The Machine:
The future of technology

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Agenda

1: Vision

2: The core technologies

- The memristor
- The photonic

3: The MACHINE

The most exciting shifts of our time are underway

Cloud

Security

Mobility

Big Data

Time to revenue is critical

Decisions must be rapid

Making IT critical to business success

Business needs happen anywhere

Change is constant

30 billion devices

40 trillion GB data

By 2020

10 million mobile apps

...for **8 billion** people

Today's computing infrastructure unable to keep up

You won't be able to get more capacity for less

Big Data will be too big to extract meaning from

You won't be able to move your data from where it's created – useful data may get ignored or discarded

By the time you've analyzed your data – it will be out of date

Your infrastructure will require more resources than you can get

Securing your enterprise will take more computing resources than you have

Internet of Things

Pervasive Connectivity	Smart Device Expansion	Explosion of Information

By 2020

IoT "Things" **200 Billion** (1)

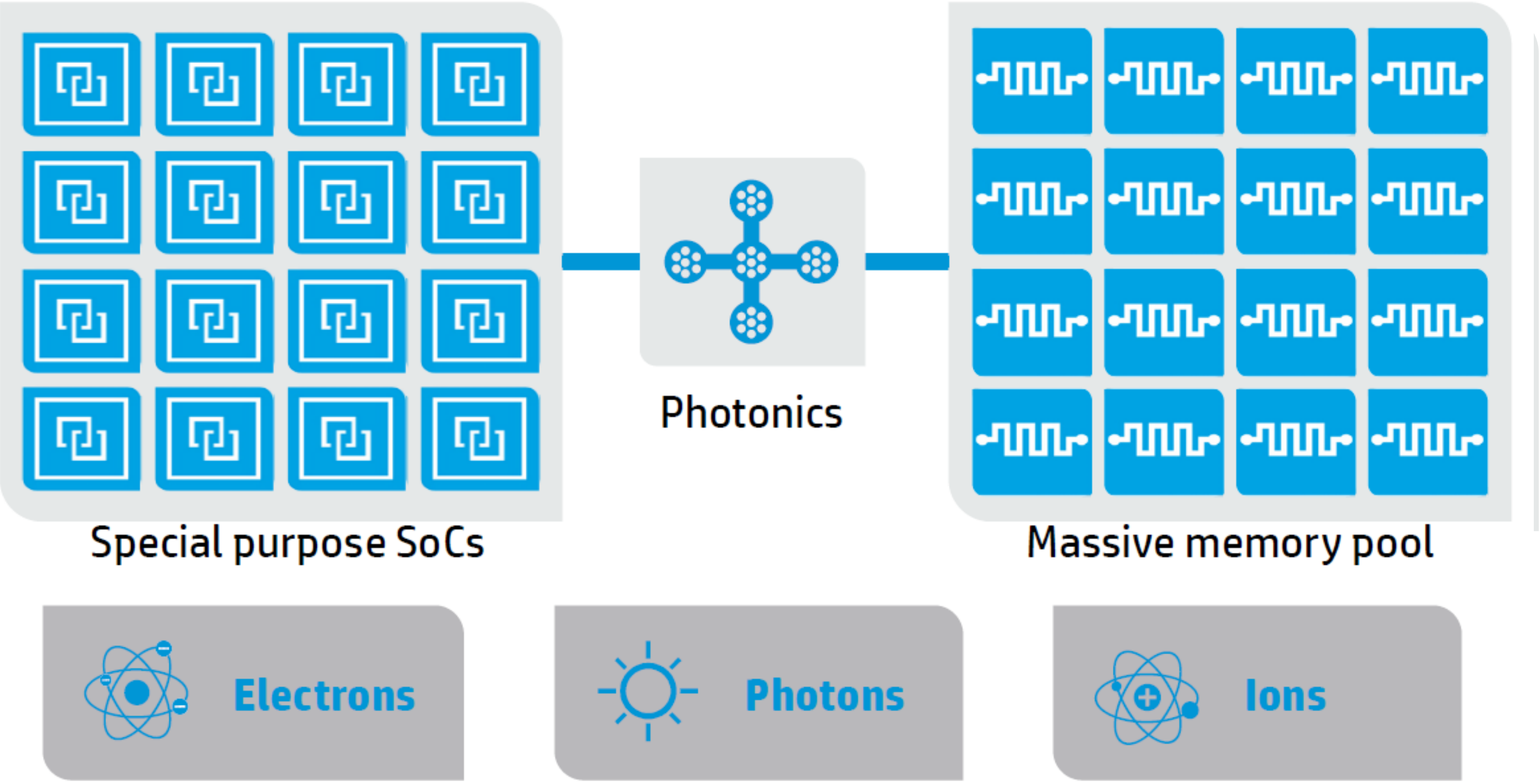
Connected Devices **30 Billion** (2)

Smart Meters **1 Billion** (3)

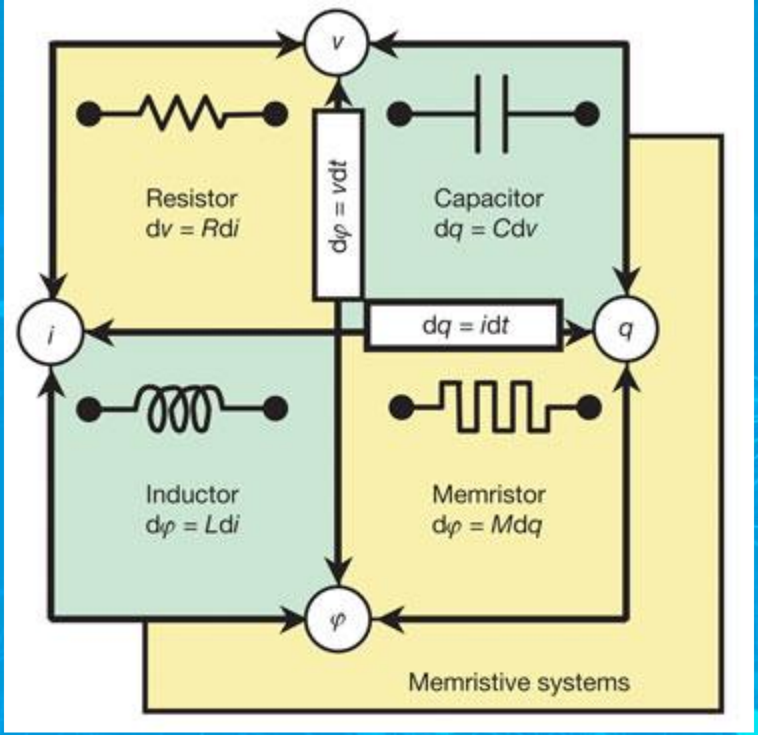
… for 8 Billion (4)

(1) IDC "Worldwide Internet of Things (IoT) 2013-2020 forecast" October 2013. (2) IDC "The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things" April 2014
(3) Global Smart Meter Forecasts, 2012-2020. Smart Grid Insights (Zypryme), November 2013 (4) http://en.wikipedia.org

3 disruptive technologies to the rescue



The memristor



Disruption #1: Non-volatile memories

Breakthrough in storage and memory technology

Scientists Create First Memristor: Missing Fourth Electronic Circuit Element

By Bryan Gardiner | April 30, 2008 | 10:03 am | Categories: Uncategorized

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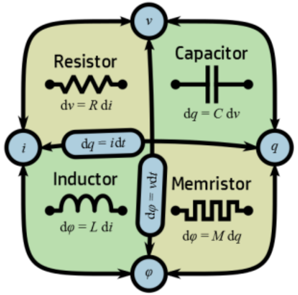
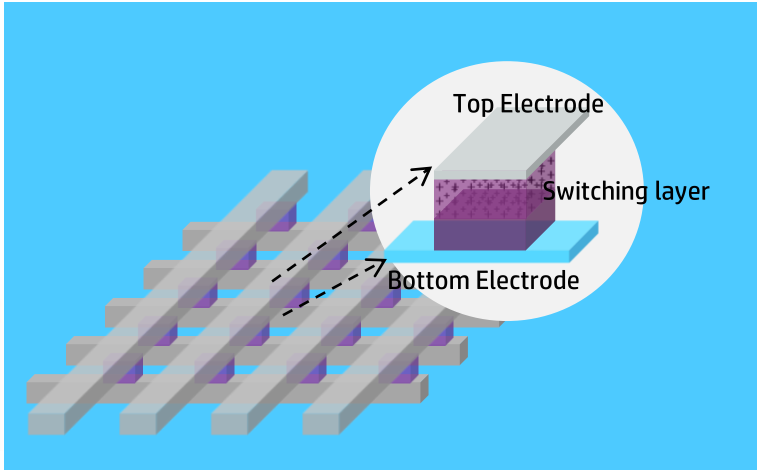
Researchers at HP Labs have built the first working prototypes of an important new electronic component that may lead to instant-on PCs as well as analog computers that process information the way the human brain does.





