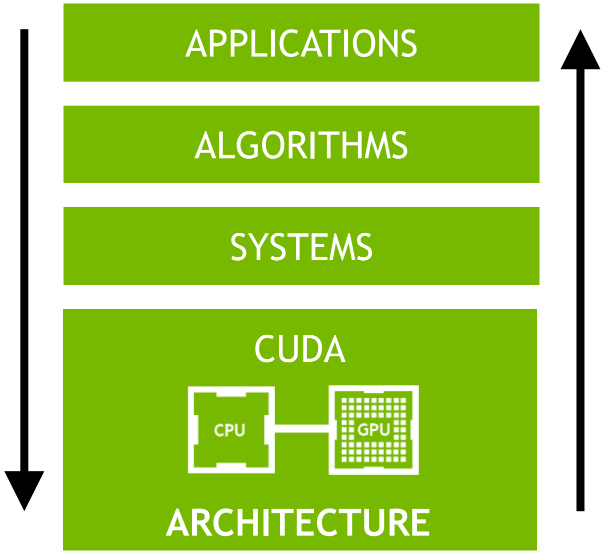
GPU COMPUTING

What’s now ?

NVIDIA

Guillaume BARAT
gbarat@nvidia.com
EMEA Higher-Education & Research

RISE OF GPU COMPUTING



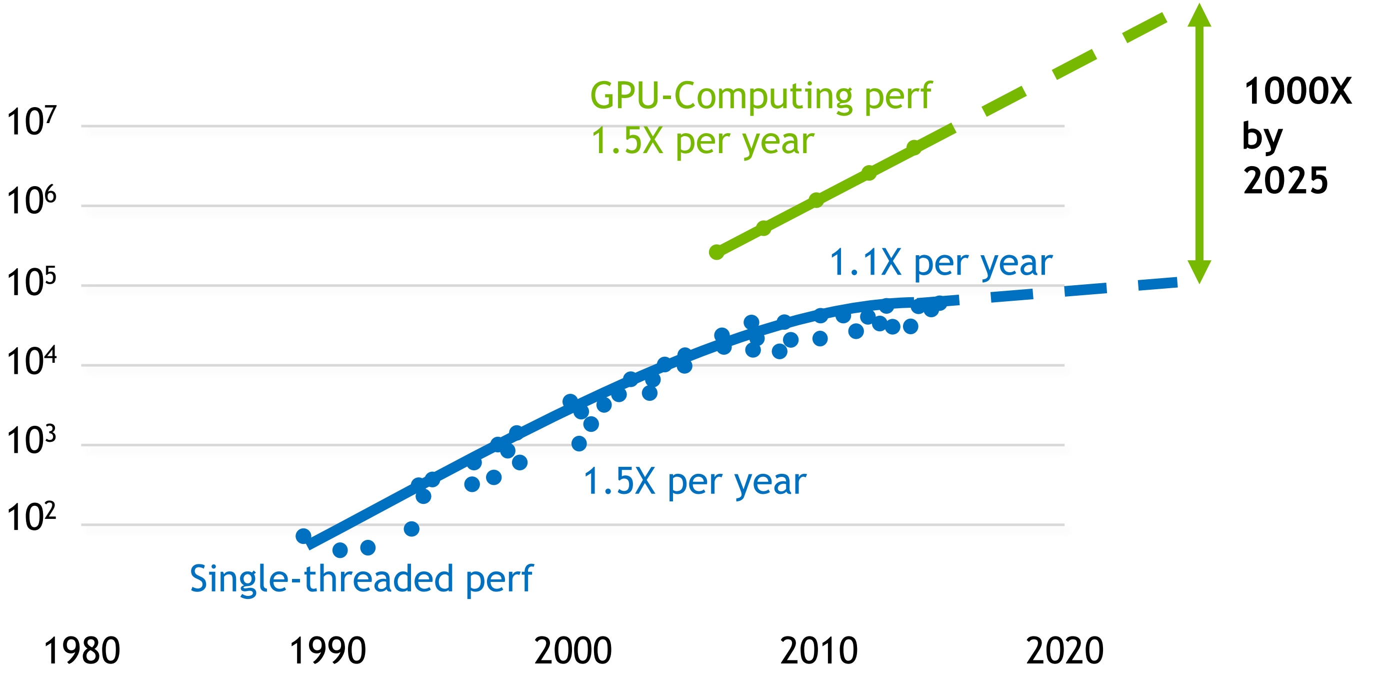
APPLICATIONS

ALGORITHMS

SYSTEMS

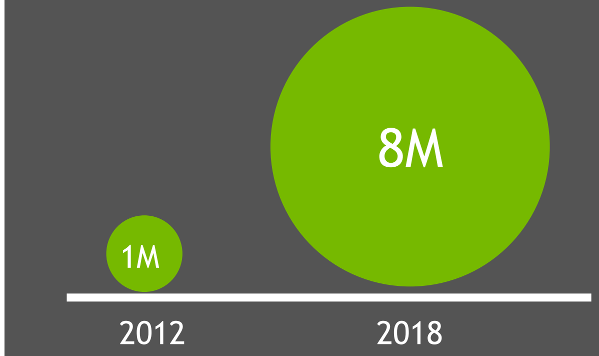
CUDA

ARCHITECTURE



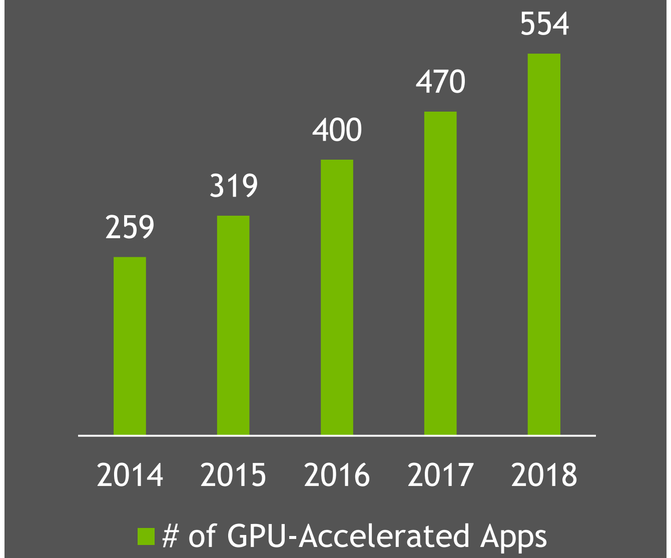
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten New plot and data collected for 2010-2015 by K. Rupp

MOST ADOPTED PLATFORM FOR ACCELERATING HPC



8X CUDA DOWNLOADS

550+ Applications Accelerated



ALL TOP 15 APPLICATIONS ACCELERATED

OAK RIDGE SUMMIT
US’s next fastest supercomputer
200+ Petaflop HPC; 3+ Exaflop of AI

ABCI Supercomputer (AIST)
Japan’s fastest AI supercomputer

Piz Daint
Europe’s fastest supercomputer

DEFINING THE NEXT GIANT WAVE IN HPC

GPU-ACCELERATED HPC APPLICATIONS

550+ APPLICATIONS

LIFE SCIENCES

50+ app

Including:
- Gaussian
- VASP
- AMBER
- HOOMD-Blue
- GAMESS

MFG, CAD, & CAE

111 apps

Including:
- Ansys Fluent
- Abaqus SIMULIA
- AutoCAD
- CST Studio Suite

PHYSICS

25 apps

Including:
- QUDA
- MILC
- GTC-P

OIL & GAS

18 apps

Including:
- RTM
- SPECFEM 3D

CLIMATE & WEATHER

3 apps

Including:
- Cosmos
- Gales
- WRF

DEEP LEARNING

38 apps

Including:
- Caffe2
- MXNet
- Tensorflow

MEDIA & ENT.

142 apps

Including:
- DaVinci Resolve
- Premiere Pro CC
- Redshift Renderer

FEDERAL & DEFENSE

14 apps

Including:
- ArcGIS Pro
- EVNI
- SocetGXP

DATA SCI. & ANALYTICS

23 apps

Including:
- MapD
- Kinetica
- Graphistry

SAFETY & SECURITY

19 apps

Including:
- Cyllance
- FaceControl
- Syndex Pro

COMP. FINANCE

16 apps

Including:
- O-Quant Options Pricing
- MUREX
- MISYS

TOOLS & MGMT.

16 apps

Including:
- Bright Cluster Manager
- HPCtoolkit
- Vampir

70% OF THE WORLD’S SUPERCOMPUTING WORKLOAD ACCELERATED

GROMACS

ANSYS Fluent

Gaussian

VASP

NAMD

Simula Abaqus

WRF

OpenFOAM

ANSYS

LS-DYNA

NCBI-BLAST

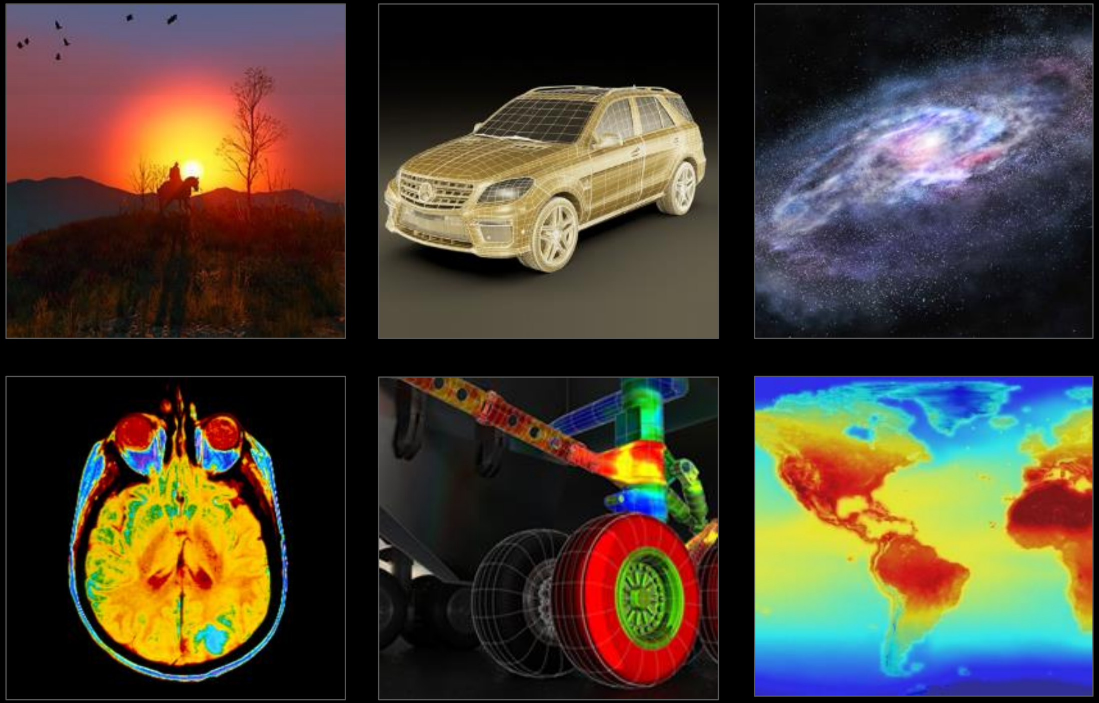
LAMMPS

AMBER

Quantum Espresso

GAMESS

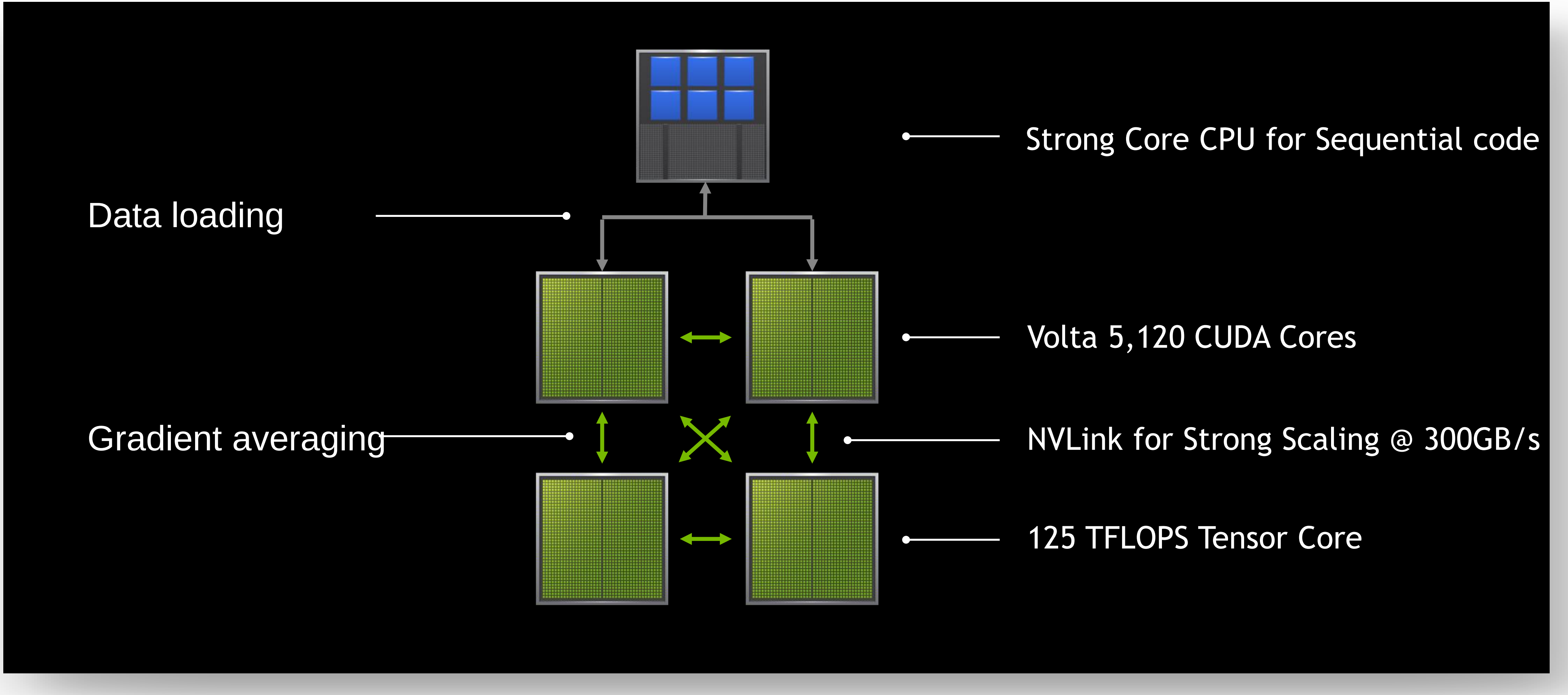
Top 15 HPC Applications



500+ Accelerated Applications

Intersect360, Nov 2017 “HPC Application Support for GPU Computing”

