Hewlett Packard Labs

EXTRAORDINARY CLAIMS DEMAND EXTRAORDINARY ENGINEERING

Hewlett Packard Enterprise
March 2023

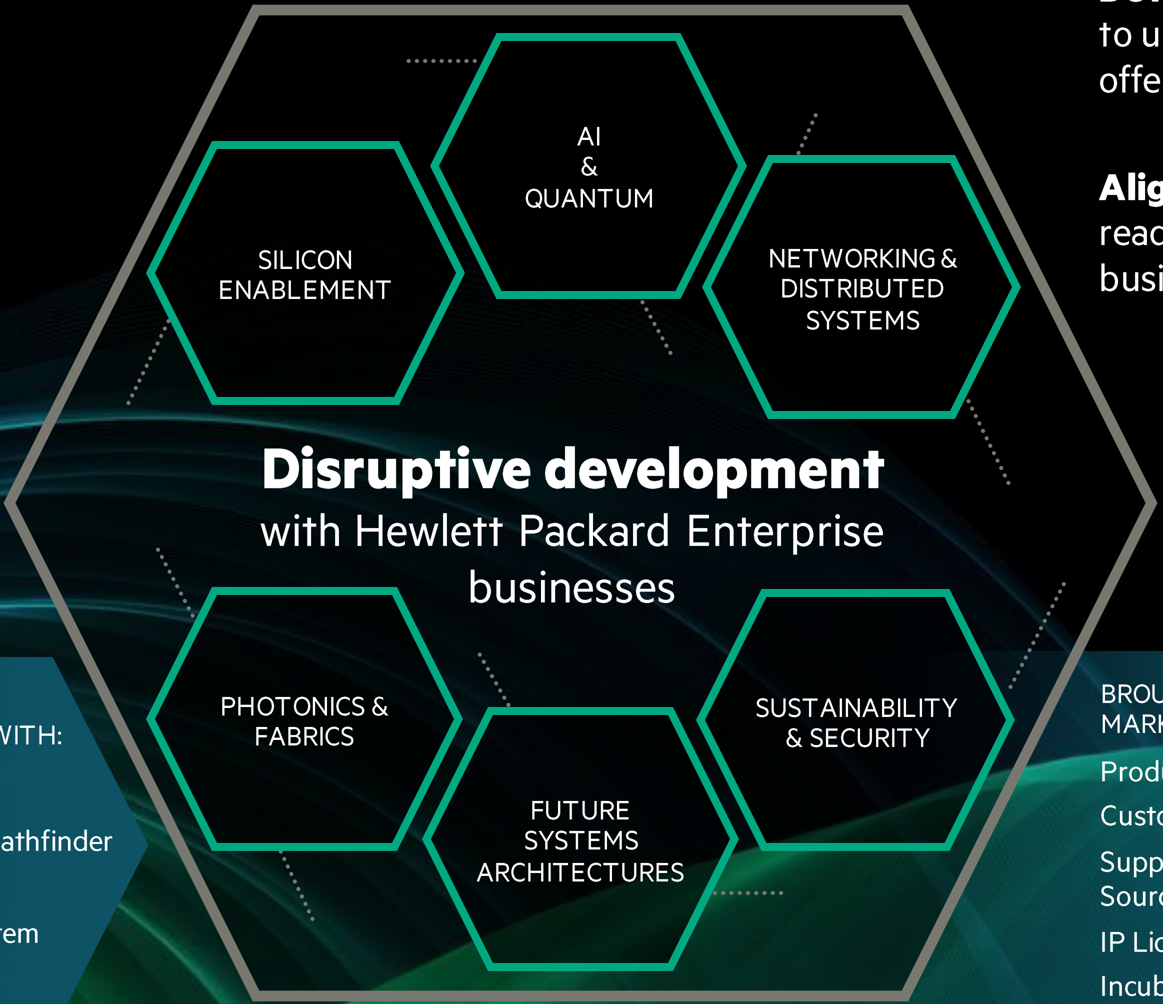
HEWLETT PACKARD LABS INNOVATION AGENDA

Hewlett Packard
Labs

Hewlett Packard Labs drives breakthrough innovations to **help customers solve their most complex challenges today** and **reimagine a better future** to advance the way we live and work.

