# HIGH PERFORMANCE COMPUTING

*Technology Evolution & Emerging Trends*

NAMAL - 2023

FORBMAX

# Agenda

- HPC Evolution & Architecture
- HPC Technology adoption drivers & trends
- AI Boom
- HPC Systems Software/Hardware
- HPC Applications Software
- Open-Source Software

# Transforming Visions into Reality

- Forbmax is on groundbreaking journey in Pakistan to provide end-to-end services on HPC.
- Our portfolio of services include but not limited to:
  - Infrastructure Solutions
  - HPC, AI/ML
  - Open Source Consultancy

## Our Ecosystem Partners / Tools

# Our Significant Clients

FORBMAX

PAK-AUSTRIA FACHHOCHSCHULE: INSTITUTE OF APPLIED SCIENCES AND TECHNOLOGY

AF-IAST Skilling Pakistan

PIEAS

PTV NETWORK

Pakistan Television Network
PTV - Netapp Storage Project

KAPCO

Data Center Passive work

relacom

IT Consulting Services

PTV news

Data Center CISCO Switches

AlliedBank

DESCON

MCB

INFORMATION TECHNOLOGY BOARD
Government of Khyber Pakhtunkhwa

Fatima Group

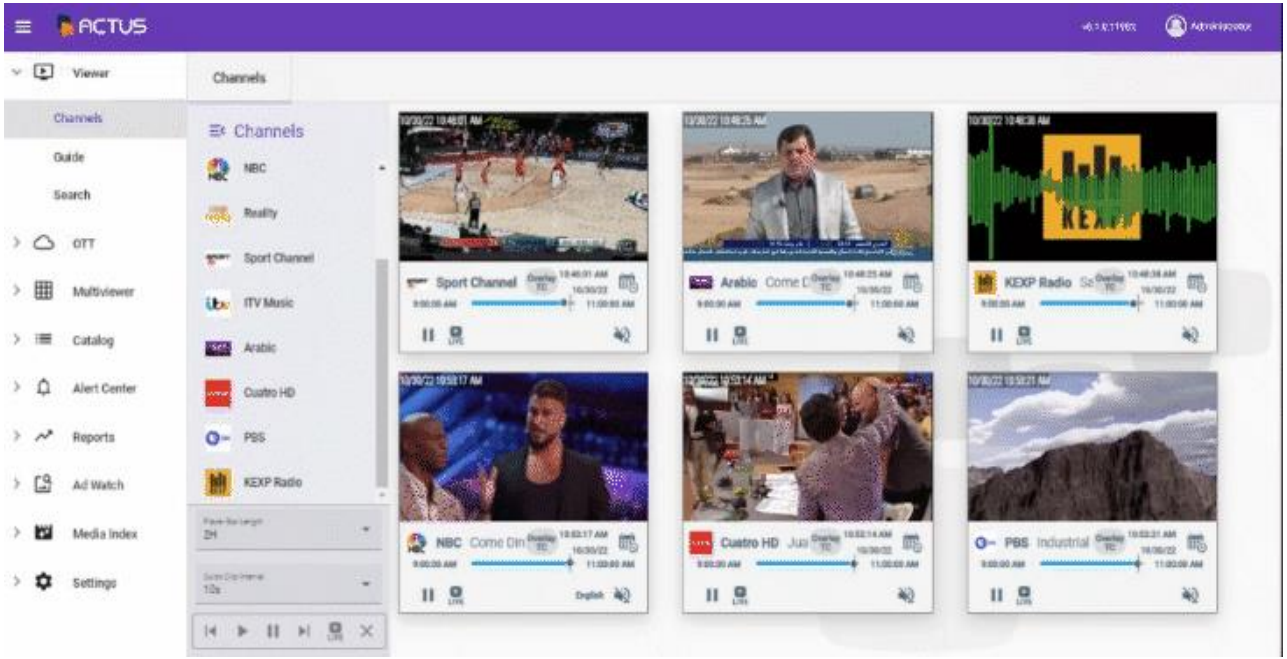
DG CEMENT

EXCISE, TAXATION & NARCOTICS CONTROL DEPARTMENT
GOVERNMENT OF THE PUNJAB

# Success Stories – Media Asset Manager & Compliance Logger

- Monitor and influence the political landscape and other trends
- Don't miss any important developments: risks, opportunities, …
- Make briefing material to relevant stakeholders, provide analyses and recommendations on key developments
- Plan effectively
- Identify key influencers and trends

## Application Interface



# Success Stories

## News Monitoring and Analysis

- Monitor TV, Radio, Internet
- Central Monitoring,  multiple locations
- Monitor the aired media in Live or from the archive
- Easy navigation to find the relevant content fast
- Archive the content for any duration
- Accessible from anywhere, anytime, from any device (PC, Mac, Mobile)
- Easy to Use (from any  Web Browser), no need to install any client
- User friendly UI


Monitor the media: anytime, from anywhere

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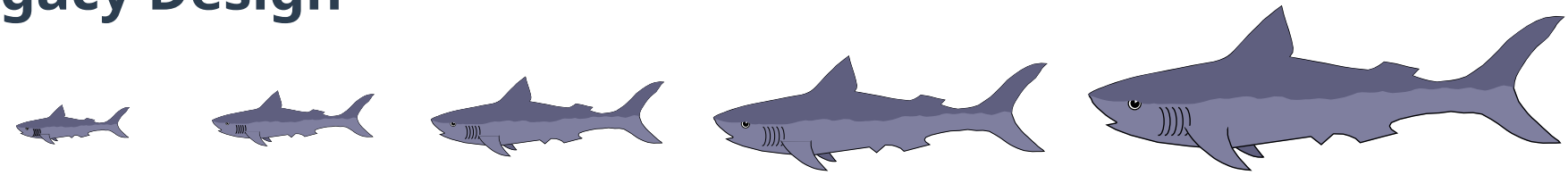
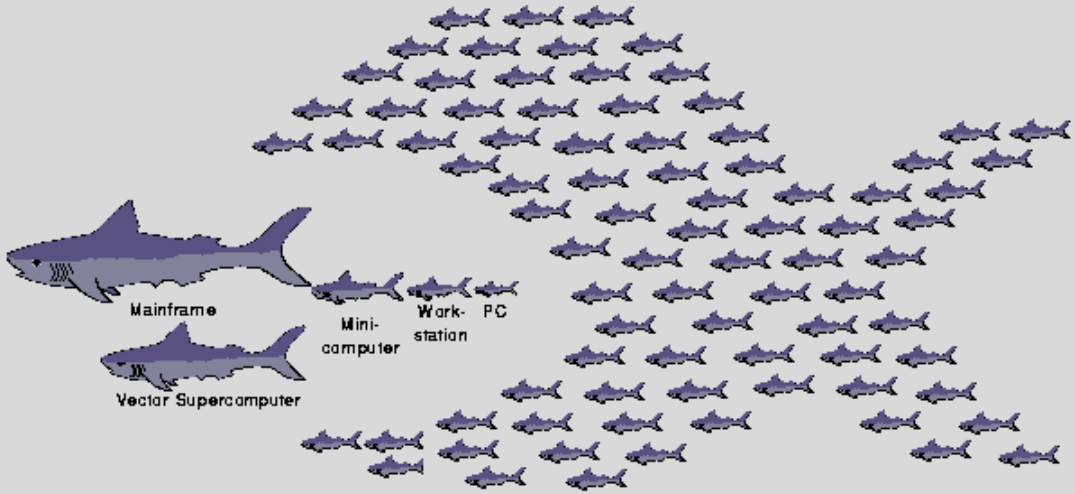
# HPC Evolution

## Legacy Design



PC Workstation Minicomputer Vector Supercomputer Mainframe

## Modern Distributed Cluster Computing



# HPC Performance Measurements

- High Performance Computing (HPC) units are:
  - Flop/s: floating point operations per second

- Typical sizes are millions, billions, trillions…
  - Mega  Mflop/s = $10^6$ flop/sec  Mbyte = $10^6$ byte
  - Giga  Gflop/s = $10^9$ flop/sec  Gbyte = $10^9$ byte
  - Tera  Tflop/s = $10^{12}$ flop/sec  Tbyte = $10^{12}$ byte
  - Peta  Pflop/s = $10^{15}$ flop/sec  Pbyte = $10^{15}$ byte
  - Exa  Eflop/s = $10^{18}$ flop/sec  Ebyte = $10^{18}$ byte

# First supercomputers

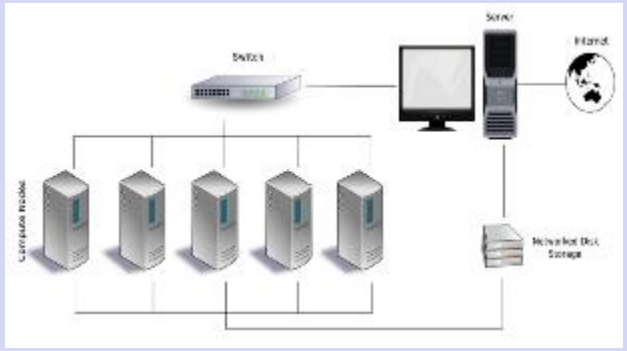
- A 60-Million-dollar investment
- **IILIAC IV** @ 200 MFlops

# HPC Paradigm

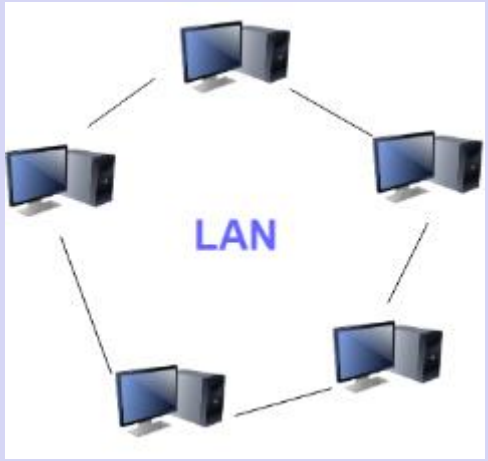
- **Big Iron / MPP**
  *(Massively Parallel Processors)*

IBM BlueGene
@ 280 TFlops


- **Beowulf clusters**

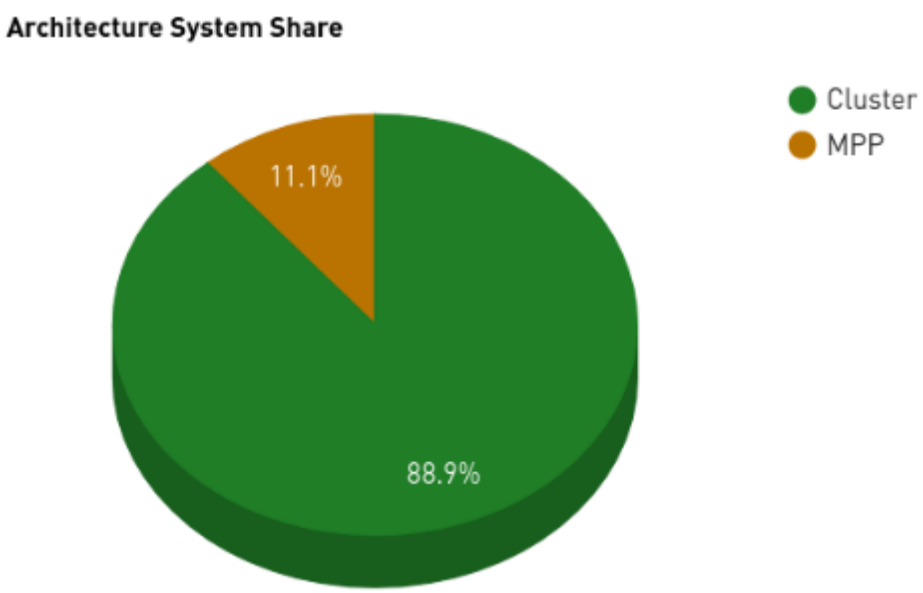


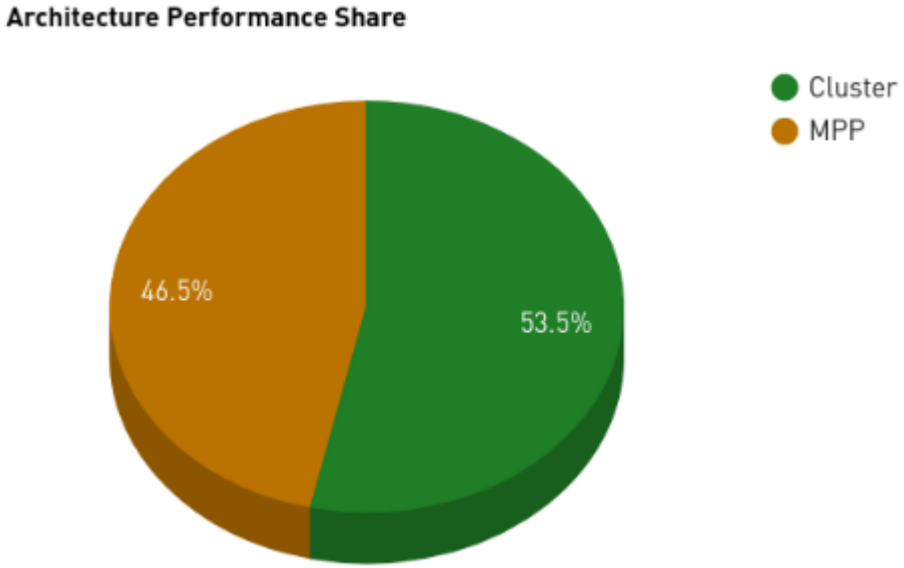
- **COW**



# Architecture Share & Performance *(2023 top500.org)*

- Clustered architecture is more suited solution within education vertical.




