Clustering 101

Rocks-A-Palooza I

Track 1

Session I

SDSC

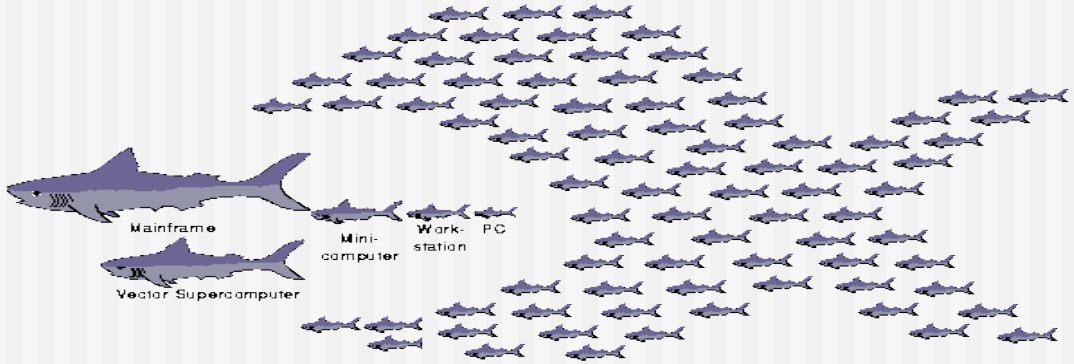
Ground Rules

- Interrupt me!
  - If you have a question and need more information
  - Would like me to go into more detail, or skip over some material
  - I already know this stuff
- Tell me to slow down
  - I tend to talk very fast
  - We have about 200 slides to go through (in six hours)
    - But we will skip some, and other are very short
    - We have plenty of time
    - Last session will be unstructured (you've been warned)
- I don't have to use my slides
  - This workshop is for you
  - Other topics are welcome (but also see track2)
- Tomorrow we will go over some of Track2

Introduction

A brief introduction to clustering and Rocks

Brief History of Clustering
(very brief)



NOW

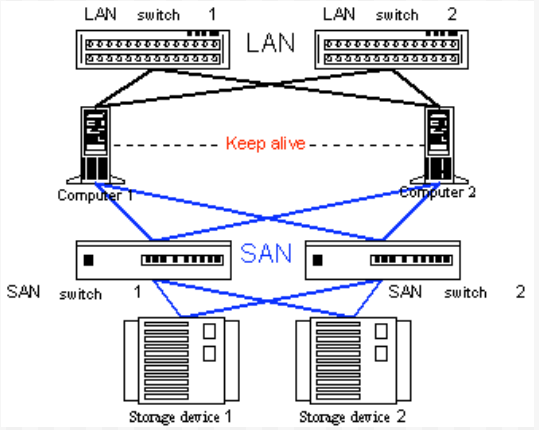
- NOW pioneered the vision for clusters of commodity processors.
  - David Culler (UC Berkeley) started early 90's
  - SunOS / SPARC
  - First generation of Myrinet, active messages
  - Glunix (Global Unix) execution environment
- Beowulf popularized the notion and made it very affordable.
  - Tomas Sterling, Donald Becker (NASA)
  - Linux