Technology	Density (µm²/bit)	Bandwidth (GB/s)	Latency Read (ns)	Latency Write (ns)	Energy Read (pJ/b)	Energy Write (pJ/b)
Hard Disk	N/A	0.5	3,000,000	3,000,000	2500	2500
Flash SSD [3] [6]	0.0021	1.0	25,000	200,000	250	250
DRAM [6] [30]	0.0038	51.2	55	55	24	24
PCRAM (22nm) [30]	0.0058	variable	48	150	2	19.2
Memristor (22nm) [8]	0.0048	variable	100	100	1-3	1-3

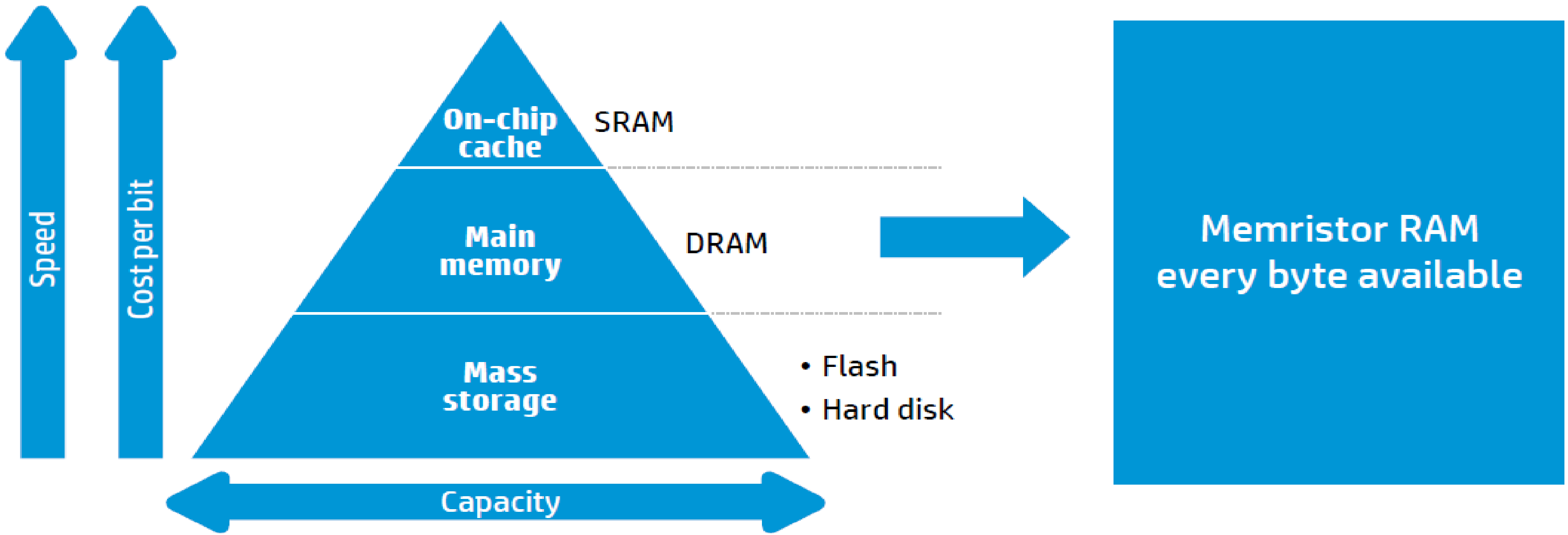
Store large amounts of data permanently like hard disks, but 100,000 times faster, and at much lower energy

UNIVERSAL MEMORY

Massive memory pool

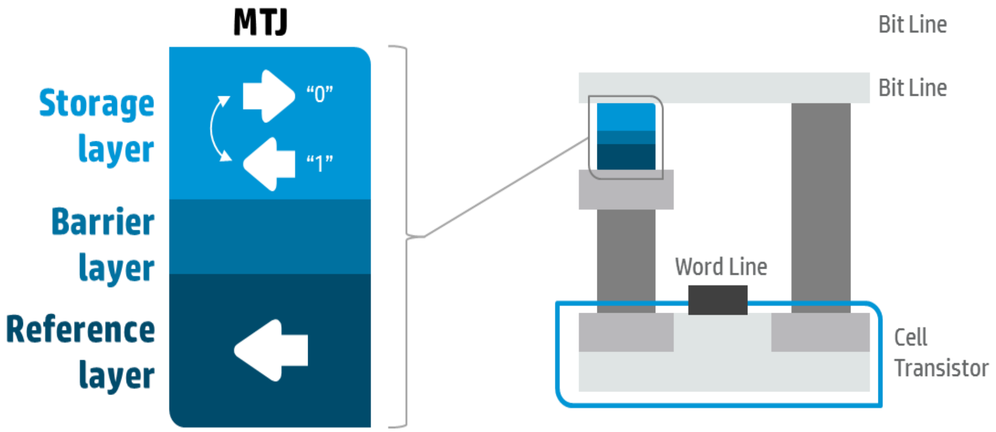
A drastic reduction of the memory stack complexity and cost

But requires a complete software stack redesign to leverage the full potentiality of the new architecture



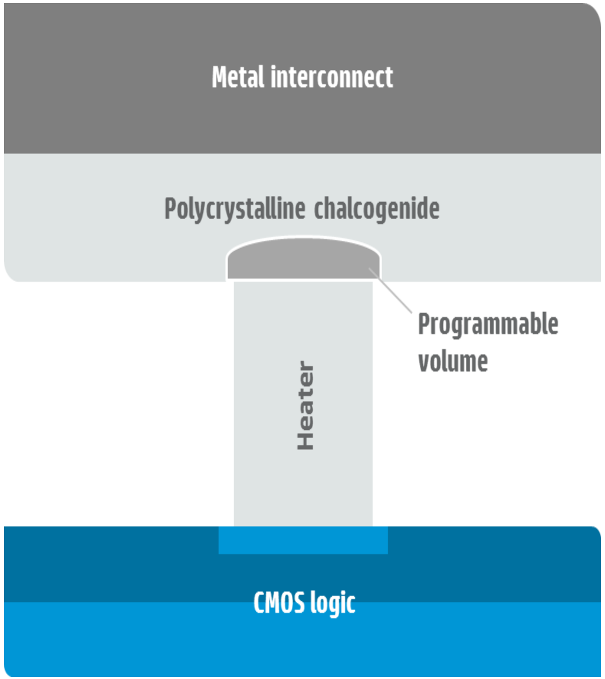
Memristors change how and where data are stored