- Cost / Scalability / Complexities are the critical driver

*Source: World Supercomputing Watchdog – Survey 2023*

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# Technology Advancements are driving adoption of HPC Solutions

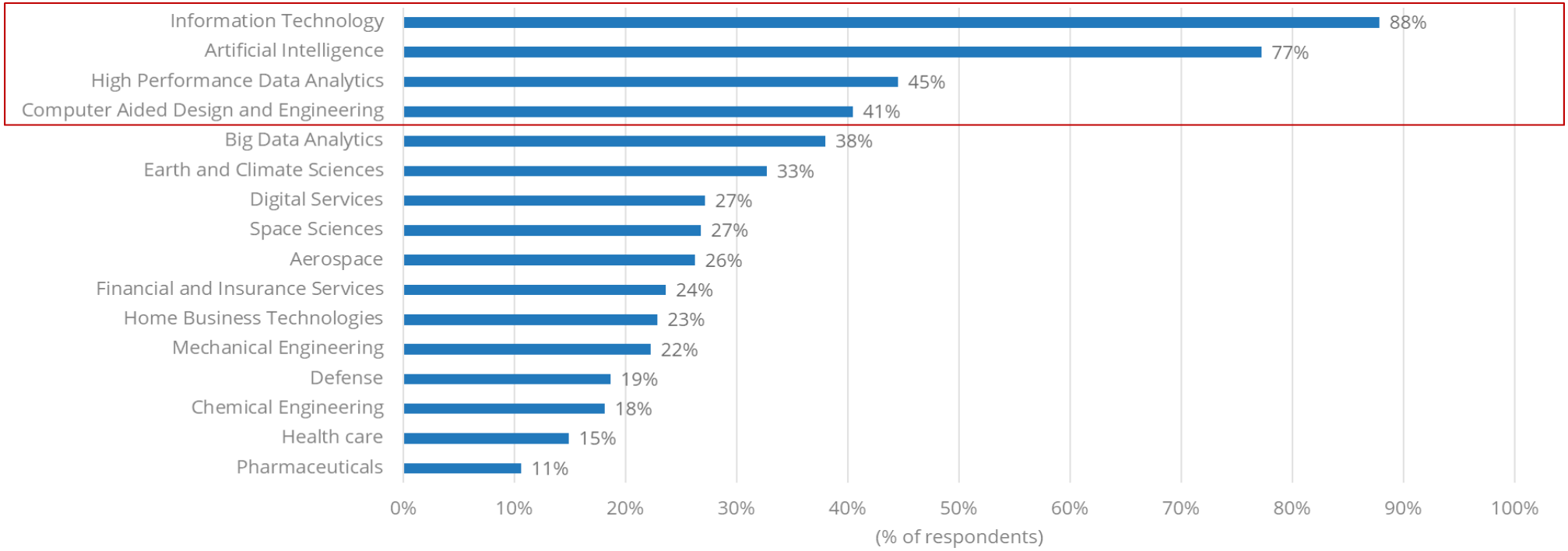
- **Artificial Intelligence and Machine Learning**

- **Hardware advancements**
  - Processors, FPGA, ASIC, GPUs, NVMe, Fast networks

- **Better API/Frameworks**
  - OpenCL, OpenACC, CUDA, OpenCV ..

# Top Use Case Groups are largely IT focused

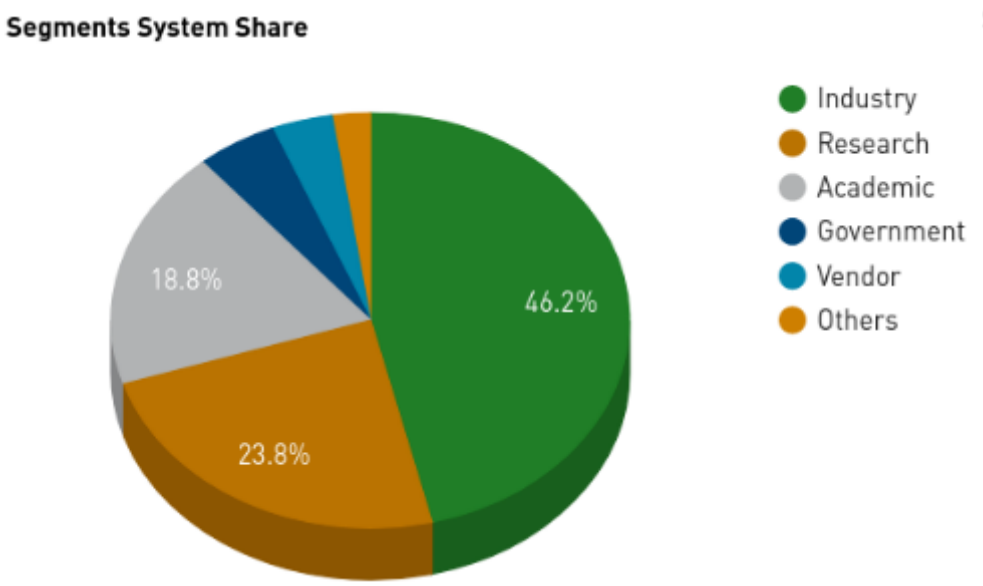
**Which of the following use cases does your organization run on its HPC environment?**

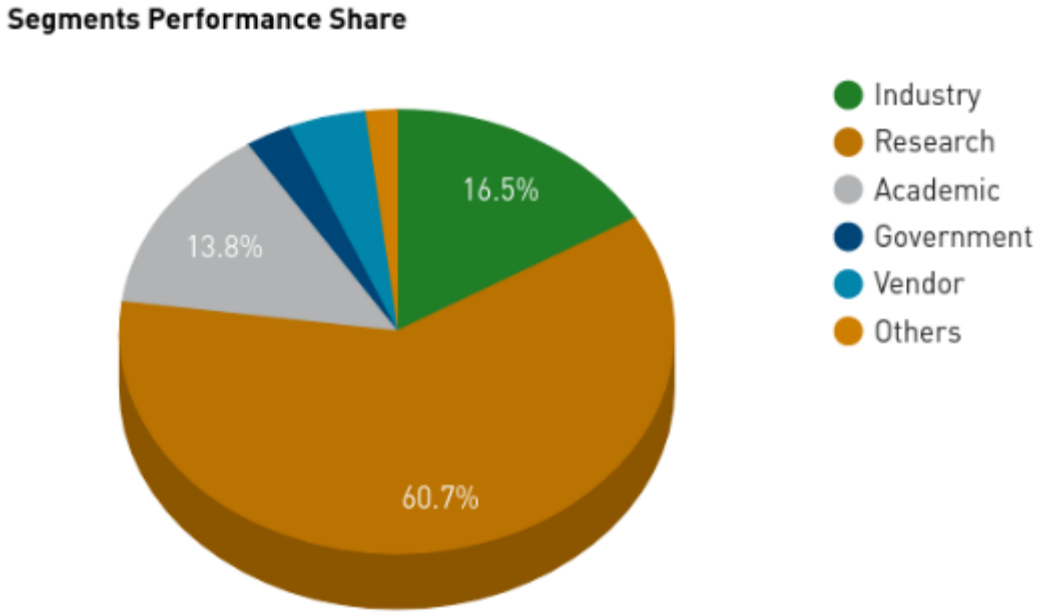



*Source: Global Research*

# HPC adoption across various verticals *(2023 top500.org)*

HPC adoption is higher among the **industrial organizations** however **performance** is critical for **Research vertical**.

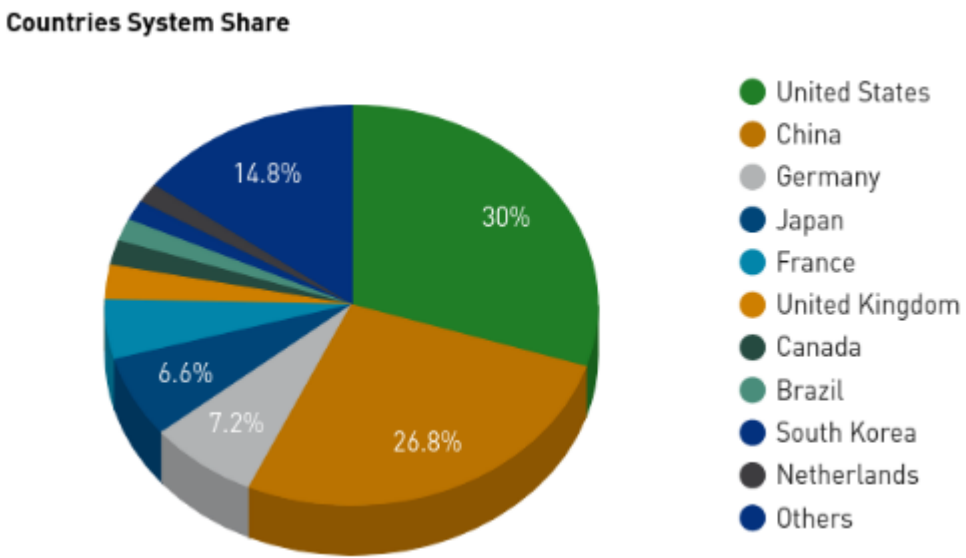


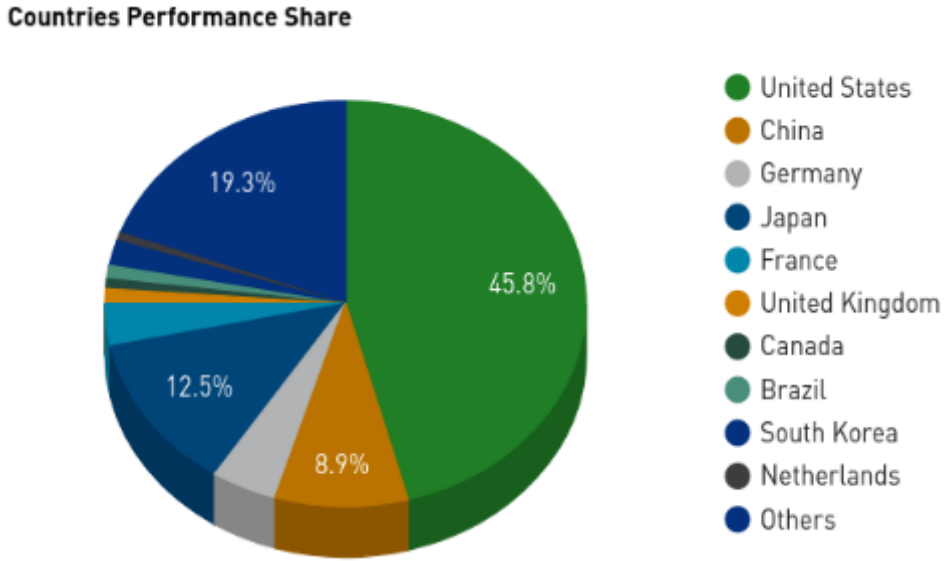




*Source: World Supercomputing Watchdog – Survey 2023*

# HPC investments is led by US followed by China

Technologically advanced countries have significant focus on HPC.




