Supercomputing in Plain English

Overview:
What the Heck is Supercomputing?

Henry Neeman, Director

OU Supercomputing Center for Education & Research
University of Oklahoma Information Technology
Tuesday January 25 2011

This is an experiment!

It's the nature of these kinds of videoconferences that
FAILURES ARE GUARANTEED TO HAPPEN!
NO PROMISES!

So, please bear with us. Hopefully everything will work out well enough.

If you lose your connection, you can retry the same kind of connection, or try connecting another way.

Remember, if all else fails, you always have the toll free phone bridge to fall back on.

Access Grid

If you aren't sure whether you have AG, you probably don't.

Tue Jan 25	Platinum
Tue Feb 1	Cactus
Tue Feb 8	**NO WORKSHOP**
Tue Feb 15	Walkabout
Tue Feb 22	Optiverse
Tue March 1	Walkabout
Tue March 8	**NO WORKSHOP**
Tue March 15	**NO WORKSHOP**
Tue March 22	Axon
Tue March 29	**NO WORKSHOP**
Tue Apr 5	Axon
Tue Apr 12	Platinum
Tue Apr 19	Mosaic
Tue Apr 26	Monte Carlo
Tue May 3	Helium

Many thanks to Patrick Calhoun of OU for setting these up for us.

H.323 (Polycom etc)

If you want to use H.323 videoconferencing – for example, Polycom – then:

- If you ARE already registered with the OneNet gatekeeper, dial 2500409.

- If you AREN'T registered with the OneNet gatekeeper (which is probably the case), then:
  - Dial `164.58.250.47`
  - When asked for the conference ID, enter: `#0409#`

Many thanks to Roger Holder and OneNet for providing this.

H.323 from Internet Explorer

From a Windows PC running Internet Explorer:

1. You **MUST** have the ability to install software on the PC (or have someone install it for you).
2. Download and install the latest Java Runtime Environment (JRE) from <u>here</u> (click on the Java Download icon, because that install package includes both the JRE and other components).
3. Download and install this <u>video decoder</u>.
4. Start Internet Explorer.
5. Copy-and-paste this URL into your IE window:
   http://164.58.250.47/
6. When that webpage loads, in the upper left, click on "Streaming".
7. In the textbox labeled Sign-in Name, type your name.
8. In the textbox labeled Conference ID, type this:
   0409
9. Click on "Stream this conference".
10. When that webpage loads, you may see, at the very top, a bar offering you options. If so, click on it and choose "Install this add-on."

EVO

There's a quick tutorial on the OSCER education webpage.

QuickTime Broadcaster

If you cannot connect via the Access Grid, H.323 or iLinc, then you can connect via QuickTime:

`rtsp://129.15.254.141/test_hpc09.sdp`

We recommend using QuickTime Player for this, because we've tested it successfully.

We recommend upgrading to the latest version at:

`http://www.apple.com/quicktime/`

When you run QuickTime Player, traverse the menus

File -> Open URL

Then paste in the rstp URL into the textbox, and click OK.

Many thanks to Kevin Blake of OU for setting up QuickTime Broadcaster for us.

WebEx

We have only a limited number of WebEx connections, so please avoid WebEx unless you have **NO OTHER WAY TO CONNECT**.

Instructions are available on the OSCER education webpage.

Thanks to Tim Miller of Wake Forest U.

Phone Bridge

If all else fails, you can call into our toll free phone bridge:

1-866-285-7778, access code 6483137#

Please mute yourself and use the phone to listen.

Don't worry, we'll call out slide numbers as we go.

Please use the phone bridge **ONLY** if you cannot connect any other way: the phone bridge is charged per connection per minute, so our preference is to minimize the number of connections.

Many thanks to Amy Apon and U Arkansas for providing the toll free phone bridge.

Please Mute Yourself

No matter how you connect, please mute yourself, so that we cannot hear you.

At OU, we will turn off the sound on all conferencing technologies.

That way, we won't have problems with echo cancellation.

Of course, that means we cannot hear questions.

So for questions, you'll need to send some kind of text.

Questions via Text: iLinc or E-mail

Ask questions via e-mail to sipe2011@yahoo.com.

All questions will be read out loud and then answered out loud.

Thanks for helping!

- OSCER operations staff (Brandon George, Dave Akin, Brett Zimmerman, Josh Alexander)
- Horst Severini, OSCER Associate Director for Remote & Heterogeneous Computing
- OU Research Campus staff (Patrick Calhoun, Mark McAvoy)
- Kevin Blake, OU IT (videographer)
- John Chapman, Jeff Pummill and Amy Apon, U Arkansas
- James Deaton and Roger Holder, OneNet
- Tim Miller, Wake Forest U

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Supercomputing Exercises

Want to do the "Supercomputing in Plain English" exercises?

- The first exercise is already posted at:

  `http://www.oscer.ou.edu/education.php`

- If you don't yet have a supercomputer account, you can get a temporary account, just for the "Supercomputing in Plain English" exercises, by sending e-mail to:

  `hneeman@ou.edu`

Please note that this account is for doing the **exercises only**, and will be shut down at the end of the series.

- This week's Introductory exercise will teach you how to compile and run jobs on OU's big Linux cluster supercomputer, which is named Sooner.

People

Things

Thanks for your attention!

Questions?
www.oscer.ou.edu

What is Supercomputing?

Supercomputing is the **biggest, fastest computing right this minute**.

Likewise, a *supercomputer* is one of the biggest, fastest computers right this minute.

So, the definition of supercomputing is **constantly changing**.

Rule of Thumb: A supercomputer is typically at least 100 times as powerful as a PC.

Jargon: Supercomputing is also known as *High Performance Computing* (**HPC**) or *High End Computing* (**HEC**) or *Cyberinfrastructure* (**CI**).

Fastest Supercomputer vs. Moore
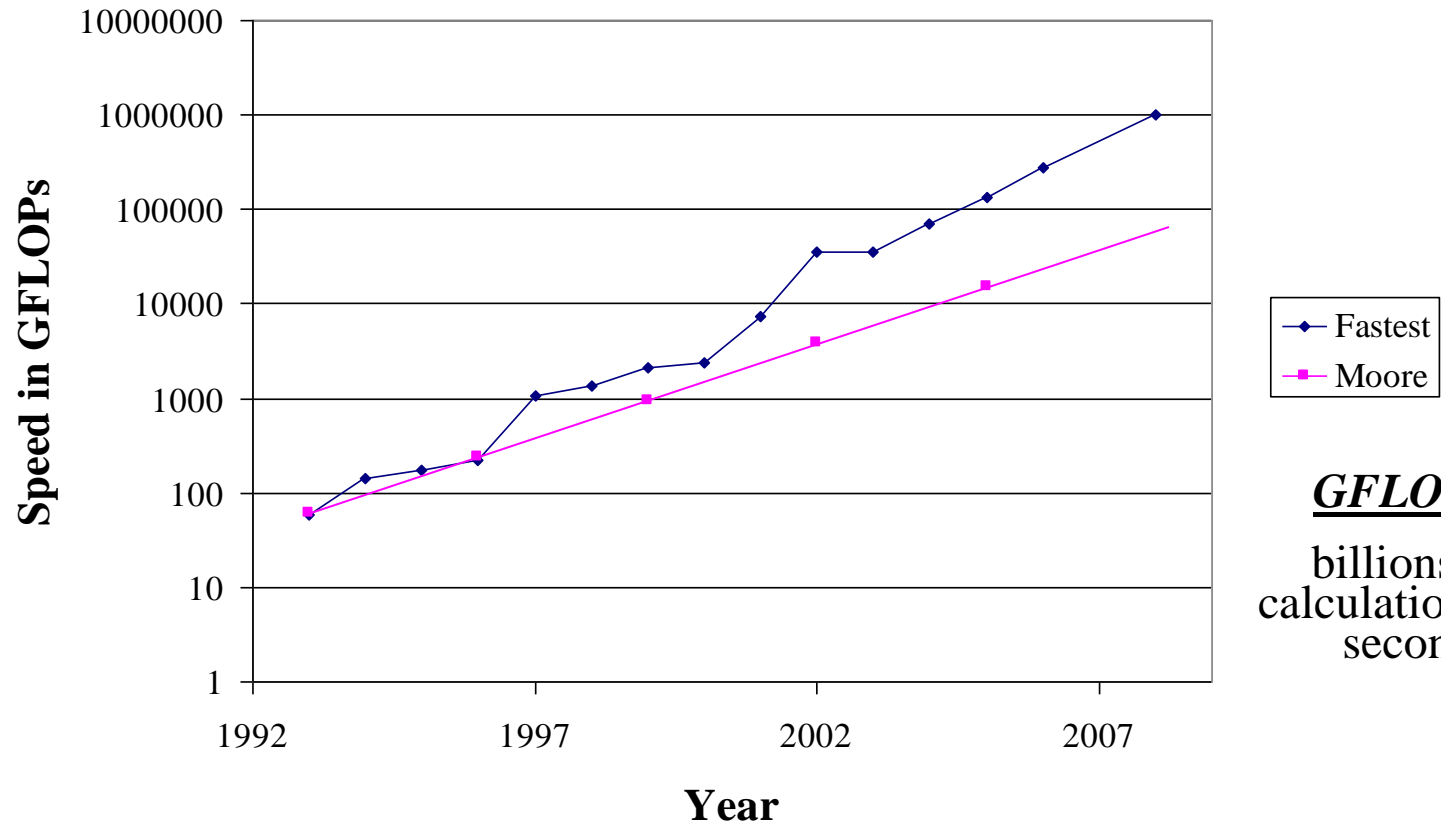
Fastest Supercomputer in the World

What is Supercomputing About?
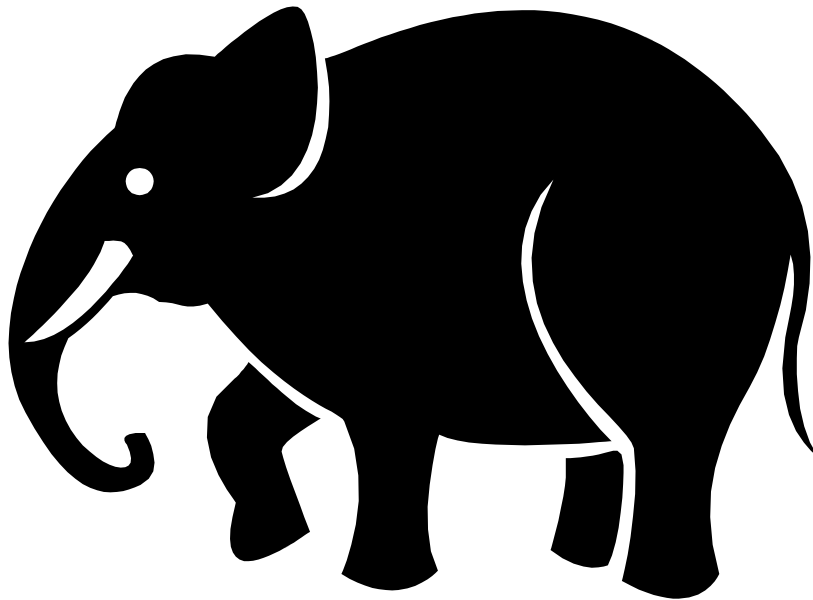
Size   Speed
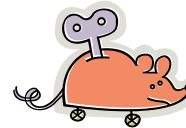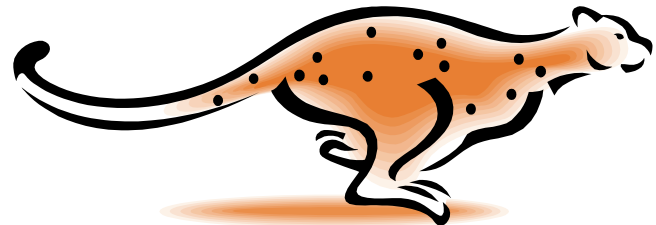
Laptop

What is Supercomputing About?