Other NVM Technologies



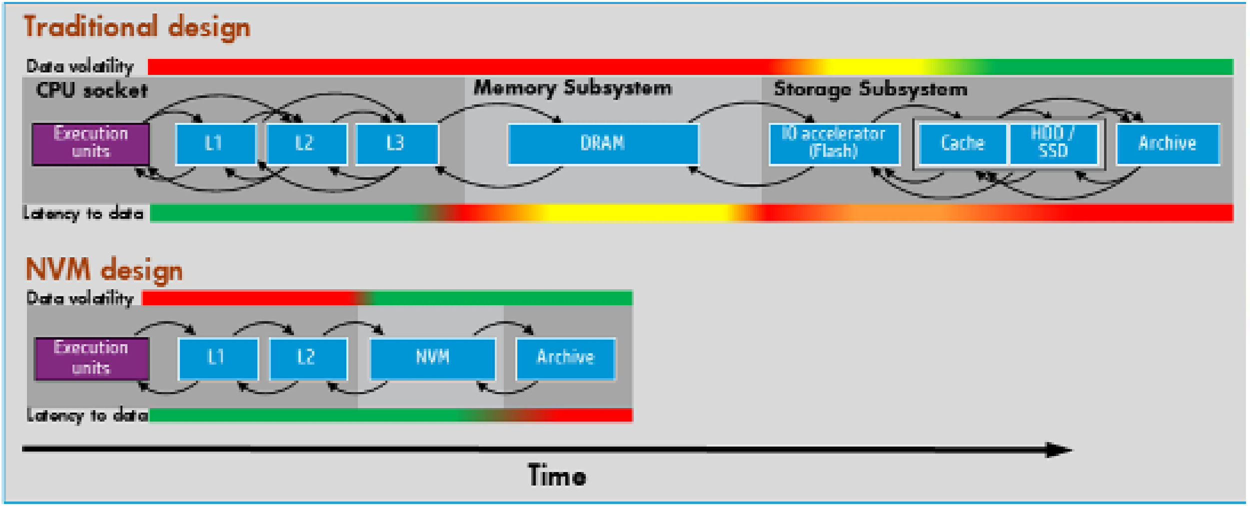
Spin-Transfer Torque (STT-RAM)

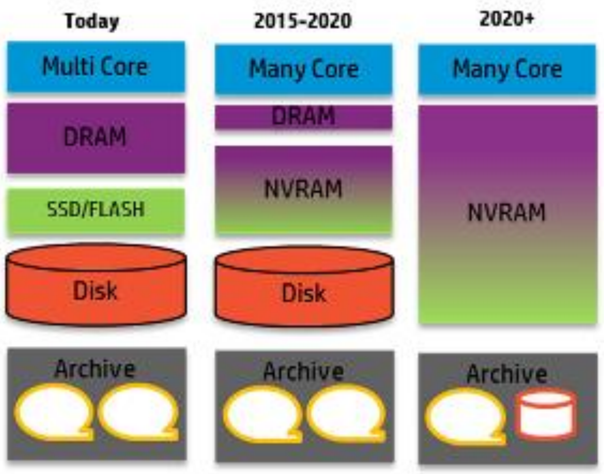
Phase-Change (PCM)



Memory Hierarchy As NVM Replaces DRAM

Step wise memory evolution to NVM

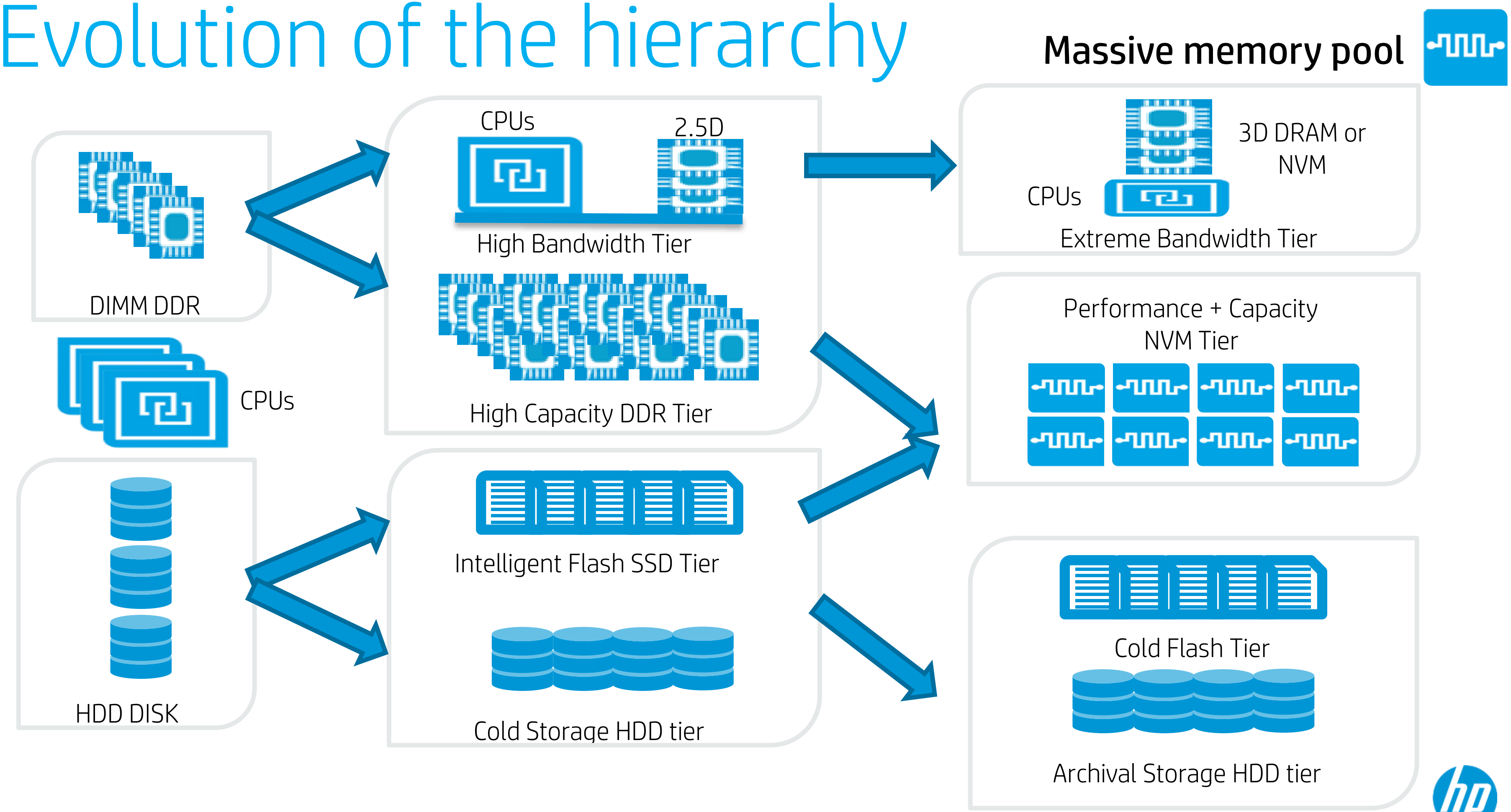




- Traditional API's designed to hide long device latencies and complex memory hierarchies will become obsolete. NVM Data Analytics can be done in-memory

- Applications such as relational databases that are structured to manage the long latencies to disk and the volatility of DRAM will be replaced by new technologies such as in-memory databases.