Develop technologies to underpin aaS offerings at scale

Align technology readiness with business roadmaps



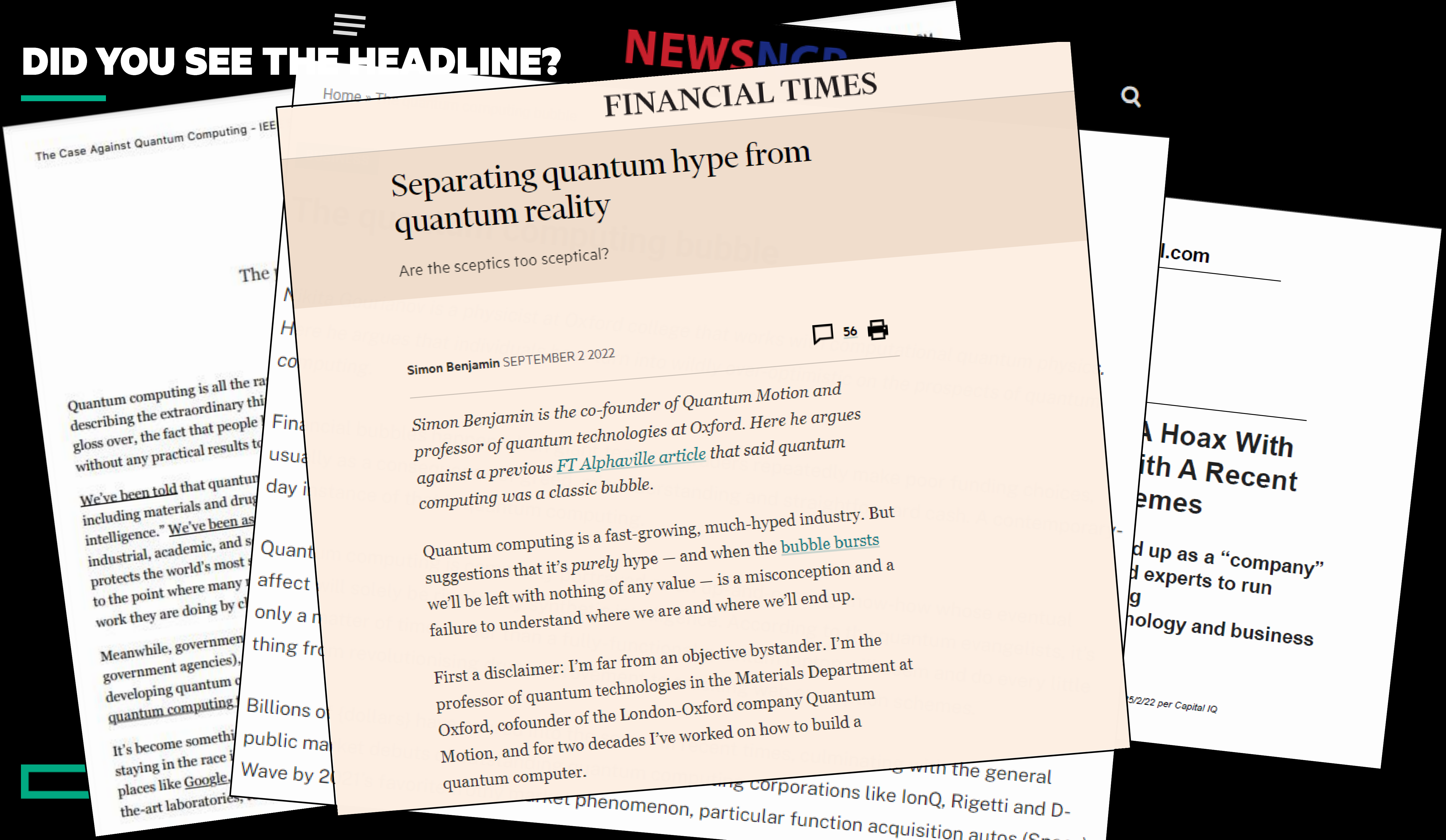
COLLABORATING WITH:

- Customers
- Hewlett Packard Pathfinder
- HPE Leadership
- Innovation Ecosystem

BROUGHT TO MARKET THROUGH:

- Product offerings
- Customer collaborations
- Supplier / Open Source partners
- IP Licensing
- Incubations

DID YOU SEE THE HEADLINE?



FINANCIAL TIMES

Separating quantum hype from quantum reality

Are the sceptics too sceptical?

