HPC Market Update During SC21

November 2021

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www.hpcuserforum.com

Earl Joseph

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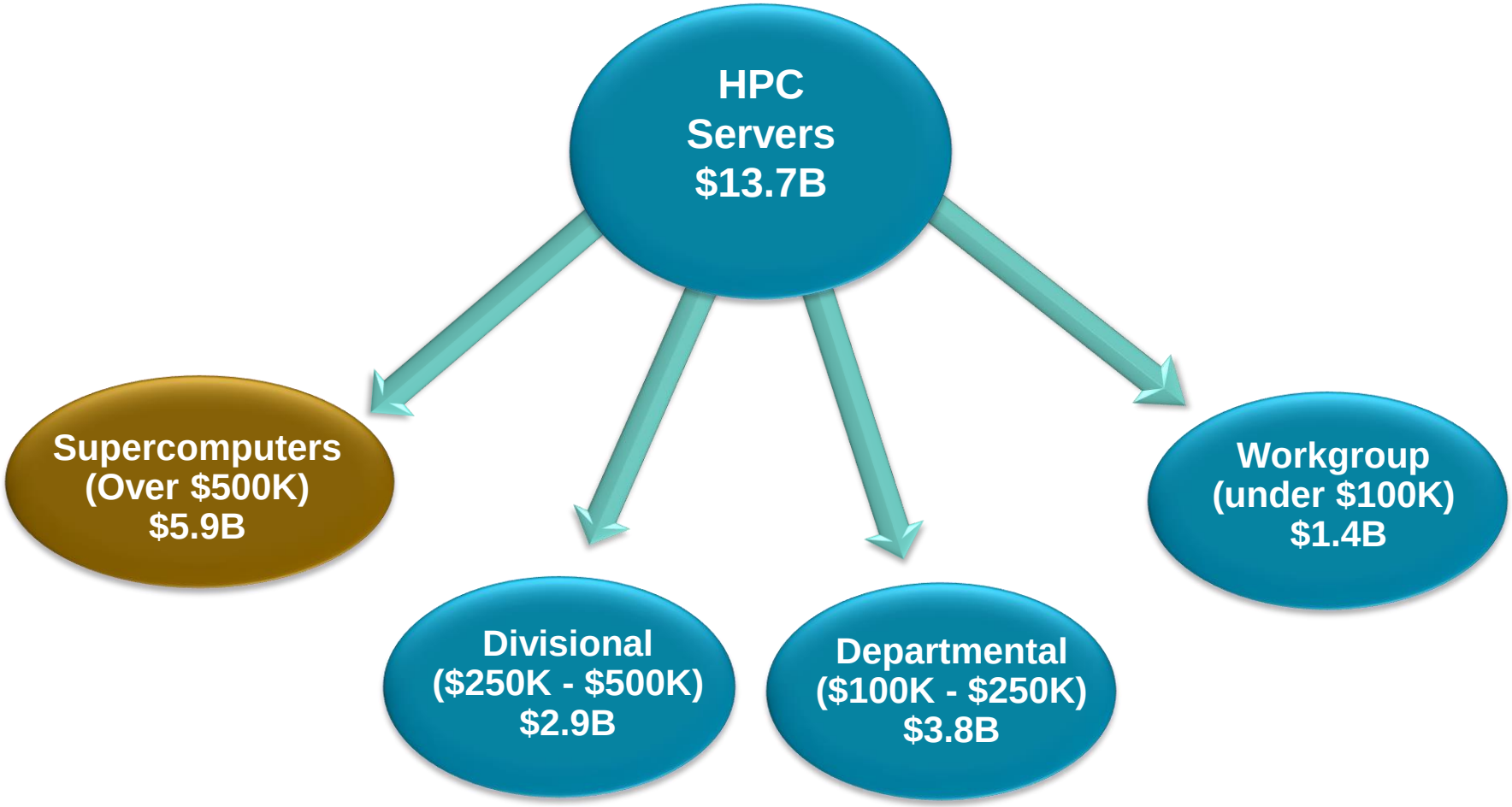
HPC Market Results

The 2020 Worldwide On-Prem HPC Server Market: $13.7 Billion (up 1.1%)



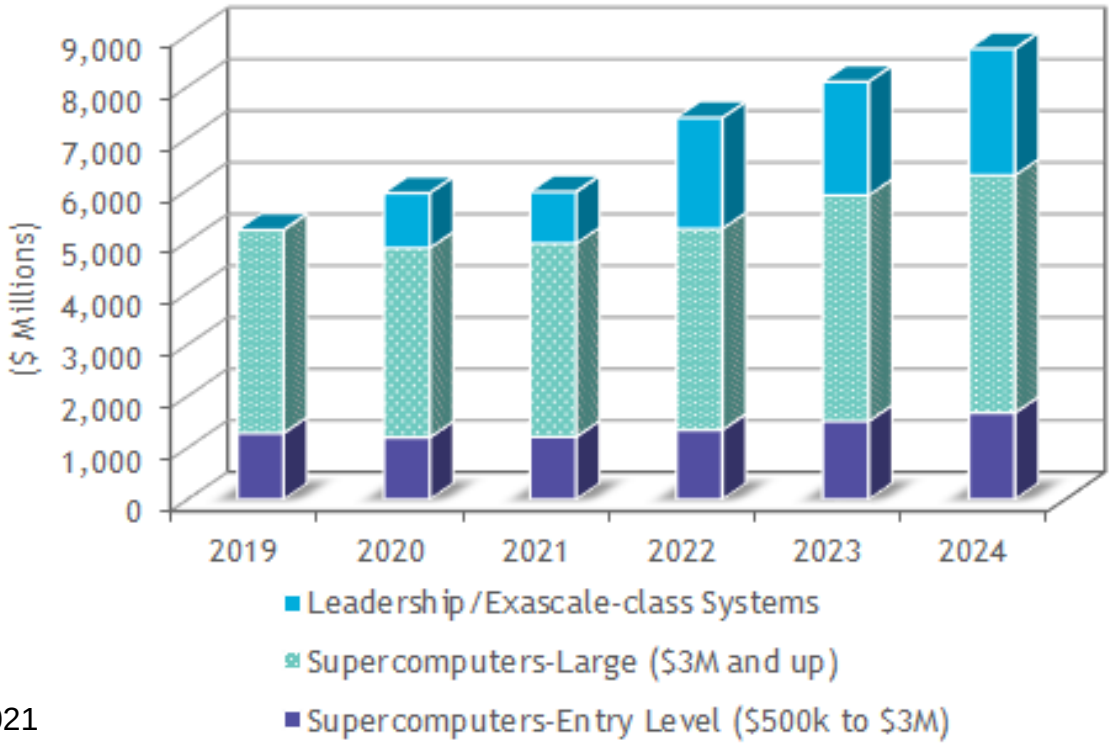
WW HPC Market By Segments ($ Millions)

2021 is looking strong for the first half of the year

Revenues	2019	2020	1H 2021
Supercomputer	5,118	6,021	2,759
Divisional	3,164	2,849	1,281
Departmental	3,193	3,324	1,838
Workgroup	1,894	1,329	745
WW Revenue ($M)	**13,368**	**13,523**	**6,623**
Units Installed	**2019**	**2020**	**1H 2021**
Supercomputer	1,619	1,547	885
Divisional	8,058	6,664	3,013
Departmental	18,785	18,526	10,254
Workgroup	55,529	37,894	22,176
WW Units	**83,991**	**64,631**	**36,329**

New Supercomputer Subsegments

New Supercomputer Subsegments							
$ Millions							
	2019	2020	2021	2022	2023	2024	CAGR 20-24
Leadership/Exascale-class Systems	0	1,065	1,000	2,150	2,200	2,450	23.2%
Supercomputers-Large ($3M and up)	3,937	3,670	3,748	3,901	4,380	4,605	5.8%
Supercomputers-Entry Level ($500k to $3M)	1,287	1,204	1,214	1,347	1,515	1,678	8.6%
Total Supercomputers ($500K and up)	5,224	5,939	5,962	7,398	8,095	8,733	10.1%
Source: Hyperion Research, June 2021							



WW HPC Market By Verticals ($ Millions)

Five segments are over a $ billion a year

WW High-Performance Revenues by Applications		
	2019	2020
Bio-Sciences	$1,421	$1,302
CAE	$1,674	$1,538
Chemical Engineering	$166	$152
DCC & Distribution	$806	$727
Economics/Financial	$688	$618
EDA / IT / ISV	$801	$726
Geosciences	$938	$858
Mechanical Design	$051	$048
Defense	$1,430	$1,332
Government Lab	$2,368	$3,342
University/Academic	$2,254	$2,160
Weather	$622	$572
Other	$151	$150
Total Revenue	**$13,368**	**$13,523**
Source: Hyperion Research, November 2021		

Worldwide HPC Vendor Market Shares

($ Millions)

Vendor	Full Year 2020 ($M)	2020 Share
HPE	4,587	33.4%
Dell Technologies	2,855	20.8%
Fujitsu	1,319	9.6%
Inspur	996	7.2%
Lenovo	929	6.8%
Atos	511	3.7%
Sugon	452	3.3%
IBM	444	3.2%
Penguin	200	1.5%
NEC	192	1.4%
Others	1,260	9.2%
Total	13,744	100.0%

The Broader On-premise Market Areas ($ Millions)

The 2020 total on-prem HPC spending exceeded $27 billion (excluding cloud spending)

Revenues by the Broader HPC Market Areas		
	2019	**2020**
Server	$13,368	$13,523
Storage	$5,288	$5,423
Middleware	$1,572	$1,590
Applications	$4,569	$4,600
Service	$2,181	$2,146
Total Revenue	**$26,979**	**$27,283**
Source: Hyperion Research, November 2021		

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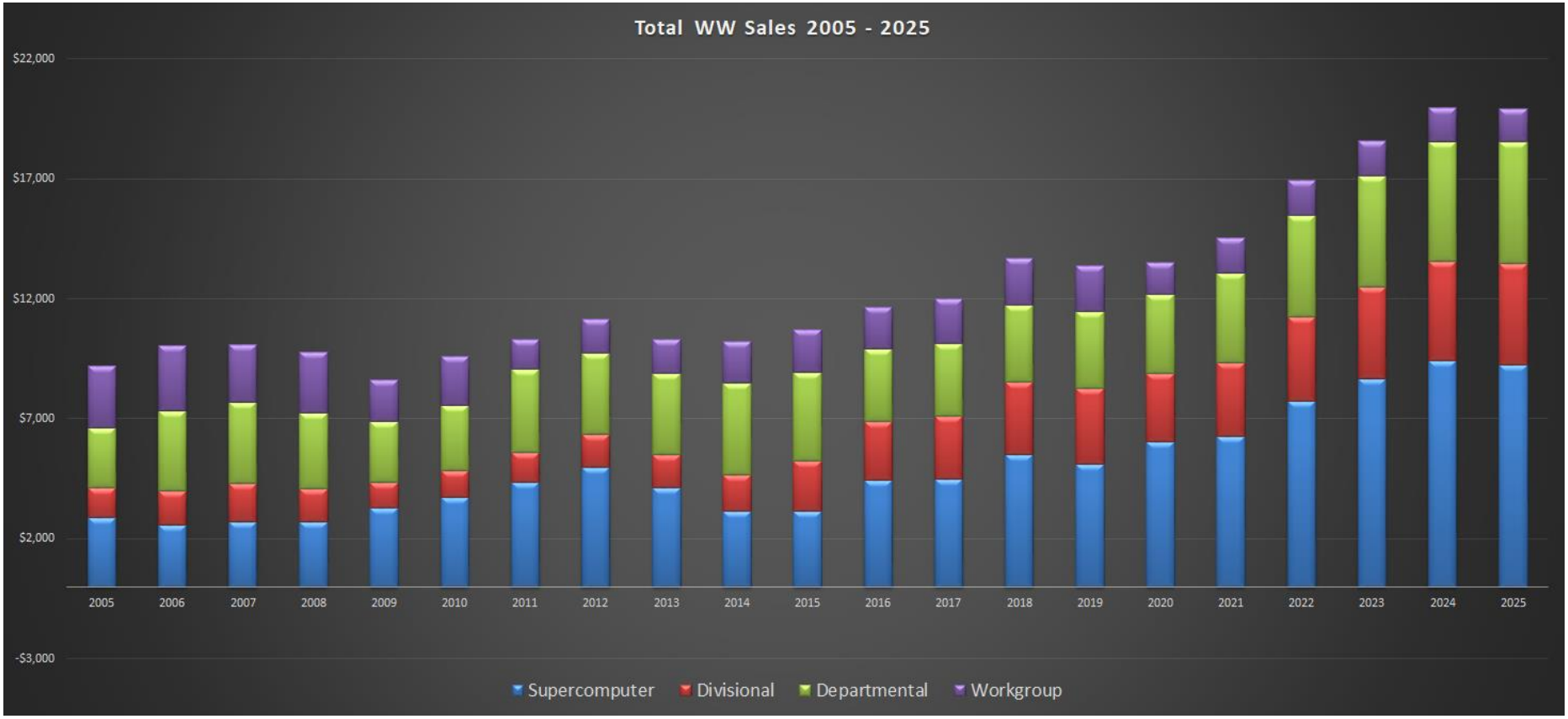
Updated HPC Forecasts

On-Prem HPC Server Forecast
($ Millions)

- **The five-year CAGR (2020 to 2025) is 8%**
  - Reaching close to $20 billion in 2025



HPC On-Prem Server Forecast
($ Millions)
The overall CAGR is now 8%

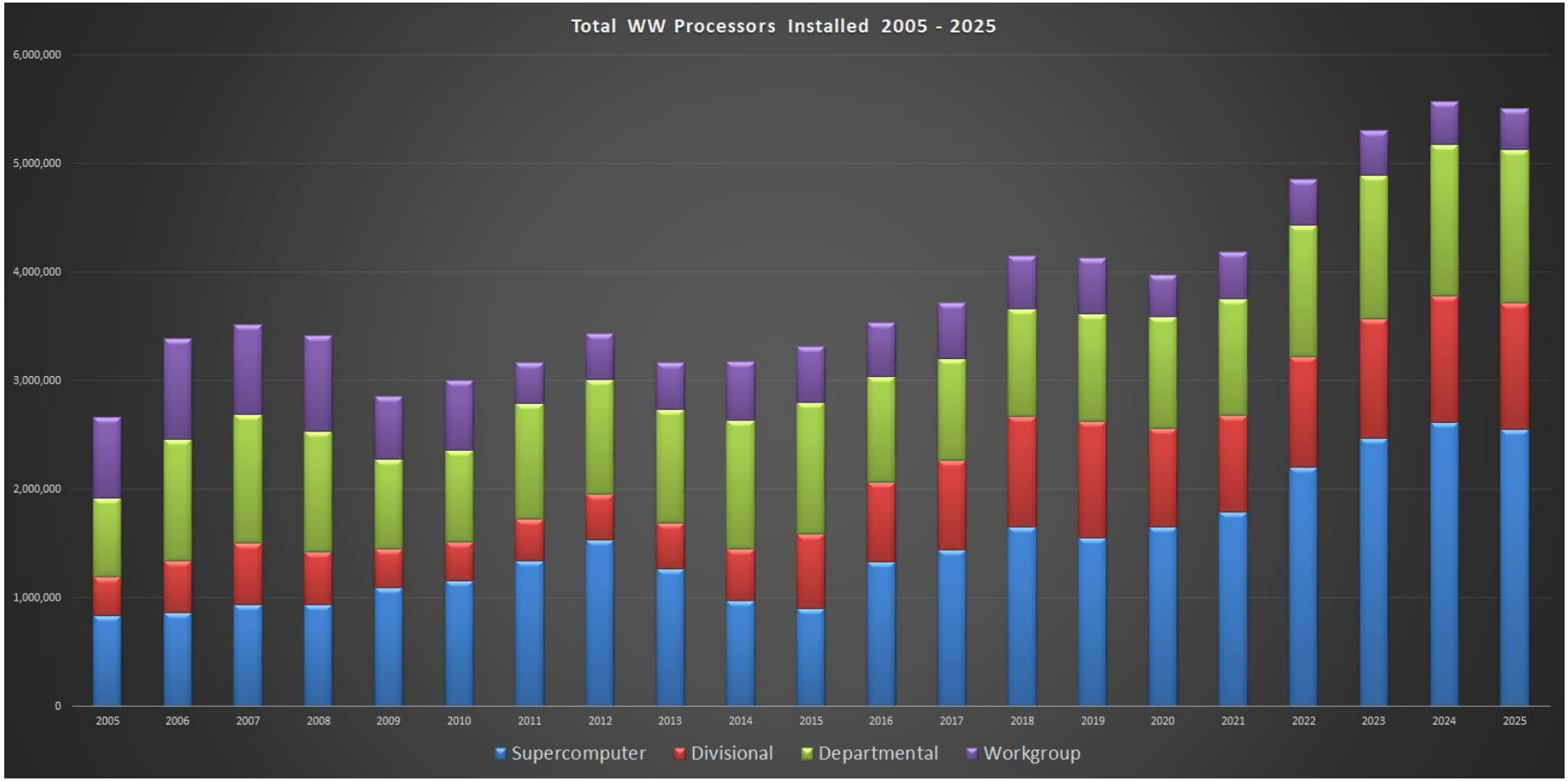
World Wide Overall Technical Computer Market Revenue								
	2019	2020	2021	2022	2023	2024	2025	CAGR 20-25
WW HPC Revenues	$13,368	$13,523	$14,550	$16,947	$18,565	$19,947	$19,901	8.0%
Source: Hyperion Research, November 2021		1.2%	7.6%	16.5%	9.5%	7.4%	-0.2%	

