Technical White Paper

Dell EMC Ready Solutions for HPC Digital Manufacturing with AMD EPYC™ Processors—Altair Performance

Abstract

This Dell EMC technical white paper discusses performance benchmarking results and analysis for Altair HyperWorks™ on Dell EMC Ready Solutions for HPC Digital Manufacturing with AMD EPYC™ processors.

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1 Introduction

This technical white paper discusses the performance of the Altair HyperWorks™ products, Altair Radioss™, and Altair AcuSolve™ on Dell EMC Ready Solutions for HPC Digital Manufacturing with AMD EPYC™ processors. Dell EMC Ready Solutions for HPC were designed and configured specifically for Digital Manufacturing workloads, where Computer Aided Engineering (CAE) applications are critical for virtual product development. The Dell EMC Ready Solutions for HPC Digital Manufacturing use a flexible building block approach to HPC system design, where individual building blocks can be combined to build HPC systems which are optimized for customer specific workloads and use cases.

The Dell EMC Ready Solutions for HPC Digital Manufacturing are one solution set among many in the Dell EMC HPC solution portfolio. Please visit www.dellemc.com/hpc for a comprehensive overview of the available HPC solutions offered by Dell EMC.

The architecture of the Dell EMC Ready Solutions for HPC Digital Manufacturing and a description of the building blocks are presented in Section 2. Section 3 describes the system configuration, software and application versions, and the benchmark test cases that were used to measure and analyze the performance of the Dell EMC HPC Ready Solutions for HPC Digital Manufacturing with AMD EPYC processors. Section 4 presents benchmark performance for Altair AcuSolve, and Section 5 contains the performance data for Altair Radioss.

2 System Building Blocks

The Dell EMC Ready Solutions for HPC Digital Manufacturing are designed using preconfigured building blocks. The building block architecture allows an HPC system to be optimally designed for specific end-user requirements, while still making use of standardized, domain-specific system recommendations. The available building blocks are infrastructure servers, storage, networking, and compute building blocks. Configuration recommendations are provided for each of the building blocks which provide good performance for typical applications and workloads within the manufacturing domain. This section describes the available building blocks along with the recommended server configurations.

With this flexible building block approach, appropriately sized HPC clusters can be designed based on individual customer workloads and requirements. Figure 1 shows three example HPC clusters designed using the Dell EMC Ready Solutions for HPC Digital Manufacturing architecture.

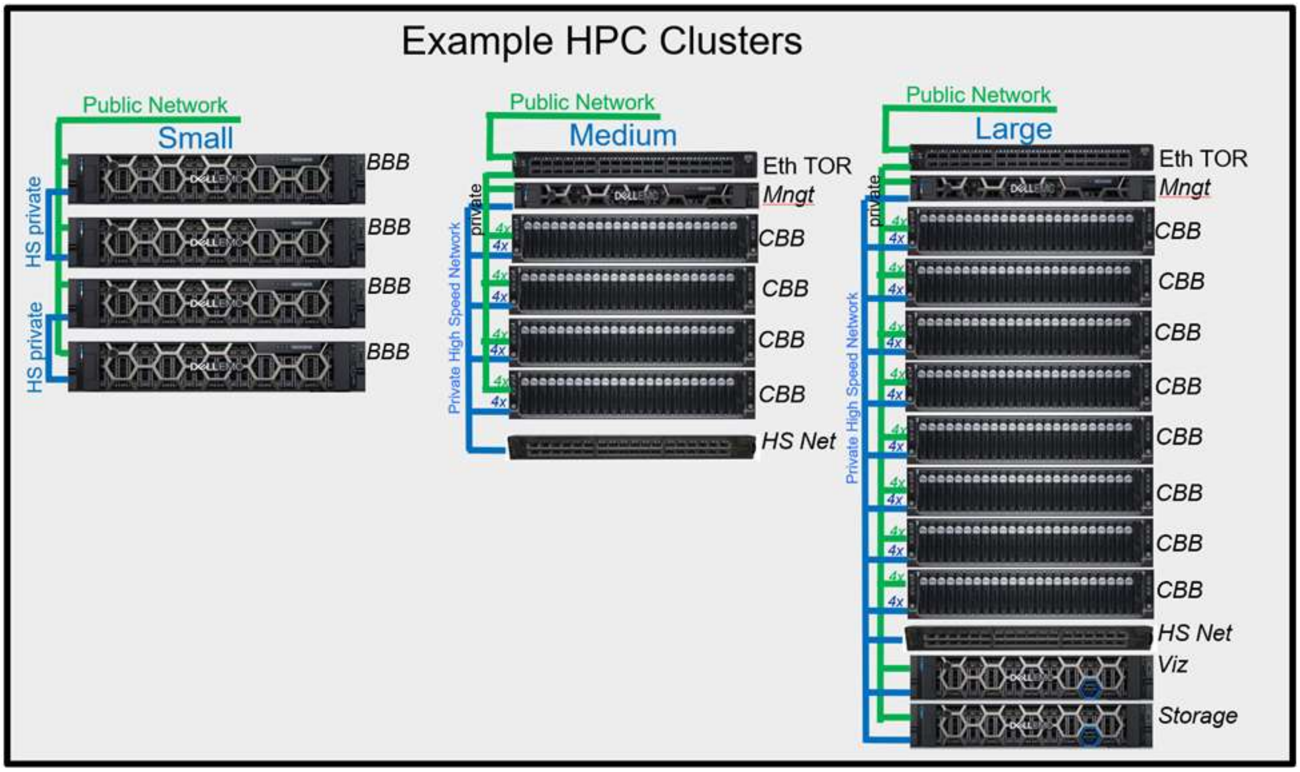


Figure 1 Example Ready Solutions for HPC Digital Manufacturing

2.1 Infrastructure Servers

Infrastructure servers are used to administer the system and provide user access. They are not typically involved in computation, but they provide services that are critical to the overall HPC system. These servers are used as the master nodes and the login nodes. For small sized clusters, a single physical server can provide the necessary system management functions. Infrastructure servers can also be used to provide storage services, by using NFS, in which case they must be configured with additional disk drives or an external storage array. One master node is mandatory for an HPC system to deploy and manage the system. If high-availability (HA) management functionality is required, two master nodes are necessary. Login nodes are optional and one login server per 30-100 users is recommended.

