manager console at https://*ip_address_of_management_server*:7002/ovm/console.
11. Enter the username and password to login, and move on to installing the hypervisor on the R920 server.

Installing Oracle VM Server 3.2.8

1. Boot to the Oracle VM Server install disk.
2. At the Oracle VM boot options screen, hit Enter.
3. Select Skip to skip the media check and continue to the installer.
4. At the Keyboard Selection screen, select US, and hit Enter.
5. Accept the OVS EULA.
6. At the initialization warning, hit Yes.
7. Repeat for all partitions.
8. At the Partitioning Type screen, select the desired disks to use for the installation, select Remove all partitions on the selected drives and create default layout, and hit OK.
9. At the Warning screen, hit Yes.
10. At the Review Layout screen, hit No.

11. At the Boot Loader Configuration screen, select the desired drive for the boot loader, and hit OK.

12. At the Oracle VM Management Interface screen, select the desired management Ethernet port, and hit OK.

13. At the IPv4 Configuration screen, enter a static IP and Netmask, and hit OK.

14. At the Miscellaneous Network Settings screen, enter a Gateway, Primary DNS, and Secondary DNS, and hit OK.

15. At the Hostname Configuration screen, enter the desired hostname for the server, and hit OK.

16. At the Time Zone Selection screen, select the desired time zone, and hit OK.

17. At the Oracle VM Agent password screen, enter and confirm the desired password, and hit OK.

18. At the Root Password screen, enter and confirm the desired root password, and hit OK.

19. At the Installation to begin screen, hit OK.

20. Once the installation complete, hit Reboot.

Configuring the Oracle VM environment in Oracle VM Manager console

1. Log back into the Oracle VM Manager console from a client system.

2. Select the Servers and VMs tab.

3. Click the Discover Servers button to begin the discovery wizard.

4. Leave the Oracle VM Agent Port at the default setting of 8899.

5. Enter a password for the Oracle VM Agent.

6. Enter the IP address for the new Oracle VM Server, and click OK.

7. After the server is added, go back to the Servers and VMs tab, and click Create Virtual NICs.

8. Click Auto Fill to automatically fill in the initial MAC address, select the number of virtual NICs to create, click Create, and click OK.

9. Back on the Servers and VMs tab, click Create Server Pool.

10. Enter a name and virtual IP address for the server pool.

11. Uncheck the box for Clustered Server Pool, and click Next.

12. On the Add Servers screen, select the newly added Oracle VM Server, click the right arrow to add it, and click Finish.

13. Once the Create Server Pool task completes, select the Repositories tab.

14. To begin adding storage repositories, click the + button.

15. Enter a name for the first repository.

16. Select Physical Disk, select the new server pool, and click the magnifying glass.

17. Select the desired physical disk from the list, and click OK.

18. Click Next.

19. Select the Oracle VM Server, add it to the list of servers to present the repository to, and click Finish.

20. Complete steps 14 through 19 for each physical disk RAID group: OS, Log, and Data.

21. For our testing, we also setup an NFS repository to store the Oracle Linux 6 Update 5 ISO and VM backups.

Creating the virtual disks for the virtual machines

1. Once all the repositories have been created, expand the OS repository, and select Virtual Disks.

2. Click the + button in the center pane to start the new virtual disk wizard.

3. Enter a name for the new virtual disk.

4. Enter a size for the new virtual disk.

5. For the Allocation Type, select Non-Sparse Allocation.

6. Click OK.

7. Complete steps 1 through 6 for each VM virtual disk with the following parameters:

    i. For the OS repository, one 60GB virtual disk.

    ii. For the Data repository, four 50GB virtual disks.

    iii. For the Log repository, four 10GB virtual disks.