Simon Benjamin SEPTEMBER 2 2022

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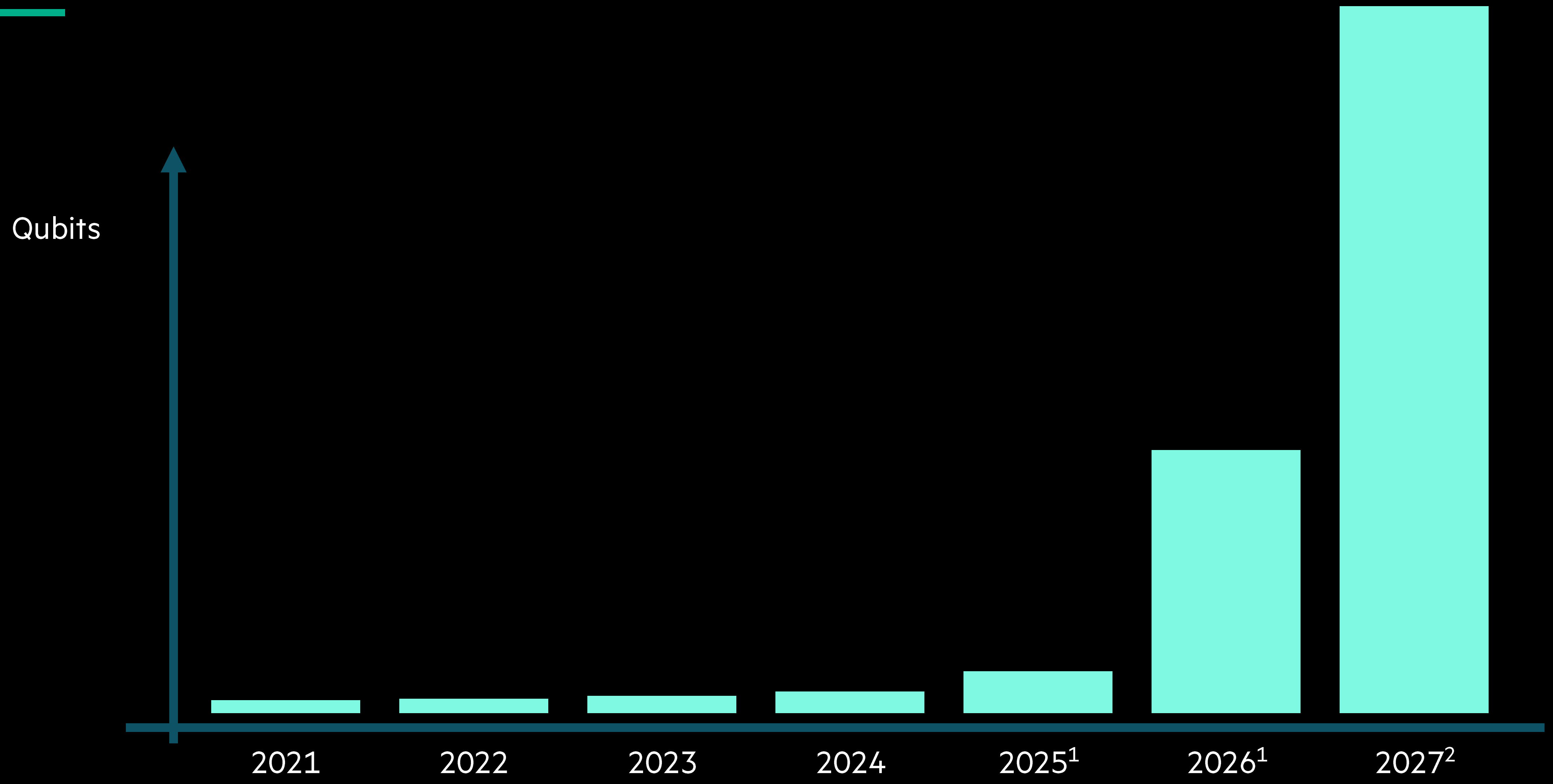
Simon Benjamin is the co-founder of Quantum Motion and professor of quantum technologies at Oxford. Here he argues against a previous FT Alphaville article that said quantum computing was a classic bubble.

Quantum computing is a fast-growing, much-hyped industry. But suggestions that it's *purely* hype — and when the bubble bursts we'll be left with nothing of any value — is a misconception and a failure to understand where we are and where we'll end up.