*Source: World Supercomputing Watchdog – Survey 2023*

# Top HPC Centers, USA


| Department of Energy (DOE) | National Science Foundation (NSF) | Government HPC Centers | Academic HPC Centers | Department of Defense (DOD) |
|---|---|---|---|---|
| Argonne National Laboratory (ANL) | Cornel Center for Advanced Computing , Cornell U (CCAC) | National Institute of Heath (NIH) | Alabama Supercomputer Center (ASC) | Army Research Lab (ARL), MD |
| Oak Ridge National Laboratory (ORNL) | National Center for Supercomputing Applications (NCSA) | National Aeronautics & Space Administration (NASA) | Cornell University Center for Advanced Computing (CAC) | Airforce Research Lab (AFRL) OH |
| Lawrence Berkeley National Laboratory (LBNL) | National Center for Atmospheric Research (NCAR) | National Institute of Standards & Technology (NIST) | Center for High Perf Computing, U. of Utah (CHPC) | Army Engineer Research & Dev Center (ERDC), MS |
| National Renewable Energy Laboratory (NREL) | Open Science Grid (OSG) U. of Wisconsin | National Oceanic and Atmospheric Administration (NOAA) | Caltech Resnick HPC Center | Maui HPC Center (MHPCC) USAF HI |
| Pacific Northwest National Laboratory (PNNL) | Pittsburgh Supercomputing Center (PSC) | **Military HPC Centers** | Ohio Supercomputing Center (OSC) | Navy DSRC Stennis Space Center, MI |
| National Energy Technology Laboratory (NETL) | Pervasive Technology Institute, Indiana U (PTI) | Army Research Lab (ARL) | Massachusetts Green HPC (MGHPCC) MIT | Wright Patterson AFB, OH |
| Lawrence Livermore National Laboratory (LLNL) | San Diego Supercomputing Center (SDSC) | Airforce Research Laboratory (AFRL) | North Carolina Supercomputing Center (NCSC) | |
| Los Alamos National Laboratory (LANL) | Texas Advanced Computing Center (TACC) | Naval Research Laboratory (NRL) | Stanford Research Computing Center | |
| Sandia National Laboratory (SNL) | | | Yale Center for Research Computing (YCRC) | |

# Top HPC Centers (Asia, Europe)

**China**

- National Supercomputing Center (NSC) (Guangzhou)
- NSC Changsha
- NSC Jinan
- Shanghai Supercomputing Center (SSC)) Shanghai Municipal Government
- NSC Shenzhen
- NSC Tianjin
- NSC Wuxi
- NSC Chengdu
- **China National Grid (CNGrid)**
- Supercomputing Center of the China Academy of Sciences (SCCAS), Beijing

**Japan**

- GSIC Tokyo Institute of Technology (TIT)
- RIKEN Institute of Physical and Chemical Research
- Japan Atomic Energy Agency (JAERI)
- University of Tokyo (UT)
- Nagasaki U Advanced Computing Center
- Japan Meteorological Agency (JMA)
- **Japan National Grid**
- National Research Grid Initiative (NAREGI)

**European HPC Joint Undertaking (EuroHPC JU)**

- Barcelona Supercomputing Center (BSC), Spain
- Bulgarian Science & Technology Park
- CINECA Italy
- CSC IT Center for Science Data Center, Finland
- Edinburgh Parallel Computing Center, (EPCC) UK
- French National Center for Scientific Research (CNRS)
- Greek Research & Technology Network (GRNET) Greece
- )
- HPC Center (HLRS), Germany
- Irish Center for High-End Computing (ICHEC)
- Institute of Information Science Maribor (IZUM) Slovenia
- Academic Computer Centre CYFRONET AGH Poland
- Governmental Agency for IT Development, Hungary
- IT3 Innovations National Computing Center, Czech Republic
- LuxProvide Data Center, Luxembourg
- Minho Advanced Computing Center, Portugal
- SURFsara, Netherlands

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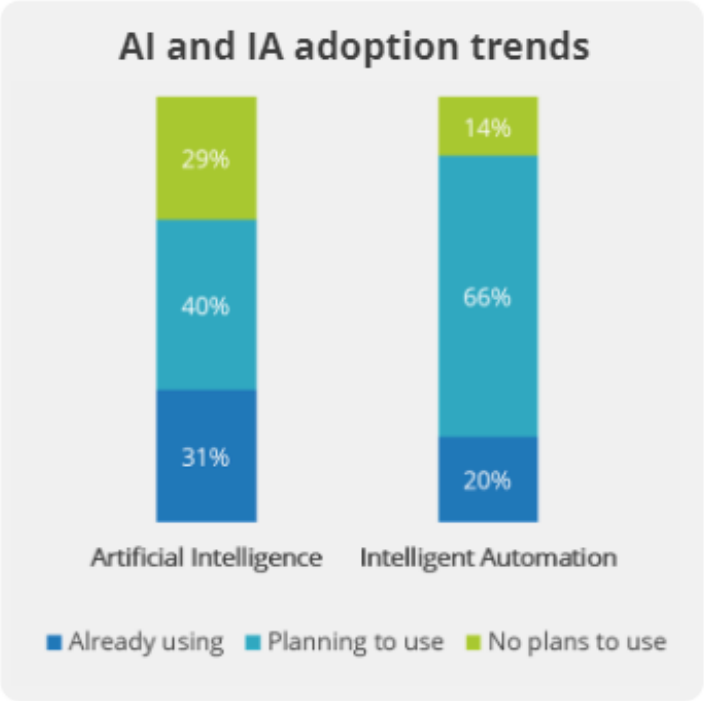
# AI will play a radical role in HPC

*What is your current state using AI in your operations?*





*Source: Global Research*

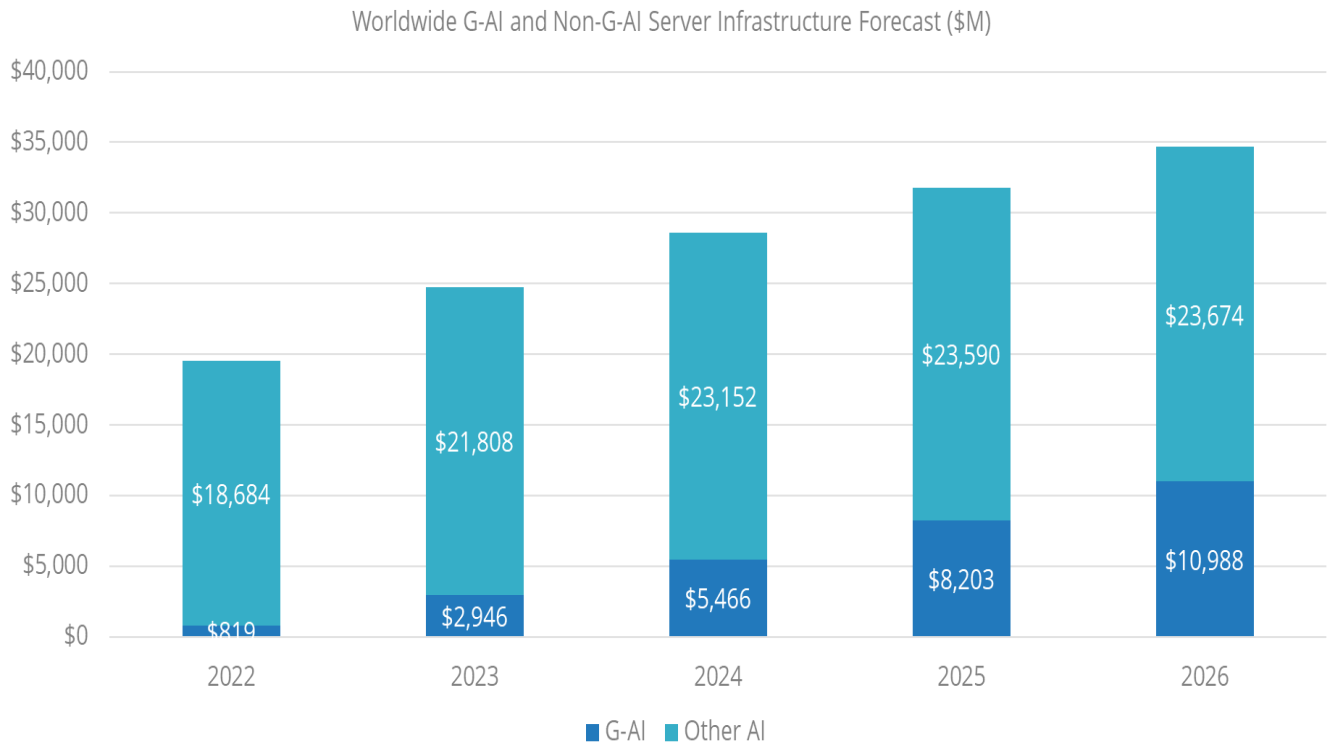
# AI market is expect to show healthy growth

- Forecast
  - Massive AI model developments, with **large language models (LLM)**, require significant amounts **of compute and storage**
  - Vendor solutions offerings of **server and storage, co-processors & interconnects**
  - Projections in worldwide **AI hardware market (server and storage),** including for running generative AI, will grow from **$18.8 billion (est.) in 2021** to **$41.8 billion (est.) in 2026**, representing close to 20% of the total server and storage infrastructure market, according IDC – 2022.

*Source: Global Research*

# Spending on Generative AI continues its growth

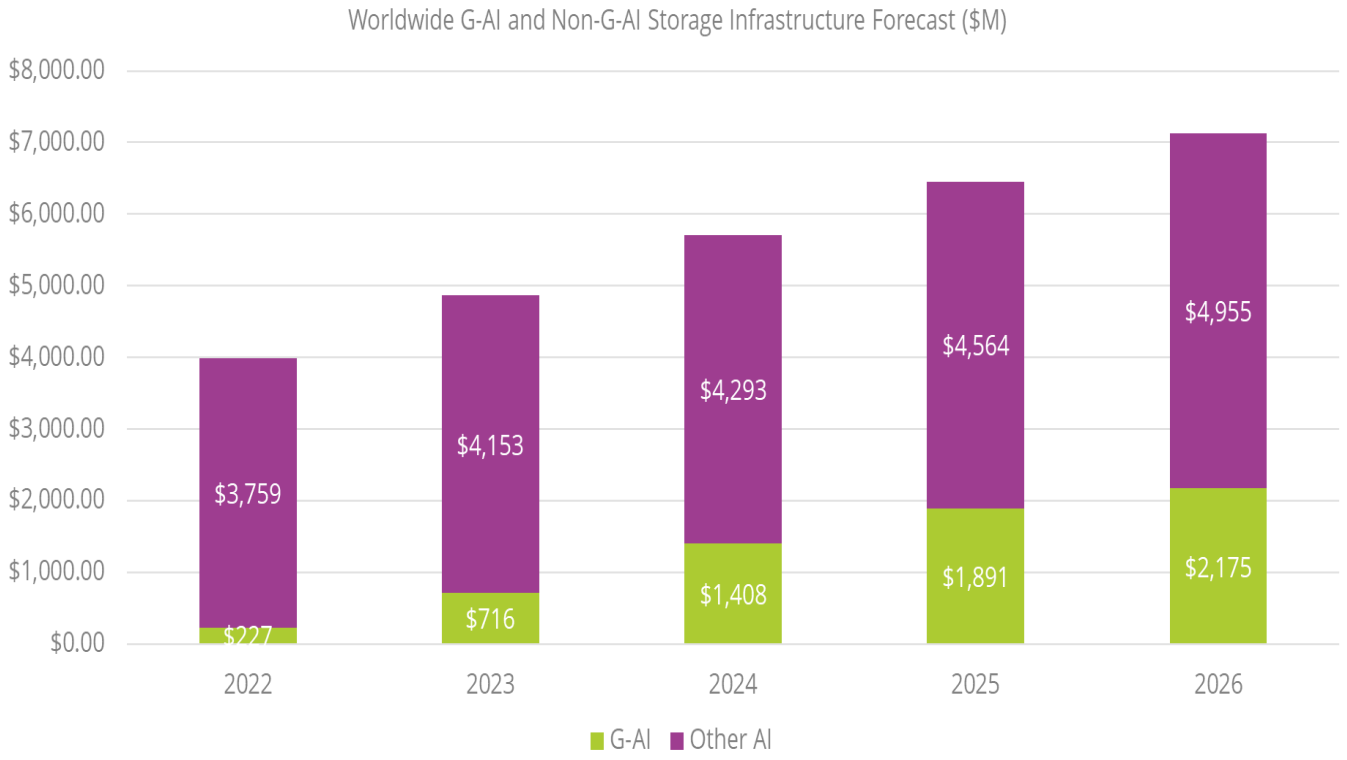
- Significant focus post launch of ChatGPT
- Focus by service providers
- Predictive / Prescriptive will continues to drive AI adoption




*Source: Global Research*

# Massive Datasets will require investment in storage

- AI requires extensive datasets
- Storage needs will continue to grow
- Big data will play more significant role




*Source: Global Research*

# Competition among the major cloud service providers for hosting generative AI workloads

**Microsoft** recently introduced the **ND H100 v5 series**, which enables on-demand scaling with sizes between eight and thousands of NVIDIA H100 GPUs

**IBM Cloud** announced its new supercomputer offering, **Vela**, which will be rolled out across IBM's global datacenters

**AWS announced** the launch of **EC2 Ultra Clusters of P5** instances, scalable to up to 20,000 H100 GPUs.

- Also competing are specialized clouds such as, for example:
  - **Paperspace**, offering NVIDIA A100 GPUs as a service and Graphcore IPUs
  - **Lamda Labs**, offering NVIDIA H100 deep learning clusters as a service
  - **Coreweave**, a purpose-built cloud for AI
- These **as-a-service providers** compete on efficiency first and foremost: training an AI model with the highest accuracy and at the lowest cost.

