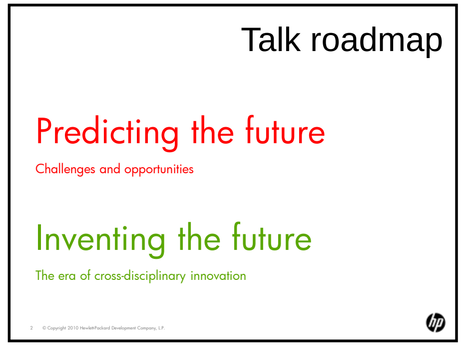
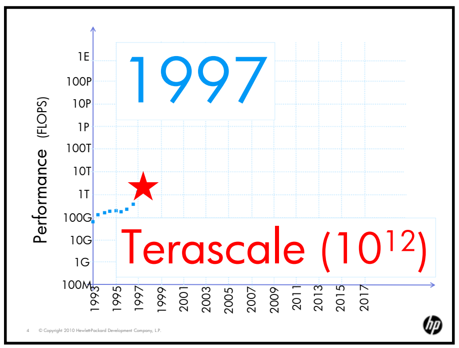
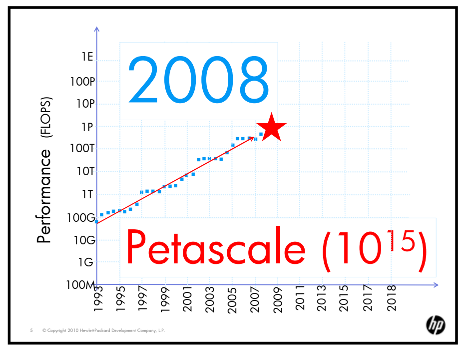
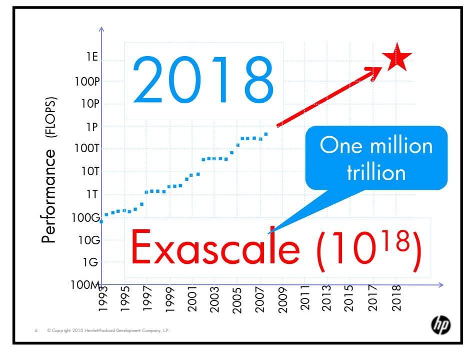

Green clouds:
the next frontier
Parthasarathy (Partha) Ranganathan
Distinguished Technologist, HP Labs

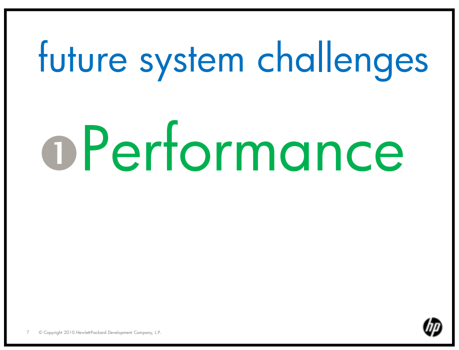

Talk roadmap
Predicting the future
Challenges and opportunities
Inventing the future
The era of cross-disciplinary innovation

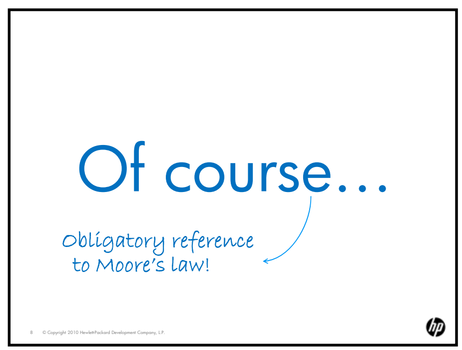

2018?

