The Need for Diversity in HPC

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Disclosure

- My research uses large-scale shared-memory machines
- SGI was my vendor partner for the winning Cluster Challenge team at Supercomputing 2007
- My team won Second Prize in VMware’s Ultimate Virtual Appliance contest in 2006
- WestGrid and Compute Canada are currently in a pre-RFP period.

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- Graphs from Top500.org
- Slides from David Patterson
- Information from Ken Koch
  - LANL Roadrunner Summary 3/12/2007

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The Audience

- High-performance computing and simulation *users*
- Not necessarily hardware or OS researchers

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Overview and Basic Argument

1. A monoculture is bad in the long term.
2. Losing expertise is the greatest risk.
3. Consequences: Hardware, Software, Research.

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Not going to emphasize…

- Databases and Web servers. Focus on computational science.
- Capability vs. capacity computing
- MPI vs. shared-memory programming **models**
- Business models and viability
- The optimal amount of diversity (likely, it should 1 < d < 5)
  - Nor what the right trade-off point is between maintaining expertise vs. buying/paying for it later (assuming you can get it)

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Monoculture

Really?

A bad thing?

What monoculture?

- Today, the dominant platform for high-performance computing (HPC) is:
  - x86 commodity processors
  - Linux
  - Ethernet, Infiniband
  - Fortran, C/C++

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Cluster Challenge 2007 (1)

- All 6 teams used x86 CPUs. 5 of 6 teams used Intel Xeon.
- 5 of 6 teams used Linux
  - Not the same 5 teams
- 5 of 6 teams used Infiniband
  - One team used Myrinet

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Cluster Challenge 2007 (2)

- All 6 teams used x86 CPUs. 5 of 6 teams used Intel Xeon. → Commodity processors
  - Great price-performance
- 5 of 6 teams used Linux → Strength in numbers
  - Not the same 5 teams
  - "Everything runs on Linux"
- 5 of 6 teams used Infiniband → Near-commodity interconnects
  - One team used Myrinet
  - Good price-performance
  - "Good" software support

Mainstream technologies have their advantages!

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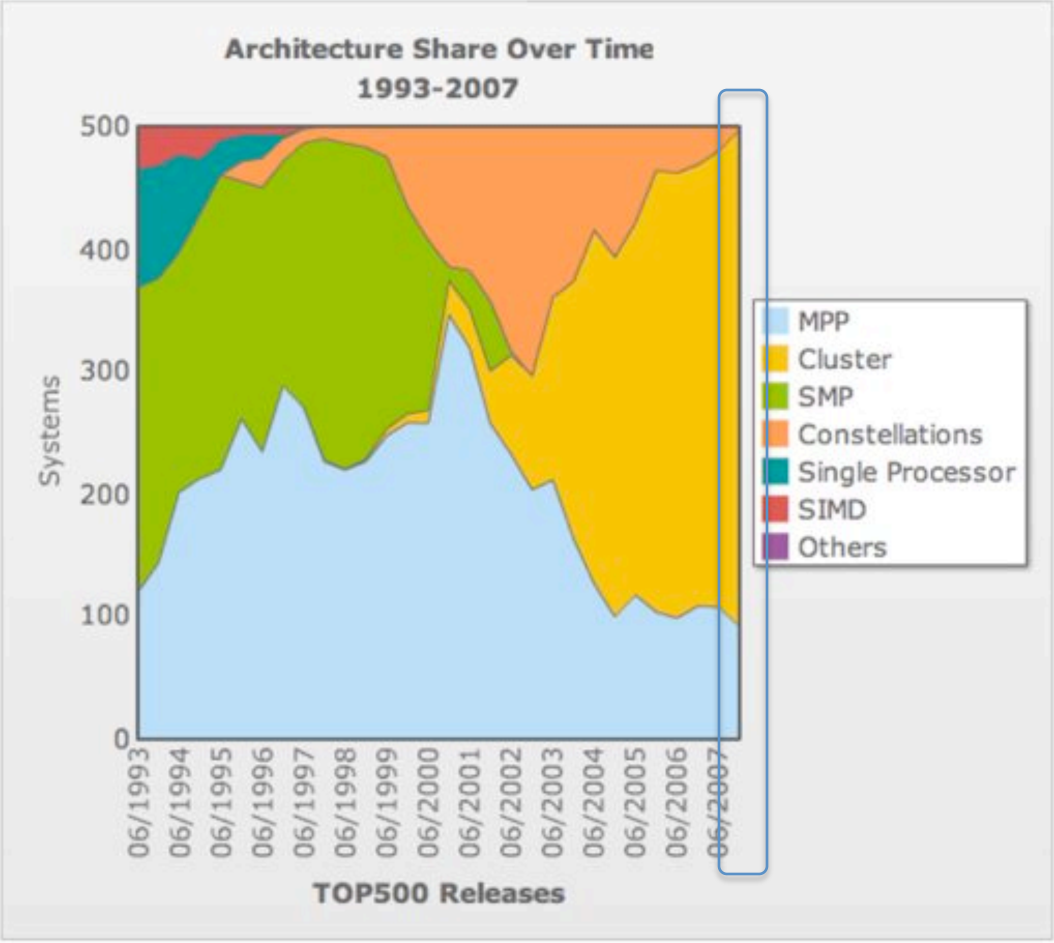
Top 500 List “Monoculture”