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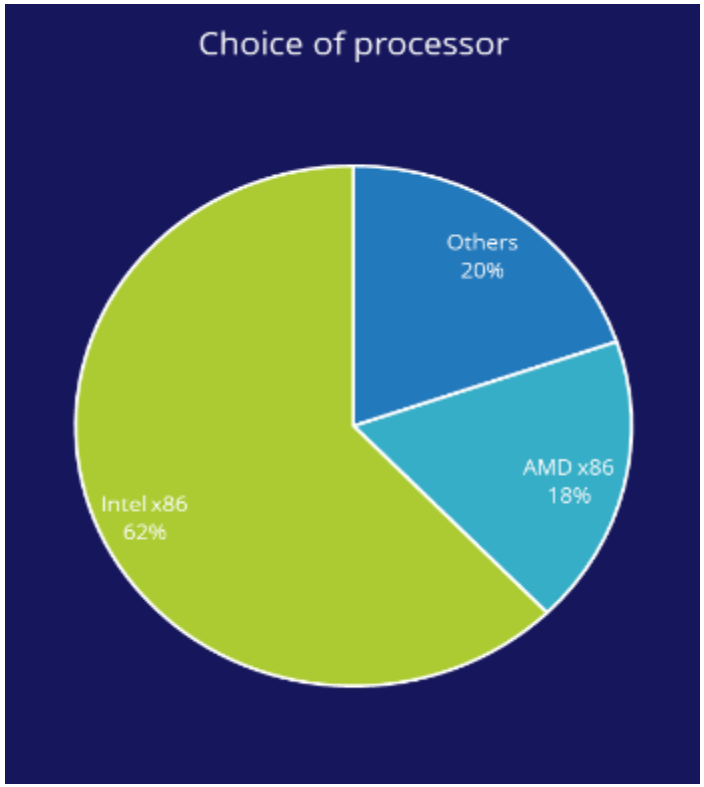
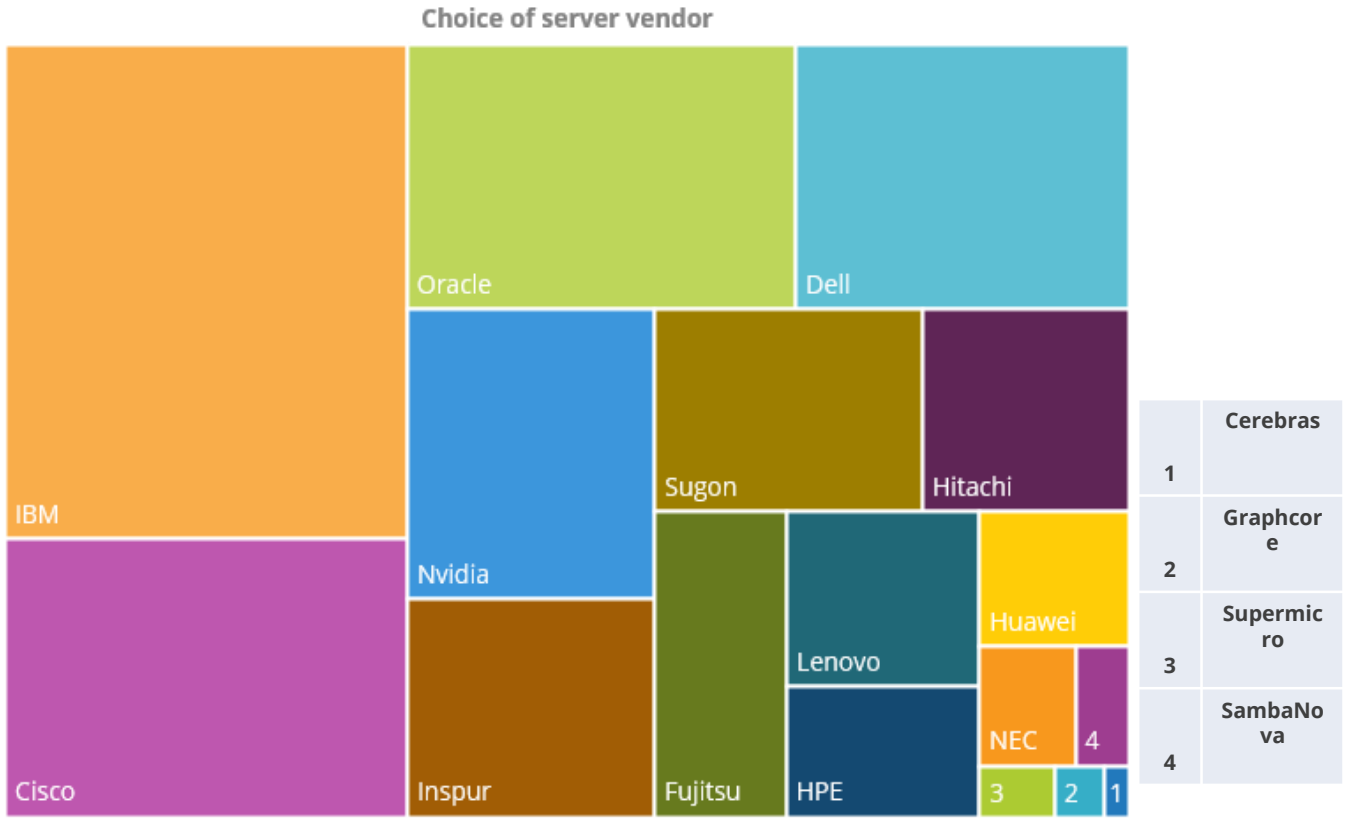
# Major hardware players withing the HPC hardware ecosystem

