Faster Innovation – Accelerating SIMULIA Abaqus Simulations with NVIDIA GPUs

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Accelerated Computing, NVIDIA

AGENDA

- Engineering & IT Challenges/Trends
- NVIDIA GPU Solutions
- Abaqus GPU Computing
- Power Consumption
- Which GPUs & Systems for CAE ?
- Remarks
- Q & A

ENGINEERING & IT CHALLENGES/TRENDS

Simulation Turn-around Time

Short Compute Time

Access Anytime, Anywhere

IT Infrastructure

Centralize Compute & Storage Assets

Faster Deployment

Lower Total Cost of Ownership

IP Protection

AGENDA

NVIDIA GPU SOLUTIONS

Visualization, Accelerated Computing & Virtualization

QUADRO
Revolutionizing Design &
Visualization

TESLA
Accelerating Momentum in
HPC and Big Data Analytics

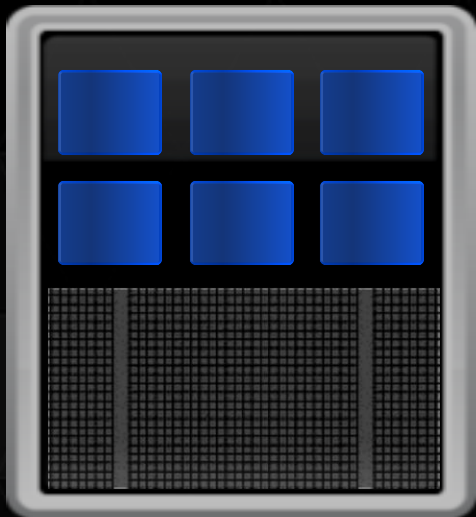**GRID**
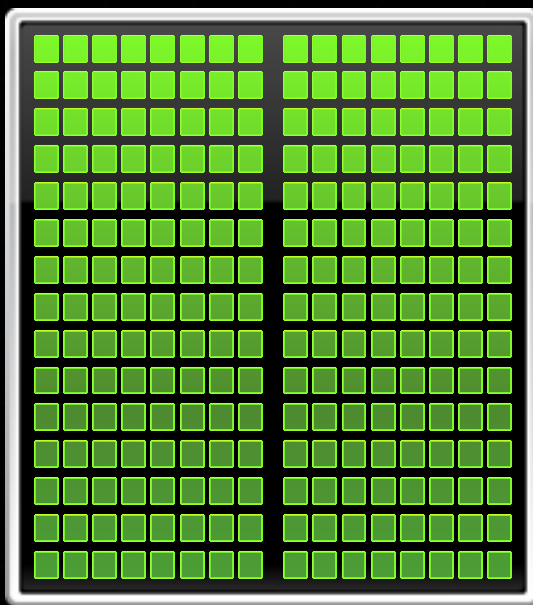Enabling End-to-End
Enterprise Virtualization

HOW DO GPUS BENEFIT SIMULATIONS ?

Efficient handling of parallel tasks in matrix solutions

GPU Accelerator
Optimized for
Parallel Tasks

CPU
Optimized for
Serial Tasks

+

2-3X

application speed-up when
paired up with a CPU

WHY TESLA GPU ?