A recommended base configuration for infrastructure servers is:

- Dell EMC PowerEdge R6515 server
- AMD EPYC 7302P processor
- 128GB of RAM (8 x 16GB 3200 MTps DIMMs)
- PERC H335 RAID controller
- 2 x 480GB Mixed-Use SATA SSD RAID 1
- Dell EMC iDRAC9 Enterprise
- 2 x 550W Power Supplies
- Mellanox ConnectX-6 InfiniBand^{TM} HCA (optional)

The recommended base configuration for the infrastructure server is described as follows. The PowerEdge R6515 server is suited for this role. Typical HPC clusters will only require a few infrastructure servers; therefore, density is not a priority, but manageability is important. The AMD EPYC 7302P processor, with 16 cores per socket, is suitable for this role. If the infrastructure server will be used for CPU intensive tasks, such as compiling software or processing data, then a more capable processor may be appropriate. 128GB of RAM provided by eight 16GB DIMMs provides sufficient memory capacity, while also providing good memory bandwidth. These servers are not expected to perform much I/O, but reliability is important, so two mixed-use SATA SSDs in RAID1 configuration are recommended for the operating system. For small systems (four nodes or less), an Ethernet network may provide sufficient application performance. For most other systems, InfiniBand is likely to be the data interconnect of choice, which provides a high-throughput, low-latency fabric for node-to-node communications or access to Dell EMC HPC Storage Ready Solutions.

2.2 Compute Building Blocks

Compute Building Blocks (CBB) provide the computational resources for most HPC systems for Digital Manufacturing. These servers are used to run the various Altair HyperWorks simulations. The best configuration for these servers depends on the specific mix of applications and types of simulations being performed by each customer. Since the best configuration may be different for each customer, a table of recommended options are provided that are appropriate for these servers. The configuration can be selected based on the specific system and workload requirements of each customer. Relevant criteria to consider when selecting a system configuration are discussed in the application performance chapters of this white paper. The recommended configuration options for the Compute Building Block are provided in Table 1.

Table 1 Recommended Configurations for the Compute Building Block

Platforms	Dell EMC PowerEdge R6525 Dell EMC PowerEdge C6525
Processor Options	Dual AMD EPYC 7302 (16 cores per socket) Dual AMD EPYC 7402 (24 cores per socket) Dual AMD EPYC 7452 (32 cores per socket) Dual AMD EPYC 7502 (32 cores per socket) Dual AMD EPYC 7552 (48 cores per socket) Dual AMD EPYC 7702 (64 cores per socket)
Memory Options	256 GB (16 x 16GB 3200 MTps DIMMs) 512 GB (16 x 32GB 3200 MTps DIMMs)
Storage Options	PERC H335 or H745 RAID controller 2 x 480GB Mixed-Use SATA SSD RAID 0
iDRAC	iDRAC9 Enterprise
Power Supplies	2 x 750W PSU (R6525) 2 x 2400W PSU (C6525)
Networking	Mellanox® ConnectX®-6 InfiniBand™ adapter

2.3 Basic Building Blocks

Basic Building Block (BBB) servers are selected by customers to create simple but powerful HPC systems. These servers are appropriate for smaller HPC systems where reducing the management complexity of the HPC system is important. The BBB is based on the 2-socket Dell EMC PowerEdge R6525 server.

The recommended configuration for BBB servers is:

- Dell EMC PowerEdge R6525 server
- Dual AMD EPYC 7502 32-Core processors
- 256 GB of RAM (16 x 16GB 3200 MTps DIMMS)
- PERC H745 RAID controller
- 2 x 240GB Read-Intensive SATA SSD RAID 1 (OS)
- 4 x 480GB Mixed-Use SATA SSD RAID 0 (scratch)
- Dell EMC iDRAC9 Enterprise
- 2 x 800W Power Supplies
- Mellanox ConnectX-6 InfiniBand Adapter (optional)
- Mellanox ConnectX-5 25 GbE Adapter (optional)

The R6525 platform is used to minimize server count and provide good compute power per server. Each server can contain up to two AMD EPYC processors. The AMD EPYC 7502 processor is a 32-core CPU with a base frequency of 2.5 GHz and a max boost frequency of 3.35 GHz. As configured, a BBB contains 64 cores, a natural number for many CAE simulations. A memory configuration of 16 x 16GB DIMMs is used to provide balanced performance and capacity. While 256GB is typically sufficient for most CAE workloads, customers expecting to handle larger production jobs should consider increasing the memory capacity to 512GB. Various CAE applications, such as implicit FEA, often have large file system I/O requirements and four Mixed-use SATA SSD's in RAID 0 are used to provide fast local I/O.

Additionally, two BBB's can be directly coupled together via a high-speed network cable, such as InfiniBand or Ethernet, without need of an additional high-speed switch if additional compute capability is required for each simulation run (HPC Couplet). BBB's provide a simple framework for customers to incrementally grow the size and power of the HPC cluster by purchasing individual BBBs, BBB Couplets, or combining the individual and/or Couplets with a high-speed switch into a single monolithic system.

We did not carry out any explicit performance testing on BBB configurations for this paper. For Linux based systems, the single node and two-node couplet BBB clusters with InfiniBand would be comparable to the results reported for the two-node 7452 based CBB benchmarks below. For Windows based clusters, the use of InfiniBand for node-to-node connectivity in a two-node couplet requires complex setup and administration, likely beyond the intended scope for most customers seeking a Windows based solution. It is recommended that Windows based two-node couplets be networked with high speed Ethernet, such as 25GbE. Our experience with Windows for HPC workloads indicates the performance differential between Windows and Linux can be highly variable and problem dependent, making the use of standard benchmarks as an indication of projected performance of limited value. Customers wishing for the highest level of performance and potential cluster expansion would be advised to use Linux as an operating system.

2.4 Storage

Dell EMC offers a wide range of HPC storage solutions. For a general overview of the entire HPC solution portfolio please visit www.dellemc.com/hpc. There are typically three tiers of storage for HPC: scratch storage, operational storage, and archival storage, which differ in terms of size, performance, and persistence.