Creating the first virtual machine

1. On the Servers and VMs tab, click the Create Virtual Machine button.

2. Select Create a new VM, and click Next.

3. Select the new Oracle VM Server.

4. Select the OS repository to store the VM files.

5. Enter a name for the new VM

6. Select Oracle Linux 6 for the Operating System.

7. For the Domain Type, select Xen HVM, PV drivers.

8. For Max Memory and Memory, enter 131072.

9. For Max Processors and Processors, enter 8.

10. Click Next.

11. On the Set up Networks, select an unassigned VNIC on the desired test network, and click Add VNIC.

12. Click Next.

13. For Slot 0, select CD/DVD.

14. Click the magnifying glass, and select the Oracle Linux 6 Update 5 ISO uploaded on the NFS, and click OK.

15. For Slot 1, select Virtual Disk.

16. Click the magnifying glass, and select the OS virtual disk created in the previous section.

17. Repeat for all Log and Data virtual disks in the next eight consecutive slots.

18. Click Next.

19. Add Disk and CDROM to the boot options list, ensure that CDROM is the first option.

20. Click Finish.

21. Once Oracle Linux 6 Update 5 is installed, we shut down the VM, change Slot 0 to empty, and edit the VM type to Xen PVM for the best performance. PVM natively does not allow boot from CDROM.

Virtual Machines: Oracle Linux 6 Update 5 and Oracle Database 12*c*

We configured each VM with one virtual disk on our OS repository running Oracle Linux 6 Update 5 with Oracle Database 12c, four virtual disks on our log repository presented to Oracle ASM for redo logs, and four virtual disks on our data repository presented to Oracle ASM for database data files. Below are the detailed steps we used to configure the software.

Installing Oracle Linux 6 Update 5

1. Configure the first VM to boot to the Oracle Linux 6 Update 5 ISO, and power it on.

2. Click the console button for the VM in the Oracle VM management console from a client with VNC Viewer installed.

3. Once the install screen loads, Select Install or upgrade an existing system.
4. If you are unsure of the fidelity of the installation disk, select OK to test the installation media; otherwise, select Skip.
5. In the opening splash screen, select Next.
6. Choose the language you wish to use, and click Next.
7. Select the keyboard layout, and click Next.
8. Select Basic Storage Devices, and click Next.
9. Select Fresh Installation, and click Next.
10. Insert the hostname, and select Configure Network.
11. In the Network Connections menu, configure network connections.
10. After configuring the network connections, click Close.
11. Click Next.
12. Select the nearest city in your time zone, and click Next.
13. Enter the root password, and click Next.
14. Select Use All Space, and click Next.
15. Select the appropriate Data Store Device and select where the Bootloader will go.
16. Modify the Swap file to 20GB.
17. When the installation prompts you to confirm that you are writing changes to the disk, select Write changes to disk.
18. Select Software Basic Server, and click Next. Oracle Linux installation begins.
19. When the installation completes, select Reboot to restart the VM.

Initial configuration tasks

Complete the following steps to provide the functionality that Oracle Database requires. We performed all of these tasks as root.

1. Disable firewall services. In the command line (as root), type:
   ```
   # service iptables stop
   # chkconfig iptables off
   # service ip6tables stop
   # chkconfig ip6tables off
   ```
2. Disable SELinux:
   ```
   # vi /etc/selinux/config
   SELINUX=disabled
   ```
3. Modify /etc/hosts to include the IP address of the VM and the hostname.
4. Install 12*c* RPM packages, resolve package dependencies and modify kernel parameters:
   ```
   # yum install oracle-rdbms-server-12cR1-preinstall -y
   ```
5. Install automatic system tuning for database storage through yum:
   ```
   # yum install tuned
   # chkconfig tuned on
   # tuned-adm profile enterprise-storage
   ```
6. Using yum, install the following prerequisite packages for Oracle Database:
   ```
   # yum install elfutils-libelf-devel
   # yum install xhost
   # yum install unixODBC
   # yum install unixODBC-devel
   ```

```
          # yum install oracleasm-support oracleasmlib oracleasm
```
7. Create the oracle user account and groups and password:
```
   # groupadd -g 1003 oper
   # groupadd -g 1004 asmadmin
   # groupadd -g 1005 asmdba
   # groupadd -g 1006 asmoper
   # usermod -G dba,oper,asmadmin,asmdba,asmoper oracle
   # passwd oracle
```
8. Create the /u01 directory for Oracle inventory and software and give it to the oracle user:
```
   # mkdir -p /u01/app/oracle/product/12.1.0/grid
   # mkdir -p /u01/app/oracle/product/12.1.0/dbhome_1
   # chown -R oracle:oinstall /u01
   # chmod -R 775 /u01
```
9. Edit bash profiles to set up user environments:
```
 # vim /home/oracle/.bash_profile


       # Oracle Settings
       export TMP=/tmp
       export TMPDIR=$TMP
       export ORACLE_HOSTNAME=orcl.localdomain
       export ORACLE_BASE=/u01/app/oracle
       export GRID_HOME=$ORACLE_BASE/product/12.1.0/grid
       export DB_HOME=$ORACLE_BASE/product/12.1.0/dbhome_1
       export ORACLE_HOME=$DB_HOME
       export ORACLE_SID=orcl
       export ORACLE_TERM=xterm
       export BASE_PATH=/usr/sbin:$PATH
       export PATH=$ORACLE_HOME/bin:$BASE_PATH
       export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
       export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
       alias grid_env='. /home/oracle/grid_env'
       alias db_env='. /home/oracle/db_env'


 # vim /home/oracle/grid_env


       export ORACLE_SID=+ASM
       export ORACLE_HOME=$GRID_HOME
       export PATH=$ORACLE_HOME/bin:$BASE_PATH
       export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
       export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib



 # vim /home/oracle/db_env


       export ORACLE_SID=orcl
       export ORACLE_HOME=$DB_HOME
       export PATH=$ORACLE_HOME/bin:$BASE_PATH
       export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
       export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
```

