NetApp Verified Architecture

VMware End-User Computing with NetApp HCI and NVIDIA GPUs

NVA Design
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Abstract
VMware End User Computing with NetApp® HCI is a prevalidated, best-practice data center architecture for deploying graphics-intensive workloads at an enterprise scale. This document describes the architectural design and best practices for deploying the solution at production scale in a reliable and risk-free manner.
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1 Executive Summary

The right info at the right time becomes more crucial than ever for business success. Smart phones and tablets can retrieve info easily from the internet, but securely retrieving data from workspaces is always challenging. VMware Horizon Virtual Desktops and Hosted Apps along with VMware Workspace One have helped address this issue by providing secure access to virtual desktop environments or to specific applications connected to end devices.

Modern operating systems and other applications like Microsoft Office have now become more graphic intensive, which adds CPU cycles to virtual desktops and applications and reduces user density on host servers. Having a graphics acceleration card on the server offloads graphic processing and rendering work from the CPU, creates a better user experience, and increases user density.

NetApp HCI provides scale-out all-flash storage and guaranteed quality of service (QoS), which makes it easier to run virtual desktops and applications along with other workloads. With the NetApp HCI vCenter Plug-In, administrators can provision datastores, expand clusters, and perform other vital functions directly from vCenter. NetApp HCI makes it the ideal platform for consolidating your workloads.

2 NetApp HCI and VMware End-User Computing Architecture

This combination of technologies from NetApp and VMware allows customers to experience the benefits of the End User Computing ecosystem. This NetApp Verified Architecture (NVA) details the design decisions made to deploy VMware End User Computing on NetApp HCI.

NetApp HCI is a hybrid cloud infrastructure solution capable of transforming and empowering organizations to move faster, drive operational efficiencies, and reduce costs. NetApp HCI is the foundation of the End User Computing strategy, which can run multiple applications with the predictable performance that enterprises and customers demand. NetApp HCI enables the independent scaling of compute and storage resources, making sure that systems are right sized. NetApp HCI along with VMware Horizon can provision desktops for users in minutes along with the required applications, eliminating the complex management of traditional architectures. Integration into the NetApp Data Fabric means that you can easily integrate your infrastructure with the cloud, with the required data services.

NetApp HCI frees you from the limitations of current infrastructure solutions that are complex, cannot consolidate all workloads, force customers to scale in ways that strand resources, and throttle the performance required by next-generation applications. With VMware Horizon and NetApp HCI, customers can quickly deploy virtual desktops and applications on an infrastructure that can be deployed quickly and scaled as needs change. Figure 1 demonstrates that VMware Horizon On-Premises Infrastructure and Cloud Providers running NetApp HCI and VMware Horizon can be managed centrally using the VMware Horizon Cloud Service.
2.1 NetApp HCI

NetApp HCI offers various benefits to consumers seeking a hybrid cloud infrastructure by combining industry best practices and the VMware vSphere hypervisor. NetApp HCI delivers features and capabilities that first-generation HCI vendors could not. NetApp HCI is predictable, flexible, and scalable; provides simple administration and deployment; and is integrated into the NetApp Data Fabric.

**Predictable**

One of the biggest challenges for anyone managing infrastructure is delivering predictable performance, especially in the face of proliferating applications and workloads. Dedicated platforms and massive overprovisioning are not economically viable. However, when multiple applications share infrastructure, one application might interfere with the performance of another. NetApp HCI alleviates this concern with quality of service (QoS) limits available natively with NetApp Element® software. Element enables the granular control of each application and volume, eliminates noisy neighbors, and satisfies all performance SLAs. All applications can be deployed on a shared platform, predictably and with confidence. The multitenancy capabilities of NetApp HCI can help eliminate more than 90% of traditional performance-related problems.

**Flexible and Scalable**

Previous generations of hyper converged infrastructures required fixed resource ratios, limiting deployments to four-node to eight-node configurations. NetApp HCI, however, scales compute and storage resources independently. Independent scaling avoids costly and inefficient overprovisioning, eliminates the 10% to 30% “HCI tax” from controller VM overhead, and simplifies capacity and performance planning.

With NetApp HCI, licensing costs are reduced. NetApp HCI is available in mix-and-match small, medium, and large storage and compute configurations. The architectural design choices offered enable customers to confidently scale on their terms, making HCI viable for core data center applications and platforms.

No data center scales linearly, because business needs change constantly, and each application has different requirements from the infrastructure. NetApp HCI enables independent scaling of compute and storage resources, allowing on-demand scaling, avoiding costly and inefficient overprovisioning, and simplifying capacity and performance planning.
NetApp HCI is architected in building blocks at either the chassis or the node level. Each chassis can hold four nodes that made up of storage nodes, compute nodes, or both. A minimum configuration is two chassis with six nodes, consisting of four storage nodes and two compute nodes. Two additional blank spots can be used for expansion. Compute and storage nodes can be mixed if best practices are followed. Resources can be scaled nondisruptively through a simple GUI-driven process.

**Simple**

A driving imperative within the IT community is to automate all routine tasks, eliminating the risk of user error while freeing up resources to focus on more interesting, higher-value projects. NetApp HCI allows IT departments to become more agile and responsive by simplifying deployment and ongoing management.

The new NetApp Deployment Engine (NDE) eliminates most manual steps needed to deploy infrastructure, such as assigning names, network settings, and IP addresses, and provisioning ESXi hosts and VMware datastores. You can expect the infrastructure to be functional in less than 30 minutes.

The VMware vCenter Plug-in simplifies management in an intuitive way. Additionally, NetApp HCI uses a robust suite of APIs to promote integration into higher-level management, orchestration, backup, and disaster recovery tools.

**NetApp Data Fabric**

Traditional HCI platforms often involved the introduction of a silo of resources into an existing data center. Such platforms have little in common with other infrastructure-consumption choices that consumers might have made already or would like to make in the future. This approach is not efficient in the long term.

In contrast, NetApp HCI integrates into the NetApp Data Fabric for enhanced data portability, visibility, and protection of workloads whether they reside on premises, in near-cloud storage, or in a public cloud. The NetApp Data Fabric removes lock-in and provides you with a new level of choices. It allows the full potential of your data to be unleashed across cloud environments.