Powerful Accelerators

Performance

Faster DP Performance

Larger Memory

Reduces CUDA Kernel Overload

HPC Solutions

Longer Life-Cycle

Form Factor

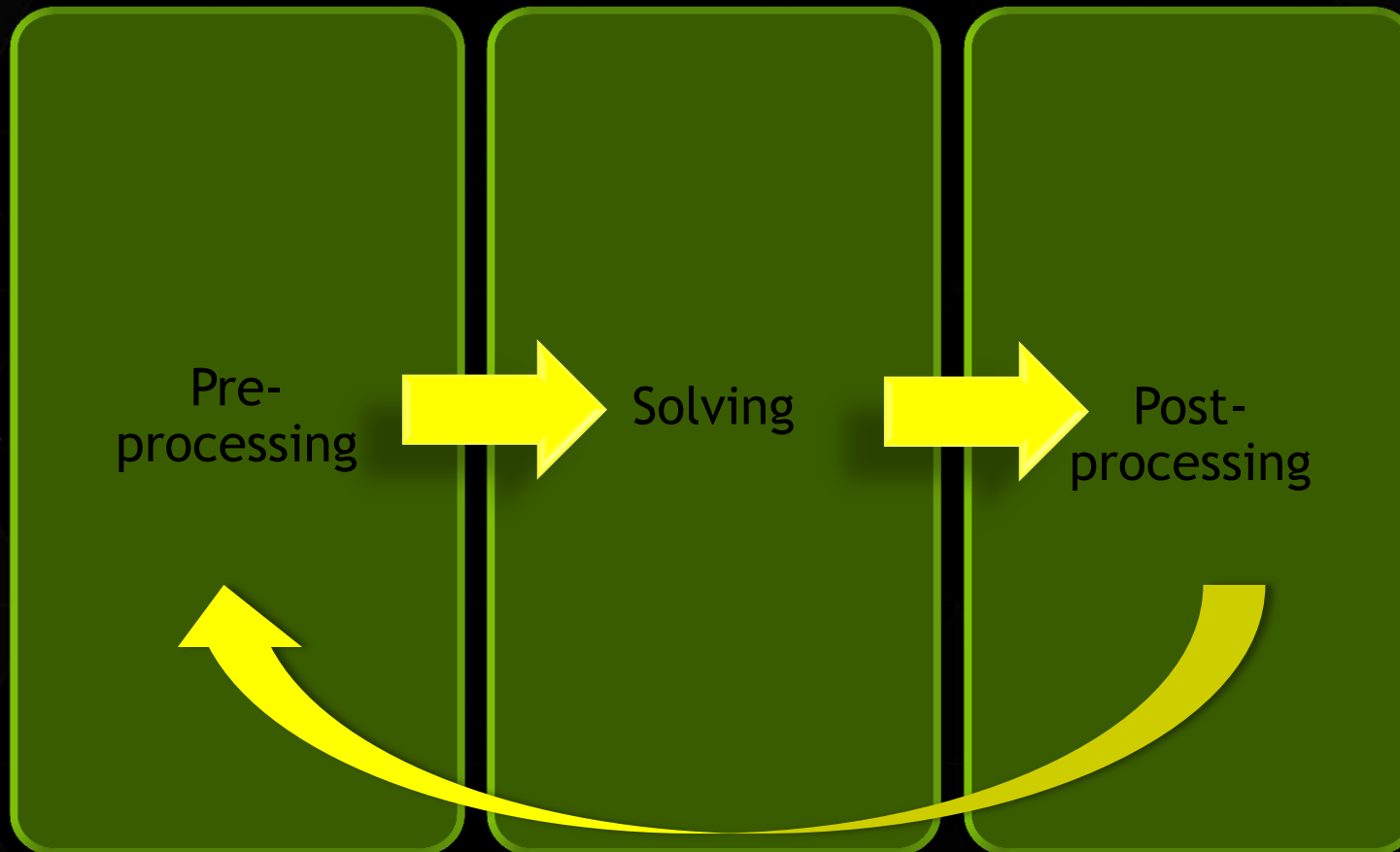Cluster Management

GPU Monitoring
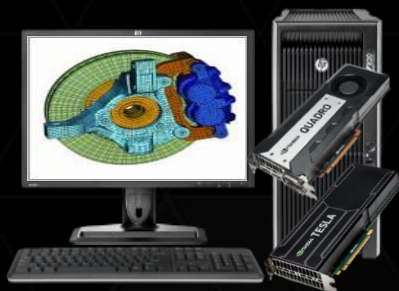
Data Reliability

ECC Protection

Zero-error Stress Tested
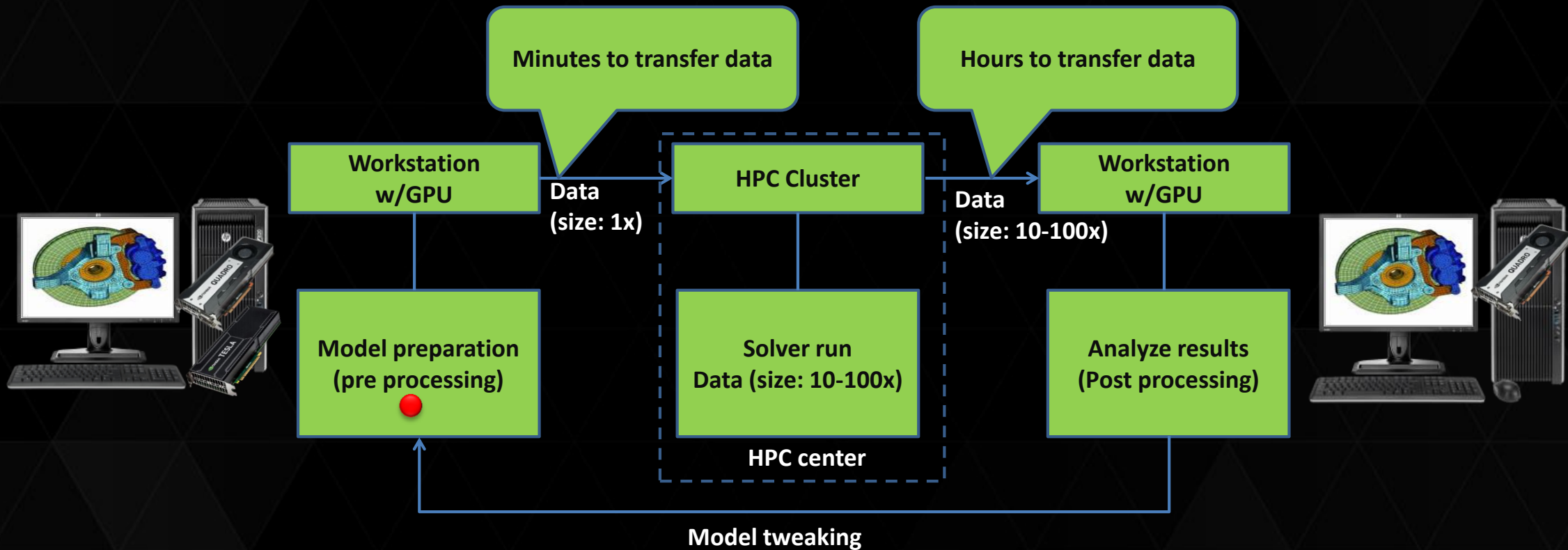
ISV Certification

NVIDIA Support

CAE WORKFLOW

Workstation Computing

Pre-processing → Solving → Post-processing

CAE WORKFLOW

Workstation + Server/Cluster Computing

Minutes to transfer data

Hours to transfer data

| Workstation w/GPU | Data (size: 1x) → | HPC Cluster | Data (size: 10-100x) → | Workstation w/GPU |

Model preparation (pre processing)

Solver run Data (size: 10-100x)