Evolution of the hierarchy



Benefits of universal memory

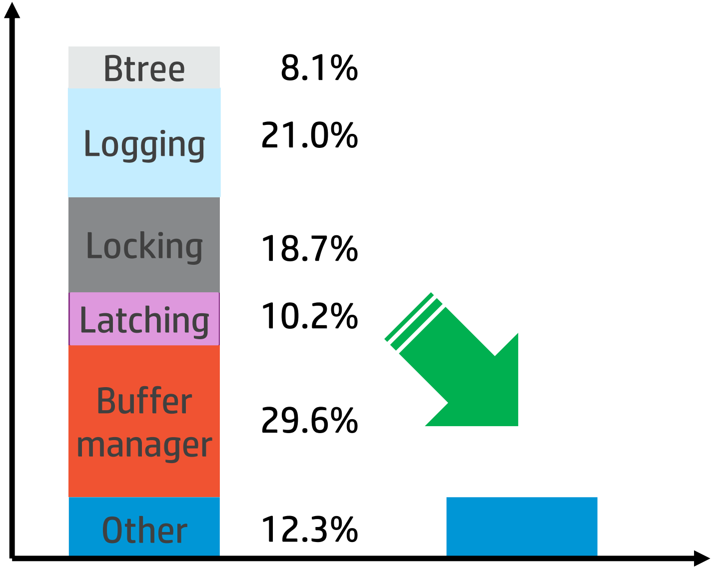
Massive memory pool

Example: a database transaction

Traditional databases struggle with big & fast data

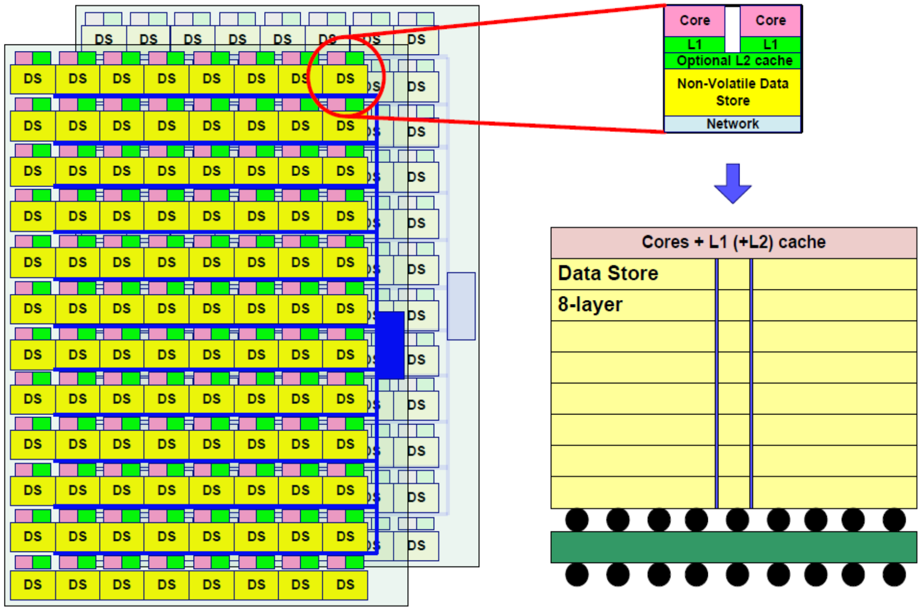
90% of a database transaction is overhead

Memory-semantics nonvolatile memory: up to 10x improvement



Source: S. Harizopoulos, D. Abadi, S. Madden, and M. Stonebraker, "OLTP Through the Looking Glass, and What We Found There," *Proc. SIGMOD*, 2008.

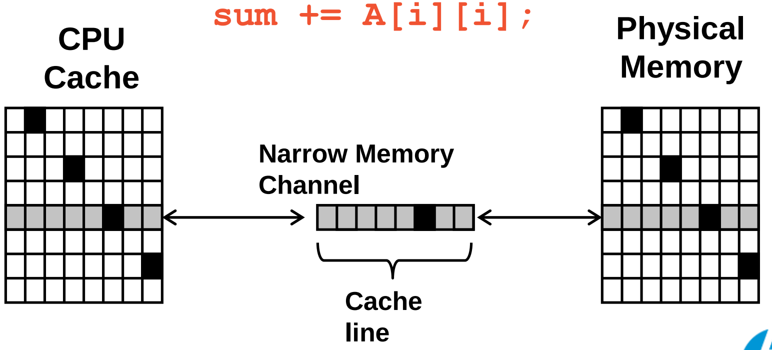
Nanostores: in-memory compute



Flat converged storage hierarchy with compute colocation for 10x-100x improvement in performance per Watt

Example: Matrix Computation

```
for (i = 0; i < n; i++)
    sum += A[i][i];
```

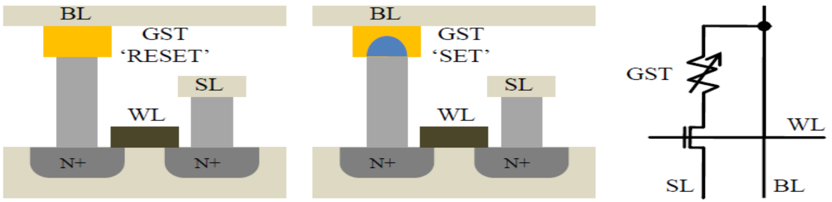


Technologies for Check-point Restart

www.nd.edu/~rich/SC09/tut157/SC2009_Jouppi_Xie_Tutorial_Final.pdf

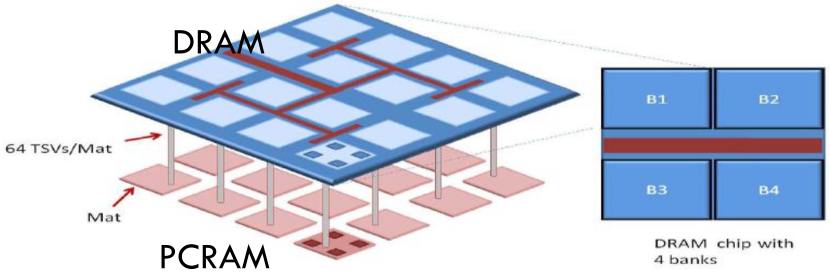
Architecture

PCRAM



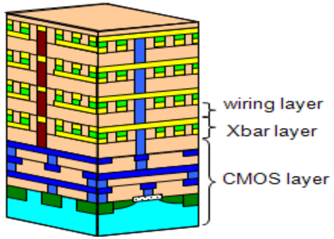
The schematic view of a PCRAM cell with NMOS access transistor (BL=Bitline, WL=Wordline, SL=Sourceline)

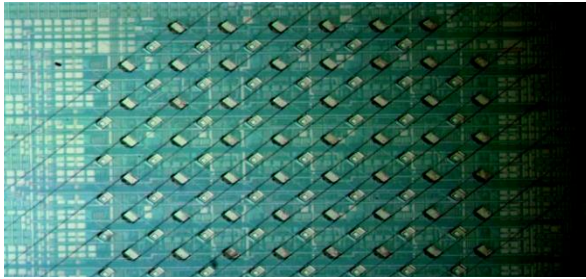
	HDD	NAND Flash	PCRAM
Taille cellule	-	4-6F^2	4-6F^2
Cycle lecture	~4ms	5us-50us	10ns-100ns
Cycle écriture	~4ms	2ms-3ms	100-1000ns
Watt à arrêt	~1W	~0W	~0W
Endurance cycles	10^15	10^5	10^8