**2.2 VMware End User Computing**

VMware Horizon enables IT organizations to provide virtual desktops and hosted applications to their users. As users start using smart phones, tablets, and other portable devices to access information, managing such devices becomes a challenge. VMware Workspace One provides unified management for all endpoints. It also provides single sign-on to hosted apps, desktops, intranet applications and SaaS based applications, as is depicted in Figure 2.
THE VMware Horizon Just-In-Time Management Platform (JMP) technology allows customers to perform ultra-fast desktop or remote desktop session host provisioning with instant clones, real-time application delivery with App Volumes, and contextual policy management with User Environment Manager (UEM).

Horizon Instant Clone, App Volume, and UEM are all part of Horizon 7 Enterprise edition, which also includes other components such as the following:

- vRealize Operations Manager for performance monitoring of desktop and application pools
- vRealize Log Insight for centralized log collection and analysis
- VMware NSX for vSphere for software defined networking; securing desktops with microsegmentation; and edge services like a load balancer, the Dynamic Host Configuration Protocol (DHCP), and so on.
2.3 NetApp HCI and VMware End-User Computing Design Principles

NetApp HCI and VMware End User Computing products provide an integrated system that offers all the benefits of VMware Horizon and the scalability and granularity of NetApp HCI. The underlying NetApp HCI platform allows you to expand or resize a data center according to CPU, memory, storage capacity, and storage IOPS requirements.

NetApp HCI also lets you add and repurpose compute and storage nodes of various capacities to expand or contract any of the compute or storage parameters according to data center’s needs. This scaling is managed through vCenter and the NDE.

The NDE manages hardware configuration and deployment of the HCI environment. This means that compute and HCI storage nodes can be added or deleted easily in any configuration. Compute nodes can easily be added to a VMware cloud configuration by adding them to the vCenter data center and compute clusters. Storage nodes are added to the NetApp HCI cluster and the datastores are provisioned from the vCenter Plug-in. Capacity and throughput are added by adding additional datastores to the desktop pools.

3 Solution Overview

Media content usage has significantly increased recently with users watching training videos, using the latest office applications, or using image editing tools. An increased media streaming workload is a challenge for a virtualization environment because it adds load to the environment and degrades performance. If the environment is not virtualized, it can become difficult for administrators to provide security updates for workstations spread across the enterprise because they can only push updates when mobile devices are connected to the network.

NetApp HCI with a graphics adapter allows users to stream media (even at 4K resolution) with a virtual desktop or in a hosted app environment. With VMware Horizon, customers can securely host their virtual desktop and apps in the data center, which allows users to use any supported device to access their desktop or applications in the enterprise or from remote locations.

As you start designing graphic intensive workloads on virtual desktops, you face a number of questions:

- What guest operating systems can I use?
- How can I provide high availability for the solutions components?
- What versions of DirectX or OpenGL does it support?
- Does the environment support CUDA?
- How many users can I host with each server?
- How do I build a cost-effective solution to meet customer demands?
- What security features are available?
- How do I scale the infrastructure for workload demands?
- How do I manage the infrastructure?

This solution addresses all of these questions.

3.1 Target Audience

The target audience for the solution includes the following groups:

- Field consultants to help with design decisions with the VMware End User Computing environment
- Executives and sales engineers to understand the value of the solution
- Professional services and IT managers to understand and identify the components of the solution
- Partners to learn and assist the customers who face similar challenges
3.2 NetApp HCI Use Cases

In addition to the previously mentioned benefits, NetApp HCI is ideal for the use cases described in this section. For customers performing the following tasks, NetApp HCI is architected to deliver exceptional value:

- Deploying private clouds
- Designing end-user computing environments including hardware accelerated graphics applications
- Considering workload consolidation

Private Cloud

NetApp HCI is an optimal foundation for an enterprise private cloud model, whether you choose OpenStack, VMware, or a solution developed in-house. This is because NetApp HCI uses native NetApp Element® APIs that allow the on-demand provisioning of workloads through storage drivers and management plug-ins.

As an example, NetApp HCI integrates with VMware VVols, enabling VMware administrators to achieve the most granular control over storage performance on a per-VM basis. With this functionality, you can set minimum, maximum, and burst IOPS levels, confirming exact amounts of capacity and performance for even the most sensitive VMs. You can change capacity and performance dynamically without migrating data or affecting system performance.

End-User Computing

NetApp HCI is optimal for end-user computing (EUC) environments because capacity and performance are allocated independently for every virtual desktop and every application. The allocations can be easily adjusted as workloads shift or needs evolve without complexity. If an application needs more performance, the initial configuration can become a bottleneck, but NetApp HCI eliminates the penalty for underestimating requirements. Modification of the QoS policies can easily change the settings for minimum, maximum, and burst, and the new settings take effect immediately.

Workload Consolidation

NetApp HCI eliminates workload silos, allowing customers to predictably run multiple applications on the same infrastructure. Traditionally, when multiple applications share infrastructure, all performance resources, both IOPS and bandwidth, are freely available to all applications all the time across the shared resources. Without a more precise resource allocation, one application or "noisy neighbor" can easily consume an unfair share of the resources, leaving little available for others. This “first-come, first-served” allocation methodology can have a huge negative effect on all the other applications on the system.

Performance expectations on an application-by-application basis are erratic and unpredictable. One misbehaving application can cripple the entire system. To keep these variances in check, customers must constantly monitor and manage which applications share resources. Often, alleviating resource contention requires migration of either the "noisy neighbor" or the unhappy customer to a new system.

The NetApp HCI QoS settings eliminate resource contention and the variable application performance caused by noisy neighbors. Each volume on the system is assigned its own minimum, maximum, and burst settings, enabling predictable performance for each application without incurring the capacity sprawl and low utilization that are common in today's hyper converged infrastructures.