10. Set up partitions for asm using parted GPT

```
# parted /dev/sdb
(parted)mklabel gpt
(parted)print
(parted)mkpart primary 0GB 50GB
```
Repeat on all other virtual disks.

11. Configure ASMlib:

```
# oracleasm configure -i

      Configuring the Oracle ASM library driver.

      This will configure the on-boot properties of the Oracle ASM library
      driver.  The following questions will determine whether the driver is
      loaded on boot and what permissions it will have.  The current values
      will be shown in brackets ('[]').  Hitting <ENTER> without typing an
      answer will keep that current value.  Ctrl-C will abort.

      Default user to own the driver interface []: oracle
      Default group to own the driver interface []: asmadmin
      Start Oracle ASM library driver on boot (y/n) [n]: y
      Scan for Oracle ASM disks on boot (y/n) [y]: y
      Writing Oracle ASM library driver configuration: done
```

12. Load ASM kernel module:

```
# oracleasm init
```

13. Add ASM disks

```
# oracleleasm createdisk DISK1 /dev/sdb1
```
Repeat on all eight virtual disks.

Installing Oracle Grid Infrastructure 12c

1. Unzip linuxamd64_12c_grid_1of2.zip and linuxamd64_12c_grid_2of2.zip
2. Open a terminal to the unzipped database directory.
3. Set the Oracle grid environment.
4. To start the installer, type `./runInstaller`
5. At the software Updates screen, select Skip updates.
6. In the Select Installation Option screen, select Install and Configure Grid Infrastructure for a Standalone Server, and click Next.
7. Choose the language, and click Next.
8. In the Create ASM Disk Group screen, choose the Disk Group Name, change redundancy to External
9. Select the four ASM disks that you are planning to use for the database, and click Next.
10. In the Specify ASM Password screen, write the passwords for the ASM users, and click Next.
11. Leave the default Operating System Groups, and click Next.
12. Leave the default installation, and click Next.
    a. Leave the default inventory location, and click Next.
    b. Under Root script execution select Automatically run configuration scripts and enter root credentials.
    c. In the Prerequisite Checks screen, make sure that there are no errors.
    d. In the Summary screen, verify that everything is correct, and click Finish to install Oracle Grid Infrastructure.

e. At one point during the installation, the installation prompts you to execute two configuration scripts as root. Follow the instructions to run the scripts.
f. At the Finish screen, click Close.
13. Run the ASM Configuration Assistant by typing `asmca`
14. In the ASM Configuration Assistant, click Create.
15. In the Create Disk Group window, name the new disk group `log` choose redundancy External (None), select the four remaining ASM disks, and click OK.
16. Exit the ASM Configuration Assistant.