ARCHITECTING MODERN DATACENTERS



Data loading

Gradient averaging

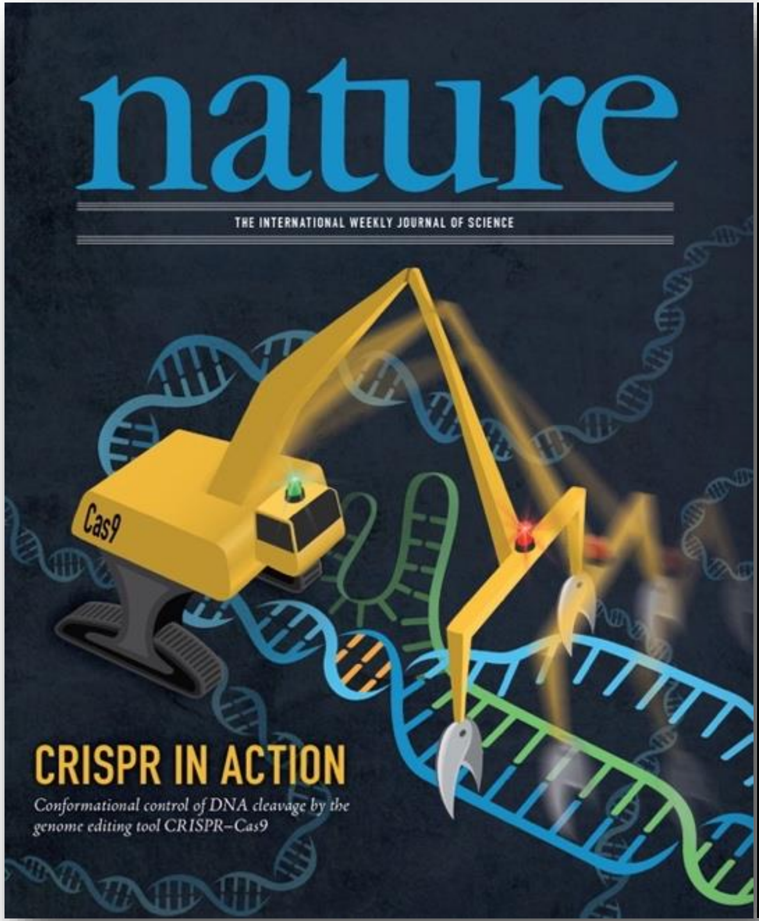
Strong Core CPU for Sequential code

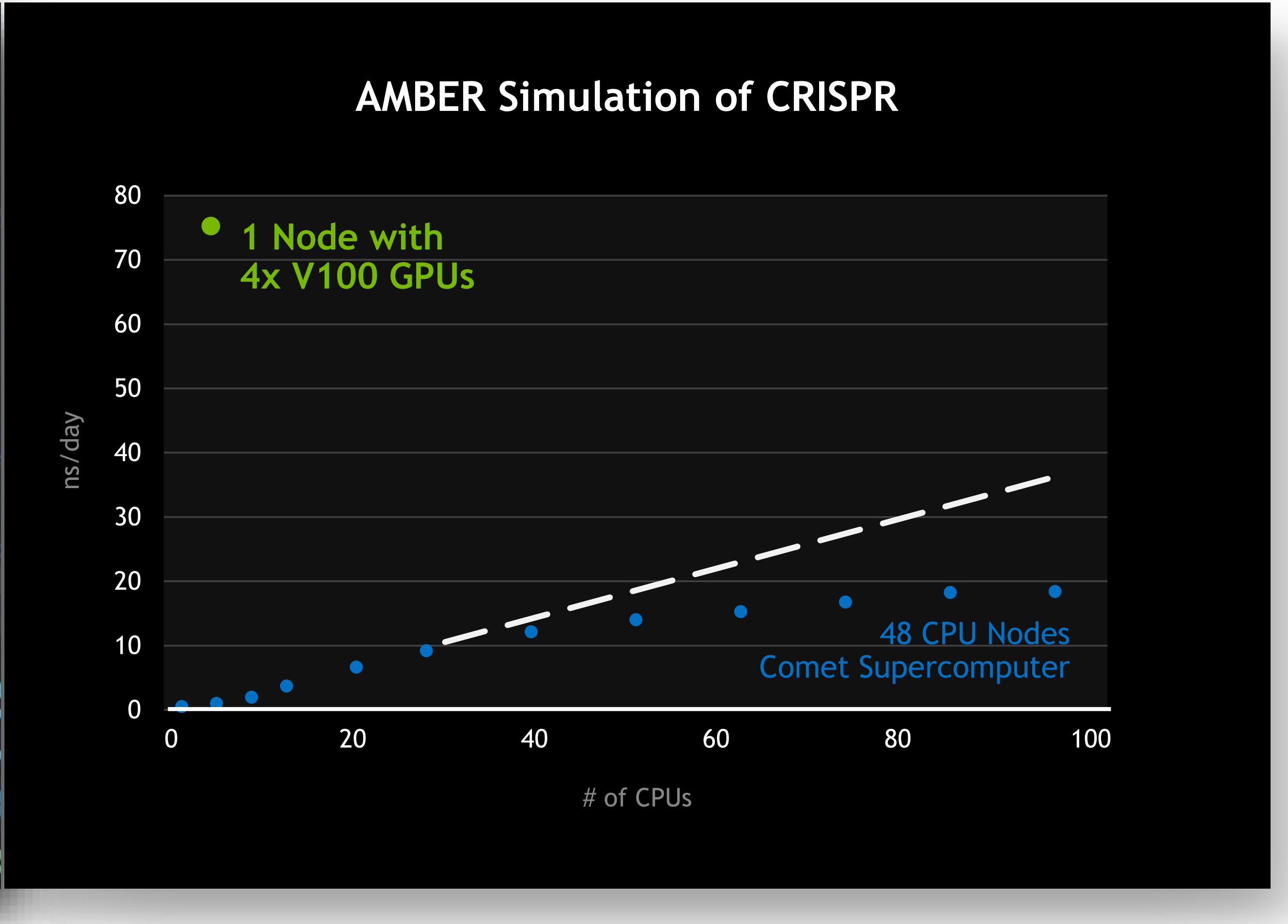
Volta 5,120 CUDA Cores

NVLink for Strong Scaling @ 300GB/s

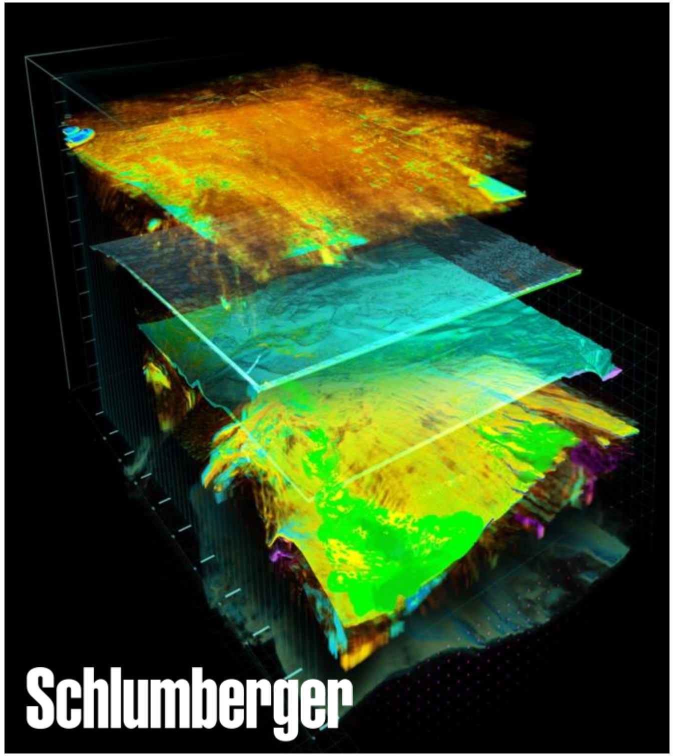
125 TFLOPS Tensor Core

THE POWER OF ACCELERATED COMPUTING


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
Cas9
CRISPR IN ACTION
Conformational control of DNA cleavage by the genome editing tool CRISPR–Cas9

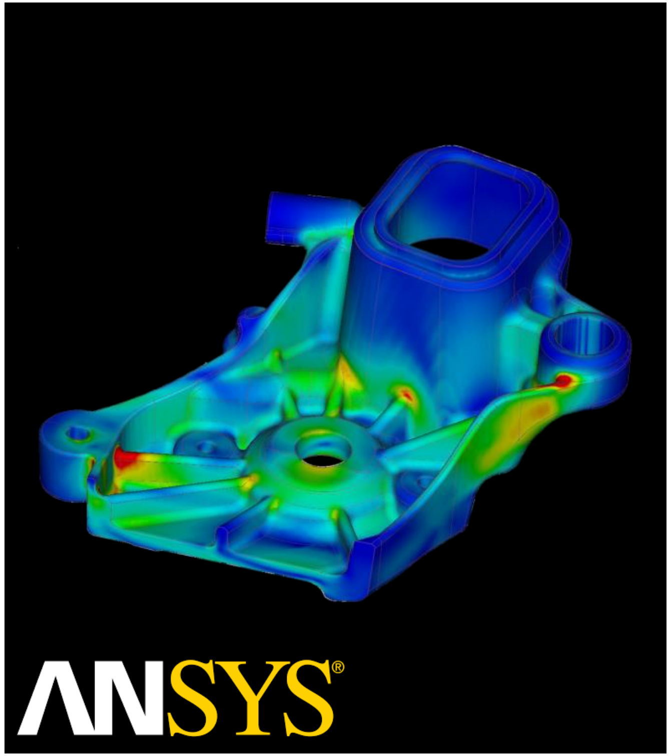

AMBER Simulation of CRISPR

INDUSTRY EMBRACING GPU SUPERCOMPUTING



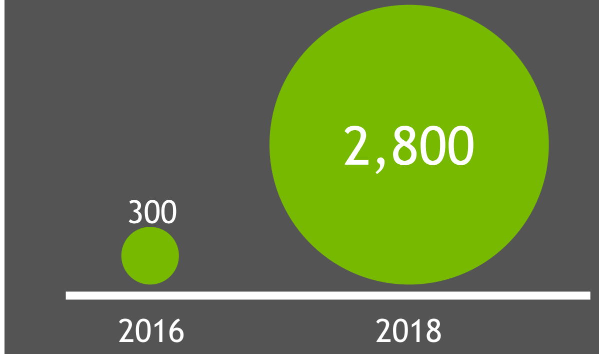
OIL AND GAS DISCOVERY
10X increase in data processing

REALTIME FLEET ANALYTICS
Streamline routes to save >$28M



ENGINEERING DESIGN
Accelerate from hours to minutes

MOST ADOPTED PLATFORM FOR ACCELERATING AI



9X STARTUPS ENGAGED
VIA INCEPTION PROGRAM

Caffe2

Chainer

KALDI

Microsoft
Cognitive
Toolkit

mxnet

PaddlePaddle

PYTORCH

TensorFlow

EVERY DEEP LEARNING
FRAMEWORK ACCELERATED

Alibaba Cloud
aliyun.com

aws

Google Cloud

IBM Cloud

Microsoft
Azure

Tencent Cloud

Cloud Services

DELL

Hewlett Packard
Enterprise

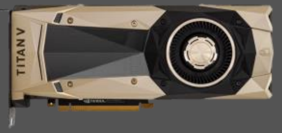
IBM

inspur

Lenovo

SUPERMICRO

Systems



Desktops

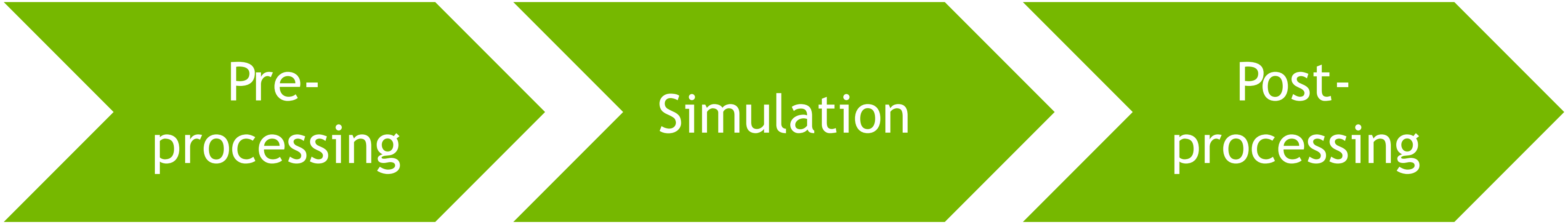
AVAILABLE EVERYWHERE

INTELLIGENT HPC

DL Driving Future HPC Breakthroughs

- Trained networks as solvers
- Super-resolution of coarse simulations
- Low- and mixed-precision
- Simulation for training, network in production

From calendar time to real time?



