

# Dell EMC Ready Solution for HPC Digital Manufacturing—LSTC LS-DYNA® Performance

## Abstract

This Dell EMC technical white paper discusses performance benchmarking results and analysis for LSTC LS-DYNA® on the Dell EMC Ready Solution for HPC Digital Manufacturing.

April 2019

## Revisions

Date	Description
January 2018	Initial release with Intel® Xeon® Scalable processors (code name Skylake)
April 2019	Revised with 2 <sup>nd</sup> generation Intel Xeon Scalable processors (code name Cascade Lake)

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# 1 Introduction

This technical white paper discusses the performance of LSTC LS-DYNA® on the Dell EMC Ready Solution for HPC Digital Manufacturing. This Dell EMC Ready Solution for HPC was designed and configured specifically for Digital Manufacturing workloads, where Computer Aided Engineering (CAE) applications are critical for virtual product development. The Dell EMC Ready Solution for HPC Digital Manufacturing uses 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 Solution for HPC Digital Manufacturing is one of many solutions in the Dell EMC HPC solution portfolio. Please visit [www.dell.com/hpc](http://www.dell.com/hpc) for a comprehensive overview of the available HPC solutions offered by Dell EMC.

The architecture of the Dell EMC Ready Solution 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 Solution for HPC Digital Manufacturing. Section 4 presents benchmark performance for LSTC LS-DYNA.

## 2 System Building Blocks

The Dell EMC Ready Solution for HPC Digital Manufacturing is 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.