- **<u>Size</u>**: Many problems that are interesting to scientists and engineers **<u>can't fit on a PC</u>** – usually because they need more than a few GB of RAM, or more than a few 100 GB of disk.
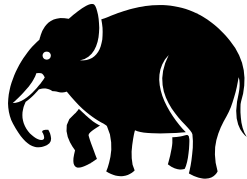
- **<u>Speed</u>**: Many problems that are interesting to scientists and engineers would take a very very long time to run on a PC: months or even years. But a problem that would take **<u>a month on a PC</u>** might take only **<u>a few hours on a supercomputer</u>**.

What Is HPC Used For?

- *__Simulation__* of physical phenomena, such as
    - Weather forecasting
    - Galaxy formation
    - Oil reservoir management

[1]

- *__Data mining__*: finding __needles__ of information in a __haystack__ of data, such as
    - Gene sequencing
    - Signal processing
    - Detecting storms that might produce tornados

Moore, OK Tornadic Storm

May 3 1999[2]

- *__Visualization__*: turning a vast sea of __data__ into __pictures__ that a scientist can understand
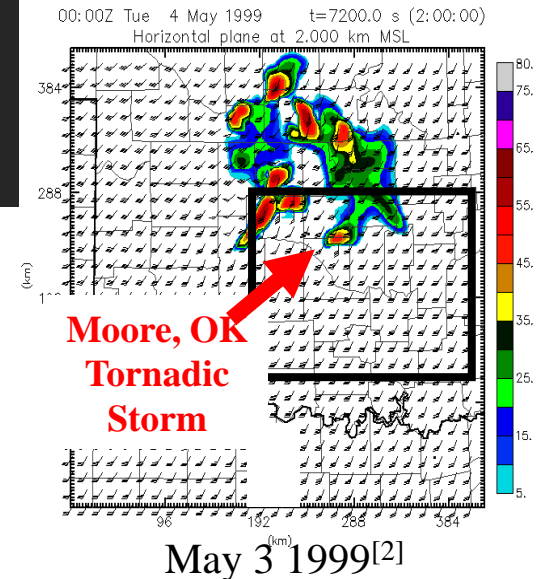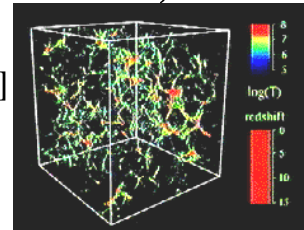
[3]
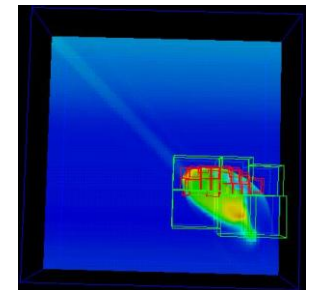
Supercomputing Issues

- The tyranny of the ***storage hierarchy***
- ***Parallelism***: doing multiple things at the same time

OSCER

What is OSCER?

- Multidisciplinary center
- Division of OU Information Technology
- Provides:
    - Supercomputing **education**
    - Supercomputing **expertise**
    - Supercomputing **resources**: hardware, storage, software
- For:
    - Undergrad students
    - Grad students
    - Staff
    - Faculty
    - Their collaborators (including **off campus**)

Who is OSCER? Academic Depts

- Aerospace & Mechanical Engr
- Anthropology
- Biochemistry & Molecular Biology
- Biological Survey
- Botany & Microbiology
- Chemical, Biological & Materials Engr
- Chemistry & Biochemistry
- Civil Engr & Environmental Science
- Computer Science
- Economics
- Electrical & Computer Engr
- Finance
- Health & Sport Sciences

- History of Science
- Industrial Engr
- Geography
- Geology & Geophysics
- Library & Information Studies
- Mathematics
- Meteorology
- Petroleum & Geological Engr
- Physics & Astronomy
- Psychology
- Radiological Sciences
- Surgery
- Zoology

More than 150 faculty & staff in **26 depts** in Colleges of Arts & Sciences, Atmospheric & Geographic Sciences, Business, Earth & Energy, Engineering, and Medicine – with **more to come**!

Who is OSCER? Groups

- Advanced Center for Genome Technology
- Center for Analysis & Prediction of Storms
- Center for Aircraft & Systems/Support Infrastructure
- Cooperative Institute for Mesoscale Meteorological Studies
- Center for Engineering Optimization
- Fears Structural Engineering Laboratory
- Human Technology Interaction Center
- Institute of Exploration & Development Geosciences

- Instructional Development Program
- Interaction, Discovery, Exploration, Adaptation Laboratory
- Microarray Core Facility
- OU Information Technology
- OU Office of the VP for Research
- Oklahoma Center for High Energy Physics
- Robotics, Evolution, Adaptation, and Learning Laboratory
- Sasaki Applied Meteorology Research Institute
- Symbiotic Computing Laboratory

Who? External Collaborators

1. California State Polytechnic University Pomona (**masters**)
2. Colorado State University
3. Contra Costa College (CA, **2-year**)
4. Delaware State University (**EPSCoR**, **masters**)
5. Earlham College (IN, **bachelors**)
6. East Central University (OK, **EPSCoR**, **masters**)
7. Emporia State University (KS, **EPSCoR**, **masters**)
8. Great Plains Network
9. Harvard University (MA)
10. **Kansas State University** (**EPSCoR**)
11. Langston University (OK, **EPSCoR**, **masters**)
12. Longwood University (VA, **masters**)
13. Marshall University (WV, **EPSCoR**, **masters**)
14. Navajo Technical College (NM, **EPSCoR**, **2-year**)
15. NOAA National Severe Storms Laboratory (**EPSCoR**)
16. NOAA Storm Prediction Center (**EPSCoR**)
17. Oklahoma Baptist University (**EPSCoR**, **bachelors**)
18. Oklahoma City University (**EPSCoR, masters**)
19. Oklahoma Climatological Survey (**EPSCoR)**
20. Oklahoma Medical Research Foundation (**EPSCoR**)
20. Oklahoma School of Science & Mathematics (**EPSCoR**, **high school**)
21. Oklahoma State University (**EPSCoR)**
22. Purdue University (IN)
23. Riverside Community College (CA, **2-year**)
24. St. Cloud State University (MN, **masters**)
25. St. Gregory's University (OK, **EPSCoR**, **bachelors**)
26. Southwestern Oklahoma State University (**EPSCoR**, **masters**)
27. Syracuse University (NY)
28. Texas A&M University-Corpus Christi (**masters**)
29. University of Arkansas (**EPSCoR**)
30. University of Arkansas Little Rock (**EPSCoR**)
31. University of Central Oklahoma (**EPSCoR**)
32. University of Illinois at Urbana-Champaign
33. University of Kansas (**EPSCoR**)
34. University of Nebraska-Lincoln (**EPSCoR**)
35. University of North Dakota (**EPSCoR**)
36. University of Northern Iowa (**masters**)

Who Are the Users?

Over 750 users so far, including:

- Roughly equal split between students vs faculty/staff (students are the bulk of the active users);
- many off campus users (roughly 20%);
- … more being added **every month**.

Comparison: TeraGrid, consisting of 11 resource provide sites across the US, has ~5000 unique users.

Biggest Consumers

- **<u>Center for Analysis & Prediction of Storms</u>**: daily real time weather forecasting

- **<u>Oklahoma Center for High Energy Physics</u>**: simulation and data analysis of banging tiny particles together at unbelievably high speeds

- **<u>Chemical Engineering</u>**: lots and lots of molecular dynamics
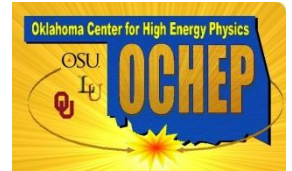
Why OSCER?

- Computational Science & Engineering has become **sophisticated enough** to take its place alongside experimentation and theory.

- **Most students** – and most faculty and staff – **don't learn much CSE**, because CSE is seen as needing too much computing background, and as needing HPC, which is seen as very hard to learn.

- **HPC can be hard to learn**: few materials for novices; most documents written for experts as reference guides.

- **We need a new approach**: HPC and CSE for computing novices – **OSCER's mandate!**

Why Bother Teaching Novices?

- Application scientists & engineers typically know their applications very well, much better than a collaborating computer scientist ever would.

- Commercial software lags far behind the research community.

- Many potential CSE users don't need full time CSE and HPC staff, just some help.

- One HPC expert can help dozens of research groups.

- Today's novices are tomorrow's top researchers, especially because today's top researchers will eventually retire.

What Does OSCER Do? Teaching

Science and engineering faculty from all over America learn
supercomputing at OU by playing with a jigsaw puzzle (NCSI @ OU 2004).

What Does OSCER Do? Rounds

OU undergrads, grad students, staff and faculty learn
how to use supercomputing in their specific research.

OSCER Resources

OK Cyberinfrastructure Initiative

- All academic institutions in Oklahoma are eligible to sign up for free use of OU's and OSU's centrally-owned CI resources.

- Other kinds of institutions (government, NGO, commercial) are eligible to use, though not necessarily for free.

- Everyone can participate in our CI education initiative.

- The Oklahoma Supercomputing Symposium, our annual conference, continues to be offered to all.

Dell Intel Xeon Linux Cluster

1,076 Intel Xeon CPU chips/4288 cores

- 528 dual socket/quad core Harpertown 2.0 GHz, 16 GB each
- 3 dual socket/quad core Harpertown 2.66 GHz, 16 GB each
- 3 dual socket/quad core Clovertown 2.33 GHz, 16 GB each
- 2 x quad socket/quad core Tigerton, 2.4 GHz, 128 GB each

8,800 GB RAM

~130 TB globally accessible disk

QLogic Infiniband

Force10 Networks Gigabit Ethernet

Red Hat Enterprise Linux 5

Peak speed: 34.5 TFLOPs*

*TFLOPs: trillion calculations per second

sooner.oscer.ou.edu

Dell Intel Xeon Linux Cluster

DEBUTED NOVEMBER 2008 AT:

- **#90 worldwide**
- **#47 in the US**
- **#14 among US academic**
- **#10 among US academic excluding TeraGrid**
- **#2 in the Big 12**
- **#1 in the Big 12 excluding TeraGrid**

`sooner.oscer.ou.edu`

Dell Intel Xeon Linux Cluster

Purchased mid-July 2008

First friendly user Aug 15 2008

Full production Oct 3 2008

Christmas Day 2008: >~75% of nodes and ~66% of cores were in use.

`sooner.oscer.ou.edu`

What is a Cluster?