First a disclaimer: I'm far from an objective bystander. I'm the professor of quantum technologies in the Materials Department at Oxford, cofounder of the London-Oxford company Quantum Motion, and for two decades I've worked on how to build a quantum computer.

AN EXAMPLE ROADMAP – ROSE ≠ MOORE YET



1: Breakthrough in error correction

2: Breakthrough in integration

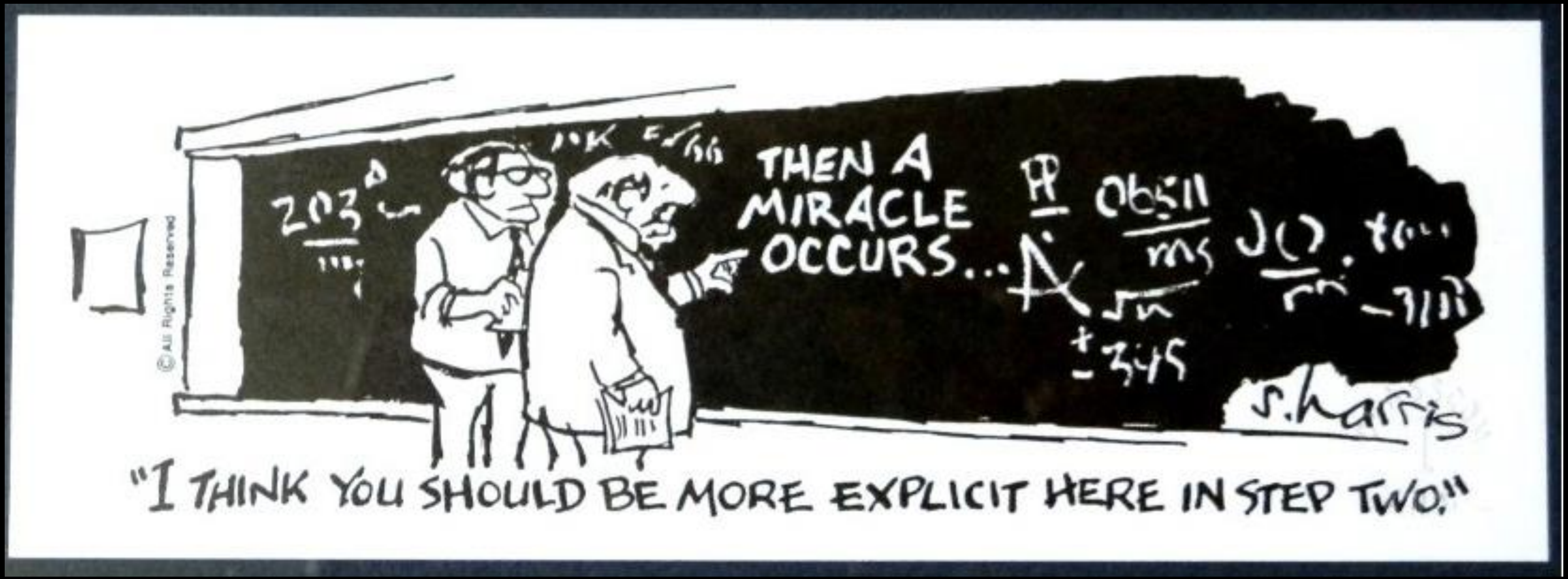
AREN'T WE RIGHT ON THE CUSP?