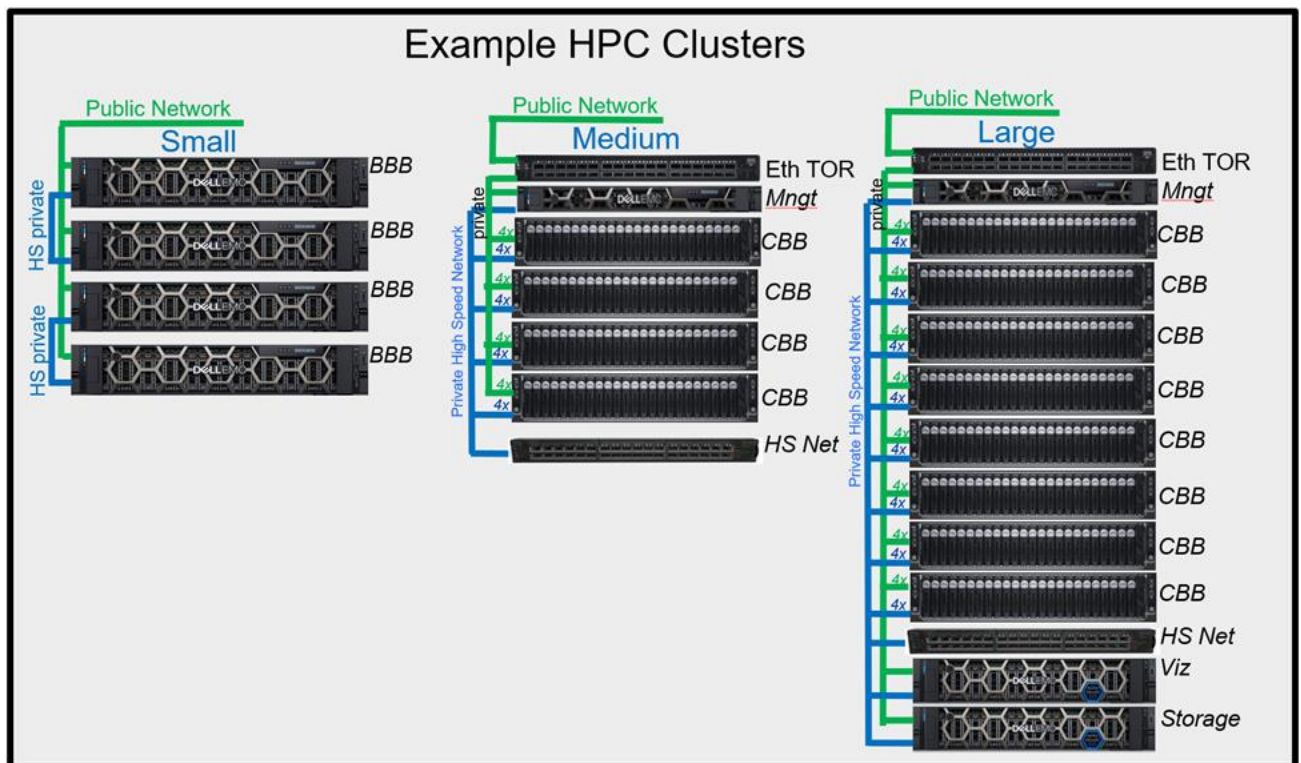


Figure 1 Example Ready Solutions for HPC Digital Manufacturing

### 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 R640 server
- Dual Intel® Xeon® Bronze 3106 processors
- 192 GB of RAM (12 x 16GB 2667 MTps DIMMs)
- PERC H330 RAID controller
- 2 x 480GB Mixed-Use SATA SSD RAID 1
- Dell EMC iDRAC9 Enterprise
- 2 x 750 W power supply units (PSUs)
- Mellanox EDR InfiniBand™ (optional)

The recommended base configuration for the infrastructure server is described as follows. The PowerEdge R640 server is suited for this role. Typical HPC clusters will only use a few infrastructure servers; therefore, density is not a priority, but manageability is important. The Intel Xeon Bronze 3106 processor, with 8 cores per socket, is a basic recommendation 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. 192 GB of memory provided by twelve 16 GB DIMMs provides sufficient memory capacity, with minimal cost per GB, while also providing good memory bandwidth. These servers are not expected to perform much I/O, so a single mixed-use SATA SSD should be sufficient for the operating system. For small systems (four nodes or less), an Ethernet network may provide sufficient application performance. For most other systems, EDR 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 a Dell EMC Ready Solution for HPC NFS Storage solution or a Dell EMC Ready Solution for HPC Lustre Storage solution.

## 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 LS-DYNA 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 specific configuration can then be selected based on the specific system and workload requirements of each customer. Relevant criteria to consider when making these selections 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

<b>Platforms</b>	Dell EMC PowerEdge R640 Dell EMC PowerEdge C6420
<b>Processors</b>	Dual Intel Xeon Gold 6242 (16 cores per socket) Dual Intel Xeon Gold 6248 (20 cores per socket) Dual Intel Xeon Gold 6252 (24 cores per socket)
<b>Memory Options</b>	192 GB (12 x 16GB 2933 MTps DIMMs) 384 GB (12 x 32GB 2933 MTps DIMMs) 768 GB (24 x 32GB 2933 MTps DIMMs, R640 only)
<b>Storage Options</b>	PERC H330, H730P or H740P RAID controller 2 x 480GB Mixed-Use SATA SSD RAID 0 4 x 480GB Mixed-Use SATA SSD RAID 0
<b>iDRAC</b>	iDRAC9 Enterprise (R640) iDRAC9 Express (C6420)
<b>Power Supplies</b>	2 x 750W PSU (R640) 2 x 2000W PSU (C6400)
<b>Networking</b>	Mellanox® ConnectX®-5 EDR 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 4-socket Dell EMC PowerEdge R840 server.

