The science behind the report:

# Refresh to a Dell EMC PowerEdge MX modular chassis with a PowerEdge MX840c server and improve the performance of critical workloads

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report Refresh to a Dell EMC PowerEdge MX modular chassis with a PowerEdge MX840c server and improve the performance of critical workloads.

We concluded our hands-on testing on October 12, 2020. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on September 30, 2020 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

## Our results

Table 1: Results of our testing.

| | Dell EMC™ PowerEdge™ MX840c | HPE ProLiant DL380 Gen9 |
|---|---|---|
| **VDI workload** | | |
| **Number of VMs each solution supported** | 170 | 60 |
| OLTP processing workload (orders per minute or OPM) | | |
| OPM supported on VM #1 | 22,221 | 19,453 |
| OPM supported on VM #2 | 22,065 | 18,091 |
| OPM supported on VM #3 | 22,473 | 18,215 |
| OPM supported on VM #4 | 25,508 | 18,012 |
| **Total OPM** | **92,267** | **73,771** |
| Data analytics workload (min:sec) | | |
| VM 1 | 1:12 | 2:06 |
| VM 2 | 1:28 | 2:07 |
| VM 3 | 1:12 | 2:07 |
| VM 4 | 1:13 | 2:07 |
| **Time it took for all four VMs to complete workload (i.e., slowest elapsed time)** | **1:28** | **2:07** |

Table 2: CPU utilization (percentage) on the Dell EMC PowerEdge MX840c.

|  | CPU utilization (percentage) on the Dell EMC PowerEdge MX840c |
|---|---|
| While running three workloads concurrently (VDI, OLTP, and analytics) + infrastructure VMs | 89.8% |

Table 3: CPU utilization (percentage) on the HPE ProLiant DL380 Gen9.

|  | CPU utilization (percentage) on the HPE ProLiant DL380 Gen9 |
|---|---|
| While running only VDI workload | 99.2% |
| While running only OLTP workload | 89.2% |
| While running only data analytics workload | 98.7% |

# System configuration information

Table 4: Detailed configuration information for the server under test.

| System configuration information | HPE ProLiant DL380 Gen9 | Dell EMC PowerEdge MX840c |
| --- | --- | --- |
| BIOS name and version | HP P89 v2.64 | Dell 2.8.1 |
| Non-default BIOS settings | Maximum Performance mode | Performance mode |
| Operating system name and version/build number | VMware ESXi™ 7.0.0 (Build 16324942) | VMware ESXi 7.0.0 (Build 16324942) |
| Date of last OS updates/patches applied | 8/17/2020 | 8/24/2020 |
| Power management policy | Maximum Performance | Performance |
| Processor | | |
| Number of processors | 2 | 4 |
| Vendor and model | Intel® Xeon® E5-2650 v3 | Intel Xeon Platinum 8270 |
| Core count (per processor) | 10 | 26 |
| Core frequency (GHz) | 2.3 | 2.7 |
| Stepping | 2 | 5 |
| Memory module(s) | | |
| Total memory in system (GB) | 256 | 1,536 |
| Number of memory modules | 8 | 24 |
| Vendor and model | Samsung® M393A4K40BB1-CRC0Q | Samsung M393A8G40MB2-CVFCQ |
| Size (GB) | 32 | 64 |
| Type | DDR-4 PC4-19200 Dual-Rank | DDR-4 PC4-23466U Dual-Rank |
| Speed (MHz) | 2,400 | 2,933 |
| Speed running in the server (MHz) | 2,400 | 2,933 |
| Storage controller | | |
| Vendor and model | HPE SmartArray P440ar | Dell PERC H730P MX |
| Cache size (MB) | 2048 | 2048 |
| Firmware version | 6.60 | 25.5.6.0009 |
| Driver version | 2.0.50 | 7.712.50.00 |
| Local storage (type A) | | |
| Number of drives | 8 | 2 |
| Drive vendor and model | Intel S3510 | Intel 2280 |
| Drive size (GB) | 800 | 120 |
| Drive information (speed, interface, type) | 6Gbps SATA SSD | 6Gbps SATA M.2 SSD |
| Network adapter | | |
| Vendor and model | HPE Ethernet 1Gb 4-port 331i Adapter | Intel Ethernet 25G 2-Port XXV710 Mezz |
| Number and type of ports | 4x 1GbE RJ45 | 2x 25GbE |
| Driver version | 20.14.54 | 19.5.12 |

| System configuration information | HPE ProLiant DL380 Gen9 | Dell EMC PowerEdge MX840c |
|---|---|---|
| Network adapter | | |
| Vendor and model | Emulex OneConnect OCe14102-UM 10Gb 2-Port SFP+ CNA | N/A |
| Number and type of ports | 2x 10GbE SFP | N/A |
| Driver version | 10.2.370.19 | N/A |
| Cooling fans | | |
| Vendor and model | NMB 06038DA-12S-E2H | N/A |
| Number of cooling fans | 6 | 0 |
| Power supplies | | |
| Vendor and model | HPE DPS-800AB-11A | N/A |
| Number of power supplies | 2 | N/A |
| Wattage of each (W) | 800 | N/A |

Table 5: Configuration information for the server enclosure.

| Server enclosure configuration information | Dell EMC PowerEdge MX7000 |
|---|---|
| I/O modules | |
| Vendor and model number | Dell EMC MX7116n Fabric Expander Module, MX9116n Fabric Engine |
| Occupied bay(s) | 1,2 |
| Power supplies | |
| Number of power supplies | 4 |
| Vendor and model number | Dell EMC |
| Wattage of each (W) | 3,000 |
| Cooling fans | |
| Total number of fan modules | 9 |
| Vendor and model number | Dell EMC |

Table 6: Detailed configuration information for the Dell EMC storage solution.

| Storage configuration information for the Dell EMC MX840c testbed | Dell EMC PowerStore Unity 350F |
|---|---|
| Controller firmware revision | 4.0 |
| Number of storage controllers | 1 |
| Number of storage shelves | 1 |
| Number of drives per shelf, RAID type | 10, RAID 10 |
| Drive vendor and model number | Samsung MZ ILS400N |
| Drive size (GB) | 400 |
| Drive information (speed, interface, type) | 12Gb, SAS, SSD |

Table 7: Detailed configuration information for the HPE storage solution.

| Storage configuration information for the HPE ProLiant DL380 Gen9 testbed | Legacy NFS |
|---|---|
| Number of storage controllers | 2 |
| Number of storage shelves | 2 |
| Number of drives per shelf, RAID type | 24 |
| Drive vendor and model number | Hitachi HUC10600 |
| Drive size (GB) | 600 |
| Drive information (speed, interface, type) | 6Gb, SAS, 10k sas |
| Cache drive vendor and model number | Samsung SS160520 |
| Drive size (GB) | 200 |
| Drive information (speed, interface, type) | 6Gb, SATA, Flash |

