HPC Overview

SHWETA DAS

shwetad@cdac.in

Agenda

- HPC History
- HPC Global Scenario
- Recent Trends
- Importance of multi core and many core architecture
- Application Areas of HPC in Science & Engineering

Supercomputing and High Performance Computing (HPC)

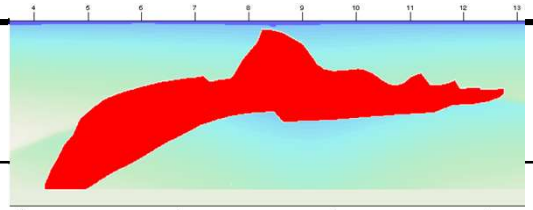
- **Supercomputing**
  - Use of the fastest and biggest machines to solve large problems
  - Supercomputer (in the 1980's and 1990's)
    - Very expensive, custom-built computer systems
  - Supercomputer (since end of 1990's)
    - Large number of "off-the-shelf" components
    - "Parallel Computing"

- **High Performance Computing (HPC)**
  - Solving a problem via supercomputers + fast networks + large storage + visualization

Complementing theory and experimentation, HPC now offers the third paradigm of scientific discovery and innovation enabling faster, safer and economical path

Why High Performance Computing?

- High speed because of Grand Challenge problems
- Novel applications which are not possible otherwise
- Strategic and Technology advancement
- Scalability : More processors more power
- Human Advancement: Economy

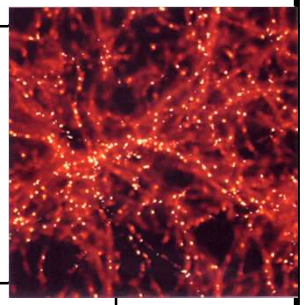


Geological Structure and Physical Properties

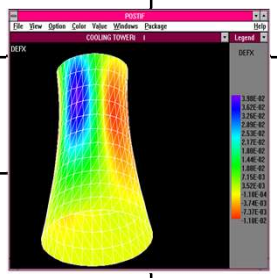
Water Resource Modelling

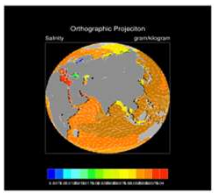
Atmospheric Sciences

Astrophysics & Astronomy

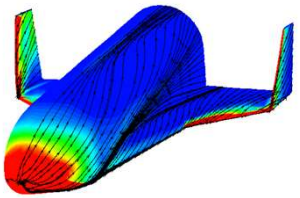


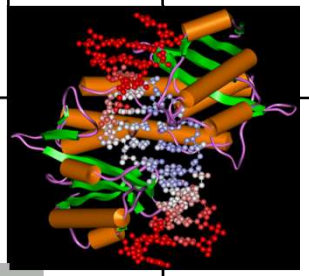
Seismic Exploration





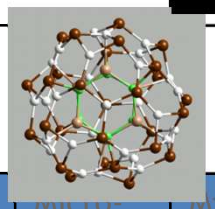
Structural Mechanics
Fluid dynmaics





Bioinformatics

Materials Modelling



Length vs Time Scale	Pico-sec	Nano-sec	Micro-sec	Milli-sec	Secs	Min	Hrs	days	Weeks-years	centuries	Miilions of years
Nano-metre											
Up to 100 nano-metre											
Micro-metre											
Milli-metre											
Metre											
Km											
10s to 100s Km											
Light years											

Length

Time

Why High Performance Computing?

- To simulate a bio-molecule of 10000 atoms

  Non-bond energy term ~ 10^8 operations

  For 1 microsecond simulation ~ 10^9 steps

  ~ 10^{17} operations

- On a 500 MFLOPS machine ($5x10^8$ operations per second) takes $2x10^9$ secs (About 60 years)

(This may be on a machine of 5000 MFLOPS peak)

- Need to do large no of simulations for even larger molecules

If we focus on some set of priorities, HPC can be guaranteed to produce important results. The grand challenge applications should not be regarded as problems that can be "solved". Instead they should be regarded as focus areas in which improved products, new products, and new engineering or scientific insights can be generated. Additionally, we can guarantee that eventually fallout will occur in other computational science and engineering areas.