HPC center

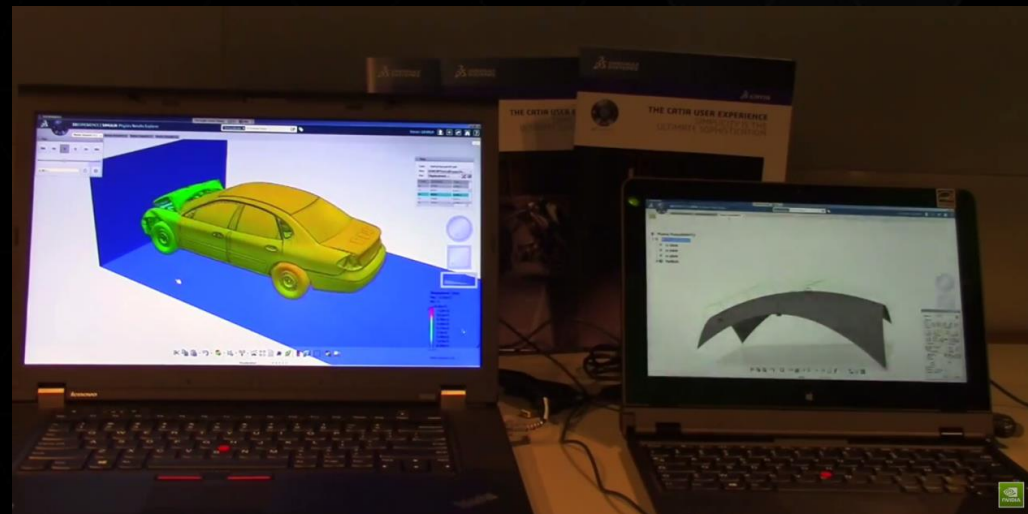**Analyze results (Post processing)**

Model tweaking

Traditional workflow

DASSAULT SYSTÈMES & NVIDIA GRID

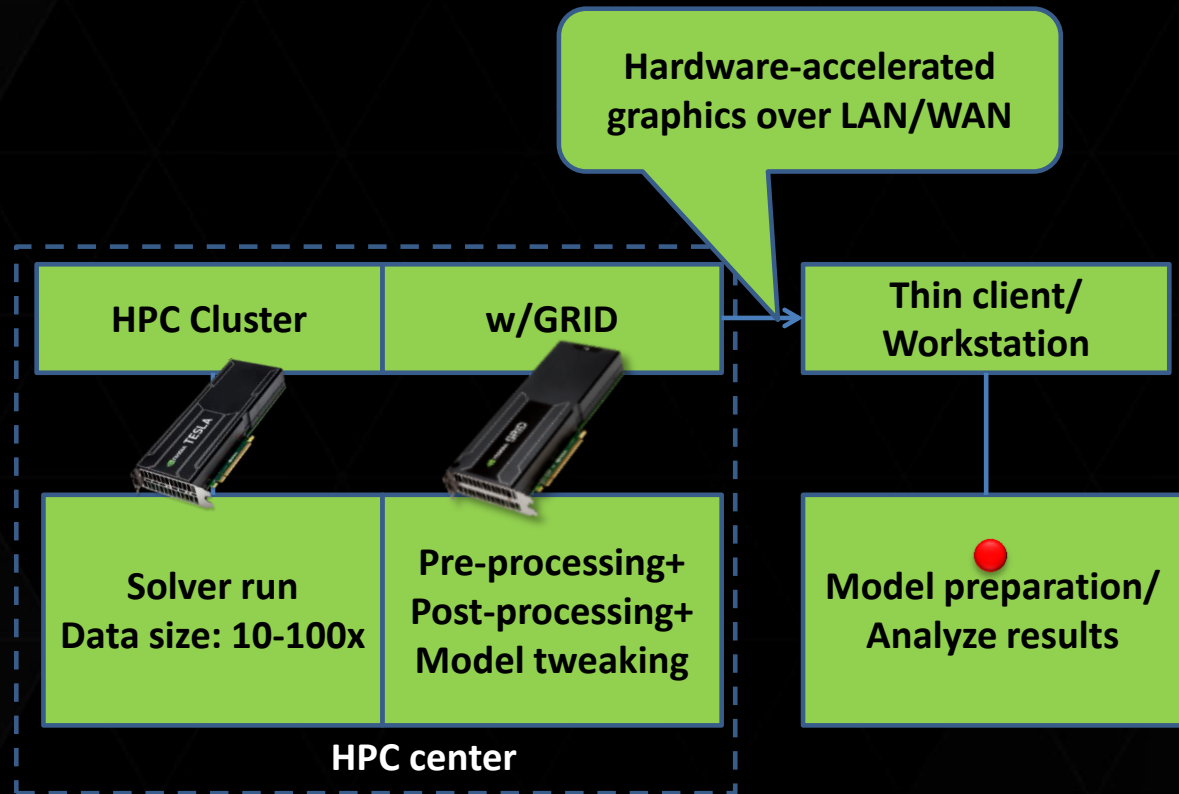## Visualizing complex industrial design from a continent away

- ▶ Showcase of a Proof Of Concept at SIGGRAPH 2014 with NVIDIA

- ▶ Remote graphics from DS Cloud with GRID K2 with H264 HW encoding

- ▶ Real-time interactive crash test visualization with no data transport integrated into the 3DEXPERIENCE platform

http://blogs.nvidia.com/blog/2014/08/21/visualizing-complex-industrial-design-from-a-continent-away/#sthash.NEMQyf6F.dpuf

CAE WORKFLOW WITH NVIDIA GRID

Remote Client + Server Computing

Hardware-accelerated graphics over LAN/WAN

HPC Cluster	w/GRID

Solver run Data size: 10-100x	Pre-processing+ Post-processing+ Model tweaking

HPC center

Thin client/ Workstation

Model preparation/ Analyze results

AGENDA

- Engineering & IT Challenges/Trends

- NVIDIA GPU Solutions

- Abaqus GPU Computing

- Power Consumption
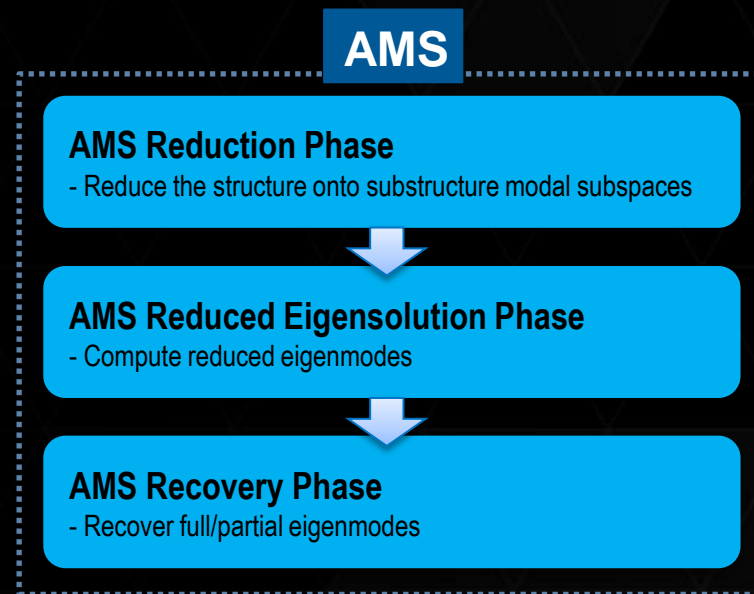
- Which GPUs & Systems for CAE ?

- Remarks

- Q & A

ABAQUS/STANDARD GPU COMPUTING

	2011	2012	2013	2014
Abaqus Release	6.11	6.12	6.13	6.14
GPU Acceleration	Direct Sparse solver Single GPU	Multi-GPU/node Multi-node DMP clusters Flexibility to run jobs on specific GPUs	Un-symmetric Sparse Solver	Direct Sparse solver DMP Split, less memory AMS Solver Reduced Eigen Phase
GPUs	Tesla 20-series Quadro 6000	Fermi + Kepler Hotfix	Tesla K20/K20X/K40	Tesla K20/K20X/K40/K80

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ABAQUS/STANDARD GPU COMPUTING