Worldwide Total Technical Computer Market Revenue Forecast by Competitive Segment								
	2019	2020	2021	2022	2023	2024	2025	CAGR 20-25
Supercomputer	$5,118	$6,021	$6,258	$7,726	$8,653	$9,401	$9,251	9.0%
Divisional	$3,164	$2,849	$3,091	$3,532	$3,858	$4,156	$4,199	8.1%
Departmental	$3,193	$3,324	$3,726	$4,234	$4,625	$4,968	$5,078	8.8%
Workgroup	$1,894	$1,329	$1,475	$1,456	$1,430	$1,422	$1,373	0.7%
Total	$13,368	$13,523	$14,550	$16,947	$18,565	$19,947	$19,901	8.0%
Source: Hyperion Research, November 2021								

On-Prem HPC Processor Forecast

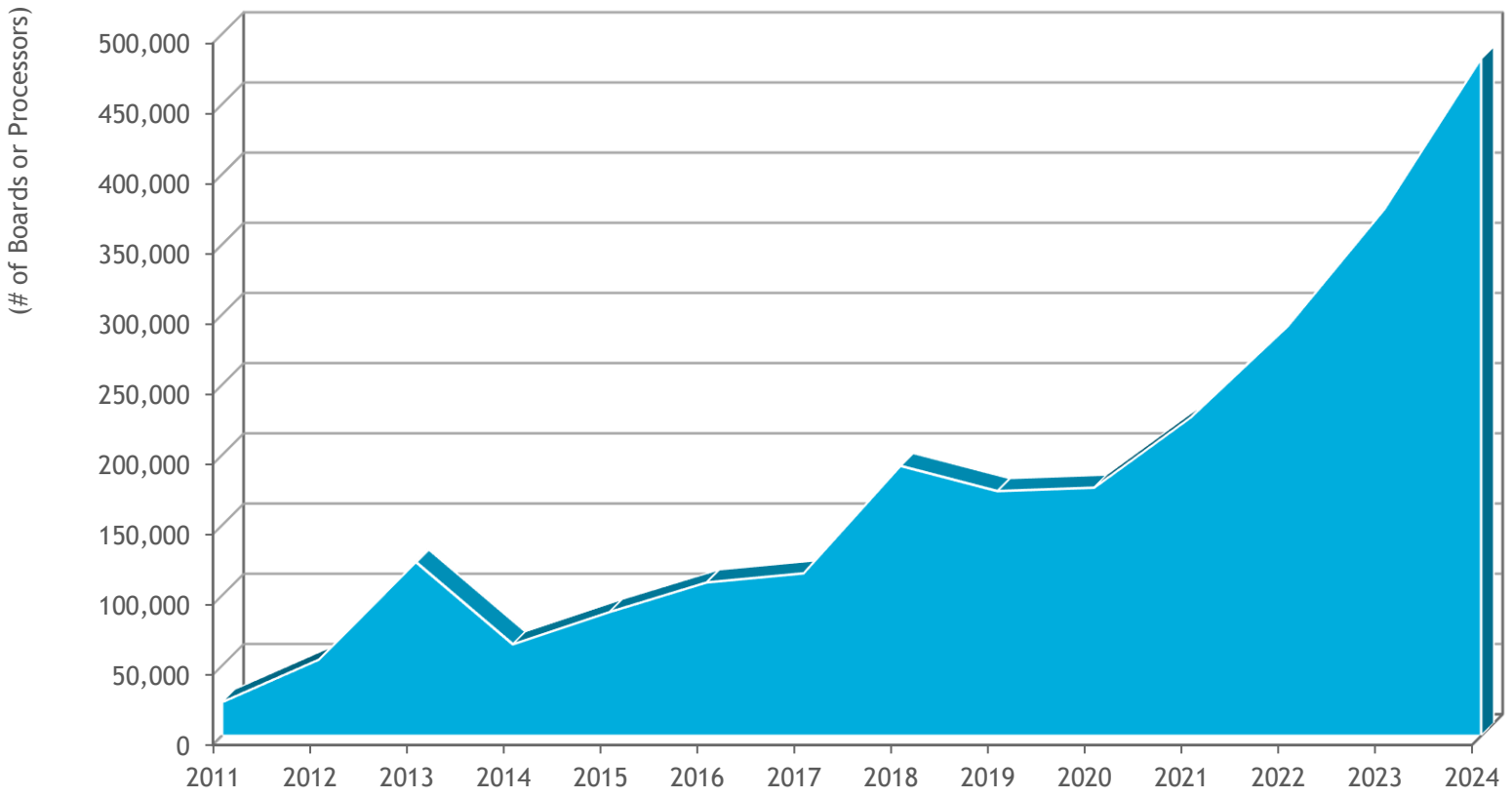
($ Millions)

- **The five-year CAGR (2020 to 2025) is 6.8%**
  - Exceeding 5.5 million base processors in 2025



GPU/Accelerator Forecast

Anticipated high growth for accelerators over next 5 years



On-Prem Forecasts For The Broader Market Areas ($ Millions)

Storage is expected to grow the most at 9.3% CAGR

Revenues by the Broader HPC Market Areas							
	2020	2021	2022	2023	2024	2025	CAGR 20-25
Server	$13,523	$14,550	$16,947	$18,565	$19,947	$19,901	8.0%
Storage	$5,423	$5,931	$6,981	$7,835	$8,479	$8,454	9.3%
Middleware	$1,590	$1,736	$2,035	$2,244	$2,426	$2,420	8.8%
Applications	$4,600	$4,913	$5,626	$6,060	$6,396	$6,353	6.7%
Service	$2,146	$2,254	$2,531	$2,674	$2,767	$2,738	5.0%
Total Revenue	**$27,283**	**$29,383**	**$34,121**	**$37,378**	**$40,015**	**$39,867**	**7.9%**
Source: Hyperion Research, November 2021							

The Exascale Market (System Acceptances)

Over 30 systems and over $11 billion in value

Exascale and Near-Exascale Systems (2021 to 2026)

Year Accepted	China	EU, UK, Germany	Japan	US	Other Countries*	Total Systems	Total Value
2020			1 near-exascale system ~$1 B			1	$1B
2021	1 or 2 near-exascale systems ~$400M each	1 pre-exascale system ~$185M	?	1 pre-exascale system ~$200M	--	3-4	$.8B - $1.2B
2022	1 or 2 exascale systems ~$350M - $400M each	2 pre-exascale systems ~$400 total	1 near-exascale system ~$200M	1 exascale systems ~$600 M	--	5-6	$2B - $2.3B
2023	1 or 2 exascale system ~$350M - $400M each	1 or 2 exascale systems ~$375M	1 near-exascale system ~200M	2 exascale system ~1.1M	--	5-7	$2B - $2.8B
2024	1 exascale system ~$350M - $400M each	2 exascale (Germany & UK) ~ $350M	?	1 or 2 exascale systems ~$600M each	1 exascale system ~$200M	5-6	$1.9B - $2.5B
2025	1 exascale systems ~$350M - $400M each	1 or 2 exascale systems ~$375M (each)	1 exascale system ~$200M	1 or 2 exascale systems ~$500M each	1 exascale system ~$200M	5-7	$1.5B - $2.3B
2026	1 or 2 exascale systems ~$350M - $400M each	1 or 2 exascale systems ~$375M	?	2 exascale systems ~$500M each	1 or 2 exascale systems ~$200M	5-8	$1.9B - $2.8B
Total	**6-10**	**8-10**	**3+**	**7-9**	**3-4**	**28-39**	**$11B - $15B**

* Includes S. Korea, Singapore, Australia, Russia, Canada, India, Israel, Saudi Arabia, etc.

Source: Hyperion Research, May 2021

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Some Results From Our End-user Study

4.2 Years Is The Average Life Of An HPC System Today

From our just released end-user MCS study

Regarding your LARGEST HPC system -- How many years do you plan to keep this system?		
	Responses	**Percent**
Less than two years	11	8.3%
Two years	12	9.0%
Three years	24	18.0%
Four years	27	20.3%
Five years	33	24.8%
Six years	13	9.8%
Seven years	7	5.3%
Eight years or more	6	4.5%
n = 133		
Source: Hyperion Research, 2021		

83% Of Sites Have Accelerators Or Co-processors Today

From our just released end-user MCS study

How many co-processors or accelerators are in your largest HPC technical server?		
	Responses	**Percent**
None	23	17.3%
Less than 32	28	21.1%
32 to less than 64	18	13.5%
64 to less than 100	19	14.3%
100 to less than 500	18	13.5%
500 to less than 1,000	11	8.3%
1,000 to less than 5,000	10	7.5%
5,000 to less than 10,000	4	3.0%
10,000 or more	2	1.5%
n = 133		
Source: Hyperion Research, 2021		

Use Of Different AI/ML/DL Approaches

From our just released end-user MCS study

36) Which categories will your top AI and/or data-intensive analytics applications fall under in the next 1 to 2 years?		
	Responses	Percent
Machine learning	99	70.2%
Deep learning	86	61.0%
Graph analysis	25	17.7%
Cognitive computing	24	17.0%
Semantic analysis	22	15.6%
Other big data/analytics	41	29.1%
We don't plan to run applications of these types	9	6.4%
n = 141		
Source: Hyperion Research, 2021		

Largest Application Runtime

From our just released end-user MCS study

- ~33% of the #1 applications run for over 24 hours

32.a.i) Please characterize the TOP #1 APPLICATION (most important) used at your site - Typical run time:		
	Responses	Percent
Less than 5 minutes	3	2.1%
5 minutes to less than 1 hour	11	7.8%
1 hour to less than 5 hours	20	14.2%
5 hours to less than 10 hours	16	11.3%
10 hours to less than 24 hours	27	19.1%
24 hours to less than 100 hours	28	**19.9%**
100 hours to less than 250 hours	15	**10.6%**
250 hours to less than 1,000 hours	3	**2.1%**
1,000 hours or more	11	7.8%
n = 141		

Source: Hyperion Research, 2021

Programming Models Used Today

A large mix of models are used today

15) What parallel programming languages/models do you use?		
	Responses	Percent
C/C++ (all types)	112	79.4%
Python	104	73.8%
CUDA	74	52.5%
MPI	73	51.8%
OpenMP	68	48.2%
Fortran (all types)	67	47.5%
R	59	41.8%
MATLAB	55	39.0%
Java	42	29.8%
OpenCL	34	24.1%
Mathematica	26	18.4%
Pthreads	24	17.0%
Scala	20	14.2%
Ruby	18	12.8%
Julia	15	10.6%
SHMEM	15	10.6%
Coarray Fortran	14	9.9%
PGAS	14	9.9%
PVM	4	2.8%
Cilk	3	2.1%
Other	8	5.7%
n = 141		

Source: Hyperion Research, 2021

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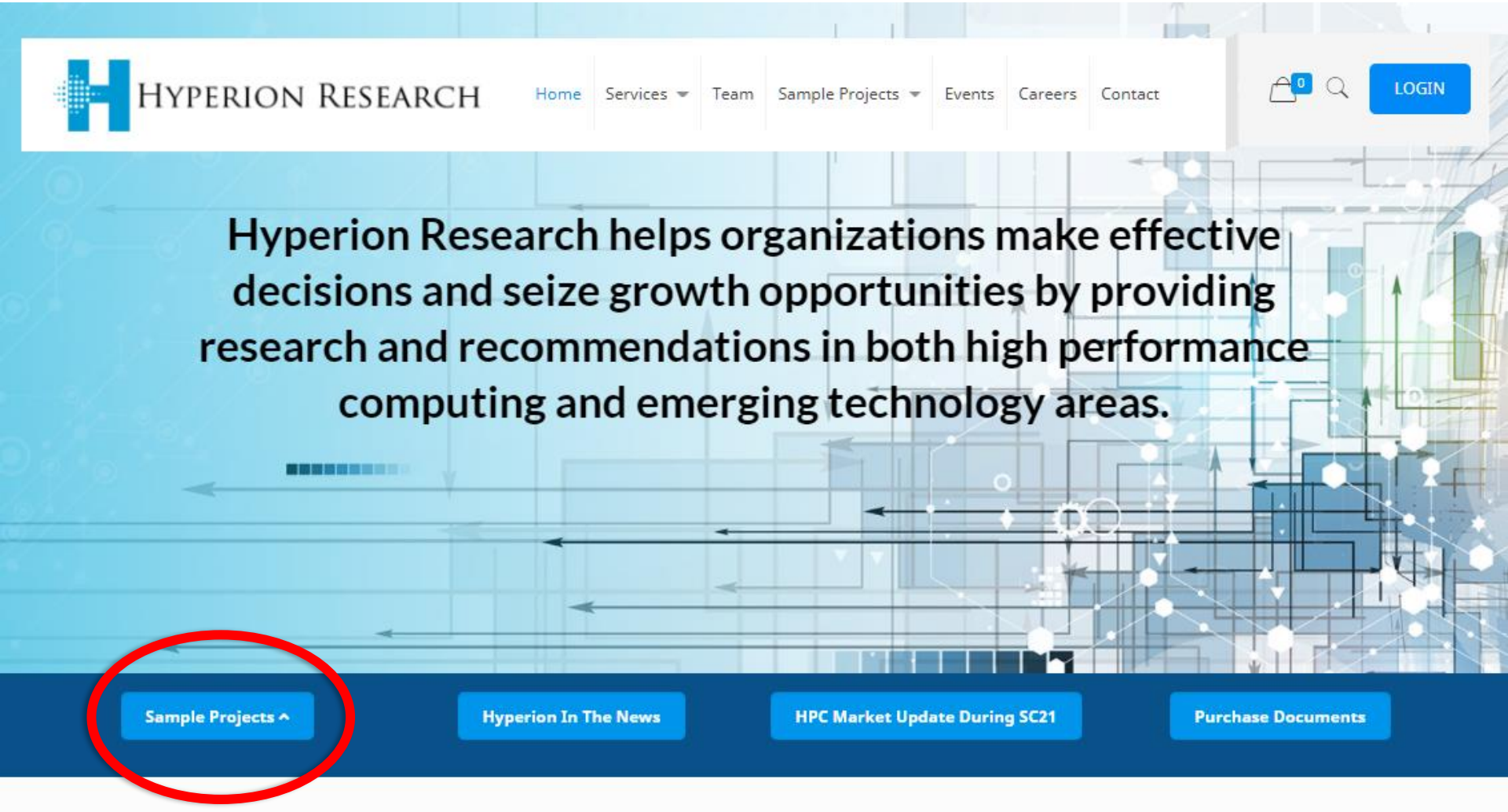