Pre-processing

Simulation

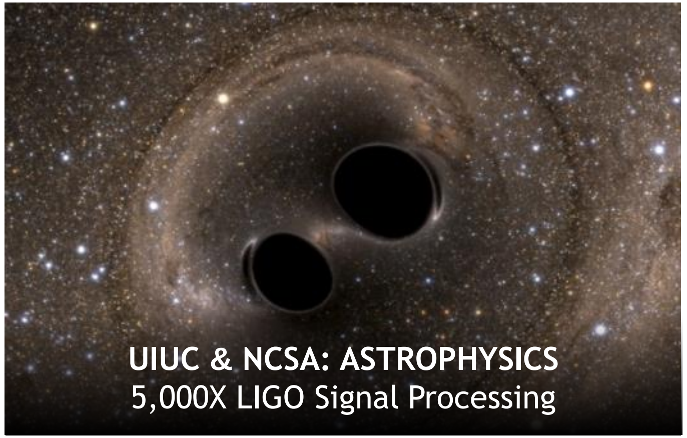
Post-processing

- Select/classify/augment/ distribute input data
- Control job parameters

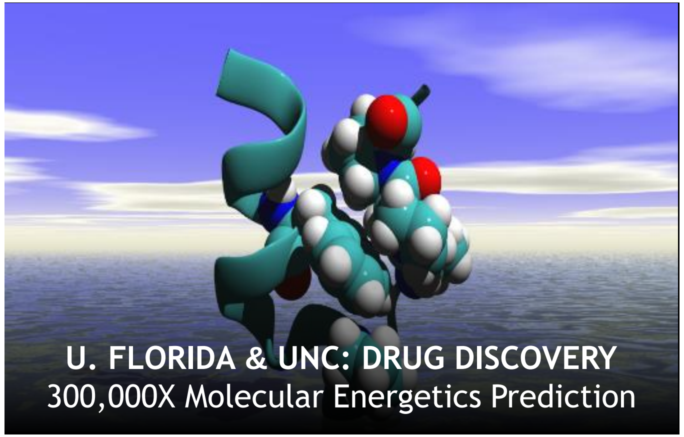
- Analyze/reduce/augment output data
- Act on output data

DEEP LEARNING COMES TO HPC

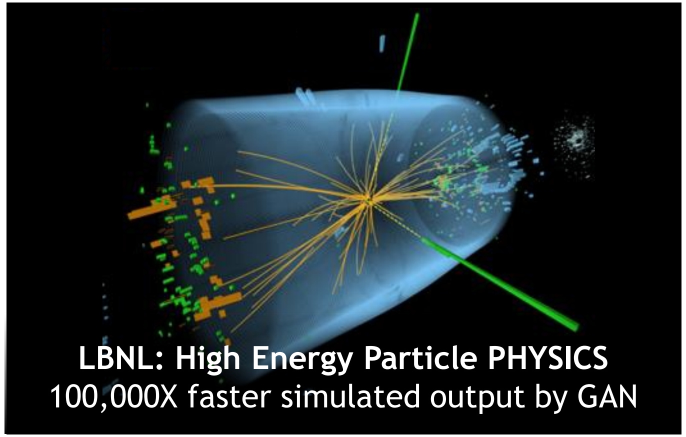
Accelerates Scientific Discovery



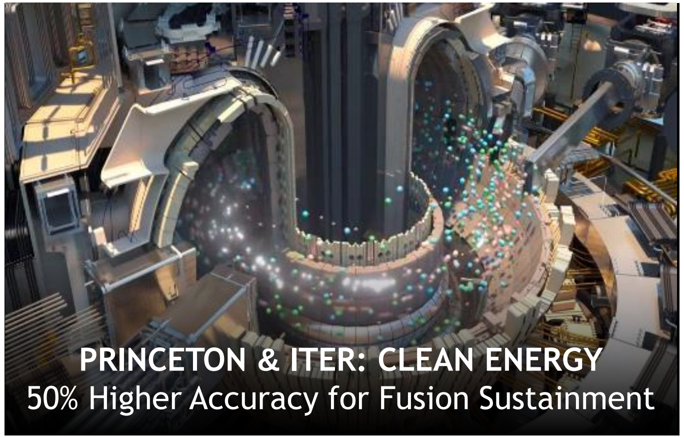
UIUC & NCSA: ASTROPHYSICS
5,000X LIGO Signal Processing



U. FLORIDA & UNC: DRUG DISCOVERY
300,000X Molecular Energetics Prediction

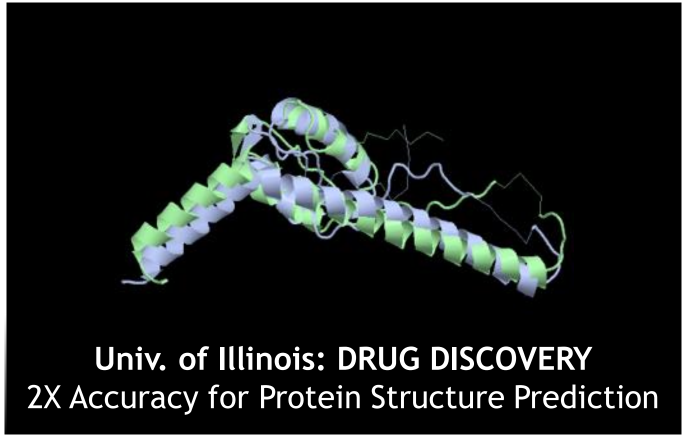


LBNL: High Energy Particle PHYSICS
100,000X faster simulated output by GAN



PRINCETON & ITER: CLEAN ENERGY
50% Higher Accuracy for Fusion Sustainment

U.S. DoE: PARTICLE PHYSICS
33% More Accurate Neutrino Detection



Univ. of Illinois: DRUG DISCOVERY
2X Accuracy for Protein Structure Prediction

ONE PLATFORM BUILT FOR BOTH DATA SCIENCE & COMPUTATIONAL SCIENCE

Tesla Platform

Accelerating AI

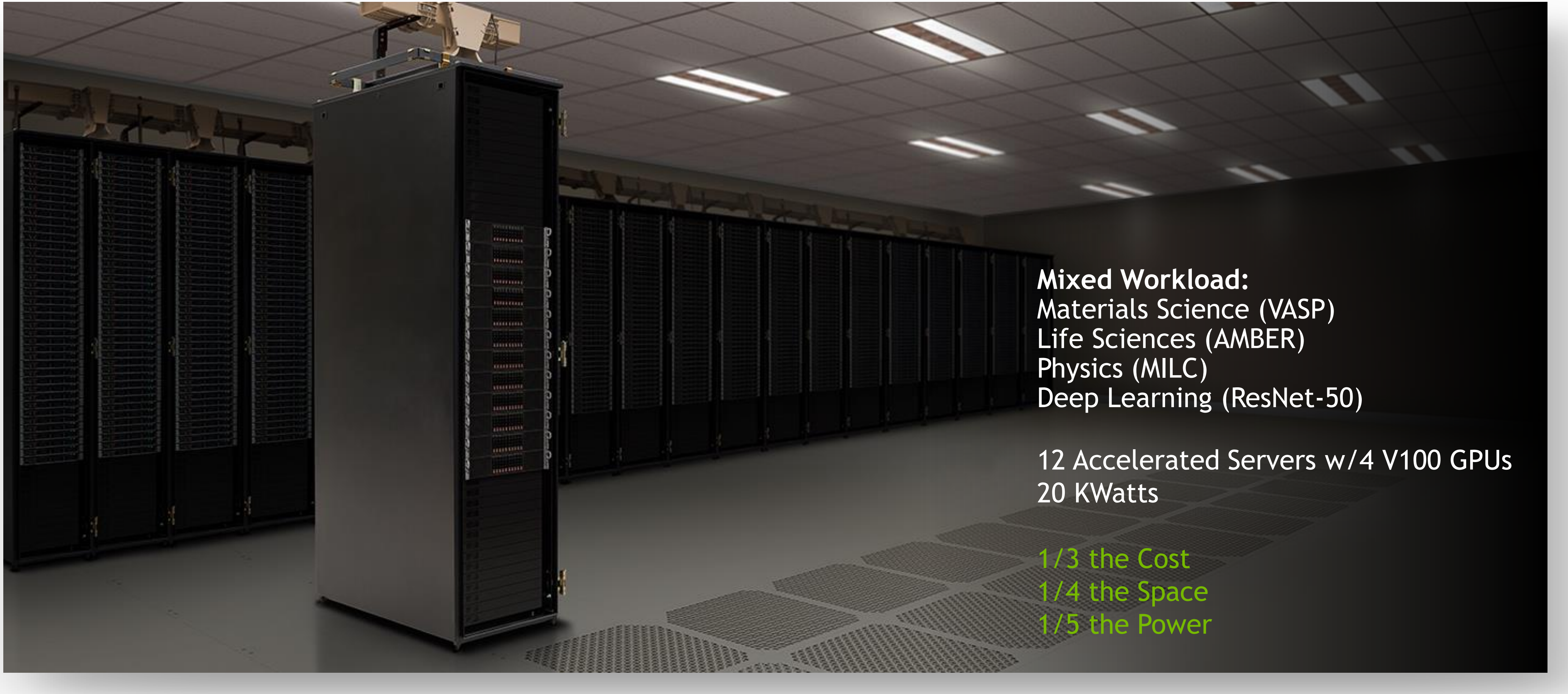
Accelerating HPC

4X BETTER HPC SYSTEM TCO

Mixed Workload:
Materials Science (VASP)
Life Sciences (AMBER)
Physics (MILC)
Deep Learning (ResNet-50)

160 Self-hosted Servers
96 KWatts

4X BETTER HPC SYSTEM TCO



Mixed Workload:
Materials Science (VASP)
Life Sciences (AMBER)
Physics (MILC)
Deep Learning (ResNet-50)

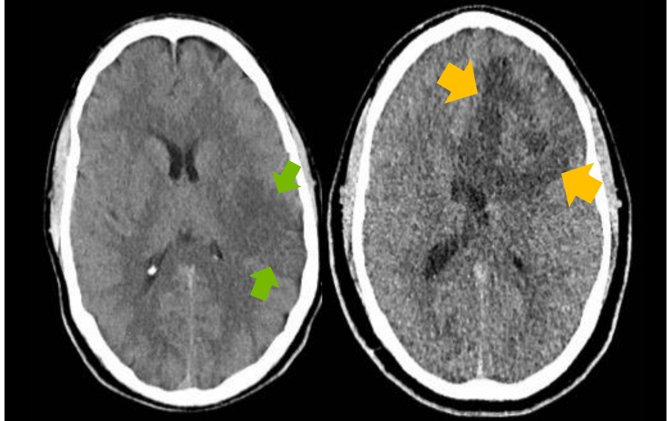
12 Accelerated Servers w/4 V100 GPUs
20 KWatts

1/3 the Cost
1/4 the Space
1/5 the Power

CUSTOMERS WANT MORE

AI TO TRANSFORM EVERY INDUSTRY

HEALTHCARE



>80% Accuracy & Immediate Alert to Radiologists

INFRASTRUCTURE

KANSAS CITY
MISSOURI

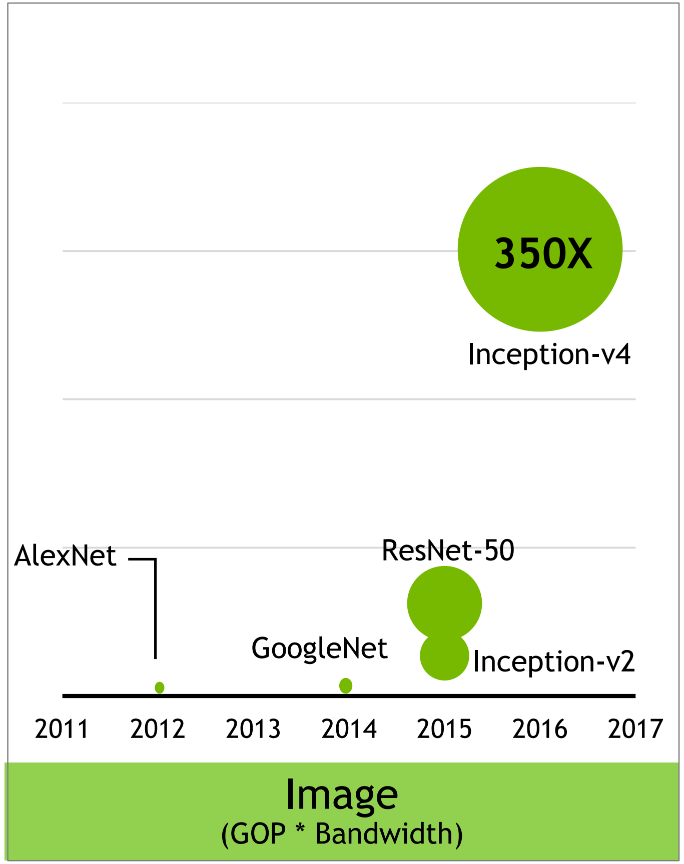
50% Reduction in Emergency Road Repair Costs