"… [W]hat a ship is … It's not just a keel and hull and a deck and sails. That's what a ship needs. But what a ship is ... is freedom."

– Captain Jack Sparrow
"Pirates of the Caribbean"

What a Cluster is ….

A cluster **needs** of a collection of small computers, called ***nodes***, hooked together by an ***interconnection network*** (or ***interconnect*** for short).

It also **needs** software that allows the nodes to communicate over the interconnect.

But what a cluster **is** … is all of these components working together as if they're one big computer ... a **super** computer.

An Actual Cluster
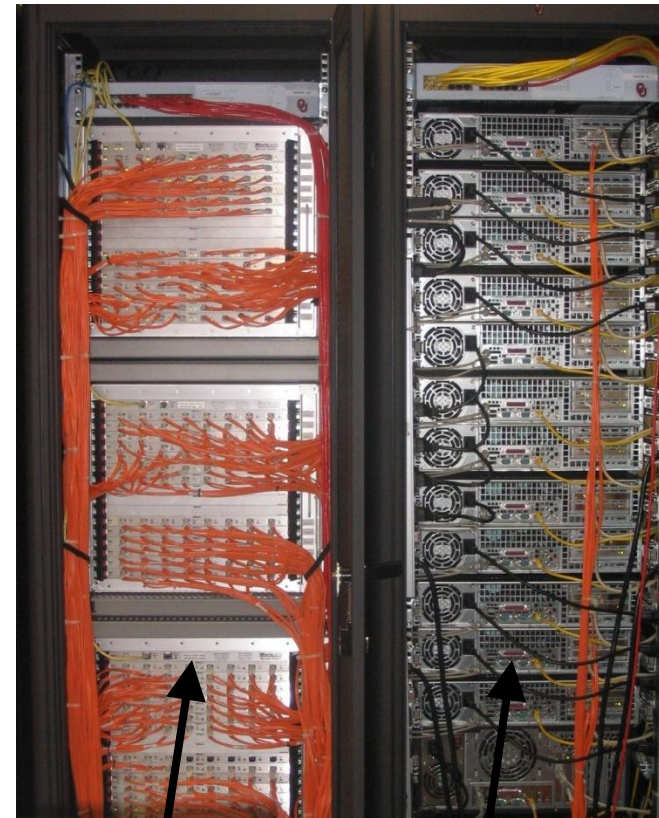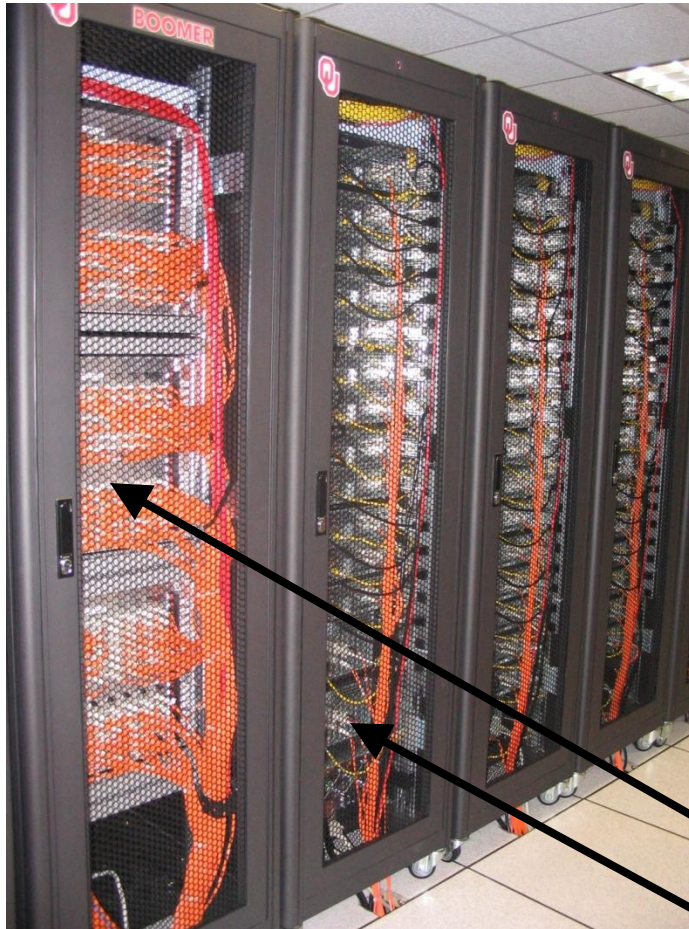
Interconnect

Nodes

Condor Pool

Condor is a software technology that allows idle desktop PCs to be used for number crunching.

OU IT has deployed a large Condor pool (795 desktop PCs in IT student labs all over campus).

It provides a huge amount of additional computing power – more than was available in all of OSCER in 2005.

20+ TFLOPs peak compute speed.
And, the cost is very very low – almost literally free.

Also, we've been seeing empirically that Condor gets about 80% of each PC's time.

National Lambda Rail

Internet2

NEW GRANT! NSF EPSCoR C2

Oklahoma has been awarded an NSF EPSCoR RII Intra-campus and Inter-campus Cyber Connectivity (C2) grant (PI Neeman), a collaboration among OU, OneNet and several other academic and nonprofit institutions, which will:

- upgrade the statewide ring from routed components to optical components, making it straightforward and affordable to provision dedicated "lambda" circuits within the state;

- upgrade several institutions' connections;

- provide telepresence capability to institutions statewide;

- provide networking professionals to speak to data networks courses about what it's like to do networking for a living.

NEW GRANT: Petascale Storage

OU has been awarded an NSF Major Research Instrumentation (MRI) grant (PI Neeman).

We'll purchase and deploy a combined disk/tape bulk storage archive:

- the NSF budget will pay for the hardware, software and warranties/maintenance for 3 years;

- OU cost share and institutional commitment will pay for space, power, cooling and labor, as well as maintenance after the 3 year project period;

- individual users (e.g., faculty across Oklahoma) will pay for the media (disk drives and tape cartridges).

A Quick Primer on Hardware

Henry's Laptop

Dell Latitude Z600[4]

- Intel Core2 Duo SU9600 1.6 GHz w/3 MB L2 Cache
- 4 GB 1066 MHz DDR3 SDRAM
- 256 GB SSD Hard Drive
- DVD+RW/CD-RW Drive (8x)
- 1 Gbps Ethernet Adapter

Typical Computer Hardware

- Central Processing Unit
- Primary storage
- Secondary storage
- Input devices
- Output devices

Central Processing Unit

Also called ***CPU*** or ***processor***: the "brain"

Components

- ***Control Unit***: figures out what to do next – for example, whether to load data from memory, or to add two values together, or to store data into memory, or to decide which of two possible actions to perform (***branching***)

- ***Arithmetic/Logic Unit***: performs calculations – for example, adding, multiplying, checking whether two values are equal

- ***Registers***: where data reside that are **being used right now**

Primary Storage

- ***Main Memory***
    - Also called ***RAM*** ("Random Access Memory")
    - Where data reside when they're **being used by a program that's currently running**
- ***Cache***
    - Small area of much faster memory
    - Where data reside when they're **about to be used** and/or **have been used recently**
- Primary storage is ***volatile***: values in primary storage disappear when the power is turned off.

Secondary Storage

- Where data and programs reside that are going to be used **in the future**

- Secondary storage is ***non-volatile***: values **don't** disappear when power is turned off.

- Examples: hard disk, CD, DVD, Blu-ray, magnetic tape, floppy disk

- Many are ***portable***: can pop out the CD/DVD/tape/floppy and take it with you

Input/Output

- Input devices – for example, keyboard, mouse, touchpad, joystick, scanner

- Output devices – for example, monitor, printer, speakers

The Tyranny of the Storage Hierarchy

The Storage Hierarchy

Fast, expensive, few
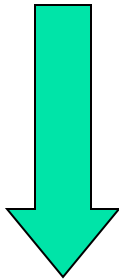
- Registers
- Cache memory
- Main memory (RAM)
- Hard disk
- Removable media (CD, DVD etc)
- Internet

Slow, cheap, a lot

[5]

RAM is Slow

CPU 307 GB/sec[6]

The speed of data transfer between Main Memory and the CPU is much slower than the speed of calculating, so the CPU spends most of its time waiting for data to come in or go out.

Bottleneck

4.4 GB/sec[7] (1.4%)

Why Have Cache?

CPU
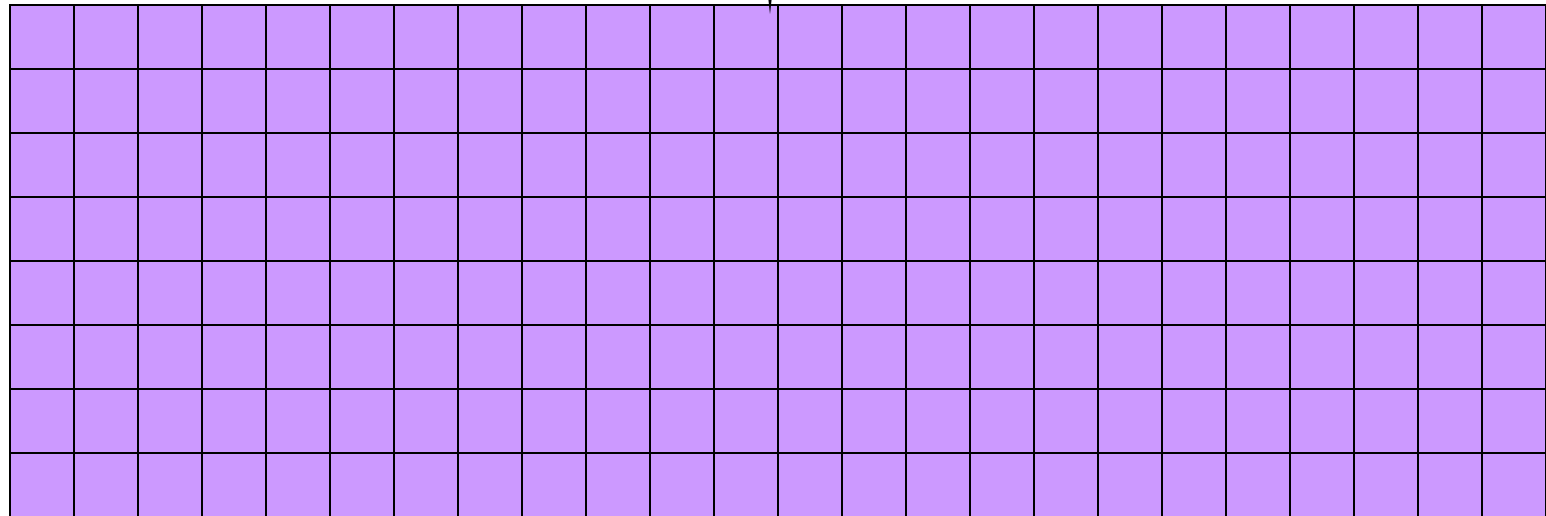
Cache is much closer to the speed of the CPU, so the CPU doesn't have to wait nearly as long for stuff that's already in cache: it can do more operations per second!
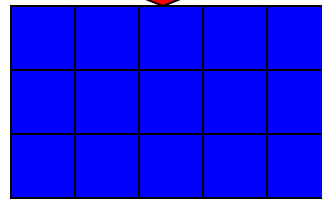
27 GB/sec (9%)[7]