(from top500.org)



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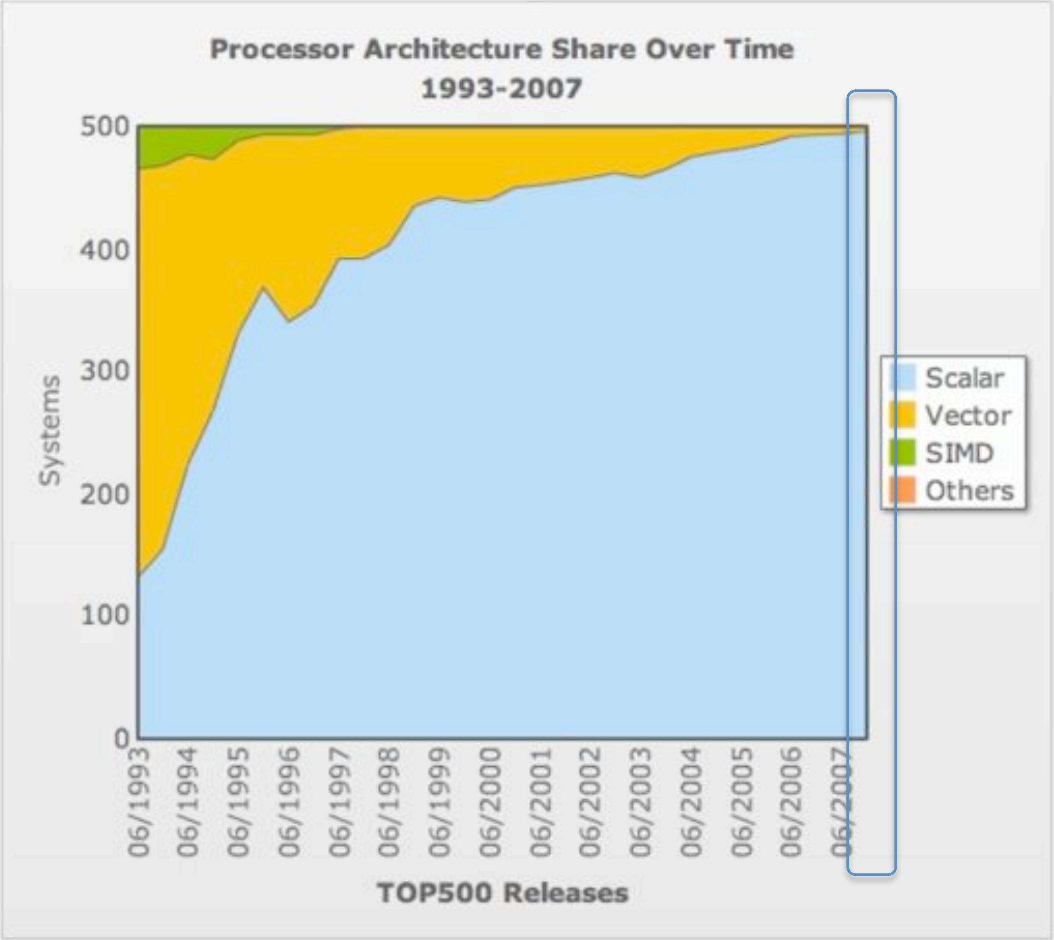