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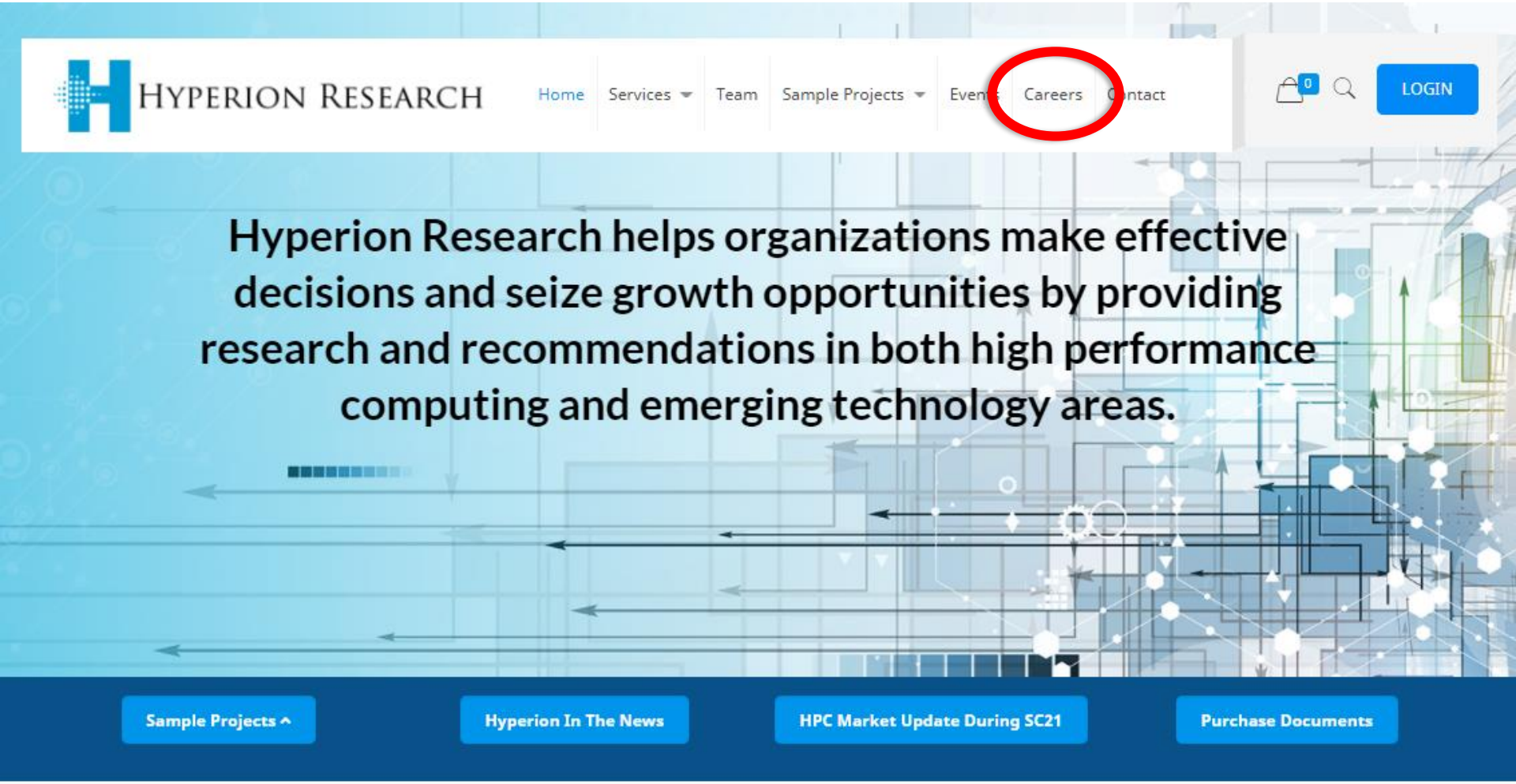

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QUESTIONS?

Questions or comments are welcome.

Please contact us at:

info@hyperionres.com

Please take a minute to do a short survey to help us improve our update briefings

Highlights of Growth of AI and HPDA in HPC

November 2021

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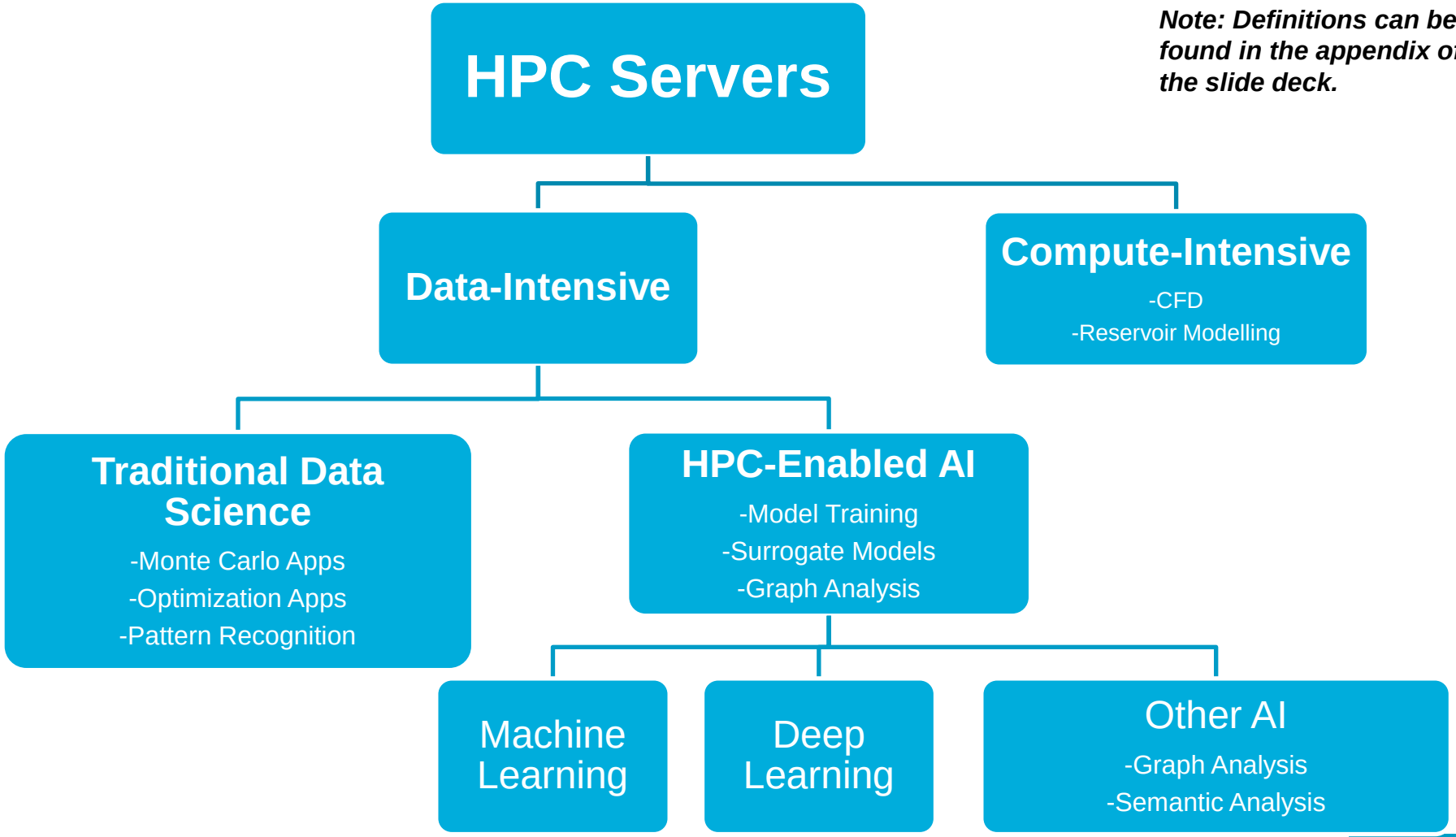
Alex Norton

On-Prem HPC Market Segmentation

Server classification based on end-user application



Note: Definitions can be found in the appendix of the slide deck.

The HPC Server Market Segmented

Data-Centric focused servers comprise ~25% today

Worldwide HPC Server Revenue Breakout by Compute-Intensive and Data-Intensive Focuses								
($M)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**CAGR '20-'25**
Compute-Centric Server Revenue	$9,771	$10,024	$10,900	$12,547	$13,637	$14,428	$13,719	6.5%
Data-Centric Server Revenue	$3,598	$3,499	$3,649	$4,400	$4,928	$5,519	$6,182	12.1%
HPC Server Revenue Forecast	$13,368	$13,523	$14,550	$16,947	$18,565	$19,947	$19,901	8.0%

- **Data-centric servers are growing nearly twice as fast as compute-centric servers, due to:**
  - A rise in data-intensive simulations
  - Aggressive growth of AI applications
  - The integration of AI techniques in traditional HPC apps

Within the Data-Centric Market

HPC-Enabled AI systems growing to ~50% of data-intensive market by 2025

($M)	2019	2020	2021	2022	2023	2024	2025	CAGR '20-'25
HPC-Enabled AI (ML, DL & Other) Server Revenue	$918	$1,039	$1,216	$1,618	$2,034	$2,429	$2,905	22.8%
Traditional Data Science (non-AI HPDA) Focused Server Revenue	$2,680	$2,460	$2,433	$2,782	$2,894	$3,091	$3,276	5.9%
Total Data-Centric HPC Server Revenue	$3,598	$3,499	$3,649	$4,400	$4,928	$5,519	$6,182	12.1%

- **HPC-enabled AI servers today account for less than $^1/_3$ of the data-intensive servers**
  - That portion is expected to grow to nearly ½ by 2025
  - AI-focused servers growing more than 3x faster than traditional data science servers

HPC-Enabled AI Market

ML-focused machines the bulk of the AI market today

($M)	2019	2020	2021	2022	2023	2024	2025	CAGR '20-'25
Machine Learning	$667	$719	$806	$1,018	$1,213	$1,368	$1,569	16.9%
Deep Learning	$209	$263	$341	$501	$692	$899	$1,133	33.9%
Other AI	$42	$57	$70	$98	$129	$162	$204	29.0%
Total HPC-Enabled AI Server Revenue	$918	$1,039	$1,216	$1,618	$2,034	$2,429	$2,905	22.8%

- **Within HPC-enabled AI servers, DL-focused servers growing aggressively**
- **Machine-learning-focused servers comprise majority of revenue today**

Future HPC System Designs

Users are building heterogeneous systems to handle AI & HPDA workloads

- **As workloads become more diverse, system designs have shifted:**
  - Some sites are building heterogeneous systems
  - Some sites are building out multiple systems to handle different workloads specifically
  - Some sites are looking to the cloud to address specific subsets of their workload portfolio
- **Technology options have diversified as well**
  - New accelerator options
  - ASICs designed for specific AI applications
  - Various memory, interconnect, and storage products
- **Compute resource allocation should be treated as an optimization problem:**
  - Find a balance among diverse technology options
  - Optimize for key workloads

Use of Surrogates in HPC

The injection of AI models to support large simulations

- **Using deep learning models to approximate simulations and speed up time to solution**
  - While these models lack the accuracy of true simulation, they allow researchers to search the solution space and complete large simulations faster
- **Surrogate models are a prime example of the convergence of HPC and AI**
- **Examples of the use of surrogates have emerged in:**
  - Earth system modelling
  - Genetics applications
  - Drug design
  - High-energy physics

For more information about surrogates: https://bit.ly/3o0L2uL

Future Research Directions

Topics of interest for the next year of research

- **New Components**
  - Emergent processors and accelerators
  - New memory technologies
  - Interconnect solutions
- **Application considerations**
  - Changes in data privacy and sharing laws
  - Data storage and sharing considerations
- **Continued intersection of AI and HPC**
  - Use of AI methodologies to augment traditional HPC apps
  - Use of large-scale simulations to generate synthetic data
  - Growing adoption of HPC-enabled AI techniques by traditional IT enterprises
- **Ethics of AI**
  - Explainability, transparency, and reproducibility concerns
  - Societal impacts of AI applications

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Want to continue the conversation?

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Appendix

Definitions

- **Compute-Centric HPC Application**: HPC applications that focus primarily on being able to scale across multiple processors for the most computation power possible. Examples of compute-centric HPC applications include crash simulation, reservoir modelling, genome sequencing, and many others. This category is usually referred to as HPC Modelling and Simulation workloads.
- **Data-Centric HPC Application**: HPC applications that rely primarily on the use of large data sets and involve high data transfer between nodes during the execution of the application. Examples of data-centric HPC applications include big data, HPDA, AI, ML, DL, and other data-driven simulation workloads. Many data intensive applications require larger memory profiles on the systems they are run on.

Definitions (cont.)

- **High Performance Data Analysis (HPDA):** refers to data-intensive computing that exploits HPC resources. HPDA includes long-standing, data-intensive modelling and simulation (M&S) methods in the HPC industry/application segments, and newer high-performance analytics methods that are used in these segments, as well as by commercial organizations that are adopting HPC for the first time. HPDA may employ either long-standing numerical modelling and simulation methods, newer methods such as for big data and large-scale graph analytics, semantic technologies, and knowledge discovery algorithms, or some combination of long-standing and newer methods.
- **Artificial Intelligence (AI):** a broad, general term for the ability of computers to do things human thinking does, but in different ways. AI includes machine learning, deep learning (a.k.a. cognitive computing) and other methodologies.

Definitions (cont.)

- **HPC-Enabled AI:** a term to highlight the specific AI applications tracked by Hyperion Research and classified in this forecast. Similar to the definition of HPC applications overall, HPC-enabled AI applications are those that are run by scientists, researchers, engineers, etc. Social media-type AI applications, mainly simple image recognition or tagging, are not included in the forecast. Hyperion Research focuses on the cutting edge, scientific or highly computational AI applications.
- **Machine Learning (ML):** a process where examples are used to train computers to recognize specified patterns, such as human blue eyes or numerical patterns indicating fraud. The computers are unable to learn beyond their training and human oversight is needed in the recognition process.
- **Deep Learning (DL):** an advanced form of machine learning that often uses digital neural networks to enable a computer to go beyond its training and learn on its own, without explicit programming or human oversight.

A Quick Update on Exascale Systems

November 2021

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Bob Sorensen

Near-Term US Exascale Plans

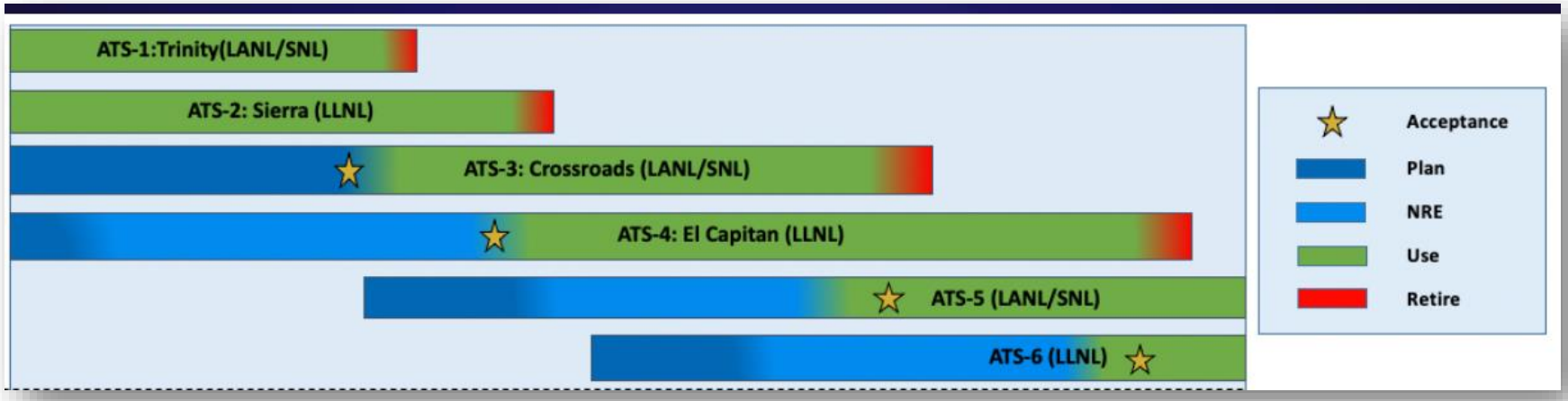
Three systems over two years with budget of ~ $1.8 billion

- **Frontier: DOE Office of Science: Oak Ridge National Laboratory**
  - Currently being installed: >9,000 nodes, ~29MW, >1.5EF
  - Cray Slingshot with AMD EPYC CPU and AMD Radeon Instinct GPUs
  - Delivery in late 2021, full access in 3Q 2022
- **Aurora: DOE Office of Science, Argonne National Laboratory**
  - >9,000 nodes, **60MW**, > 1EF DP sustained
  - Delivery in late 2022, acceptance in 2023 (delayed at least 12 months)
  - Cray Shasta architecture with Intel Xeons and Intel Xe GPU
  - 08/21: Polaris testbed system (44PF DP and 1.5EF AI)
    - Stand up in 2Q2022
- **El Capitan: DOE NNSA's LLNL**
  - Early access RZNevada (100 of TFs) delivered in 02/2021
  - Full system delivery in late 2022, with full production, late 2023
  - Cray Shasta architecture AMD EPYC processors, next generation Radeon Instinct GPUs

Mid-Size US Exascale Plan

Crossroads on the horizon: LANL

- **Procurements by the Alliance for Computing at Extreme Scale (ACES) partnership between Los Alamos National Laboratory and Sandia National Laboratories**
- **$105 million contract awarded to Hewlett Packard Enterprise (HPE) to deliver Crossroads, a next-generation HPE Cray EX supercomputer to be sited at Los Alamos for 2022 operation**
- **Crossroads will be among the first to receive a supercomputer equipped with NVIDIA's Grace CPUs**



Source: Gary Grider LANL, DoE, LA-UR-21-22315

The Cycle Continues

Looking ahead started already

Post-Exascale Computing for the National Nuclear Security Administration

As requested in section 3172 of the FY 2021 National Defense Authorization Act, an ad hoc committee of the National Academies of Sciences, Engineering, and Medicine will conduct a consensus study "reviewing the future of computing beyond exascale computing to meet national security needs at the National Nuclear Security Administration." (Exascale refers to a computer that performs near or above 10^18 floating point operations per second.)