The recommended configuration for BBB servers is:

- Dell EMC PowerEdge R840 server
- Quad Intel Xeon Gold 6142 processors
- 384 GB of RAM (24 x 16GB 2666 MTps DIMMS)
- PERC H740P 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 1600W power supply units (PSUs)
- Mellanox ConnectX-5 EDR InfiniBand (optional)
- Mellanox 25 GbE (optional)

The R840 platform is used to minimize server count and provide good compute power per server. Each server can contain up to four Intel Xeon processors, where each BBB is essentially two CBB's fused into a single server. The Intel Xeon Gold 6142 processor is a sixteen-core CPU with a base frequency of 2.6 GHz and a max all-core turbo frequency of 3.3 GHz. With four processors, a BBB contains 64 cores, a natural number for many CAE simulations. A memory configuration of 24 x 16GB DIMMs is used to provide balanced performance and capacity. While 384GB is typically sufficient for most CAE workloads, customers expecting to handle larger production jobs should consider increasing the memory capacity to 768GB. 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. The compute nodes do not normally require extensive OOB management capabilities; therefore, an iDRAC9 Express is recommended.

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.

Performance testing for BBB's has been done using both Linux and Windows Server 2016. In general, Linux provides better overall performance, and an easier path to combining BBB's to create larger, more capable HPC clusters. We have tested up to two BBB's with Linux using both 25 Gigabit Ethernet and EDR InfiniBand adapters/cable in the two-node couplet configuration. With Linux, the EDR couplet gave the best overall performance across our tests. While the performance of the 25GbE based couplet was often comparable to the EDR based couplet, we saw little reason not to use EDR to ensure better overall performance at a similar cost and complexity. However, for customers not wishing to deploy InfiniBand in their environment, choosing a 25GbE based couplet is a suitable alternative.

For Windows testing, we tested only a couplet with a 25 GbE network. Support for InfiniBand on Windows is not currently feasible for most customers. 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.dell EMC.com/hpc](http://www.dell EMC.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, typically in a sequential manner, 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 R740xd is often an appropriate choice. A suitably equipped storage server may be:

- Dell EMC PowerEdge R740xd server
- Dual Intel® Xeon® Bronze 4110 processors
- 96 GB of memory, 12 x 8GB 2667 MT/s DIMMS
- PERC H730P RAID controller
- 2 x 250GB Mixed-use SATA SSD in RAID-1 (For OS)
- 12 x 12TB 3.5: nSAS HDDs in RAID-6 (for data)
- Dell EMC iDRAC9 Express
- 2 x 750 W power supply units (PSUs)
- Mellanox EDR InfiniBand Adapter
- Site specific 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 Solution for HPC NFS Storage (NSS), shown in Figure 2, with up 840 TB of raw storage capacity may be appropriate:

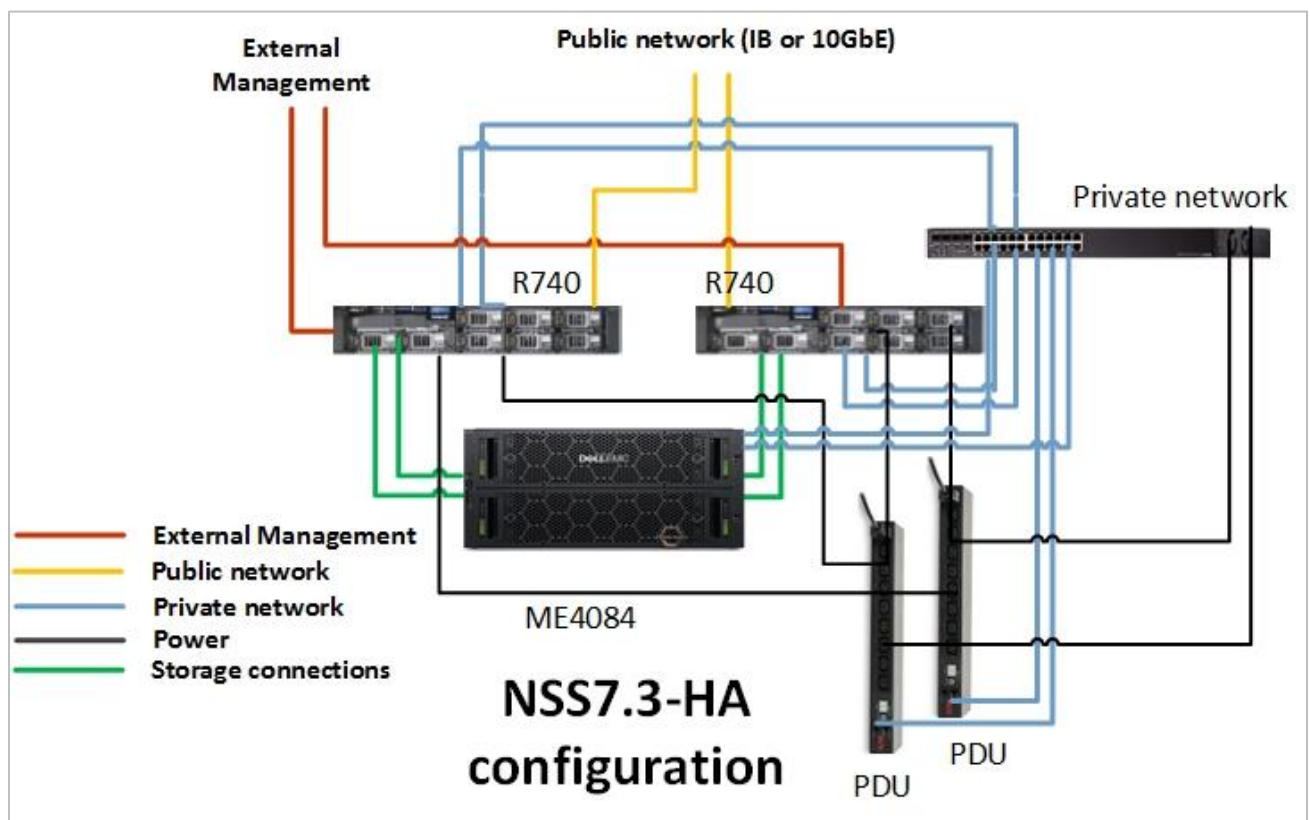


Figure 2 NSS7.3-HA Storage System Architecture

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

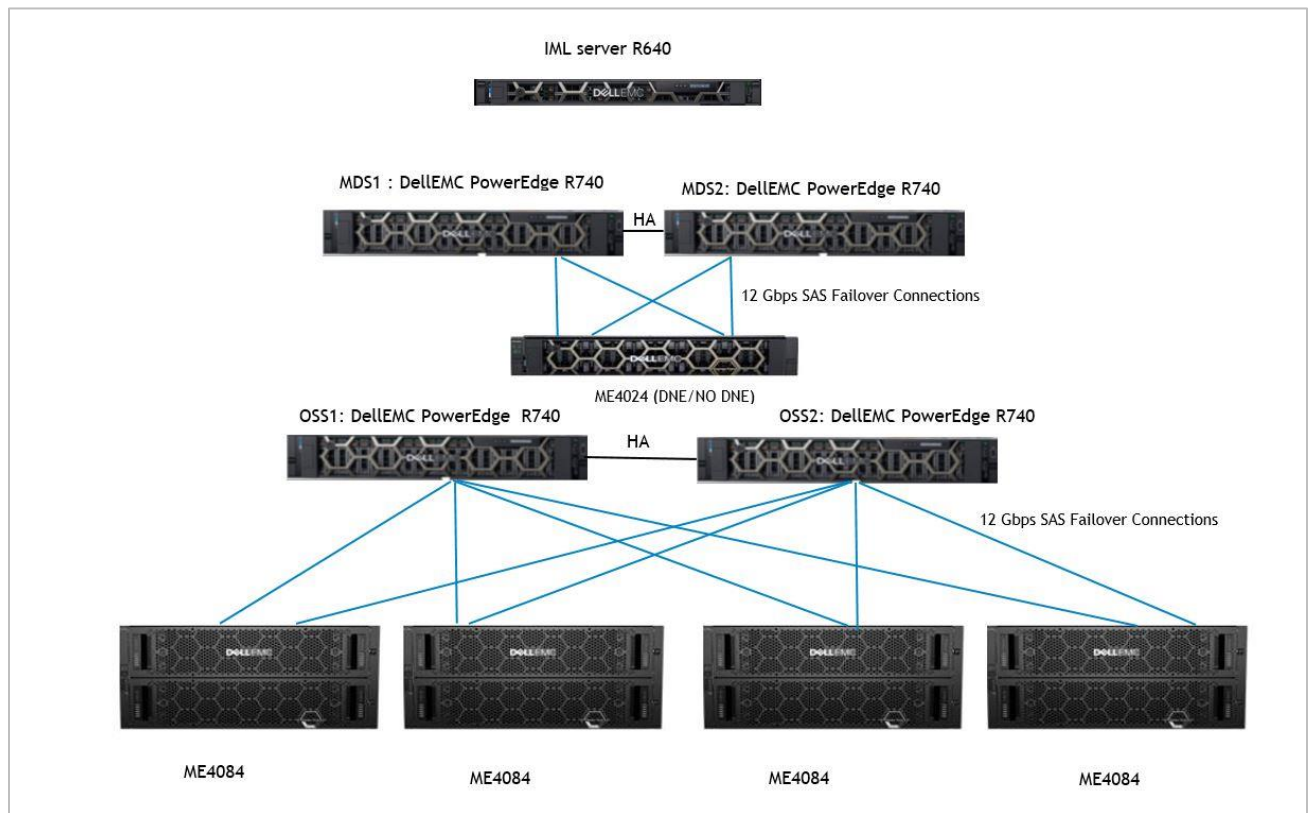


Figure 3 Dell EMC Ready Solution for Lustre Storage Reference Architecture

## 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 will also be used for IPMI hardware management. For infrastructure and storage servers, the iDRAC Enterprise ports may be connected to this network for OOB server management. The management network typically uses the Dell Networking S3048-ON Ethernet switch. If there is more than one switch in the system, multiple switches should 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 an EDR InfiniBand fabric. The fabric will typically be assembled using Mellanox SB7890 36-port EDR 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 Solution for HPC Digital Manufacturing is available with full hardware support and deployment services, including additional HPC system support options.

### 3 Reference System

The reference system was assembled in the Dell EMC HPC and AI Innovation Lab using the building blocks described in section 2. The building blocks used for the reference system are listed in Table 2.

Table 2 Reference System Configuration

Building Block	Quantity
Infrastructure Server	1