application	planar quantum ISA requirements				qubit parameters	QEC optimization			resource requirements		Cost at $0.01 per qubit second
	Q	$C_{\min}$	C	M		d	F	factory ratio	physical qubits	physical run time	
quantum dynamics	230	$1.5 \cdot 10^5$	$1.5 \cdot 10^5$	$2.4 \cdot 10^6$	(μs, 10^{-3})	19	199	95%	3.0M	29 mins	$ 52,200,000
			$1.5 \cdot 10^5$		(μs, 10^{-4})	9	199	95%	0.68M	14 mins	$ 5,712,000
			$1.5 \cdot 10^5$		(ns, 10^{-3})	19	242	98%	8.2M	1.1 secs	$ 90,200
			$1.5 \cdot 10^5$		(ns, 10^{-4})	9	199	95%	0.68M	0.56 secs	$ 3,808
			$1.5 \cdot 10^5$		(ns, 10^{-4})*	9	260	99%	5.8M	0.42 secs	$ 24,360
			$1.5 \cdot 10^5$		(ns, 10^{-6})*	5	224	95%	0.62M	0.23 secs	$ 1,426
quantum dynamics (reduced T factories)	230	$1.5 \cdot 10^5$	$1.5 \cdot 10^6$	$2.4 \cdot 10^6$	(μs, 10^{-3})	21	18	56%	0.46M	5.3 hours	$ 92,736,000
			$1.5 \cdot 10^6$		(μs, 10^{-4})	11	17	50%	0.11M	2.8 hours	$ 11,088,000
			$1.5 \cdot 10^6$		(ns, 10^{-3})	21	22	78%	0.94M	13 secs	$ 122,200
			$1.5 \cdot 10^6$		(ns, 10^{-4})	11	17	50%	0.11M	6.7 secs	$ 7,370
			$1.5 \cdot 10^6$		(ns, 10^{-4})*	11	22	79%	0.61M	5.0 secs	$ 30,500
			$1.5 \cdot 10^6$		(ns, 10^{-6})*	5	23	66%	0.09M	2.3 secs	$ 2,070
quantum chemistry	2740	$4.1 \cdot 10^{11}$	$4.1 \cdot 10^{11}$	$5.4 \cdot 10^{11}$	(μs, 10^{-3})	33	15	6.9%	6.4M	260 years	$ 524,759,040,000,000
			$4.1 \cdot 10^{11}$		(μs, 10^{-4})	17	14	5.9%	1.6M	130 years	$ 65,594,880,000,000
			$4.1 \cdot 10^{11}$		(ns, 10^{-3})	33	17	14%	6.9M	2.0 months	$ 178,848,000,000
			$4.1 \cdot 10^{11}$		(ns, 10^{-4})	17	17	15%	1.9M	1.0 month	$ 1,641,600,000
			$4.1 \cdot 10^{11}$		(ns, 10^{-4})*	17	19	22%	4.5M	24 mins	$ 64,800,000
			$4.1 \cdot 10^{11}$		(ns, 10^{-6})*	9	19	22%	1.3M	12 days	$ 13,478,400,000
factoring	25481	$1.2 \cdot 10^{10}$	$1.2 \cdot 10^{10}$	$1.5 \cdot 10^{10}$	(μs, 10^{-3})	27	13	0.6%	37M	6.2 years	$ 72,343,584,000,000
			$1.2 \cdot 10^{10}$		(μs, 10^{-4})	13	14	0.8%	8.6M	3.0 years	$ 8,136,288,000,000
			$1.2 \cdot 10^{10}$		(ns, 10^{-3})	27	15	1.3%	37M	1.5 days	$ 47,952,000,000
			$1.2 \cdot 10^{10}$		(ns, 10^{-4})	13	18	1.1%	8.7M	18 hours	$ 5,637,600,000
			$1.2 \cdot 10^{10}$		(ns, 10^{-4})*	15	15	0.9%	26M	15 hours	$ 14,040,000,000
			$1.2 \cdot 10^{10}$		(ns, 10^{-6})*	7	13	1.2%	6.2M	7.1 hours	$ 1,600,056,000

arXiv:2211.07629 - Assessing requirements to scale to practical quantum advantage

Doug Finke – Global Quantum Intelligence - Q2B22 SV Conference - https://youtu.be/erAq1VsWWaw