Installing Oracle Database 12c

1. Unzip linuxamd64_12c_database_1_of_2.zip and linuxamd64_12c_database_2_of_2.zip.
2. Open a terminal to the unzipped database directory.
3. Set the Oracle database environment.
4. To start the installer, type `./runInstaller`
5. In the Configure Security Updates screen, uncheck I wish to receive security updates via My Oracle Support, and click Next.
6. If you receive a warning about the email address not being specified, click Yes to continue.
7. At the Software Updates screen select Skip Software Updates and click Next.
8. In the Select Installation Option screen, select Install database software only, and click Next.
9. Select Single instance database installation, and click Next.
10. Select the language, and click Next.
11. In the Select Database Edition screen, select Enterprise Edition, and click Next.
12. In the Specify Installation Location screen, accept the defaults, and click Next.
13. At the operating Sytem groups screen select the appropriate groups and click Next.
14. At the summary screen click Install.

Installing and configuring the Oracle database

1. Enter `dbca` and press enter to open the Database configuration assistant.
2. At the Database Operation screen select Create Database, and click Next.
3. Under Creation Mode select Advanced Mode, and click Next.
4. At the Select Template screen select General Purpose or Transaction Processing. Click Next
5. Enter a Global database name and the appropriate SID.
6. At the Management Options screen select Configure Enterprise Manager (EM) Database Express. Click Next.
7. At the Database Credentials screen select Use the Same Administrative Password for All Accounts. Enter a password, and click Next.
8. At the Network Configuration screen click Next.
9. At the Storage Configuration screen select Automatic Storage Management, and select `+DATA` as the Database File Location, and /backup as the Fast Recovery Area with a 150GB Fast Recover Area size.
10. At the Database Options screen click Next.
11. At the Initialization Parameters screen, click Next.
12. At the Creation Options select Create Database, and click Next.
13. At the summary screen click Finish.
14. Close the Database Configuration Assistant.

We then configured our database with a custom spfile. For details on the specific Oracle database configuration, see [Appendix D](#).

Creating redo logs

1. Log into sqlplus and create two log groups with 250GB files on +LOG.
   ```
   # sqlplus / as sysdba
   ALTER DATABASE ADD LOGFILE GROUP 10 ('+LOG/ORCL/ONLINELOG/log1.rdo')size 19g;
   ALTER DATABASE ADD LOGFILE GROUP 11 ('+LOG/ORCL/ONLINELOG/log2.rdo')size 19g;
   ```
2. Remove the three default redo log groups.

Backing up and restoring the database

To back up the database, do the following:

4. Log into the server as the oracle user.
5. Log into RMAN.
   ```
   # rman target /
   ```
6. Once in the RMAN console, run the following:
   ```
   SHUTDOWN IMMEDIATE;
   STARTUP FORCE DBA;
   SHUTDOWN IMMEDIATE;
   STARTUP MOUNT;
   CONFIGURE DEVICE TYPE DISK PARALLELISM 8;
   BACKUP AS COMPRESSED BACKUPSET SECTION SIZE 1G DATABASE TAG
   'BACKUP_DS2_100GB';
   ALTER DATABASE OPEN;
   ```

To restore the database, do the following:

4. Log into the server as the oracle user.
5. Log into RMAN.
   ```
   # rman target /
   ```
6. Once in the RMAN console, run the following:
   ```
   SHUTDOWN ABORT;
   STARTUP MOUNT;
   CONFIGURE DEVICE TYPE DISK PARALLELISM 8;
   RESTORE DATABASE FROM TAG 'BACKUP_DS2_100GB';
   RECOVER DATABASE FROM TAG 'BACKUP_DS2_100GB';
   ALTER DATABASE OPEN RESETLOGS;
   ```

Measuring power consumption

To record each server's power consumption during each test, we used an Extech Instruments (www.extech.com) 380803 Power Analyzer/Datalogger. We connected the power cord from the server under test to the Power Analyzer's output load power outlet. We then plugged the power cord from the Power Analyzer's input voltage connection into a power outlet.

We used the Power Analyzer's Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on a separate Intel processor-based PC, which we connected to the Power Analyzer via an RS-232 cable. We captured power consumption at one-second intervals.