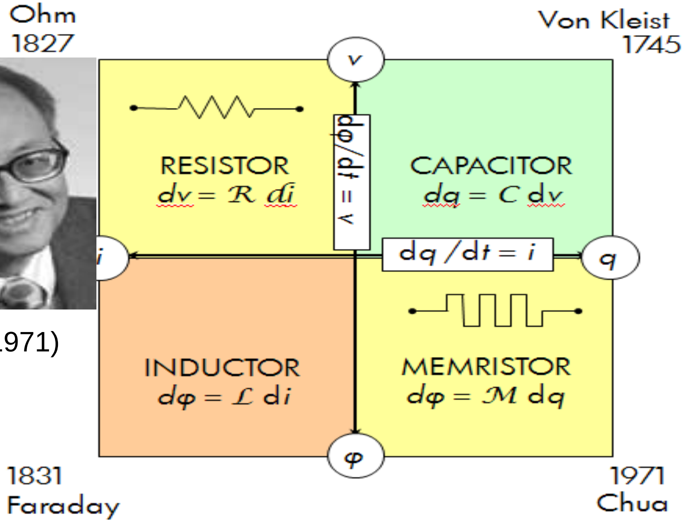
Memristor

CMOS chip avec des composants memrésistifs

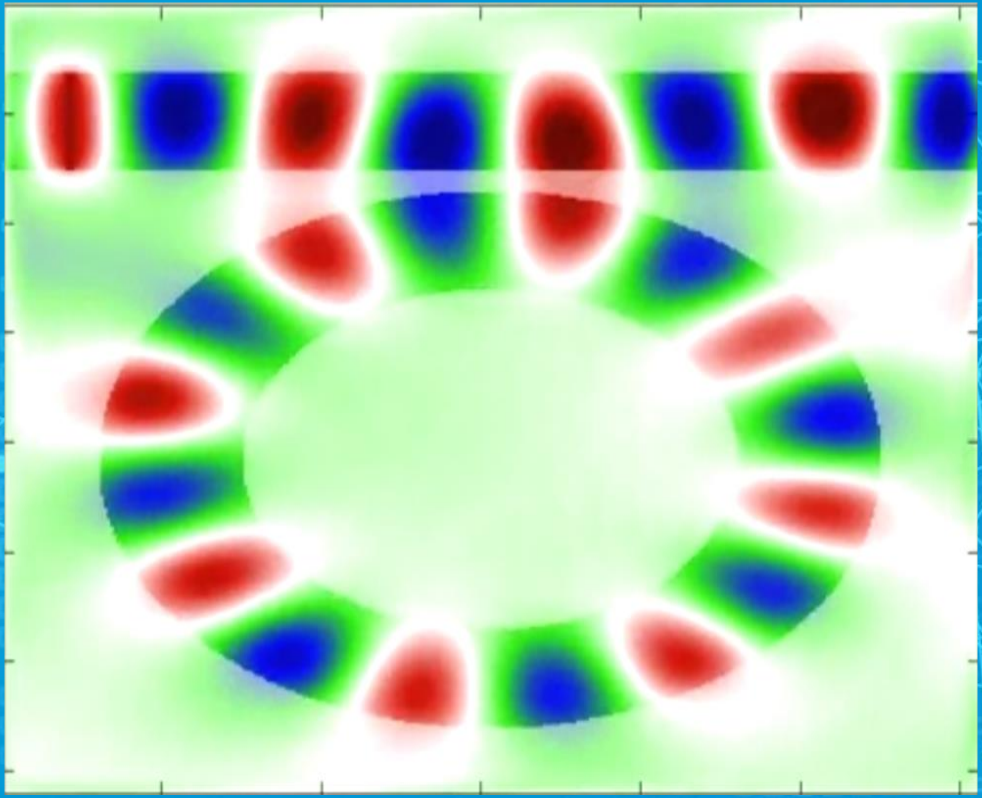




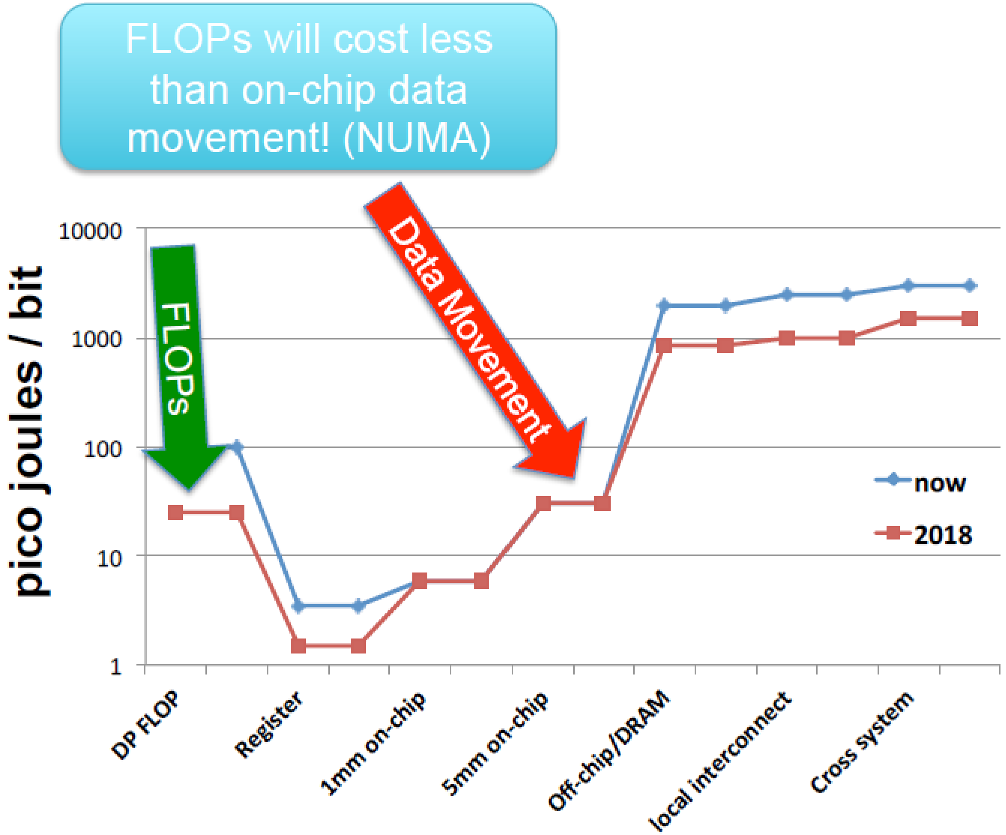
L. O. Chua, (1971)



Photonic



Why photonics?



10^18 ops*
1Byte/ops=
10^19bits*
1pj/bit=
10MWatts!!

Katharine Schmidtke, Finisar

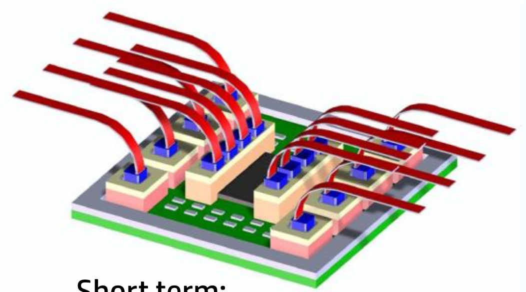
Photonics technologies

Communication fire hose for memristor stores

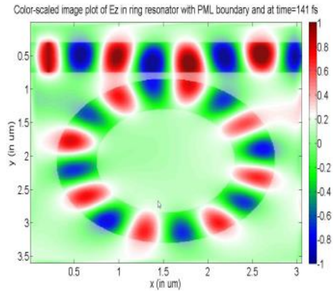
Why Photonics?

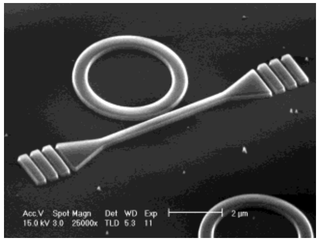
- Huge increases in the *volume* of data
- Enables efficient access to that data
- Shrink *time* and *space* to gain immediate access without regard for location

Transmit data using light for 30-fold more bandwidth at one-tenth the energy



Short term:
short range, low cost VCSEL



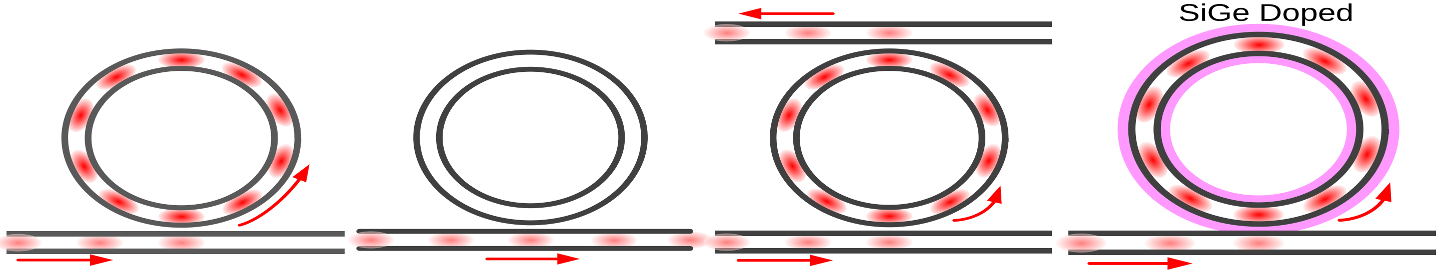


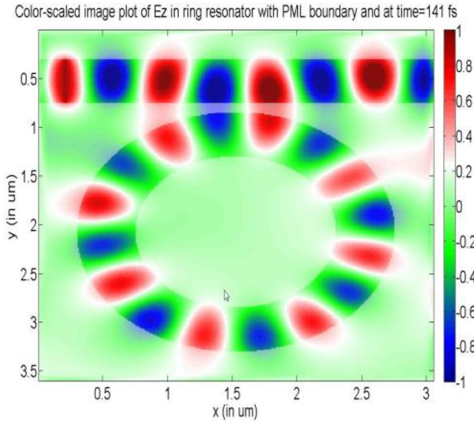
Long term: micro-ring resonator

(low cost, long distance, integrated on silicon)