4.4 GB/sec[7]
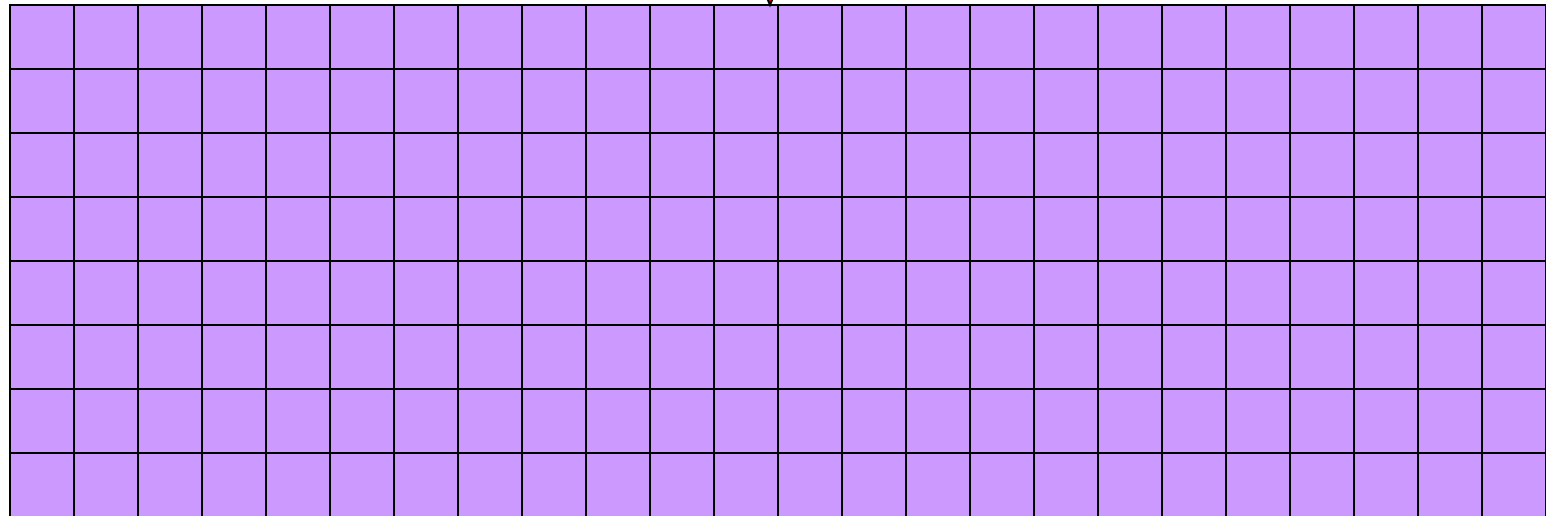
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Dell Latitude Z600[4]

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- 4 GB 1066 MHz DDR3 SDRAM
- 256 GB SSD Hard Drive
- DVD+RW/CD-RW Drive (8x)
- 1 Gbps Ethernet Adapter

Storage Speed, Size, Cost

Henry's Laptop	Registers (Intel Core2 Duo 1.6 GHz)	Cache Memory (L2)	Main Memory (1066MHz DDR3 SDRAM)	Hard Drive (SSD)	Ethernet (1000 Mbps)	DVD±R (16x)	Phone Modem (56 Kbps)
Speed (MB/sec) [peak]	314,573[6] (12,800 MFLOP/s*)	27,276 [7]	4500 [7]	250 [9]	125	22 [10]	0.007
Size (MB)	464 bytes** [11]	3	4096	256,000	unlimited	unlimited	unlimited
Cost ($/MB)	–	$285 [12]	$0.03 [12]	$0.002 [12]	charged per month (typically)	$0.00005 [12]	charged per month (typically)

* <u>MFLOP/s</u>: millions of floating point operations per second

** 16 64-bit general purpose registers, 8 80-bit floating point registers,
   16 128-bit floating point vector registers

Parallelism

Parallelism

Parallelism means doing multiple things at the same time: you can get more work done in the same time.

Less fish …
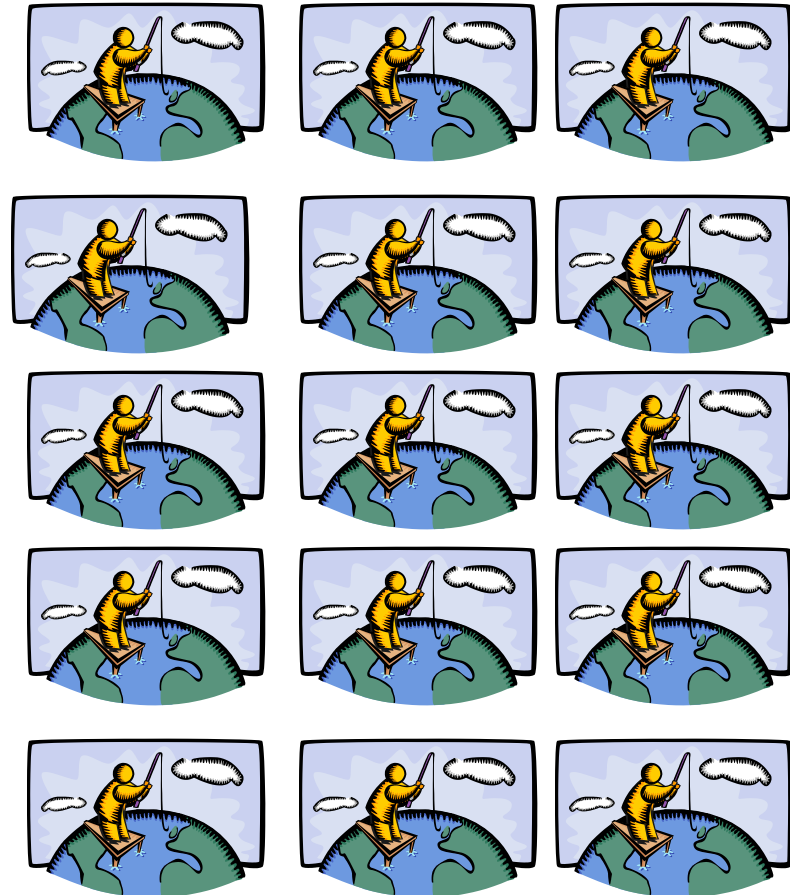
More fish!

The Jigsaw Puzzle Analogy
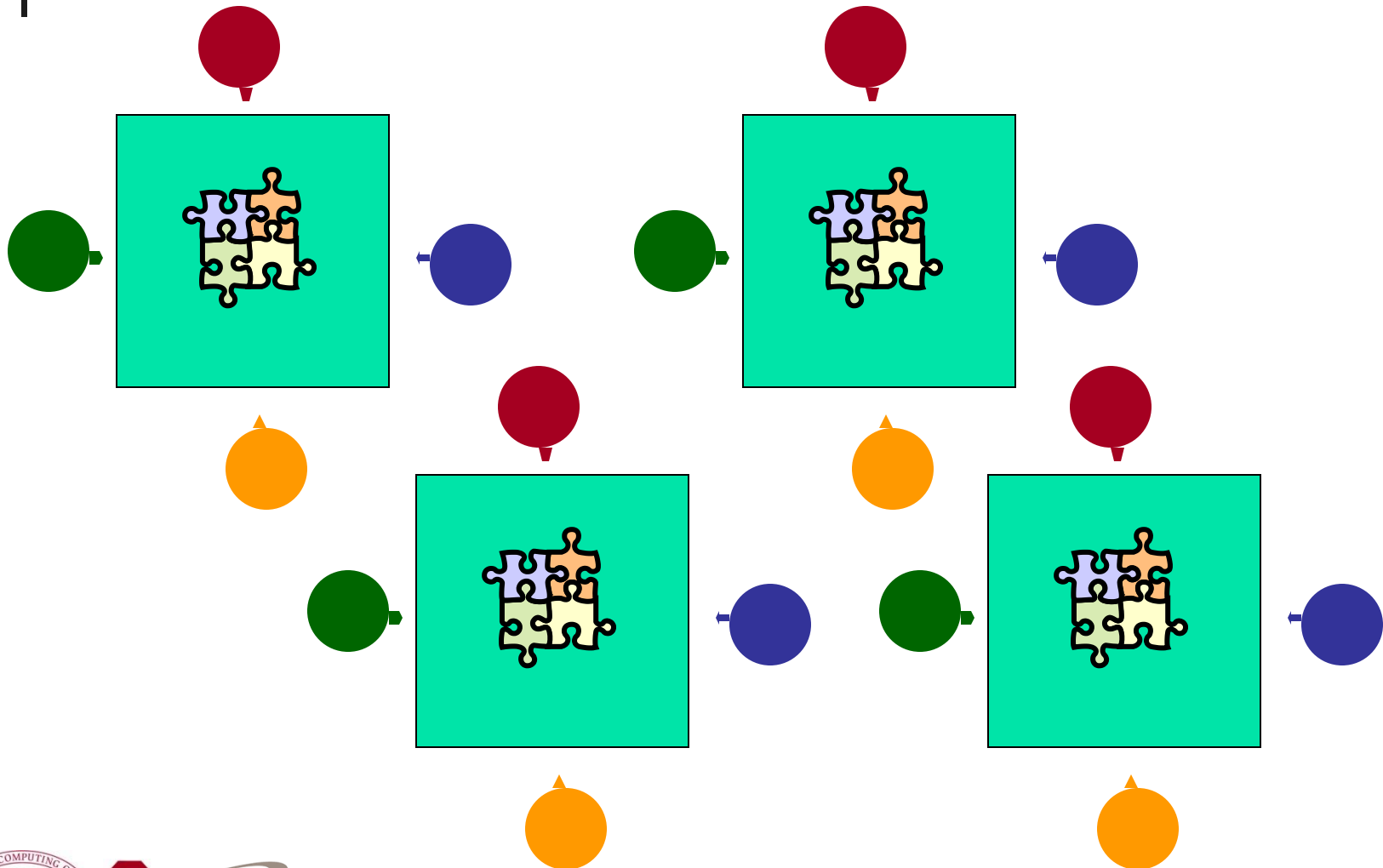
Serial Computing

Suppose you want to do a jigsaw puzzle that has, say, a thousand pieces.
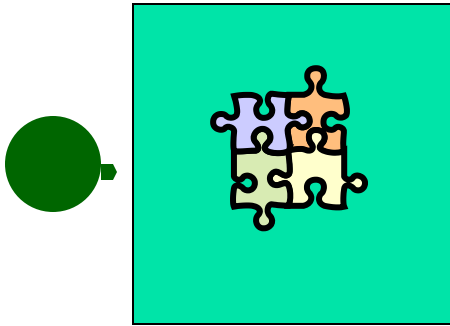
We can imagine that it'll take you a certain amount of time. Let's say that you can put the puzzle together in an hour.