3.3 Solution Use Case Summary

This solution applies to the following use cases:

- Hardware-based graphics acceleration for multimedia workloads
- On-demand desktop and application deployment for end users
4 Technology Overview

VMware Horizon 7 Enterprise edition provides components to deploy and manage virtual desktops and hosted apps. To deploy virtual desktops for users in minutes, VMware introduced the JMP technology which uses Horizon Instant Clones for quick virtual desktop provisioning, Application assignments from App Volumes, and the association of virtual desktop policies managed by UEM.

NetApp HCI H610C includes the NVIDIA Tesla M10 graphics adapter which helps accelerate the media streaming for Horizon Desktops and apps.

Figure 4 shows the logical diagram of the components of the VMware Horizon solution on NetApp HCI.

4.1 NetApp HCI

NetApp HCI is scale-out architecture that permits the independent expansion of storage or compute capacity. It can scale up to 40 storage nodes and 64 compute nodes per cluster. The form factor of NetApp HCI varies by model. Mixed nodes (nodes of various NetApp HCI models) are supported in a cluster, thus protecting your investment. NetApp HCI provides APIs that provide deep ecosystem integration with various automation tools. The NetApp HCI H610C is a 2U compute node with two NVIDIA Tesla M10 graphics adapter for greater user density of task and knowledge workers who use graphics-intensive media. An NVIDIA Tesla M10 graphics card is a dual PCIe slot device. Each board is equipped with the following components:

- Four mid-tier NVIDIA Maxwell GPUs.
- 32GB of GDDR5 memory (8GB per GPU)
- 2560 NVIDIA CUDA cores (640 per GPU)
• 28 H.264 1080p30 streams

Figure 5) Common Element OS.

The NetApp HCI Portfolio
One software stack for multiple consumption models

ELEMENT OS Software

NetApp HCI provides the NDE to minimize the number of inputs and steps required to configure the system for a VMware vSphere environment. The NDE creates the storage cluster and the compute cluster, configures networks including iSCSI, and creates an initial datastore. Additional datastores can be provisioned and managed from the vCenter plug-in that it provides. NetApp HCI storage supports hardware acceleration (VAAI – vSphere API for Array Integration) out-of-the-box and no further tuning is required for VMFS6 volumes.

Figure 6) SolidFire-to ONTAP disaster recovery solution.

SolidFire-to-ONTAP disaster recovery solution
New functionality available with ONTAP 9.4 and Element 10.3

• ONTAP LUNs can now be replicated to Element OS
• Create new LUNs while failed over to ONTAP and restore to HCI on failback
• Migrate volumes to NetApp HCI using SnapMirror
• Increased fan-in ratio of up to 32 HCI clusters to one ONTAP cluster
• SnapMirror to ONTAP Select now supported
• ONTAP Cloud support planned for Element 11.0
NetApp HCI storage provides in-line duplication, QoS, and restful APIs to integrate into any automation framework. NetApp HCI can perform synchronous and asynchronous replication between HCI systems or to ONTAP-based system on-premises or in the cloud.

NetApp HCI uses 10/25Gb ports for the iSCSI, virtual machine, and vMotion traffic and 1Gb for the Intelligent Platform Management Interface (IPMI) and management ports. Although NDE supports both VLAN untagged and tagged networks, we find it easier to work with tagged networks. Configure any uplink ports used in vSphere distributed switches as trunk ports on the network switches, thus creating appropriate VLANs.

### 4.2 VMware vSphere

Separate vSphere clusters are recommended for management, desktop pools, and application pools to provide logical separation and fault isolation between the components. NetApp recommends that you enable high Availability (HA) and the Dynamic Resource Scheduler (DRS) on those vSphere clusters. HA provides fault tolerance to host failures which results in only a short outage before VMs are automatically brought back online.

Enable host monitoring and admission control so that at least one host failure or maintenance operation can be tolerated while sufficient resources are still provided to run the entire workload of the cluster. Additional capacity can be reserved to provide greater headroom for concurrent host failures or maintenance.

DRS automatically balances CPU and memory workloads across the cluster members. vSphere supports up to 64 nodes per cluster. VMware Horizon supports up to 32 nodes for Linked Clones and up to 64 nodes for the Instant Clones.

vCenter server provides the control pane for the vSphere environment. Up to 15 vCenter instances can be joined together in the linked mode. NDE deploys one vCenter server, or it can join to any existing vCenter server. The NetApp HCI vCenter plug-in supports linked mode and can provision datastores for hosts within that vCenter. A vSphere host can exist in only one vCenter.

<table>
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<th>Item</th>
<th>Maximum</th>
<th>Description</th>
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<td>VMs per host</td>
<td>1024</td>
<td>For H610C nodes, with vGPU – 128.</td>
</tr>
<tr>
<td>Virtual disks per host</td>
<td>2048</td>
<td></td>
</tr>
<tr>
<td>VMFS volume size</td>
<td>64TB</td>
<td></td>
</tr>
<tr>
<td>Volumes per host</td>
<td>1024</td>
<td></td>
</tr>
<tr>
<td>Hosts per volume</td>
<td>64</td>
<td></td>
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<tr>
<td>Powered-on VMs per VMFS</td>
<td>2048</td>
<td>volume</td>
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<tr>
<td>Max file size on VMFS5/VMFS6</td>
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<td>Shared GPUs per ESXi host</td>
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<tr>
<td>Hosts per vCenter server</td>
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<tr>
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<td>Hosts in linked vCenter</td>
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<td>Powered-on VMs in linked vCenter servers</td>
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<tr>
<td>Latency between vCenter instances in linked mode</td>
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Graphics adapters in vSphere host can be used in three ways.

- Virtual Dedicated Graphics Acceleration (vDGA)
- Virtual Shared Graphics Acceleration (vSGA)
- Virtual Shared Pass-Through Graphics Acceleration (with NVIDIA, it is referred to as vGPU; with AMD, it is referred to as multiuser GPU or MxGPU)

### 4.3 Virtual Dedicated Graphics Acceleration (vDGA)

VMs access the graphics adapter using a PCI pass-through device. You must enable DirectPath for that device on the vSphere host (see Figure 7). Using the pass-through device, the VMs cannot be suspended, be migrated with vMotion, or utilize VM snapshot features.