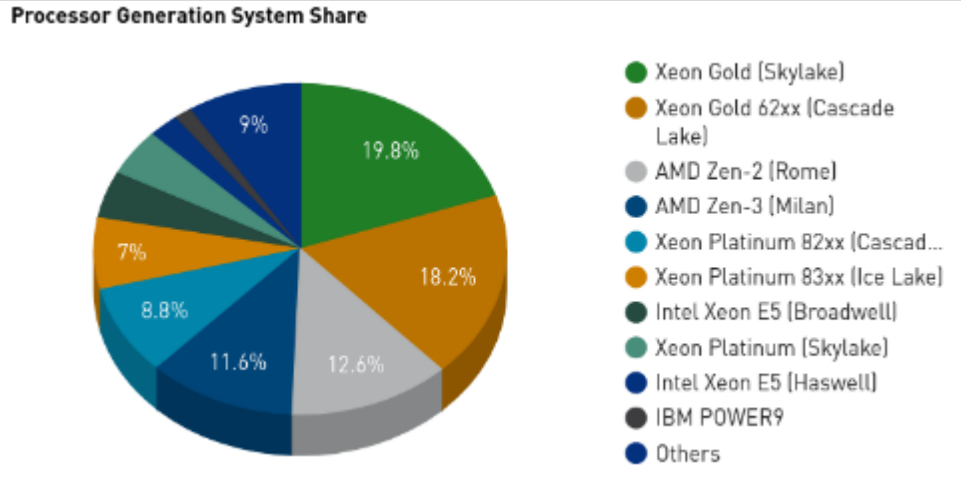


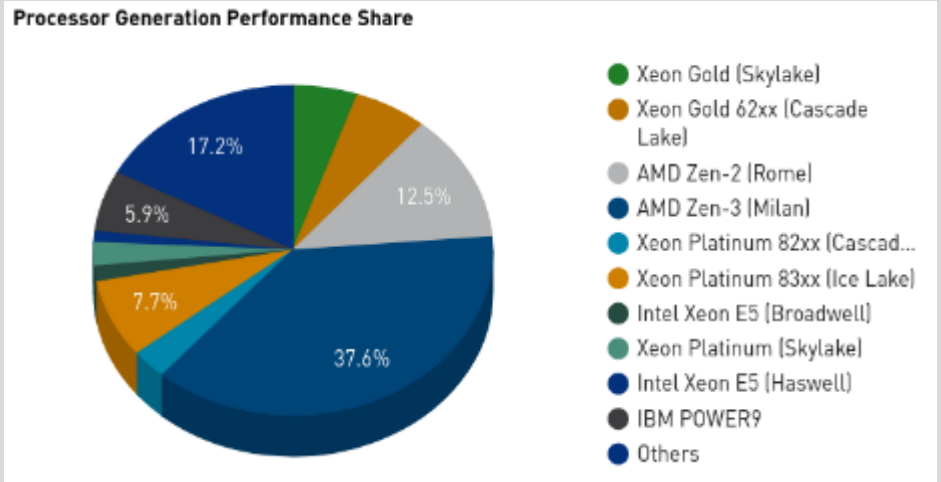




*Source: Global Research*

# Core CPU Generation & Performance Share

- Newer generation CPU’s are better value for money

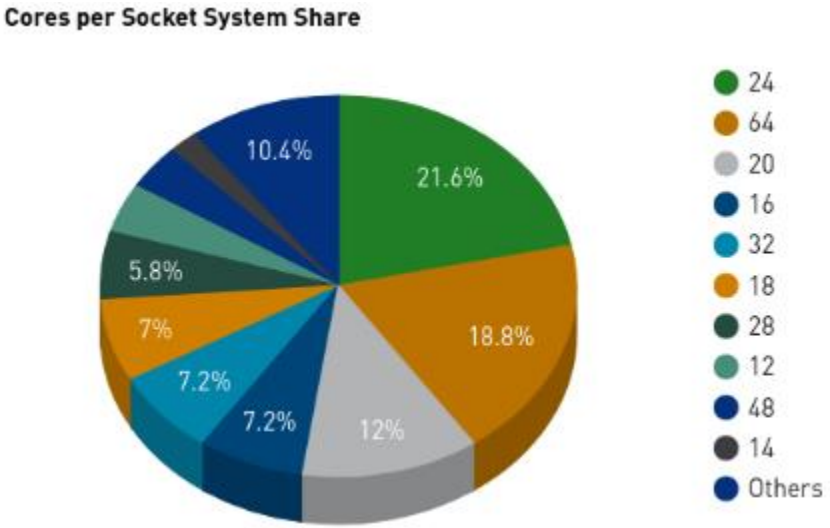


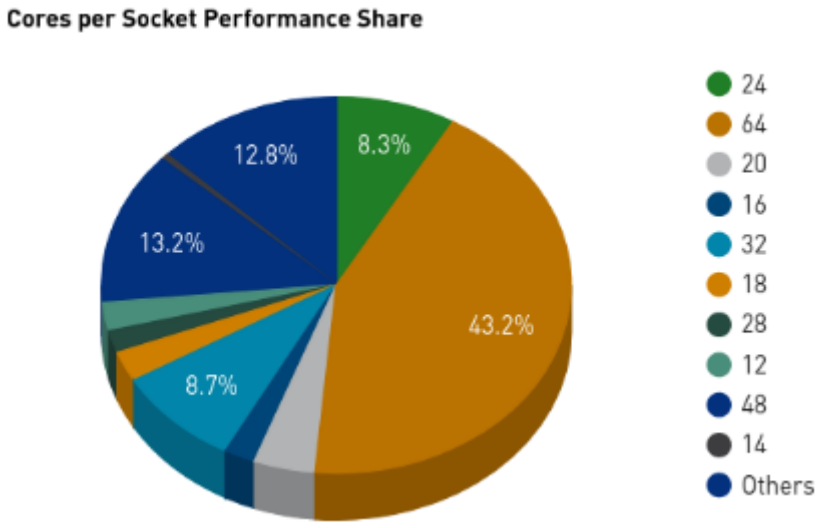




*Source: World Supercomputing Watchdog – Survey 2023*

# CPU Cores and Performance Shares

- Condensing Cores for better performance & scalability

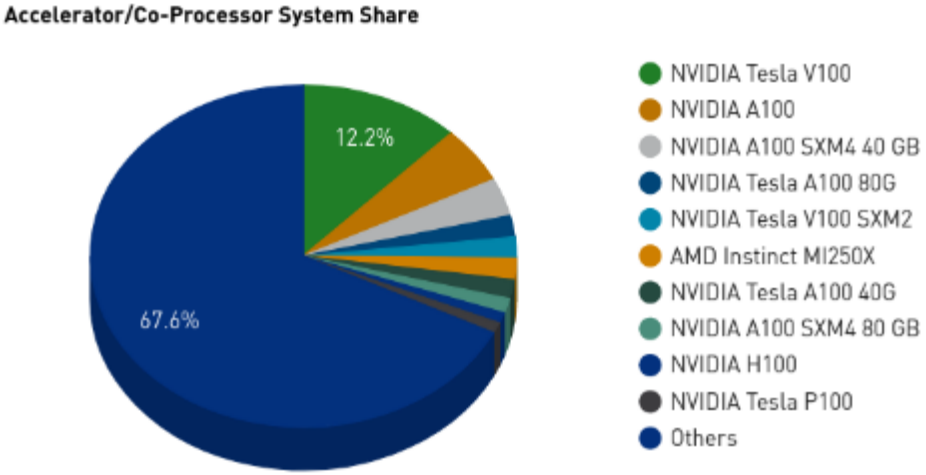


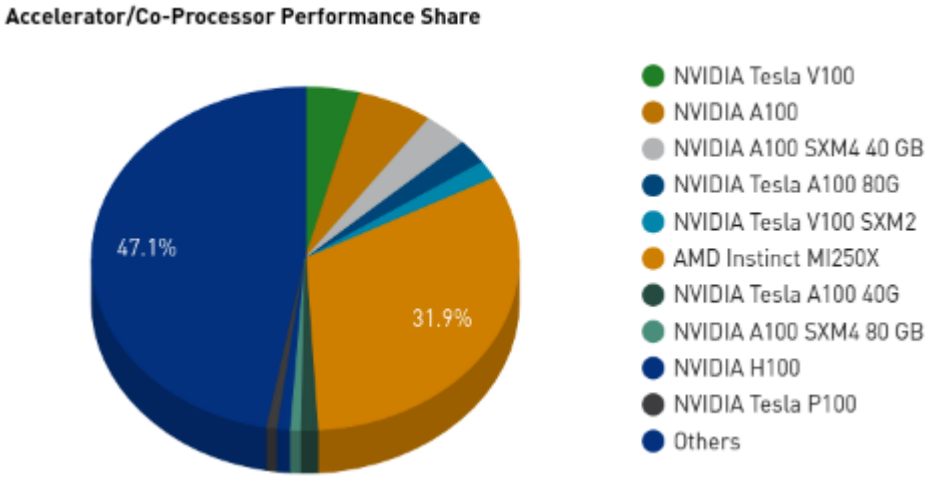




*Source: World Supercomputing Watchdog – Survey 2023*

# Server accelerators generation & performance share

- Cluster market is dominated by the GPU's.

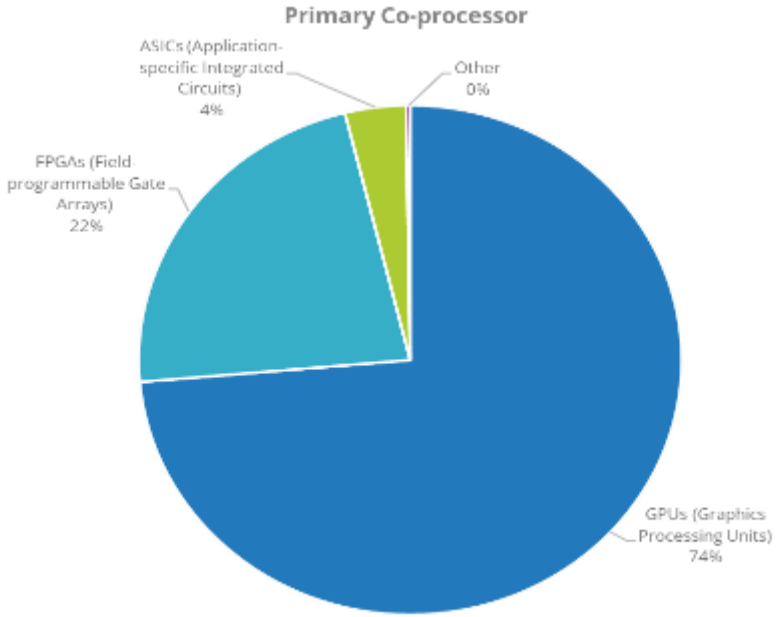


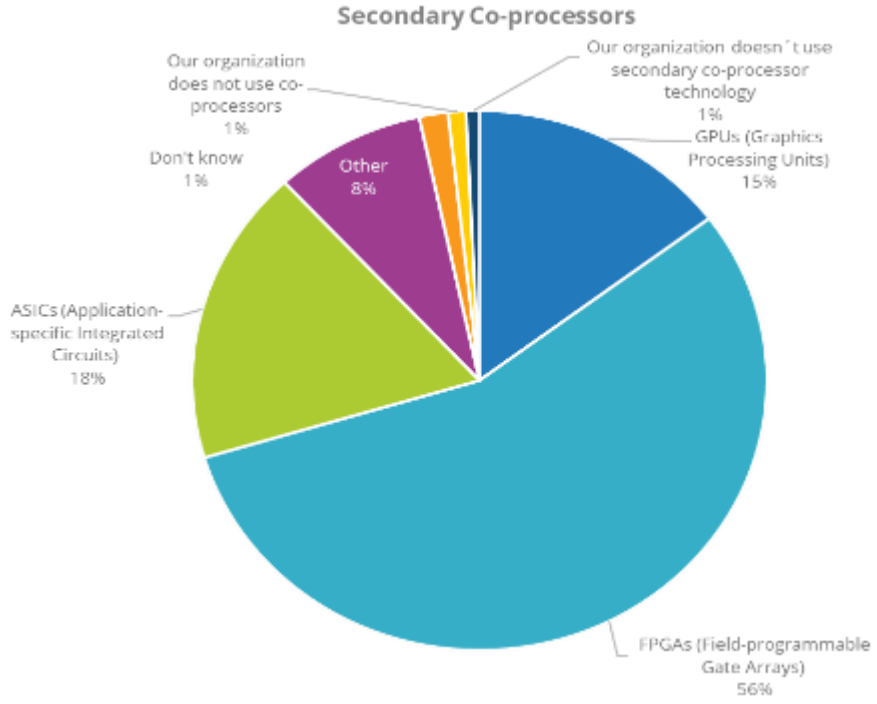




*Source: World Supercomputing Watchdog – Survey 2023*

# Around 60% of enterprise HPC environments are accelerated

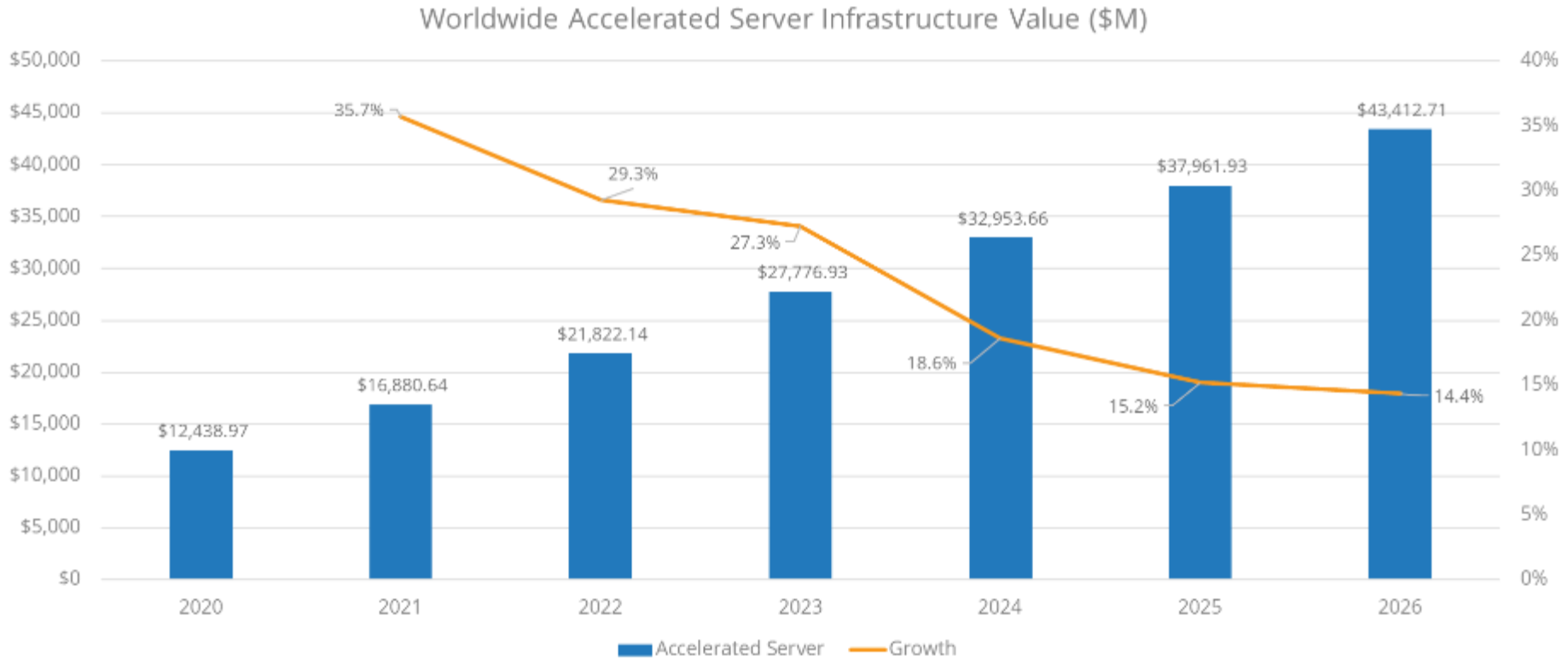
- Majority of organizations use primary or secondary co-processor for executing all of part of HPC workload