David J. Kuck

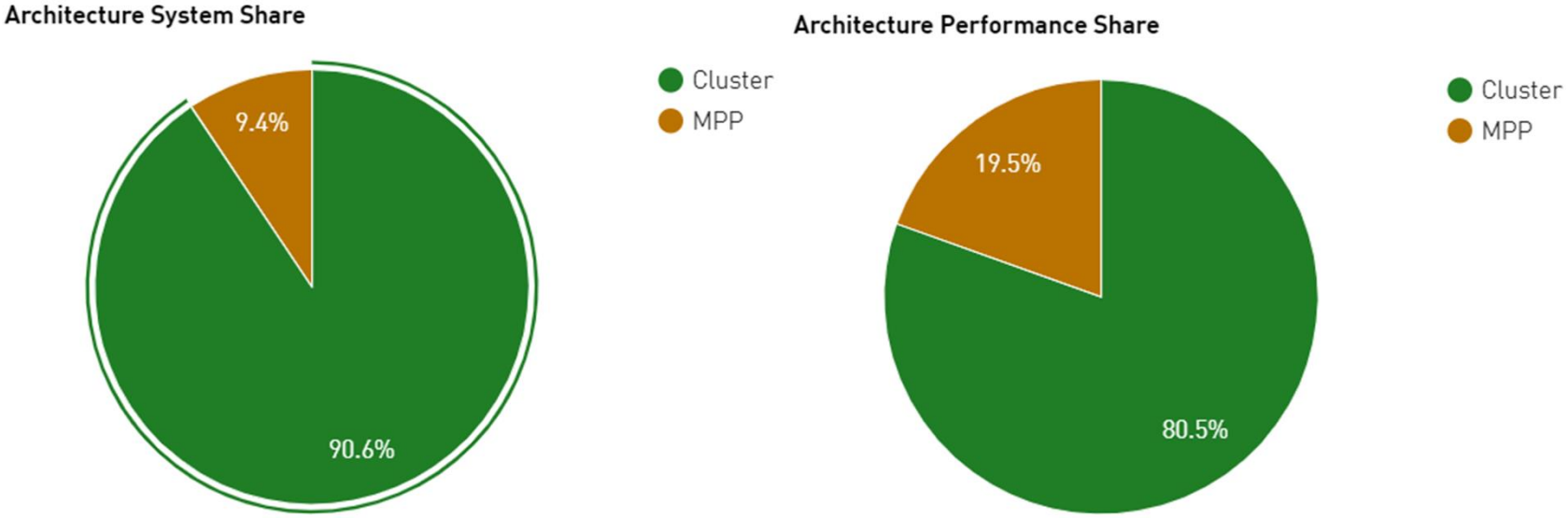
HPC: Challenges for Future Systems

HPC Global scenario

Performance development

Source: Top500.org

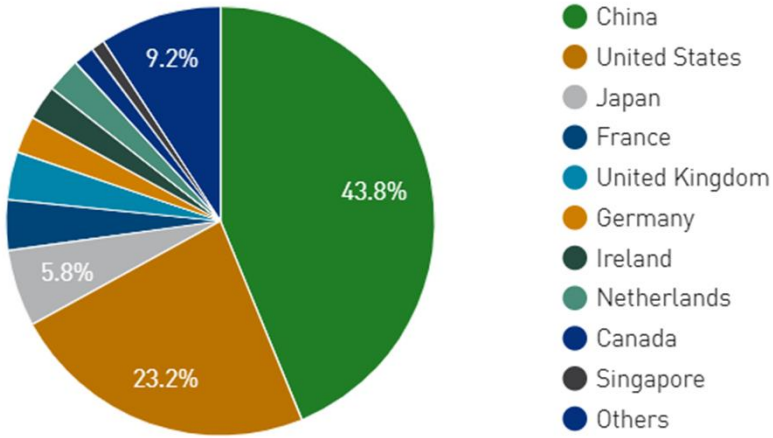
Architecture



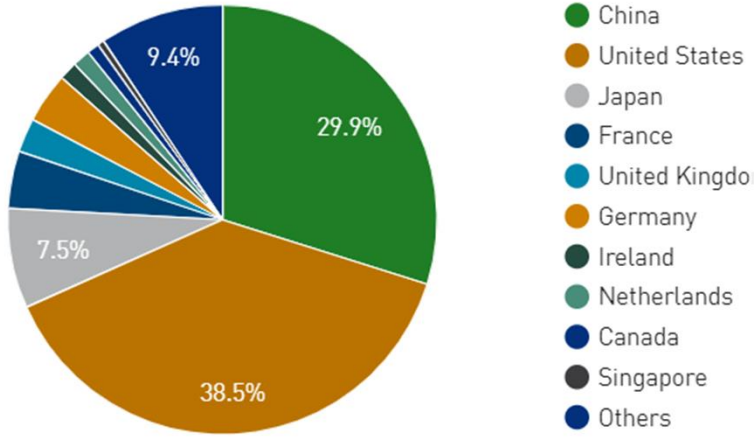
Source: Top500.org

Countries share

Countries System Share

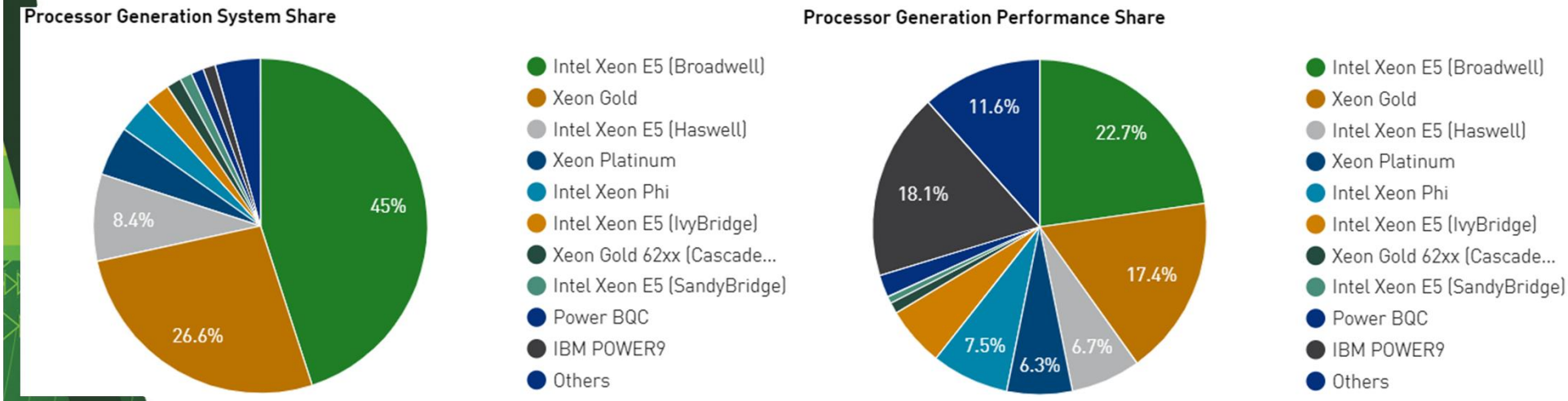


Countries Performance Share



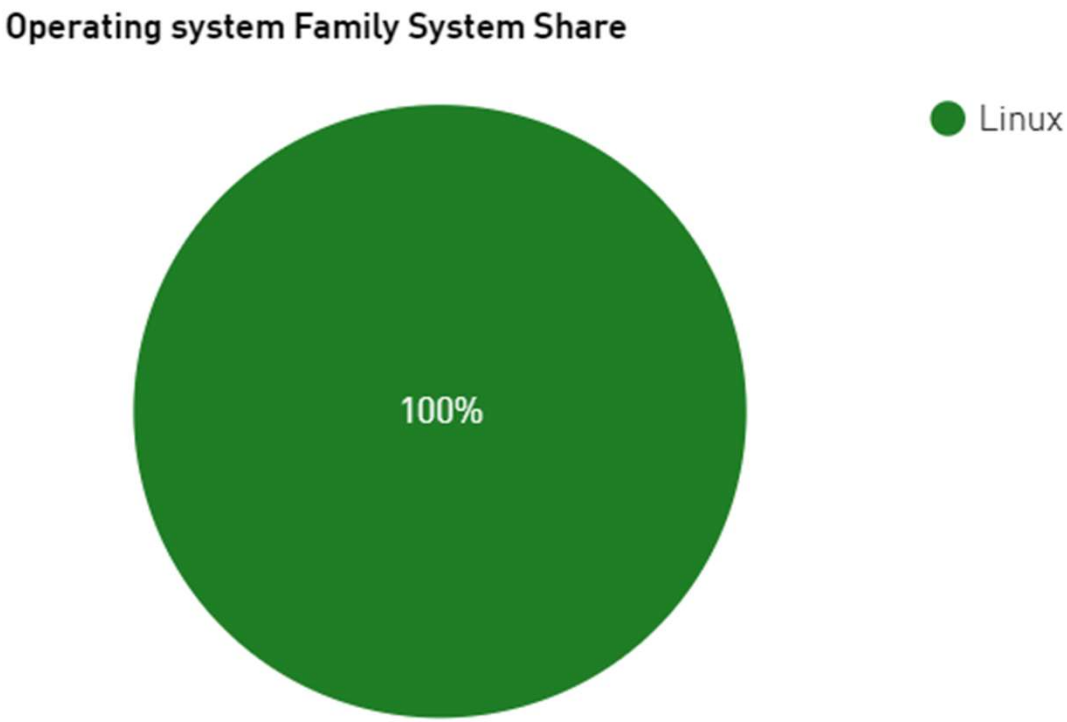
Source: Top500.org

Processor Family/systems



Source: Top500.org

Operating systems family



Recent trends

10 Biggest HPC Systems from Top500 Trends

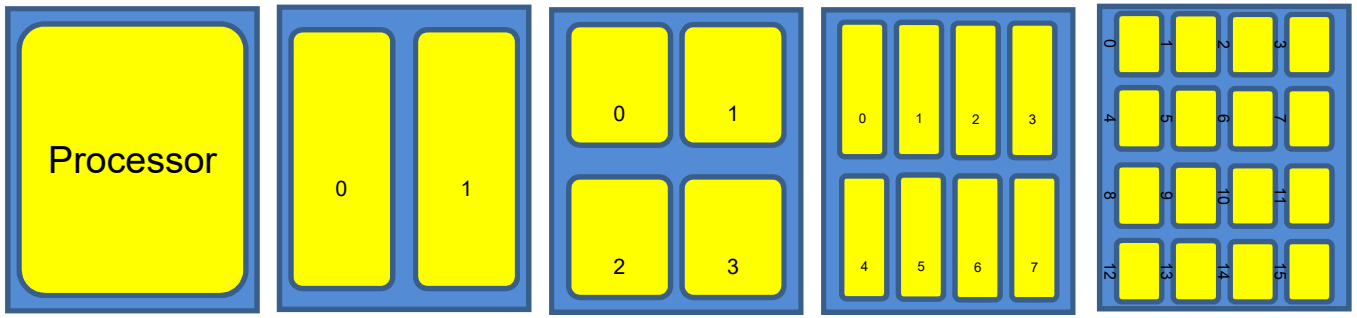
Rank	System	Cores	(TFlop/s)	(TFlop/s)	(kW)
1	**Summit** - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM DOE/SC/Oak Ridge National Laboratory United States	2,414,592	148,600.0	200,794.9	10,096