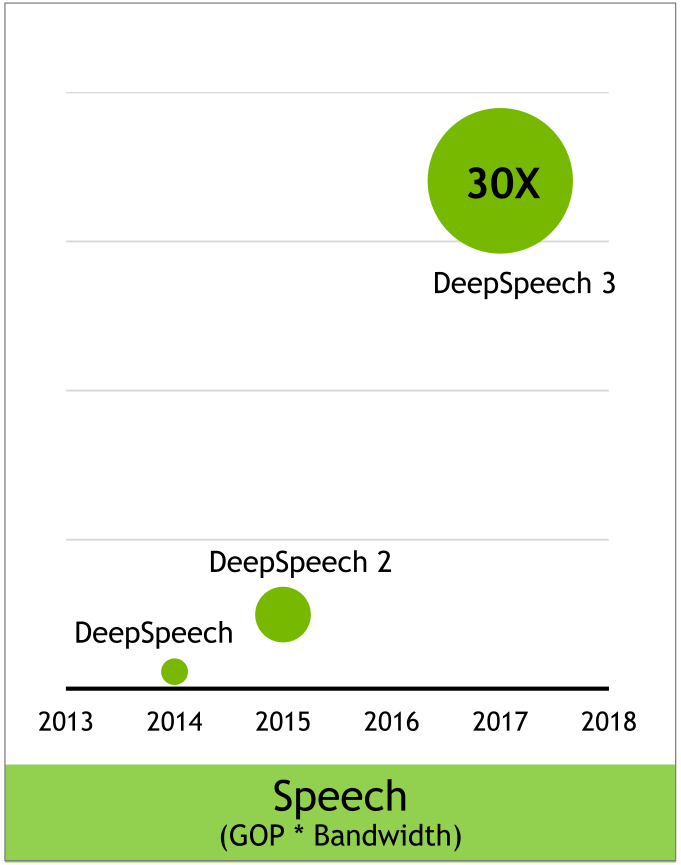
IOT

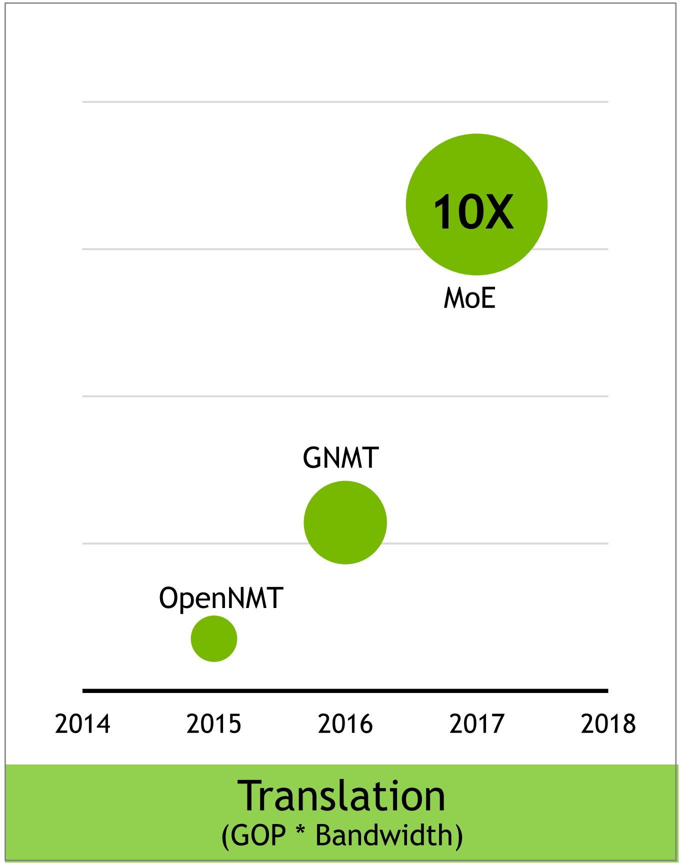
>$6M / Year Savings and Reduced Risk of Outage

NEURAL NETWORK COMPLEXITY IS EXPLODING

Bigger and More Compute Intensive







TESLA V100 32GB

WORLD’S MOST ADVANCED DATA CENTER GPU
NOW WITH 2X THE MEMORY

5,120 CUDA cores

640 NEW Tensor cores

7.8 FP64 TFLOPS | 15.7 FP32 TFLOPS | 125 Tensor TFLOPS

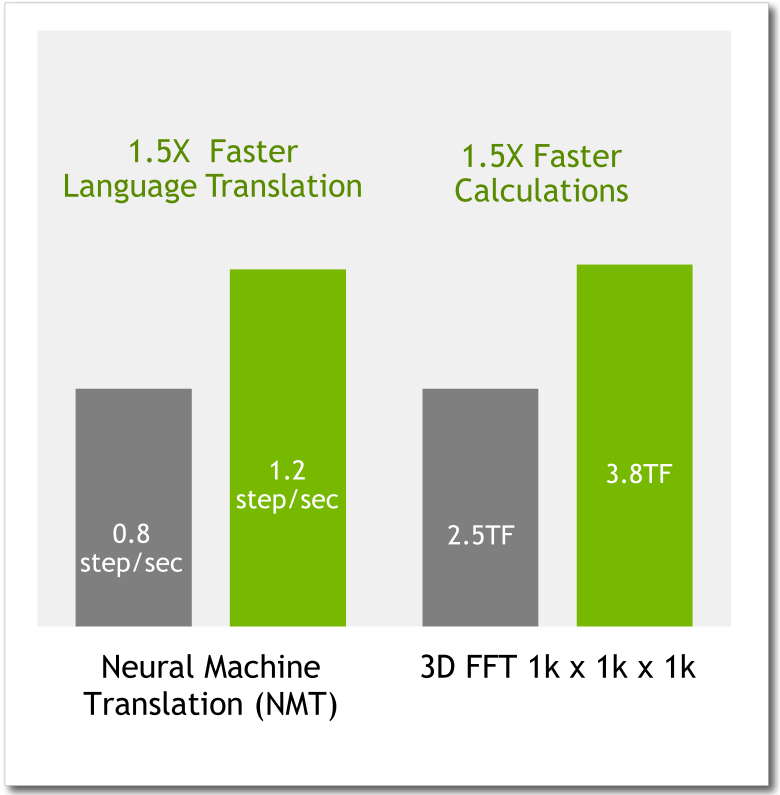
20MB SM RF | 16MB Cache

32GB HBM2 @ 900GB/s | 300GB/s NVLink

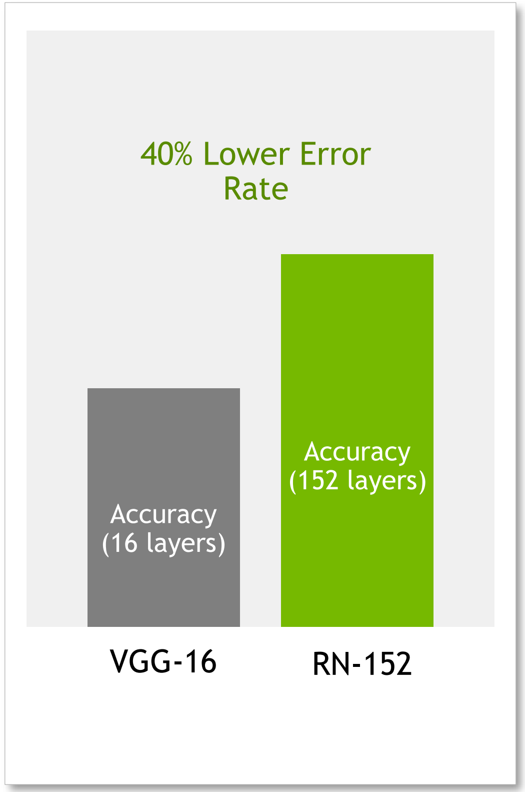
FASTER RESULTS ON COMPLEX DL AND HPC

Up to 50% Faster Results With 2x The Memory

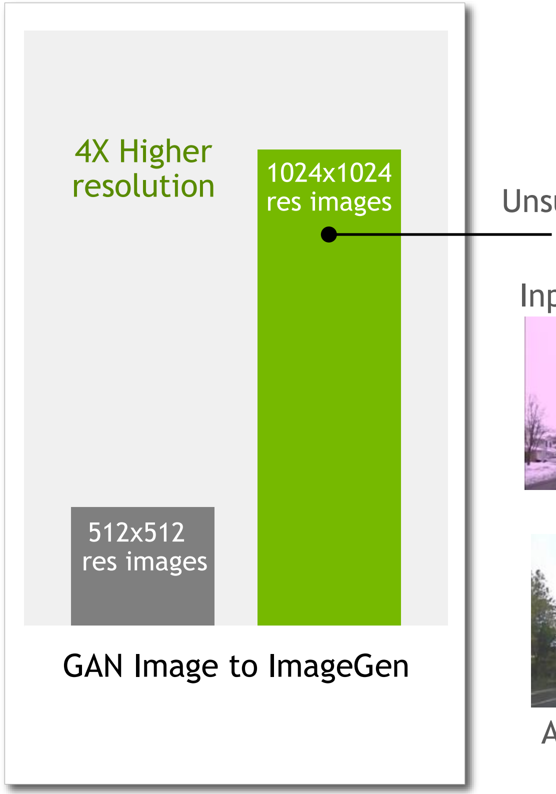
FASTER RESULTS



HIGHER ACCURACY



HIGHER RESOLUTION



Unsupervised Image Translation

Input winter photo

AI converts it to summer

■ V100 16GB   🟩 V100 32GB

Dual E5-2698v4 server, 512GB DDR4, Ubuntu 16.04, CUDA9, cuDNN7| NMT is GNMT-like and run with TensorFlow NGC Container 18.01 (Batch Size= 128 (for 16GB) and 256 (for 32GB) | FFT is with cufftbench 1k x 1k x 1k and comparing 2 V100 16GB (DGX1V) vs. 2 V100 32GB (DGX1V)

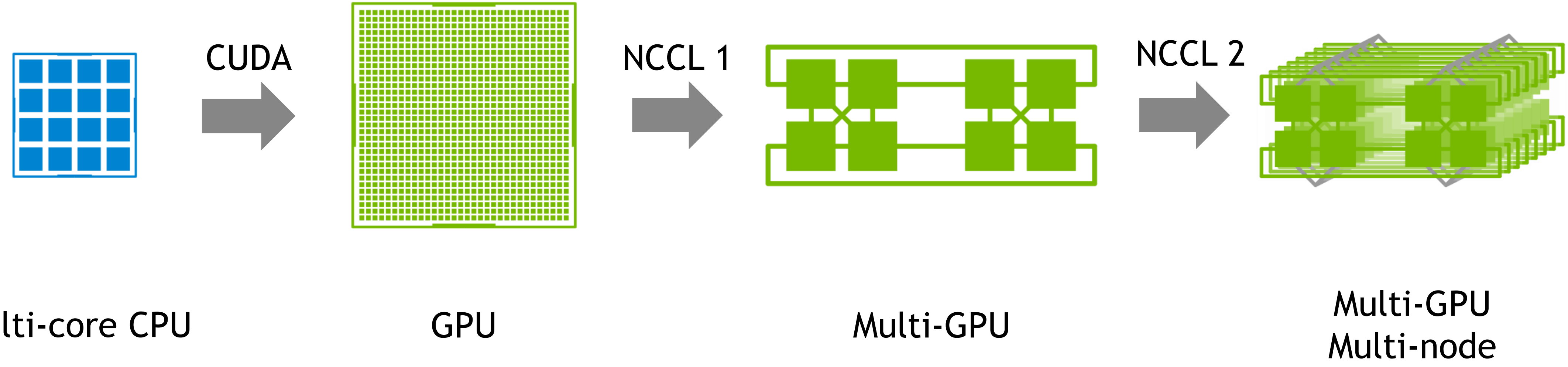
R-CNN for object detection at 1080P with Caffe | V100 16GB uses VGG16| V100 32GB uses Resnet-152

GAN by NVRESEARCH (https://arxiv.org/pdf/1703.00848.pdf) | V100 16GB and V100 32GB with FP32

DEEP LEARNING ON GPUS

Making DL training times shorter

Deeper neural networks, larger data sets … training is a very, very long operation !



NVLINK MULTI-GPU SCALING

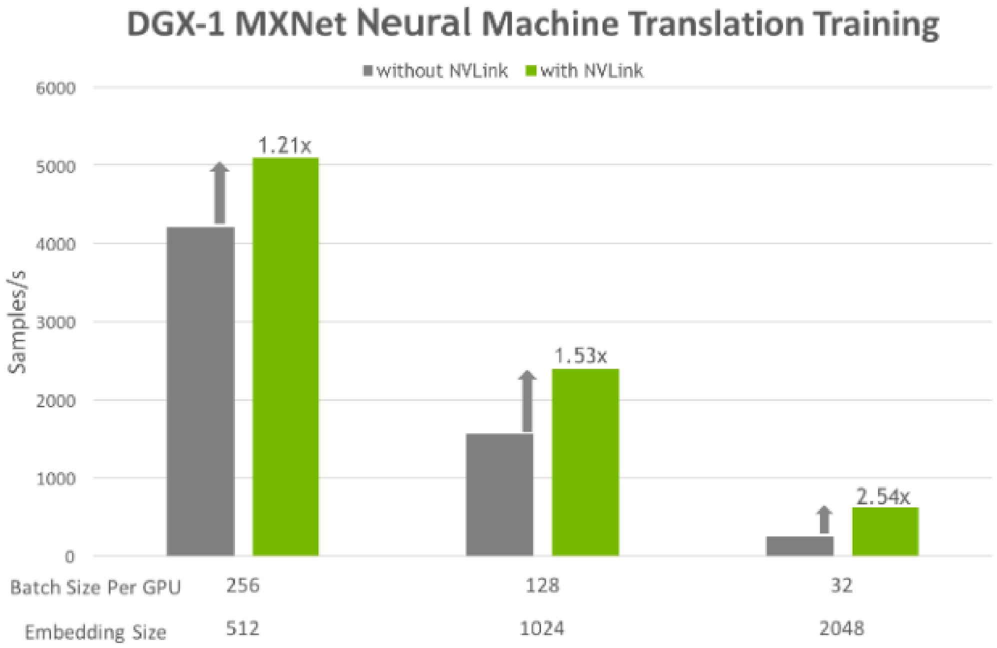


Figure 7 Sockeye neural machine translation single-precision training with MXNet using MLP attention on DGX-1, demonstrating significant NVLink performance benefits. The bars present performance on eight Tesla V100 GPUs in a DGX-1 when using NVLink for communication (green), and when using PCIe for communication (gray). Performance benefits increase with the encoder/ decoder embedding size. Results are the average number of samples per second processed during a single epoch of training with the German to English dataset. Tests used NVIDIA DGX MXNet container version 17.11, processing real data with cuDNN 7.0.4, NCCL 2.1.2.