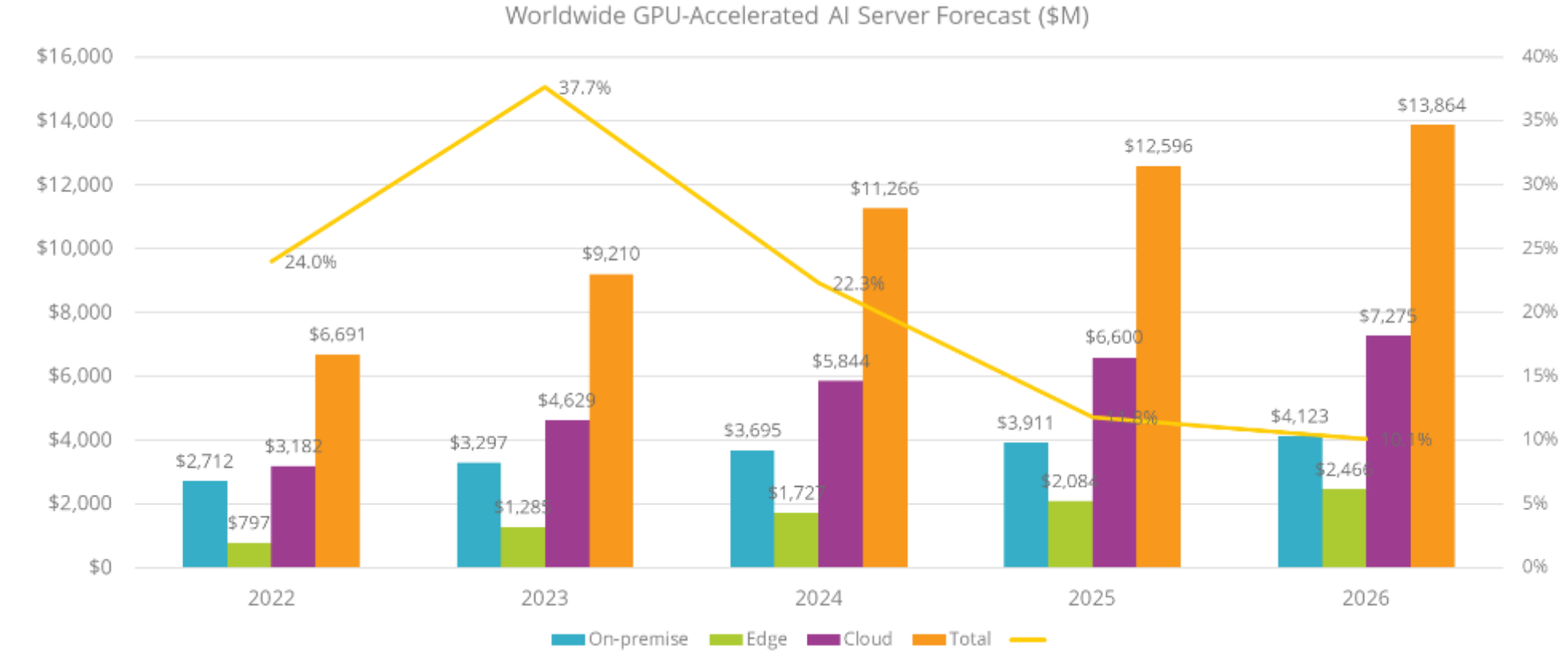

*Source: Global Research*

# Market for accelerated server infrastructure will grow at a five-year CAGR of 20.6% and reach $43.4B in 2026




*Source: Global Research*

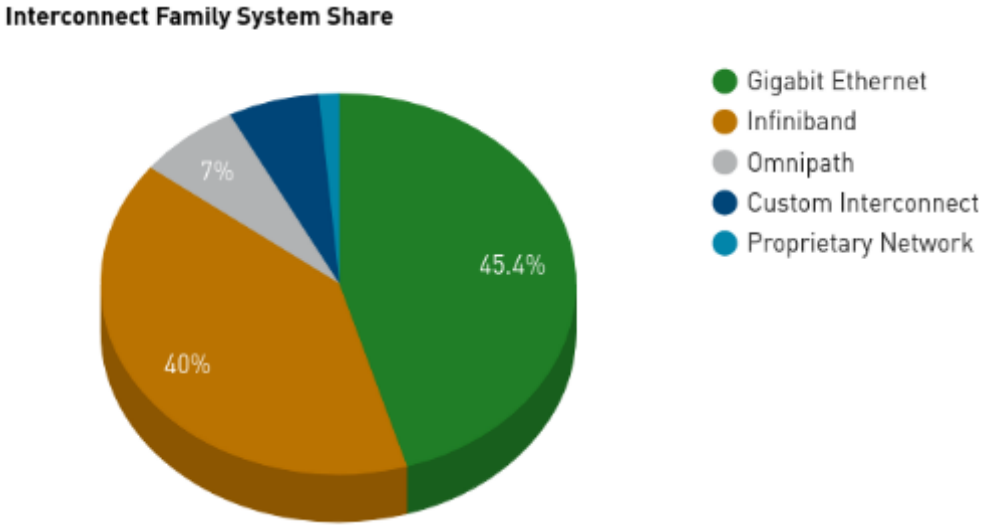
# The biggest deployment scenario for GPU-accelerated AI servers is the cloud

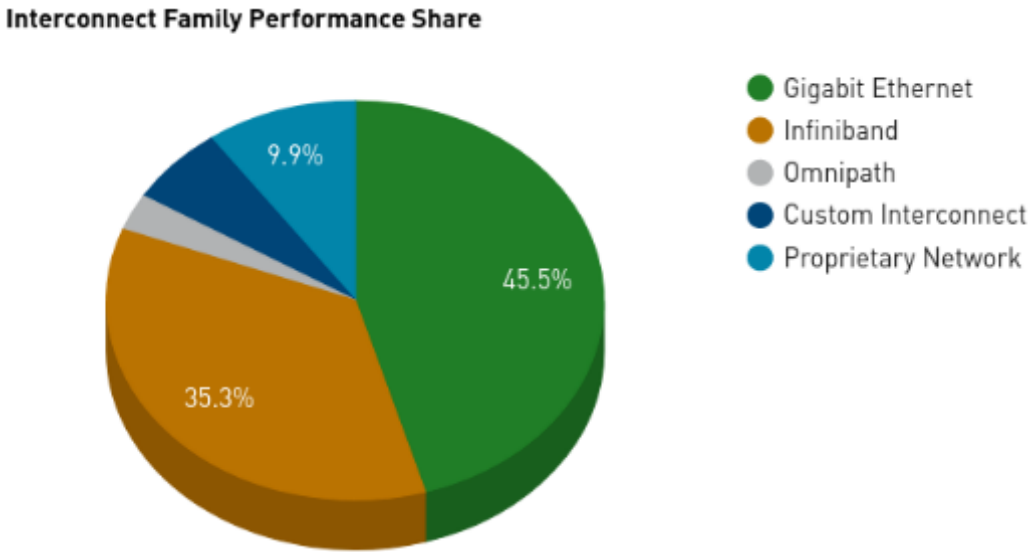



*Source: Global Research*

# HPC Interconnect vendors & performance share

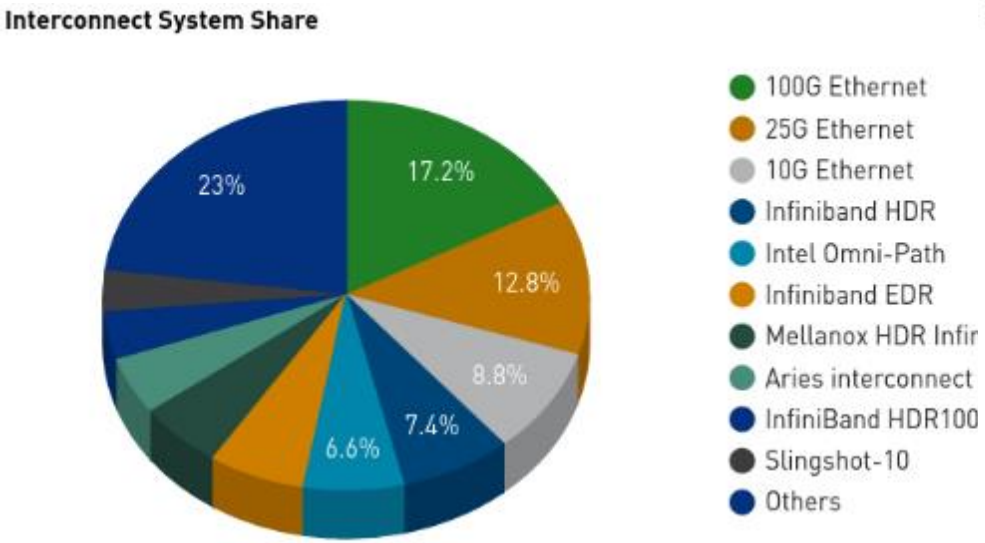
- Primarily dominated by Infiniband and Ethernet

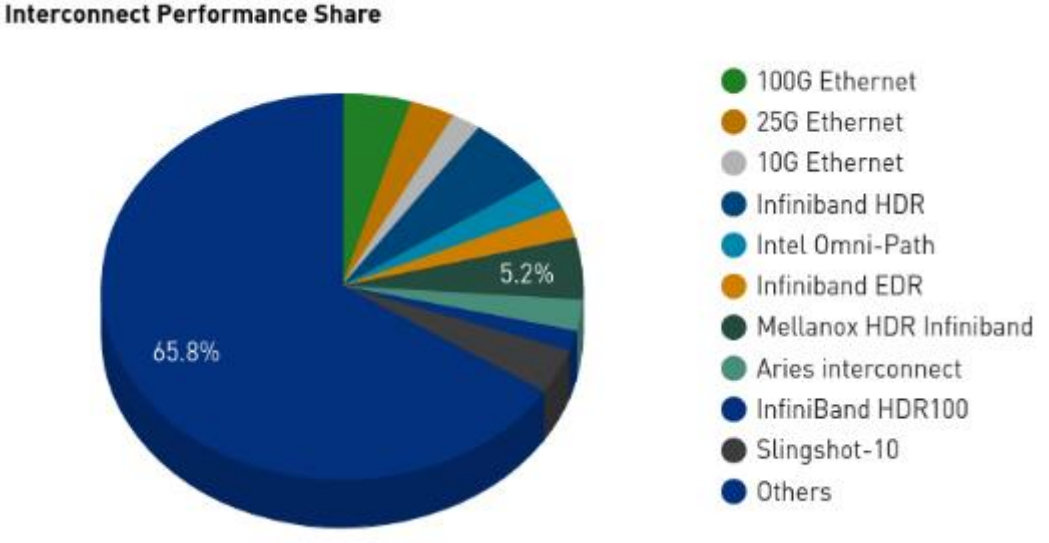



*Source: World Supercomputing Watchdog – Survey 2023*

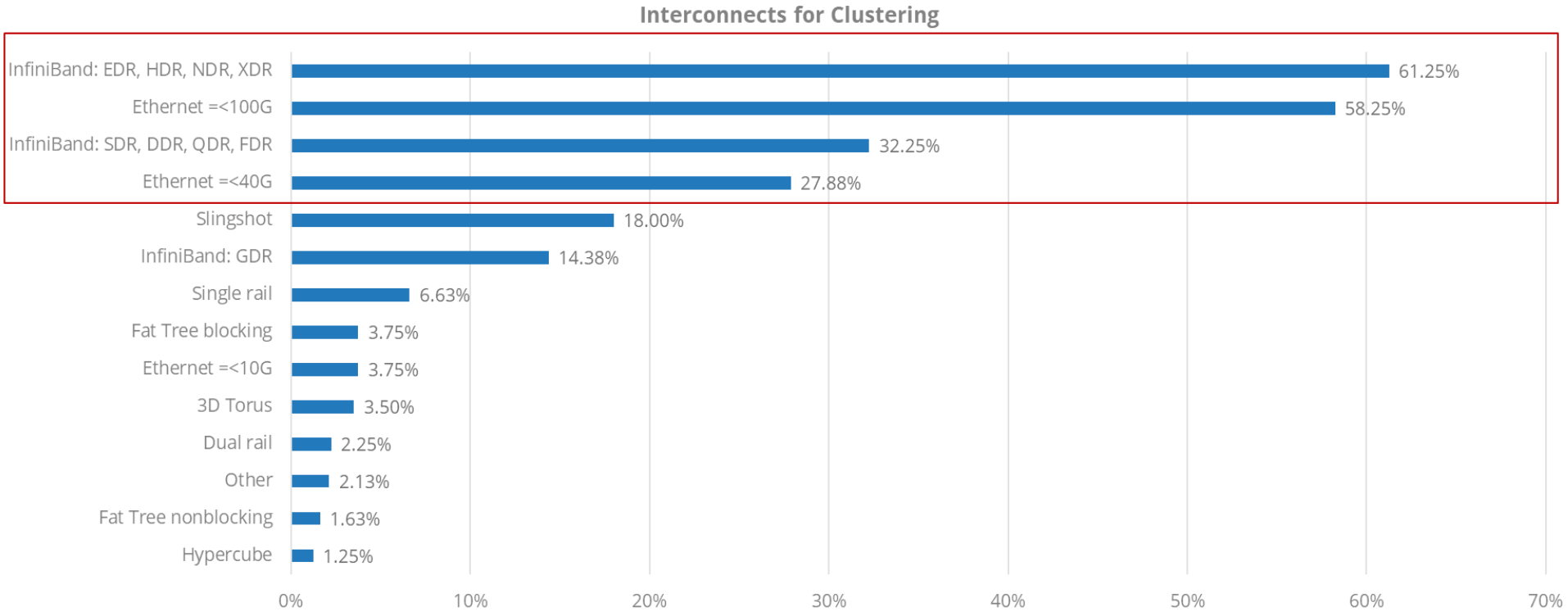
# HPC Interconnect generation & performance share