**Figure 7** Enable DirectPath.
A native graphics adapter driver must be installed on the VM, but no drivers are required on the hypervisor. The VM has access to the complete GPU and GPU memory even if it is idle or powered off. We don’t recommend using vDGA, because it doesn’t support many vSphere features and it provides low resource utilization.

One use case that might be helpful for partners is, they need to demo the NVIDIA vGPU vMotion feature and have single server for demo purpose & need to use vSphere nested virtualization. We haven’t tested this functionality, and you should know its limitations before you consider it. With NVIDIA, it requires a Quadro virtual datacenter workstation license or a GRID Virtual Apps license.

4.4 Virtual Shared Graphics Acceleration

vSGA provides hardware 3D acceleration by sharing GPUs across multiple VMs. This is an attractive solution for users who require a GPU’s full potential during brief periods. The NVIDIA vGPU Manager or the GRID software driver is installed on hypervisor hosts, and the VMware 3D Driver, which is part of VMware Tools, in installed on the guest OS. Graphics API support is limited to vSGA, and only selective versions of DirectX and OpenGL are supported. There is no CUDA support.
To install the NVIDIA driver on multiple hypervisor hosts, VMware Update Manager can be used with the host extension type. VM GPU association can be monitored with the vSphere web client or by using the gpvm CLI command.

Figure 10) gpvm CLI.

The vSGA mode provides higher user density with little management overhead. This is the default option when you install the NVIDIA driver. All the vSphere features like vMotion, Suspend, and snapshots are supported with a wide range of NVIDIA driver versions.
When no graphics adapter driver is installed on the hypervisor, it shows the memory size as zero on the vSphere web client.

4.5 Virtual Shared Pass-Through Graphics Acceleration with the NVIDIA vGPU

When users demand more graphics performance than is provided by the consolidation ratio in a given environment, the NVIDIA vGPU provides the balance of dedicated resource features like vDGA and shared across multiple users like vSGA.

In a manner similar to how vSphere virtualizes hardware resources, NVIDIA vGPU Manager and the GRID software virtualizes the GPU hardware.

Figure 11) NVIDIA vGPU architecture.

NVIDIA vGPU Architecture

From their user guide

To use this mode after installing the NVIDIA driver on the hypervisor host, switch the graphics adaptor mode, as is shown in Figure 12.
A shared PCI device is added to the VM, and the appropriate GPU profile is selected. The GPU profile list is provided in Figure 13.

Figure 13) vGPU profiles for Tesla M10 (from NVIDIA documentation).
A GRID Virtual PC (profiles typically end with B) is used for virtual desktops, and a GRID Virtual Application (profiles end with A) is used for Hosted Apps. Most of the Q profiles (Quadro virtual datacenter workstation) support the 4K resolution, which provides an enhanced user experience for image editing tools.

vGPU Manager schedules a VM to the GPU based on the policy set to either spread the VMs (best performance) or to group VMs (GPU consolidation) as is shown in figure 9.

This release of NVIDIA vGPU only supports homogeneous virtual GPUs. At any given moment, the virtual GPUs resident on a single physical GPU must all be of the same type. However, this restriction doesn’t extend across physical GPUs on the same card. Different physical GPUs on the same card can host different types of virtual GPUs at the same time, provided that the vGPU types on any one physical GPU are the same.

Figure 14) Homogenous virtual GPU profile combination.

![Homogenous virtual GPU profile combination](image)

To monitor this relationship, either the vSphere web client or the nvidia-smi vgpu can be used.

Figure 15) nvidia-smi vgpu cli.

**VM GPU Info**

*With vSphere Web Client/ nvidia-smi vgpu cli*
The vGPU 8Q profile supports CUDA applications. Figure 16 shows a screenshot of CUDA-Z for the 8Q profile.

Figure 16) CUDA-Z screenshot.

The combination of VMware vSphere 6.7 Update 1 and NVIDIA Grid software 7.0 supports vMotion, making it easier to manage the host.

Using the frame buffer for the NVIDIA hardware-based H.264/HEVC video encoder (NVENC) can cause memory exhaustion with vGPU profiles that have 512 Mbytes or less of frame buffer. To reduce the risk of memory exhaustion, the NVENC is disabled on profiles that have 512 Mbytes or less of frame buffer.

Application GPU acceleration remains fully supported and available for all profiles, including profiles with 512 MBytes or less of frame buffer. NVENC support from both Citrix and VMware is a recent feature, so you should experience no change in functionality if you are using an older version.

The following vGPU profiles have 512 Mbytes or less of frame buffer:

- Tesla M6-0B, M6-0Q
- Tesla M10-0B, M10-0Q
- Tesla M60-0B, M60-0Q

If you require NVENC, use a profile that has at least 1 Gigabytes of frame buffer.
To use vGPU, the NVIDIA driver must be installed on the guest OS. You must also have other ways to access the VM like VNC, Horizon Direct Console, and so on, because the vSphere web console can't be used to access the VM console session after driver installation and reboot.

Use of vGPU requires an NVIDIA license for the appropriate profile.

### 4.6 VMware Horizon 7 Enterprise

With VMware, you can pick a subscription-based license or a perpetual license for desktop pools or application pools. Subscription pricing options are available for Horizon 7, Horizon Cloud with Hosted Infrastructure, and Horizon Cloud on Microsoft Azure. Horizon 7 subscription licenses can be used on-premises or with VMware Cloud on AWS to burst to the cloud. Horizon 7 provides IT with a new streamlined approach to deliver, protect, and manage Windows and Linux desktops and applications while containing costs and making sure that end users can work anytime, anywhere, and on any device.