2	**Sierra** - IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM / NVIDIA / Mellanox DOE/NNSA/LLNL United States	1,572,480	94,640.0	125,712.0	7,438
3	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway , NRCPC National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
4	**Tianhe-2A** - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000 , NUDT National Super Computer Center in Guangzhou China	4,981,760	61,444.5	100,678.7	18,482
5	**Frontera** - Dell C6420, Xeon Platinum 8280 28C 2.7GHz, Mellanox InfiniBand HDR , Dell EMC Texas Advanced Computing Center/Univ. of Texas United States	448,448	23,516.4	38,745.9	
6	**Piz Daint** - Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect , NVIDIA Tesla P100 , Cray Inc. Swiss National Supercomputing Centre (CSCS) Switzerland	387,872	21,230.0	27,154.3	2,384
7	**Trinity** - Cray XC40, Xeon E5-2698v3 16C 2.3GHz, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect , Cray Inc. DOE/NNSA/LANL/SNL United States	979,072	20,158.7	41,461.2	7,578
8	**AI Bridging Cloud Infrastructure (ABCI)** - PRIMERGY CX2570 M4, Xeon Gold 6148 20C 2.4GHz, NVIDIA Tesla V100 SXM2, Infiniband EDR , Fujitsu National Institute of Advanced Industrial Science and Technology (AIST) Japan	391,680	19,880.0	32,576.6	1,649
9	**SuperMUC-NG** - ThinkSystem SD650, Xeon Platinum 8174 24C 3.1GHz, Intel Omni-Path , Lenovo Leibniz Rechenzentrum Germany	305,856	19,476.6	26,873.9	
10	**Lassen** - IBM Power System S922LC, IBM POWER9 22C 3.1GHz, Dual-rail Mellanox EDR Infiniband, NVIDIA Tesla V100 , IBM / NVIDIA / Mellanox DOE/NNSA/LLNL	288,288	18,200.0	23,047.2	