We then recorded the power usage (in watts) for each system during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results.

Configuring the database (DVD Store)

Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1 (DS2), providing the parameters for our 100GB database size and the database platform on which we ran: Oracle Database. We ran the Install.pl script on the SUT. The database schema was also generated by the Install.pl script.

On the older server, we built the 100GB database in Oracle Database 11*g* Release 2 using the generated schema creation scripts with customizations we outline in the "DVD Store modifications" section below, and then performed a full backup, storing the backup file on NFS storage for quick access. We used that backup file between test runs. For our virtual machines on the R920, we used the same generated data and schema creation scripts with some edits for 12*c* and used the same backup/restore from an NFS procedure we used on the legacy setup.

We created additional indexes to improve lookup performance and reduce table scans. We configured the tablespaces to use ASM and created 1 BIGFILE file per tablespace to simplify data file layout. Additionally, we modified the login stored procedure to bypass using the temporary tablespace. Finally, we also modified the data generation scripts (see DVD store modifications section below). Specifically, we followed the steps below:

- We generated the data and created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 100GB database and the appropriate ASM drive groups.
- We created database tables, stored procedures, and objects using the provided DVD Store scripts.
- We loaded the data we generated into the database using sqlldr and the provided DVD Store load scripts.
- We created indices, full-text catalogs, primary keys, and foreign keys using our modified database-creation scripts.
- We created a database user, and mapped this user to the Oracle Database login.
- We then performed a full backup of the database. This backup allowed us to restore the databases to a pristine state relatively quickly between tests.

DVD Store modifications

We made a few modifications to the database creation scripts for DVD store to increase the databases' performance. The files we modified and their changes are listed below:

- oracleds2_create_ind.sql
    - Created a new index on the CUST_HIST table that included the CUSTOMERID and PROD_ID columns.
    - Changed the PK_ORDERS index to a reverse index.
    - Created a new index on the ORDERS table that included the CUSTOMERID column.
    - Changed the PK_ORDERLINES index to a reverse index.
    - Created a new index on the PRODUCTS table that included the PROD_ID and COMMON_PROD_ID columns.
    - Created a new index on the PRODUCTS table that included the SPECIAL, CATEGORY, and PROD_ID columns.
    - Changed the IX_INV_PROD_ID index to a unique index and made it the primary key.
    - Created a new index on the REORDER table that included the PROD_ID column.
- oracleds2_create_sp.sql
    - Removed the "derivedtable" global temporary table creation.
    - Modified the LOGIN procedure to not use the "derivedtable" global temporary table.
- oracleds2_create_tablespaces_100GB_asm.sql
    - Modified to use ASM datastore.
    - Used one BIGFILE data file for the CUSTTBS tablesplace.

- o Used one BIGFILE data file for the INDXTBS tablesplace.
- o Used one BIGFILE data file for the ORDERTBS tablesplace.
- o Used one BIGFILE data file for the DS_MISC tablespace.

Running the DVD Store tests

DVD Store outputs an orders-per-minute metric, which is a running average calculated through the test. In this report, we use the average OPM reported by each client/target pair to calculate the advantage of the new solution during 20 minutes of steady state performance, and before check pointing occurred. We downloaded the latest Oracle Data Provider for .NET 4.x. We used an enterprise class server hosting five client VMs, each targeting a single PDB. One client VM targeted our older server as well. For test timing, we ran the older server for one hour and the R920 for two hours, both running 24 threads, in order to allow each server's RAM utilization to stabilize and measured performance prior to checkpoints occurring. We ran the benchmark with 20ms think time.

Each complete test cycle consisted of the general steps listed below. For each scenario, we ran three test cycles and chose the median outcome.

- Clean up prior outputs from the host system and all client driver systems.
- Reboot the SUT and all client systems.
- Wait for a ping response from the SUT and all client systems.
- Power on the VMs for Oracle VM testing.
- Restore the database.
- Begin recording power and system statistics (iostat and vmstat).
- Start the DVD Store driver on all respective clients.