VMware Horizon 7 Enterprise Edition includes the following components:

- VMware Identity Manager
- VMware Horizon (Connection Server, Agent, Client, and Unified Access Gateway [UAG])
- VMware ThinApp
- App Volumes
- UEM
- JMP
- VMware Mirage
- VMware vSphere Hypervisor
- VMware vCenter Server
- VMware NSX for vSphere
- VMware vRealize Operations Manager (including for Published Applications)
- VMware vRealize Orchestrator Plug-in for Horizon
- VMware vRealize Log Insight
- VMware Workstation
- VMware Fusion

### 4.7 VMware Identity Manager

VMware Identity Manager provides Single Sign-On (SSO) for virtual desktops and applications which includes SaaS, Web, ThinApp, and mobile applications. With SSO, users do not need to remember multiple user names and passwords. It provides a central location to instantly disable user access to all resources, which protects systems from data leakage. It also acts as an app store for the company, and it provides a self-service catalog that can be customized to add branding.
Figure 17 shows the web launcher portal with apps from various resources. This is an optional component for this solution. Notably, the Horizon client can show the links to virtual desktops and published apps. VMware Identity Manager is part of the private cloud solution to provide SSO. If you are looking to implement SSO, see the Reviewer’s Guide for On-Premises VMware Identity Manager.

4.8 VMware Horizon

VMware Horizon deploys and manages desktop pools and application pools, manages the connection broker and user entitlements, and so on. For virtual desktops, it can automatically provision Full Clones, Linked Clones, or Instant Clones on VMware vSphere environments. It can also broker connections to preexisting physical machines or vCenter VMs including Remote Desktop Session Hosts (RDSHs) to provide session based desktops (like terminal services).

The connection server can provide dedicated or floating assignments to desktop pools. With dedicated assignments, a one-to-one relationship is maintained between users and computers. Therefore, when a user logs in, the user always gets the same desktop. The assignments can be made manually or auto assigned when they first log in. If you do not need a one-to-one user-to-machine relationship, for example if users are working multiple shifts sharing the same computer, you should use a floating pool.

A Full Clone is cloned from an existing vSphere template whereas a Linked Clone or an Instant Clone is provisioned from VMware snapshots.

If you are not using thin provisioning from vCenter or from the storage vendor, then the storage requirements for virtual desktops are huge. The storage I/O requirements for virtual desktops with spinning disks were challenging, and many companies have kept a separate silo infrastructure for virtual desktops as a result. With NetApp HCI, you can consolidate these workloads along with other infrastructure workloads on an all-flash storage system with guaranteed service levels.

Linked Clones help organizations to save on storage space. However, the provisioning time is longer, and Linked Clones require additional components like a SQL database, a composer service, and so on. An Instant Clone doesn’t require any external databases, and it uses fewer vCenter operations than a Linked Clone.
Primed or Image Push operation includes the creation of an internal template that is a Linked Clone of the master image snapshot. The internal template joins the computer to the Windows domain and reboots the computer, and then the replica is created for every datastore that is chosen for the provision of pools. The replica is a thin-provisioned, full clone of the internal template. The parent VM is booted from the replica on every host that is part of the resource pool selected for the desktop pool. The booted-up parent VM is quiesced and "hot-cloned" to rapidly produce derivative (child) VMs, leveraging the same disk and memory as the parent VM. The clone starts in an booted-up state.

An Instant Clone, even though the initial priming process takes some time, can expand a pool in seconds. An Instant Clone uses vSphere VMFork technology to provision desktops, and it joins the domain using cloneprep without any reboots required.

The master image should have the Horizon Agent installed so that it can communicate with Horizon connection servers, and virtual desktops can be managed from the connection server. The default option is to install the Horizon View Composer Agent. Make sure to disable the VMware Horizon View Composer Agent and use the VMware Horizon Instant Clone Agent.

Horizon 7 supports both Windows and Linux-based desktops including the RHEL, Ubuntu, CentOS, and NeoKylin operating systems. For Application Pools, it needs RDSH servers deployed in a farm. On supported Windows Servers, enable the Remote Desktop Services role and select the Remote Desktop Session Host role services. Install a Horizon Agent with the 3D RDSH option enabled if you plan to host graphics applications.

A connection server can create a farm automatically from the VM snapshot, or it can manage manually deployed physical machines or vCenter VMs. The manual option can also be used for the VMs provisioned from other tool like VMware vRealize Automation as part of a private cloud.

While deploying an automated farm, remember to set the max sessions per RDS host at 60.
In one FARM, up to 200 RDSH hosts can be added. After the Farms are defined, RDS-based desktop pools or application pools can be created from the farm. While creating the application pool, the pool can automatically senses the installed applications from the Farm and pick the applications to publish. If an app is not listed, you can add it manually by providing the name for the app and the executable path.

Within a connection server, you have the option of entitling desktop pools or application pools to users or groups. After entitlement, users can launch a Horizon client to connect to the desktop or application.

If an HTML access agent is installed and enabled on pool, the users can launch the desktop or application from a web browser, which makes access from any device easy. VMware Horizon 7 provides the Blast communication protocol along with PCoIP. Blast Extreme is a new display technology built on the H.264 protocol. Blast Extreme Adaptive Transport (BEAT) maintains a great user experience across a wide variety of network types, ranging from a corporate LAN to public Wi-Fi and mobile networks.

Blast Multimedia provides high-performance multimedia streaming for a rich user experience. Blast 3D provides rich virtualized graphics that deliver workstation-class performance. Blast Local Access provides access to local devices, USB, and device peripherals.

The Session Collaboration feature of Horizon Agent allows multiple users to view and modify the same desktop. This feature can be very useful in healthcare, design, engineering, and education organizations for peer reviews, design iterations, and training. The desktop owner can invite multiple additional users to collaborate in real time on their desktop and do so with a great user experience for all users.

One connection server can handle up to 4000 sessions (2000 sessions is recommended), and additional connection servers (total up to seven) can be added for high availability with N+1 and load balancing. The Horizon clients can access the connection servers through a load balancer to distribute the load. If NSX is deployed, the load balancer is available as part of edge services.

When a user tries to connect remotely, they can access the desktop pools, hosted applications, intranet resources, or SaaS-based applications through the UAG without the need for access by the VPN. One UAG can support 2000 connections.
NetApp recommends having the Horizon 7 Enterprise components in the management block and keeping the desktop pool and application pool in the resource blocks with its own vCenter and NSX server as shown in Figure 4. A Horizon pod is a combination of management blocks and resource blocks. A Horizon pod can support up to 10,000 connections. If more connections are required, you must enable the Cloud Pod Architecture (CPA) feature, which is a federated pod.

Table 2: Horizon sizing.