Definition: Beowulf

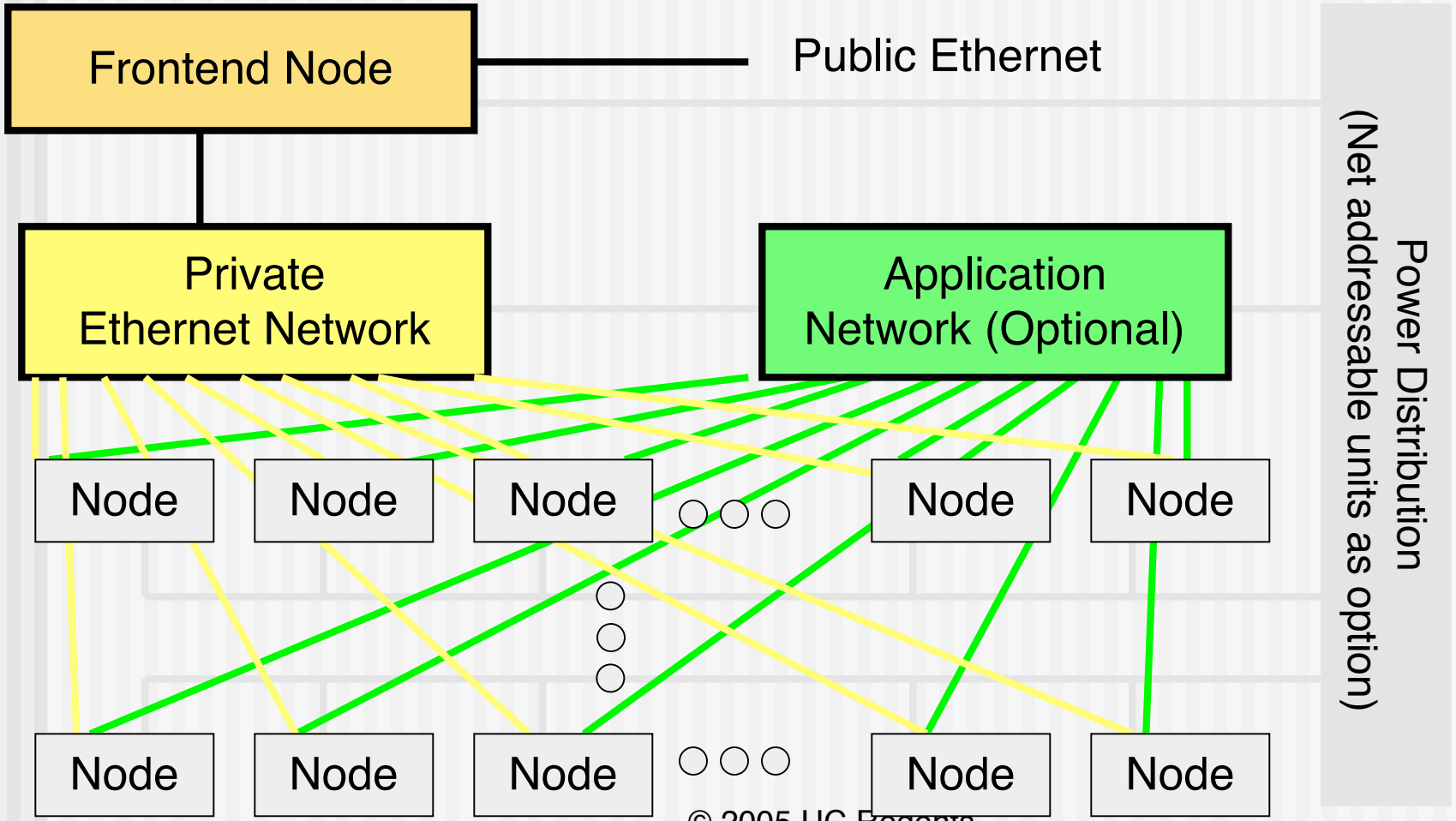
- Collection of *commodity PCs* running an *opensource* operating system with a *commodity network*
- Network is usually Ethernet, although non-commodity networks are sometimes called Beowulfs
- Come to mean any Linux cluster
- www.beowulf.org