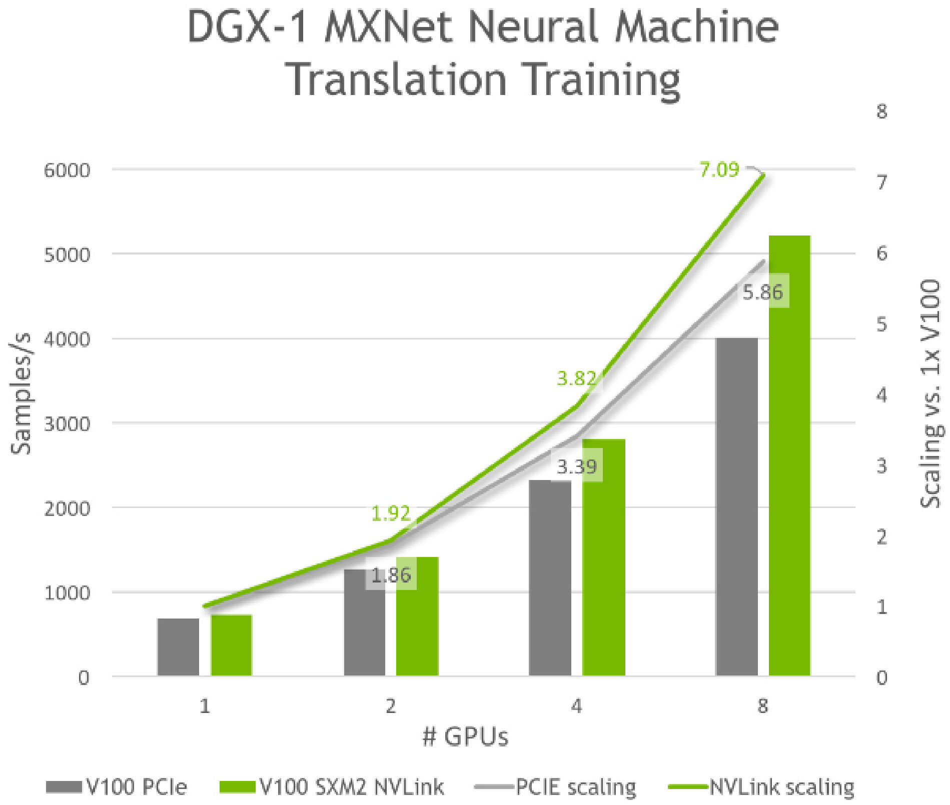
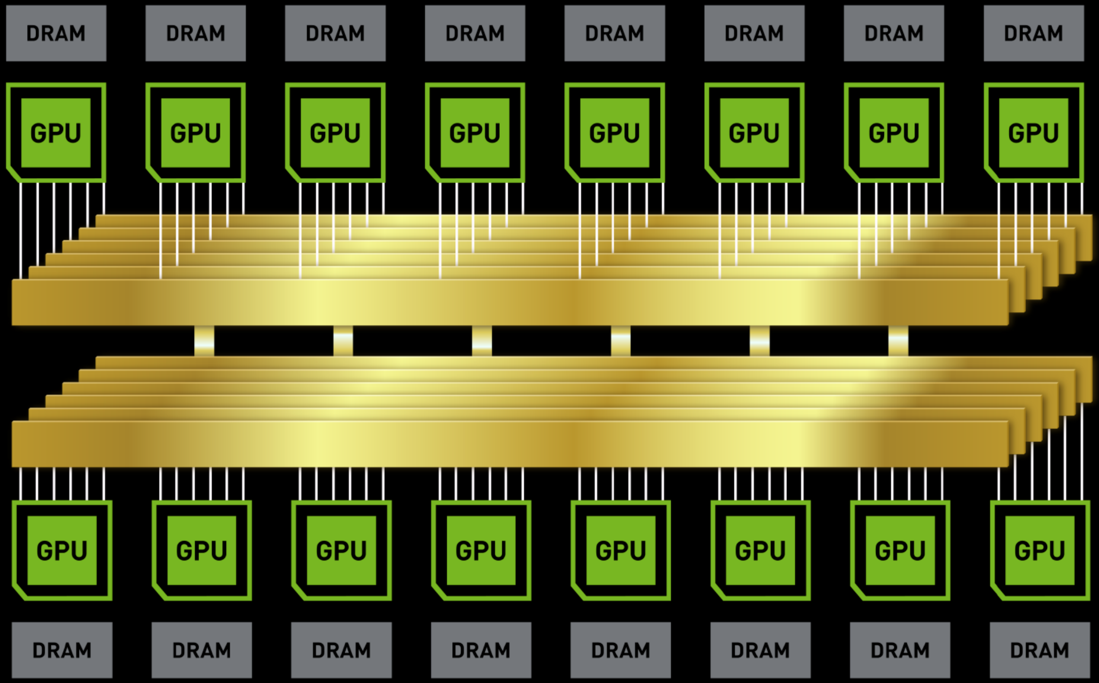


Figure 6 DGX-1 and V100 PCIe performance and scaling for single-precision training of a neural machine translation model with MLP attention and encoder/decoder embedding size of 512 and a batch size of 256 per GPU. The bars show performance on one, two, four, and eight GPUs, comparing an off-the-shelf system of eight Tesla V100 GPUs using PCIe for communication (gray) with eight Tesla V100 GPUs in a DGX-1 using NVLink for communication (green). The lines show the speedup compared to a single GPU. Tests used NVIDIA DGX containers version 17.11, processing real data with cuDNN 7.0.4, NCCL 2.1.2.

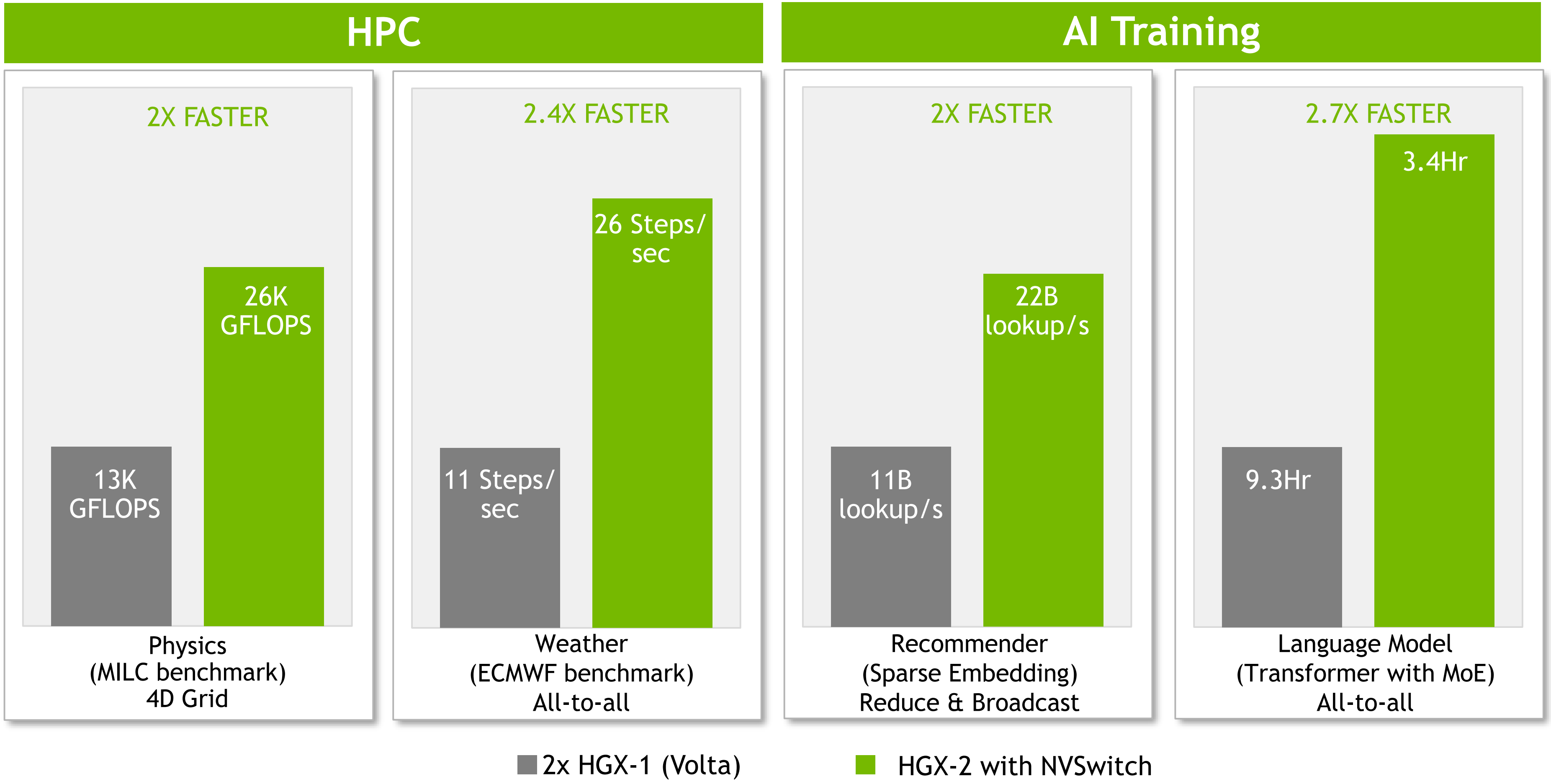
NVSWITCH

ENABLES THE WORLD'S LARGEST GPU

16 Tesla V100 32GB Connected by New NVSwitch
2 petaFLOPS of DL Compute
Unified 512GB HBM2 GPU Memory Space
300GB/sec Every GPU-to-GPU
2.4TB/sec of Total Cross-section Bandwidth



UP TO 3X HIGHER PERFORMANCE WITH NVSWITCH



2 HGX-1V servers have dual socket Xeon E5 2698v4 Processor. 8 x V100 GPUs. Servers connected via 4XIB ports | HGX-2 server has dual-socket Xeon Platinum 8168 Processor. 16 V100 GPUs

THE WORLD'S FIRST 2 PETAFLOPS SYSTEM

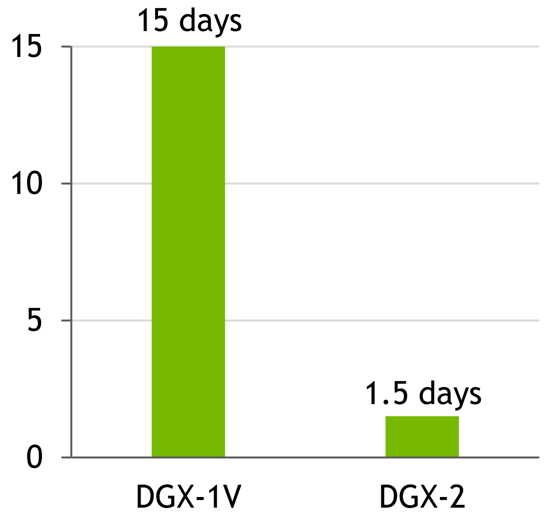
INTRODUCING NVIDIA DGX-2

THE WORLD'S MOST POWERFUL AI SYSTEM FOR THE MOST COMPLEX AI CHALLENGES

- DGX-2 is the newest addition to the DGX family, powered by DGX software
- Deliver accelerated AI-at-scale deployment and simplified operations
- Step up to DGX-2 for unrestricted model parallelism and faster time-to-solution

10X PERFORMANCE GAIN LESS THAN A YEAR

DGX-1, SEP'17



PyTorch Stack: Time to Train FAIRSEQ

DGX-2, Q3'18

software improvements across the stack including NCCL, cuDNN, etc.