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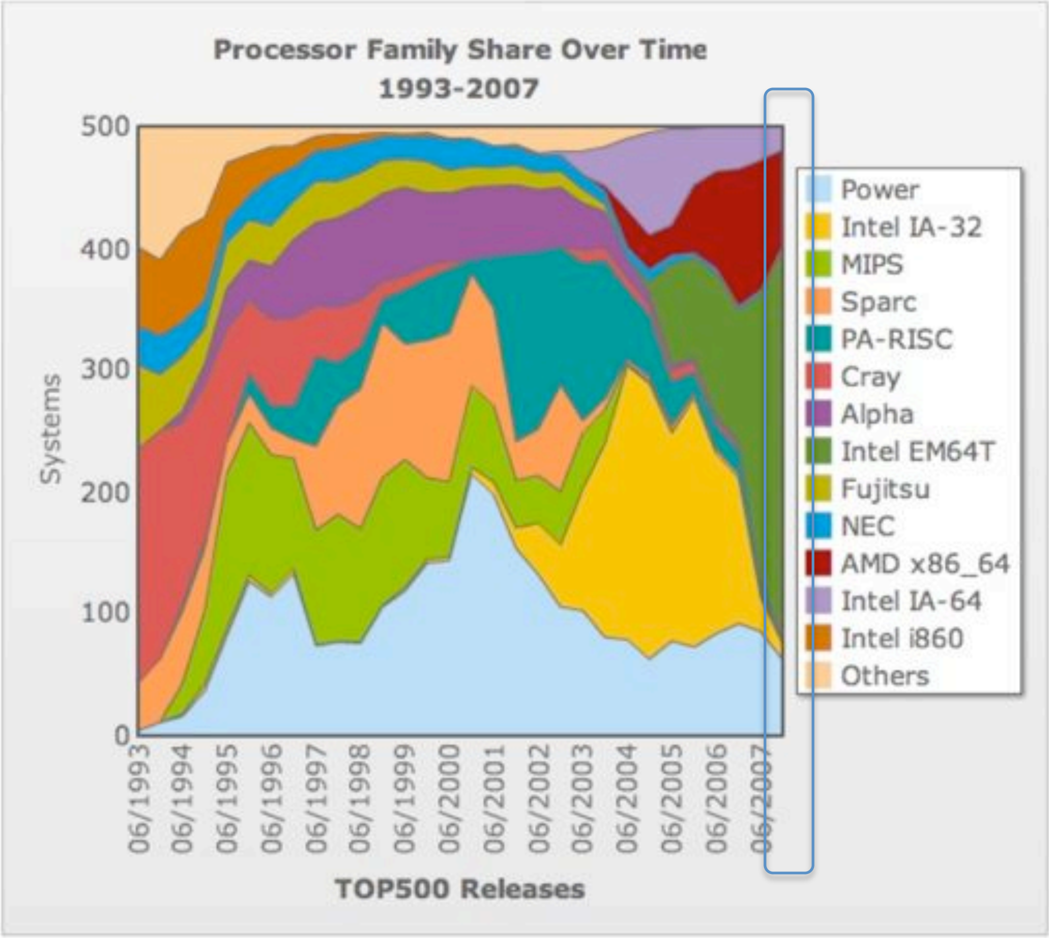

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Monocultures

- Hardware
  - Commodity x86 CPUs
  - Currently, 8-way or less, quad-core processors
  - Ethernet or Infiniband
- Software
  - Linux

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Monoculture, bad?

- Clusters are great, but…
- What if there was only…
  - one computer programming language?
  - one operating system?
  - one GUI?
  - one text editor?
  - one browser?