Types of Clusters

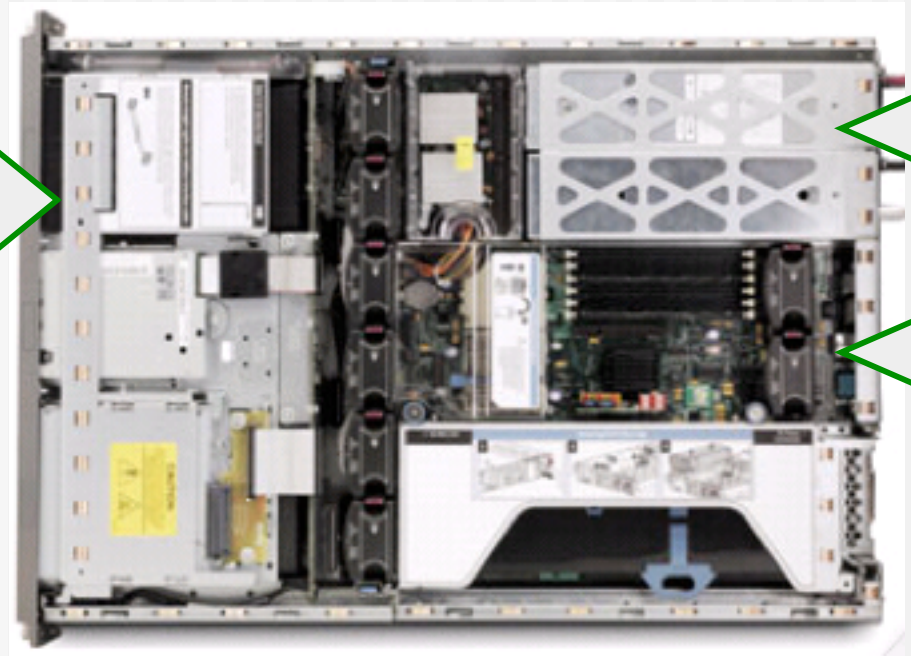
- Highly Available (HA)
  - Generally small, less than 8 nodes
  - Redundant components
  - Multiple communication paths
  - This is not Rocks
- Visualization Clusters
  - Each node drives a display
  - OpenGL machines
  - This is not core Rocks
  - But, there is a Viz Roll
- Computing (HPC Clusters)
  - AKA Beowulf
  - This is the core of Rocks



Definition: HPC Cluster Architecture



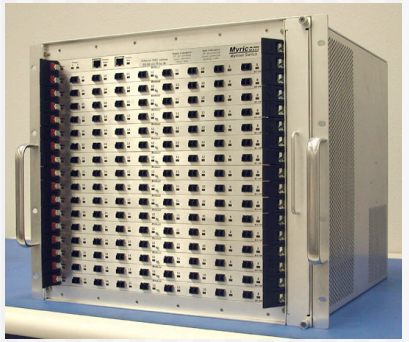
Minimum Components



i386 (Pentium/Athlon)
x86_64 (Opteron/EM64T)
ia64 (Itanium) server

Optional Components

- High-performance network
  - Myrinet
  - Infiniband (Infinicon or Voltaire)
- Network-addressable power distribution unit
- Keyboard/video/mouse network not required
  - Non-commodity
  - How do you manage your management network?