Scratch storage tends to persist for the duration of a single simulation. It may be used to hold temporary data which is unable to reside in the compute system's main memory due to insufficient physical memory capacity. HPC applications may be considered "I/O bound" if access to storage impedes the progress of the simulation. For these HPC workloads, typically the most cost-effective solution is to provide sufficient direct-attached local storage on the compute nodes. For situations where the application may require a shared file system across the compute cluster, a high-performance shared file system may be better suited than relying on local direct-attached storage. Typically, using direct-attached local storage offers the best overall price/performance and is considered best practice for most CAE simulations. For this reason, local storage is included in the recommended configurations with appropriate performance and capacity for a wide range of production workloads. If anticipated workload requirements exceed the performance and capacity provided by the recommended local storage configurations, care should be taken to size scratch storage appropriately based on the workload.

Operational storage is typically defined as storage used to maintain results over the duration of a project and other data, such as home directories, such that the data may be accessed daily for an extended period of time. Typically, this data consists of simulation input and results files, which may be transferred from the scratch storage or from users analyzing the data, often remotely. Since this data may persist for an extended period, some or all of it may be backed up at a regular interval, where the interval chosen is based on the balance of the cost to either archive the data or regenerate it if need be. Archival data is assumed to be persistent for a very long term, and data integrity is considered critical. For many modest HPC systems, use of the existing enterprise archival data storage may make the most sense, as the performance aspect of archival data tends to not impede HPC activities. Our experience in working with customers indicates that there is no 'one size fits all' operational and archival storage solution. Many customers rely on their corporate enterprise storage for archival purposes and instantiate a high-performance operational storage system dedicated for their HPC environment.

Operational storage is typically sized based on the number of expected users. For fewer than 30 users, a single storage server, such as the Dell PowerEdge R7515 is often an appropriate choice. A suitably equipped storage server may be:

- Dell EMC PowerEdge R7515 server
- AMD EPYC 7302P processor
- 128GB of memory, 8 x 16GB 3200 MTps DIMMs
- PERC H745 RAID controller
- 2 x 240GB Mixed-use SATA SSD in RAID-1 (For OS)
- 12 x 12TB 3.5" NLSAS HDDs in RAID-6 (for data)
- Dell EMC iDRAC9 Enterprise
- 2 x 750W Power Supplies
- Mellanox ConnectX-6 InfiniBand Adapter (optional)
- High-speed Ethernet Adapter (optional)

This server configuration would provide 144TB of raw storage. For customers expecting between 25-100 users, an operational storage solution, such as the Dell EMC Ready Solutions for HPC NFS Storage (NSS), shown in Figure 2, with up 1008TB of raw storage capacity may be appropriate:

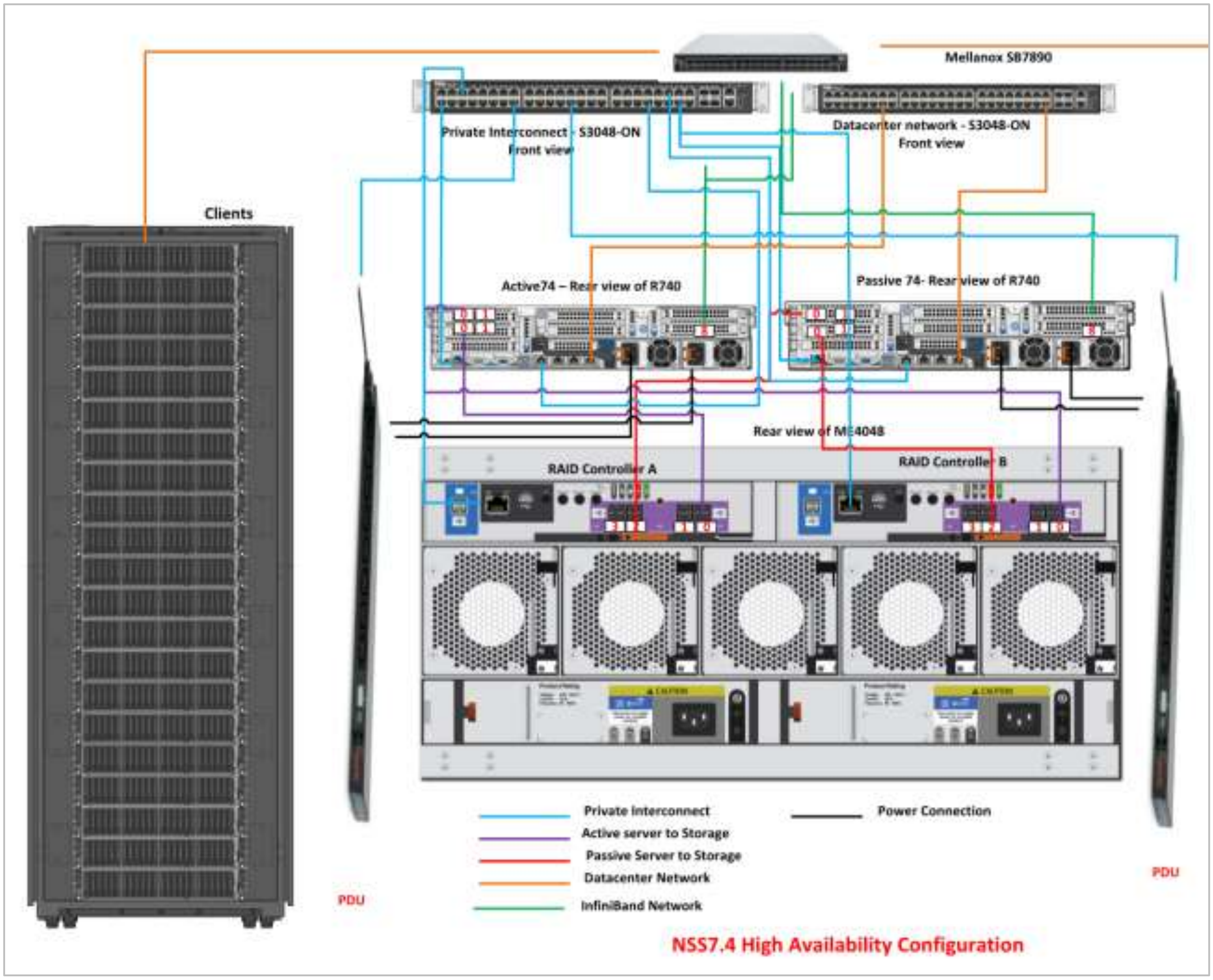


Figure 2 NSS7.4-HA Storage System Architecture

For customers desiring a shared high-performance parallel filesystem, the Dell EMC Ready Solutions for HPC Lustre Storage solution shown in Figure 3 are appropriate. These solutions can scale up to multiple petabytes of storage.