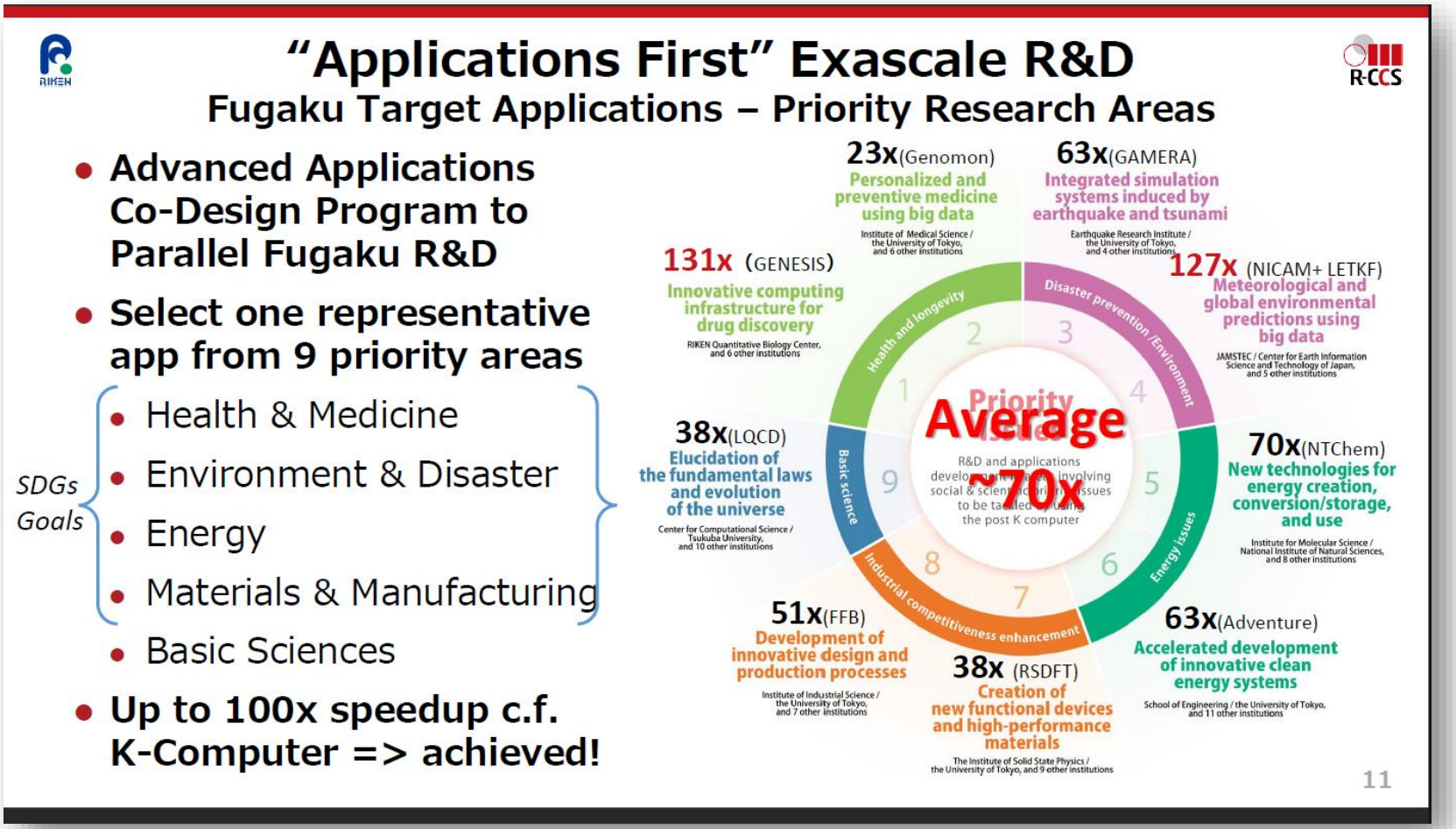
The study will review:
(1) NNSA's computing needs over the next 20 years that exascale computing will not support;
(2) Future computing technologies for meeting those needs including quantum computing and other novel hardware, computer architecture, and software;
(3) The likely trajectory of promising hardware and software technologies and obstacles to their development and their deployment by NNSA; and
(4) The ability of the U.S. industrial base, including personnel and microelectronics capabilities, to meet NNSA's needs.

Dates		Amounts	
Date Signed *(mm/dd/yyyy)* :	05/28/2021	Action Obligation:	$1,077,278.00
Period of Performance Start Date *(mm/dd/yyyy)* :	06/01/2021	Base And Exercised Options Value:	$1,077,278.00
Completion Date *(mm/dd/yyyy)* :	05/31/2023	Base and All Options Value (Total Contract Value):	$1,077,278.00
Est. Ultimate Completion Date *(mm/dd/yyyy)* :	05/31/2023	Fee Paid for Use of IDV:	$0.00
Solicitation Date *(mm/dd/yyyy)* :	04/12/2021		

Source: National Academies, 2021

Japan's Exascale System

Riken's Fugaku #1: June 2020 - June 2021 Top 500 list



Source: Riken, 2021

China Exascale Status

Two (and first) exascale systems are already operating, the 3rd is delayed

- **Sunway Pro OceanLight**
  - Completed March 2021, ~1.3 EFlops Rpeak, ~1.05 EFlops Rmax
  - Full Linpack run
  - 35 MW
  - ShenWei post-Alpha CPU
  - Est. 96 cabinets X 1024 SW39010 (390 core) cpus -> 38 million cores
  - National Supercomputing Center in Wuxi
- **NSCC-Tianjin Tianhe-3**
  - Dual-chip FeiTeng ARM and matrix accelerator node
  - Full completion this month
  - Est ~ 1.7 EFlops Rpeak, 1.3 EFlops Rmax
  - No Linpack results currently
- **NSCC-Shenzhen Phase 2 - Sugon 2-Flops at Guangdong Province**
  - Scheduled for 2022—delayed with possible platform change
  - Hygon processors (low confidence), may go AMD Zen4
- **Skipped June Top 500 listing? Maybe again?**

EU HPC Plans

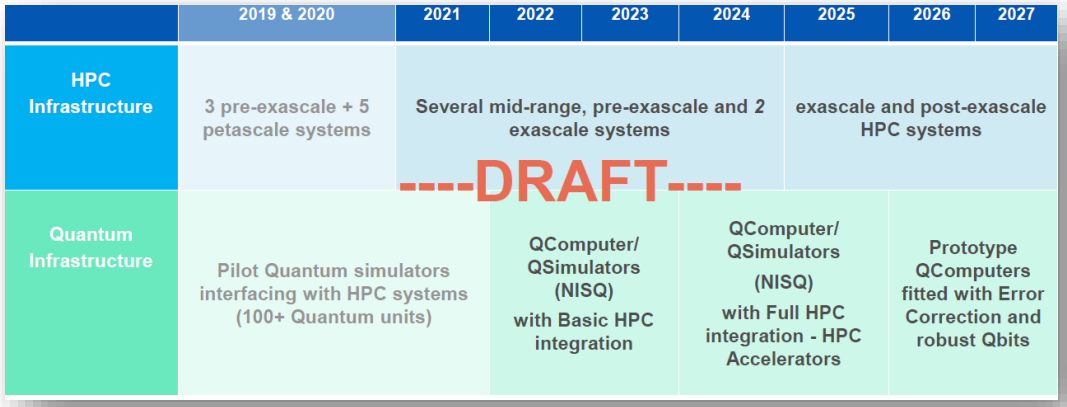
EuroHPC program: confusion in the making

- **Chartered to develop EU-wide HPC development program**
  - 33 participating States + EU
  - Operational duration: November 2018-2026
- **Three sites recently selected for 150-200 Pflops systems**
  - Kajaani Finland, Barcelona Spain, and Bologna Italy
  - Total investment: 650 million Euros
    - 50% EU
    - 50% Consortium
- **Systems are owned by EuroHPC Joint Undertaking**
- **Trouble afoot :**
  - July 2021: EuroHPC JU canceled the public procurement process for the MareNostrum 5 supercomputer
    - The voting result did not achieve the needed majority to reach an agreement to adopt the selected tender
    - Officials expect that it will be reopened in autumn, leading to a selection early in 2022

EU HPC Plans (continued)

Exascale plans going forward

- **EU plan calls for acquisition of two exascale systems in the 2021-2024 timeframe**
  - At least one to use European technology: specifically using an EPI-developed processor
  - Additional procurements in Germany in 2024, 2025
  - EU may include 2 additional ES systems in 2023-2026
- **Post Exascale System around 2027**
  - Plans call for integration and deployment of the first hybrid HPC/quantum infrastructure in Europe



Source: Leonardo Flores Añover, Senior Expert

DG CNECT, HPC & Quantum Technology Unit - European Commission 2021

UK EU Plans

UK looking at 2024

- **The UK, which will not likely be eligible to fully take part in EuroHPC projects or access calls when Horizon 2020, has plans for a domestic exascale system**
  - Exascale project requirements include support for both traditional modeling and simulation as well as AI/Deep Learning
  - System targeted for both scientific community and industrial users
- **Exascale rollout schedule**
  - Procurement during 2022
  - Assembly and installation 2023
  - Final changes to hosting environment 2023
  - Planned service opening April 2024
- **System will be hosted at Advanced Computing Facility of EPCC, formerly the Edinburgh Parallel Computing Centre, a supercomputing centre based at the University of Edinburgh**

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QUESTIONS?

Questions or comments are welcome.

Please contact us at:

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Edge Computing and HPC

November 2021

www.HyperionResearch.com
www.hpcuserforum.com

Steve Conway
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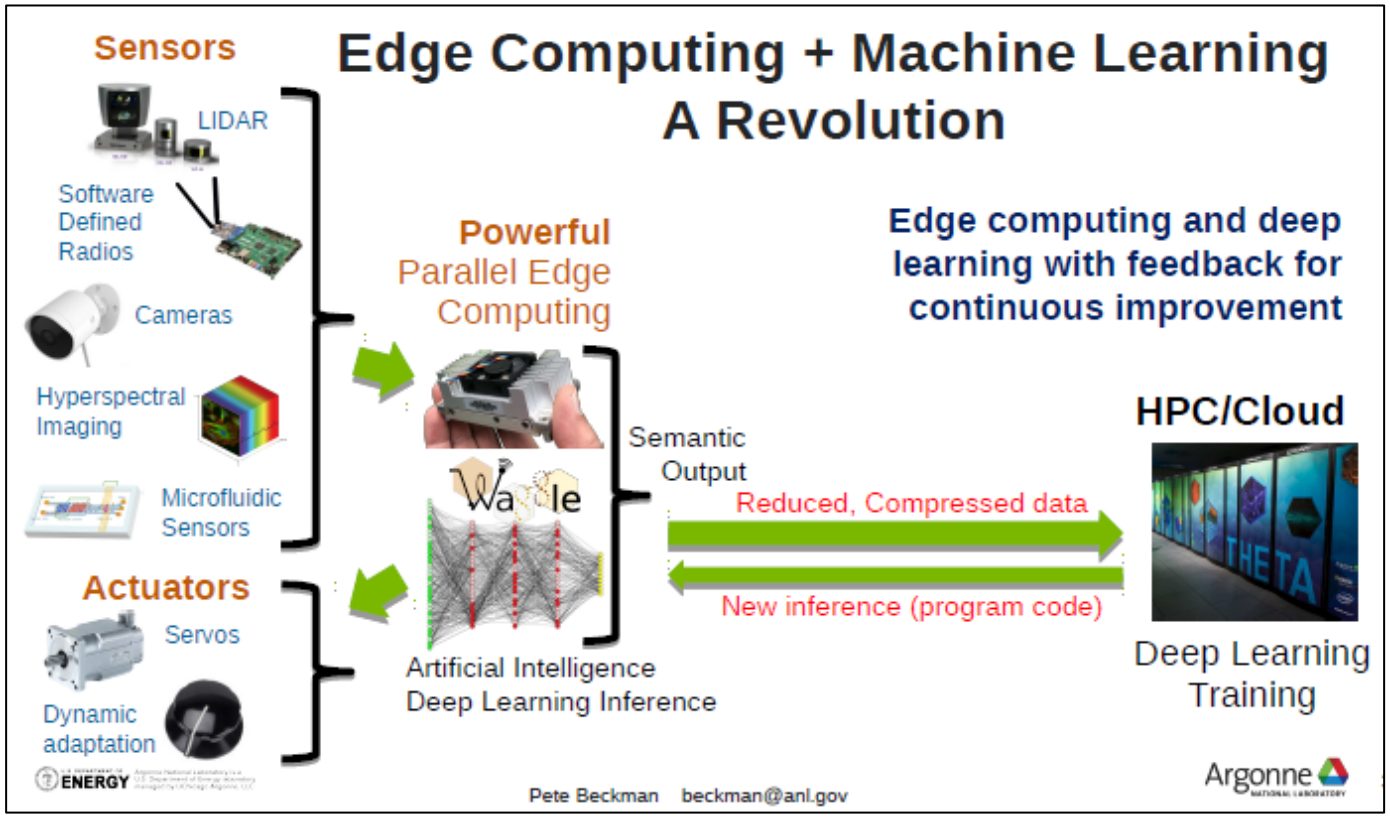
What Is Edge Computing? What Is HPC's Role?

- **LOCAL: Computing at or near data sources (IoT devices)**
  - Computing *inside* edge devices (e.g., vehicles, medical devices, satellites)
  - Computing *attached* to edge devices (e.g., traffic sensors)
  - Computing *close to* edge devices ("fog computing")

- **LOCAL-DISTANT: HPC in more-distant clouds or data centers (e.g., citywide traffic control)**
  Only small subset of edge data might be sent here for wide-area analysis and control.