Computational Building Block (CBB) PowerEdge C6420 Dual Intel Xeon Gold 6242 192GB RAM 12x16GB 2933 MTps DIMMs Mellanox ConnectX-5 EDR adapter	2
Computational Building Block (CBB) PowerEdge C6420 Dual Intel Xeon Gold 6252 192 GB RAM 12x16GB 2933 MTps DIMMs Mellanox ConnectX-5 EDR adapter	8
Basic Building Block	2
Dell Networking S3048-ON Ethernet Switch	1
Mellanox SB7700 EDR InfiniBand Switch	1

The BIOS configuration options used for the reference system are listed in Table 3.

Table 3 BIOS Configuration

BIOS Option	Setting
Logical Processor	Disabled
Virtualization Technology	Disabled
System Profile	Performance Profile
Sub NUMA Cluster	Enabled (CBB) Disabled (BBB)

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

Table 4 Software Versions

<b>Component</b>	<b>Version</b>
Operating System	RHEL 7.6 Windows Server 2016 (BBB)
Kernel	3.10.0-957.el7.x86_64
OFED	Mellanox 4.5-1.0.1.0
Bright Cluster Manager	8.2
LS-DYNA	R10.1 AVX2 Single-Precision
Intel MPI	2018u4

## 4 LSTC LS-DYNA Performance

LSTC LS-DYNA is a multi-physics Finite Element Analysis (FEA) software commonly used in multiple engineering disciplines. Depending on the specific problem types, FEA codes may or may not scale well across multiple processor cores and servers. The two benchmark problems presented here use the LS-DYNA explicit FEA solver, which typically scales much more efficiently than the implicit FEA solver.