Shared Memory Parallelism
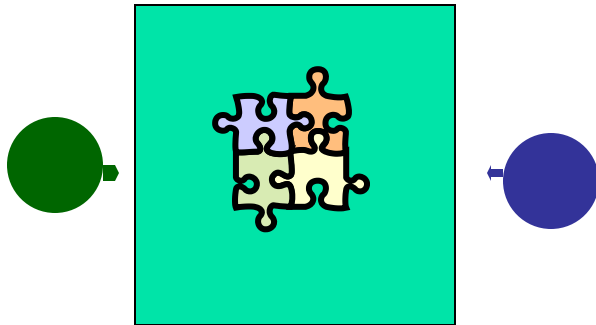
If Scott sits across the table from you, then he can work on his half of the puzzle and you can work on yours. Once in a while, you'll both reach into the pile of pieces at the same time (you'll ***contend*** for the same resource), which will cause a little bit of slowdown. And from time to time you'll have to work together (***communicate***) at the interface between his half and yours. The speedup will be nearly 2-to-1: y'all might take 35 minutes instead of 30.

The More the Merrier?
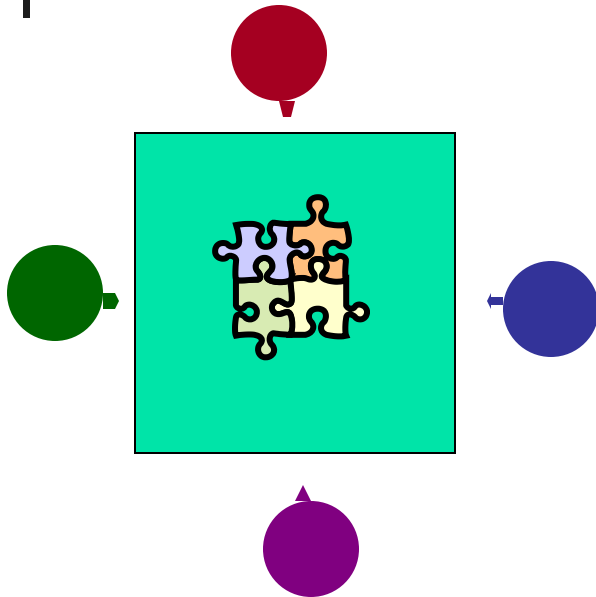
Now let's put Paul and Charlie on the other two sides of the table. Each of you can work on a part of the puzzle, but there'll be a lot more contention for the shared resource (the pile of puzzle pieces) and a lot more communication at the interfaces. So y'all will get noticeably less than a 4-to-1 speedup, but you'll still have an improvement, maybe something like 3-to-1: the four of you can get it done in 20 minutes instead of an hour.

Diminishing Returns
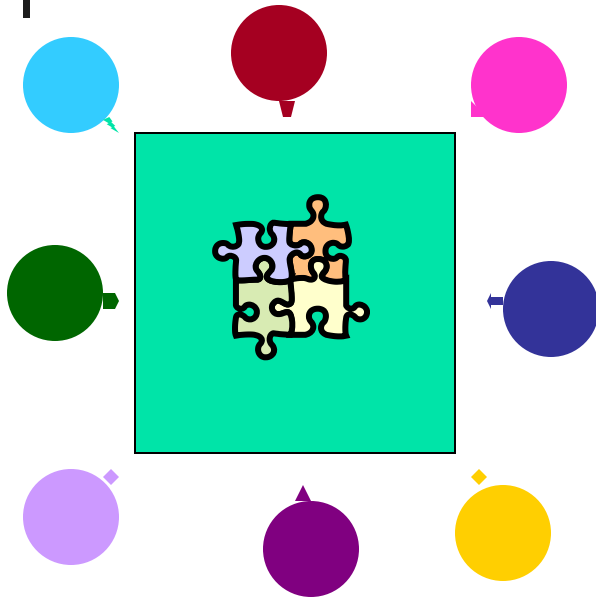
If we now put Dave and Tom and Horst and Brandon on the corners of the table, there's going to be a whole lot of contention for the shared resource, and a lot of communication at the many interfaces. So the speedup y'all get will be much less than we'd like; you'll be lucky to get 5-to-1.

So we can see that adding more and more workers onto a shared resource is eventually going to have a diminishing return.
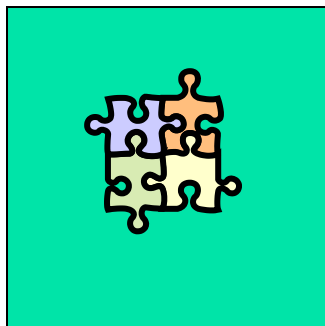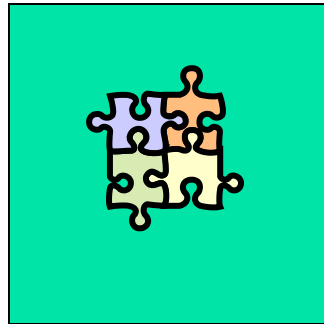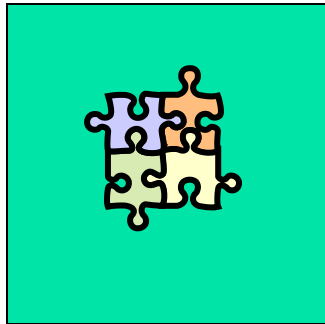
Distributed Parallelism
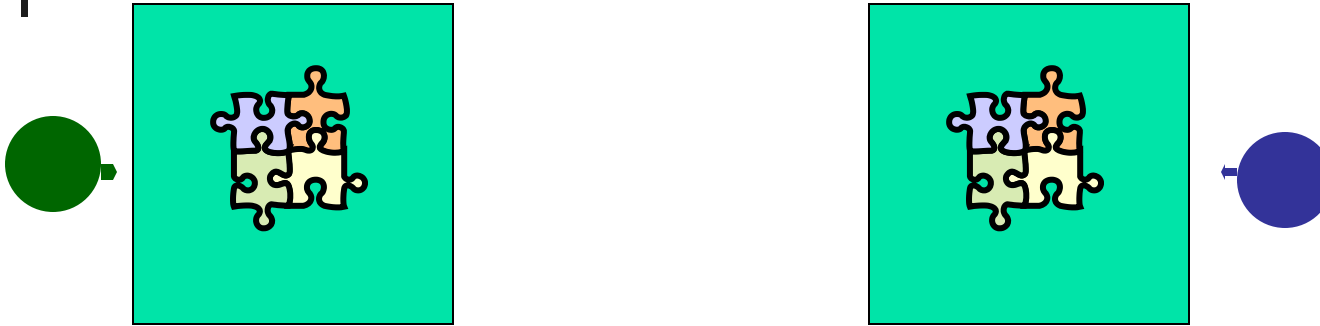
Now let's try something a little different. Let's set up two tables, and let's put you at one of them and Scott at the other. Let's put half of the puzzle pieces on your table and the other half of the pieces on Scott's. Now y'all can work completely independently, without any contention for a shared resource. **BUT**, the cost per communication is **MUCH** higher (you have to scootch your tables together), and you need the ability to split up (***decompose***) the puzzle pieces reasonably evenly, which may be tricky to do for some puzzles.
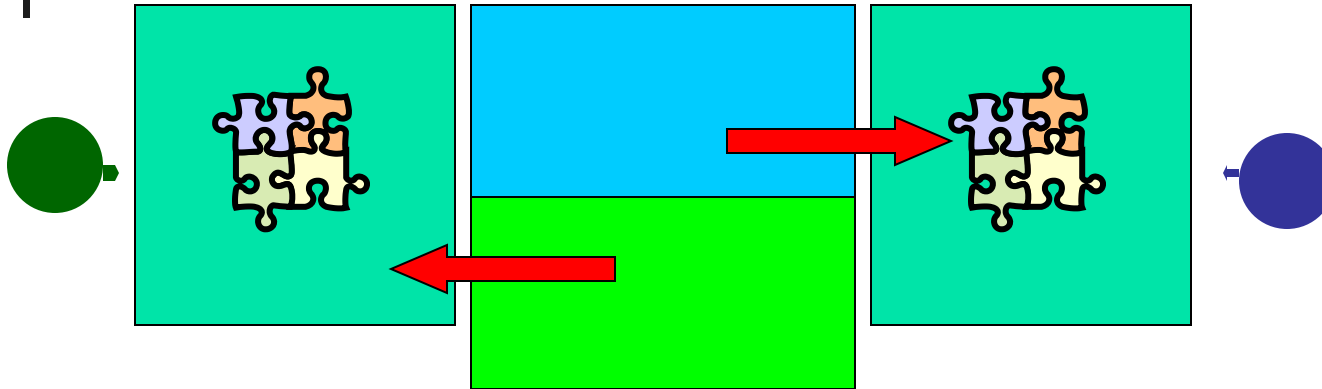
More Distributed Processors
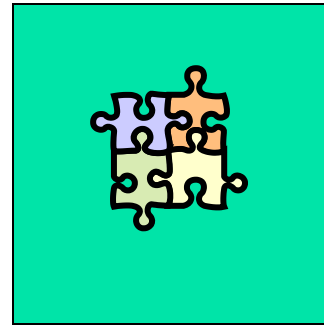
It's a lot easier to add more processors in distributed parallelism. But, you always have to be aware of the need to decompose the problem and to communicate among the processors. Also, as you add more processors, it may be harder to **_load balance_** the amount of work that each processor gets.
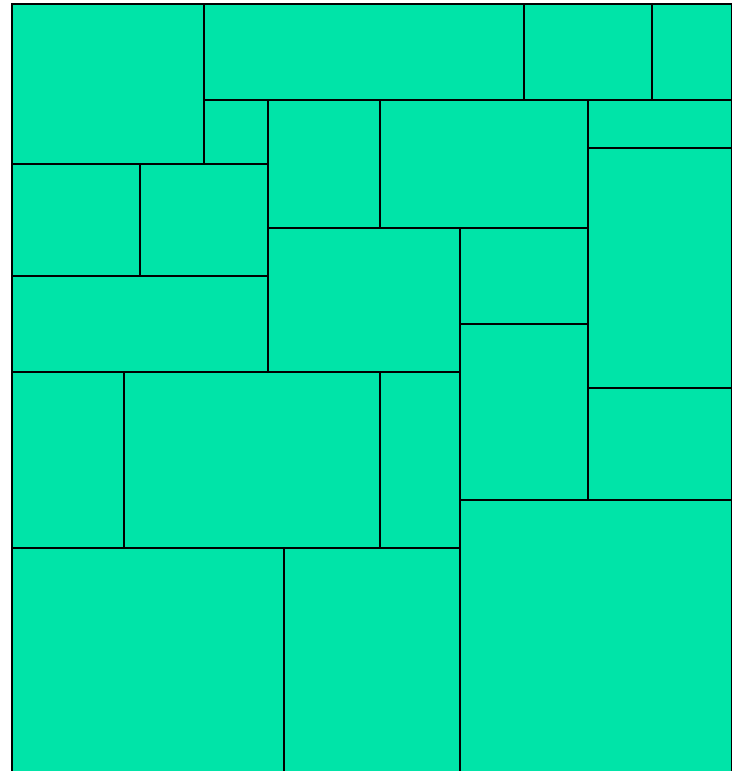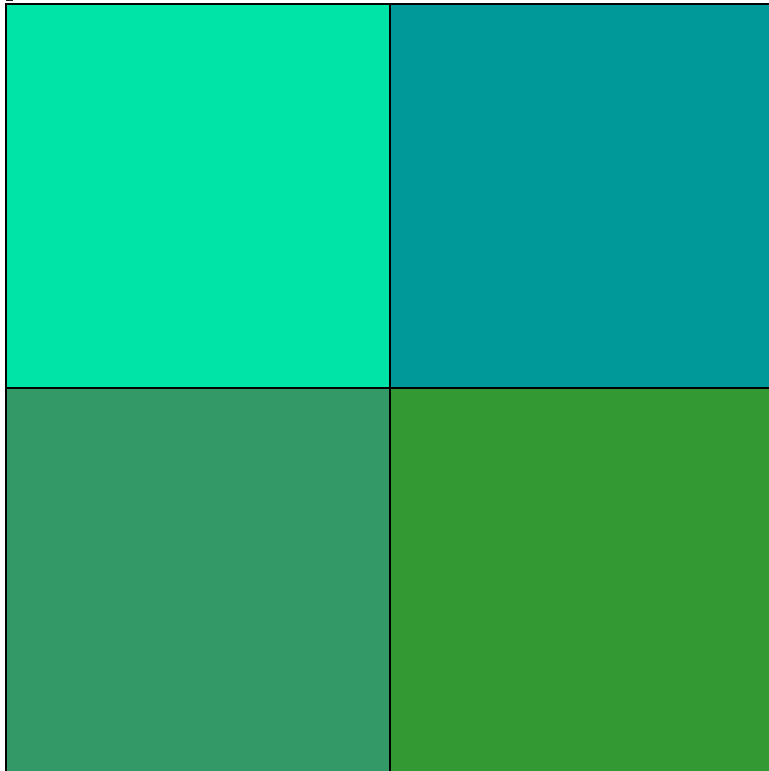
Load Balancing