# How we tested

## Testing overview

We installed a Dell EMC PowerEdge MX7000 chassis and connected it to an upstream Dell Networking 4048 ON switch via 40GB connections. We connected our storage and the HPE ProLiant DL380 Gen9 to the Dell Networking 4048 ON switch via 10Gbps connections. We then connected a Dell EMC PowerStore Unity 350F array and our Legacy NFS storage to the Dell Networking 4048 ON switch via 2x 10Gbps connections. We enabled Jumbo frames and provisioned a single mount point on each storage platform. We installed VMware ESXi 7.0 on both the dual-socket HPE ProLiant DL380 Gen9 server and the four-socket Dell EMC PowerEdge MX840c compute node. We created a single VMware VMFS datastore on each mount point, attaching the Dell EMC PowerEdge MX840c compute node to the Dell EMC PowerStore Unity 350F array mount point via 2x 10Gbps NFS, and attaching the HPE ProLiant DL380 Gen9 to the legacy NFS mount point via 2x 10Gbps NFS.

We created the VMs outlined in Table 9 and ran three workloads on each system (independently on the HPE ProLiant DL380 Gen9 server, and simultaneously on the MX840c): A VDI workload using VMware View Planner, an OLAP workload using HammerDB, and an OLTP workload using DVD Store 2.
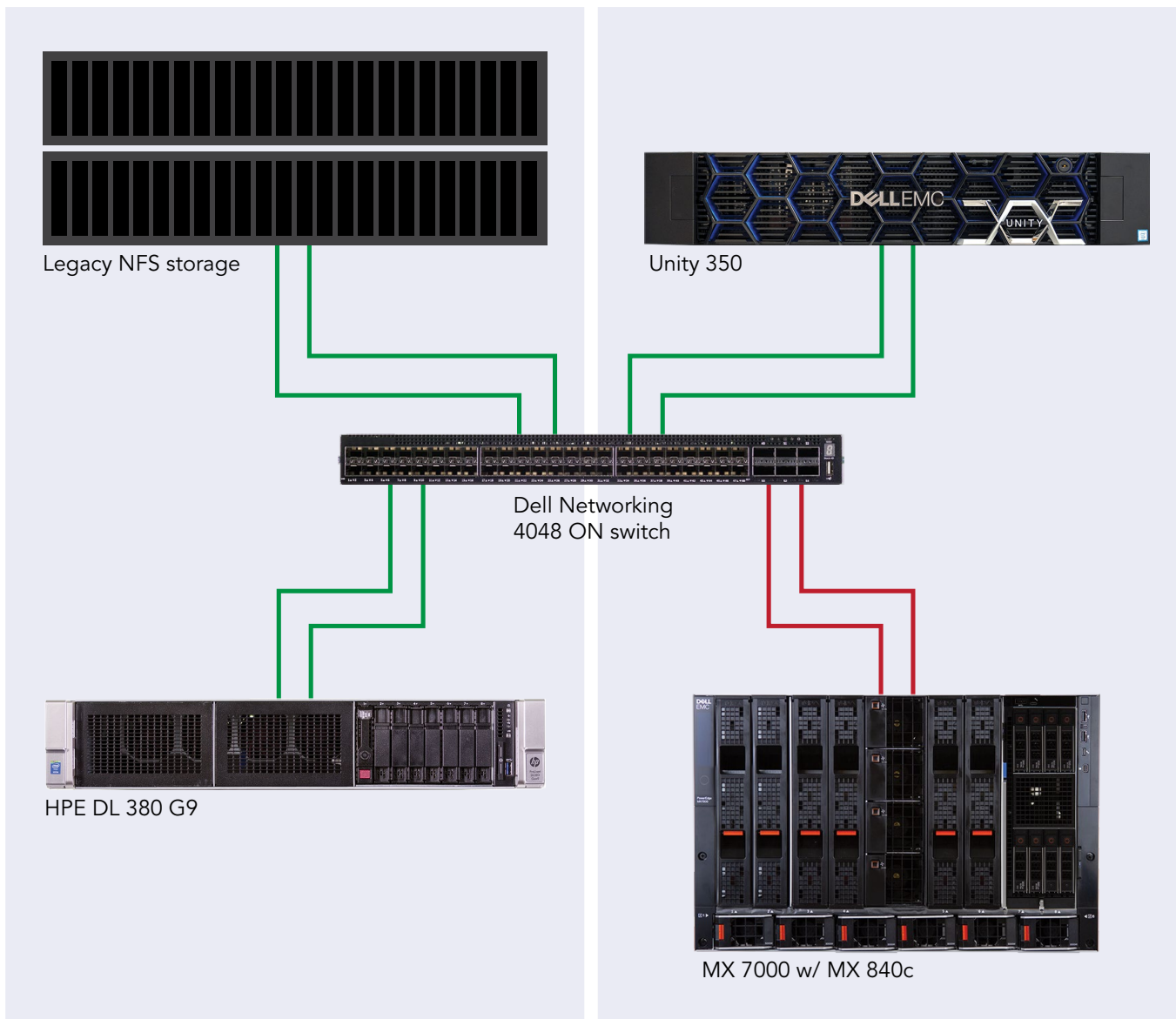


Figure 1: Testbed diagram of both solutions under test.

## Physical servers

Table 8: OS and role information for the servers we tested.

| Server | OS | Role(s) |
|---|---|---|
| Infrastructure | VMware ESXi 7.0 | ADDS, SQL. DNS, DHCP, NTP, vCenter, View connection and composer, View Planner harness |
| HPE ProLiant DL380 Gen9 | VMware ESXi 7.0 | Server under test |
| Dell EMC PowerEdge MX840c | VMware ESXi 7.0 | Server under test |

## Virtual machines

Table 9: Detailed configuration information for the VMs we tested.

| VM name | OS/role | vCPU count | Memory size (GB) | Disk size (GB) | Server host/cluster |
|---|---|---|---|---|---|
| DC1 | Windows Server 2019/Domain controller, DNS, DHCP | 4 | 8 | 40 | Infrastructure |
| vCenter | VMware vCenter Server® Virtual Appliance | 4 | 20 | Appliance determined | Infrastructure |
| Composer | Windows Server 2019/VMware Horizon 7 Composer | 4 | 16 | 40 (C:\)<br>50 (D:\) | Infrastructure |
| View | Windows Server 2019/ VMware Horizon® 7 Connection Server | 8 | 8 | 40 | Infrastructure |
| VMware View Planner-harness | VMware Photon™/VMware View Planner-harness | 8 | 8 | 12<br>50 | Infrastructure |
| OLTP client | Windows Server 2019/Client | 4 | 8 | 50 | Infrastructure |
| Gold Win10 VM | Windows 10 x64 | 2 | 4 | 50 | HPE ProLiant DL380 Gen9, Dell EMC PowerEdge MX840c |
| OLTP VM | Windows Server 2019/ system under test | 10 | 60 | 50 (C:\)<br>100 (E:\)<br>30 (F:\)<br>50 (G:\) | HPE ProLiant DL380 Gen9, Dell EMC PowerEdge MX840c |
| OLAP VM | Windows Server 2019/ system under test | 10 | 60 | 50 (C:\)<br>40 (E:\)<br>10 (F:\)<br>15 (G:\) | HPE ProLiant DL380 Gen9, Dell EMC PowerEdge MX840c |

## Installing VMware ESXi 7.0 on the HPE ProLiant DL380 Gen9

### Changing the system profile to performance

1. Boot the server.
2. At the POST menu, for System Configuration, select F2.
3. Select BIOS/Platform Configuration (RBSU).
4. Select Power Management.
5. Select Power Profile.
6. Click the Power Profile dropdown menu, and select Maximum Performance.
7. To save and exit, press F10.
8. Click Exit, and reboot the server.