<table>
<thead>
<tr>
<th>Item</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of active sessions in the CPA</td>
<td>200,000</td>
</tr>
<tr>
<td>Number of pods in the CPA</td>
<td>25</td>
</tr>
<tr>
<td>Number of sites in CPA</td>
<td>10</td>
</tr>
<tr>
<td>Active connections per pod</td>
<td>20,000 (10,000 recommended)</td>
</tr>
<tr>
<td>Number of active connection server instances per pod</td>
<td>7</td>
</tr>
<tr>
<td>Active sessions per connection server with direct connection, RDP, tunnel connection, or PCoIP</td>
<td>4000 (2000 recommended)</td>
</tr>
<tr>
<td>Sessions per RDSH</td>
<td>150 (60 recommended)</td>
</tr>
<tr>
<td>RDSH per farm</td>
<td>200</td>
</tr>
<tr>
<td>VMs per vCenter instance</td>
<td>10,000 (5000 for Instant Clones)</td>
</tr>
<tr>
<td>VMs per Pool</td>
<td>4000 (2000 recommended)</td>
</tr>
<tr>
<td>Item</td>
<td>Maximum</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>VMs per LUN</td>
<td>500</td>
</tr>
<tr>
<td>Hosts per vSphere cluster</td>
<td>64 (Instant Clones)</td>
</tr>
<tr>
<td></td>
<td>32 (Linked Clones)</td>
</tr>
<tr>
<td>vGPU-enabled VMs per vSphere host</td>
<td>128</td>
</tr>
<tr>
<td>Connection servers per pod</td>
<td>7</td>
</tr>
<tr>
<td>Connections per UAG</td>
<td>2000</td>
</tr>
</tbody>
</table>

The CPA allows customers to dynamically move and locate Horizon desktop pools and application pools across multiple data centers for efficient management of end users across distributed locations.

4.9 VMware ThinApp

VMware ThinApp is an agentless architecture for application virtualization and packaging. This product is primarily provided for backward compatibility. If you are already using VMware ThinApp, you can continue to use it in the Horizon 7 environment. VMware App Volumes is preferred for any new deployments.

4.10 VMware App Volumes

VMware App Volumes is a Ruby-based application running on NGNIX to provide applications on demand to users and computers. App Volumes Manager runs this application and requires an external SQL database to store metadata. An App Stack is a collection of applications packaged as a virtual disk. An App Volume agent is installed on virtual desktops or a RDSH that are used for capturing applications and also on virtual desktops or a RDSH that must consume Appstacks.

Figure 21) VMware App Volumes.
When AppStack is assigned to users and computers, it only has read-only access to the app stack volumes. User writable volumes are used to allow users to install their own applications and for creating the profiles.

A major benefit of using App Volumes is to reduce the number of master images in virtual desktop environments by removing the application dependencies on the base image.

**Note:** An AppStack can only be used with the same OS that is used for capture.

App Stack capture is an easy process. Start App Stack creation by using App Volumes Manager and pick an App Stack template that was provisioned as part of the deployment process. Also pick one of the machines in your desktop pool or RDSH farm. You must have an App Volumes agent installed on that machine that is registered with App Volumes manager. Deploy applications manually on that machine, and, after you have installed all the required applications, notify the agent that you have completed the task. The machine reboots and App Stack is created.

**Figure 22) AppStacks and Writable Volumes.**

A storage group in an App Volume is a collection of datastores that are used to serve AppStack volumes or user-writable volumes. Storage group used for AppStack volumes are primarily used for replicating the AppStack volumes across multiple LUNs for availability and to load balance.

VMware recommends that you not assign more than 8 to 10 AppStacks for each user or device. You must mount the writable volume first before mounting AppStack volumes to avoid the reboot prompt. If you are using writable volumes, assign AppStack volumes to the users rather than to machines. To reduce the performance effect, set the number of AppStack volumes for each user or machine to a low number.

**4.11 User Environment Manager**

A user profile contains many personalization options for the operating systems in addition to application settings. User Environment Manager captures these details to a network share and imports them back based on the defined conditions. It doesn’t require the user to have a roaming profile to work. UEM can set smart policies for the Horizon client, like enabling printing when in the office and disabling it when accessed from the outside.
Figure 23) UEM file shares.

Because this configuration is CIFS-share based, each environment (like testing, production, HR, sales, and engineering) can have their own network configuration shares.

4.12 Just-In-Time Management Platform

JMP is a new administrative interface for Horizon connection servers that allows you to pick desktops from the pool and AppStacks from App Volumes. You can also manage UEM settings like ADMX, the display language, drive mappings, environment variables, file and folders, logon tasks, application personalization, registry settings, shortcuts, trigged tasks, and Horizon Client smart policies in a single workflow. JMP reduces the number of management interfaces needed for onboarding users.
4.13 VMware Mirage

VMware Mirage provides streamlined image management for physical desktops, full-clone virtual machines, and point-of-sale devices. VMware Mirage categorizes a PC into logical layers owned by either IT or the end-user. It also sends a complete copy of the system to the Mirage Server in the data center and keeps it synchronized. With the layering technology in Mirage, IT has three options for desktop recover:

- Restore the entire device (OS, applications, user data, and profile)
- Restore just the applications, user data, and profile
- Restore just the user data and profile

VMware Mirage can manage Horizon FLEX (an optional component not included with Horizon 7 Enterprise) virtual images. Horizon FLEX provides virtual desktop access in offline/disconnected mode with VMware Workstation and Fusion products.

If you plan to use VMware Mirage, see Deployment and Design Considerations for VMware Mirage.

4.14 VMware NSX for vSphere

VMware NSX for Horizon brings speed and simplicity to virtual desktop infrastructure networking, with policies that dynamically follow virtual desktops. You can create, change, and manage security policies across all virtual desktops with a few clicks. Map these policies to user groups to accelerate virtual desktop onboarding. The security policies can be mapped to users based on role, logical grouping, desktop operating system, and more. VMware NSX Edge services include load balancing (which can be used for connection servers, UAG, and so on), DHCP/DHCP relay (for desktop/application pools), firewall, NAT, routing, VPN, and so on.
4.15 VMware vRealize Operations Manager

VMware vRealize Operations Manager provides the five key features listed in Figure 26.