The Waggle Project



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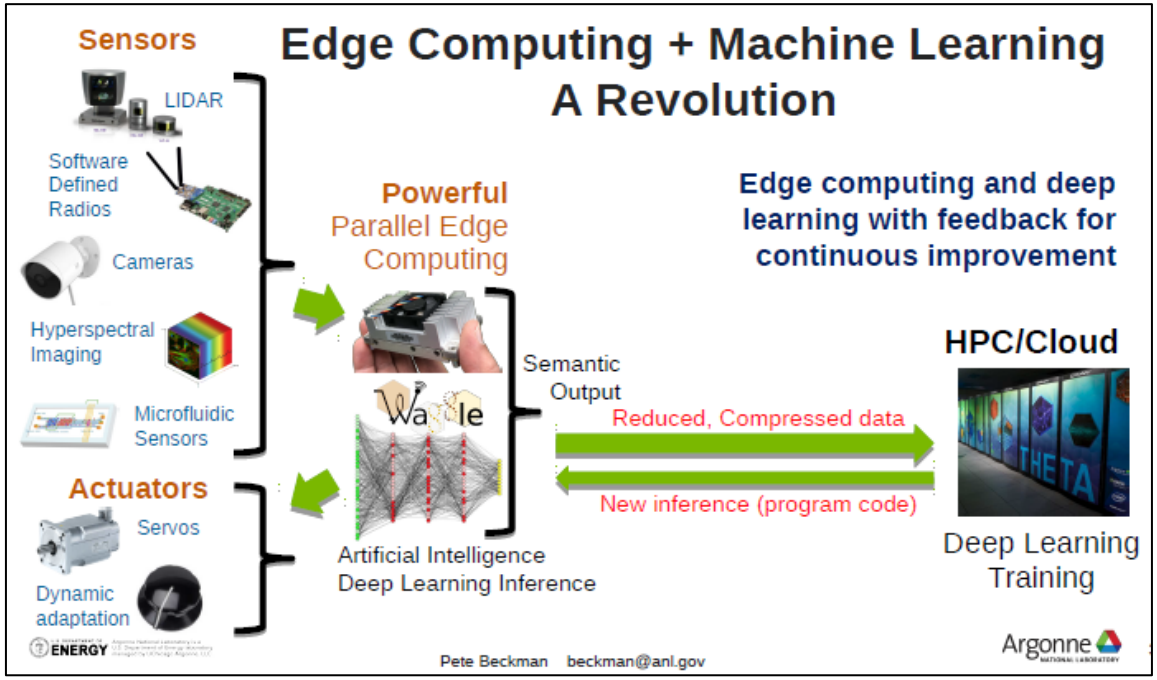

HPC & Edge Computing

"A supercomputer is a device for turning compute-bound problems into I/O-bound problems."

The late supercomputer architect Ken Batcher

"Edge computing is a device for turning I/O-bound problems into compute-bound problems."

Pete Beckman, Argonne National Laboratory

Supercomputers aren't new to edge computing. Since the 1960s-1970s:

- Governments have used HPC to monitor telco traffic.
- Governments have used HPC to forecast weather based on data from sounding balloons and ground observations.
- NASA has used HPC to analyze satellite data

Advantages of Edge Computing

- **Faster responses to local events (latency)**
  - Traffic congestion, lawbreakers, severe storms
- **Lower costs (economics)**
  - Moving all data to clouds/data centers & storing it there could become prohibitively expensive
- **Higher autonomy & reliability**
  - Avoid multi-tenancy, multiple network connections
- **Greater privacy & security**
  - Avoid multi-tenancy, decide rules for local network
- **Scalability**
  - Easier to add small, inexpensive local units than to increase cloud and data center footprint.

Edge Computing & Cybersecurity

- **Advantages of Edge Computing for Cybersecurity**
  - Large amounts of data are more difficult to steal from many edge locations than from one central server.
  - Large amounts of computing power are more difficult to hijack for nefarious purposes (e.g., cryptocurrency mining).
  - “Small data” processed at the edge its usually less mission-critical than the subset of edge data sent to central servers.
  - Keeping most data at the edge makes central servers less likely to be attacked.
- **Disadvantages of Edge Computing for Cybersecurity**
  - Edge devices may not be designed with cybersecurity in mind.
  - Commercial edge devices typically not tested for resilience to attacks, which is an important consideration of the DoD.
  - Visibility and control of edge locations via the network may be limited.
  - Loopholes and vulnerabilities in the edige security may provide network access to central servers.
  - Edge devices may be physically small enough to steal or manipulate.

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THANK YOU!

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HPC Applications Update

November 2021

www.HyperionResearch.com
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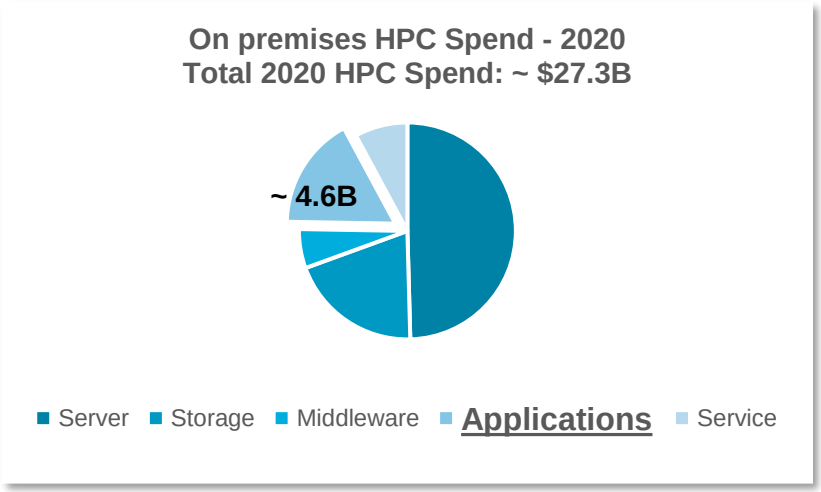
Melissa Riddle

HPC Applications Market View

Applications form sizeable broader market area



Source: Hyperion Research, 2021

- **Applications are 17% of overall broader market view spend**
- **For every $ spent on servers, an additional 34% is spent on applications**

Area ($M)	2020	2021	2022	2023	2024	2025	CAGR 20-25
Server	$13,523	$14,550	$16,947	$18,565	$19,947	$19,901	8.0%
Add-on Storage	$5,423	$5,931	$6,981	$7,835	$8,479	$8,454	9.3%
Middleware	$1,590	$1,736	$2,035	$2,244	$2,426	$2,420	8.8%
Applications	**$4,600**	**$4,913**	**$5,626**	**$6,060**	**$6,396**	**$6,353**	**6.7%**
Service	$2,146	$2,254	$2,531	$2,674	$2,767	$2,738	5.0%
Total Revenue	$27,283	$29,383	$34,121	$37,378	$40,015	$39,867	7.9%

Source: Hyperion Research, 2021

ISV Application Growth

Modest application software budget increases are expected

- **On average, users expect application spending to increase 4% in the next year**
- **About half of MCS respondents (52%) expect application spending to stay flat**
- **In addition, ISV license revenues expected to increase due to cloud growth**
- **Most MCS respondents (77%) use ISV software for at least part of their HPC workload**
- **On average, an HPC workload consists of:**
  - 22% ISV software applications
  - 44% in-house applications
  - 34% open-source (free) applications

Motivators for ISV Application Spending Growth

Expanding HPC resources are increasing ISV licenses

- **Demand for more differentiated resources (e.g., accelerators or specialized AI processors) is driving up the average number of HPC systems per site**
- **HPC sites are using the cloud to address expanding workloads**
  - Many HPC users value continuity between their on-prem and cloud applications but licenses in the cloud (when available) come with additional premiums
  - Code may need to be refactored to run in the cloud vs. on-prem
- **Many HPC users perceive ISV software as producing faster, more accurate results when compared to open-source applications**

Study: Top Applications by Vertical

Many applications are critical across multiple verticals

- **HPC users were asked to list their top 3 critical applications only**
- **Large breadth of ISV applications in some verticals**
  - Government Lab, Academic/University, Other
- **Some verticals esp. favored in-house/open-source**
  - DCC & Distribution, Economics/Financial, Weather
- **Many ISVs represented across multiple verticals**
  - Ansys, FLUENT, GAMESS, Gaussian, Hadoop, LS-DYNA, MATLAB, NAMD, SAP, Spark, VASP
- **Many open-source apps also span verticals**
  - Gromacs, LAMMPS, OpenFOAM, Quantum ESPRESSO, TensorFlow, WRF
- **Programming languages frequently in top 3**
  - MATLAB, R, Python

AI and Big Data Applications

Software used to support AI/big data spans many verticals

- **In 2021 MCS, HPC users were asked to list their top 2 successful AI/big data applications (if any)**
- **Several applications cited across multiple verticals**
  - Hadoop (CAE, EDA/IT/ISV)
  - MATLAB (Academic, EDA/IT/ISV, CAE)
  - R (Academic, CAE)
  - Python (Bio-Sciences, EDA/IT/ISV)
  - PyTorch (Academic, Government Lab)
  - TensorFlow (Academic, Defense, Government Lab)
- **Consistent with top choices for data-intensive middleware (Hadoop) and AI/ML frameworks (PyTorch, TensorFlow), and also ranked as top HPC applications overall**

Applications in the Cloud

Applications are a notable barrier to increasing cloud use

- **In 2021 MCS, HPC users were asked to list their top 2 successful cloud applications (if any)**
- **Wide variety of responses, but a couple were commonly cited**
  - Abaqus (CAE)
  - Python (Bio-Sciences, EDA/IT/ISV, CAE)
- **Interestingly, a large number of sites stated their top cloud application was AI/ML/DL**
- **Respondents were asked to give their top 3 barriers to expanding HPC cloud use**
  - 18% cited 3rd party application costs
  - 13% cited availability of desired applications
  - 8% of respondents ranked an application issue as their #1 top barrier to increasing cloud use

Applications as Decision Criteria

Application performance essential for on-premises purchasing decisions

- **Respondents were also asked to give their top 3 barriers to explaining HPC on-premises**
  - 16% cited 3rd party application costs
  - 13% cited availability of desired applications
- **Application performance is the top selection criterion for HPC server purchase**
  - 28% of users consider this #1 most important attribute
  - 45% of users rank in their top 3 criteria

ISV Applications Database

Database recently updated from new survey data

- **Hyperion Research maintains ISV application/tool/software database**
  - Leaders/major/minor players by vertical
  - Leading ISV vendors
- **Recently updated from newest survey data. Ex:**
  - VASP added to university and government
  - MATLAB added to university and EDA/IT/ISV
  - Converge added to CAE

Conclusion

Applications continue to be key to HPC decisions

- **Application performance, cost, and availability are critical for HPC decisions both on-premises and in the cloud**
- **Increasing ISV availability and accessibility in the cloud could encourage further cloud growth**
- **The definition of an HPC application is evolving**
  - ISVs, open source, in-house
  - Packaged software, middleware, programming languages
  - AI/ML/DL considered applications in their own right, and changing utilization of ISVs

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New Trends on Using Cloud for HPC Workloads

November 2021

www.HyperionResearch.com
www.hpcuserforum.com

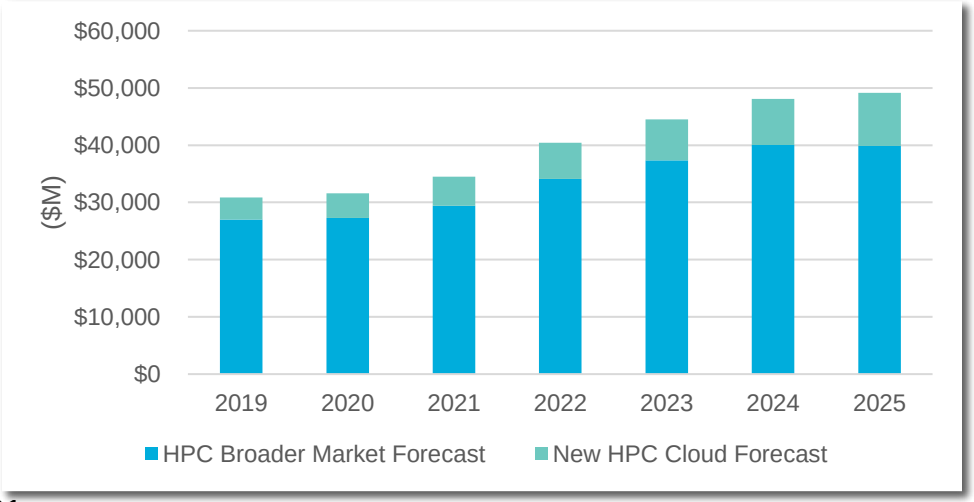
Alex Norton and Mark Nossokoff

HPC Cloud Forecast

HPC cloud market forecast to surpass $9B 2025

($M)	2019	2020	2021	2022	2023	2024	2025	CAGR '20-'25
HPC Cloud Forecast	$3,910	$4,300	$5,100	$6,300	$7,150	$8,100	$9,300	16.7%
HPC Broader Market Forecast	$26,979	$27,283	$29,383	$34,121	$37,378	$40,015	$39,867	7.9%

Source: Hyperion Research, 2021



Source: Hyperion Research, 2021

HPC Cloud Vertical Forecast

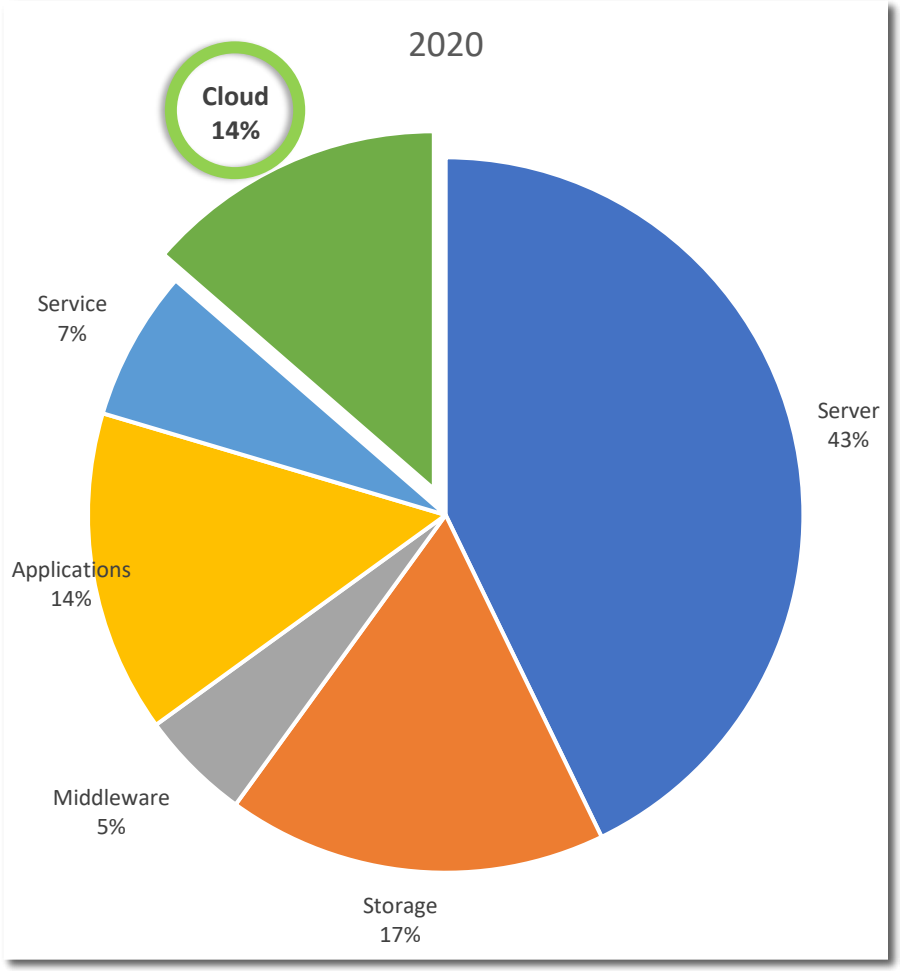
Bio-sciences and CAE the early adopting verticals; weather, geosciences and academia show highest growth

($M)	2019	2020	2025	2020-2025 CAGR
Bio-Sciences	$1,221	$1,297	$2,331	12.4%
CAE	$733	$795	$1,798	17.7%
Chemical Engineering	$98	$108	$223	15.7%
DCC & Distribution	$222	$244	$549	17.6%
Economics/Financial	$205	$248	$699	23.0%
EDA	$285	$316	$723	18.0%
Geosciences	$240	$269	$622	18.2%
Mechanical Design	$20	$21	$36	10.8%
Defense	$296	$330	$753	18.0%
Government Lab	$274	$304	$594	14.3%
University/Academic	$196	$215	$360	10.8%
Weather	$42	$65	$361	41.1%
Other	$79	$88	$251	23.4%
Total	$3,910	$4,300	$9,300	16.7%