Load balancing means ensuring that everyone completes their workload at roughly the same time.

For example, if the jigsaw puzzle is half grass and half sky, then you can do the grass and Scott can do the sky, and then y'all only have to communicate at the horizon – and the amount of work that each of you does on your own is roughly equal. So you'll get pretty good speedup.
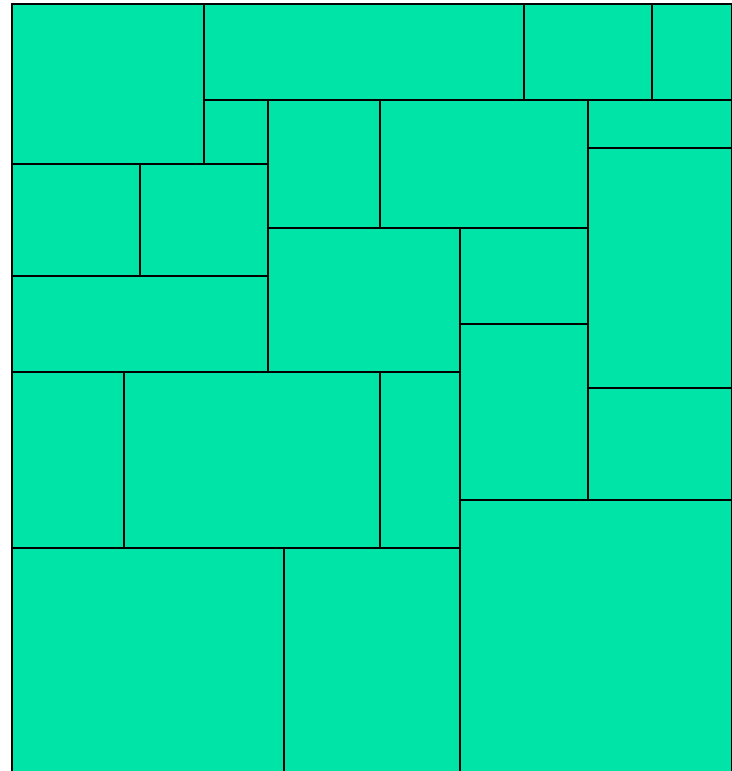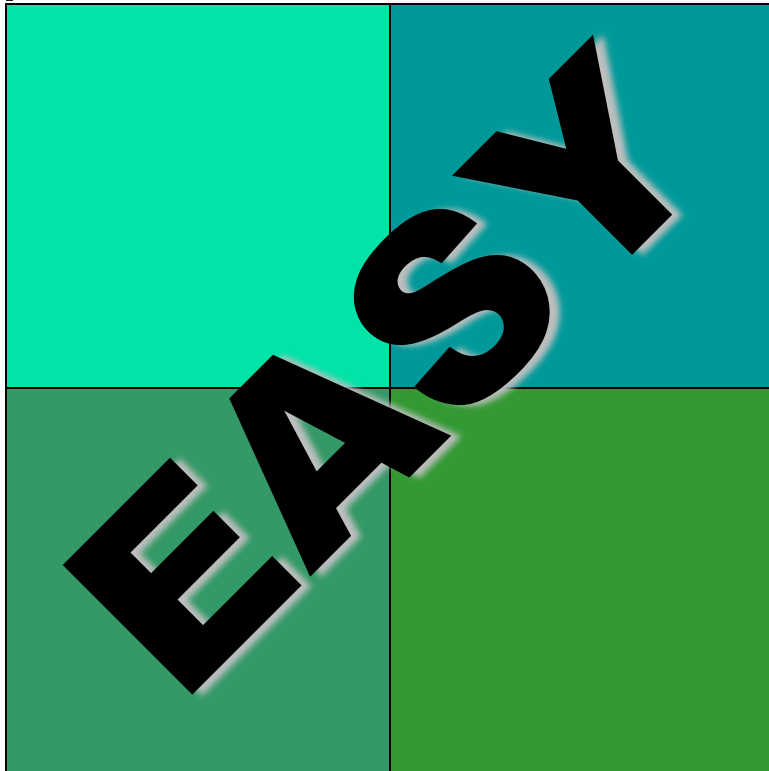
Load Balancing

Load balancing can be easy, if the problem splits up into chunks of roughly equal size, with one chunk per processor. Or load balancing can be very hard.
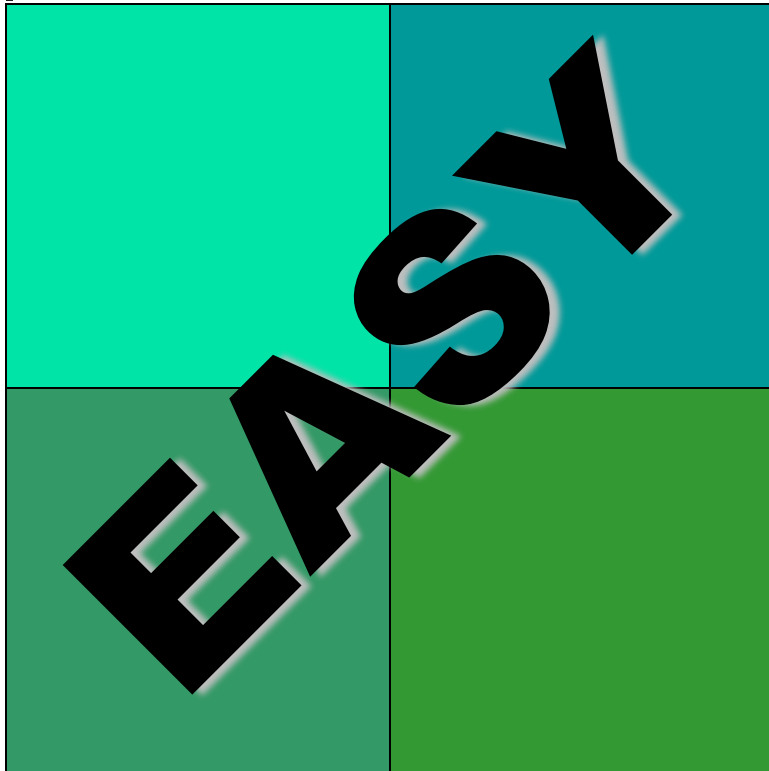
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Moore's Law

Moore's Law

In 1965, Gordon Moore was an engineer at Fairchild Semiconductor.

He noticed that the number of transistors that could be squeezed onto a chip was doubling about every 18 months.