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Example: Browsers

- Not good to have *only* one, viable, dominant Web browser, despite the "benefits"…
  - But, it is free (i.e., great price-performance)
  - And, everyone will be compatible with it
- Because, what if the developers turn their focus elsewhere?
  - Mobile computing, smart phones, social networks

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Monoculture, good?

- Can there be too much diversity? Yes.
  - Networks: **Ethernet**, Token Ring, FDDI?
  - OS: BSD, System V, Windows, Mac OS, **Linux**?
  - Threading Libraries: Solaris, SGI, **Pthreads**?
  - Message Passing Libraries: PVM, **MPI**
- But, usually good to have a viable second choice

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Good vs. Bad Monocultures

"Monocultures" can be good too

- Standardization of *specifications* is good
  - e.g., HTML
  - In HPC, Message-Passing Interface (MPI), Pthreads, and OpenMP are important standards.
- Diversity of *implementations* (**and** architectures) should be maintained
  - Open-source software helps, but is not a substitute for multiple implementations and innovation in architecture

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Expertise

What if we forgot how to do something?

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Technology Tends to Be Cyclical

- Languages
  - Fortran, C/C++, HPF, OpenMP C and Fortran, scripting languages, Fortran-something
- Processor architecture
- Co-processors and special processors

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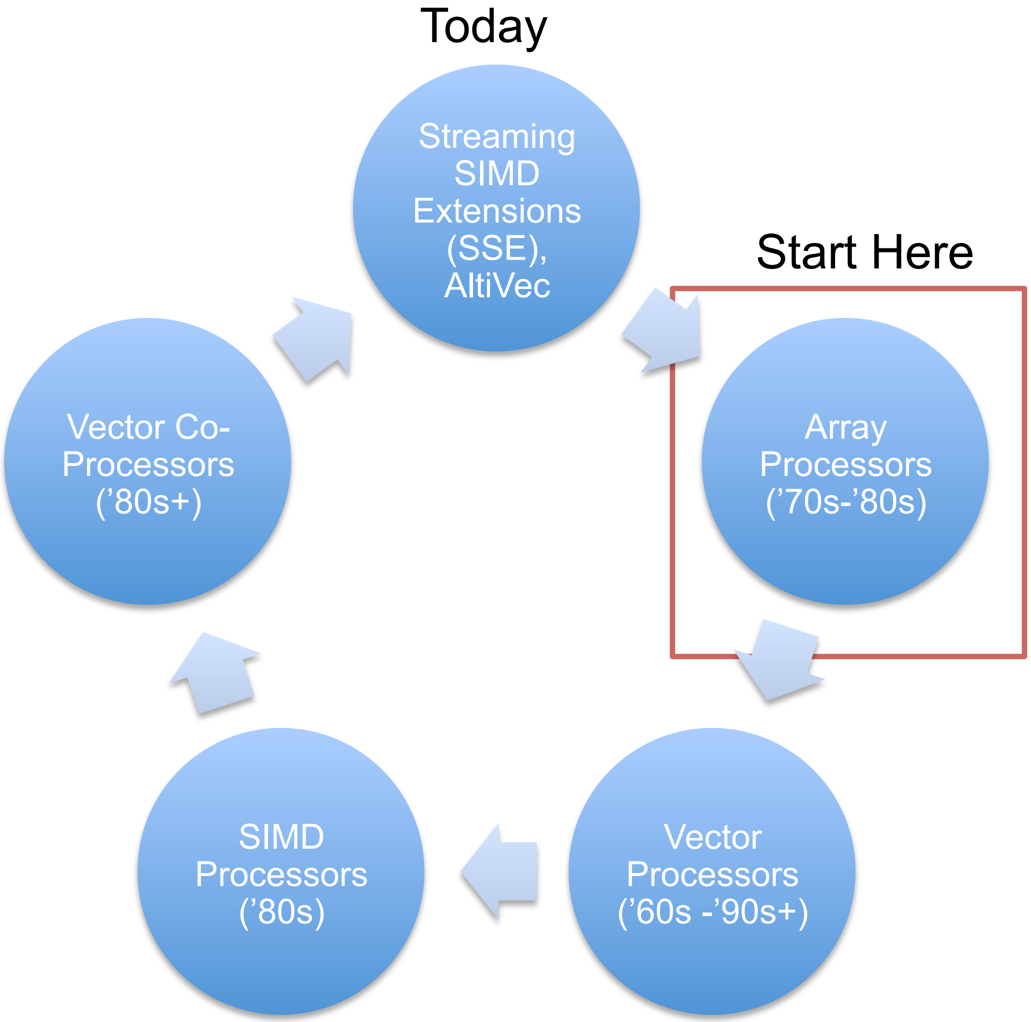
Life, Death, and Life of SIMD