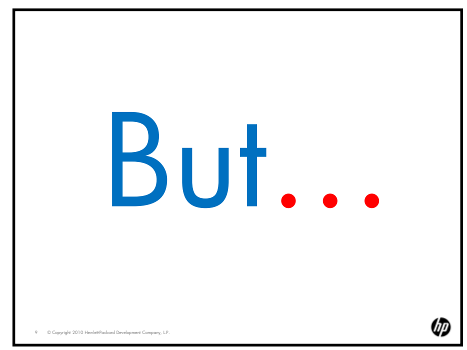

1997
Performance (FLOPS)
1E
100P
10P
1P
100T
10T
1T
100G
10G
1G
100M
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
Terascale (10^12)

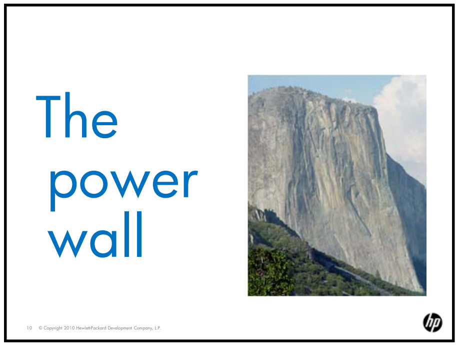

2008
Performance (FLOPS)
1E
100P
10P
1P
100T
10T
1T
100G
10G
1G
100M
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2018
Petascale (10^15)

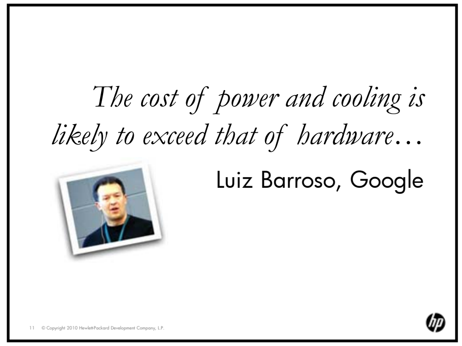

2018
Performance (FLOPS)
1E
100P
10P
1P
100T
10T
1T
100G
10G
1G
100M
One million trillion
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2018
Exascale (10^18)

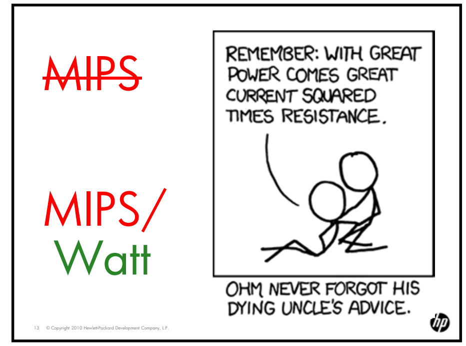

future system challenges
1 Performance

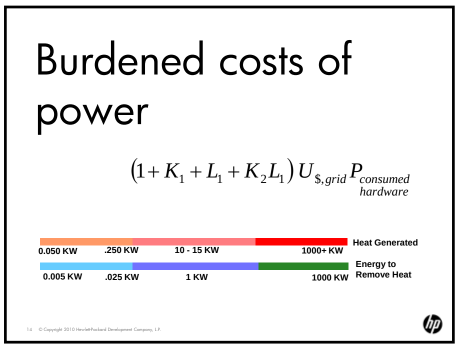

Of course…
obligatory reference
to Moore's law!

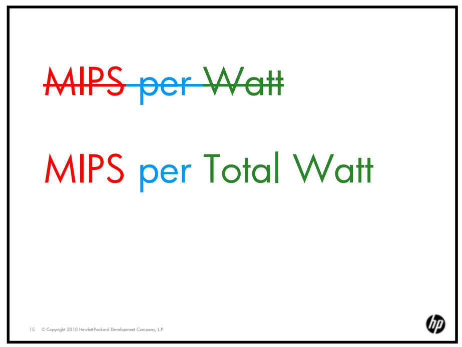

But…

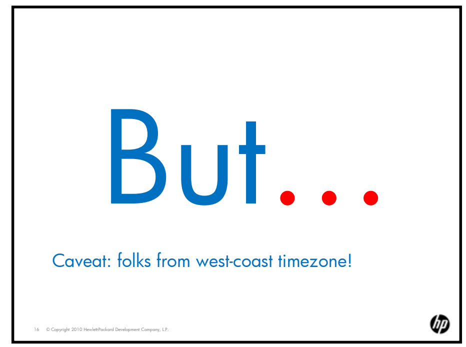

The power wall


The cost of power and cooling is likely to exceed that of hardware…
Luiz Barroso, Google


MIPS
MIPS/Watt
REMEMBER: WITH GREAT POWER COMES GREAT CURRENT SQUARED TIMES RESISTANCE.
OHM NEVER FORGOT HIS DYING UNCLE'S ADVICE.