The car2car benchmark is a simulation of a two-vehicle collision. This benchmark model contains 2.4 million elements, which is relatively small compared to current automotive industry usage. The ODB-10M benchmark is a simulation of a vehicle colliding into an offset deformable barrier. This benchmark model contains 10.6 million elements, which is similar to current automotive industry usage. For these benchmarks, the simulation end time was set to 0.02 sec. The performance for LS-DYNA is measured using the Elapsed Time metric. This metric is the total elapsed time in seconds as reported by LS-DYNA, so a smaller elapsed time is better performance.

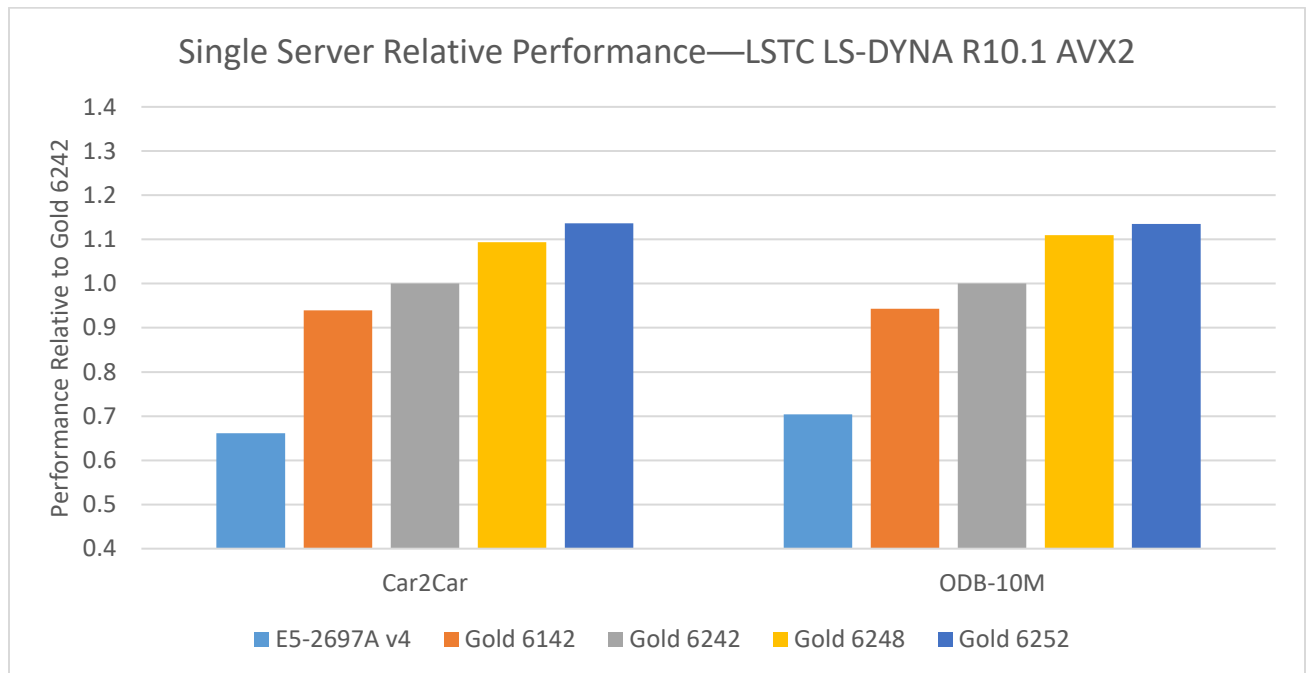


Figure 4 Single Server Relative Performance—LSTC LS-DYNA R10.1 AVX2

The results in Figure 4 are plotted relative to the performance of a single server configured with Intel Xeon Gold 6242 processors. For comparison, the figure also includes performance data for prior generations of the Ready Solution for HPC Digital Manufacturing. This includes the 14G CBB with Intel Xeon Gold 6142 processors and the 13G CBB with 16-core Intel Xeon E5-2697A v4 processors. Higher results indicate better overall performance. These results show the performance advantage available with 14G servers with 2<sup>nd</sup> generation Intel Xeon Scalable processors (code name Cascade Lake). The Intel Xeon Gold 6242 and 6248 processors provide very good performance for these benchmarks, while the Intel Xeon Gold 6252 offers a small performance advantage over the Gold 6248.