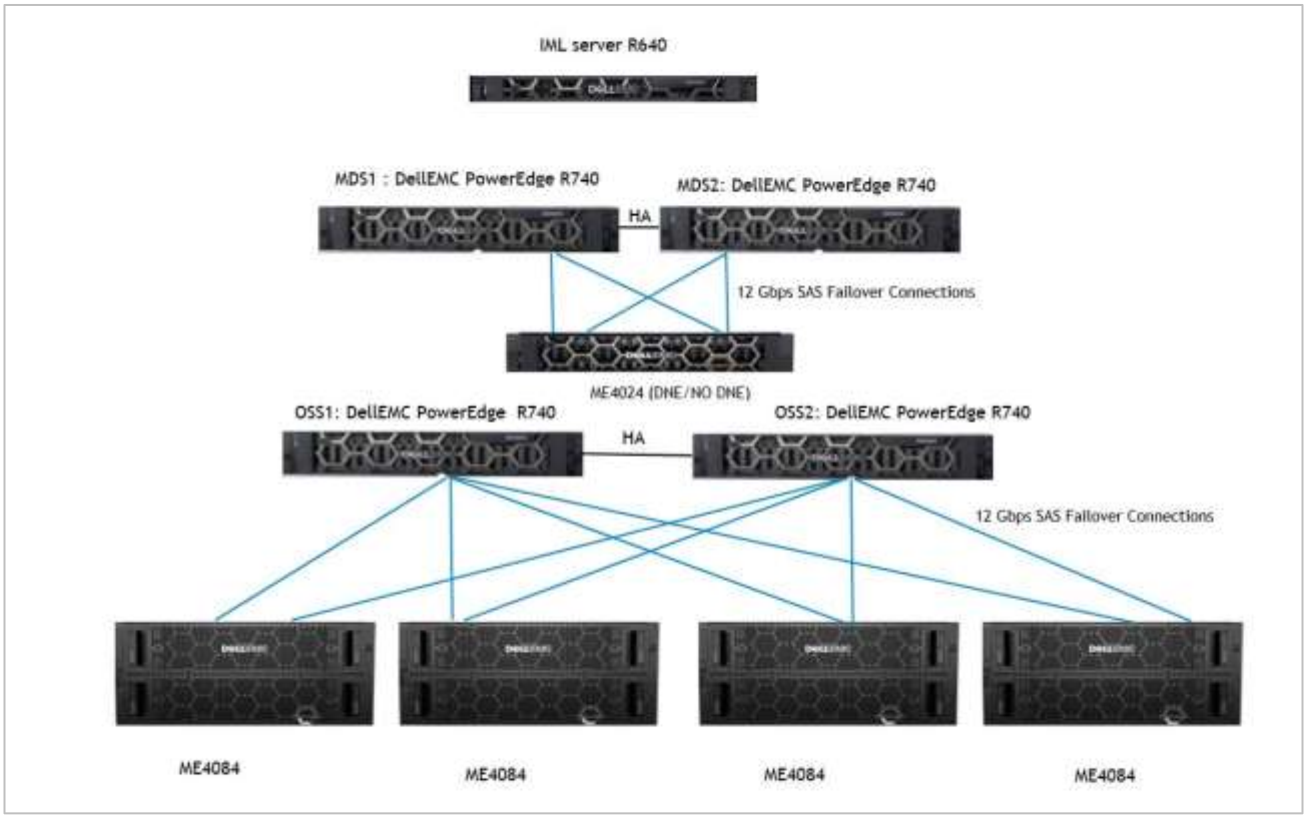

IML server R640
MDS1 : DellEMC PowerEdge R740
MDS2: DellEMC PowerEdge R740
HA
12 Gbps SAS Failover Connections
ME4024 (DNE/NO DNE)
OSS1: DellEMC PowerEdge R740
OSS2: DellEMC PowerEdge R740
HA
12 Gbps SAS Failover Connections
ME4084
ME4084
ME4084
ME4084

Figure 3 Dell EMC Ready Solutions for Lustre Storage Reference Architecture

2.5 System Networks

Most HPC systems are configured with two networks—an administration network and a high-speed/low-latency switched fabric. The administration network is typically Gigabit Ethernet that connects to the onboard LOM/NDC of every server in the cluster. This network is used for provisioning, management and administration. On the CBB servers, this network is also normally used for IPMI hardware management. For infrastructure and storage servers, the iDRAC Ethernet interfaces may be connected to this network for OOB server management. The management network is typically deployed using Dell EMC PowerSwitch S3048-ON Ethernet switches. If there is more than one switch in the system, multiple switches can be stacked with 10 Gigabit Ethernet cables.

A high-speed/low-latency fabric is recommended for clusters with more than four servers. The current recommendation is a Mellanox HDR or EDR InfiniBand fabric. The fabric will typically be assembled using Mellanox QM8700 series or SB7800 series InfiniBand switches. The number of switches required depends on the size of the cluster and the blocking ratio of the fabric.

2.6 Cluster Management Software

The cluster management software is used to install and monitor the HPC system. Bright Cluster Manager (BCM) is the recommended cluster management software.

2.7 Services and Support

The Dell EMC Ready Solutions for HPC Digital Manufacturing are available with full hardware support and deployment services, including additional HPC system support options.

2.8 Workload Management

Workload management and job scheduling on the Dell EMC Ready Solutions for HPC Digital Manufacturing can be handled efficiently with Altair PBS Professional™, part of the Altair PBS Works™ suite. PBS Professional features include policy-based scheduling, OS provisioning, shrink-to-fit jobs, preemption, and failover. Its topology-aware scheduling optimizes task placement, improving application performance and reducing network contention. Many applications from Altair and other leading ISV's incorporate PBS Professional specific interfaces into their applications to improve the ease of use and performance for these applications with PBS Professional.