END-TO-END PRODUCT FAMILY

NVIDIA GPU CLOUD

HPC/TRAINING

FULLY INTERGRATED DL SUPERCOMPUTER

DGX-1

DGX-2

DESKTOP

TITAN

WORKSTATION

Quadro

DGX Station

DATA CENTER

Tesla V100

INFERENCE

DATA CENTER

Tesla P4

Tesla V100

AUTOMOTIVE

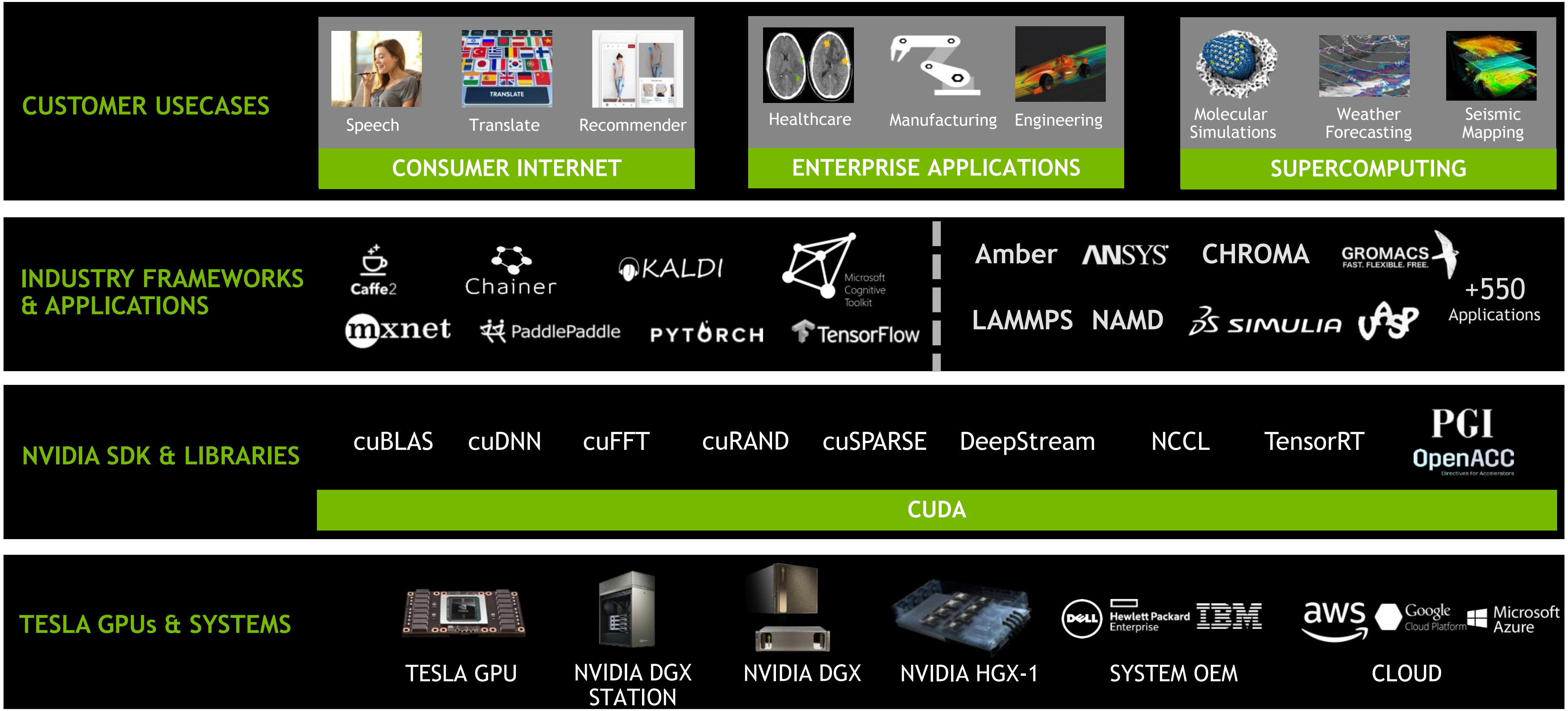
Drive PX2

EMBEDDED

Jetson TX1

TESLA STACK

World’s Leading Data Center Platform for Accelerating HPC and AI



CUSTOMER USECASES

Speech · Translate · Recommender — CONSUMER INTERNET

Healthcare · Manufacturing · Engineering — ENTERPRISE APPLICATIONS

Molecular Simulations · Weather Forecasting · Seismic Mapping — SUPERCOMPUTING

INDUSTRY FRAMEWORKS & APPLICATIONS

Caffe2 · Chainer · KALDI · Microsoft Cognitive Toolkit · mxnet · PaddlePaddle · PYTORCH · TensorFlow

Amber · ANSYS · CHROMA · GROMACS FAST. FLEXIBLE. FREE. · LAMMPS · NAMD · SIMULIA · VASP · +550 Applications

NVIDIA SDK & LIBRARIES

cuBLAS · cuDNN · cuFFT · cuRAND · cuSPARSE · DeepStream · NCCL · TensorRT · PGI · OpenACC Directives for Accelerators