Importance of multicore and manycore architecture

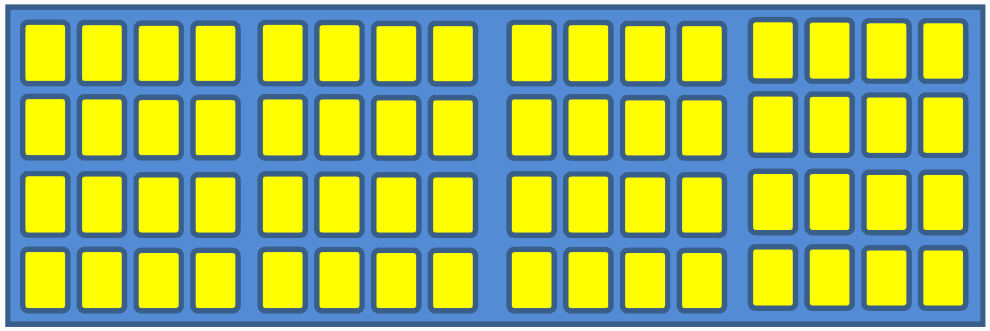
Sea Change in Chip Design Today

- Moore's law has hit the wall!
- Reduced to 20% improvement of Processor Performance per year from 2002(earlier 52%).
- Brick Wall = (Heat Wall + ILP Wall + Memory Wall)
- Maximum Power Dissipation of Air-Cooled Chips reached its limits ~ 130 Watts
- Little Instruction Level Parallelism (ILP) left to exploit efficiently.
- Memory wall has been hit, unchanged memory latency
- 2, 4, 8, 16 Cores/Chip are Common.
- 100 Cores chip have already been announced!
- Thousands of cores chips already at Drawing Board Level!

Multicore & ManyCore



Single core CPU | Dual core CPU | Quad core CPU | Eight core CPU | Sixteen core CPU