3 Reference System

Performance benchmarking was performed in the Dell EMC HPC and AI Innovation Lab using system configurations as listed in Table 2.

Table 2 Benchmark System Configurations

Building Block	Quantity
Compute Building Block (CBB) PowerEdge C6525 Dual AMD EPYC 7452 32-Core Processors 256GB RAM 16x16GB 3200 MTps DIMMs Mellanox ConnectX-6 HDR100 InfiniBand	8
Compute Building Block (CBB) PowerEdge C6525 Dual AMD EPYC 7402 24-Core Processors 256GB RAM 16x16GB 3200 MTps DIMMs	1
Compute Building Block (CBB) PowerEdge C6525 Dual AMD EPYC 7502 32-Core Processors 256GB RAM 16x16GB 3200 MTps DIMMs	1
Compute Building Block (CBB) PowerEdge C6525 Dual AMD EPYC 7702 64-Core Processors 256GB RAM 16x16GB 3200 MTps DIMMs	1
Mellanox QM8700 InfiniBand Switch	1

The BIOS configuration options used for the benchmark systems are listed in Table 3.

Table 3 BIOS Configuration

BIOS Option	Setting
Logical Processor	Disabled
Virtualization Technology	Disabled
System Profile	Performance Profile
CCX as NUMA Domain	Disabled
NUMA Nodes Per Socket	4

The software versions used for the benchmarks are listed in Table 4.

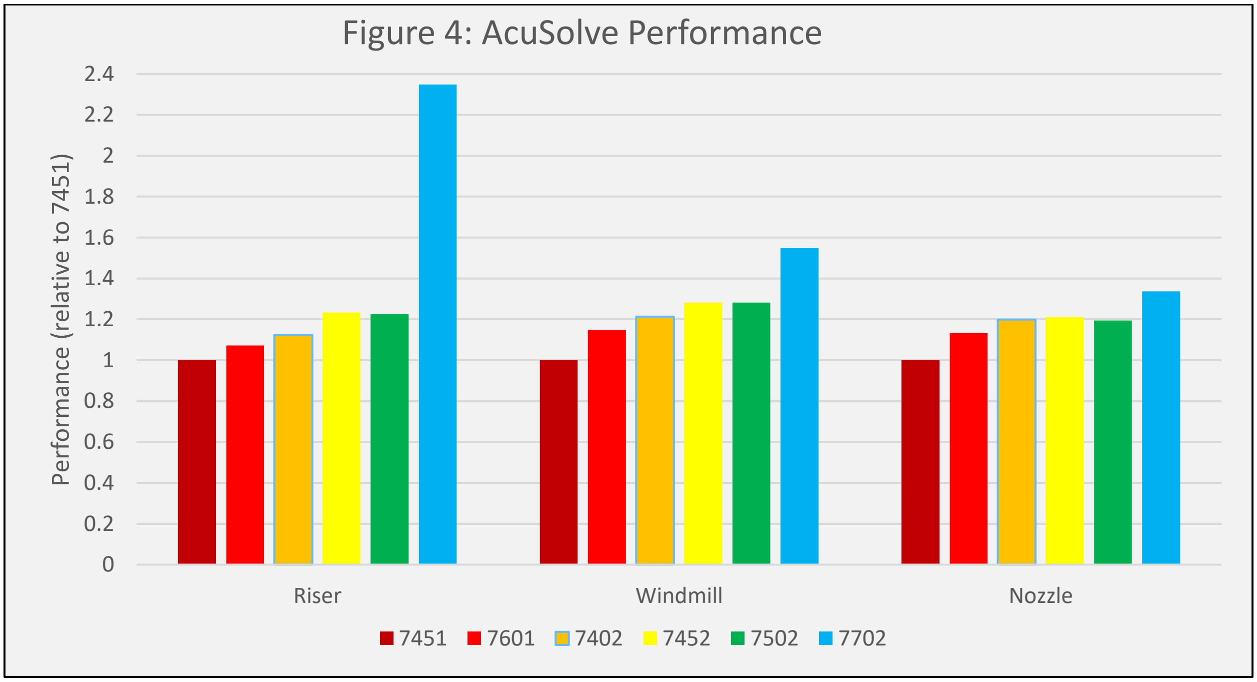
Table 4 Software Versions

Component	Version
Operating System	RedHat Enterprise Linux 7.6
Kernel	3.10.0-957.27.2.el7.x86_64
OFED	Mellanox 4.6-1.0.1.1
Bright Cluster Manager	8.2
Altair Radioss	2018
Altair AcuSolve	2018