It turns out that computer speed is roughly proportional to the number of transistors per unit area.
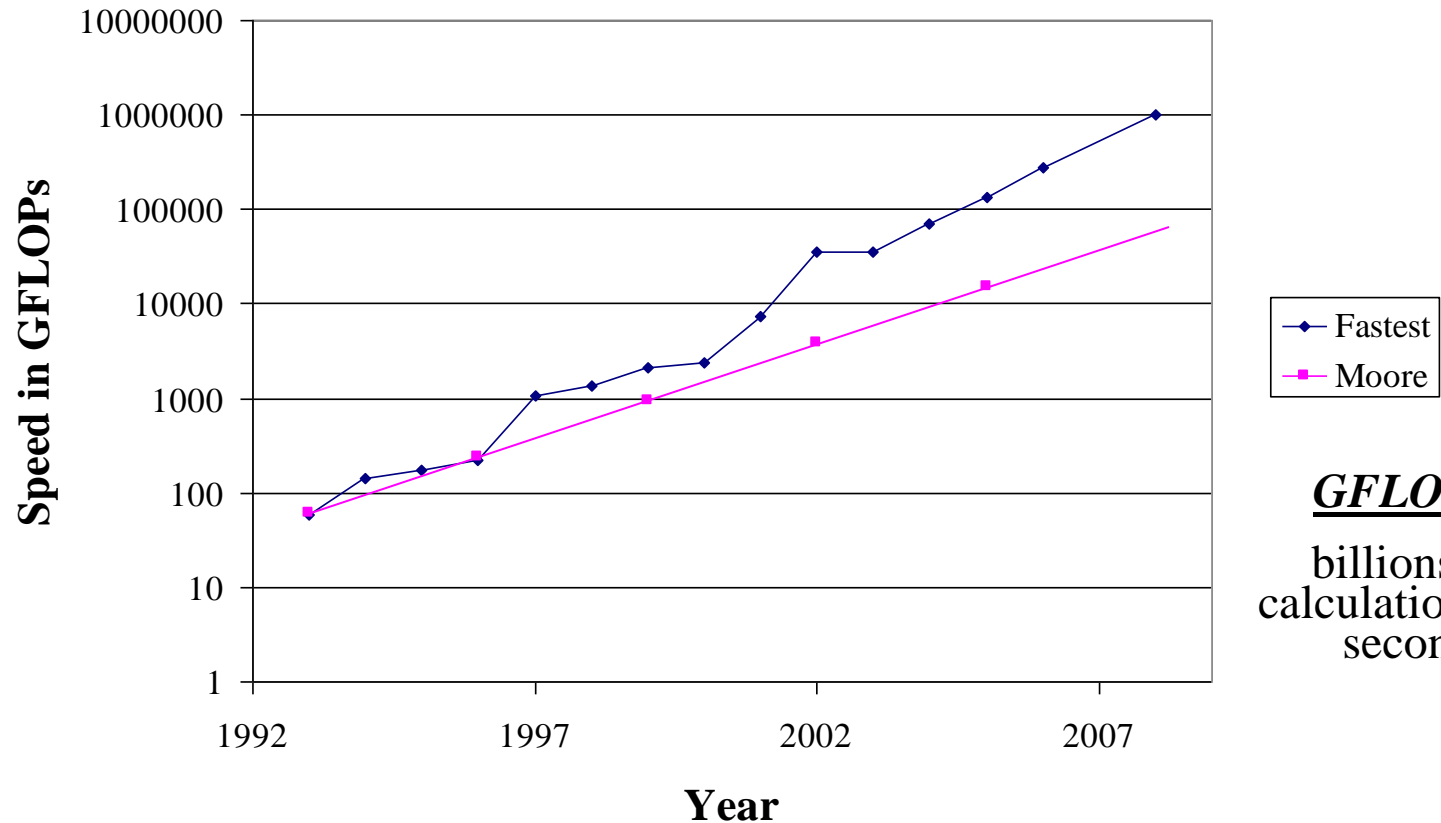
Moore wrote a paper about this concept, which became known as _**"Moore's Law."**_
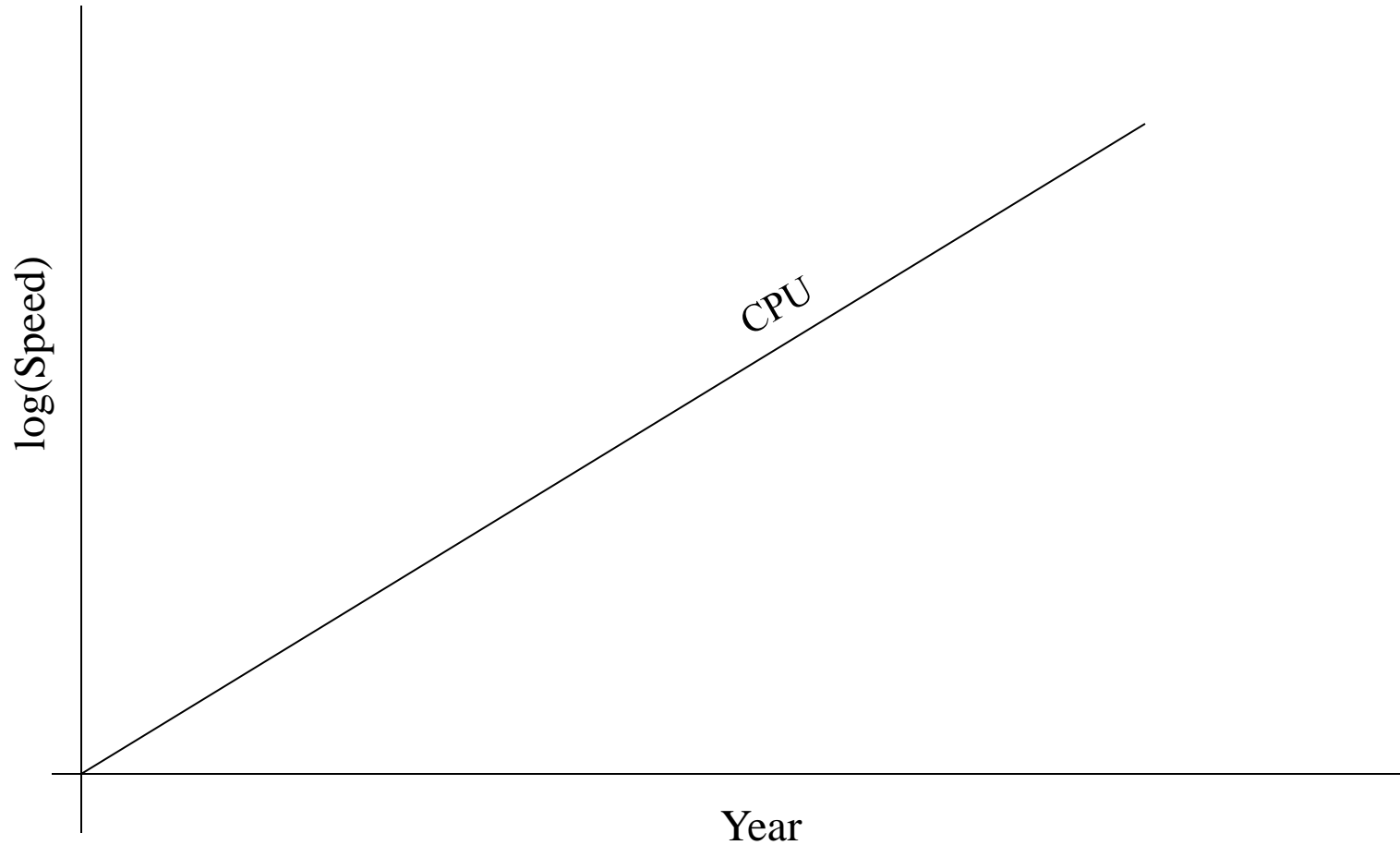
Fastest Supercomputer vs. Moore

Fastest Supercomputer in the World

***GFLOPs*:**

billions of calculations per second

Moore's Law in Practice

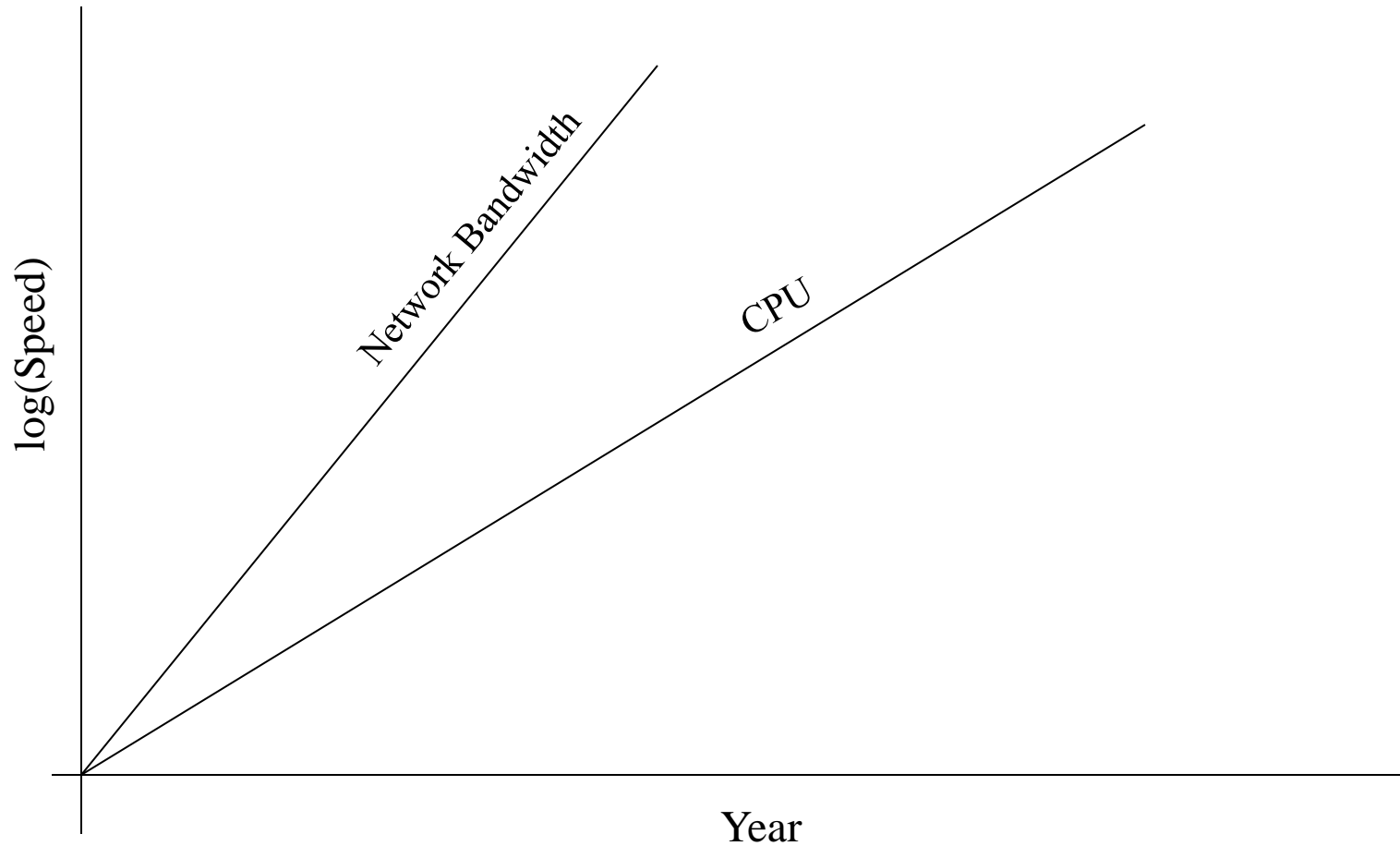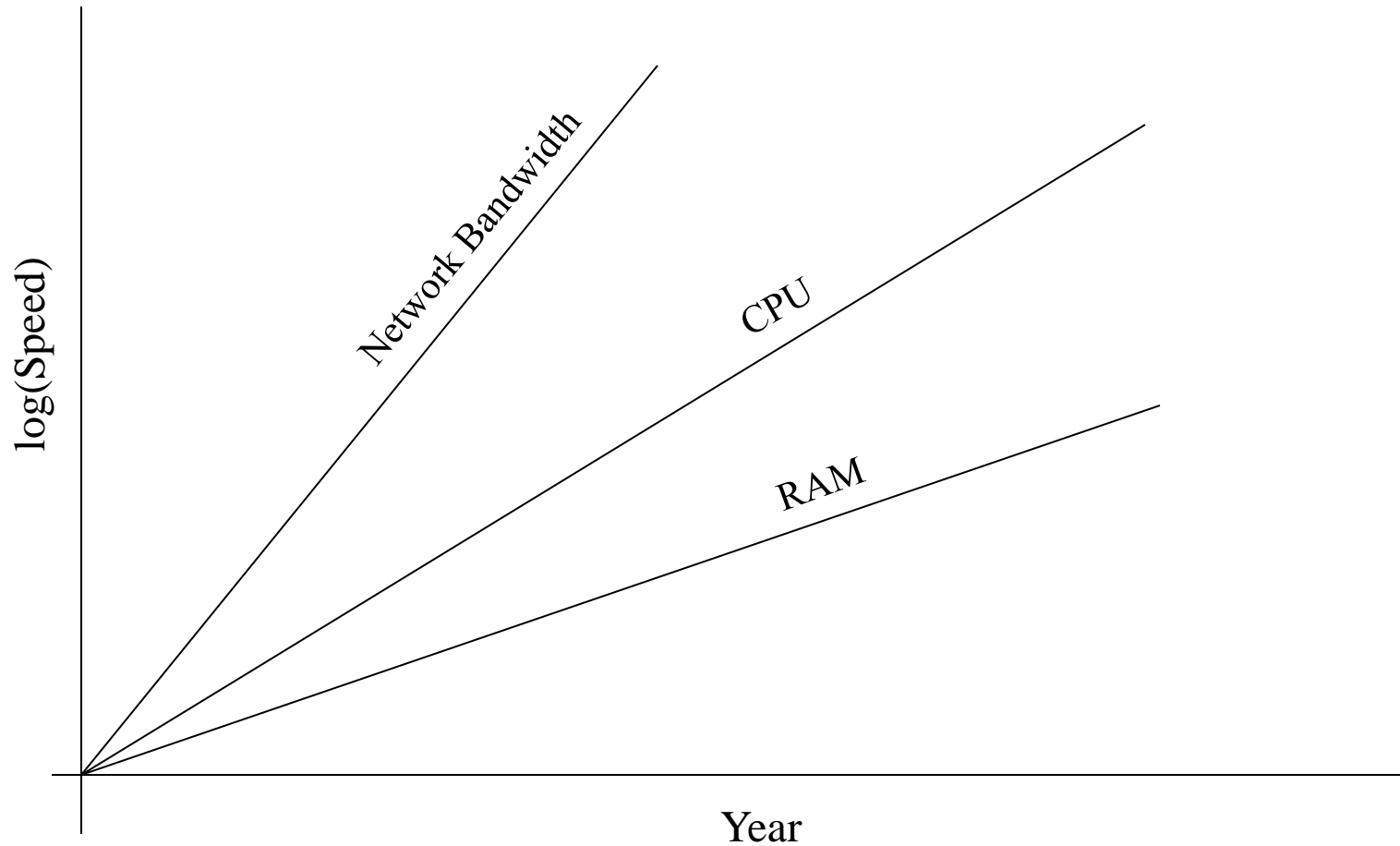log(Speed) vs. Year graph showing CPU as a straight increasing line.