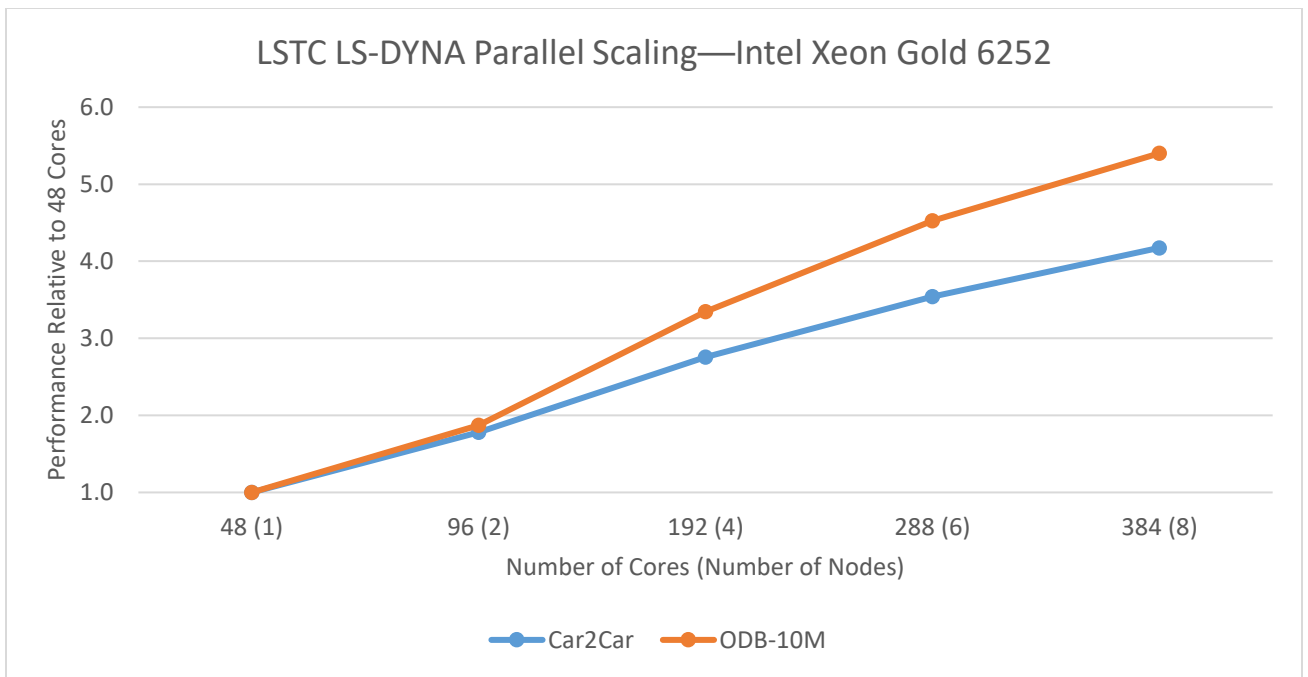


Figure 5 LSTC LS-DYNA Parallel Scaling—Intel Xeon Gold 6252

Figure 5 presents the parallel scalability when running LS-DYNA using up to eight CBB nodes configured with Intel Xeon Gold 6252 processors. The performance is presented relative to the performance of a single node (48 cores total).

The parallel scalability for these models is as expected, with the larger ODB-10M model demonstrating better scalability than the Car2Car benchmark model.

## 5 Conclusion

This technical white paper presents the Dell EMC Ready Solution for HPC Digital Manufacturing. 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 system performance with LSTC LS-DYNA.