Today
Streaming SIMD Extensions (SSE), AltiVec
Start Here
Array Processors ('70s-'80s)
Vector Processors ('60s -'90s+)
SIMD Processors ('80s)
Vector Co-Processors ('80s+)

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Life, Death, and Life of SIMD

- Fast, general-purpose processors usually win in the marketplace
- But, SIMD keeps returning to provide a performance edge
- Notably, with SSE, it is “bundled” with fast, general-purpose processing power
- GROMACS molecular dynamics code uses SSE/3DNow for a boost

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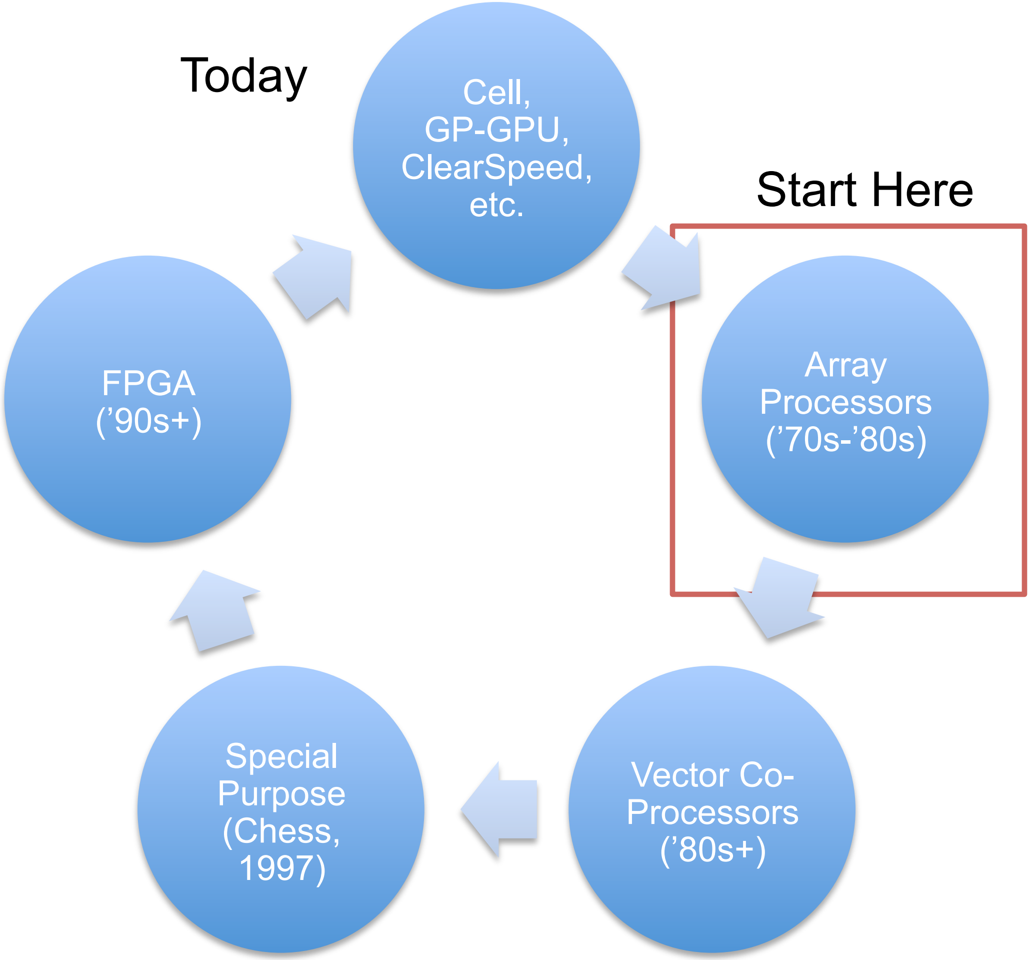
Life, Death, and Life of Co-Processors



Today

Start Here

Cell,
GP-GPU,
ClearSpeed,
etc.