TAMO ISN'T AN OPTION

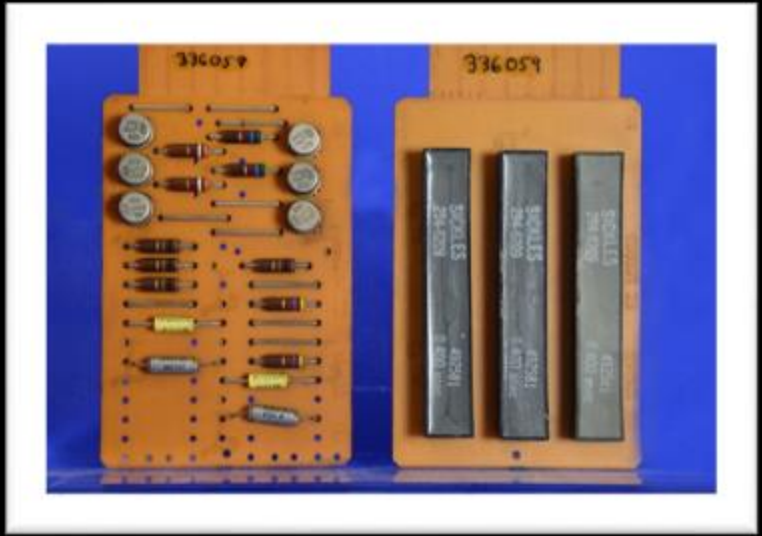


SOME LESSONS FROM HISTORY

The power of SWaP advantage in an established design

First Transistor
Bell Labs
1947

First 9V Transistor
Consumer Radio
Sony TR-63
1957



First Commercial Transistor
Computer
IBM 7070
1958

WE'RE CLOSER TO RAMAC THAN EDVAC

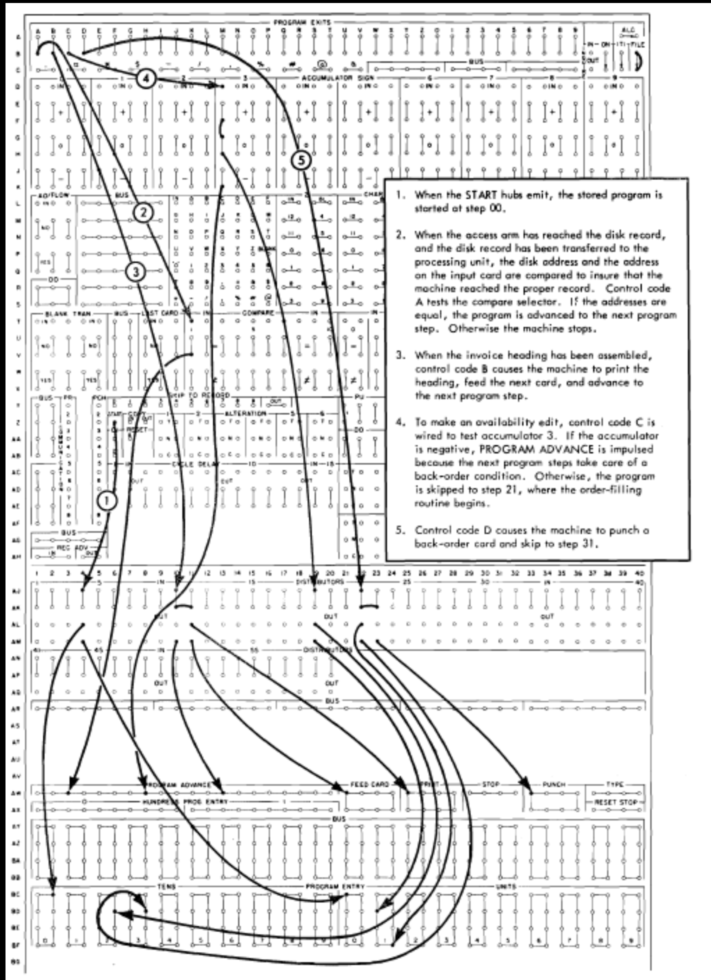


FIGURE 35. SAMPLE PROGRAM — CONTROL PANEL WIRING — PART 1

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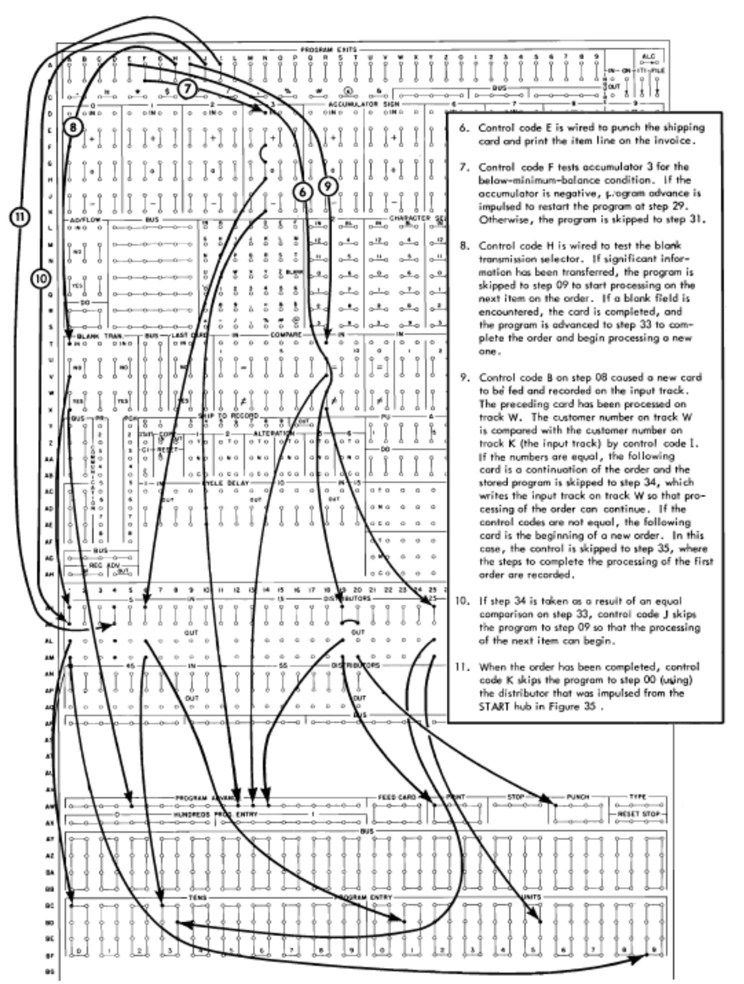

FIGURE 36. SAMPLE PROGRAM — CONTROL PANEL WIRING — PART 2

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LEARN FROM HISTORY

IRDS.IEEEE.ORG

The Different Ages of Scaling

(Different methods for different times)

1 Geometrical Scaling (1975-2002)

- Reduction of horizontal and vertical physical dimensions in conjunction with improved performance of planar transistors

2 Equivalent Scaling (2003~2024)

- Reduction of only horizontal dimensions in conjunction with introduction of new materials and new physical effects. New vertical structures replace the planar transistor

3 3D Power Scaling (2025~2040)

- Transition to complete vertical device structures. Heterogeneous integration in conjunction with reduced power consumption become the technology drivers

NTRS ITRS ITRS IRDS

FROM BOTTOM UP TO TOP DOWN: A CO-DESIGN ALTERNATIVE FOR QC