### Installing VMware ESXi

1. Attach the installation media.
2. Boot the server.
3. At the POST menu, for Boot Menu, select F11.
4. Select One Time Boot Menu.
5. Select the installation media.
6. At the VMware Installer screen, press Enter.
7. At the EULA screen, to Accept and Continue, press F11.
8. Under Storage Devices, select the appropriate virtual disk, and press Enter.
9. Select US as the keyboard layout, and press Enter.
10. Enter the root password twice, and press Enter.
11. To start the installation, press F11.
12. After the server reboots, press F2, and enter root credentials.
13. Select Configure Management Network, and press Enter.
14. Select the appropriate network adapter, and click OK.
15. Select IPv4 settings, and enter the desired IP address, subnet mask, and gateway for the server.
16. Select OK, and restart the management network.

## Installing VMware ESXi 7.0 on the Dell EMC PowerEdge MX840c

### Changing the system profile to performance

1. Boot the server.
2. At the POST menu, for System Setup, select F2.
3. Select System BIOS.
4. Select System Profile Settings.
5. Click the System Profile dropdown menu, and select Performance.
6. Click Back.
7. Click Finish.
8. Click Finish again, and reboot the server.

### Installing VMware ESXi

1. Attach the installation media.
2. Boot the server.
3. At the POST menu, select F11 for Boot Manager.
4. Select One-shot UEFI Boot Menu.
5. Select the installation media.
6. At the VMware Installer screen, press Enter.
7. At the EULA screen, to Accept and Continue, press F11.
8. Under Storage Devices, select the appropriate virtual disk, and press Enter.
9. Select US as the keyboard layout, and press Enter.
10. Enter the root password twice, and press Enter.
11. Press F11 to start the installation.
12. After the server reboots, press F2, and enter root credentials.

13. Select Configure Management Network, and press Enter.
14. Select the appropriate network adapter, and click OK.
15. Select IPv4 settings and enter the desired IP address, subnet mask, and gateway for the server.
16. Select OK, and restart the management network.

## Deploying VMware vCenter 7.0

1. On a Windows machine or VM, locate the VMware-VCSA installer image.
2. Mount the image, navigate to the vcsa-ui-installer folder, and double-click win32.
3. Double-click installer.exe.
4. Click Install.
5. Click Next.
6. Accept the terms of the license agreement, and click Next.
7. Leave the default "vCenter Server with an Embedded Platform Services Controller" selected, and click Next.
8. Enter the FQDN or IP address of the host onto which the vCenter Server Appliance will be deployed.
9. Provide the servers credentials, and click Next.
10. At the Configure Network Settings page, configure the network settings for your environment, and click Next.
11. Review your settings, and click Finish.
12. When the deployment completes, click Next.
13. At the Introduction page, click Next.
14. At the Appliance configuration page, select the time synchronization mode and SSH access settings, and click Next. We used a local NTP server and enabled SSH.
15. Select Create a new SSO domain.
16. Provide a password, and confirm it.
17. Provide an SSO Domain name and SSO Site name, and click Next.
18. At the CEIP page, click Next.
19. At the Ready to complete page, click Finish.
20. When the installation completes, click Close.
21. Using the VMware vSphere web client, log into the vCenter server using the credentials previously provided.

## Creating a datacenter in VMware vCenter and adding hosts

### Creating the datacenter
1. Log into vCenter, and navigate to Hosts and Clusters.
2. Select the primary site management vCenter.
3. Right-click the vCenter object, and select New Datacenter…
4. Enter a name for the new datacenter, and click OK.
5. Right-click the new datacenter, and click New Cluster…
6. Enter SUT as the name for the new cluster.
7. Click OK.
8. To create an infrastructure cluster, repeat steps 1 through 7.

### Adding the hosts
1. Right-click the cluster you created, and click Add Host.
2. Enter the FQDN or IP address of the first host, and click Next.
3. Enter the root credentials for the server, and click Next.
4. To accept the server's certificate, click Yes.
5. Review the server details, and click Next.
6. Assign the desired license, and click Next.
7. Disable Lockdown mode, and click Next.
8. Click Finish.
9. Repeat steps 1 through 8 for the remaining SUTs and the client host.

## Creating and configuring a baseline Microsoft SQL Server 2019 VM

For the OLAP and OLTP workloads, we tested Microsoft Windows Server 2019 Enterprise with Microsoft SQL Server 2019 Enterprise databases. We created a base VM with Windows Server 2019, then altered the settings to the necessary vCPUs, memory, and drive sizes before installing Microsoft SQL Server and cloning out the VMs for each workload. This section has the steps to create the base VM, install and configure Windows Server 2019, and install and configure Microsoft SQL Server 2019. See each workload section for the specific VM configurations and SQL Server adjustments.

### Creating the VM

1. Launch the VMware vCenter HTML5 client.
2. Right-click the infrastructure host, and choose New Virtual Machine.
3. Choose Create a new virtual machine, and click Next.
4. Name the virtual machine, and click Next.
5. Choose the correct host, and click Next.
6. Choose the correct datastore, and click Next.
7. Choose ESXi 7.0, and click Next.
8. For the Guest OS Family, choose Windows. For Guest OS Version, choose Microsoft Windows Server 2019 (64-bit). Click Next.
9. Set the vCPU count to 10, memory to 60GB, New Hard Disk capacity to 50GB, choose the proper network from the dropdown menu, and attach the CD drive.
10. Add three more new hard sisks. The size of each drive will be modified based on the workload specifics: for OLTP set the database volume to 100GB, the log volume to 30GB, and the backup volume to 50GB. For OLAP, set the database volume to 40GB, the log volume to 10GB, and the backup volume to 15GB.
11. Double-check your settings on the summary page, and click Finish.