- Abaqus 6.14, July 2014

  - Direct Sparse Solver

    - Relaxation of memory requirements for GPU

    - Improved performance / DMP split

  - AMS eigensolver

    - Reduced eigen solution phase

- Abaqus 2016, Fall 2015

  - AMS: Reduction Phase

  - Mode-based steady state dynamics

AMS: Automatic Multi-level Substructuring

AMS

AMS Reduction Phase
- Reduce the structure onto substructure modal subspaces

AMS Reduced Eigensolution Phase
- Compute reduced eigenmodes

AMS Recovery Phase
- Recover full/partial eigenmodes

ABAQUS 6.14 GPU SUPPORT

Supported & recommended features

- General, Linear, and Nonlinear Analyses
  - Static Stress & Displacement
  - Dynamic Stress & Displacement
  - Heat transfer (steady-state & transient)
  - Multi-Physics
    - Thermo-electrical-structural
    - Pore-fluid flow-mechanical-thermal

- Linear Perturbation Analysis
  - Static Stress & Displacement
    - Linear Static
  - Dynamic Stress & Displacement
    - Steady-state dynamics (direct)

ABAQUS 6.14 GPU SUPPORT

Supported & recommended features

▸ Solution Techniques

  ▸ Parallel execution on both shared memory & distributed memory parallel (cluster) systems

  ▸ Parallel direct sparse solver with dynamic load balancing

  ▸ Parallel AMS eigenvalue solution

  ▸ GPGPU-accelerated sparse solver

▸ Abaqus/AMS

  ▸ High-performance automatic multi-level substructuring eigensolver

ABAQUS GPU LICENSING

A single GPU board is treated as one core for token count

▸ 5 tokens unlocks a single CPU core

▸ 1 additional token unlocks additional CPU core <u>OR</u> unlocks 1 entire GPU
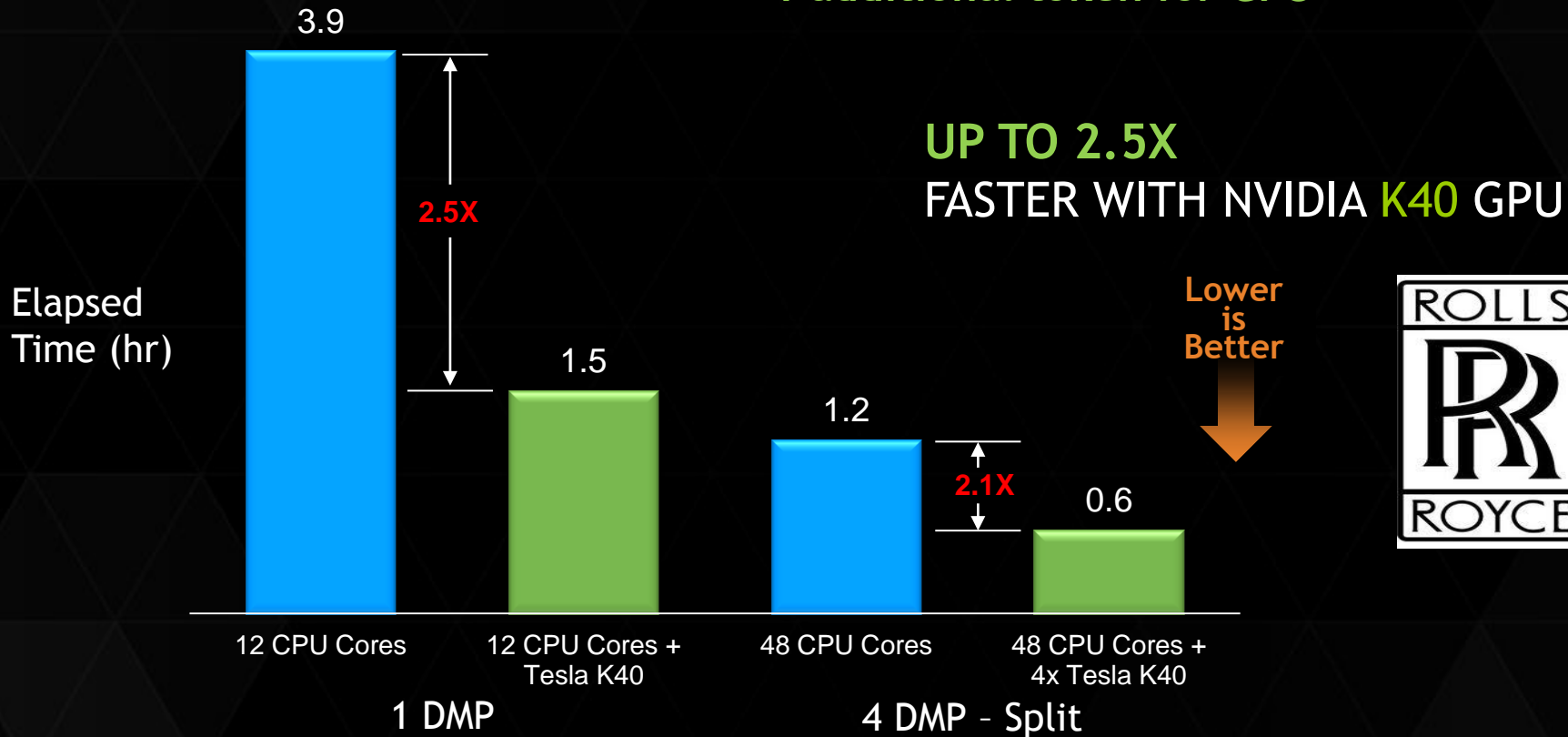
▸ GPUs help in reducing consumption of licensing tokens

* # of Tokens = INT(5*cores^0.422)

Cores	CPU Tokens*	GPU	GPU Tokens* (1)	GPU	GPU Tokens* (2)
1	5	1	6	2	7
2	6	1	7	2	8
3	7	1	8	2	9
4	8	1	9	2	10
5	9	1	10	2	11
6	10	1	11	2	12
7	11	1	12	2	12
8 (1 CPU)	12	1	12	2	13
9	12	1	13	2	13
10	13	1	13	2	14
11	13	1	14	2	14
12	14	1	14	2	15
13	14	1	15	2	15
14	15	1	15	2	16
15	15	1	16	2	16
16 (2 CPUs)	16	1	16	2	16