To monitor NetApp HCI with vRealize Operations Manager, use BlueMedora’s management pack for NetApp HCI.
NVIDIA provides a GPU management pack for vRealize Operations Manager to monitor metrics from the graphics adaptor.
The vRealize for Horizon adapter is required to monitor the virtual desktops, application pools, App Volumes, and so on. vRealize Operations Manager Agent must be installed on the VMware Horizon connection servers, and agents must be installed on virtual desktop templates.

See the vRealize Operations Manager sizing guidelines for more information.

4.16 VMware vRealize Orchestrator Plug-In for Horizon

VMware Horizon provides vRealize Orchestrator Plug-In to extend vCenter or vRealize Automation with custom workflows. This plug-in allows users to pick and choose which tool they would like to deploy to
manage the desktop and application pools. With Horizon Agent Direct Connect, users can connect to desktops directly without going through the connection broker. VMware Horizon also supports HTML Direct Connection. See the plug-in documentation to identify which features are available out of the box and additional features that can be created with custom code.

Figure 30) Horizon vRealize Orchestrator Plug-In architecture.

4.17 VMware vRealize Log Insight

VMware vRealize Log Insight delivers heterogeneous and highly scalable log management with intuitive, actionable dashboards, sophisticated analytics, and broad third-party extensibility, providing deep operational visibility and faster troubleshooting.

To collect logs from desktops, you need to install vRealize Log Insight Agent on the desktops. For hosts like vSphere hypervisor or NetApp HCI storage, you can configure it to forward the logs to vRealize Log Insight as syslog server.
Figure 31) VMware vRealize Log Insight architecture.

Figure 25) vRealize Log Insight UI.

For sizing info, see this link.
4.18 VMware Workstation
VMware Workstation is a desktop hypervisor tool that can run on Windows and Linux desktops or laptops to create VMs running multiple Windows or Linux instances at the same time. When used with the optional product Horizon Flex, a virtual desktop from the desktop pool can be used in offline/disconnected mode.

4.19 VMware Fusion
VMware Fusion is for Apple macOS to create Windows, Linux, or MacOS VMs. When used with the optional product Horizon Flex, a virtual desktop from the desktop pool can be used in offline/disconnected mode.

5 Solution Design
As is shown in Figure 1, our solution keeps infrastructure VMs separate from workload VMs in the management block and in the resource block. Having a resource block keeps the workloads contained in a secure and isolated way. With NetApp HCI, each resource block corresponds to an account and a separate VLAN for storage traffic. Every block requires at least four compute nodes when used with NSX. Keep the three controllers on separate hosts and keep an additional one for fault tolerance.

In linked mode, 15 vCenter servers are allowed. Therefore, 14 resource blocks and one management block are possible for each Horizon pod. The number of compute nodes in vCenter linked mode is 5000. If you exceed the maximum storage space available in each cluster, you are able to deploy additional clusters for the resource blocks and manage them centrally from the vCenter plug-in.

Figure 32) Resource block scalability.

Based on VMware guidelines, keeping 10,000 sessions for each Horizon pod and 2000 sessions for each resource block provides five resource blocks for each Horizon pod. If you require more sessions, use the CPA feature to create global entitlement for users across the Horizon pods within the same site, across the sites, or to cloud.
We have seen user density for NetApp HCI GPU compute nodes in the range of 130-150 virtual desktops/node for vSGA mode. To be conservative, we picked 128 users/node. That number is also valid if we use vGPU mode.

The configuration of desktop VMs is described in Table 3.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>vCPU</td>
<td>2</td>
</tr>
<tr>
<td>RAM</td>
<td>4GB</td>
</tr>
<tr>
<td>NIC (VMXNet3 adapter)</td>
<td>1</td>
</tr>
<tr>
<td>VMDK</td>
<td>• 70GB (OS)</td>
</tr>
<tr>
<td></td>
<td>• 10GB (UWV + profile)</td>
</tr>
<tr>
<td></td>
<td>• 20GB (AppStack)</td>
</tr>
</tbody>
</table>

AppStack only supports Windows OS. Supported Linux VMs with Horizon can use hosted applications on Windows RDSH served by AppStack.

An Instant Clone provides a delta disk for every virtual desktop. The size of the delta disk depends on the change rate. We assumed a 10% change rate for the sizing calculations, and we also assumed no backup volumes configured on App Volumes and considered 500GB for AppStacks. Table 4 provides a rough estimate for the number of datastores required for 1.5TB volumes.

<table>
<thead>
<tr>
<th>Component</th>
<th>800 Users</th>
<th>1200 Users</th>
<th>2000 Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetApp HCI compute nodes (resource block)</td>
<td>8</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>NetApp HCI compute nodes (management block)</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>NetApp HCI storage nodes (based on the model used)</td>
<td>&gt; or = 4</td>
<td>&gt; or = 4</td>
<td>&gt; or = 4</td>
</tr>
<tr>
<td>1.5TB datastore for hosting virtual desktops</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>1.5TB datastore for user writable volumes</td>
<td>8</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>

The datastores that hold AppStack volumes are mostly for read-only access, and the datastores that holds use-writable volumes provide read-write access. With NetApp HCI, there is no need to separate those workloads, and both can coexist on same datastore.

Hosted Application serves the needs of task oriented users like nurses in hospitals who require access to specific application and don’t have time to wait for desktops to boot. The application pool is hosted on a farm of RDSH hosts. If the RDSH host reboots while accessing the application, the user gets an error. When the application is relaunched, it is served from the other surviving hosts.

For desktop pools serving Instant Clones, Horizon refreshes the desktop on another host if one of vSphere host crashes. Typically, the desktop is protected by vSphere HA.
UAG, App Volumes Manager, and connection servers are accessed through a load balancer, and the traffic is redirected to the server in service. AppStack volumes are replicated to multiple datastores using the storage group, and writable volumes are distributed based on the following two policy sets:

- **Spread.** Distributes files evenly across all the storage locations. When a file is created, the storage with the most available space is selected.
- **Round-robin.** Distributes files by sequentially using the storage locations. When a file is created, the storage with the oldest used time is selected.