### Installing and configuring Windows Server 2019 Enterprise

1. In the VMware vCenter HTML5 client, click the VM you created, and click Launch Remote Console.
2. Attach the Windows Server 2019 Enterprise ISO to the VM, and turn the VM on.
3. When prompted to boot from DVD, press any key.
4. When the installation screen appears, leave language, time/currency format, and input method as default, and click Next.
5. Click Install now.
6. When prompted, enter the product key.
7. Select Windows Server 2019 Datacenter Edition (Server with a GUI), and click Next.
8. Check I accept the license terms, and click Next.
9. Click Custom: Install Windows only (advanced).
10. Select Drive 0 Unallocated Space, and click Next. This will start the installation automatically, and afterwards Windows will restart automatically.
11. When the Settings page appears, fill in the Password and Reenter Password fields with the password of your choice.
12. Log in with the password you set.
13. In the VMware Remote Console, attach VMware tools to the VM.
14. In Windows Server, the VMware tools should show up in the CD drive. Double-click to start the install.
15. Choose Typical as the install type, and reboot the VM when the install is finished.
16. Log back into Windows Server. In Server Manager, set the time zone, enable RDP if desired, and disable the firewall.
17. Run Windows Updates until you have no new updates to install.
18. Go to Disk Manager, and make sure the additional drives are online, formatted, and presented to the OS.

### Installing Microsoft SQL Server 2019 Enterprise

1. Mount the ISO to the VM.
2. Double-click the Setup application.
3. Click Installation→New SQL Server Standalone installation or add features to an existing installation.
4. Enter the product key, and click Next.
5. Check the I accept the license terms and Privacy Statement box, and click Next.
6. Check the Use Microsoft Update to check for updates (recommended) box, and click Next.
7. On the Install Rules page, click Next.
8. Check the boxes for the following features, and click Next:

    a. Database Engine Services
    b. Full-Test and Semantic Extractions for Search
    c. Client Tools Connectivity
    d. Client Tools Backwards Compatibility

9. Leave the Default instance, and click Next.
10. Leave the default Service Accounts, and click Next.
11. On the Server Configuration tab, choose Mixed Mode, and enter and confirm a Password for the SQL Server system administrator (sa) account.
12. To Specify the SQL Server administrators, click Add Current User.
13. On the Data Directories tab, change the Data root directory to the database volume.
14. Choose the log volume for the User database log directory.
15. If you plan to have a locally stored backup, change the Backup directory to point to that drive.
16. Click Next.
17. Once you've passed the rule check, click Next.
18. Click Install.
19. When the installation has finished, go back to the SQL Server Installation Center, and click Install SQL Server Management Tools.
20. Download the SSMS file, and install with defaults.
21. Reboot the server when prompted.

## Enabling Lock Pages in Memory (OLAP VMs only)
1. Click Start, and type `Local Security Policy`. Open the program when it pops up in the search.
2. Expand Local Policies, and click User Rights Assignment.
3. In the right-hand pane, scroll down and double-click Lock pages in memory.
4. Click Add User or Group, type `NT Service\MSSQLSERVER`, and click OK.
5. To close the Properties window, click OK.
6. Close the Local Security Policy window.

# Conducting OLTP database testing with DVD Store 2.1

We ran the OLTP DVD Store 2 (DS2) workload using the ds2sqlserver driver. We created a 40-scale DVD Store 2 database, then put a copy on each VM. We created a total of four VMs across the data center. The VMs under test had the following hardware configuration: 10 vCPUs, 60GB RAM, 50GB OS drive, 100GB database drive, 30GB log drive, and 50GB backup drive. Once we configured and created the database on one VM, we cloned out the additional three. We also created four barebones client VMs running Windows Server 2019, one for each SQL VM, which drove the test using the previously mentioned driver.

We generated the data using the Install.pl script included with DVD Store version 2.1, providing the parameters for our 40GB database size and the database platform we used. We ran the Install.pl script on a utility system running Linux to generate the database schema. After processing the data generation, we transferred the data files and schema creation files to a Windows-based system running SQL Server 2017. We built the 40GB database in SQL Server, then performed a full backup, storing the backup file remotely for quick access. We used that backup file to restore the database when necessary.

The only modification we made to the schema creation scripts were the specified file sizes for our database. We explicitly set the file sizes higher than necessary to ensure that no file-growth activity would affect the outputs of the test. Other than this file size modification, we created and loaded the database in accordance to the DVD Store documentation. Specifically, we followed these steps:

## Creating the DS2 database
1. Generate the data, and create the database and file structure using database creation scripts in the DS2 download. Make size modifications specific to 40GB database, and make the appropriate changes to drive letters.
2. Transfer the files from Linux data generation system to a Windows system running SQL Server.
3. Create database tables, stored procedures, and objects using the provided DVD Store scripts.
4. Set the database recovery model to bulk-logged to prevent excess logging.
5. Load the data we generated into the database. For data loading, use the import wizard in SQL Server Management Studio. Where necessary, retain options from the original scripts, such as Enable Identity Insert.
6. Create indexes, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. Update statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. On the SQL Server instance, create a ds2user SQL Server login.
9. Set the database recovery model back to full.
10. Create the necessary full text index using SQL Server Management Studio.
11. Create a database user, and map this user to the SQL Server login.
12. Perform a full backup of the database. This backup allows you to restore the database to a pristine state.

## Cloning additional SQL Server VMs

Once you have generated the database, created the ds2user login, and stored the backup on the primary SQL Server VM, you can clone the rest of your VMs from the primary. For our testing, we created four SQL Server VMs:

1. From a web browser, log into vCenter.
2. Right-click the primary SQL Server VM, and select Clone→Clone to Virtual Machine.
3. Select a name for the VM and a datastore location to store it on, and click Next.
4. Select the compute resource which the VM will reside on, and click Next.
5. Set Select virtual disk format to Same format as source.
6. Set VM Storage Policy to Keep existing VM storage policies.
7. Select the appropriate datastore, and click Next.
8. Deselect all clone options, and click Next.
9. Review your settings, and click Next.
10. Repeat steps 2 through 9 until you have four SQL VMs.

## Running the DVD Store 2 tests

We created a series of batch files, SQL Server scripts, and shell scripts to automate the complete test cycle. In addition to the SQL Server VMs, we created barebones client VMs running Windows Server 2019, which drove the DS2 workload on the systems under test. We created one client per system under test. DS2 outputs an orders-per-minute metric, which is a running average calculated throughout the test. In this report, we report the last OPM that each target reported.