Current NISQ Hardware: **Build from Qubits to Architectures (bottom-up)**

Build **Qubits** addressed by Controllers
Build **Controllers** to make Gates
Build **Gates** to run Algorithms
Build **Compilers** for Algorithms
Add **QEC** to increase fidelity
Run **Fault-tolerant** Algorithms

Fault Tolerant Architectures: **Build from Architectures to Qubits (top-down)**

Build **Architectures** for Algorithms
Determine target fidelities with **Compilers**
Design **QEC** codes to achieve fidelities
Design **Gates** to perform QEC
Simulate **Qubits** to design Controllers
Build **Controllers** to realize Gates

CO-DESIGN AND ENGINEERING AT EACH LEVEL

1. Physical
2. Cyber-physical
3. Productivity

PITTSBURGH SUPERCOMPUTING CENTER

DEMOCRATIZING AI TO SOLVE THE WORLD'S BIGGEST PROBLEMS

Neocortex high-performance AI system under development

to democratize access for researchers to game-changing compute power for training

Pathfinding

a new approach to building an unconventional architecture consisting of a large system powered by extreme accelerators

SIGN IN / UP — The Register

HPC

HPE, Cerebras build AI supercomputer for scientific research

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Wafer madness hits the LRZ in HPE Superdome supercomputer wrapper

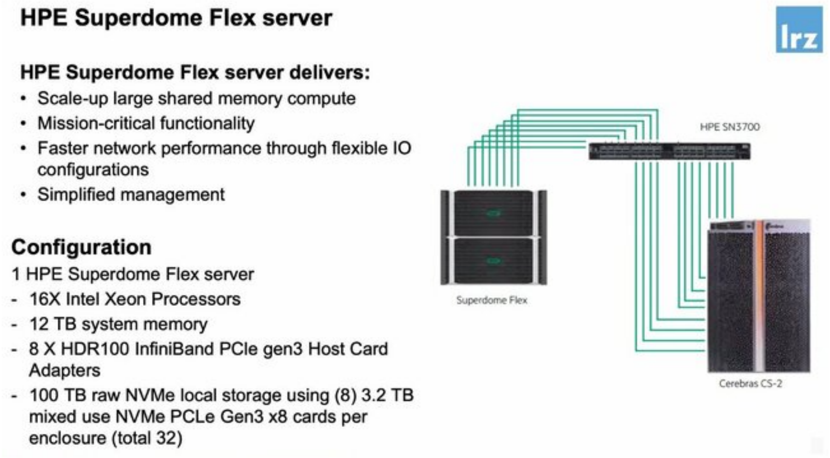
Dan Robinson — Wed 25 May 2022 // 12:45 UTC