Burdened costs of power
$(1+K_1+L_1+K_2L_1)\,U_{\$,grid}\,P_{\substack{consumed\\hardware}}$
0.050 KW
.250 KW
10 - 15 KW
1000+ KW
Heat Generated
0.005 KW
.025 KW
1 KW
1000 KW
Energy to Remove Heat

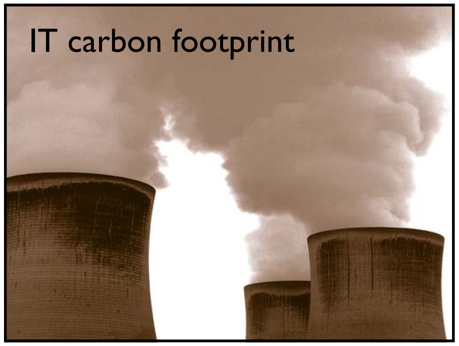

MIPS per Watt
MIPS per Total Watt

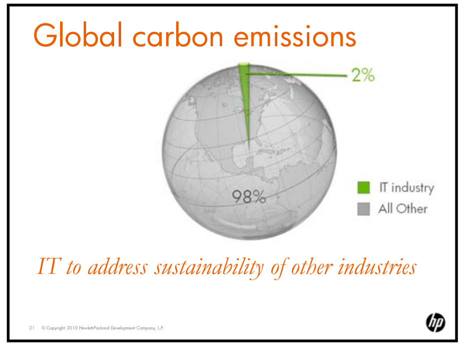

But…
Caveat: folks from west-coast timezone!

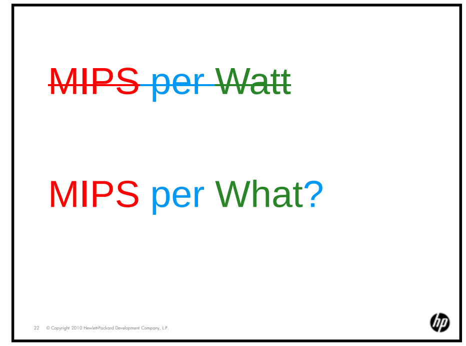

Ecospot contest "grand prize" winner
Sustainability video: http://current.com/groups/ecospot/new/


Beyond energy efficiency to…
Sustainability

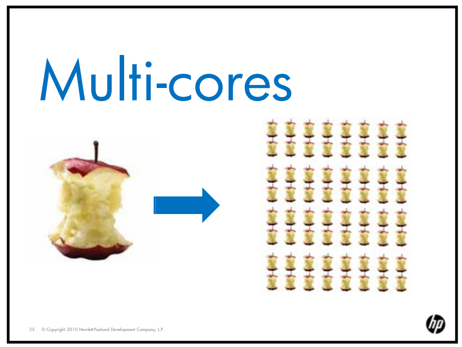

191 TeraWatt Hours
Estimated annual electricity use by all servers in 2012
Equivalent to powering all of Mexico in 2007


IT carbon footprint

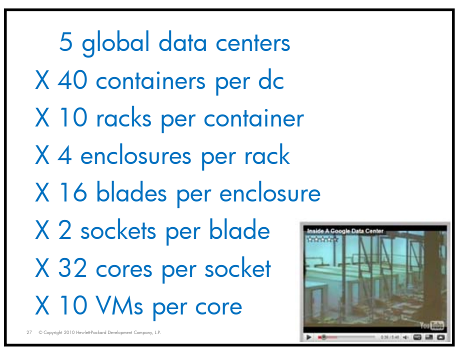

Global carbon emissions
2%
98%
IT industry
All Other
IT to address sustainability of other industries

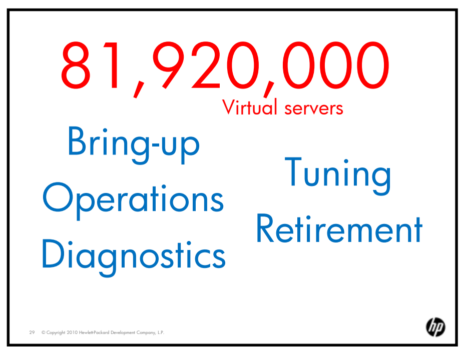

~~MIPS per Watt~~
MIPS per What?