Array Processors ('70s-'80s)

Vector Co-Processors ('80s+)

Special Purpose (Chess, 1997)

FPGA ('90s+)

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Life, Death, and Life of Co-Processors

- As with SSE, GP-GPU may become a “bundled” feature of fast processors
- Loss of low-level architectural and coding expertise is quite common
- Of course, do NOT jump on every bandwagon. But, remember how to jump.

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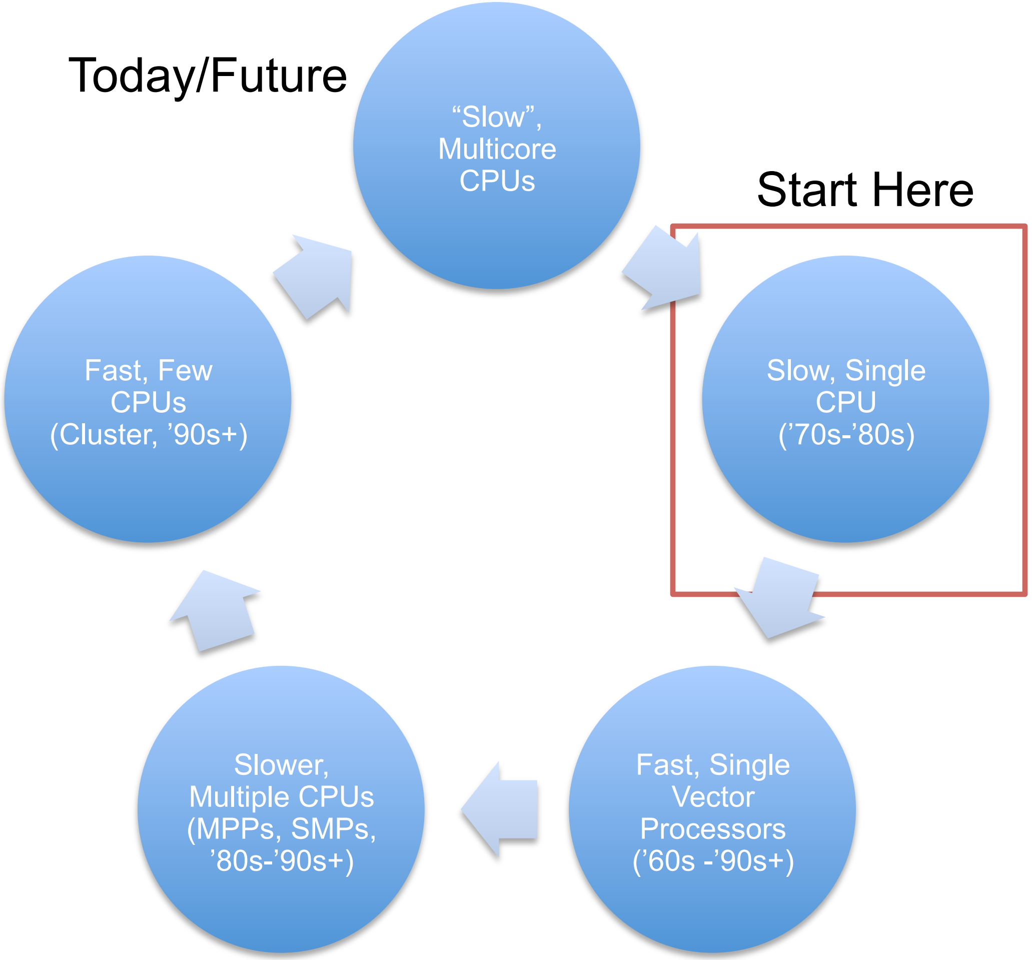
Life, Death, and Life of "Massive Parallelism"