HPE and Cerebras Systems have built a new AI supercomputer in Munich, Germany, pairing a HPE Superdome Flex with the AI accelerator technology from Cerebras for use by the scientific and engineering community.

The new system, created for the Leibniz Supercomputing Center (LRZ) in Munich, is being deployed to meet the current and expected future compute needs of researchers, including larger deep learning neural network models and the emergence of multi-modal problems that involve multiple data types such as images and speech, according to Laura Schulz, LRZ's head of Strategic Developments and Partnerships.

"We're seeing an increase in large data volumes coming at us that need more and more processing, and models that are taking months to train, we want to be able to speed that up," Schulz said.

"And then we're also seeing multi-modal problems, such as integration of natural language processing (NLP) and medical imaging or documents, so we have this complexity, we have this the need for faster, we have this need for bigger that's coming from our user side, from our facility side, and we need to make sure that we're constantly evaluating to have these different novel architectures, to have different usage models to be able to understand all that."



LESSONS FROM CRAY: PROVIDING THE USER WITH COMPILER CHOICE

- Compiler and library choice, performance and programmability
  - Appropriate math, scientific, and communication libraries with chosen compiler
  - Scientific libraries for accelerators
  - Tools to work with selected compiler or framework

HPE Cray Programming Environment	AMD Programming Environment	Intel Programming Environment	NVIDIA Programming Environment	GNU Programming Environment
Compiling Environment (CCE)	**AMD AOCC and ROCm compilers**	**Intel® C, C++, and Fortran compilers**	**NVIDIA compilers**	**GNU Compiler Collection**

Cray MPI and SHMEM

Performance Analysis Tools

Debugger Support Tools

Het Comp Extended Scientific and Math Libraries

Environment Setup and Compiling Support

Third Party Products and APUs, QPUs, QuICC

QUANTUM COMPUTING INTEGRATION AT HEWLETT PACKARD ENTERPRISE

Innovating for the future

Integrating classical and quantum systems

to harness diverse accelerators that maximize run-time, efficiency, sustainability and security

Unified workflow environment

Simplify the end user experience

Software framework to harness accelerators most suitable for each segment of a workflow

Large-scale quantum simulation

Toward industrial scale

HPC systems used to simulate and test quantum advancements

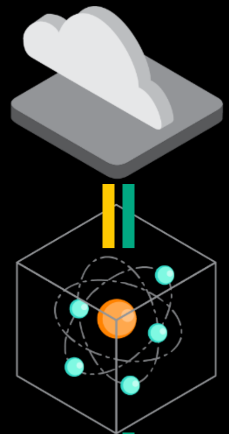
Quantum-inspired accelerators

Solve intractable problems

Non-conventional acceleration of algorithms explored by the quantum computing community

Hewlett Packard **Labs** + **HPE HPC & AI Business Group** + **Innovation Partners** (academic, industrial, government)

Integration of quantum accelerators



Accelerators

FPGAs

GPUs

CPUs

Heterogenous computing development

Quantum computing development

FUTURE ACCELERATORS R&D

Developing the next generation of non-Von Neumann accelerators

Application-specific accelerators

Resistive-RAM or Photonics accelerators for heterogenous computing
Optimize performance, sustainability, explainability, and time-to-answer

Algorithms and applications

SW/HW co-design to leverage emerging physics-based approaches for different problem classes

Automata Processing
Pattern matching engine

Deep NN
Accelerate machine learning

Quantum-inspired
Constrained optimization

Integration

Develop device-to-API strategy across multiple programs and use cases

Packaging
3D chip integration

New architectures
PUMA, TONN

SW stack
API for optimization

Hewlett Packard Labs + **US Government partners** (DARPA, ARO, etc.) + **Innovation Partners** (UCSB, FZJ, etc.)

Heterogeneous integration

FPGAs

GPUs

CPUs

Accelerators development

Quantum