Each complete test cycle consisted of the following general steps:

1. Clean up prior outputs from the target system.
2. Drop the database from the target.
3. Restore the database on the target.
4. Shut down the target.
5. Reboot the target VMs.
6. Wait for a ping response from the systems under test and the client systems.
7. Let the systems under test idle for 10 minutes.
8. Start the DVD store driver on the four clients.
9. We used the following DVD Store 2 parameters for testing:

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 --run_time=30 --n_threads=16 --db_
size=40GB --think_time=0.01 --detailed_view=Y --warmup_time=30 --report_rate=1 pct_newcustomers=20
--csv_output=<drivepath>
```

## Setting up the OLAP workload test

To create the 30-scale database, we made a new database in SQL Server Management Studio. In addition to the default Primary SQL Server filegroup, we created a secondary data filegroup in the new database. We created four files in this filegroup and sized them all at approximately 7.5 GB. We resized the single transaction log file to 20.9 GB as well. We created the specific tables required for a TPC-H-like database according to TPC and HammerDB documentation: Part, Supplier, PartSupp, Customer, Nation, Lineitem, Region, and Orders. We then created a partition function using a date data type, with weekly values as follows:

```
CREATE PARTITION FUNCTION [DATEPARTITION](date) AS RANGE LEFT FOR VALUES (N'1992-01-07T00:00:00.000',
N'1992-01-14T00:00:00.000' [, ……n])
```

We then applied this partition function, using a partition scheme, to the secondary filegroup containing the four data files. The HammerDB tool and dbgen defined the remainder of the schema definition. We created the test data using the dbgen tool and loaded the data into the prepared database. We used clustered columnstore indexing where possible, and applied the partition scheme specifically to the ShipDate and OrderDate columns, in the LineItem and Orders table, respectively. For our specific schema DDL scripts, contact us at info@principledtechnologies.com.

## Creating the database and tables

1. Open SQL Server Management Studio.
2. Right-click Databases, and choose New Database…
3. Name the database.
4. Click the Filegroups tab, and click Add Filegroup.
5. Name the new filegroup, and set it to Default.
6. Back in the general tab, to create four additional data files, click Add.
7. Name each file, and set the initial size for each new file to 7.5 GB. Make sure all new files are on the new Filegroup you created.
8. If necessary, change all data and log file paths to point to the data and log drives on the system.
9. On the options tab, set the Recovery Model to simple.
10. To start the build, click OK. This may take a while.

## Generating the data and loading it into the database

In this step, we used a tool called dbgen to create the flat files for the 30-scale database that we then loaded into the empty database. In order to ensure enough room to simultaneously hold the flat files and load the database, we conducted these steps on a separate infrastructure server with SQL Server installed. We then created a backup file and used it to restore the finished database to the server under test.

1. Download the dbgen tool from GitHub: https://github.com/electrum/tpch-dbgen.
2. Unzip the file to a volume with roughly 40GB capacity.
3. Download and install the Community edition of VisualStudio.
4. Navigate to the dbgen folder, and build the tpch.vcproj in Visual Studio.
5. Navigate to the debug folder in the dbgen folder, and click shift+right-click in the folder. Click Open PowerShell Window.
6. In PowerShell, test to make sure dbgen.exe works by typing `./dbgen.exe -h`. If the help menu pops up, you are good to go. If you get an error, try copying the dbgen.exe file to the dbgen folder, opening PowerShell there, and running the command again.
7. Once you have dbgen.exe working properly, create the 30-scale files with the following command:

   ```
   ./dbgen.exe -s 30
   ```

8. Once the files have finished building, you can load them into the database.
9. Open Microsoft SQL Management Studio, and run bulk insert commands to load the files into the tables.

## Creating the database indexes and finalizing the database

When the data finished loading, we created clustered columnstore indexes to improve database performance:

1. Open Microsoft SQL Management Studio, and run the index creation query.
2. Once the index creation has finished, right-click the TPC-H database, and click Properties.
3. On the Options tab, set the Recovery model to Full, and click OK.
4. Right-click the TPC-H database, and navigate to Tasks→Shrink→Database.
5. Check the box for Reorganize files before releasing unused space, and set the Maximum free space to 0%.
6. Click OK.
7. Once the shrink task is done, the database is ready for backup.

## Backing up the database

While we didn't perform any write tasks in the workload test, we made sure to always have a backup of a clean database that we could restore from to make sure we had a fresh database to test on. We stored this backup file on a separate infrastructure server. Follow these steps to create a database backup file:

1. Open Microsoft SQL Management Studio, and right-click the TPC-H database.
2. Navigate to tasks→Backup.
3. To set the name of your backup file and the location to store the file, on the General tab, click Add…
4. On the Backup Options tab, in the Set backup compression dropdown menu, choose Compress backup.
5. Click OK.

## Testing the OLAP workload using the HammerDB benchmark suite

We ran an OLAP workload using the HammerDB benchmark. As instructed in the documentation, we ran the HammerDB test directly on the server under test, as the overhead on the hardware is negligible. Thus, no clients were needed for this test. We configured HammerDB to target all the SQL VMs under test. We build a schema using the ODBC Driver 17 for SQL, set the scale to to 30, and MAXDOP to 8. We used four users for all of our tests. See https://www.hammerdb.com/document.html for more details about running analytics workloads.

For the OLAP database tests, we used dbgen to create a 30-scale TPC-H-like database, then put a copy on each VM. In this paper, we created a total of four VMs across the datacenter. The VMs under test had the following hardware configuration: 10 vCPUs, 60GB RAM, 50GB OS drive, 40GB database drive, 10GB log drive, and 15GB backup drive. Once we configured and created the database on one VM, we cloned out the additional three.

### Configuring SQL Server for running the OLAP workload on the SQL Server VM

1. Open SQL Server Management Studio.
2. Select SQL Server Authentication, type `sa` and your password as your login and password respectively, and click Connect.
3. Set the maximum degree of parallelism (MAXDOP) to 8 in accordance with TPC-H best practices with the following SQL query:

   ```
   exec sp_configure 'max degree of parallelism', '8'
   ```

### Restoring the database on the VM

1. Copy the backup file to the gold VM.
2. Open SQL Server Management Studio.
3. Select SQL Server Authentication, type `sa` and your password as your login and password respectively, and click Connect.
4. Right-click Databases, and select Restore Database…
5. Select Device, and click …
6. Click Add, and select the backup file. Click OK, and click OK.
7. Click Files in the left-hand pane, and ensure that the files are pointing to the correct data and log directories.
8. After reviewing, click OK to restore the database.

### Installing HammerDB on the VM

1. Download HammerDB: https://hammerdb.com/download.html.
2. Double-click the .exe file, choose English, and click OK.
3. Click Yes.
4. Click Next.
5. Chose a destination location, and click Next.
6. Click Next.
7. Click Finish.

### Cloning the SQL Server VMs

Once you have installed SQL Server and Windows, configured all the settings, and created the db, you can clone your VMs.

1. Open the vCenter console, and ensure that the VM is powered off.
2. Right-click the SQL VM→Clone→Clone to Virtual Machine…
3. Name the VM, select your vSAN Datacenter, and click Next.
4. Choose the host for your VM, and click Next.
5. Choose the datastore, and select vSAN Default Storage Policy from the VM Storage Policy drop-down menu. Click Next.
6. Click Next.
7. Click Finish.
8. Repeat steps 1 through 7 until you have four SQL VMs total.

## Conducting VDI testing with VMware View Planner 4.5

We ran the VMware View Planner 4.5 benchmark standard workload to determine the maximum number of virtual desktop users a platform could support. We installed and set up a VMware Horizon 7 environment and supporting infrastructure. We deployed 65 virtual desktops on the HPE DL380 Gen9 and 70 virtual desktops on the Dell EMC MX840c. We then ran the VMware View Planner 4.5 benchmark against each.

### Installing the Active Directory Server DC1 VM

We installed and configured a VM to host Active directory, DNS, DHCP, NTP and was a certificate authority. In addition, we created a OU for virtual desktops and applied group policy to ensure testing executed correctly. All these functions are necessary to run our testing.

1.  Log into the vSphere client as `administrator@vsphere.local`
2.  On the infrastructure server, deploy a Windows Server 2019 VM from the template using the appropriate specs from the table on page 6, named DC1, and log in as an administrator.
3.  Launch Server Manager.
4.  Click Manage→Add Roles and Features.
5.  At the Before you begin screen, click Next.
6.  At the Select installation type screen, leave Role-based or feature-based installation selected, and click Next.
7.  At the Server Selection Screen, select the server from the pool, and click Next.
8.  At the Select Server Roles screen, select Active Directory Domain Services.
9.  When prompted, click Add Features, and click Next.
10. At the Select Features screen, click Next.
11. At the Active Directory Domain Services screen, click Next.
12. At the Confirm installation selections screen, check Restart the destination server automatically if required, and click Install.

### Configuring Active Directory and DNS services on DC1

1.  After the installation completes, a screen should pop up with configuration options. If a screen does not appear, click the Tasks flag in the upper-right section of Server Manager.
2.  Click Promote this server to a Domain Controller.
3.  At the Deployment Configuration screen, select Add a new forest.
4.  In the Root domain name field, type `test.local`, and click Next.
5.  At the Domain Controller Options screen, leave the default values, and enter a password twice.
6.  Click Next four times to accept default settings for DNS, NetBIOS, and directory paths.
7.  At the Review Options screen, click Next.
8.  At the Prerequisites Check dialog, allow the check to complete.
9.  If there are no relevant errors, check Restart the destination server automatically if required, and click Install.
10. When the server restarts, log in using `test\Administrator` and the password you chose in step 5.

### Configuring the Windows time service on DC1

1.  To ensure reliable time, we pointed our Active Directory server to a physical NTP server.
2.  Open a command prompt.
3.  Type the following:

```
W32tm /config /syncfromflags:manual /manualpeerlist:"<ip address of a NTP server>"
W32tm /config /reliable:yes
W32tm /config /update
W32tm /resync
Net stop w32time
Net start w32time
```

### Setting up DHCP services on DC1

1.  Open Server Manager.
2.  Select Manage, and click Add Roles and Features.
3.  Click Next twice.
4.  Select DHCP Server, and click Next.
5.  At the Introduction to DHCP Server screen, click Next.
6.  At the Specify IPv4 DNS Settings screen, type `test.local` for the parent domain.
7.  Type the preferred DNS server IPv4 address, and click Next.
8.  At the Specify IPv4 WINS Server Settings screen, select WINS is not required for applications on the network, and click Next.
9.  At the Add or Edit DHCP Scopes screen, click Add.

10. At the Add Scope screen, enter the Name DHCP Scope name.
11. Set the following values, and click OK.
    a. Start IP address = 172.16.10.1
    b. End IP address = 172.16.100.254
    c. Subnet mask = 255.255.0.0
12. Check the Activate This Scope box.
13. At the Add or Edit DHCP Scopes screen, click Next.
14. Click the Enable DHCP v6 Stateless Mode radio button, and click Next.
15. Leave the default IPv6 DNS Settings, and click Next.
16. At the Authorize DHCP server dialog box, select Use current credentials.
17. At the Confirm Installation Selections screen, click Next. If the installation is set up correctly, a screen displays saying that DHCP server install succeeded.
18. Click Close.

## Installing and configuring SSL Certificate in Microsoft Active Directory on the DC1 VM

1. Before you can configure View Planner, you need to setup the Active Directory server as a certificate authority. To do this, follow the guide at https://social.technet.microsoft.com/wiki/contents/articles/2980.ldap-over-ssl-ldaps-certificate.aspx.
2. Log onto DC1 as `administrator@test.local`
3. Open Server Manager.
4. Select Manage, and click add Roles and Features.
5. When the Add roles and Features Wizard begins, click Next.
6. Select Role-based or feature-based installation, and click Next.
7. Select DC1.test.local, and click Next.
8. At the server roles menu, select Active Directory Certificate Services, and click Next.
9. Leave server features as default, and click Next.
10. Select Certificate Authority and Certificate Authority web interface, click Add Features to add the IIS web server, and click Next.
11. Click Install, and close.
12. In Server Manager, click the yellow triangle titled Post-deployment configuration.
13. On the destination server, click Configure Active Directory Certificate Services.
14. Leave credentials as test\administrator, and click Next.
15. Select Certificate Authority, and Select Certificate Authority web Enrollment. Click Next.
16. Select Enterprise CA, and click Next.
17. Select Root CA, and click Next.
18. Select Create a new private key, and click Next.
19. Select SHA256 with a 2048 Key length, and click Next.
20. Leave the name fields and defaults, and click Next.
21. Change expiration to 10 years, and click Next.
22. Leave Certificate database locations as default.
23. Click Next.
24. Click Configure.
25. Open a command prompt, and type `ldp`
26. Click Connection, and connect.
27. For server, type `dc1.test.local`
28. Change the port to `636`
29. Check SSL, and click OK.

## Configuring secure LDAP on DC1.test.local on the DC1 VM

1. Open administrative tools, and click Certification Authority.
2. Click test-DC1-CA➔Certificate Templates.
3. Right-click Manage.
4. Right-click Kerberos Authentication, and select Duplicate Template.
5. Click Request Handling.
6. Check the box for Allow private key to be exported, and click OK.
7. Right-click the new template, and rename it `LDAPoverSSL`
8. Return to the Certificates console. In the right pane, right-click New➔Certificate Template to issue.
9. Select LDAPoverSSL, and click OK.

## Configuring AD GPOs for target VMs on the DC1 VM

To run the tests correctly, we created an OU named target in the test.local domain. We then created assigned group policies objects for the following:

- Autologin as a domain admin user
- Disable windows updates
- Disable screen lock
- Disable firewall
- Accept defaults Windows media player
- Suppress Office first time user messages

You can change these settings individually on the gold Windows 10 VM, but we found it easier to make ad hoc changes by using GPOs. You will need the Office 2016 Administrative Template files (ADMX/ADML) and the Office Customization Tool for Microsoft Active Directory to configure these settings. The software is available at Microsoft.com.

## Setting up VMware Horizon 7 Composer on the composer VM

We installed a Microsoft Windows 2019 VM and installed Microsoft SQL Server Express 2019 and Microsoft SQL Server Management Studio.

1. On the infrastructure server, deploy a Windows Server 2019 VM from the template using the appropriate specs from the table on page 6. Set the name as `composer`, and log in as an administrator.
2. Download and open SQL2019-SSEl-Expr.exe.
3. Select Basic install.
4. Accept the License agreement.
5. Select the appropriate install directory.
6. SQL Server 2019 Express will download the install files and install itself. Click install SSMS to launch a web browser to the SQL Server Management Studio page.
7. Click download SSSMS.
8. Run SSMS-Setup-ENU.exe.
9. Click Install.
10. Click Restart, and log back in after the reboot.
11. Open SQL Server 2019 configuration manager.
12. Click on SQL Server services→SQL Server browser, right-click, and click Properties.
13. In the service tab, change the start mode to automatic, and click OK.
14. Right-click SQL Server Browser, click Start, and close SQL Server Configuration Manager.

## Creating a SQL Server Express Database for composer and an ODBC connection on the composer VM

1. Open SQL Server Management Studio.
2. Select Windows authentication, and click Login.
3. In the security tab login, right-click, and create a user named `composer`. Click server roles, select sysadmin, and click OK.
4. Right-click the databases folder, and click new database.
5. Name the database composer, and select the composer user as owner.
6. Click OK, and close SQL Server Management Studio.
7. Select Run, and type `odbcad64.exe`
8. Press Enter.
9. Click the system DSN tab.
10. Click Add.
11. Click SQL Server Native Client 11, and click Finish.
12. In the Create a New Data Source to SQL Server text box, type the connection name `composer`
13. For Server, select composer\sqlexpress, and click Next.
14. Change authentication to With SQL Server authentication using the composer login and password, and click Next.
15. Type `composer` for the Login ID and the appropriate password.
16. Click Next.
17. Click Finish.
18. Click Test Data Source…
19. To create the Composer ODBC connection, click OK.

## Installing VMware Horizon 7 Composer on the composer VM

1. Open the View 7 media folder, and run VMware-viewcomposer-7.12.0-15747753.
2. At the Welcome screen, click Next.
3. Accept the VMware End User License Agreement, and click Next.
4. Leave the Destination folder as default, and click Next.
5. In the Database information box, type composer as the source name, and composer as the user name. Enter the password, and click Next.
6. Leave the default SOAP port, and click Next.
7. Click Install, and click Finish.
8. Restart the server.

## Installing the VMWare Horizon 7 Connection Server on the view VM

1. On the infrastructure server, deploy a Windows Server 2019 VM from the template using the appropriate specs from the table on page 6. Name this VM `view`, and log in as an administrator.
2. Log in as an administrator.
3. Browse to VMware View installation media, and click VMware-viewconnectionserver-x86_64-7.12.0-15770369.exe.
4. Click Run.
5. At the Welcome screen, click Next.
6. Agree to the End User License Agreement, and click Next.
7. Keep the default installation directory, and click Next.
8. Select View Standard Server, and click Next.
9. At the Data Recovery screen, enter a backup password, and click Next.
10. Allow View Server to configure the Windows firewall automatically, and click Next.
11. Authorize the local administrator to administer View, and click Next.
12. Choose whether to participate in the customer experience improvement program, and click Next.
13. Complete the installation wizard to finish installing View Connection Server.
14. Click Finish.
15. Reboot the server.

## Configuring the VMWare Horizon 7 Connection Server on the view VM

1. Open a Web browser, and navigate to http://<view connection1 FQDN>/admin.