CUDA

TESLA GPUs & SYSTEMS

TESLA GPU · NVIDIA DGX STATION · NVIDIA DGX · NVIDIA HGX-1

DELL · Hewlett Packard Enterprise · IBM — SYSTEM OEM

aws · Google Cloud Platform · Microsoft Azure — CLOUD

NVIDIA GPU CLOUD
SIMPLIFYING AI & HPC

Cloud container registry for GPU accelerated apps

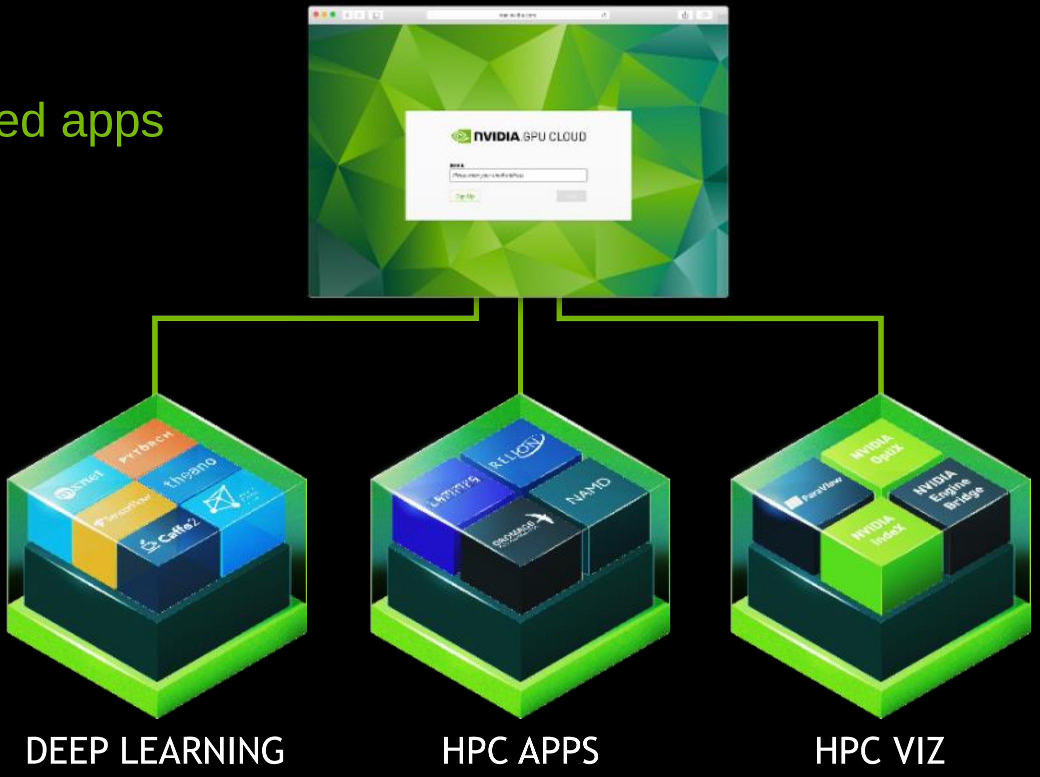
Containerized in NVDocker

Optimized for GPU-accelerated Systems

Up-to-Date Containers

Available NOW

Sign up at nvidia.com/gpu-cloud

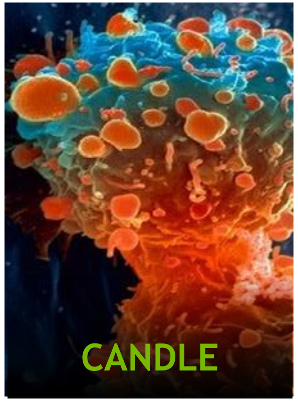


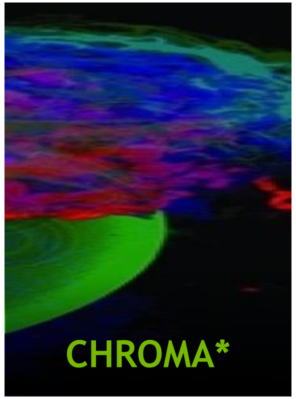
DEEP LEARNING

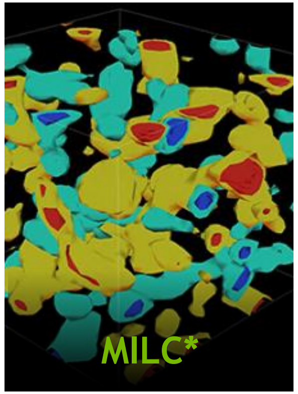
HPC APPS

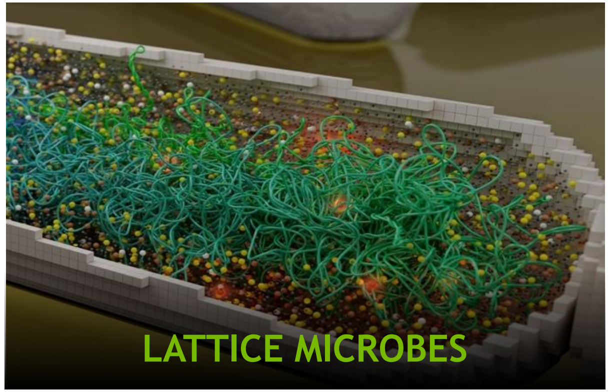
HPC VIZ

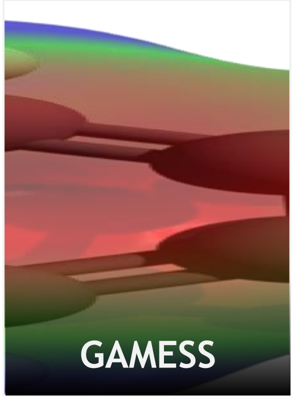
HPC APPS CONTAINERS ON NVIDIA GPU CLOUD

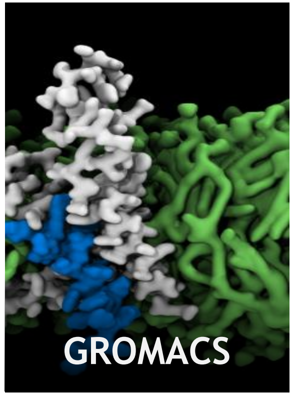

CANDLE

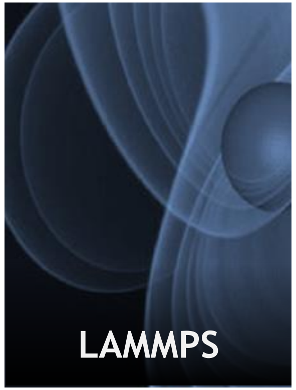

CHROMA*

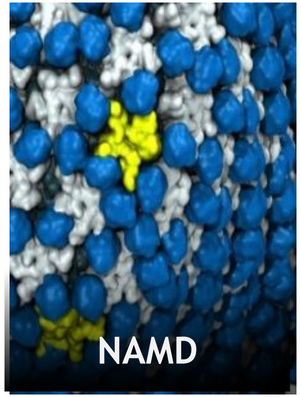

MILC*

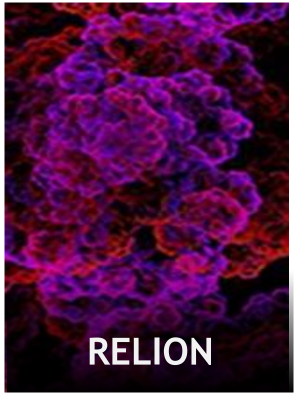

LATTICE MICROBES


GAMESS


GROMACS


LAMMPS


NAMD


RELION

DKRZ DEUTSCHES KLIMARECHENZENTRUM

JOHNS HOPKINS UNIVERSITY

KAUST

京都大学 KYOTO UNIVERSITY

MONASH University

Pfizer

PennState

Schlumberger

Stanford University

UNIVERSITY OF CAMBRIDGE

東京大学 THE UNIVERSITY OF TOKYO

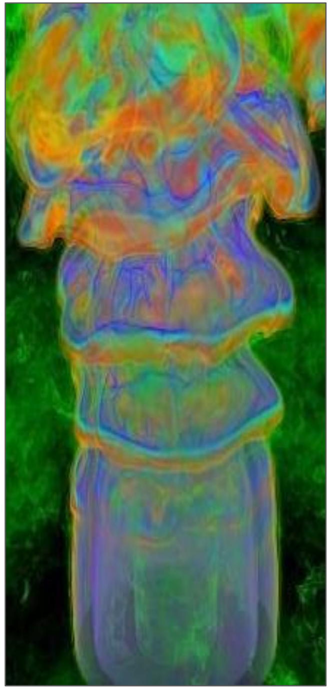
YONSEI UNIVERSITY

RAPID CONTAINER ADDITION

RAPID USER ADOPTION

*Coming soon

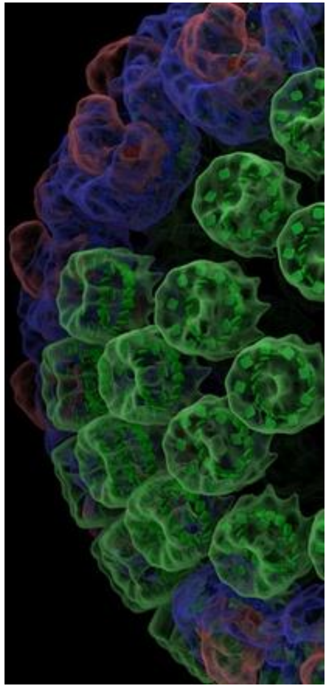
NVIDIA GPU CLOUD FOR HPC VISUALIZATION



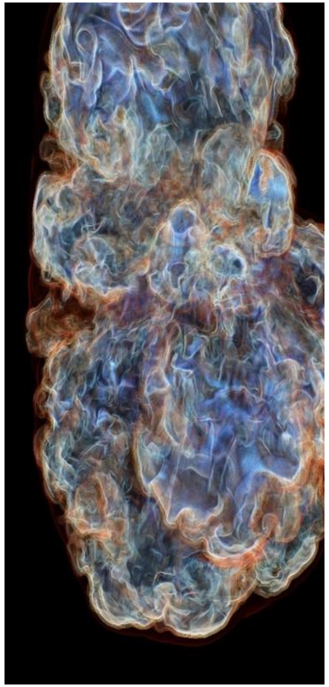
ParaView with NVIDIA IndeX

ParaView with NVIDIA OptiX

ParaView with NVIDIA Holodeck

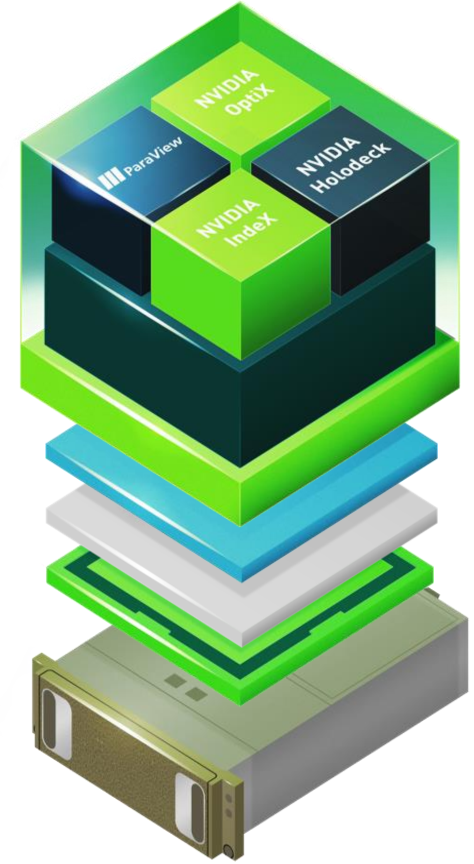


VMD

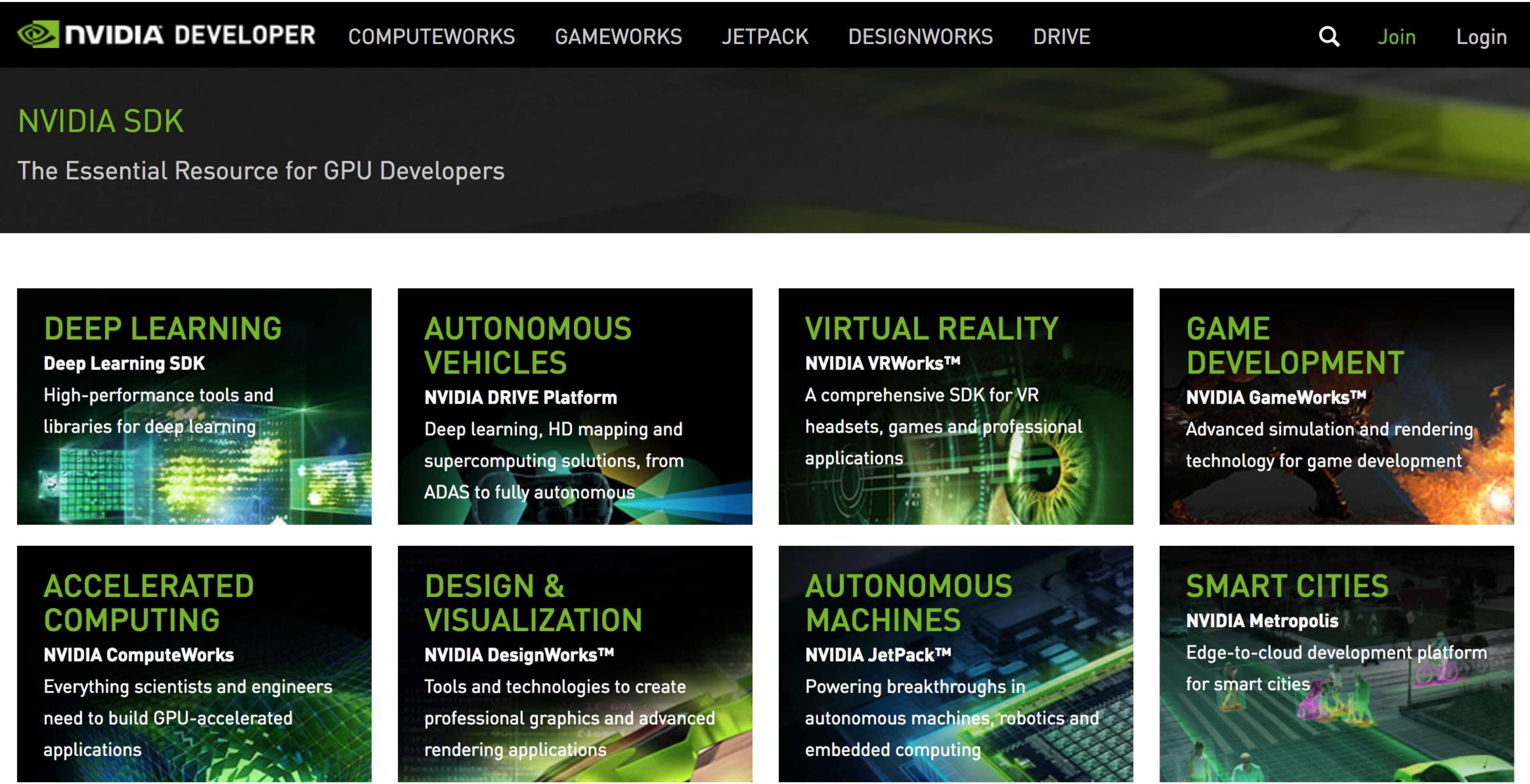


IndeX

NEW CONTAINERS



TESLA PLATFORM FOR DEVELOPERS



NVIDIA SDK

The Essential Resource for GPU Developers

DEEP LEARNING

Deep Learning SDK

High-performance tools and libraries for deep learning

AUTONOMOUS VEHICLES

NVIDIA DRIVE Platform

Deep learning, HD mapping and supercomputing solutions, from ADAS to fully autonomous

VIRTUAL REALITY

NVIDIA VRWorks™

A comprehensive SDK for VR headsets, games and professional applications

GAME DEVELOPMENT

NVIDIA GameWorks™

Advanced simulation and rendering technology for game development

ACCELERATED COMPUTING

NVIDIA ComputeWorks

Everything scientists and engineers need to build GPU-accelerated applications

DESIGN & VISUALIZATION

NVIDIA DesignWorks™

Tools and technologies to create professional graphics and advanced rendering applications

AUTONOMOUS MACHINES

NVIDIA JetPack™

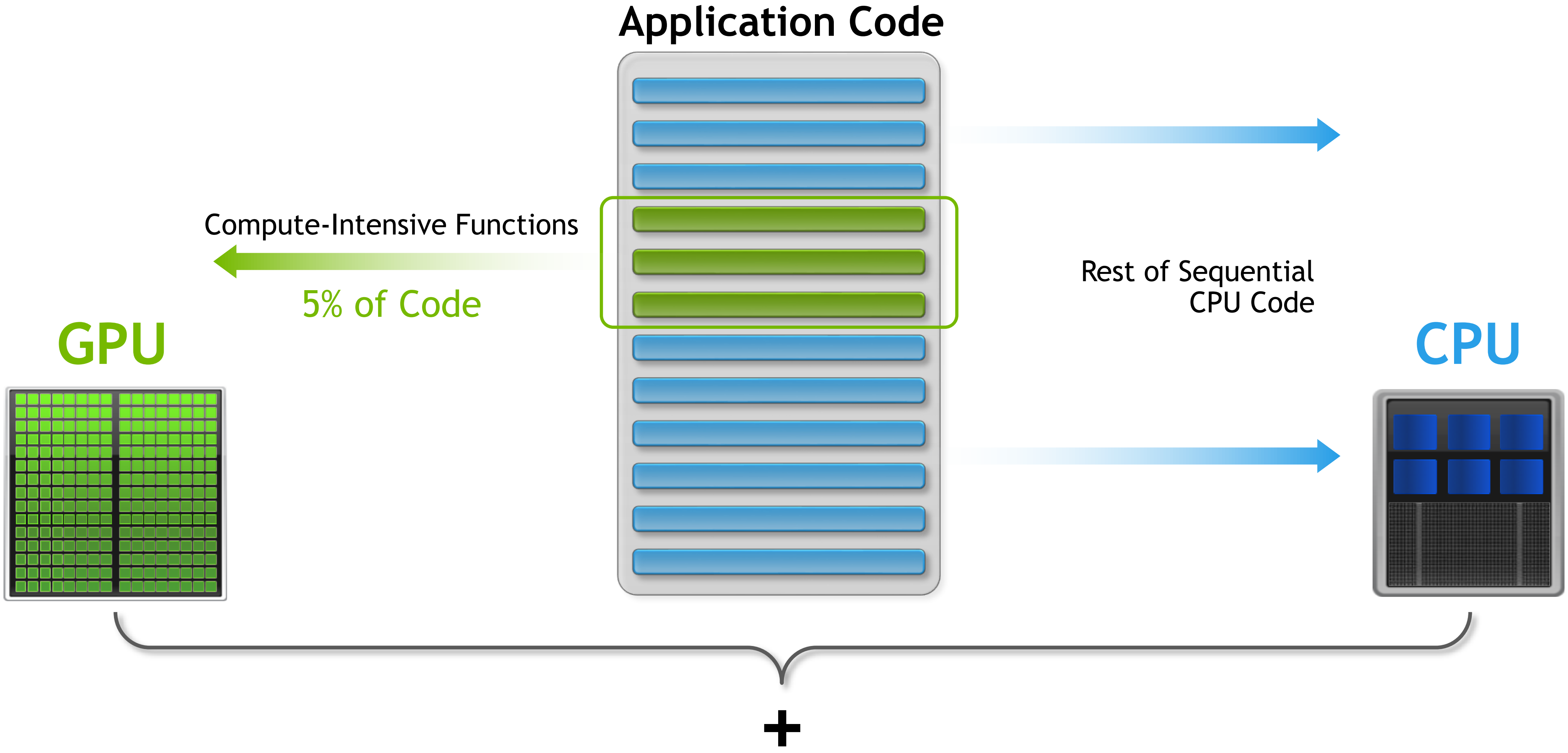
Powering breakthroughs in autonomous machines, robotics and embedded computing

SMART CITIES

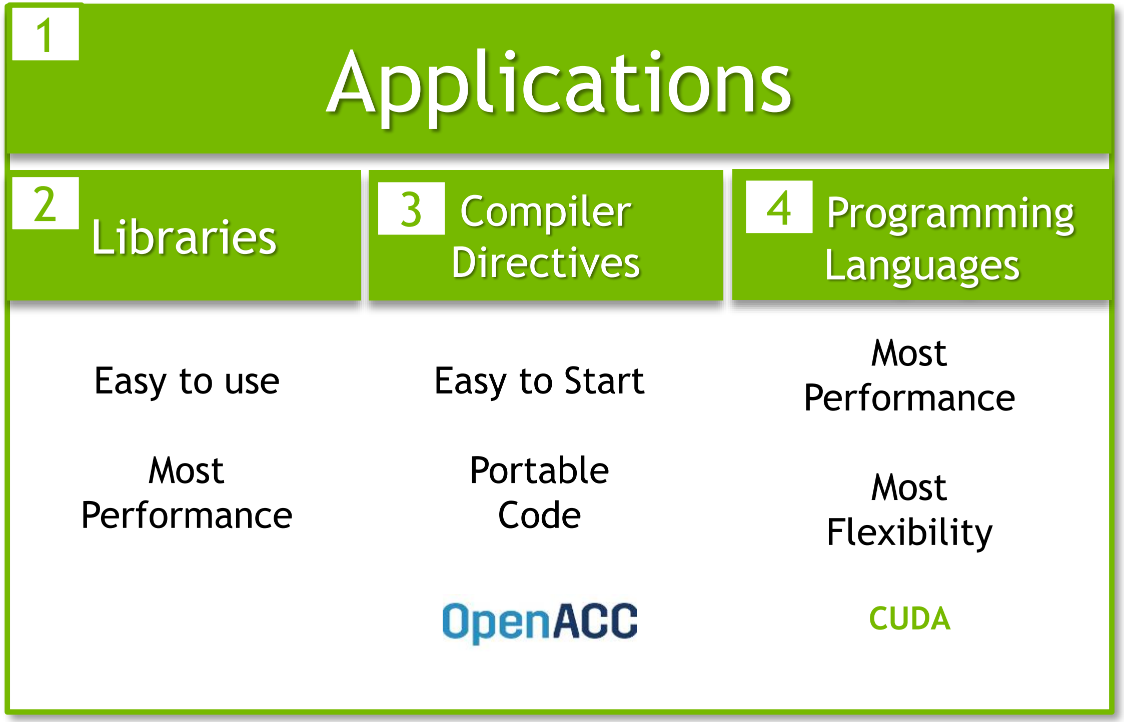
NVIDIA Metropolis

Edge-to-cloud development platform for smart cities

HOW GPU ACCELERATION WORKS



HOW TO START WITH GPUS



1 Applications

2 Libraries	3 Compiler Directives	4 Programming Languages
Easy to use	Easy to Start	Most Performance
Most Performance	Portable Code	Most Flexibility
	OpenACC	CUDA

1. Review available GPU-accelerated applications
2. Check for GPU-Accelerated applications and libraries
3. Add OpenACC Directives for quick acceleration results and portability
4. Dive into CUDA for highest performance and flexibility

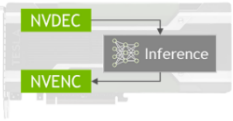
GPU ACCELERATED LIBRARIES

“Drop-in” Acceleration for Your Applications

DEEP LEARNING

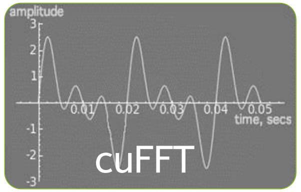
cuDNN

TensorRT



DeepStream SDK

SIGNAL, IMAGE & VIDEO

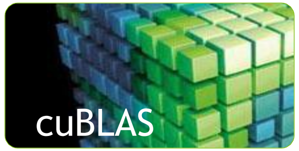


cuFFT

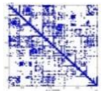
NVIDIA NPP

CODEC SDK

LINEAR ALGEBRA



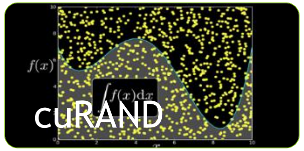
cuBLAS



cuSPARSE

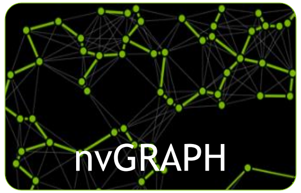
CUDA Math library

cuSOLVER

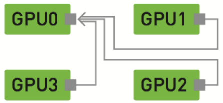


cuRAND

PARALLEL ALGORITHMS



nvGRAPH



NCCL

WHAT IS OPENACC

Programming model for an easy onramp to GPUs

Directives-based programming model for **parallel computing**

Add Simple Compiler Directive

```
main()
 {
  <serial code>
  #pragma acc kernels
  {
    <parallel code>
  }
 }
```