Moore's Law in Practice

Moore's Law in Practice

Moore's Law in Practice

Graph with y-axis labeled "log(Speed)" and x-axis labeled "Year", showing lines from steepest to shallowest: Network Bandwidth, CPU, RAM, 1/Network Latency.
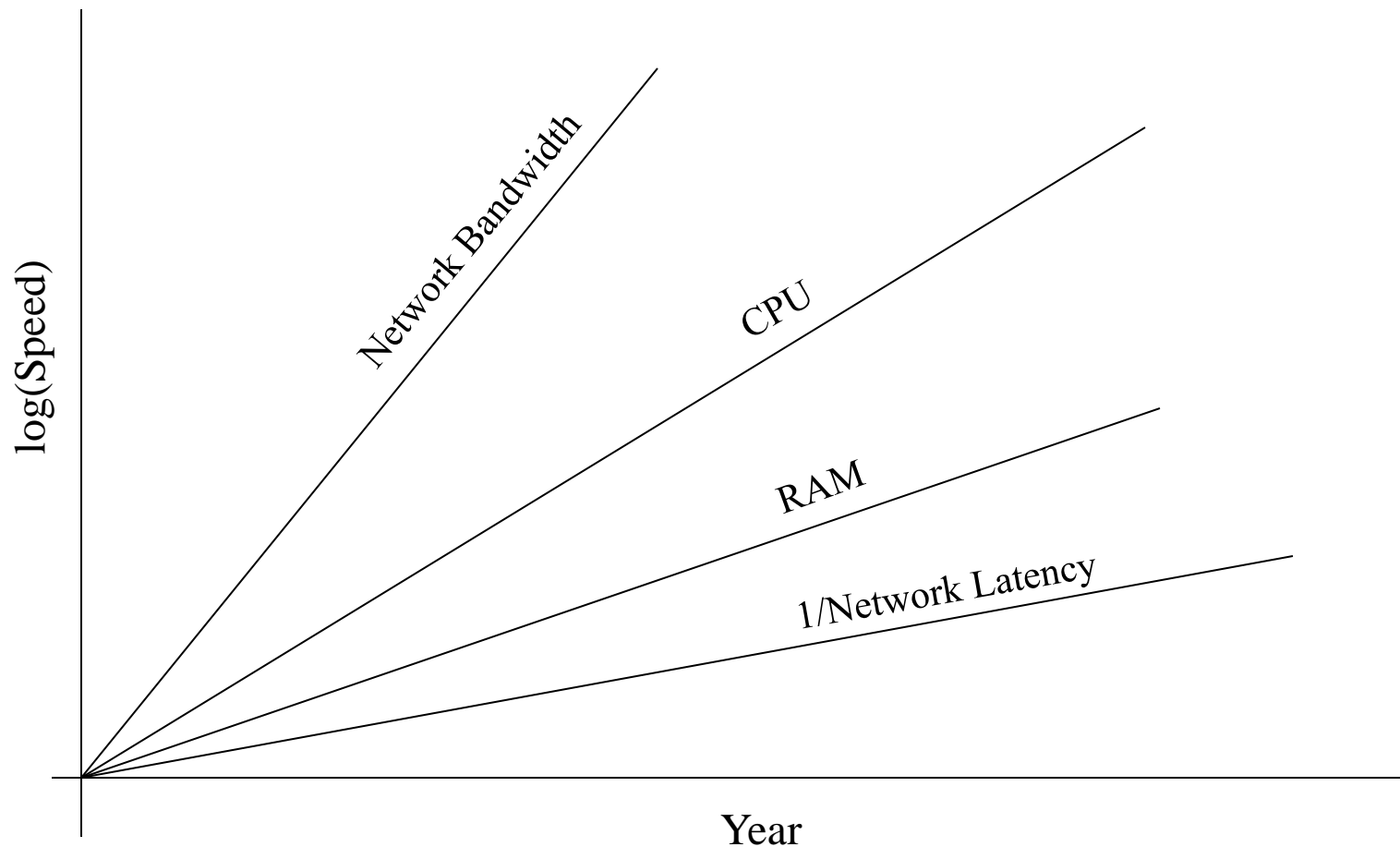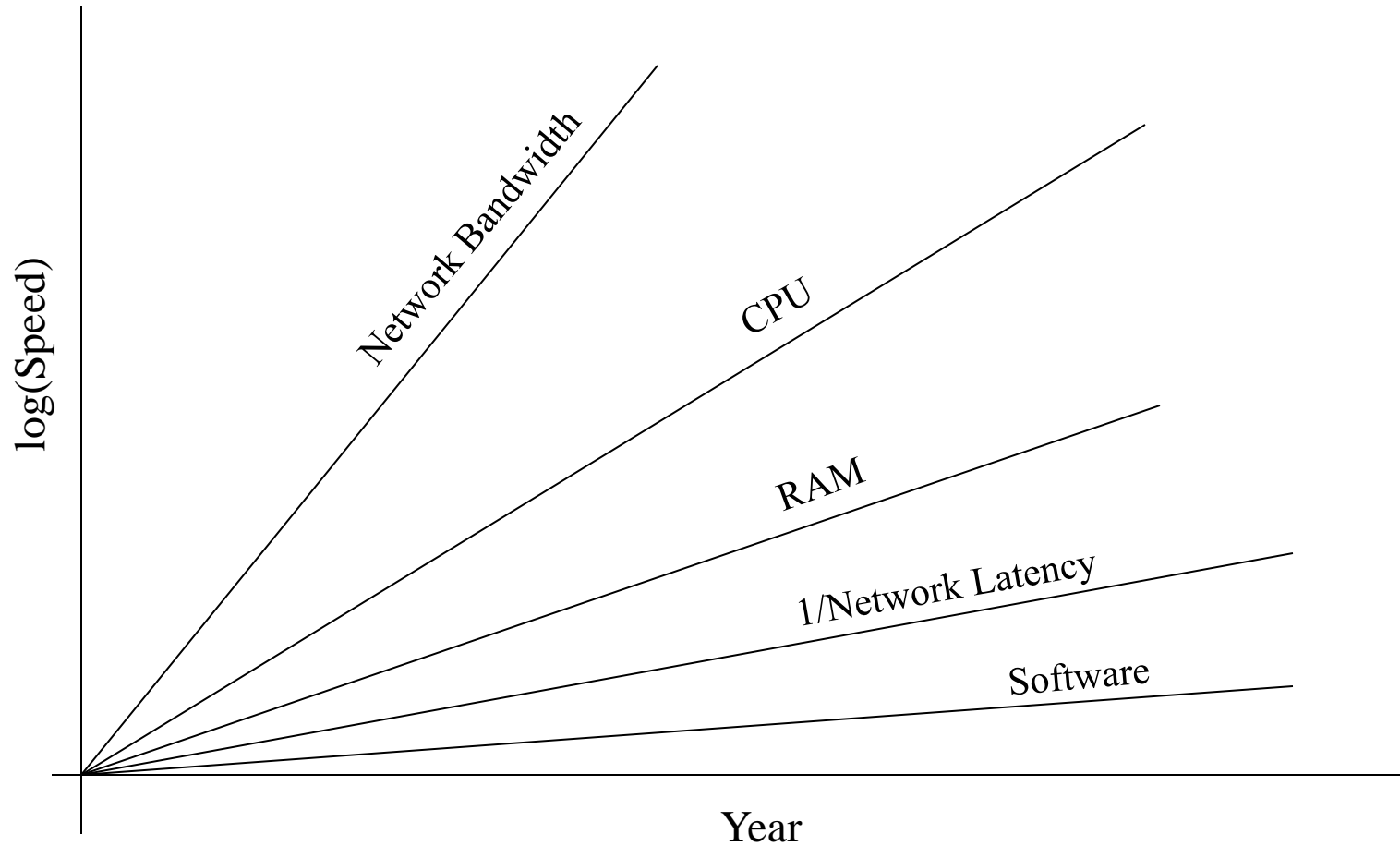
Moore's Law in Practice

Why Bother?

Why Bother with HPC at All?

It's clear that making effective use of HPC takes quite a bit of effort, both learning how and developing software.

That seems like a lot of trouble to go to just to get your code to run faster.

It's nice to have a code that used to take a day, now run in an hour. But if you can afford to wait a day, what's the point of HPC?

Why go to all that trouble just to get your code to run faster?

Why HPC is Worth the Bother

- What HPC gives you that you won't get elsewhere is the ability to do **bigger, better, more exciting science**. If your code can run faster, that means that you can tackle much bigger problems in the same amount of time that you used to need for smaller problems.

- HPC is important not only for its own sake, but also because what happens in HPC today will be on your desktop in about 10 to 15 years: it puts you **ahead of the curve**.

The Future is Now

Historically, this has always been true:

> **Whatever happens in supercomputing today will be on your desktop in 10 – 15 years.**

So, if you have experience with supercomputing, you'll be ahead of the curve when things get to the desktop.

Thanks for your attention!

Questions?
www.oscer.ou.edu

References

[1] Image by Greg Bryan, Columbia U.

[2] "Update on the Collaborative Radar Acquisition Field Test (CRAFT): Planning for the Next Steps."
  Presented to NWS Headquarters August 30 2001.

[3] See `http://hneeman.oscer.ou.edu/hamr.html` for details.

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[5] `http://www.vw.com/newbeetle/`

[6] Richard Gerber, The Software Optimization Cookbook: High-performance Recipes for the Intel
Architecture. Intel Press, 2002, pp. 161-168.

[7] RightMark Memory Analyzer. `http://cpu.rightmark.org/`

[8] `ftp://download.intel.com/design/Pentium4/papers/24943801.pdf`

[9] `http://www.samsungssd.com/meetssd/techspecs`

[10] `http://www.samsung.com/Products/OpticalDiscDrive/SlimDrive/OpticalDiscDrive_SlimDrive_SN_S082D.asp?page=Specifications`

[11] `ftp://download.intel.com/design/Pentium4/manuals/24896606.pdf`

[12] `http://www.pricewatch.com/`