Source: Hyperion Research, 2021

A Complete HPC Market Picture

Incorporating the cloud to the broader market forecast



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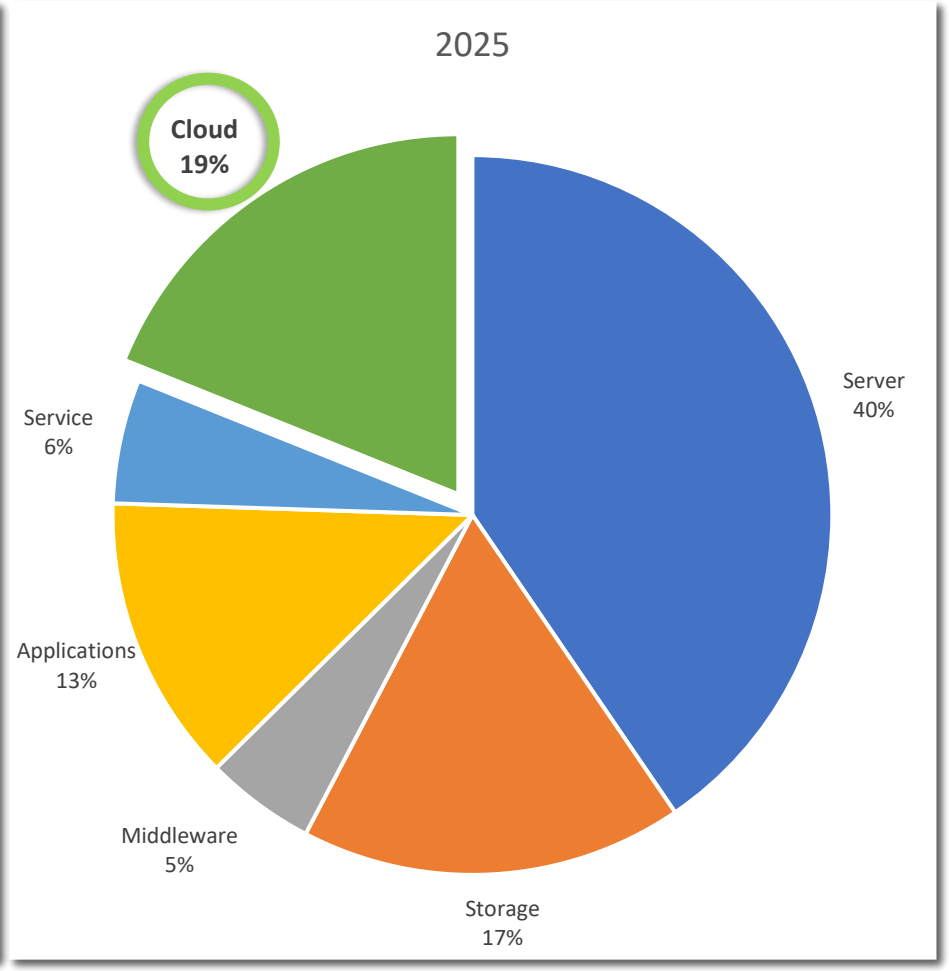

Source: Hyperion Research, 2021

Impact of HPC Cloud on On-Premises

Organizations are increasingly factoring cloud into future on-premises deployment plans

- **Today, public cloud resources are complementary to many on-premises deployments**
  - Many longitudinal studies show that cloud is used primarily for burst capabilities by many HPC users
- **A recent study showed that almost 50% of the users are altering on-premises deployments due to cloud**
- **Migrating HPC workloads to cloud platforms requires new skills for datacenter managers and researchers**
  - Much of this education and training on using the cloud addresses which workloads can and should be run in the cloud versus remain on-premises
  - IT departments are factoring in data movement and security as they expand their resource pools to consist of cloud resources

Differing Approaches

"Cloud" deployments showing up in different ways

- **What is the UK Met deal actually like?**
  - Azure hosting multiple Cray machines
  - Working with UK Met on porting code and data
  - Currently in development phase, with compute to arrive around mid-2022
- **Where do offerings like HPE's Greenlake fit in "hybrid" cloud segment?**
  - Greenlake offers elastic compute capabilities, similar to cloud, but on-premises
  - Some off-prem hosting available
  - Example: HPE to provide NSA with "secure cloud services on-premises…"[1]
  - Services like this allows users to keep more "on-premises" rather than in a third-party environment

1: Hewlett Packard Enterprise wins $2B HPE GreenLake contract with the National Security Agency. https://bit.ly/3o1FBLW

What is Next for the Cloud?

Cloud computing for HPC workloads is changing the compute landscape

- **Continued rise of cloud-born HPC users**
  - Sites without previous on-premises infrastructure
  - Startups running computationally intensive or data-intensive workloads at scale on cloud
  - Cloud offers elastic capabilities with limited overhead
- **Cloud usage will boil down to an optimization problem among these requirements/restrictions:**
  - Cost
  - Time-to-solution
  - Performance
  - Data locality
  - Expertise

Conclusions

HPC in the cloud continues to evolve, as well as augment the broader HPC market

- **HPC users continue to increase their cloud usage and cloud spend, resulting in an aggressive growth**
- **Many barriers to increased HPC cloud usage have remained consistent over a few years**
  - CSPs are working to address these barriers
  - Users should look to educate themselves on current capabilities and improvements CSPs have made
- **Established and emerging HPC user sites should look to balance on-premises and cloud compute resources based on:**
  - Budget
  - Time to solution required
  - Skillsets
  - Current resources

HYPERION RESEARCH

Want to continue the conversation?

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Perspectives on HPC Storage and Interconnects

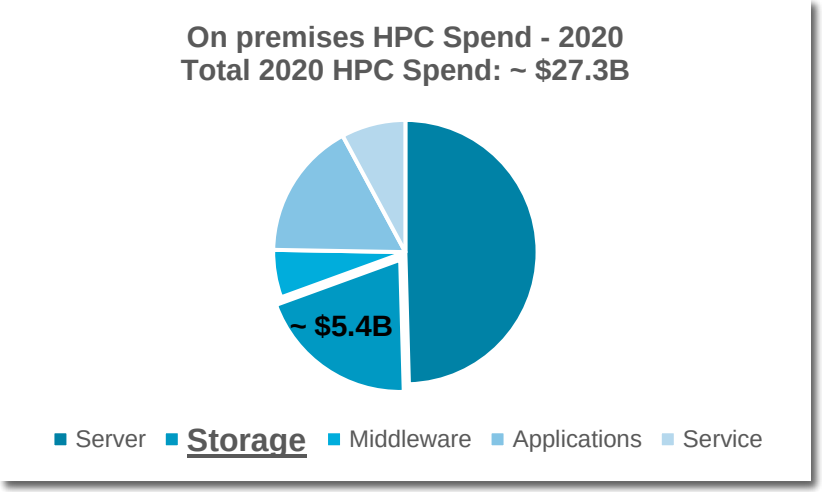
November 2021

www.HyperionResearch.com
www.hpcuserforum.com

Mark Nossokoff

HPC Storage Demand Continues

Data-intensive workloads primary storage growth driver



Source: Hyperion Research, 2021

- **Storage historically the highest growth HPC element**
- **Storage represents ~ 20% of HPC spending and growing**
- **Slight on-prem decline in 2025**
  - Declining exascale spending
  - Cyclical nature of the market
  - Accelerated adoption of cloud

Area ($M)	2020	2021	2022	2023	2024	2025	CAGR 20-25
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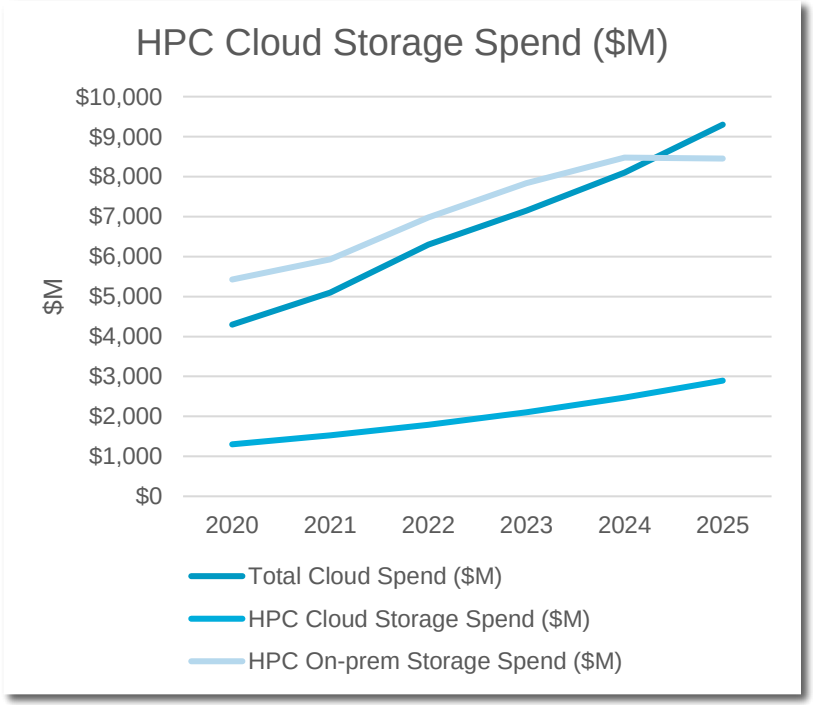
Source: Hyperion Research, 2021

HPC Cloud Storage Forecast

Cloud storage '20-25 CAGR ~1.9x on-prem storage CAGR

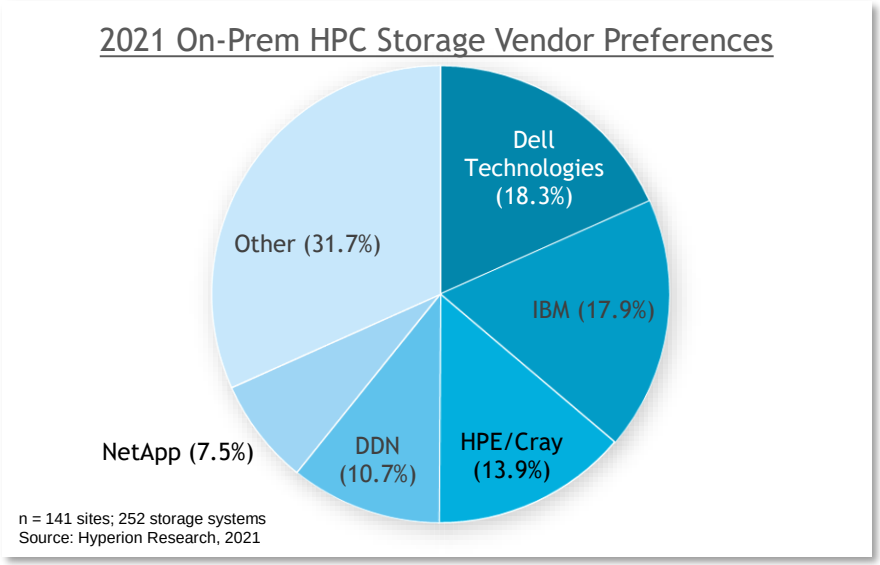
- **$1.3B of cloud storage spend in 2020**
- **Storage represented 1/3 of total cloud spend**
- **Cloud storage CAGR ~ 1.9x on-prem storage CAGR**
  - Cloud: 17.3%
  - On-prem: 9.3%

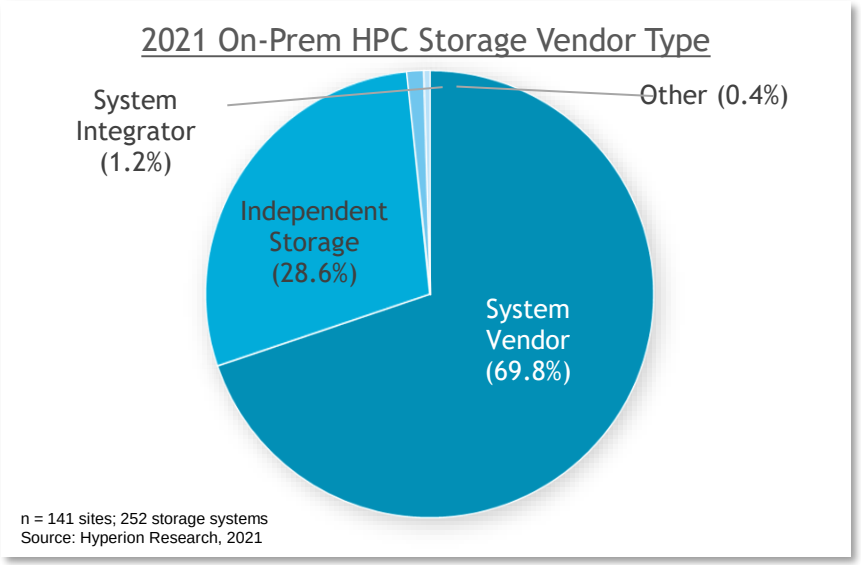


Source: Hyperion Research, 2021

2021 HPC Storage Vendor Preferences

Dell Technologies top preferred on-prem HPC storage vendor





- **Dell Technologies first overall; preferred by Industry**
- **IBM second preferred overall and in all sectors**
- **HPE/Cray preferred 3rd overall but tops in Government**
- **DDN 4th overall, preferred in Academia, and preferred independent**
- **Top others: Seagate, Lenovo, Fujitsu, Huawei, ATOS**

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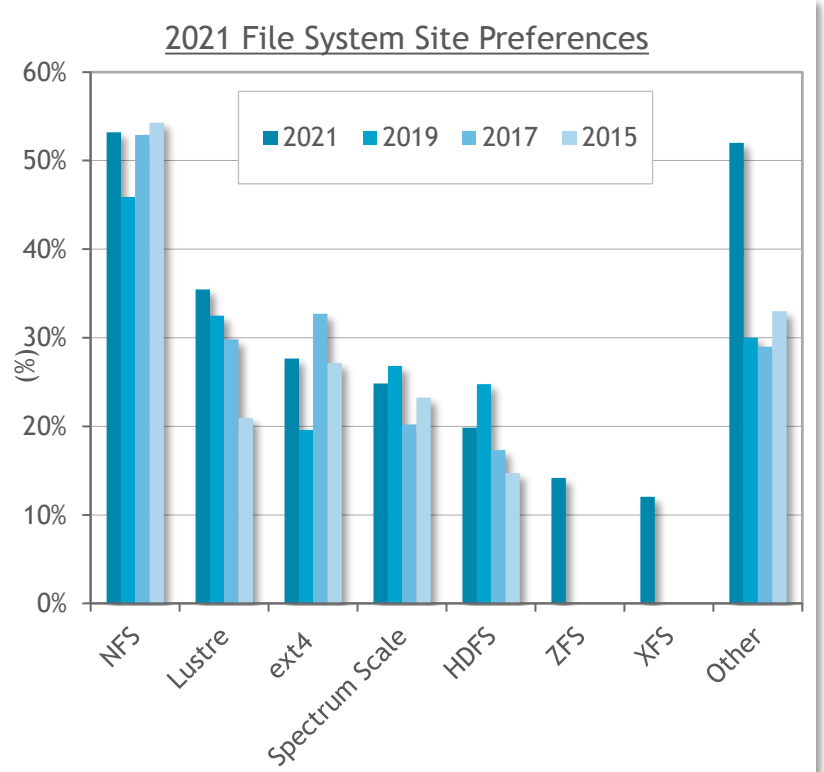
Storage Ecosystem Technology