The AppVolume datastores that hold the virtual disks for AppStacks and user-writable volumes can be replicated from NetApp HCI to any ONTAP devices on-premises or in the cloud. If the UEM file shares are also hosted on ONTAP, they can also be replicated to other ONTAP devices on-premises or in the cloud. This configuration enables users to burst into the cloud for a short duration and then to bring data back on-premises.

### 6 Technology Components

This section covers the technology components that we used for validating the End User Computing on NetApp HCI solution.

#### 6.1 Hardware Components

Table 5 lists the hardware components that we used for the solution. The hardware components that are used in any particular implementation of the solution might vary based on customer requirements.

<table>
<thead>
<tr>
<th>Component</th>
<th>Count</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetApp HCI compute nodes (resource block)</td>
<td>2</td>
<td>H610C</td>
</tr>
<tr>
<td>NetApp HCI compute nodes (Management Block)</td>
<td>2</td>
<td>H500E</td>
</tr>
<tr>
<td>NetApp HCI storage nodes</td>
<td>4</td>
<td>H500S</td>
</tr>
<tr>
<td>Cisco Nexus 9000 switch</td>
<td>2</td>
<td>iSCSI/VM/vMotion</td>
</tr>
<tr>
<td>1Gb switch</td>
<td>1</td>
<td>IPMI/Management</td>
</tr>
</tbody>
</table>

#### 6.2 Software Components

Table 6 lists the software components that are required to implement the solution. The software components that are used in any particular implementation of the solution might vary based on customer requirements.

<table>
<thead>
<tr>
<th>Software</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetApp HCI NDE</td>
<td>1.4</td>
</tr>
<tr>
<td>VMware Horizon 7 Enterprise</td>
<td></td>
</tr>
<tr>
<td>VMware Identity Manager</td>
<td>3.3.0</td>
</tr>
<tr>
<td>VMware Horizon</td>
<td>7.6</td>
</tr>
</tbody>
</table>
### 7 Solution Verification

This solution architecture is based on VMware vSphere 6.7 Update 1, VMware Horizon 7.6, and NVIDIA GRID 7.0 so that it can support vMotion for the VM running graphics workloads, including vGPU mode. In our testing, our management block was hosted on NetApp HCI 500E/410C nodes and our resource block was hosted on NetApp HCI 610C nodes. We used Cisco Nexus 9K switches for the 10Gb network, and we used a 1Gb switch for the management network.

We verified that we were able to deploy desktop pools and application pools utilizing the GPU with VMware Horizon. We performed on-demand desktop assignment and application provisioning for a test user, and we confirmed that their settings were preserved with logoff and logon.

We determined that we could put a vSphere host in maintenance mode, and we migrated a VM running a graphics workload with a vGPU profile to the other host. We were able to perform session sharing while running multiple workloads with both Horizon clients as well as using HTML with a web browser.

We validated the solution by simulating user-like workloads using the Login Virtual Session Indexer (Login VSI). Login VSI is the industry-standard load-testing tool for testing the performance and scalability of centralized Windows desktop environments, such as server-based computing and VDI.

The testing included following scenarios:

- Get VSIMax for a single server with no GPU used for a knowledge worker.
- Get VSIMax for a single server with vSGA mode for a knowledge worker.
- Get VSIMax for a single server with vGPU mode for a knowledge worker.
- Get VSIMax for a single server with vSGA mode for a multimedia workload.
- Get VSIMax for a single server with vGPU mode for a multimedia workload.

All the above testing was performed using JMP to entitle the desktop pool, an AppStack Volume for LoginVSI workloads, and the UEM policies.

### 8 Conclusion

NetApp HCI can scale or shrink based on your business needs so that you can provide flexible options for your customers. The QoS feature makes NetApp HCI simple to integrate with existing workloads. NetApp
HCI GPU compute nodes provide an enhanced user experience for knowledge-based workers who would benefit from hardware 3D acceleration. With Horizon 7, users can securely connect to desktop pools or application pools from any device, anywhere.

Where to Find Additional Information

To learn more about the information described in this document, refer to the following documents and/or websites:

**NetApp**
- NetApp Product Documentation
- NetApp HCI Documentation Center
  http://docs.netapp.com/hci/index.jsp
- NetApp Data Fabric
- NetApp HCI Datasheet
- NetApp HCI Technical docs
  http://docs.netapp.com/hci/index.jsp
- NetApp HCI Deployment Guide
  https://library.netapp.com/ecm/ecm_download_file/ECMLP2844053
- NetApp HCI Network Setup Guide
- VMware vRealize Operations Management Pack for NetApp HCI and SolidFire
- NetApp SolidFire vRealize Orchestrator Plug-in
  https://github.com/solidfire/vrealize-orchestrator-plugin
- NetApp HCI Theory of Operations
- NetApp Element software
- NetApp ONTAP Select
- NetApp Interoperability Matrix Tool
  https://mysupport.netapp.com/matrix/#welcome

**NVIDIA**
- NVIDIA Virtual GPU Software Documentation
  https://docs.nvidia.com/grid/

**VMware**
- VMware Tech Zone
  https://techzone.vmware.com/
- VMware Workspace ONE and VMware Horizon 7 Enterprise Edition On-Premises Reference Architecture
• Deploying Hardware-Accelerated Graphics with VMware Horizon 7
• VMware Horizon 7 sizing limits and recommendations
  https://kb.vmware.com/s/article/2150348
• VMware Configuration Maximums
  https://configmax.vmware.com/
• Reviewer’s Guide for On-Premises VMware Identity Manager
• Deployment and Design Considerations for VMware Mirage
• Network Ports in VMware Horizon 7
• Horizon for Linux FAQ
• vRealize Operations Manager 6.6.1 Sizing Guidelines
  https://kb.vmware.com/s/article/2150421
• Sizing the vRealize Log Insight Virtual Appliance

Version History

<table>
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<th>Date</th>
<th>Document Version History</th>
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</thead>
<tbody>
<tr>
<td>Version 1.0</td>
<td>November 2018</td>
<td>Initial version</td>
</tr>
</tbody>
</table>
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