2. Log in as administrator.
3. Under Licensing, click Edit License…
4. Enter a valid license serial number, and click OK.
5. Open View Configuration→Servers.
6. In the vCenter Servers tab, click Add…
7. Enter vCenter server credentials, and edit the following settings:

    • Max concurrent vCenter provisioning operations: `20`
    • Max concurrent power operations: `50`
    • Max concurrent View Composer maintenance operations: `20`
    • Max concurrent View Composer provisioning operations: `20`
    • Max concurrent Instant Clone Engine provisioning operations: `20`

8. Click Next.
9. At the View Composer screen, select View Composer co-installed with vCenter Server, and click Next.
10. At the View Composer domains screen, click Add…
11. Enter the full domain name and user credentials.
12. Do not use Reclaim VM disk space or Enable View Storage Accelerator.
13. At the ready to complete screen, click Finish.

## Deploying the VMware View Planner 4.5 test harness

1. Download the viewplanner-harness-4.5.0.0-16495687_OVF10.ova file from VMWare.
2. From the vCenter client, select the infrastructure host, and right-click Deploy OVF Template…
3. In the deploy OVF Template wizard, select local file, and click Browse…
4. Select viewplanner-harness-4.5.0.0-16495687_OVF10.ova, click Open, and click Next.
5. Select a DataCenter, and click Next.
6. Select the Infra host, and click Next.

7. Review details, and click Next.
8. Accept the license agreements, and click Next.
9. Select the local DAS datastore, and click Next.
10. Select the priv-net network, and click Next.
11. Click Next, and click Finish to deploy the harness.
12. Power on the new VM, and note the IP address.

## Configuring the VMware View Planner 4.5 test harness

1. Open a browser, and nagivate to http://<ip address of the harness>:3307/vp-ui/.
2. Log in as follows:
   - Username: `vmware`
   - Password: `viewplanner`
3. Click Log in.
4. Click servers.
5. Select infrastructure, and click Add New.
6. Enter the following information:
   - Name: `vCenter`
   - IP: `<IP of vCenter>`
   - Type: `vcenter`
   - DataCenter: `DataCenter`
   - Domain: `vsphere.local`
   - Username: `administrator`
   - Password: `<SSO password for vCenter >`
7. Click Save.
8. Click Identify server.
9. Click Add new.
10. Enter the following information:
    - Name: `test.local`
    - IP: `<IP of DC1>`
    - Type: `microsoft_ad`
    - Username: `administrator`
    - Password: `<password for administrator@test.local>`
11. Click Save.

## Deploying the Windows 10 Enterprise (x64) gold image VM

We created a Microsoft Windows 10 Enterprise VM, installed Microsoft Office 2016 Professional plus, Google Chrome, and Adobe Reader DC, and prepared the VM to be cloned.

1. Log into vCenter via the VMware Web client.
2. Right-click the Virtual Machines tab, and select New Virtual Machine.
3. Select Create a new virtual machine.
4. Choose Custom, and click Next.
5. Assign the name View-gold, and click Next.
6. Select the name of the server under test, and click Next.
7. Select the local DAS.
8. Choose compatible with ESXi 7.0, and click Next.
9. Choose Windows, choose Microsoft Windows 10 (64-bit), and click Next.
10. For CPUs, select 2 CPUs, 4 GB RAM, 50 GB Disk, click Next.
11. Click Finish.
12. Click the Hardware tab.
13. Click CD/DVD Drive.
14. Select Connect the VM virtual CD-ROM to the Microsoft Windows 10 x64 installation disk.
15. Click OK.
16. Power on the Microsoft Windows 10 VM.

## Installing Windows 10 Enterprise (x64) on the gold image VM

1.  When the installation prompts you, press any key to begin setup.
2.  Enter your language preferences, and click Next.
3.  Click Install.
4.  Accept the license terms, and click Next.
5.  Select Custom, and select the drive that will contain the OS.
6.  Click Install.
7.  Type `user` for the username, and click Next.
8.  Enter no password, and click Next.
9.  At the system protection screen, select Use recommended settings, and click Next.
10. Enter your time zone, and click Next.
11. Select the Work Network setting, and click Next.
12. Install VMware Tools, and select Complete Installation. For more information, visit http://kb.vmware.com/selfservice/microsites/search. do?language=en_US&cmd=displayKC&externalId=340.
13. Reboot the server.
14. Connect the machine to the internet, and install all available Windows updates. Restart as necessary.
15. Join the domain, and restart the VM.
16. Install Microsoft Office Professional Plus 2016.

## Installing the VMware Horizon 7 agent on the gold Image VM

1.  Navigate to the VMware Horizon View 7 media, and run the VMware-viewagent file.
2.  Click Run.
3.  At the Welcome screen, click Next.
4.  Accept the VMware end user license agreement, and click Next.
5.  Select defaults, and click Next.
6.  Click Install.

## Installing Google Chrome version 78.0.3904.70 on the gold Image VM

Please note that View Planner 4.3 requires specific versions of Chrome. Version 78.0.3904.70 was specified in the View Planner release notes.

1.  Download the offline 78.0.3904.70_chrome_installer.exe.
2.  Double-click the 78.0.3904.70_chrome_installer.exe file, and click Run.
3.  Close Chrome.

## Installing Adobe Reader DC version 2020.012.20043

1.  Download and install Adobe Reader from http://acrobat.adobe.com. Do not install any McAfee add-ons.

## Installing VMware View Planner agent

1.  Double-click viewplanner-agent-4.5.0.0-16495687.exe.
2.  Click Next.
3.  Accept the End User License Agreement.
4.  Click Next.
5.  Enter the IP address of the view planner harness, and click Next.
6.  Wait for the installer to complete, and click Finish.
7.  Reboot the VM.

## Configuring Regedit for QuickPrep

To clone the clone the gold image with quick prep, we disabled activation by editing the registry:

1.  Click Start➔Run, and type `regedit`
2.  Browse to HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\vmware-viewcomposer-ga.
3.  Right-click Skip License Activation, and click Modify…
4.  Change the value from 0 to 1.

## Optimizing the Windows 10 gold image VM

1. Download the Windows optimization tool from VMware.
2. Extract the zip file, and run VMwareOSOptimizationTool_b1170_16669532.exe.
3. Click Template, and select VMWare\Windows 10.
4. Click Analyze.
5. Select all suggestions, and click Optimize.
6. When te settings finish applying, reboot the VM.

## Finalizing the Windows 10 gold image VM

1. In vCenter, shut down the Windows 10 gold image, and copy it to the other two servers under test.
2. For all three gold images, right-click, and select Take a snapshot.
3. Name each snapshot, and click OK.

## Deploying virtual desktops using VMWare Horizon 7 Connection Server

1. Open View Administrator.
2. Log in as an administrator.
3. Under Inventory, click Pools, and click Add…
4. Select Automatic Pool, and click Next.
5. Select Dedicated.
6. Select Enable automatic assignment, and click Next.
7. Select View Composer linked clones.
8. Select the vCenter and composer, and click Next.
9. Type `pool` for the pool ID and display name, and click Next.
10. Leave the pool settings as defaults, and click Next.
11. Under Naming Pattern, enter an appropriate name pattern for the pool. Note this for the view planner testing settings in the next section.
12. Under Pool Sizing, type the maximum number of desktops and the number of spare (power on) desktops.
13. Select Provision all desktops up-front, and click Next.
14. Select the defaults under View Composer Disks, and click Next.
15. Under Storage Optimization, click Next.
16. Under vCenter Settings, select the following depending on where you are deploying virtual machines:

    - Parent VM
    - Snapshot
    - VM folder location
    - Host or cluster
    - Resource pool
    - DataStore

17. Under Guest customization, select the following:

    - Domain: test.local
    - AD container: OU=targets
    - Use Quick Prep

18. Click Next.
19. Click Finish. (Note: Because this testing is local, you do not need to specify any entitlements.)

## Creating the VMware View Planner benchmark run profiles

Although View Planner has a user interface, we ran our testing via the command line using the following steps:

1. Open a putty session to the View planner harness.
2. Log in as follows:

    - Username: `vmware`
    - Password: `viewplanner`

Run the following commands for the servers under test using an appropriate profile name and prefix name variable. For the HPE ProLiant DL380 Gen9, we ran a test of 65 virtual desktops. For the Dell EMC PowerEdge MX840c, we ran 75.