4 Altair AcuSolve Performance

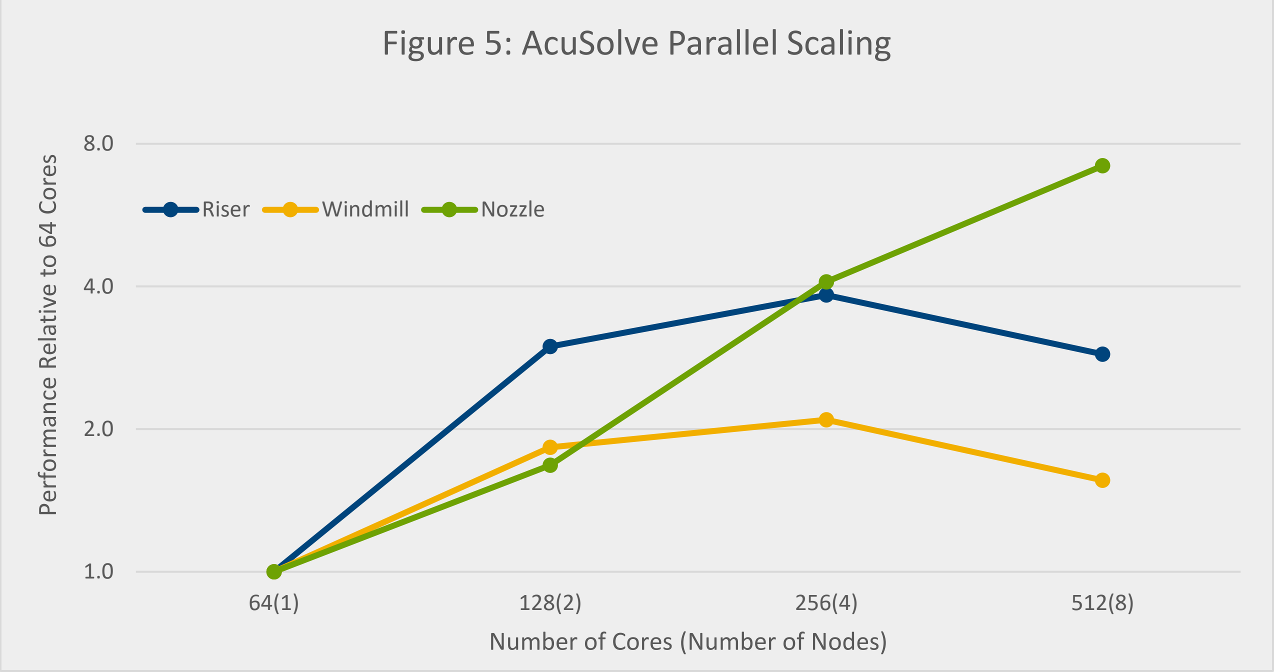
Altair AcuSolve is a Computational Fluid Dynamics (CFD) tool commonly used across a very wide range of CFD and multi-physics applications. AcuSolve is a robust solver with proprietary numerical methods that yield stable simulations and accurate results regardless of the quality and topology of mesh elements. It uses a single solver for all flow regimes, with very few parameters to adjust, and it produces rapid results by solving the fully-coupled pressure/velocity equation system using scientifically proven numerical techniques. CFD applications typically scale well across multiple processor cores and servers, have modest memory capacity requirements, and typically perform minimal disk I/O while in the solver section. However, some simulations, such as large transient analysis, may have greater I/O demands.

Figure 4 shows the relative single server performance of the CBB server types for three AcuSolve benchmarks.



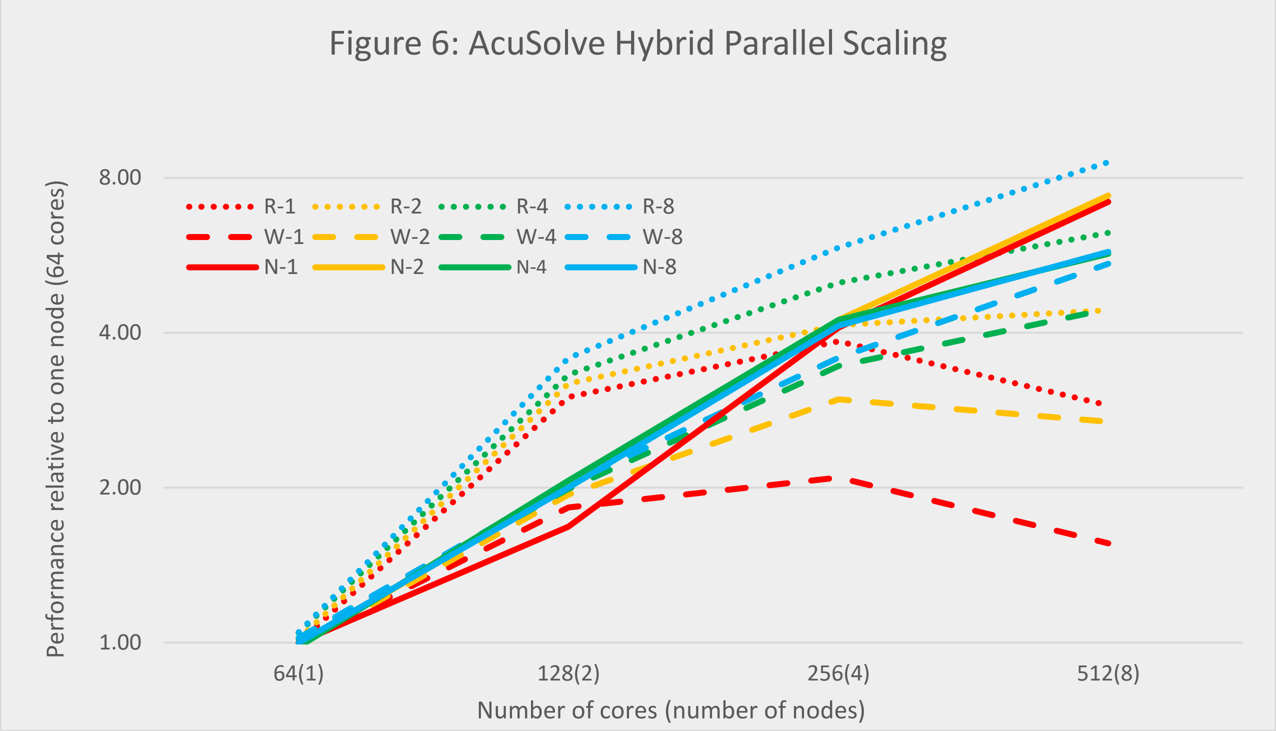
For comparison, the figure also includes performance data for PowerEdge R7425 systems using AMD EPYC 7451(24-core) and 7601(32-core) processors. Here performance was plotted in terms of the elapsed wall time, where 1.0 was the value obtained with the 7451 based server (higher is better). The 32-core AMD EPYC 7502 processor (and 7452) provide very good performance for these benchmarks. The 64-core AMD EPYC 7702 provides a significant performance advantage over the 32-core processors, particularly for smaller 'riser' benchmark, which benefits from the larger cache in the 7702 processor.

Figure 5 shows the parallel performance improvement for AcuSolve when running in parallel across multiple servers.



These benchmarks were carried out on a cluster of eight servers, each with dual 7452 processors. The results are presented in relative performance compared with the single node results. On the surface these results appear surprising for the “Riser” model where the performance increases by more than a factor of 2X going from one to two nodes. However, this behavior can be explained by “cache effects”, where when the data set is distributed among a greater number of nodes, there can be a point where the entire problem can fit into cache, and the speed of the solver can increase dramatically. Such cache effects are highly problem specific. In general, there is a tradeoff in distributed memory parallelism where the cache performance typically improves as the problem is distributed to more nodes, but the communication overhead also increases, counteracting the increased performance from the caching benefit. The largest model “Nozzle” displays nearly linear parallel scaling up to 8 nodes. The other models show limited performance improvement with 4 nodes or above (256 cores and greater).