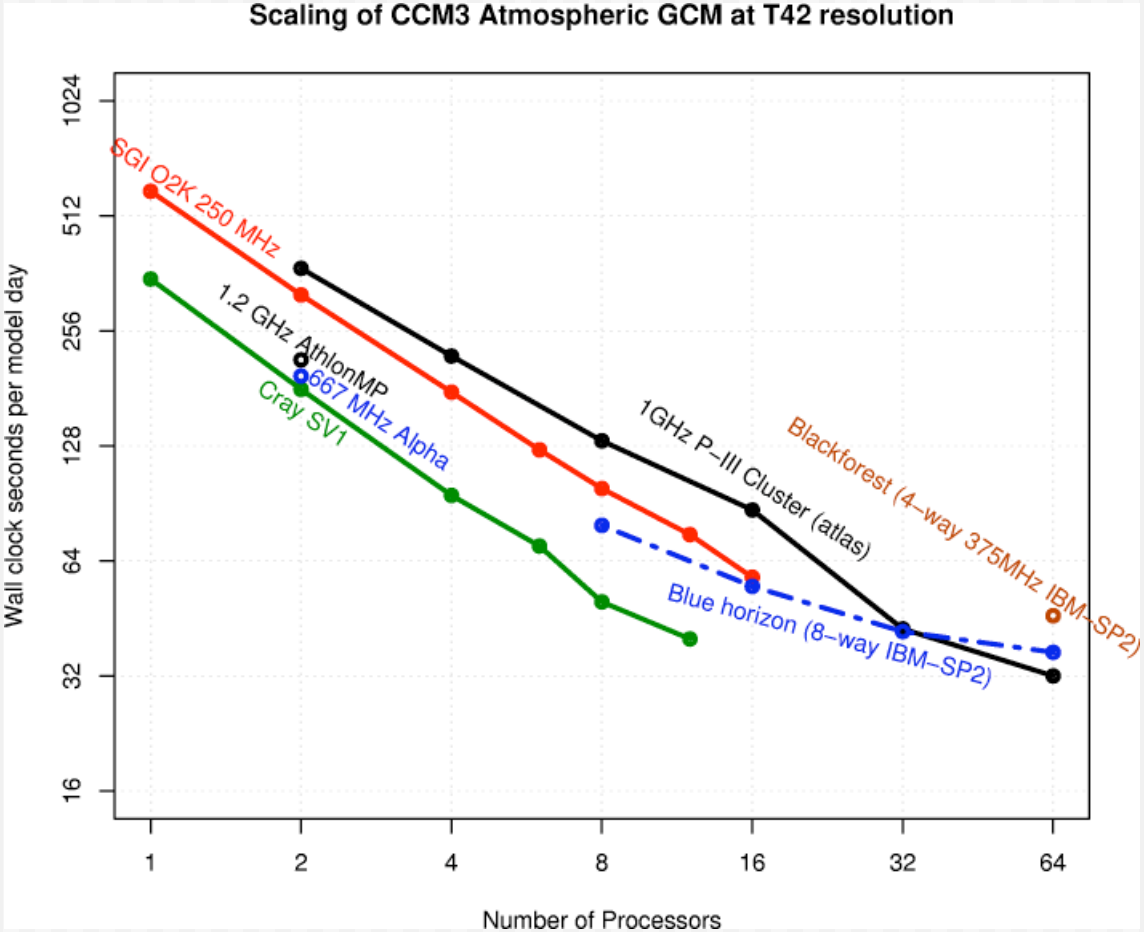


Cluster Pioneers

- In the mid-1990s, Network of Workstations project (UC Berkeley) and the Beowulf Project (NASA) asked the question:

Can You Build a High Performance Machine From Commodity Components?

The Answer is: Yes



Source: Dave Pierce, SIO

Case Scenario

What does 128-node cluster look like?

128 Node cluster

- Frontend
  - Dual-Processor (e.g. Xeon/Opteron 2.8Ghz)
  - 2GB RAM
  - Dual On board Gigabit Ethernet
  - 360 GB Storage (2 x 180 SATA Drives)
  - CDROM & Floppy
  - On board video
- Compute Nodes
  - Dual-Processor
  - 2GB RAM
  - Dual On board Gigabit Ethernet
  - 120 GB Storage
  - CDROM
  - On board video

Additional Components

- Machine Racks
- Power
  - Network addressable power units
  - Power cords
- Network
  - 48 Port gigabit Ethernet switches
  - CAT5e cables
- VGA monitor, PC101 keyboard, mouse

SPEC Benchmark

Processor	GHz	SPECint	SPECfp	Price
Athlon 64 FX-55	2.6	1854	1878	810
Pentium 4 EE	3.7	1796	2016	1075
Opteron 252	2.6	1796	2045	825
Pentium 4 Xeon	3.6	1718	1825	935
Itanium 2	1.6	1590	2712	2400
PowerPC	2.2	1040	1241	????