```
runProfile -a <profilename> --runMode local --VMcount <number of vms> --iterCount 5 --thinkTime 15
--description local_high_mem_thinktime_15

workGroup -a <profilename> --runProfile <name>_15thinktime --workProfile Standard_Profile  --percent 100


workGroup --addDesk <profilename> --runProfile <profilename> --prefix <prefixname> --infraServer <ip of
vCenter>
```

## Running the VMware View Planner benchmark

1. Open a browser to http:/<viewplanner IP address>/vp-ui and log in as vmware.
2. Click New run, select the approprate profile and run name, and click Start run.

## Running the three workloads simultaneously on the MX840c

Since the timing parameters of the three workloads each differed from each other, we attempted to stagger the tests in such a way that the three workloads would simultaneously be in their run phase (rather than warmup). The VDI workload took about 80 minutes to complete, DS2 took 60 minutes, and TPC-H took between 3 and 5 minutes to complete (note that these conditions stemmed from testing on the HPE ProLiant DL380 Gen9, upon which each of these three workloads independently saturated the CPU). Thus, we started the VDI workload first, the DS2 workload second, and the TPC-H workload last, following the DS2 warmup period.

### Running the tests
1. Start the ESXtop collection script.
2. Start the VDI workload according to the instructions above.
3. After 10 minutes, start the DS2 workload according to the instructions above.
4. After the 30-minute DS2 warmup period, begin the TPC-H single-user test according to the instructions above.
5. Once the single-user test has completed, begin the TPC-H multi-user test.
6. Once the workloads have all completed, stop the ESXtop script, and record your data

**Read the report at http://facts.pt/BmiT4kI** ▶

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