Ring Resonators

One basic structure, 3 applications





A modulator – move in and out of resonance to modulate light on adjacent waveguide

A switch – transfers light between waveguides only when the resonator is tuned

A wavelength specific detector - add a doped junction to perform the receive function

Microrings

Full link configuration

Advantages

Modulators wavelength specific, no additional mux

Same ring structure used for drop filters

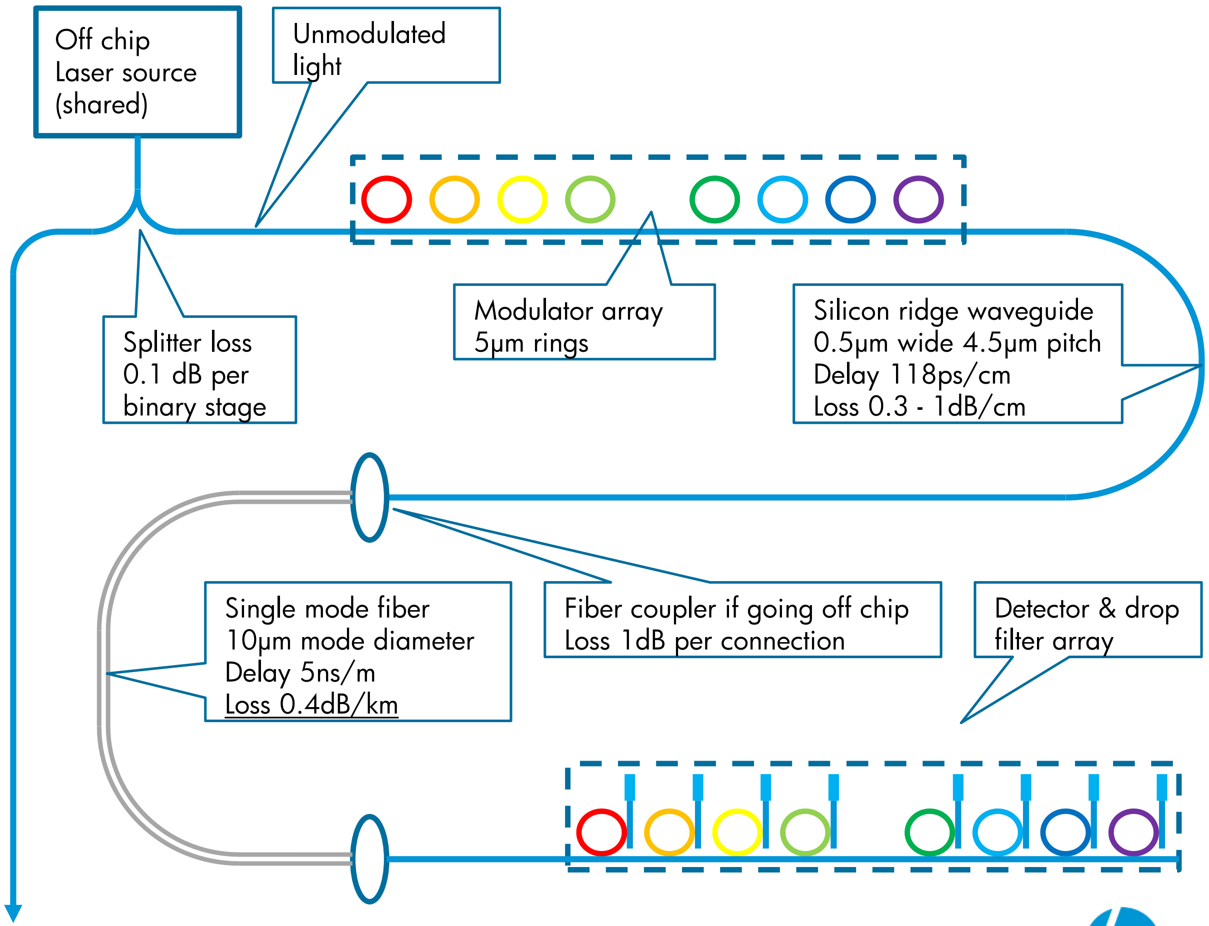
Loss budget dominated by cost

Up to 64 wavelengths

Outstanding issues

Ring tuning

Thermal stability



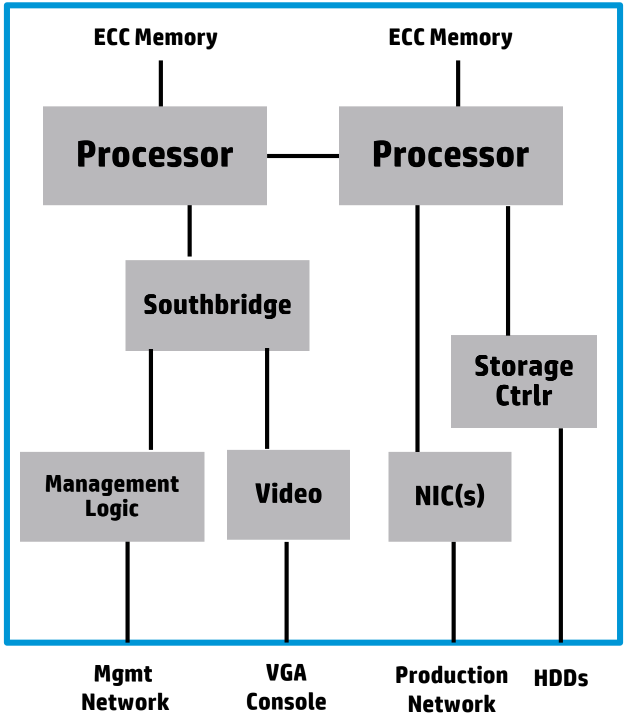
Photonics destroys distance

System On Chip

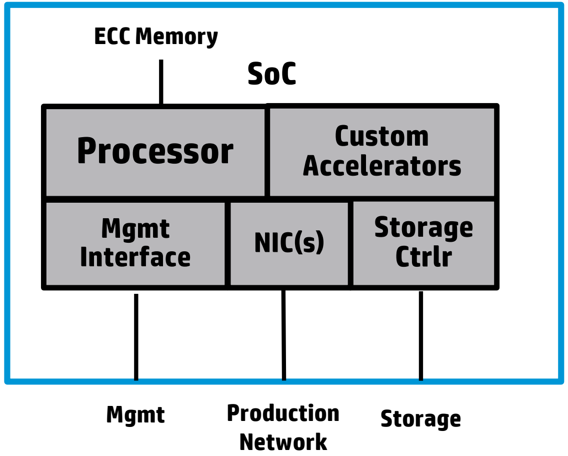
Application-focused silicon

Special purpose SoCs

Traditional Server Motherboard



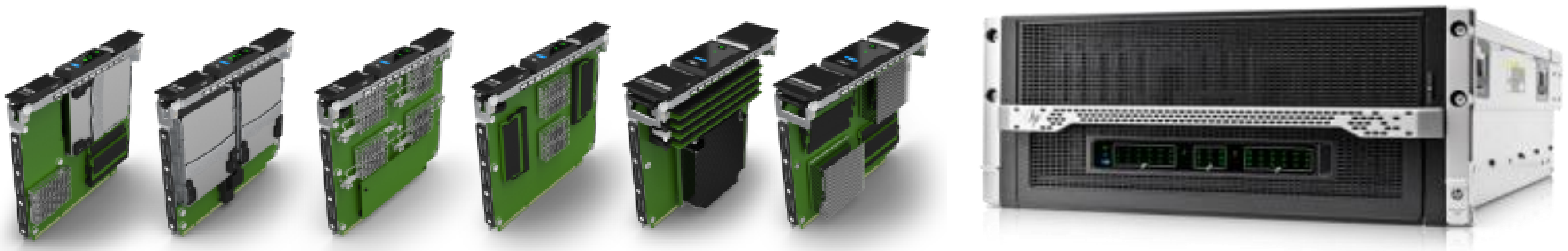
System on a Chip (SoC)-based Server



- Less general-purpose, more workload focused
- Dramatic reduction in power, cost, and space
- SoC vendors bring their own differentiated features and opportunities to disrupt markets