ABAQUS PERFORMANCE WITH GPU

No additional tokens for GPU
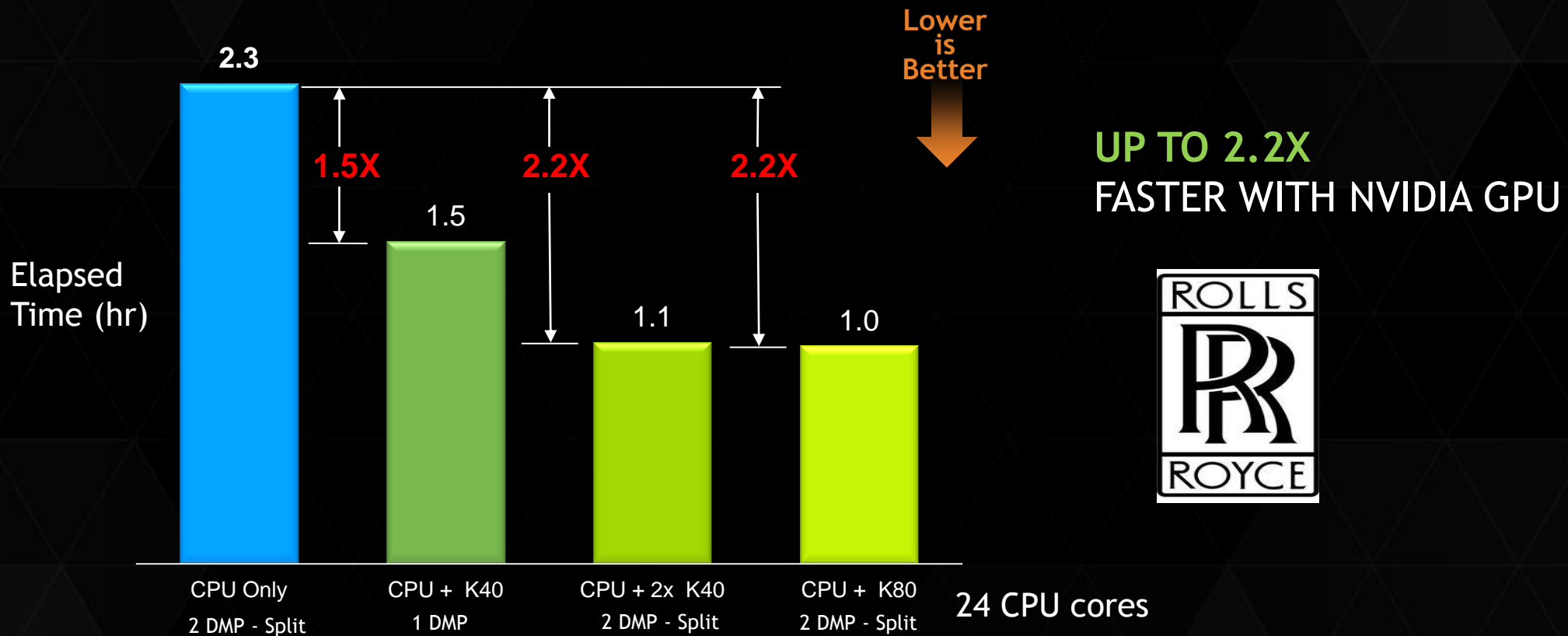
1 additional token for GPU

UP TO 2.5X
FASTER WITH NVIDIA K40 GPU

3.9

2.5X

Elapsed
Time (hr)

Lower
is
Better

1.5

1.2

2.1X

0.6

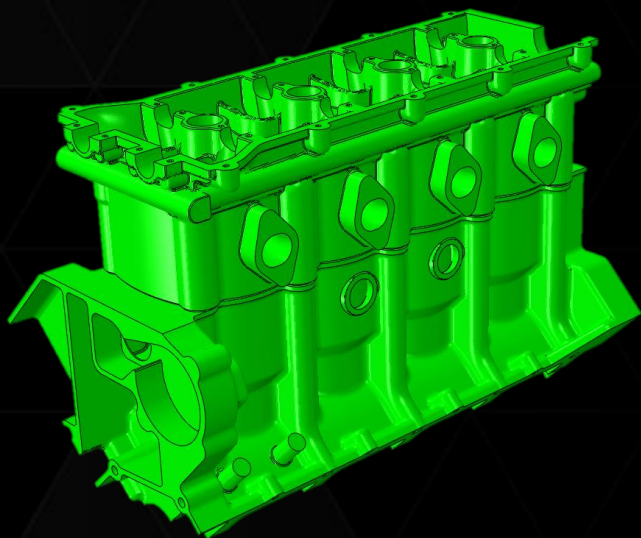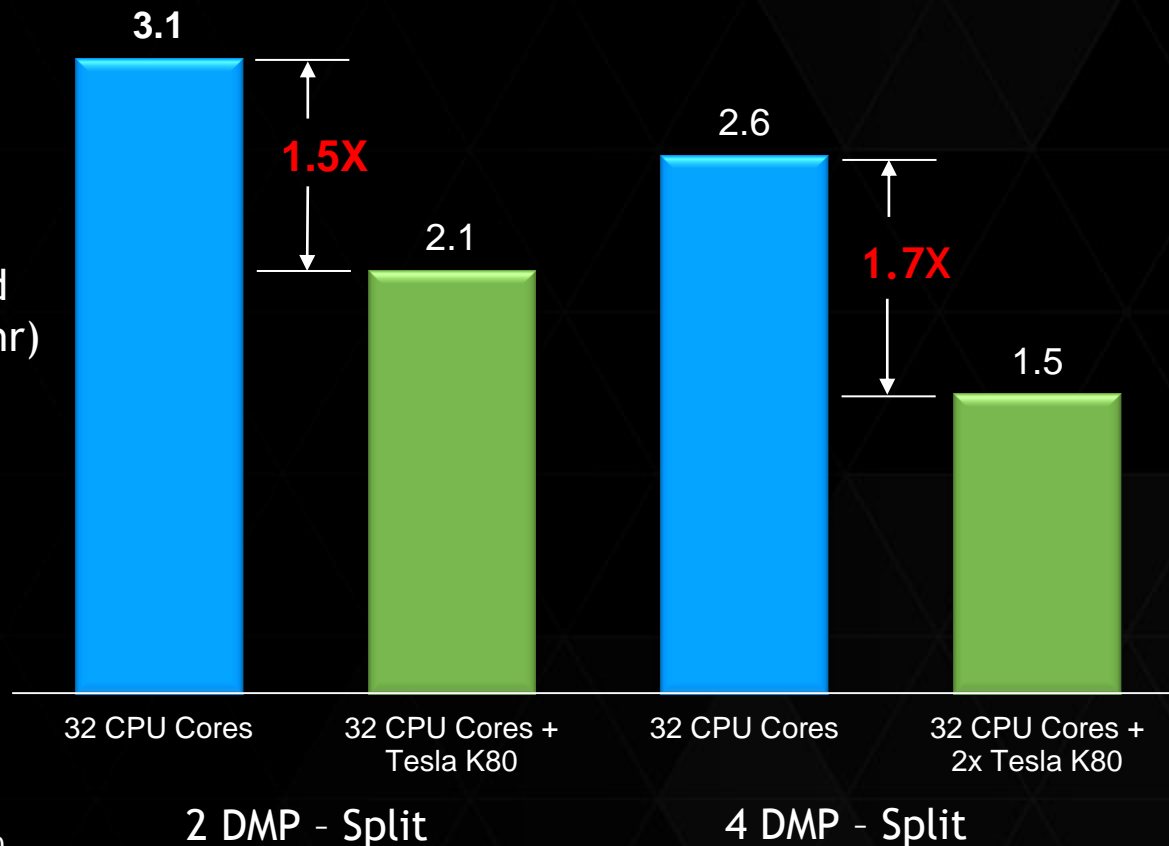| 12 CPU Cores | 12 CPU Cores + Tesla K40 | 48 CPU Cores | 48 CPU Cores + 4x Tesla K40 |