We used the following DVD Store parameters for testing the virtual machines in this study:

```
ds2oracledriver.exe --target=<target_IP> --ramp_rate=10 --n_threads=24 --
db_size=100GB --think_time=0.02 --detailed_view=Y --warmup_time=1
```

APPENDIX C: COST CALCULATIONS

Energy cost calculations

We estimate 43 percent less power consumption with Oracle Database12*c* consolidation on the Dell PowerEdge R920 solution, saving $857 per year in energy costs for power and cooling compared to the five older servers it could replace. Figure 5 shows our calculations.

12*c* consolidation energy cost savings	Five older servers	Dell PowerEdge R920	Calculation
Average watts	1,340	770	Average power usage in our tests
KW	1.34	0.77	Average watts/1000
KWh	11,746.44	6,749.82	KW multiplied by hours per year
Cost per year for power	$1,220.46	$701.31	KWh * average cost per KWh
Cost per year for power and cooling	$2,013.75	$1,157.20	Cost per year for power multiplied by PUE
Cost per year for power and cooling (rounded)	$2,014.00	$1,157.00	Cost rounded to nearest dollar
Savings		**$857**	Savings for Dell solution

Figure 5: 12*c* consolidation power consumption and energy cost savings.

Software cost calculations

We calculated software costs for this consolidation scenario. We include three-year support costs for Oracle Database 12c Enterprise Edition (EE) and Oracle Linux Premier. We also include support costs for Oracle VM in the costs of the Dell PowerEdge R920 solution.

We estimate the cost savings for the Dell PowerEdge R920 solution with 12*c* at $212,091 for consolidating the databases of five older servers onto one Dell PowerEdge R920 server.

Oracle Linux Premier

Oracle licenses Oracle Linux Premier on a per-server basis and changes only for support. We include three-year support for all the servers in both solutions at a cost of $6,897 per server.

Oracle Database 12*c* Enterprise Edition

Oracle licenses Oracle EE based on core count, with one processor license supporting two cores on servers with Intel Xeon multi-core processors. The enterprise would not need to purchase the Oracle EE perpetual licenses for either solution because it already has them for the older solution and would move licenses from it to the new Dell PowerEdge R920 solution when decommissioning the older servers. We include the three-year Oracle EE support costs for both solutions at a cost of $31,350 over three years for each pair of cores on the servers.[3]

Oracle Linux VM

Oracle licenses Oracle Linux VM Premier edition on a per-server basis and changes only for support. We include three-year support for the Dell PowerEdge R920 at a cost of $3,597. We do not include this cost for the legacy servers because we did not run workloads on those servers in VMs.

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[3] www.oracle.com/us/corporate/pricing/technology-price-list-070617.pdf

Total software costs

Figure 6 shows the license count and software cost calculations for both solutions and the software savings for the Dell PowerEdge R920 solution.

Three-year software licensing costs	Cost per license	Older servers		Dell PowerEdge R920		
		Licenses needed	Solution cost	Licenses needed	Solution cost	Savings
Oracle Database Enterprise Edition support	$31,350	30	$940,500	24	$752,400	
Oracle Linux Premier support	$6,897	5	$34,485	1	$6,897	
Oracle VM Premier support	$3,597	0	$0	1	$3,597	
Software licensing total			$974,985		$762,894	$212,091

Figure 6: The license count and software cost calculations.

To calculate the number of licenses per processor for Oracle EE, processor type and core count are considered. First, find the core factor for the relevant processor on Oracle's core factor table[4] and then multiply that number by the count of cores on the server. The core factor for both the AMD Opteron processors on the older servers and the Intel Xeon processors on the newer Dell PowerEdge R920 servers is 0.5; one license for each pair of cores in both solutions. The older server requires 30 licenses for five servers – six per server for the 12 cores on each server. The Dell PowerEdge R920 server needs 24 licenses for the 48 total cores on its four 12-core processors. We include costs for Oracle Linux support for each server, with one license per server, and for Oracle VM Premier support on the Dell PowerEdge R920 for one license per server.

Comparison of software savings to hardware costs

We priced the Dell PowerEdge R920 server that we tested on the Dell site at $59,221.00 (before discounts). The software savings of $212,091 are more than three and a half times (3.58 times) the server hardware cost.