Today/Future
"Slow", Multicore CPUs
Start Here
Slow, Single CPU ('70s-'80s)
Fast, Single Vector Processors ('60s -'90s+)
Slower, Multiple CPUs (MPPs, SMPs, '80s-'90s+)
Fast, Few CPUs (Cluster, '90s+)

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Life, Death, and Life of "Massive Parallelism"

- Next era will NOT provide "automatic" performance improvements each year via clock speed.
- Multicore may not be as well-suited for capacity computing
  - Multiple jobs sharing a processor/socket contend for (depending on architecture) memory bandwidth, I/O bandwidth, etc.
  - Performance mainly through better use of cores per-job (i.e., parallelism)
  - Requires innovation in OS, scheduling, etc.

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What if we lost the skills?

- When was the last time your group wrote a *new* Fortran program?
- Is the SSE/AltiVec capability of your CPU used at all?
  - Intel is moving towards Advanced Vector Extensions, 256-bits
- Who in your group can scale your application if you had 64 cores sharing a common memory?

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What if we missed the boat?

- We can foresee the days of 64 cores and more on one socket
- These look a lot like SMPs
- How will we deal with multicore and manycore systems if our platforms are currently 8- or 16-way?

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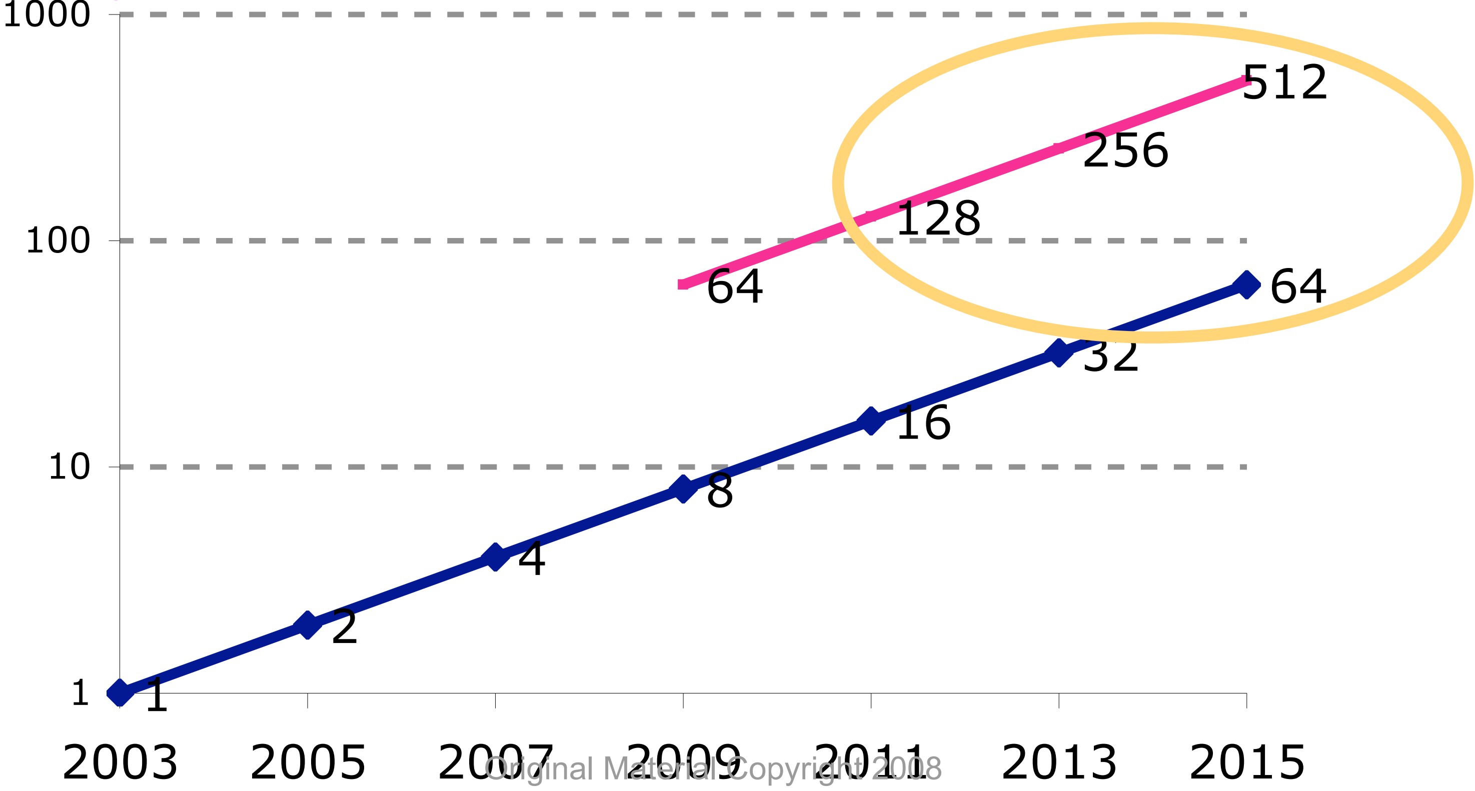
Why Target 64+ Cores?