*Source: World Supercomputing Watchdog – Survey 2023*

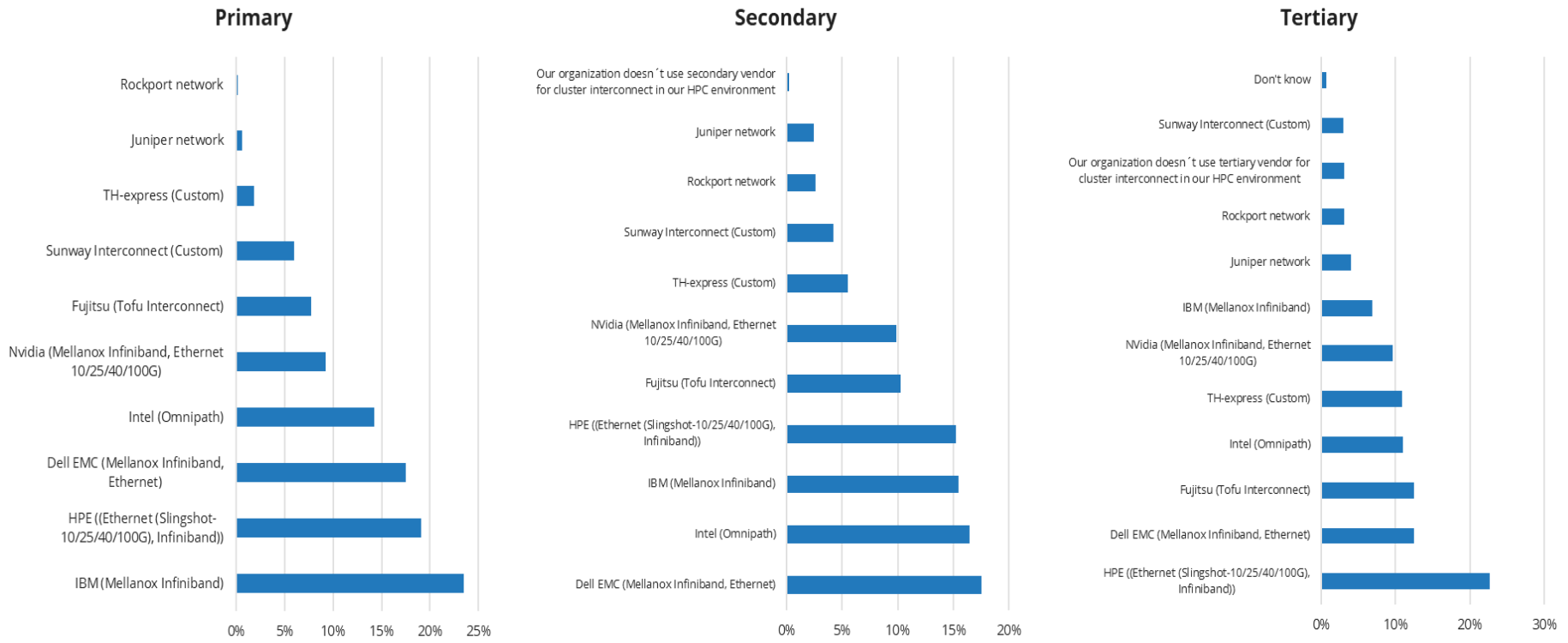
# InfiniBand remains the de-facto Cluster Interconnect, but Ethernet is quickly catching up




*Source: Global Research*

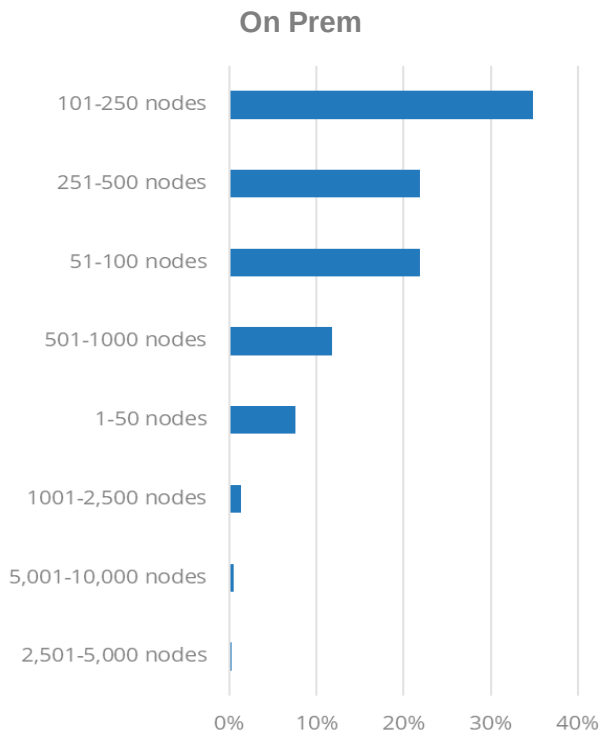
# What kinds of storage networking is used in HPC clusters?

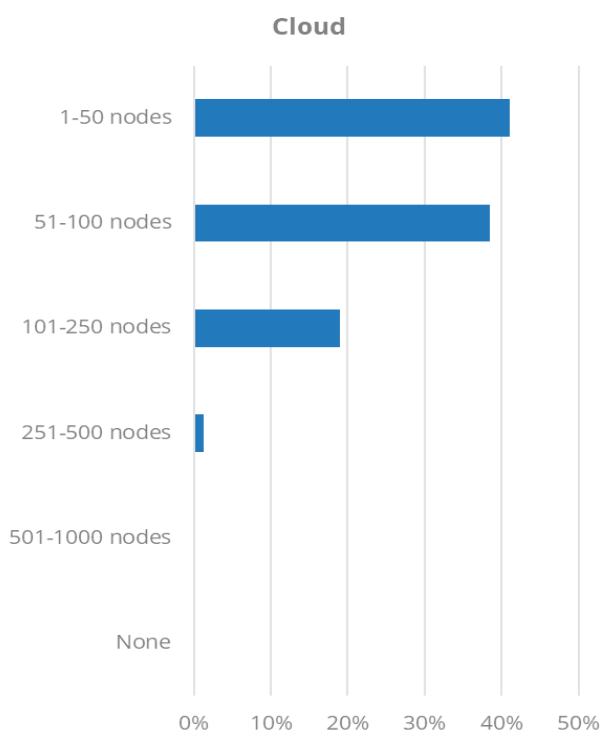
## Which vendors provide storage networking for your organization's HPC environment?

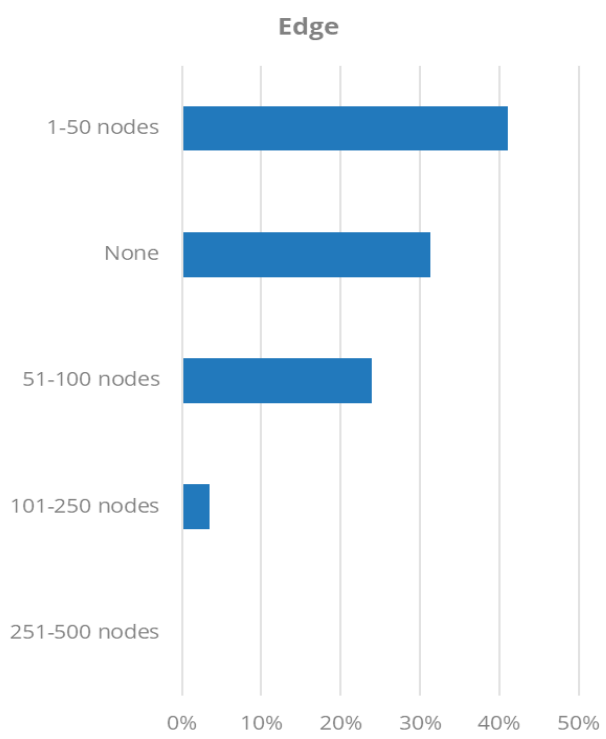



*Source: Global Research*

# Majority of HPC deployments are still on-premises based; with the largest clusters operated on self-owned/operated facilities




*Source: Global Research*

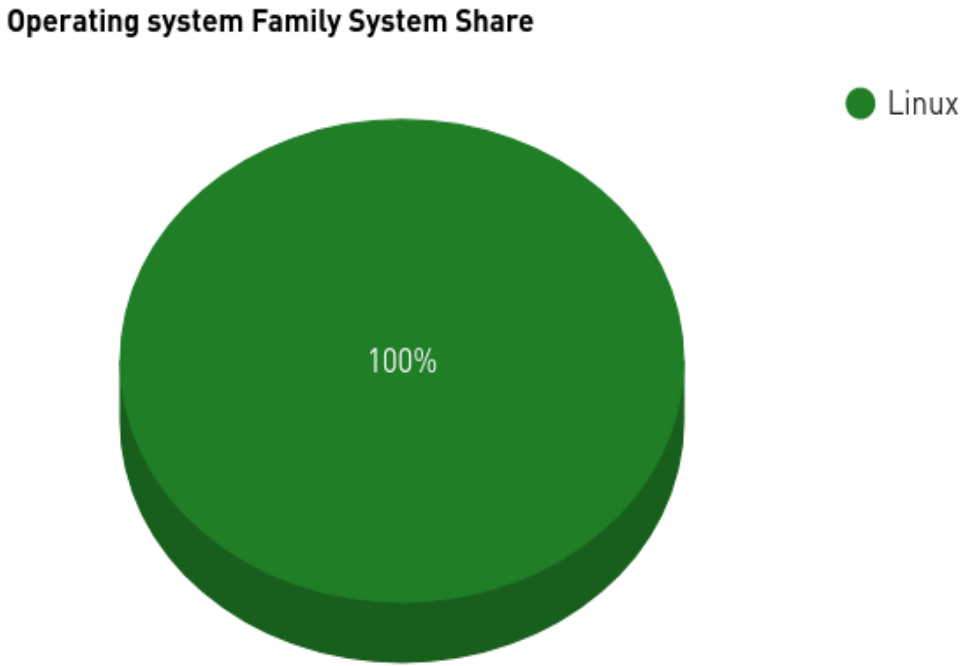
# Agenda

- HPC Evolution & Architecture
- HPC Technology adoption drivers & trends
- AI Boom
- HPC Systems Hardware & Software
- HPC Applications Software
- Open-Source Software

# HPC System Software Components

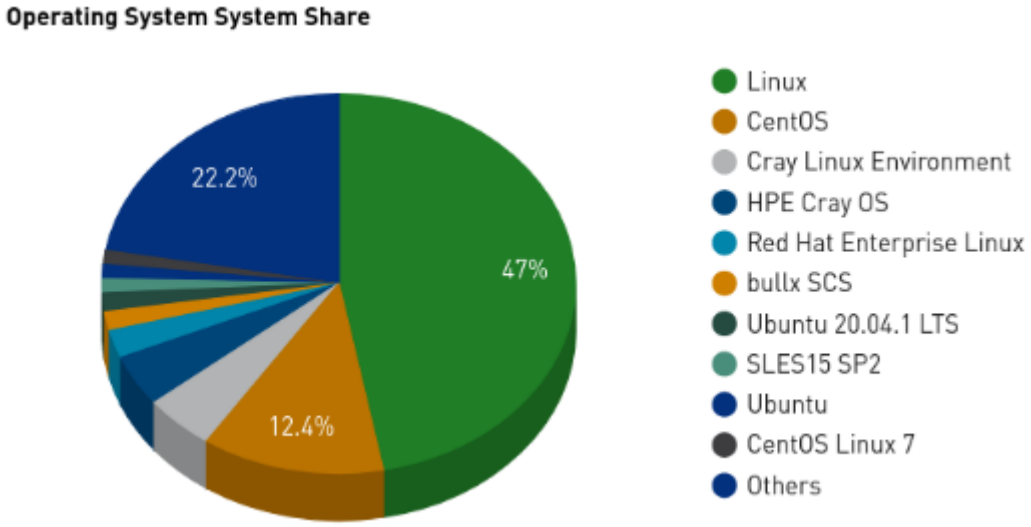
**HPC Systems Software**

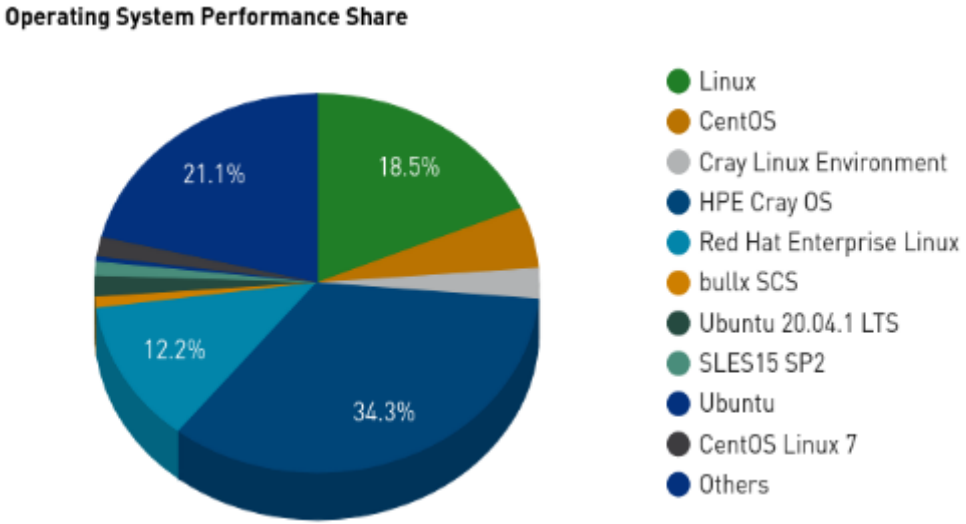
- Operating Systems
- System Management
- Scheduler, or Workload Management
- Application Software Development Ecosystem
- Programming Software Environment
- Network Fabric Software
- Storage Filesystems
- Storage Benchmarks
- Remote Visualization, or Remote Computation
- Data Management & Logistics
- Productivity Tools
- Converged, Hyperconverged & Composable Infrastructure