1 DMP

4 DMP – Split

ROLLS ROYCE

Large Model (~77 TFLOPs), 4.71M DOF, Nonlinear Static, Direct Sparse Solver
Abaqus 6.14-2 with Intel Xeon E5-2697v2, 2.70 GHz CPU, 128 GB memory; Tesla K40 GPU

NVIDIA. | hp

ABAQUS PERFORMANCE WITH GPU

Elapsed Time (hr)

Lower is Better

UP TO 2.2X
FASTER WITH NVIDIA GPU

Bar	Value	Speedup
CPU Only 2 DMP - Split	2.3	
CPU + K40 1 DMP	1.5	1.5X
CPU + 2x K40 2 DMP - Split	1.1	2.2X
CPU + K80 2 DMP - Split	1.0	2.2X

24 CPU cores

ROLLS ROYCE

Large Model (~77 TFLOPs), 4.71M DOF, Nonlinear Static, Direct Sparse Solver
Abaqus 6.14-2 with Intel Xeon E5-2697v2, 2.70 GHz CPU, 128 GB memory; Tesla GPUs

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ABAQUS PERFORMANCE WITH GPU

1.7X FASTER WITH NVIDIA K80 GPUs

Elapsed Time (hr)

3.1 — 32 CPU Cores
1.5X
2.1 — 32 CPU Cores + Tesla K80

2 DMP – Split

2.6 — 32 CPU Cores
1.7X
1.5 — 32 CPU Cores + 2x Tesla K80

4 DMP – Split

Model: s4e; 16.7 MDOF, Nonlinear Static, Direct Sparse Solver; Abaqus 6.14 with Intel Xeon Haswell E5-2698v3 (16-core), 2.3 GHz CPU, 256 GB memory; Tesla K80
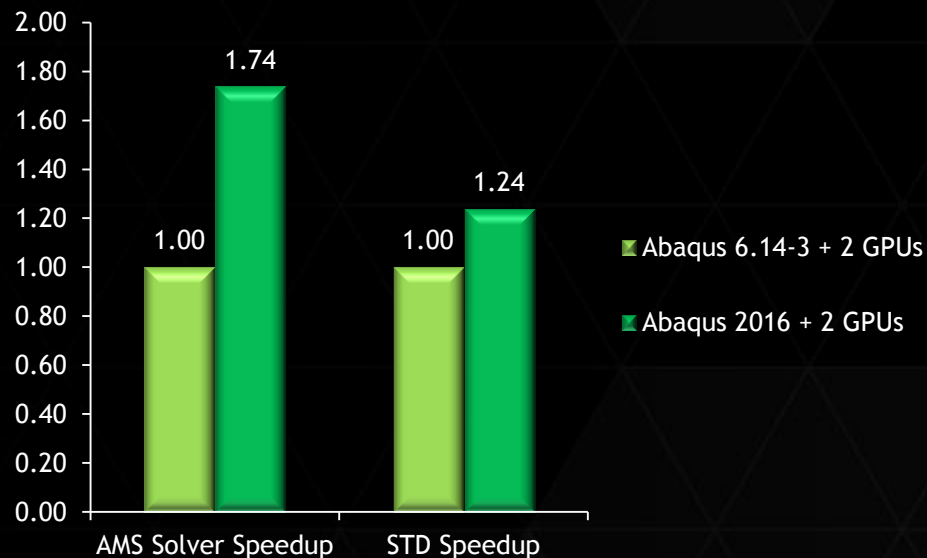
ABAQUS PERFORMANCE WITH GPU

Abaqus/AMS 2016 solver

1.5x faster than v6.14
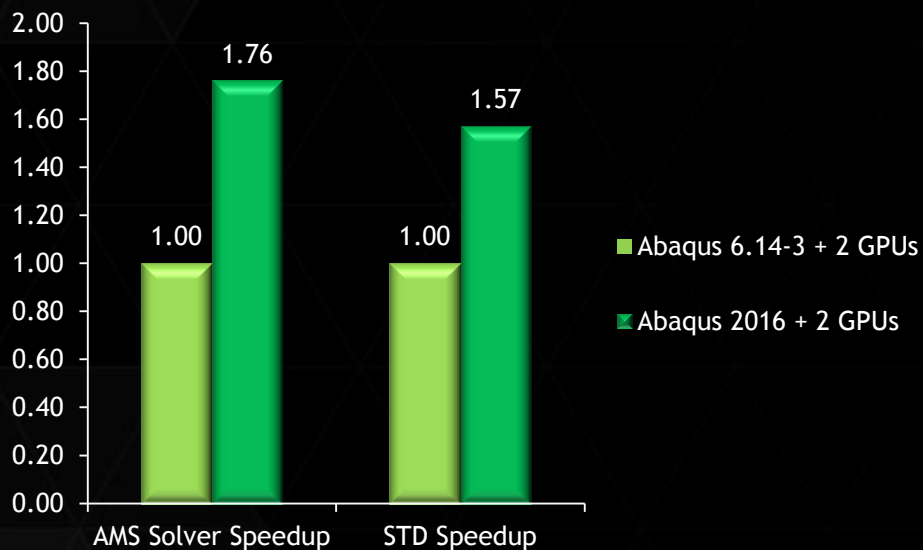
20M DOF and 12k modes

1.2x faster than v6.14

3M DOF and 5k modes

HP ProLiant SL250s Gen8, Intel Xeon Ivy Bridge E5-2680e (2x 10 cores), 2.8 GHz, 192 GB Memory and 2x Tesla K40m GPUs

ABAQUS PERFORMANCE WITH GPU

2 additional tokens for all GPUs

3.0

1.44X

2.1

Elapsed
Time (hr)