AcuSolve is a hybrid parallel application, where it is possible to use both shared memory parallelism within a node and distributed memory parallelism both within a node an across nodes. Finding the proper balance between shared memory and distributed memory parallelism within a node can be daunting. Figure 6 shows the parallel performance for these models on the cluster used for Figure 5, where the number of shared memory parallel threads is adjusted from 1 to 8 threads per domain, where the number of domains per server was the divisor of the total number of cores per server with the number of threads per domain.

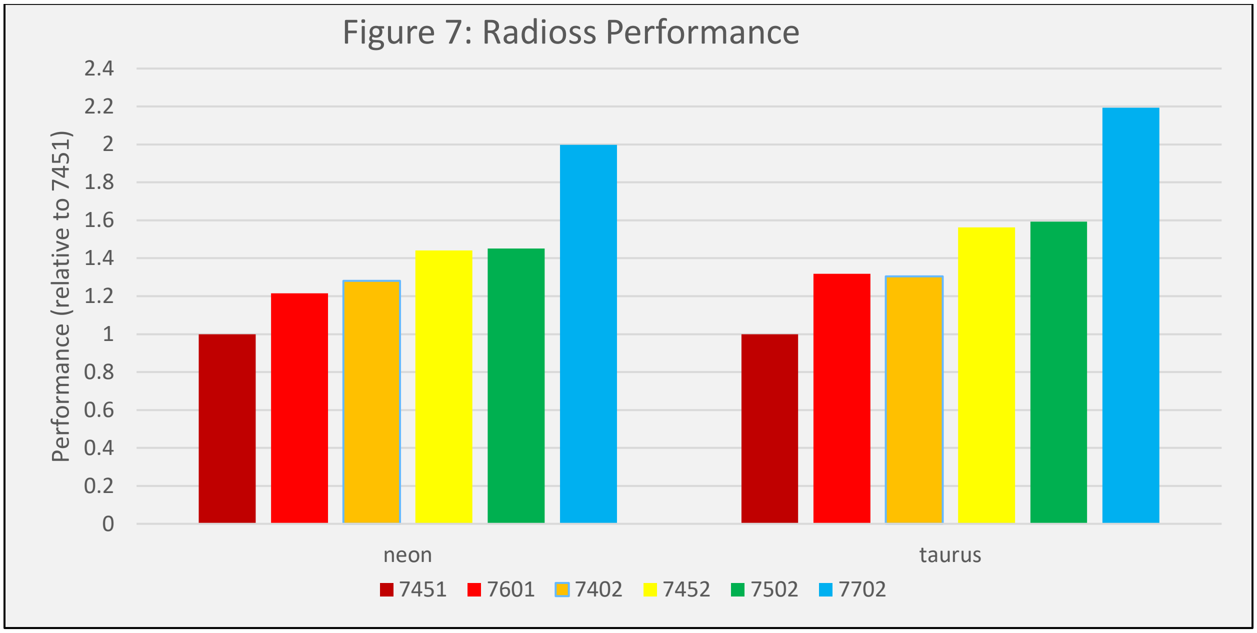


Again, the Riser(R) model shows initial better overall parallel scaling than the larger Windmill(W) and Nozzle(N) models, primarily from cache effects. All models display similar behavior when the number of shared memory threads is varied. There is little benefit in using multiple threads until four nodes are used. At eight nodes, the benefits of multiple shared memory threads are noticeable for the smaller Riser(R) and Windmill(W), where typically the more threads the better, up to a certain point. The larger Nozzle(N) model shows excellent parallel speedup over the range of thread per domain tested. It would appear that a good rule of thumb for using thread parallelism would be to use one thread for the number of nodes used in the run (i.e. 4 threads for 4-node runs). This may not be optimal for every situation but should give reasonable performance.

5 Altair Radioss Performance

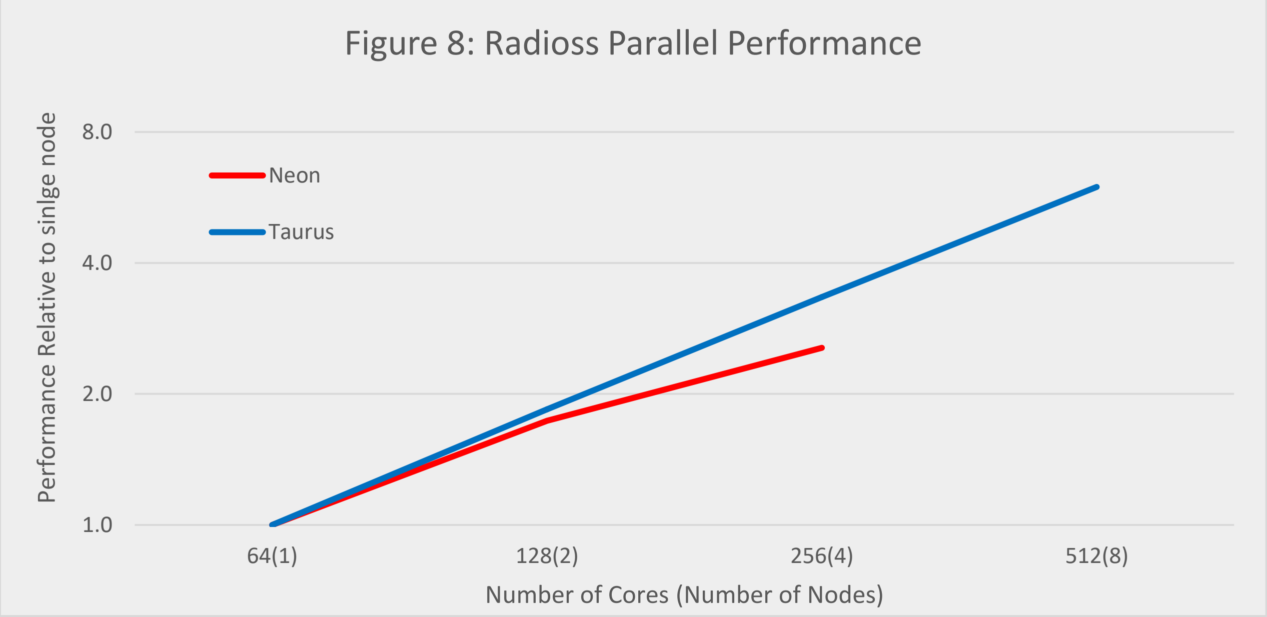
Altair Radioss is a leading structural analysis solver for highly non-linear problems under dynamic loadings. It is used across all industries worldwide to improve the crashworthiness, safety, and manufacturability of structural designs. Radioss is similar to AcuSolve in that it typically scales well across multiple processor cores and servers, has modest memory capacity requirements, and performs minimal disk I/O while in the solver section. It is tightly integrated with Altair OptiStruct™ and it comes with a comprehensive material and rupture library.