HP Moonshot

Special purpose SoCs



HP Moonshot System

Optimize your application performance

A system that truly fits the workload it is running

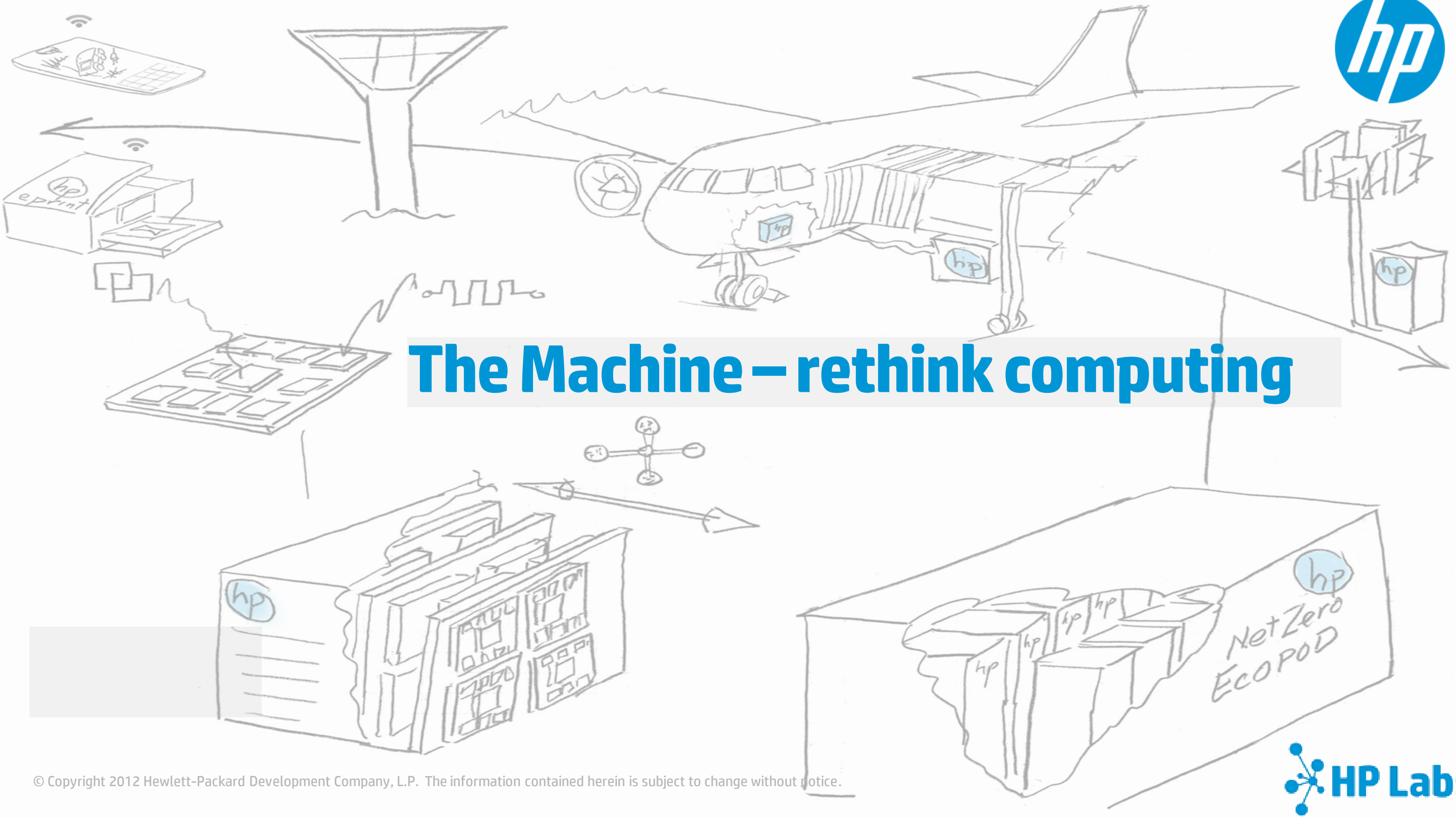
Realize breakthrough economics

Redefining the economics of your data center

Accelerate business innovation

Enabling you to be more competitive

The Machine – rethink computing



6 words to summarize the vision

Electrons → **Compute**

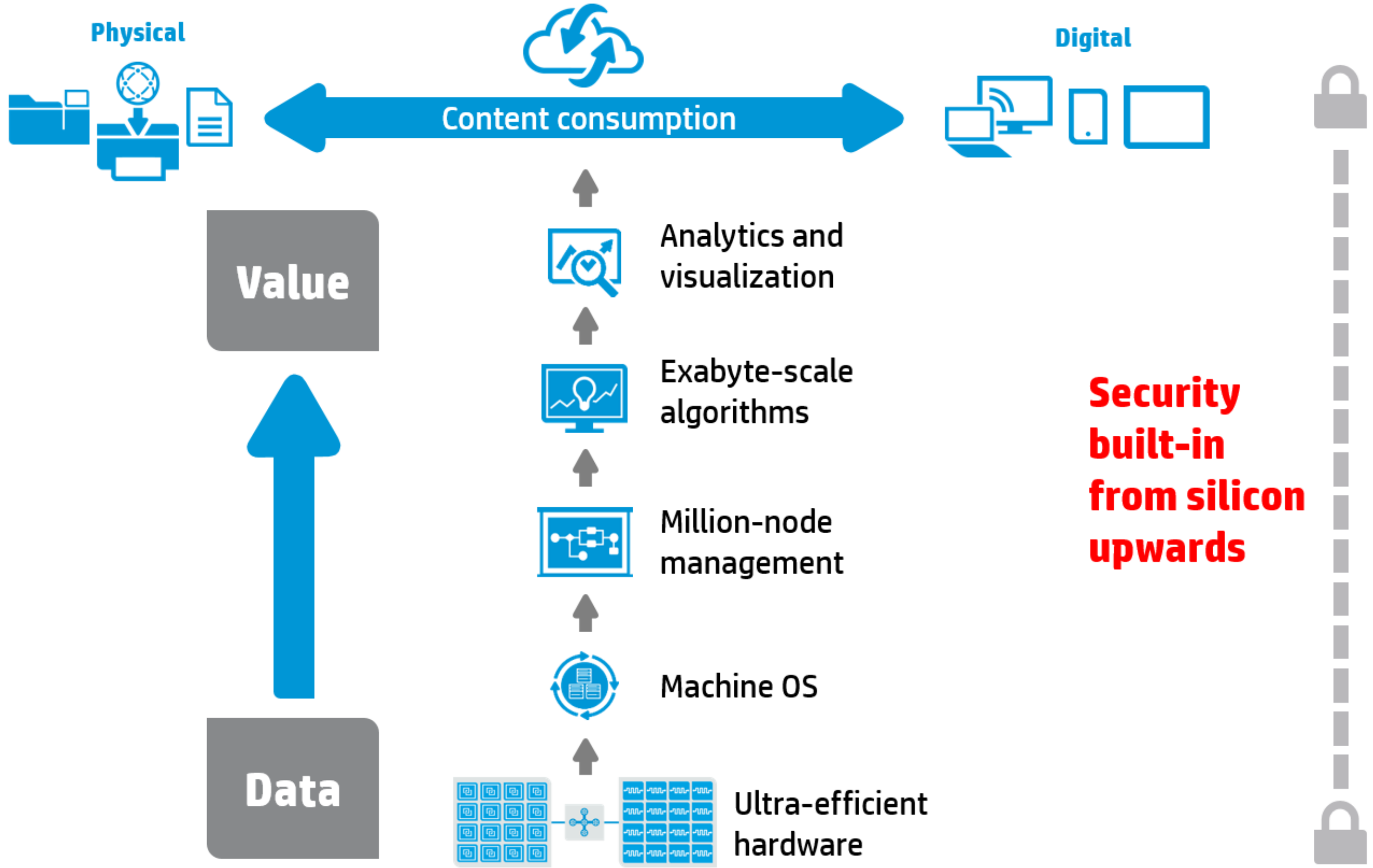
Photons → **Communicate**

Ions → **Store**

Not substitutional technologies

Holistic re-architecting to get all benefits

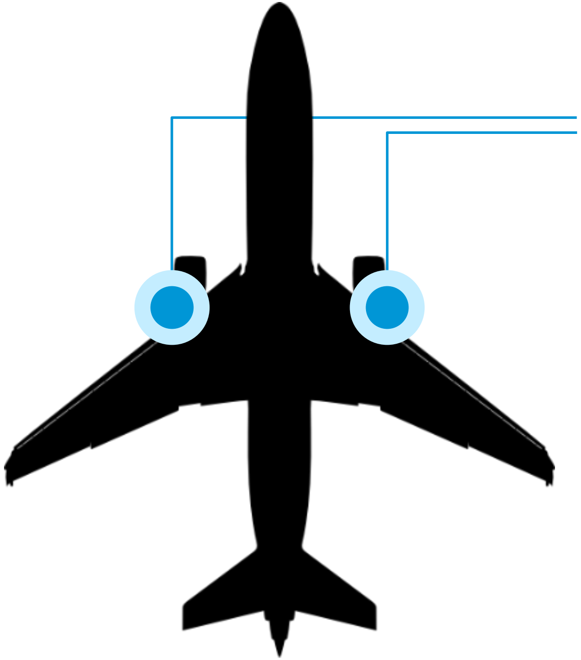
The Machine: towards a new computing paradigm



The Machine use case

Use case: aircraft sensors

Internet-of-Things big data affects all industries

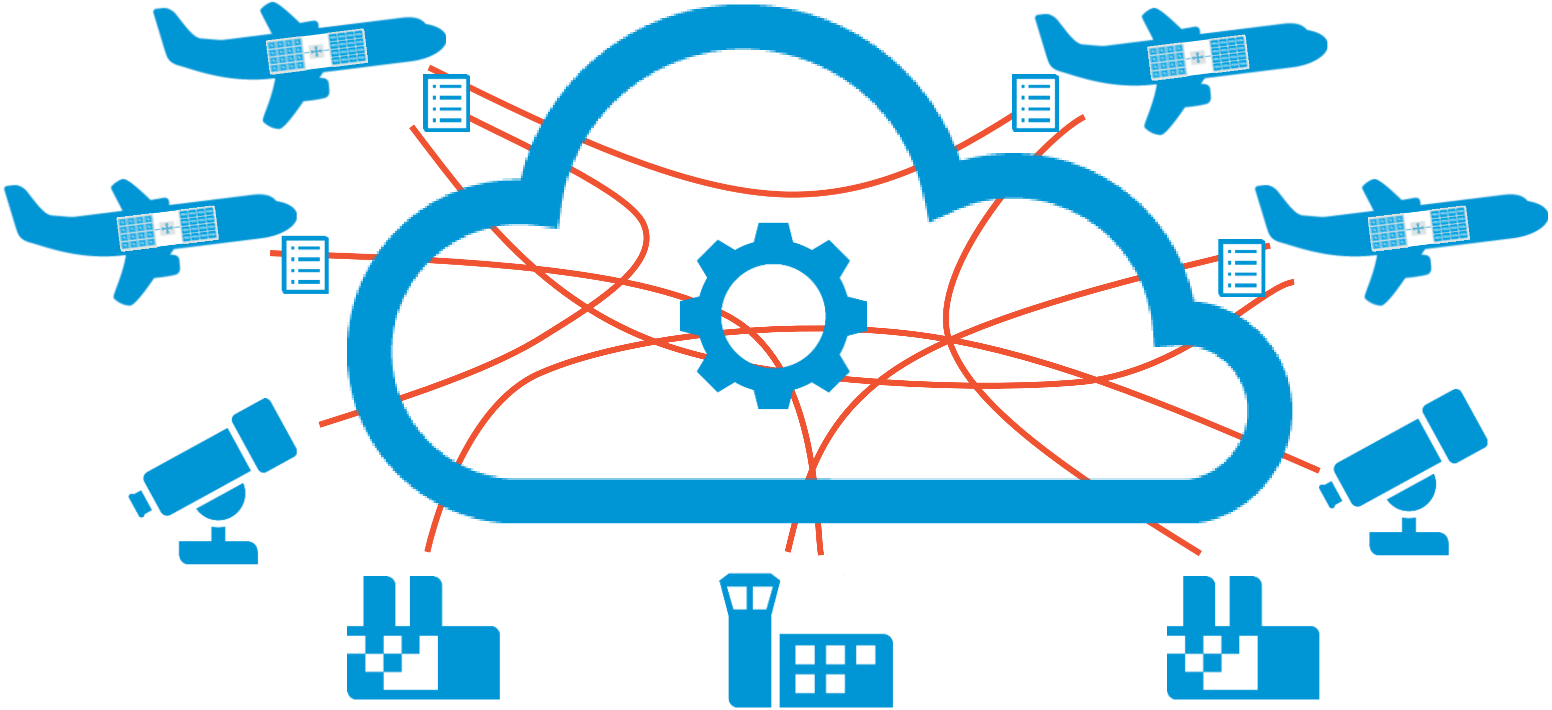


20 TB	×	2	×	3	×	25,000	×	365
20 terabytes of information per engine per hour		twin-engine aircraft		three-hour average flight duration		commercial flights per day (USA)		days in a year