CPU   CPU+GPU

43M DOF Auto OEM model
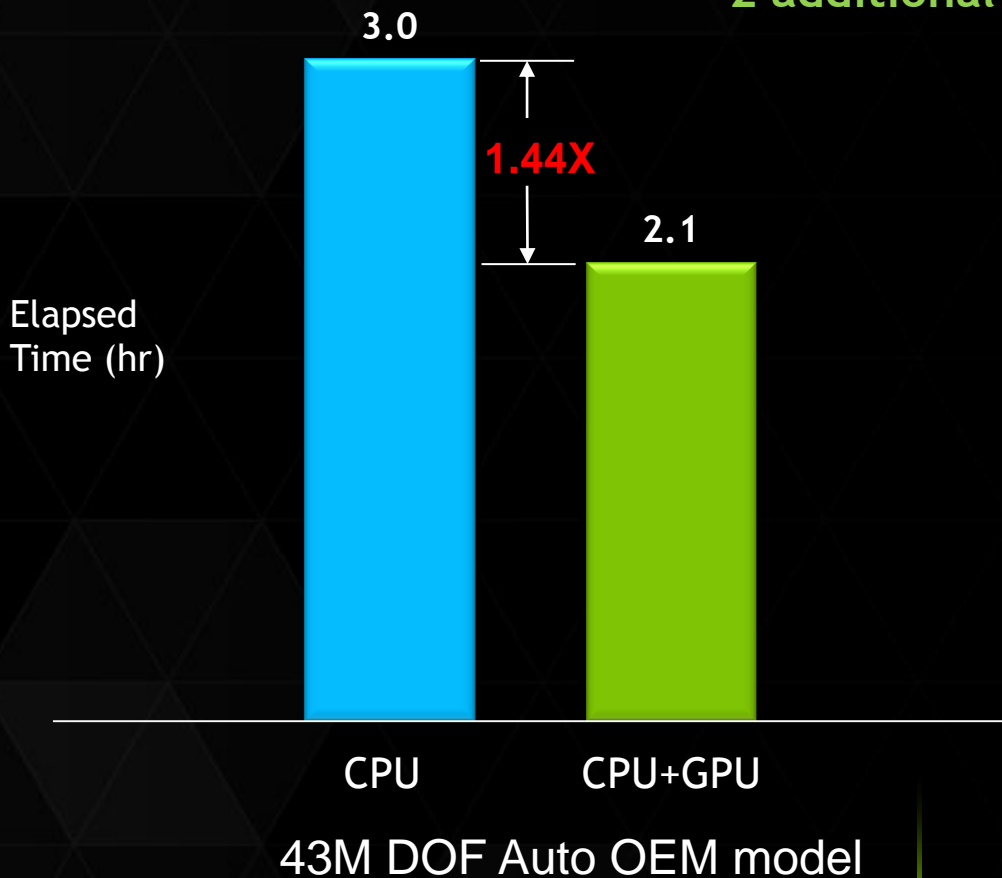
Node 0	Node 1	Node 2	Node 3	Node 4	Node 5
16 core Intel Sandybridge	16 core Intel Sandybridge	16 core Intel Sandybridge	16 core Intel Sandybridge	16 core Intel Sandybridge	16 core Intel Sandybridge
2 x NVIDIA K20m (Kepler)	2 x NVIDIA K20m (Kepler)	2 x NVIDIA K20m (Kepler)	2 x NVIDIA K20m (Kepler)	2 x NVIDIA K20m (Kepler)	2 x NVIDIA K20m (Kepler)
256 GB	256 GB	256 GB	256 GB	256 GB	256 GB

- ▸ 6 compute nodes

- ▸ 2 MPI processes per compute node

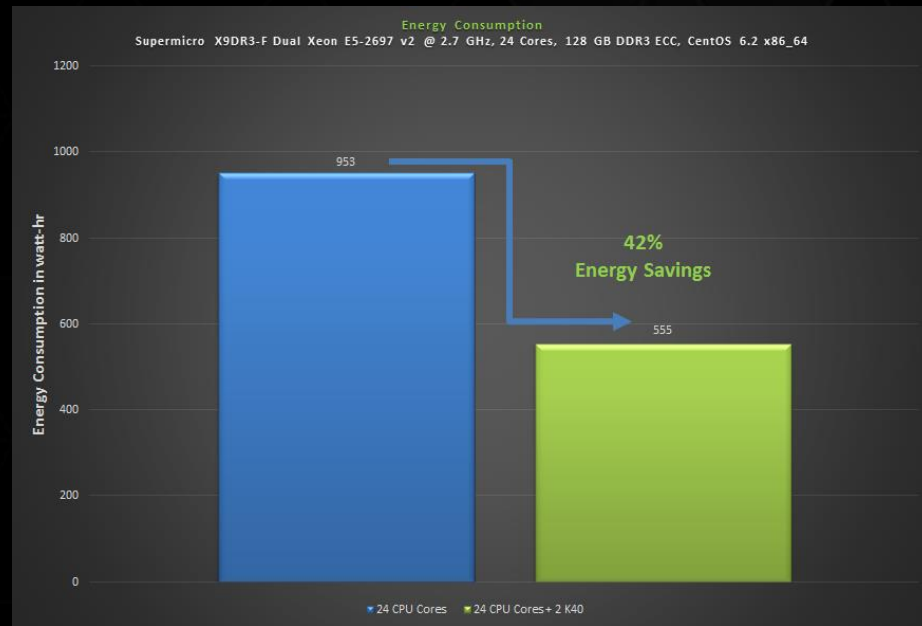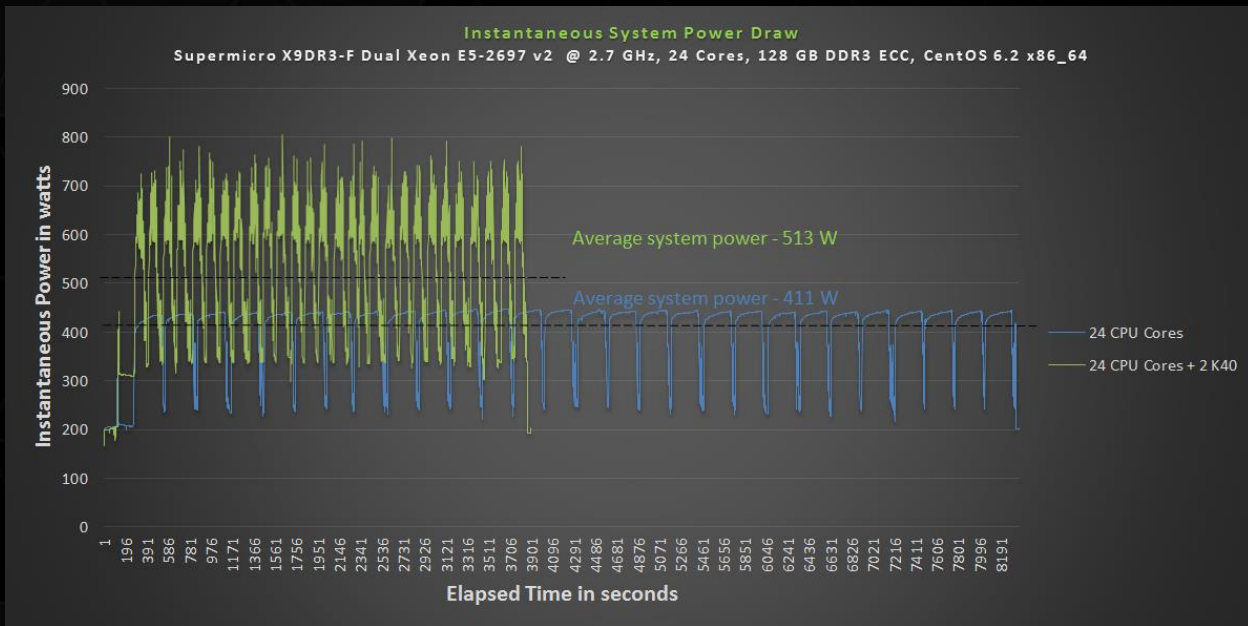- ▸ Accelerated DMP execution mode (an optional feature in 6.14)