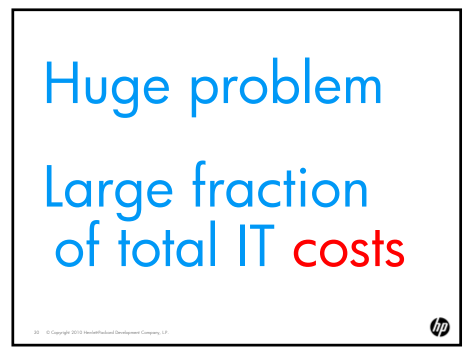

Another key challenge…
scale


Multi-cores

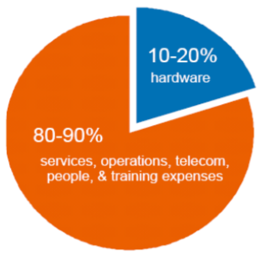

Cloud-scale


5 global data centers
X 40 containers per dc
X 10 racks per container
X 4 enclosures per rack
X 16 blades per enclosure
X 2 sockets per blade
X 32 cores per socket
X 10 VMs per core
Inside A Google Data Center


81,920,000
Virtual servers
Bring-up
Operations
Diagnostics
Tuning
Retirement


Huge problem
Large fraction of total IT costs

IT costs



Also...

Reliability challenges

Dead horses & killer sharks!

One-tenth total costs!

High-volume low-cost

We have a competitive advantage because we have the cheapest and most scalable architecture.

Eric Schmidt, Google

1. 1000X Performance @ exascale
2. Low power and sustainability
3. Scalable coordinated management
4. Reliability from increasingly unreliable components
5. Low costs and innovation over volume components

Interesting opportunities

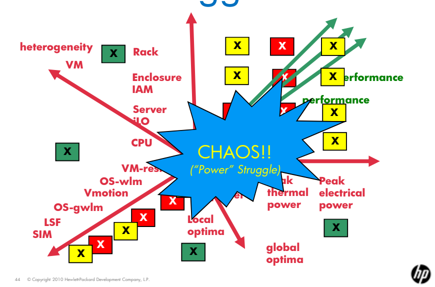
How can we address all these challenges?

Will need cross-disciplinary co-design

3 examples

"No power struggles"
Dematerialized datacenters
Nanostores

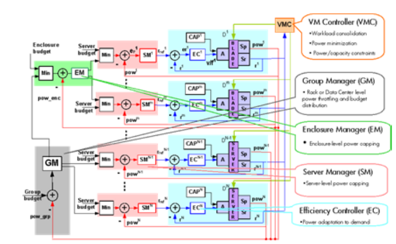
Power Struggles!



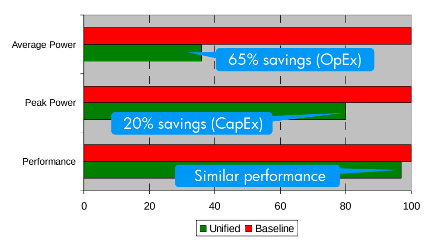
Cross-disciplinary collaboration across…

systems, architecture, power & cooling, control theory

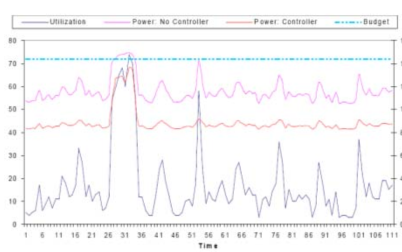
Coordinated architecture



It works well!



It works well!



But…
more opportunities…

Interfaces?

Extensibility?

Federation?

Scale?