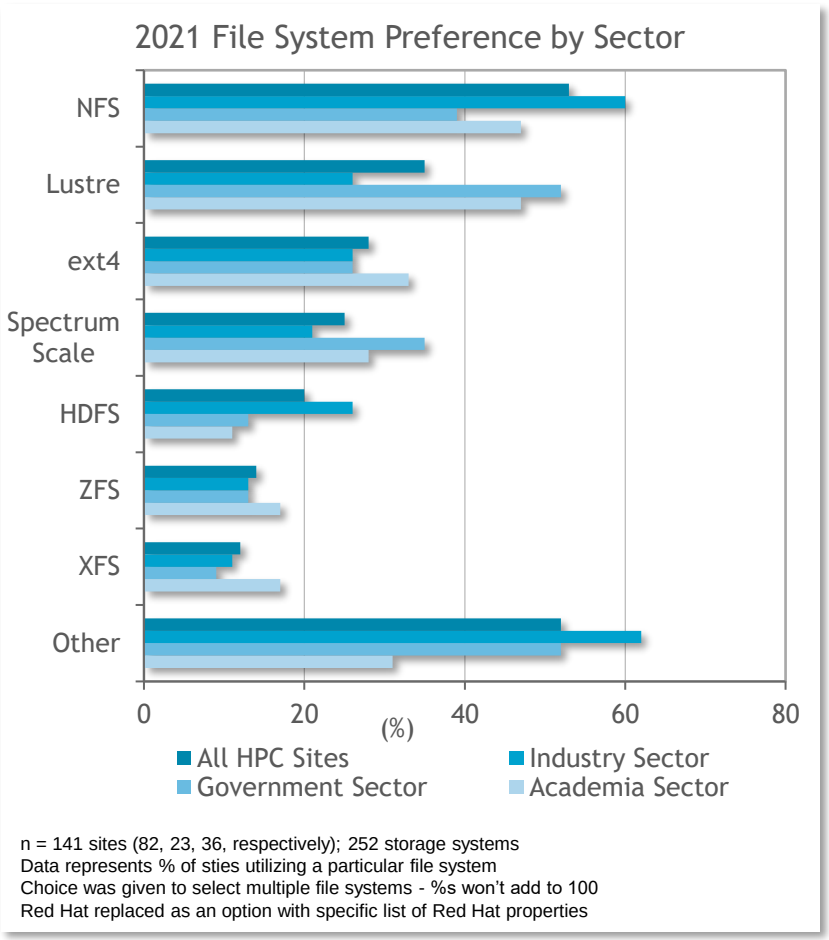
File System Preferences

Sharp increase in utilization of emerging file systems
Industry sector leading exploration of "other" file systems



n = 141 sites (82, 23, 36, respectively); 252 storage systems
Data represents % of sties utilizing a particular file system
Choice was given to select multiple file systems - %s won't add to 100
Red Hat replaced as an option with specific list of Red Hat properties

Source: Hyperion Research, 2021



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Source: Hyperion Research, 2021

File System Market Observations

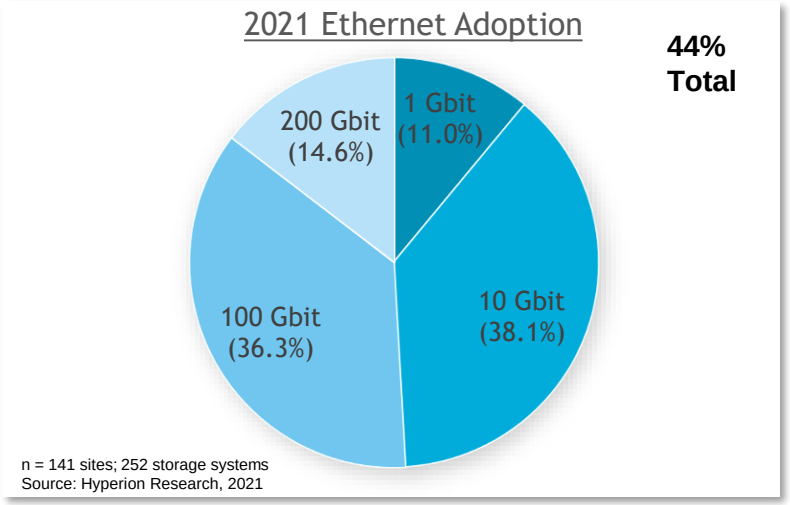
Emerging file systems gaining traction

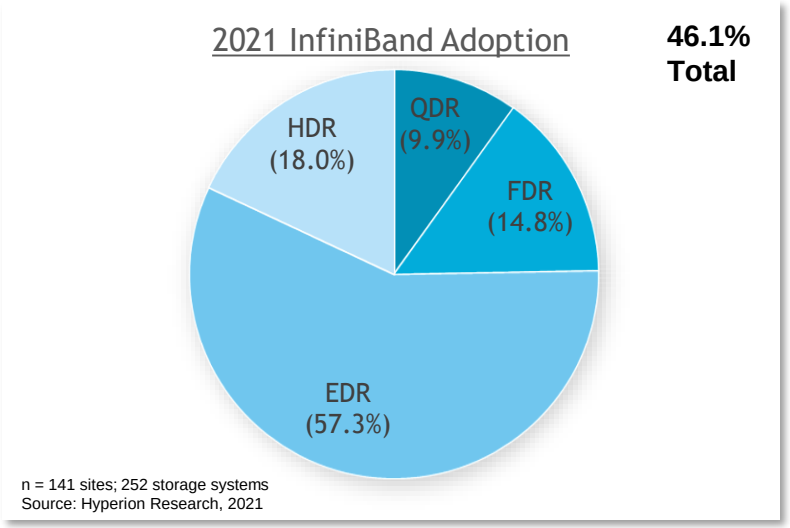
- **Sites average 1.8x file systems**
- **NFS and Lustre remain top two**
  - Both exhibited growth
  - Industry leans towards NFS
  - Government tends towards Lustre
- **ext4 rose to third most preferred**
- **Spectrum Scale dropped to fourth**
  - Sharp drop in adoption at government sites
  - Increased adoption within industry
- **Next five (10% - < 20%)**
  - HDFS, ZFS, XFS, BeeGFS, GFS
- **Next tier (2% - < 10%)**
  - CEPH, OneFS, WekaFS, Gluster, PVFS/OrangeFS, DAOS, PanFS

System Interconnect Preferences

InfiniBand edges ahead of Ethernet in aggregate adoption

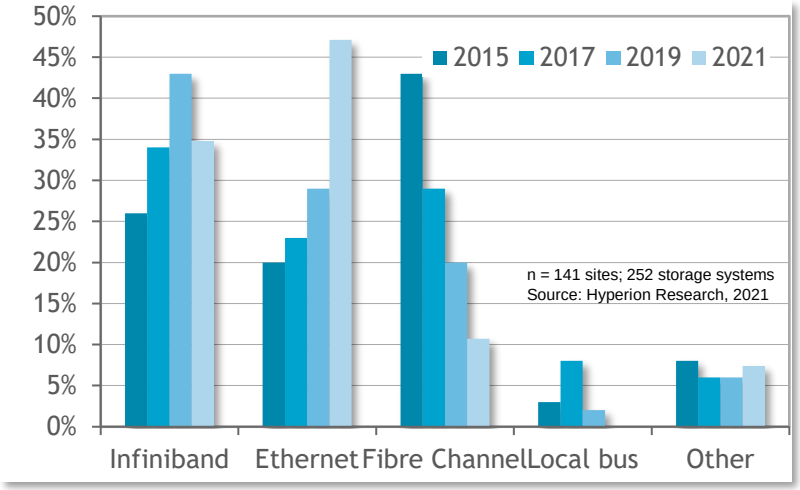
- **Initiated distinction between storage and system interconnects**
- **Ethernet**
  - Adopted at 44% of sites surveyed
  - 10 Gbit most widely adopted
- **InfiniBand**
  - Deployed at 46.1% of sites surveyed
  - EDR 100 Gbit most widely deployed
- **Omni-Path**
  - Some adoption across all sectors
  - 2nd largest deployed in academic sites (13.9%)



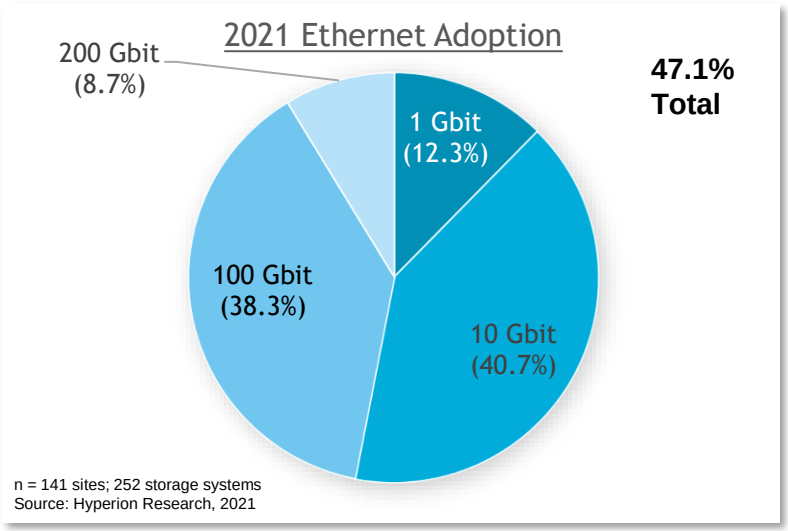


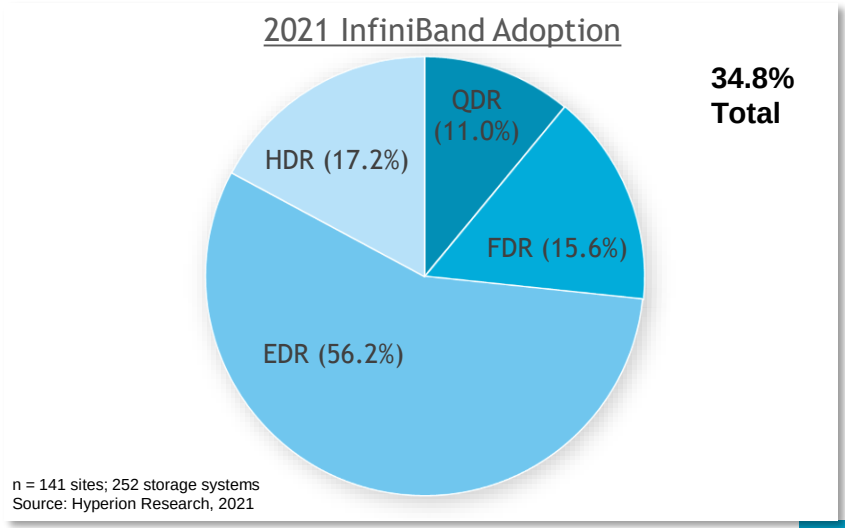
Storage Interconnect Preferences

Ethernet emerged as preferred storage interconnect



- **Initiated distinction between storage and system interconnects**
- **Sector preference differences**
  - Industry leans ethernet
  - Government split between ethernet and InfiniBand
  - Academia leans InfiniBand
- **Omni-Path large part of other**





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2H21 Storage Industry Review

2H21 HPC Storage and Interconnect Activity

Broad areas of investment and innovation

- **Pawsey 130PB system refresh**
  - Saving data for longer periods of time
  - More researchers globally accessing the data
  - In addition to Setonix announcement in 1H21
- **IBM Spectrum Fusion**
  - Red Hat bearing fruit
  - Containerized IT for increased adoption of HPC-enabled AI
- **Lustre cloud enhancements**
  - AWS
  - Azure
  - Google Cloud
- **DNA Storage financing**
  - CATALOG
  - Molecular Assemblies
  - DNA Script
- **Interconnect / Networking announcements**
  - Rockport Networks – switchless network
  - Accelerating CXL adoption plans

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Future Research Direction

Future Research Direction

Broad range of topics across diverse storage ecosystem

- **Grow on-prem census data**
  - Use cases
    - Temporal, durable
    - File, block, object
    - Scratch, user, home directory, project, campaign, archive
  - Capacity
  - Internal to servers and compute nodes
- **Expand cloud storage coverage**
  - Cloud storage landscape model
  - Cloud workload usage and requirements
- **Broaden general storage and data management areas**
  - Storage consumption models
  - Data and workflow management
    - Migration of HPC workloads to the cloud
    - Impact of edge computing
- **Develop broader technology coverage**
  - Storage for Containers
  - POSIX compliancy
  - Interconnects
  - Additional memory topics

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THANK YOU!

Want to continue the conversation?

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Quantum Computing: Moving Out of the Lab?

November 2021

Bob Sorensen

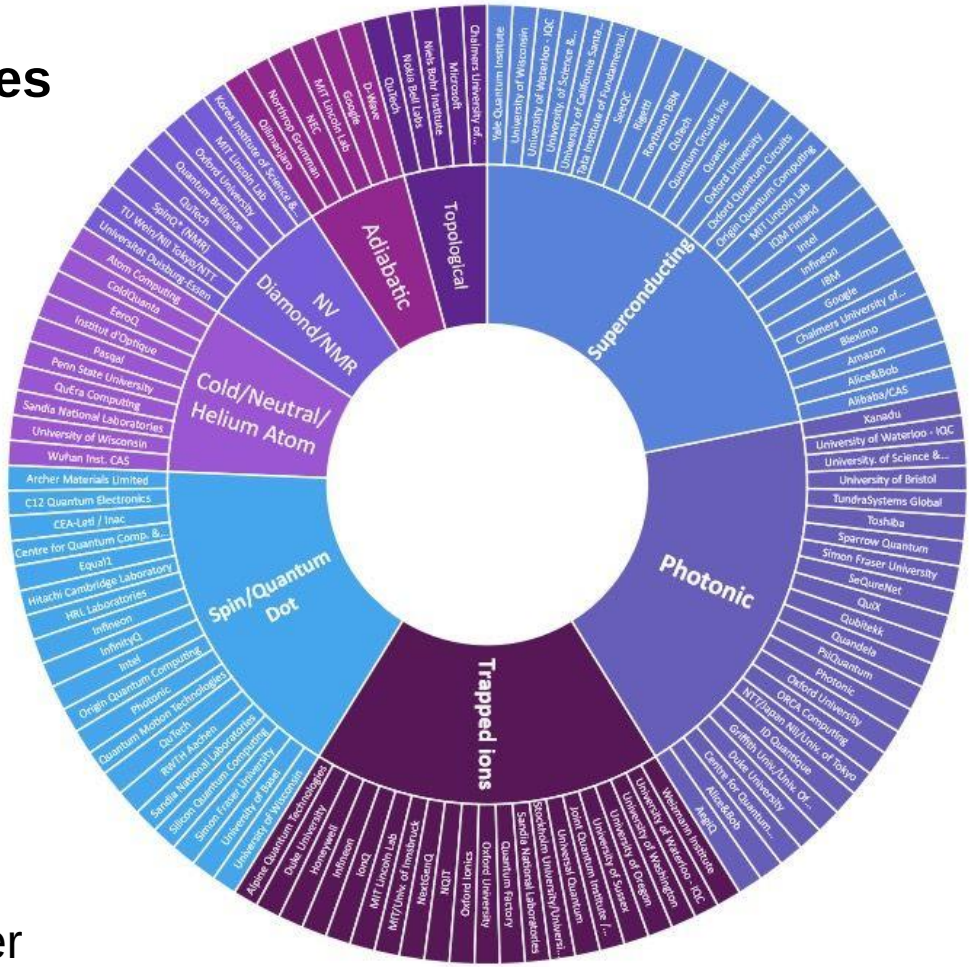
www.HyperionResearch.com
www.hpcuserforum.com

Currently, the Promise of QC is Substantial

- **QC systems have the potential to exceed the performance of conventional computers for problems of importance to humankind and businesses alike in areas such as:**
  - Physical Simulation
    - Materials science
    - Chemistry
    - Pharmaceuticals
    - Oil and gas
  - Machine learning
  - Optimization
- **And the list grows longer each day**

Broad Range of Contenders

- **Hardware-wise, several competing quantum modalities under development**
  - Superconducting
  - Photonic
  - Trapped Ions
  - Spin/Quantum Dot
  - Cold/Neutral/Helium Atom
  - NV/Diamond/NMR
  - Adiabatic
  - Topological
- **Each offers their own unique strengths and weaknesses**
  - There may not be a clear winner
  - And the ultimate winner may not be here



Source : Michel Kurek https://www.linkedin.com/in/michelkurek/

Substantial Challenges Ahead

In almost every dimension

- **Materials research**
  - Coherency, defect management, power
- **Device and processor development**
  - Gate/logic designs
  - Coherency, entanglement, control, measurement, error rates and error correction schemes
- **Architecture: memory, interconnect, storage**
  - Heterogeneity ahead
  - No cloning theorem, no broadcast theorem
  - Integration and control
  - Error correcting / Error tolerant designs
  - Designs absent applications

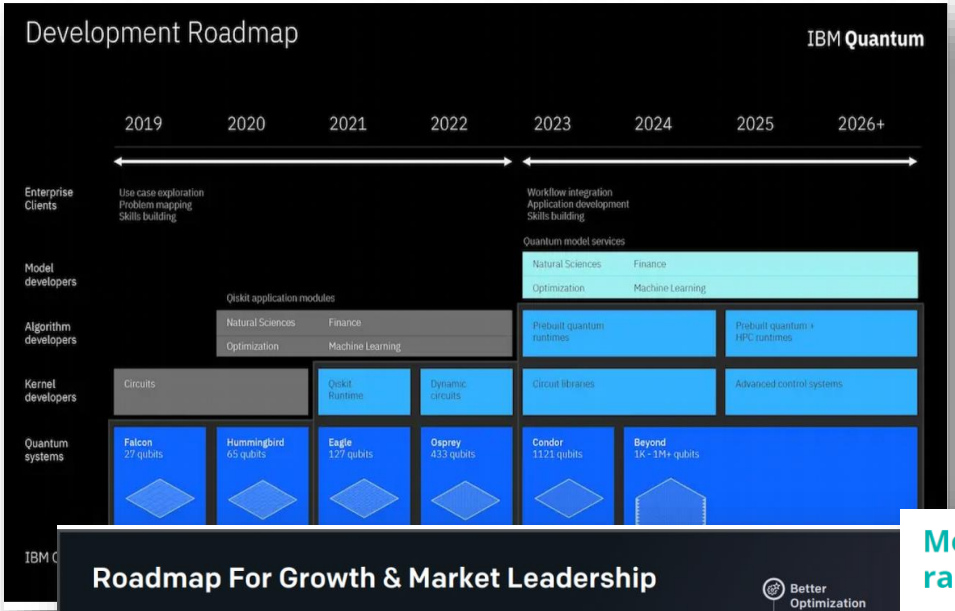
Substantial Challenges Ahead (cont.)