Figure 7 shows the relative performance for two Radioss benchmarks on single servers. For this comparison, all processor cores were utilized while running Radioss.



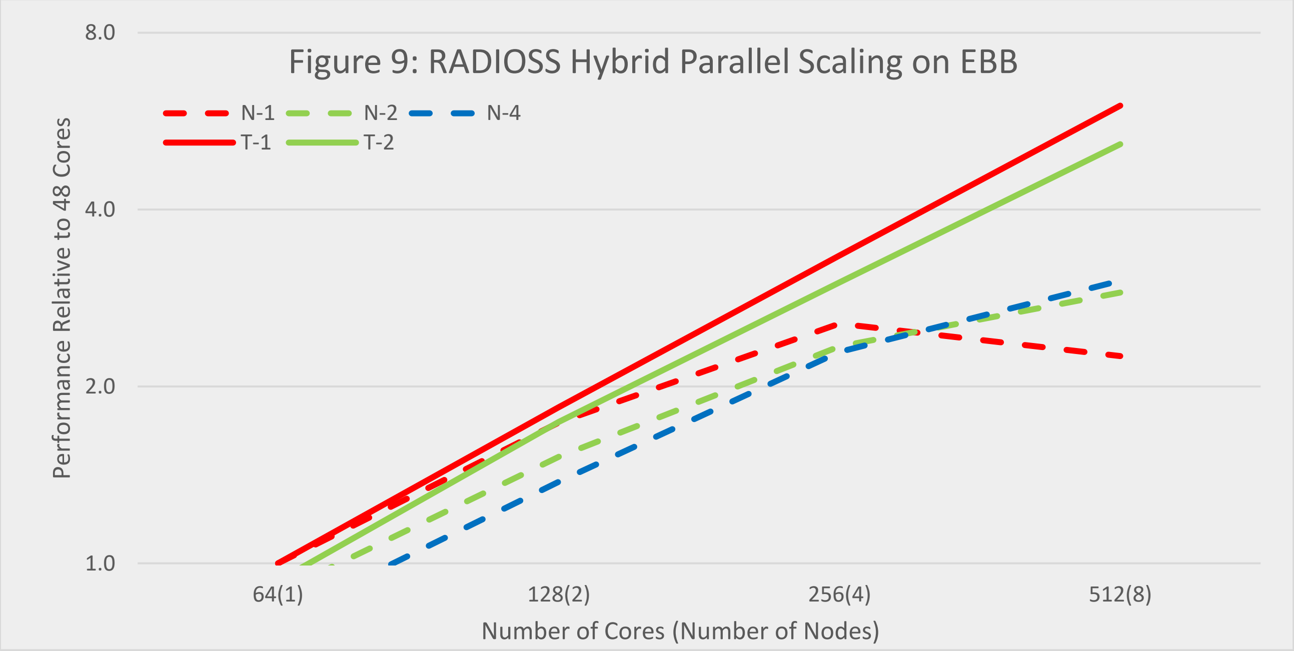
Like Figure 4, performance data for PowerEdge R7425 systems using AMD EPYC 7451(24-core) and 7601(32-core) processors was included for a comparison, with the performance from the PowerEdge R7425 equipped with dual 24-core 7451 processors used as the basis of 1.0. Here, a higher value is better. The results are similar to the AcuSolve results, where the increase in performance from the 1st generation EPYC to the 2nd generation EPYC based systems is noticeable both in terms of core performance and overall system performance. Again the 64-core EPYC 7702 system delivered noticeably better overall performance than the other systems.

Figure 8 presents the Radioss parallel performance with parallel benchmarks run across multiple servers.



These benchmarks were carried out on a cluster of eight servers, each with dual 7452 processors. The results are presented in relative performance compared with the single node results. The parallel speedup for the large Taurus model is nearly linear up to eight nodes (512 cores). However, the parallel speedup for the smaller neon model starts to fall off above two nodes (128 cores). It should be noted that the Neon benchmark model is very small by today's standards. The time required to carry out the full 80msec simulation on a single node is only 1338 seconds. As such, there is no expectation to see a good parallel speedup with this model at four or more nodes.

Like AcuSolve, it is also possible to use Radioss in hybrid parallel mode. Figure 9 shows the parallel performance for both Radioss benchmarks models using (1,2,4) shared memory threads on up to 8 compute nodes.



Here, the results are significantly different than the results obtained with the hybrid parallel version of AcuSolve. For the larger Taurus (T) model, the best performance was always obtained using a single shared memory thread (the same as non-hybrid distributed memory MPI). For the smaller Neon model, there was a small benefit using more than one thread at four or more nodes. These results indicate that users should carefully test their models for the potential benefit of using multiple threads when running on larger number of nodes, particularly with smaller models.

6 Conclusion

This technical white paper presents the Dell EMC Ready Solutions for HPC Digital Manufacturing with AMD EPYC 7002 Series processors. The detailed analysis of the building block configurations demonstrate that the system is architected for a specific purpose—to provide a comprehensive HPC solution for the manufacturing domain. Use of this building block approach allows customers to easily deploy an HPC system optimized for their specific workload requirements. The design addresses computation, storage, networking and software requirements and provides a solution that is easy to install, configure and manage, with installation services and support readily available. The performance benchmarking bears out the solution design, demonstrating the performance of the solution with Altair HyperWorks.