(adapted from David Patterson, 2007)

- Multicore: 2X / 2 yrs ⇒ ≈ 64 cores in 8 years
- Manycore: 8X to 16X multicore



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Current Multicores

(adapted from David Patterson, 2007)

Name	Clovertwn	Opteron	Cell	Niagara 2
Chips*Cores	2*4 = 8	2*2 = 4	1*8 = 8	1*8 = 8
Clock Rate	2.3 GHz	2.2 GHz	3.2 GHz	1.4 GHz
Peak MemBW	21 GB/s	21 GB/s	26 GB/s	41 GB/s
Peak GFLOPS	74.6 GF	17.6 GF	14.6 GF	11.2 GF
Naïve SpMV (median of many matrices)	1.0 GF	0.6 GF	--	2.7 GF
Efficiency %	1%	3%	--	24%

Sparse Matrix * Vector operations

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Efficiency %	1%	3%		24%

Expertise is required to approach peak FLOPS!

Sparse Matrix * Vector operations

Consequences

Would it really be so bad?

“Hardware” Consequences

If we only have 8- and 16-way nodes in a cluster today…

- Who will have the skills to scale up an applications for 100’s of cores?
- Who can make use of co-processors?
  - Chess processors a key part of Deep Blue’s success
  - SSE and GP-GPUs as part of CPU
- Will we waste cores and functional units?

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“Software” Consequences

If Linux is the “only” OS

- Who will work on scalability and NUMA issues?
  - Linux may become focused on mobile devices, or Web servers, or the next trend
- What if that desirable feature is not available on Linux (e.g., ZFS and license conflict)?
- Will we have “golden handcuffs”?

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Research Consequences

- Using co-processors, your research competitor beats you to the answer
  - Deep Blue (1997) co-processors in chess
- Stagnant innovation
  - The history of browsers, compilers, etc.
- No platforms for capability applications and algorithm development
  - Latency-sensitive, irregular applications

Current Procurements

I am troubled by the following line of reasoning in HPC procurements:

- Clusters are the best in price-performance.
- We have lots of people who need the cycles.
- Therefore, let’s spend the money on more clusters.
- Since, we don’t need any/many SMPs nor other architectures.
- Furthermore, somebody else should be paying for diversity, since I don’t even have enough for me.

I think this is very short-sighted.
To know the price of everything, but the value of nothing.

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Recommendations

- Accept that clusters *are* the new backbone of HPC.
- But, if the cluster was, say, 10% smaller, will people actually notice?
- So, leave room (and budget) as investment in diversity
  - For example, SMPs
    - Great for many applications *now.* They *will* get used!
    - Develop expertise for multi/manycores in foreseeable future
  - For example, different OSes
    - Linux is great, but it is being pulled in many directions
    - Other code bases should not be abandoned
- I am NOT saying that everybody should buy one of everything. Just don't spend everything on only one thing.

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Concluding Remarks

1. A monoculture is bad in the long term.
2. Losing expertise is the greatest risk.
3. Consequences: Hardware, Software, Research.

Key Idea: Balance, for the long-term.

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