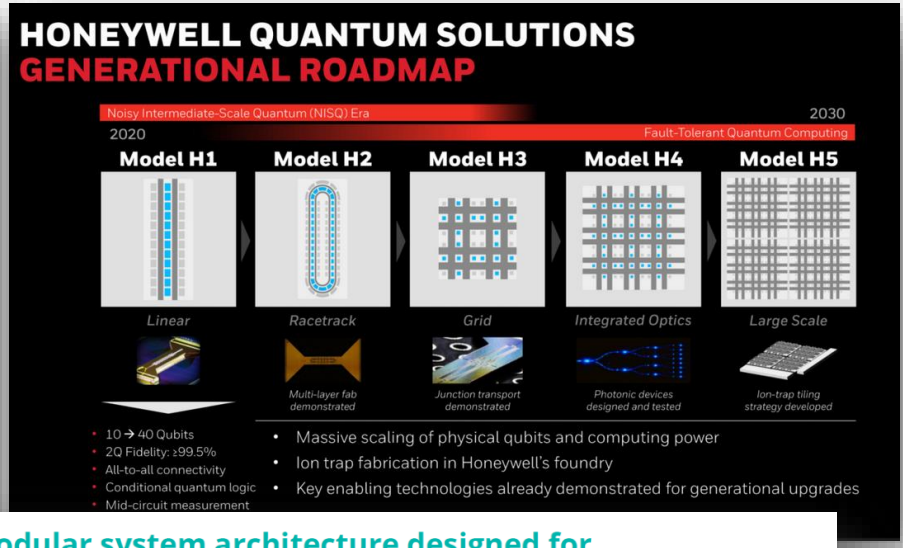
In almost every dimension

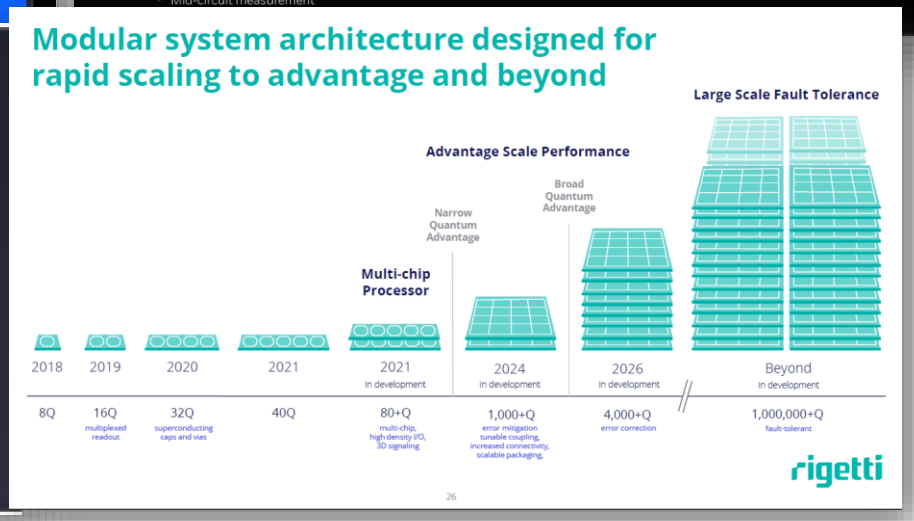
- **Software**
  - QC assembly, instruction sets, programming language and tools
  - QC interfaces to classical systems
  - Validation and verification
- **Algorithms**
  - A wide-open field
- **Despite these challenges, the lure of potential performance is driving a growing perspective within both the supplier and (potential) user base that the technology may soon be coming of age**
  - The shift from research topic to market phenomena is a growing reality

QC Supplier Roadmaps Emerging

Designed to build confidence, highlight long-term commitment



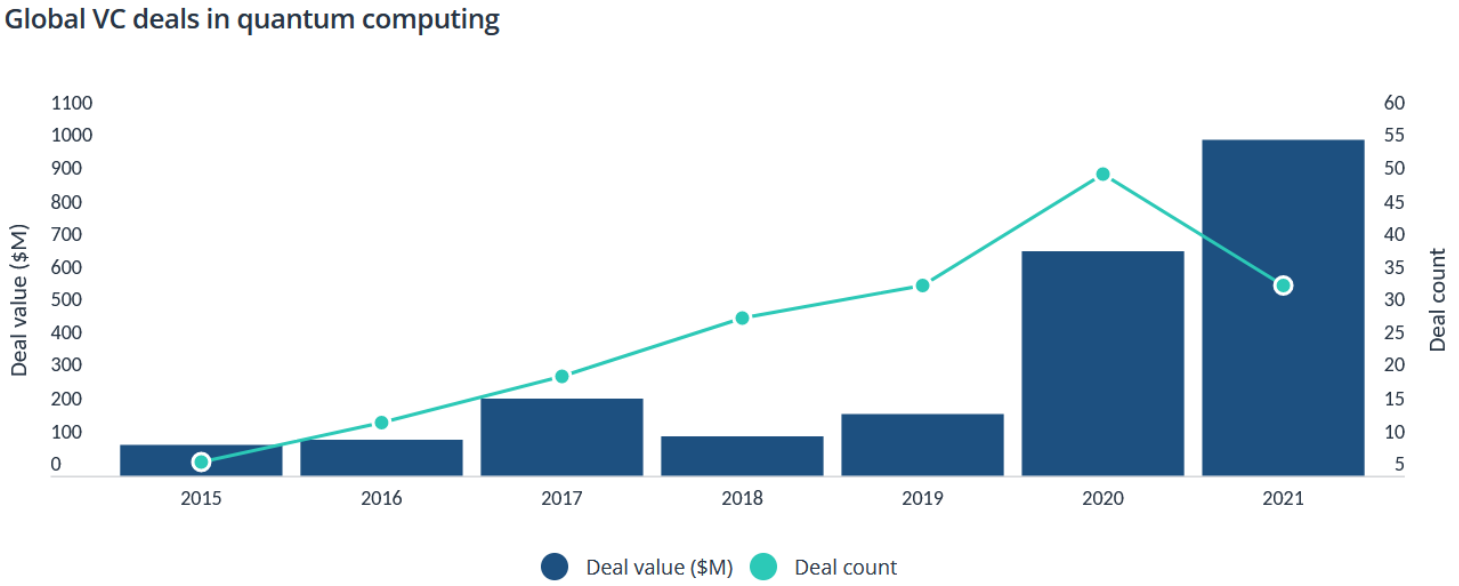




Hyperion Research 2021

Source: IBM, Honeywell, IonQ, Rigetti: 2021

Growing Interest as An Investable Technology Sector…



	Deal Date	Deal Size (millions)	Post-money Valuation (millions)	Select Investors	Company HQ
PsiQuantum	7/27/2021	$450.0	$3,150.0	Baillie Gifford, BlackRock, M12, Temasek	Palo Alto
Xanadu	5/25/2021	$100.0	N/A	Bessemer Venture Partners, Georgian, Tiger Global	Toronto
Rigetti	8/4/2020	$79.0	N/A	Andreessen Horowitz, Battery Ventures, Bessemer Venture Partners, DCVC	Berkeley, Calif.
IonQ	6/16/2020	$62.0	$192.0	Airbus Ventures, Amazon Web Services, Mubadala	College Park, Md.
Quantum Machines	9/6/2021	$50.0	N/A	Battery Ventures, Red Dot Capital Partners, Samsung NEXT Ventures, Valor Equity Partners	Tel Aviv

Source: Pitchbook: Data as of Sept. 8, 2021

...and as a Mainstream Investment Opportunity

- **March 2021: IonQ, first publicly traded full-stack QC company**
  - Merger agreement with dMY Technology Group III, $650 million in gross proceeds
  - Pro forma implied market capitalization of the combined company is approximately $2 billion
- **July 2021: Quantum Computing Inc. listed on Nasdaq**
  - QCI becomes one of a handful of first pure-play quantum software company to list there
- **October 2021: Rigetti plans to go public via a Special Purpose Acquisition Company (SPAC) merger**
  - The combined company is expected to receive approximately $458 million in gross cash proceeds
  - Plans to merge with Supernova Partners Acquisition Company II, Ltd. would value Rigetti at around $1.5 billion

Perhaps More Important, Users are Also Taking an Interest...

- **September 22, 2021: Widespread interest in quantum computing across industry sectors**
  - Majority of U.S. professionals (89.8%) believe that IT departments should have budgets dedicated to quantum computing
  - 61.9% already have budgets for quantum computing, and an additional fifth (21.6%) plan to incorporate quantum computing into their IT planning
  - Source: Classiq, quantum algorithm design platform provider, 2021

- **October 10, 2021**
  - Hyperion Research study for D-Wave: What is the current state of quantum computing activity in your organization?
  - More research on the way

Exploring options and monitoring technology development	47%
Quantum use case analysis and prioritization are being used	35%
Proof of concept research programs underway	33%
Fully funded research efforts are being used	27%
Limited in-house pilot programs underway	23%
Production use of quantum computing for one or more business processes	22%
No current activity but planning to start up activity within the next few years	21%
No activity and no plans to have any activity in the next few years	8%
Don't know/Not sure	2%

So How Does This Play Out?

- **Interest in quantum computing technology and its potential to help accelerate advanced computing workloads is growing, from both supply and demand perspectives**
- **For suppliers, it's going to be less about the technology and more about the end-use and end-users**
  - An early lead in a hardware or software capability could help ensure long-term success, but performance claims need to be realistic, and expectations need to be managed for both potential clients and investors

So How Does This Play Out? (cont.)

- **For users, it's about accelerated or new performance that they can readily integrate into existing and planned IT workloads**
  - Enabling innovation, driving research, and realizing competitive advantage are the performance indicators that increasingly will carry the day
- **Is the current enthusiasm with QC investment a good news or bad news story?**
  - A show of hands, please

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QUESTIONS?

Questions or comments are welcome.

Please contact us at:

info@hyperionres.com

HPC Market Update During SC21

November 2021

www.HyperionResearch.com
www.hpcuserforum.com

Earl Joseph

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In Summary

Conclusions

- **The pandemic was expected to impact 2020 by ~8% decline, but Fugaku made 2020 a growth year!**
  - 2021 is looking strong
  - 2022 to 2024 are expected to be strong growth years
    - Exascale systems will drive growth in 2022 to 2024
    - AI, HPDA, big data are hot growth areas
    - HPC in the cloud will lift the sector writ large
- **New technologies are showing up in larger numbers:**
  - Processors, AI hardware & software, memories, etc.
- **The cloud has become a viable option for many HPC workloads**
- **Storage will likely see major growth driven by AI, big data and the need for much larger data sets**

The ROI From HPC Is High

The average ROI is $507 for revenue, and on average $47 for profits/cost savings

Updated results continue to indicate substantial returns for investments in HPC:

- The data now covers 763 successful HPC projects
- On average $507 dollars in revenue per dollar of HPC invested was generated (excluding outliers)
- On average $47 dollars of profit (or cost savings) per dollar of HPC invested was generated (excluding outliers)
- The average HPC investment per innovation was $2.6 million

Note that this research is looking at the economic impacts based on the HPC investment compared with the output of revenue/sales and/or profits and cost savings. It excludes the additional costs of production, sales etc. that are also required for each project.

The full data and results of this research are available at: www.hpcuserforum.com/ROI/

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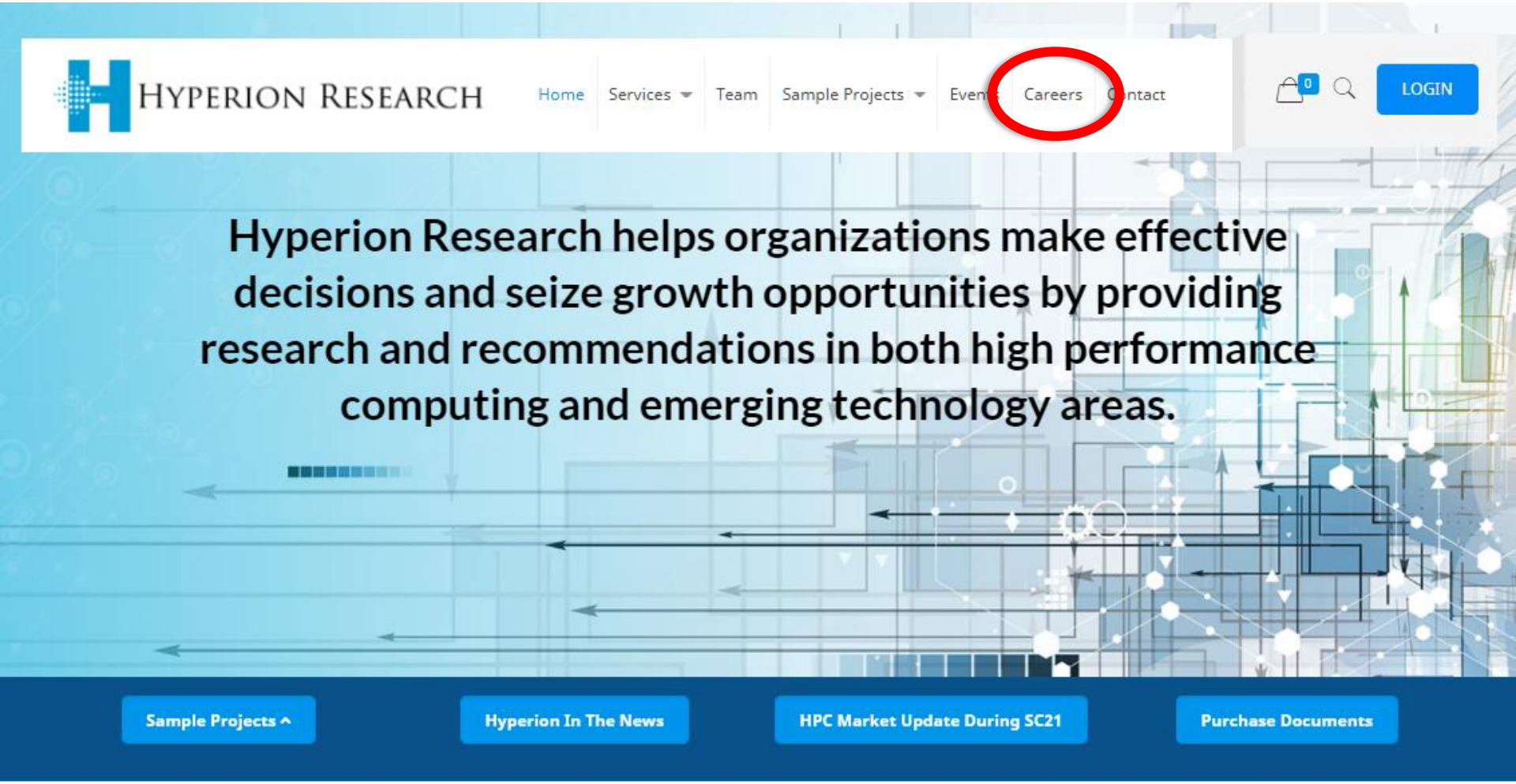
Twitter: @HPC_Hyperion



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Thank You For Joining Us Today!

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QUESTIONS?

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Please contact us at:

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Please take a minute to do a short survey to help us improve our update briefings