*Source: World Supercomputing Watchdog – Survey 2023*

# Operating System Linux distributions share & performance




*Source: World Supercomputing Watchdog – Survey 2023*

# Systems software stack *(Integrated systems management - provisioning*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Storage & Filesystem** | BPFS | CephFS | CHFS | DAOS | LUSTRE | GPFS |
| | Dell Powerstore | FlashFS | GekkoFS | IME | IBM Spectrum Scale | |
| | MadFS | NetApp | OceanFS | Panasas | Pure Storage | Quobyte |
| | VAST | WekaIO | Qumulo | Accelero | Kapok | BeeGfs |
| **Storage Benchmark** | FIO | Iometer | IOR | Iozone | Cross Platform Disk | Vdbench |
| **System Management & Monitoring** | Ansible | Apache Mesos | Aspen Cluster Management | Bright Cluster Manager® | Cycle Computing | |
| | Ganglia | Grafana | HPE Performance Cluster Manager (HPCM) | Nagios | OpenHPC | |
| | OneSIS | Prometheus | Puppet Enterprise | Scyld Clusterware | XCAT | Zabbix |
| **Schedulers, Workload Management & Orchestration** | Adaptive Moab Cluster Suite | Altair PBS Pro | Altair GridEngine (SGE) | Containers: Docker, Singularity | | |
| | Kubernetes | Runai | Spectrum LSF | SLURM | Oracle Grid Engine (SGE) | |
| **Operating System** | RedHat Enterprise | Centos/Rocky Linux | Fedora | Net/Free/OpenBSD | Open/SUSE | Ubuntu Enterprise |

# Systems software stack

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Network Fabric | Infiniband Unified Fabric | Ethernet 10/20/40/100/200/400 GigE | Fiber Channel | Nvidia NVlink | | | |
| | HPE Slingshot | Rockport Network | Sunway Interconnect | TOFU Interconnect | TH Express | | |
| Remote Visualization | NICE DCV EnginFrame | Infovision VCollab | EXceed | Paraview | Ascinema | Circos | OpenCV |
| | Lowchart | Xfig Fig2dev | Visit | | | | |
| Hyperconverged Storage | Dell VXrail | HPE Nimble dHCI | HPE Nimble dHCI | Lightbits Labs LightOS 2.1 | | | |
| | Liqid Composiable Disaggregated Infrastructure (CDI) | | Nutanix, HPE Greenlake SimpliVity HCI | | | | |

# Agenda

- HPC Evolution & Architecture
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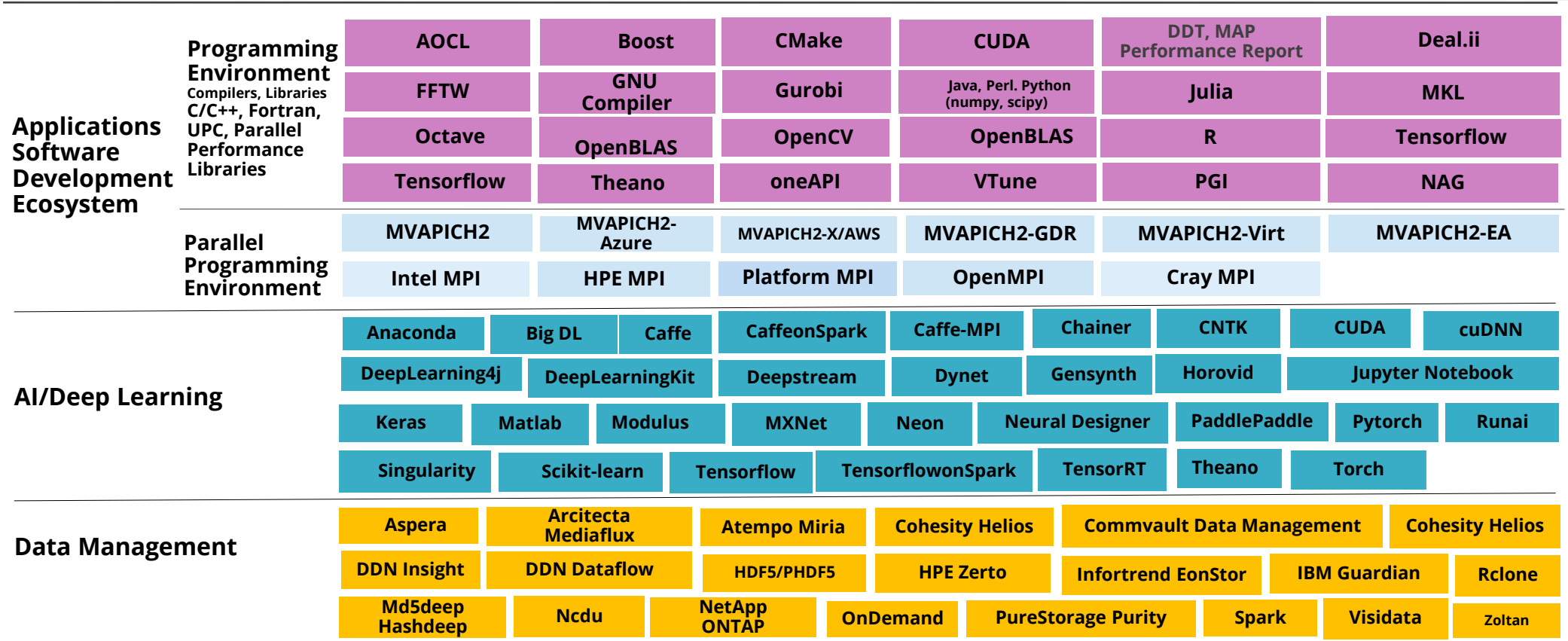
- AI Boom
- HPC Systems Software/Hardware
- HPC Applications Software
- Open-Source Software

# Applications Software stack



# Applications software stack

**Modeling & Simulation (M&S)**

**ANSYS**: *APDL Autodyn BladeModeler CFX Chemkin-Pro CM DesignModeler DGTD Discovery EMA3D EnSight Exalto FDTD FEEM FENSAP-ICE Fluent Forte GEKO Granta MI Heat ICEM Icepak LS-DYNA Lumerical Maxwell Mechanical medina Minerva MODE Model Fuel Library, ModelCenter Motion Motor-CAD MQW nCode DesignLife Nuhertz FilterSolutions, ODTK optiSLang PathFinder PathFX Pharos Polyflow PowerArtist Q3D Extractor, RaptorH RaptorX RedHawk-SC Electrothermal, RedHawk-SCm, Rocky SCADE Architect, SCADE Display, SCADE for ARINC 661, SCADE Lifecycle, SCADE Suite, SCADE Test, SCADE Vision, SeaScape Sherlock Siwave Sound SpaceClaim Speos Stack, STK Totem TurboGrid Twin Builder VeloceRF Verilog-A Platform, Vista TF VRXPERIENCE Headlamp, VRXPERIENCE*

| | | | | | |
|---|---|---|---|---|---|
| Converge | Dakota | Fine Turbo | Matlab | Materials Studio | NX |
| Nastran | Numeca | Openfoam | Power Acoustics | Questasim | |
| StarCCM+ | Simufact | Vivado | | | |

**Engineering**

| | | | | | |
|---|---|---|---|---|---|
| Alibre | ANSYS DesignSpace | AutoCAD Mechanical | BrisCAD | CATIA | Comsol Multiphysics |
| DesignSpark Mechanical | FreeCAD | Fusion 360 | Geomagic Design | KeyCreator | Mathcad |
| Mathematica | Matlab | MerchDesigner | NX | ProE | Python |
| Rhino | SimScale | Solid Edge | SolidWOrks | SolveSpace | ZW3D |

# Applications software stack

| | | | | | | |
|---|---|---|---|---|---|---|
| **Bioinformatics, Healthcare, Pharmaceutical** | Abyss | Augustus | Bamtools | CFTools | Bedops | Bedtools |
| | Blast | Blat | Bowtie2 | Busco | BWA | CheckM |
| | DReAMM | FastANI | FASTA-Splitter | FASTQ-Splitter | FASTQC | FASTX Toolkit |
| | GATK | GeNT | Guppy | HISAT2 | HMMER | Homer |
| | Infernal | Kraken2 | MCell | Methylpy | NAMD | Ncview |
| | Picard | pnetCDF | Prodigal | Prokka | RAxML | SAMtools |
| | SRA Toolkit | STAR-Fusion | STAR Aligner | Tiger | Trinity | tRNAscan-se |
| | VCFtools | Glide | MrBayes | CLC Assembly Cell | ELEM Biotech | Gromacs |
| | Bismark | Cutadapt | FLash | HTSlib | PHYLIP | SPAdes |
| | VCF2MAF | Vaxine Pty ACE2 | | | | |
| **Molecular Dynamics (MD) Computational Chemistry** | Gaussian | Vasp | Wien2K | Abinit | Amber | CP2K |
| | Lammps | Nwchem | Orca | Plumed | Quantum Expresso | Gromacs |

# Bioinformatics

- Extract meaningful information from **biological databases** to carry out **sequence or structural analyses**.
    - Homology & similarity tools
    - Protein functional analysis tools
    - Structural analysis tools
    - Sequence analysis tools
- Both **standardized & customized products**
    - **Data-mining** software that retrieve data from genomic sequence DB
    - **Visualization** tools to analyze and retrieve information from proteomic databases.
- Majority of the software are **open source**

# Applications software stack

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Financial Services Industry (FSI) Banks, Hedge Fund** | Apache Ignite | Matlogica | Quantifi | Consilient | Calc fellow | Fidessa | |
| | Murex MX.3 | PackHedge | Pico | | | | |
| **Productivity** | Git | GNU Parallel Collection | Jupyter Notebook | Lazygit | OnDemand | Tmux | OEMT |
| **Quantum Computing** | Dwave Ocean | Google Cirq | IBM Qiskit | ProjectQ | Rigetti Ocean | | |

# Agenda

- HPC Evolution & Architecture
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# Key OSS Use Categories

| Category | Examples |
| --- | --- |
| System infrastructure software | Operating systems, virtualization software |
| Private cloud infrastructure software | OpenStack |
| Modern application platform development | Container packaging, container run-times |
| Deployment platforms | PaaS, function/serverless software |
| Application server platform | Apache HTTP Sever, Websphere Community Edition |
| Middleware | API management, message queuing, handling/streaminga |

# Key OSS Use Categories

| Category | Examples |
| --- | --- |
| Data management software | Databases, data lake, nonrelational data software |
| Application development tools | IDEs, compilers, languages |
| Operations and systems management | Classic provisioning software, patching/fixing, inventory |
| DevOps software | CI/CD, repository tools, artifact management |
| Application software | Line of business applications |

# Investment Opportunities Remain Very Promising Surrounding Open-Source Software

Source: IDC, 2022

| Technology | 2022 Commercial OSS Use (%) | 2024 Commercial OSS Use (%) | Commercial Use Change (%) | 2022 Community OSS Use (%) | 2024 Community Use (%) | Community Use Change (%) | Total OSS Use Change (%) |
|---|---|---|---|---|---|---|---|
| Infrastructure Software | 18.3 | 34.1 | **15.8** | 18.4 | 36.0 | **17.6** | 33.3 |
| Private Cloud | 26.9 | 35.7 | **8.8** | 20.6 | 39.1 | **18.6** | 27.4 |
| App Modernization | 25.5 | 35.5 | **10.1** | 22.7 | 34.3 | **11.7** | 21.7 |
| Deployment Platforms | 25.1 | 34.3 | **9.2** | 20.8 | 37.1 | **16.3** | 25.5 |
| App Server | 28.6 | 34.5 | **5.8** | 23.6 | 38.6 | **15.0** | 20.8 |
| Middleware | 27.5 | 33.3 | **5.9** | 25.0 | 37.9 | **12.9** | 18.8 |
| Dev Tools | 22.5 | 33.0 | **10.5** | 19.6 | 38.2 | **18.6** | 29.0 |
| Ops Software | 26.3 | 33.5 | **7.2** | 22.6 | 37.1 | **14.4** | 21.6 |
| DevOps Software | 27.5 | 30.5 | **3.0** | 23.4 | 38.8 | **15.4** | 18.4 |
| Application Software | 28.6 | 35.9 | **7.3** | 23.4 | 36.2 | **12.9** | 20.2 |

# Open-Source Software

# OSS Linux Distributions

- Debian
- RHEL Clones
- Ubuntu
- Linux Mint
- Fedora
- Gentoo

# What we have covered today?

- HPC Evolution & Architecture
- HPC Technology adoption drivers & trends
- AI Boom
- HPC Systems Software/Hardware
- HPC Applications Software
- Open-Source Software

# Question & Answers

# THANK YOU