AGENDA

POWER CONSUMPTION STUDY

Abaqus 6.14

No additional tokens for 1 or 2 GPUs

Instantaneous System Power Draw
Supermicro X9DR3-F Dual Xeon E5-2697 v2 @ 2.7 GHz, 24 Cores, 128 GB DDR3 ECC, CentOS 6.2 x86_64

Average system power – 513 W
Average system power – 411 W

24 CPU Cores
24 CPU Cores + 2 K40

Energy Consumption
Supermicro X9DR3-F Dual Xeon E5-2697 v2 @ 2.7 GHz, 24 Cores, 128 GB DDR3 ECC, CentOS 6.2 x86_64

953
555

42% Energy Savings

24 CPU Cores
24 CPU Cores + 2 K40

▷ Adding GPUs to a CPU-only node resulted in a **2.2x** speed-up while reducing energy consumption by **42%**

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NVIDIA GPU FOR CAE

	Workstations	Clusters / Servers
Visualization	Quadro K-Series	Tesla K20X*, K40, GRID K2
Computing	Tesla K20, K40 Quadro K6000	Tesla K20, K20X, K40, K80
Remote Visualization	Quadro K6000	Tesla K20*, K20X*, K40, K80, GRID K2
Virtualization	GRID K2, K6000	GRID K2, K6000

* Passively cooled GPUs only; GOM(Graphics-Only Mode) needs to be enabled

HP SYSTEMS WITH NVIDIA GPU FOR COMPUTING

HP ProLiant Gen9 servers

HP Apollo 2000	HP Apollo 6000	HP Apollo 8000
Scalable Multi-node	**Rack-scale Efficiency**	**Performance Density**

HP ProLiant XL190r
2x NVIDIA K40

HP ProLiant XL250a
2P + 2x NVIDIA Tesla K40 or K80

HP ProLiant XL750f
2P + 2 NVIDIA Tesla K40 XL (K40d)

HP COMPUTERS WITH NVIDIA GPU FOR GRAPHICS

HP workstation-class graphics

HP Desktop Workstations	HP Graphics Server Blade	HP Graphics Server Blade with Expansion
High-end graphics & Computing	For Client Virtualization	For Client Virtualization

HP Z840
Up to 2x NVIDIA Tesla K40
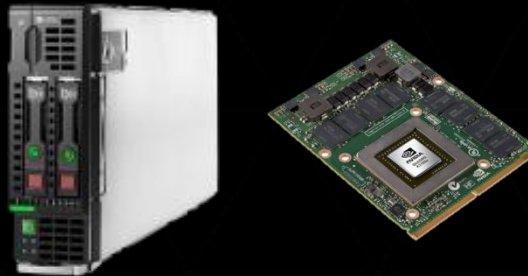
HP ProLiant WS460c Gen9
up to 6x NVIDIA Quadro K3100M

HP ProLiant WS460c Gen9
NVIDIA Quadro K6000/K5000/K4000,
GRID K2/K1

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ABAQUS GPU COMPUTING

- ▸ GPU Support for Abaqus/Standard since 2011 (v6.11)

- ▸ Current supported version: Abaqus 6.14 Refresh3

- ▸ Broad range of analysis types

- ▸ Multiple and selective GPU support

- ▸ Multi-GPU/node; multi-node DMP clusters

- ▸ Abaqus/AMS

- ▸ Abaqus GPU licensing based on tokens

  - ▸ Fewer consumption of tokens

- ▸ Performance gains vary

  - ▸ 2-3x speed-ups are common with large, solid models
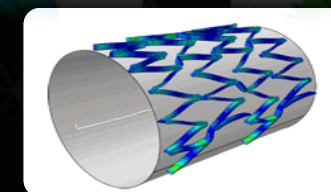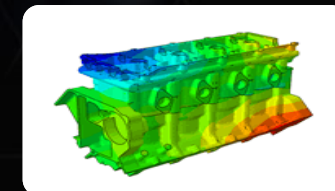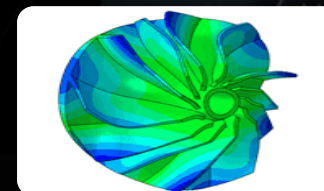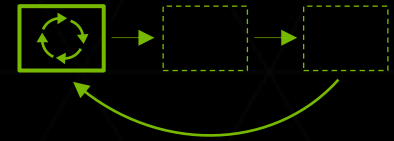
NVIDIA BENEFITS FOR ABAQUS USERS

Increased Throughput with Faster Simulation Runs

Fewer Simulation Runs for Solution Convergence

Improved Team/Supplier Collaboration

Move Simulation Early in Design Cycle

ABAQUS TEST DRIVE

www.accelerateabaqusongpu.com

- **HP ProLiant SL250s Gen8 Server & NVIDIA Tesla GPUs**

- 16 cores (2x 8-core E5-2600 Sandy Bridge), 128GB, 2x NVIDIA K20

Thank you
Q & A

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