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[4] www.oracle.com/us/corporate/contracts/processor-core-factor-table-070634.pdf

APPENDIX D: ORACLE DATABASE SPFILE CONFIGURATION

Below are the spfile configurations we used for each server. Differences are the result of the different Oracle database versions and RAM configuration on the two servers.

Older server Oracle Database 11*g* R2 spfile
```
*.aq_tm_processes=0
*.audit_file_dest='/u01/app/oracle/admin/orcl/adump'
*.audit_trail='FALSE'
*.compatible='11.2.0.0.0'
*.control_files='+DATA/orcl/control01.ctl','/u01/app/oracle/product/11.2.0/dbhome
_1/dbs/control02.ctl'#Restore Controlfile
*.db_block_checking='FALSE'
*.db_block_size=8192
*.db_cache_size=106g
*.db_create_file_dest='+DATA'
*.db_name='orcl'
*.db_recovery_file_dest='/backup'
*.db_recovery_file_dest_size=400g
*.diagnostic_dest='/u01/app/oracle'
*.disk_asynch_io=TRUE
*.dispatchers='(PROTOCOL=TCP) (SERVICE=orclXDB)'
*.dml_locks=2000
*.fast_start_mttr_target=0
*.filesystemio_options='setall'
*.java_pool_size=0
*.job_queue_processes=0
*.lock_sga=TRUE
*.log_buffer=268435456
*.log_checkpoint_timeout=0
*.log_checkpoints_to_alert=TRUE
*.parallel_max_servers=0
*.pga_aggregate_target=0
*.plsql_optimize_level=2
*.processes=2000
*.recovery_parallelism=12
*.remote_login_passwordfile='EXCLUSIVE'
*.result_cache_max_size=0
*.sessions=4096
*.shared_pool_size=4G
*.statistics_level='BASIC'
*.timed_statistics=FALSE
*.transactions=1500
*.undo_management='AUTO'
*.undo_retention=1
*.undo_tablespace='UNDOTBS1'
*.use_large_pages='ONLY'
```

Dell PowerEdge R920 Oracle Database 12*c* spfile

```
orcl.__oracle_base='/u01/app/oracle'#ORACLE_BASE set from environment
*.aq_tm_processes=0
*.audit_file_dest='/u01/app/oracle/admin/orcl/adump'
*.audit_trail='NONE'
*.compatible='12.1.0.0.0'
*.control_files='+DATA/ORCL/CONTROLFILE/current.263.847980357','+LOG/control.1'
*.db_block_size=8192
*.db_cache_size=106g
*.db_create_file_dest='+DATA'
*.db_domain=''
*.db_file_multiblock_read_count=512
*.db_name='orcl'
*.db_recovery_file_dest='/backup'
*.db_recovery_file_dest_size=150g
*.diagnostic_dest='/u01/app/oracle'
*.disk_asynch_io=TRUE
*.dispatchers='(PROTOCOL=TCP) (SERVICE=orclXDB)'
*.dml_locks=2000
*.fast_start_mttr_target=0
*.filesystemio_options='setall'
*.java_pool_size=0
*.job_queue_processes=0
*.local_listener='LISTENER_ORCL'
*.lock_sga=TRUE
*.log_buffer=268435456
*.log_checkpoint_timeout=0
*.log_checkpoints_to_alert=TRUE
*.open_cursors=300
*.parallel_max_servers=0
*.pga_aggregate_target=0
*.plsql_optimize_level=2
*.processes=2000
*.recovery_parallelism=8
*.remote_login_passwordfile='EXCLUSIVE'
*.result_cache_max_size=0
*.sessions=4096
*.shared_pool_size=4G
*.statistics_level='BASIC'
*.timed_statistics=FALSE
*.transactions=1500
*.undo_management='AUTO'
```

```
*.undo_retention=1
*.undo_tablespace='UNDOTBS1'
*.use_large_pages='FALSE'
```

ABOUT PRINCIPLED TECHNOLOGIES

![Principled Technologies logo]

Principled Technologies, Inc.
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We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help our clients assess how it will fare against its competition, its performance, its market readiness, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.