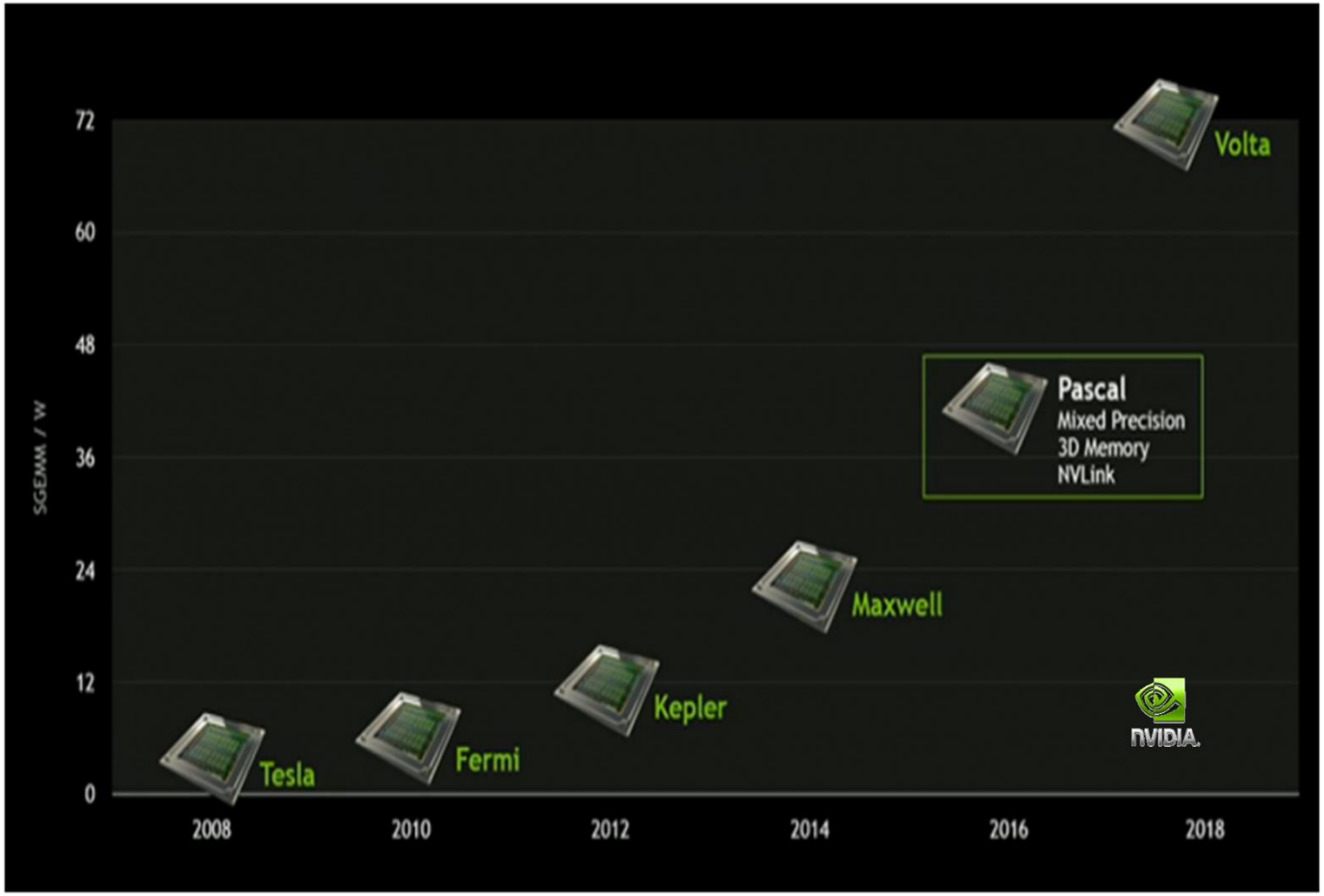
Many Core

GPU

NVIDIA V100 GPU: 100 TFLOPs

Intel Xeon Processor Roadmap

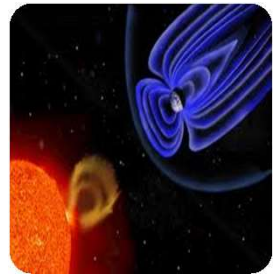
GPU Roadmap


72
60
48
36
24
12
0
SGEMM / W
2008
2010
2012
2014
2016
2018
Tesla
Fermi
Kepler
Maxwell
Pascal
Mixed Precision
3D Memory
NVLink
Volta
NVIDIA

Application Areas of HPC in Science & Engineering

HPC in science

- **Space Science**
  - Applications in Astrophysics and Astronomy



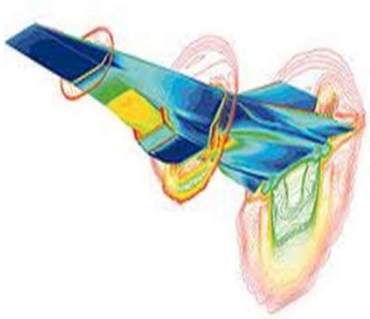
- **Earth Science**
  - Applications in understanding Physical Properties of Geological Structures, Water Resource Modelling, Seismic Exploration

- **Atmospheric Science**
  - Applications in Climate and Weather Forecasting, Air Quality

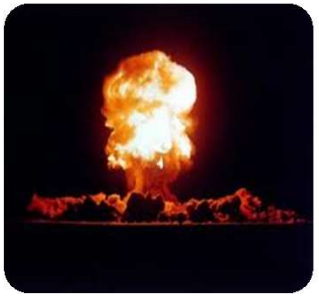
HPC in engineering

- **Crash Simulation**
  - Applications in Automobile and Mechanical Engineering

- **Aerodynamics Simulation & Aircraft Designing**
  - Applications in Aeronautics and Mechanical Engineering