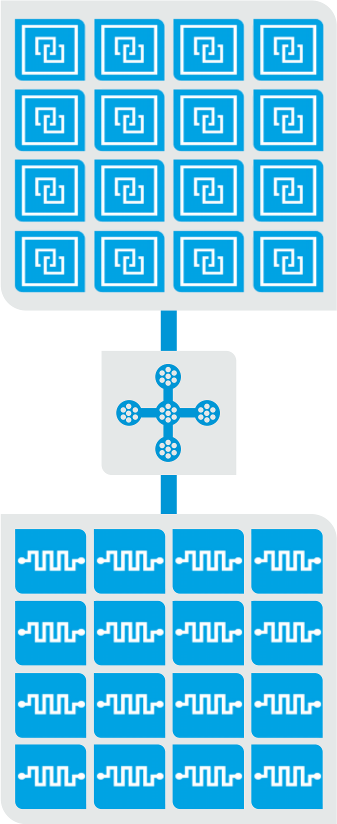
= 1,095,000,000 TB

= 1 ZB

Use case: a mesh of connected aircrafts …



Aspirational History



- SoC Partners selected for co-development
- Machine OS development begins

- Memristors begin sampling
- Physical infrastructure of Core prototypes established
- Open Source Machine OS SDK and emulators released
- ISV Partner collaborations begin

- Edge devices ship in volume
- Core Machines running real-world workloads at scale
- Machine OS released

- Core devices at volume
- Machine available as product, service, and as a business process transformation

2014 2015 2016 2017 2018 2019 2020

- Memristor DIMMs launched
- Integrated core technologies demonstrated

- Edge devices begin sampling
- Machine OS enters public beta

Distributed mesh compute goes mainstream

The MACHINE .....

[The Machine Webpage]

[The Machine 3 min video]

[Memristor Lab Tour]

[Photonics Lab Tour]

[HP Analytics Lab]

[HP Security and Cloud Lab]

This changes everything

Any questions?