SIMPLE

Designed for **performance portability** on CPUs and GPUs

POWERFUL & PORTABLE

Read more at www.openacc.org/about

OpenACC is an open specification developed by OpenACC.org consortium

SINGLE CODE FOR MULTIPLE PLATFORMS

OpenACC - Performance Portable Programming Model for HPC

OpenPOWER

Sunway

x86 CPU

x86 Xeon Phi

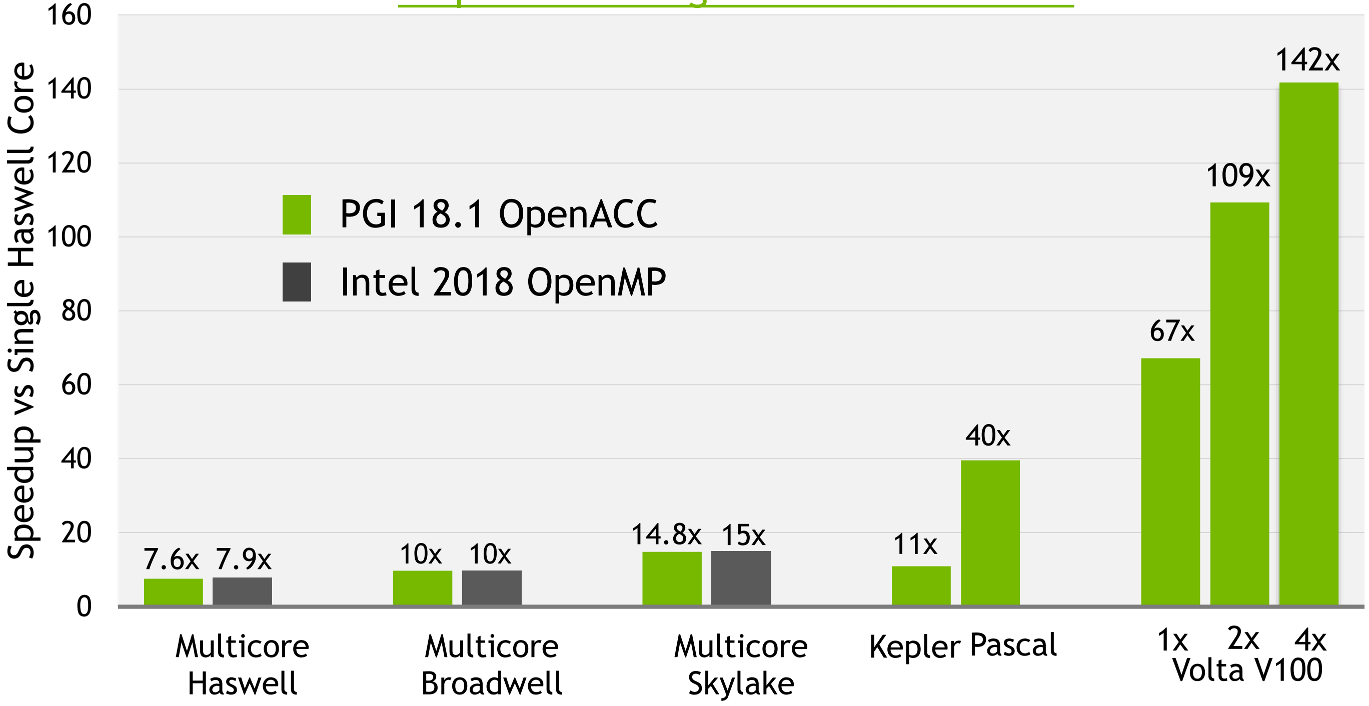
NVIDIA GPU

AMD GPU

PEZY-SC

AWE Hydrodynamics CloverLeaf mini-App, bm32 data set

http://uk-mac.github.io/CloverLeaf



Systems: Haswell: 2x16 core Haswell server, four K80s, CentOS 7.2 (perf-hsw10), Broadwell: 2x20 core Broadwell server, eight P100s (dgx1-prd-01), Broadwell server, eight V100s (dgx07), Skylake 2x20 core Xeon Gold server (sky-4).
Compilers: Intel 2018.0.128, PGI 18.1
Benchmark: CloverLeaf v1.3 downloaded from http://uk-mac.github.io/CloverLeaf the week of November 7 2016; CloverlLeaf_Serial; CloverLeaf_ref (MPI+OpenMP); CloverLeaf_OpenACC (MPI+OpenACC)
Data compiled by PGI February 2018.

OPENACC GROWING MOMENTUM

Wide Adoption Across Key HPC Codes

Over 100 Apps* Using OpenACC

ANSYS Fluent
Gaussian
VASP
LSDalton
MPAS
GAMERA

GTC
XGC
ACME
FLASH
COSMO
Numeca

VASP

Top Quantum Chemistry and Material Science Code

> "For VASP, OpenACC is ***the*** way forward for GPU acceleration. Performance is similar to CUDA, and OpenACC dramatically decreases GPU development and maintenance efforts. We're excited to collaborate with NVIDIA and PGI as an early adopter of Unified Memory."

Prof. Georg Kresse
Computational Materials Physics
University of Vienna

* Applications in production and development

OPENACC.ORG RESOURCES

Guides ● Talks ● Tutorials ● Videos ● Books ● Spec ● Code Samples ● Teaching Materials ● Events ● Success Stories ● Courses ● Slack ● Stack Overflow

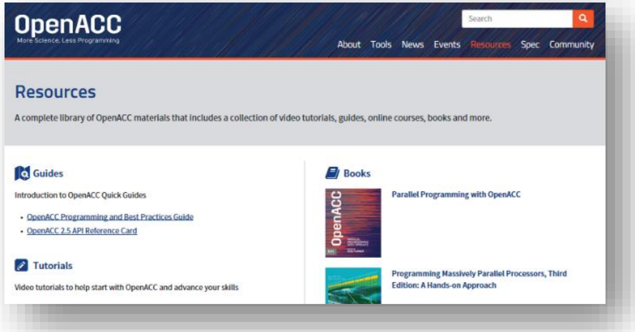
OpenACC Now in GCC

slack

https://www.openacc.org/community#slack

Resources

https://www.openacc.org/resources



Resources

A complete library of OpenACC materials that includes a collection of video tutorials, guides, online courses, books and more.

Guides

Introduction to OpenACC Quick Guides

- OpenACC Programming and Best Practices Guide
- OpenACC 2.5 API Reference Card

Tutorials

Video tutorials to help start with OpenACC and advance your skills

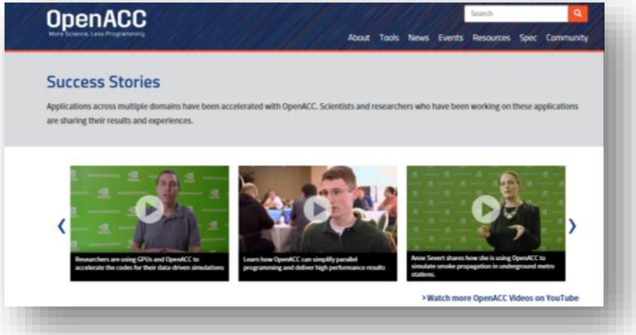
Books

Parallel Programming with OpenACC

Programming Massively Parallel Processors, Third Edition: A Hands-on Approach

Success Stories

https://www.openacc.org/success-stories



Success Stories

Applications across multiple domains have been accelerated with OpenACC. Scientists and researchers who have been working on these applications are sharing their results and experiences.

Researchers are using GPUs and OpenACC to accelerate the codes for their data-driven simulations

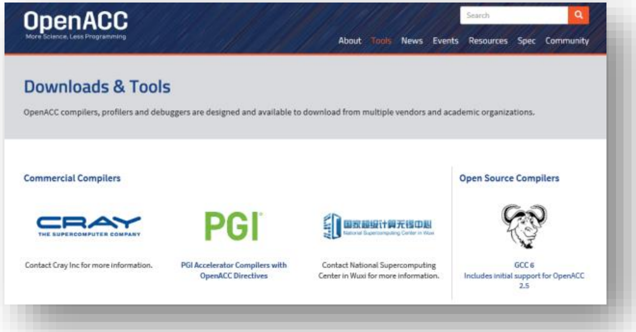
Learn how OpenACC can simplify parallel programming and deliver high performance results

Anne Severt shares how she is using OpenACC to simulate smoke propagation in underground metro stations.

› Watch more OpenACC Videos on YouTube

Compilers and Tools

https://www.openacc.org/tools


OpenACC
More Science, Less Programming
Search
About
Tools
News
Events
Resources
Spec
Community
CRAY
THE SUPERCOMPUTER COMPANY
PGI
国家超级计算无锡中心
National Supercomputing Center in Wuxi

Downloads & Tools

OpenACC compilers, profilers and debuggers are designed and available to download from multiple vendors and academic organizations.

Commercial Compilers

Contact Cray Inc for more information.

PGI Accelerator Compilers with OpenACC Directives

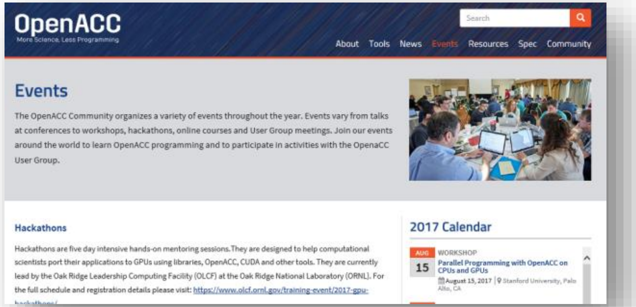
Contact National Supercomputing Center in Wuxi for more information.

Open Source Compilers

GCC 6
Includes initial support for OpenACC 2.5

Events

https://www.openacc.org/events



Events

The OpenACC Community organizes a variety of events throughout the year. Events vary from talks at conferences to workshops, hackathons, online courses and User Group meetings. Join our events around the world to learn OpenACC programming and to participate in activities with the OpenaCC User Group.

Hackathons

Hackathons are five day intensive hands-on mentoring sessions.They are designed to help computational scientists port their applications to GPUs using libraries, OpenACC, CUDA and other tools. They are currently lead by the Oak Ridge Leadership Computing Facility (OLCF) at the Oak Ridge National Laboratory (ORNL). For the full schedule and registration details please visit: https://www.olcf.ornl.gov/training-event/2017-gpu-hackathons/

2017 Calendar

AUG 15 WORKSHOP
Parallel Programming with OpenACC on CPUs and GPUs
August 15, 2017 | Stanford University, Palo Alto, CA

PGI COMPILERS FOR EVERYONE

The PGI 17.10 Community Edition

	FREE PGI Community EDITION	PGI Professional EDITION	PGI Enterprise EDITION
PROGRAMMING MODELS OpenACC, CUDA Fortran, OpenMP, C/C++/Fortran Compilers and Tools	✓	✓	✓
PLATFORMS X86, OpenPOWER, NVIDIA GPU	✓	✓	✓
UPDATES	1-2 times a year	6-9 times a year	6-9 times a year
SUPPORT	User Forums	PGI Support	PGI Premier Services
LICENSE	Annual	Perpetual	Volume/Site

NVIDIA ACADEMIC PROGRAMS

EDUCATION

NVIDIA Teaching kits

CAL POLY
SAN LUIS OBISPO

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

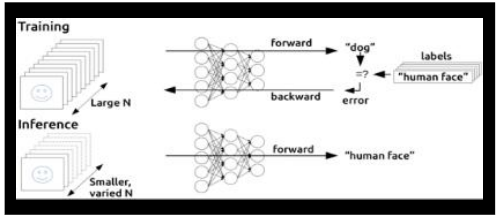
NYU

Complete course solutions:

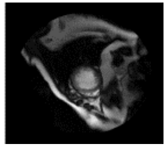
1. Deep Learning
2. Accelerated Computing
3. Robotics

DLI Ambassador Hands-on training

Fundamentals



Autonomous Vehicles


Healthcare

Robotics

Both Fundamentals and Industry-Specific Labs Available

Free for DLI Ambassador

GPU ACCESS

To start / teach GeForce, Jetson

Perfect platform to prototype

Accelerating your ideas
Enabling
new scientific publication

To scale DGX, Tesla, GRID, Cloud

Get an academic discount on Tesla, DGX, Jetson TX2 or GRID from our NPN partners

https://developer.nvidia.com/academia

GPU TECHNOLOGY CONFERENCE

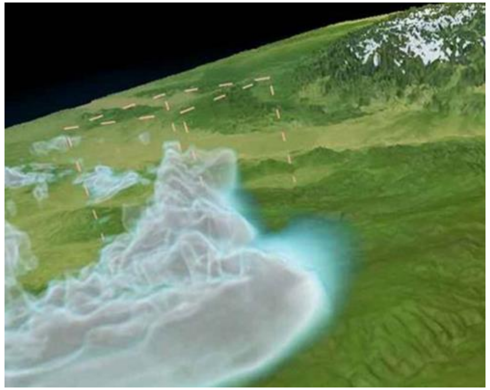
Oct 9 -11, 2018 | Munich
www.gputechconf.eu #GTC18

EUROPE’S BRIGHTEST MINDS & BEST IDEAS

DEEP LEARNING &
ARTIFICIAL INTELLIGENCE

SELF-DRIVING CARS

VIRTUAL REALITY &
AUGMENTED REALITY



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NVIDIA