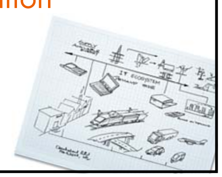
Cross-disciplinary collaboration across…

computer engg, environmental engg, mechanical engg…

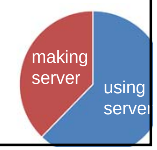
Supply vs demand side energy consumption

Energy in extraction, transport, manufacturing, reclamation…

Energy in operation

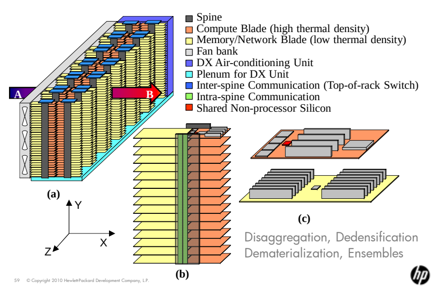


Exergy to capture destruction of resources



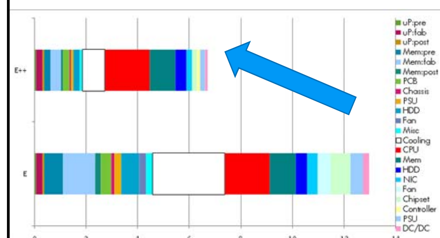
Revisit systems management/design for total lifecycle exergy…

Dematerialized datacenters



Disaggregation, Dedensification
Dematerialization, Ensembles

2X better exergy!



2X better exergy

...over aggressive energy-optimized baseline

New tradeoffs for optimization...

New opportunities

Cross-disciplinary collaboration across...

device physics, computer engineering, systems software...

Cloud 2018 will be about data

5 exabytes in 2002 to 280 exabytes in 2009 of online data
"Physics of data, Myers, Google"

56X

in seven years

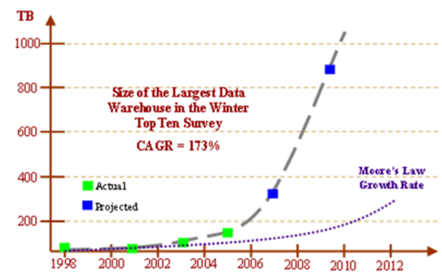
5 exabytes in 2002 to 280 exabytes in 2009 of online data
"Physics of data, Myers, Google"

56X

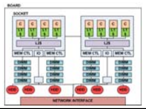
in seven years

16X
Moore's law

Data on faster exponential vs compute



Hierarchy helps data-centric performance but…

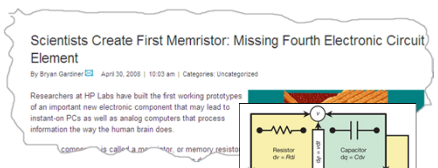


Exergy overhead

Materials

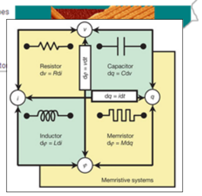
Power

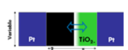
Technology trends enable new designs…


Scientists Create First Memristor: Missing Fourth Electronic Circuit Element

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

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.





Ionic & electronic switching

3D-stacked Memristors for non-volatile storage?

Diode-less architecture ($4F^2$), Stack multiple layers, Materials integration w/ CMOS

Technology	Density (μm^2/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

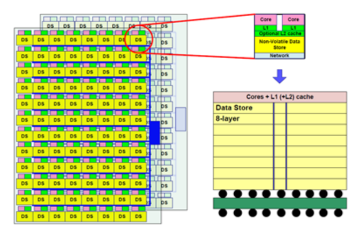
What would you do with TBytes nonvolatile storage on-chip?

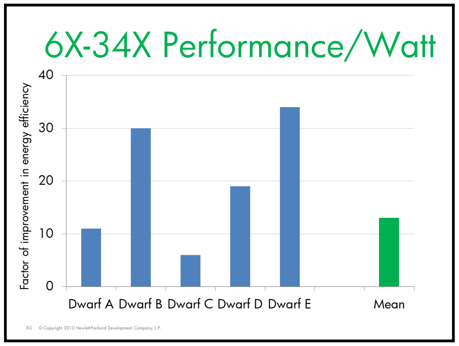
+ Simpler processors at near-threshold voltage for higher energy efficiency

+ Photonics for improved bandwidth, energy efficiency, high radix…

Discontinuity in assumptions that led to traditional system designs?

From μprocessors to nanostores…





New designs…

New opportunities

Just a few examples…

Closing…

What does all of this mean for you?

Green clouds:
The next frontier

Exciting times ahead

Era of cross-disciplinary codesign

Thanks !!