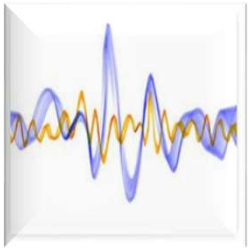
- **Weapon Designing &Testing**
  - Applications in Developing New Warfare Capabilities, High Technology Weapons, Precision Testing



HPC in engineering

- **Structural Analysis**
  - Applications in Civil Engineering and Architecture

- **Image Processing**
  - Applications in Remote Sensing, Medical, Real-time processing, Surveillance



- **Signal Processing**
  - Applications in Communications, Intelligence, Radio Astronomy

Multimedia and animation

- **DreamWorks Animation SKG produces all its animated movies using HPC graphic technology**

- **Graphical Animation Application in Multimedia and Animation**

Some impacts in business

HPC Drives a "Can-Do" Attitude at Alcoa

- **Alcoa is world's leading producer of aluminium products and components for a variety of industries such as aerospace, automotive, building & construction and packaging, with $30 billion revenue in 2006**
- **Was founded in 1888 and one of the first companies to make major use of HPC in 1987**
- **Tough business competition!**
  - Plastic bottles with different sizes were replacing Tab-top Aluminium containers
  - Designing cans with new volume sizes required about 15 different dimensions to be handled.
  - Used complex, non-symmetric modelling techniques called Monte Carlo simulations.
    - On Alcoa systems a simulation would have taken weeks while on HPC system* simulation containing 1000 designs took just a day or two.
- **This enabled Alcoa to offer customers a wide variety of options in order to compete with plastic and glass containers**

* Done at Pittsburgh Supercomputing Center

Oil and Gas Exploration

- Finding oil forty years ago was mainly hit or miss. A wrong drill decision can incur losses of hundreds of millions of bucks, more than the cost of a supercomputer!
- Seismic surveys is the principal tool for identification of Oil & Gas reserves. The practice of interpretation of resultant data is revolutionized by HPC
- Compute-intensive Algorithms in use: Reverse Time Migration (RTM), Lattice Boltzmann Method (LBM)
- Some Companies: BP, Exxon, Shell, China Petroleum & Chemical Corporation, Schlumberger
- Some Facts:
  - This was one of the first industries to make use of supercomputing, as early as 1980s.
  - Comprises about 10% of top supercomputers
  - 5 PFLOPS supercomputer coming up in Norway

Goodyear puts the Rubber to the Road with HPC

- Slump
  - Goodyear Tire and Rubber company found itself in definite slump in 2003 and 2004 because of competitors

- Mileage by HPC
  - In response, rather than designing, building and testing physical prototypes, Goodyear engineers used HPC to test virtual models and significantly cut time to market

- Success
  - The result was the huge hit Assurance® all-weather tire featuring TripleTred Technology®

More Examples

Portland Cement Association

GE Aviation and Energy

The NASDAQ Stock Exchange

Texaco

Procter & Gamble

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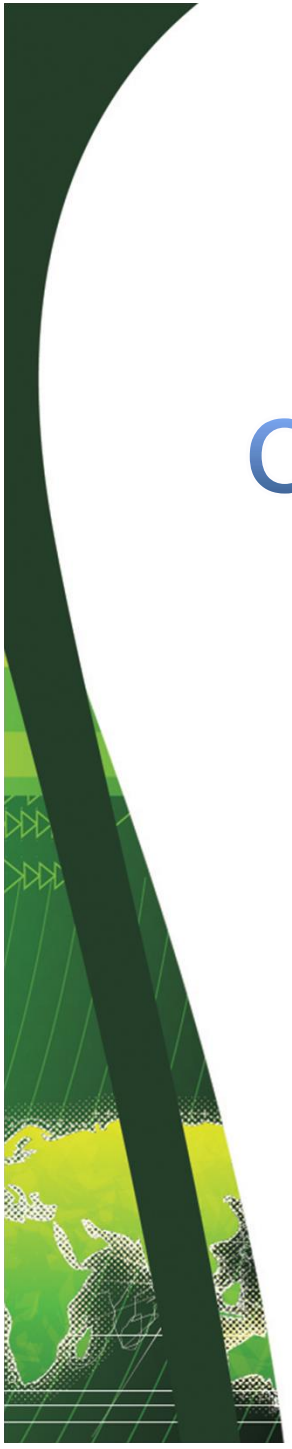

Outcompete is to Outcompute!

Thank You