ROCKS

Processors

Itanium 2

PowerPC 970

Itanium 2

PowerPC 970

Pentium 4

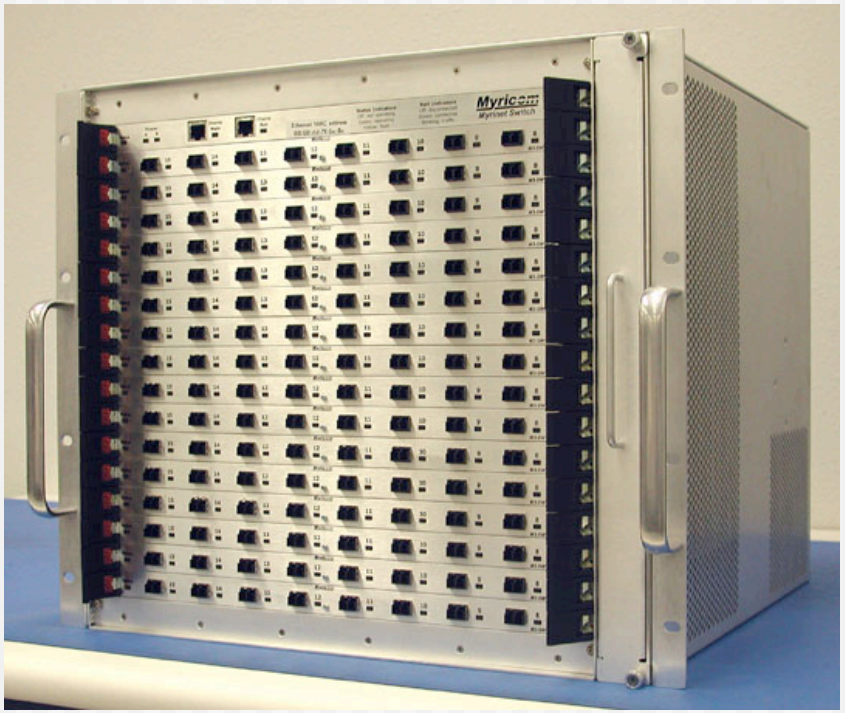
1	IBM/DOE United States/2004	*BlueGene/L beta-System* **BlueGene/L DD2 beta-System (0.7 GHz PowerPC 440)** / 32768 IBM	70720 91750
2	NASA/Ames Research Center/NAS United States/2004	*Columbia* **SGI Altix 1.5 GHz, Voltaire Infiniband** / 10160 SGI	51870 60960
3	The Earth Simulator Center Japan/2002	**Earth-Simulator** / 5120 NEC	35860 40960
4	Barcelona Supercomputer Center Spain/2004	*MareNostrum* **eServer BladeCenter JS20 (PowerPC970 2.2 GHz), Myrinet** / 3564 IBM	20530 31363
5	Lawrence Livermore National Laboratory United States/2004	*Thunder* **Intel Itanium2 Tiger4 1.4GHz - Quadrics** / 4096 California Digital Corporation	19940 22938
6	Los Alamos National Laboratory United States/2002	*ASCI Q* **ASCI Q - AlphaServer SC45, 1.25 GHz** / 8192 HP	13880 20480
7	Virginia Tech United States/2004	*System X* **1100 Dual 2.3 GHz Apple XServe/Mellanox Infiniband 4X/Cisco GigE** / 2200 Self-made	12250 20240
8	IBM - Rochester United States/2004	**BlueGene/L DD1 Prototype (0.5GHz PowerPC 440 w/Custom)** / 8192 IBM/ LLNL	11680 16384
9	Naval Oceanographic Office (NAVOCEANO) United States/2004	**eServer pSeries 655 (1.7 GHz Power4+)** / 2944 IBM	10310 20019.2
10	NCSA United States/2003	*Tungsten* **PowerEdge 1750, P4 Xeon 3.06 GHz, Myrinet** / 2500 Dell	9819 15300

Interconnects

- Weak interconnect
  - Gigabit Ethernet
- Strong interconnect
  - Myrinet ($1000 / port)
  - Fibre Channel ($1500 / port)
- Dual Xeon compute node
  - Node cost $2000
  - All of the above interconnects = $2500
- One of the surprising, but often essential, costs of a cluster

Myrinet

- Long-time interconnect vendor
  - Delivering products since 1995
- Deliver single 128-port full bisection bandwidth switch
- Performance:
  - Latency: 6.7 us
  - Bandwidth: 245 MB/s
  - Cost/port (based on 64-port configuration): $1000
    - Switch + NIC + cable
    - http://www.myri.com/myrinet/product_list.html



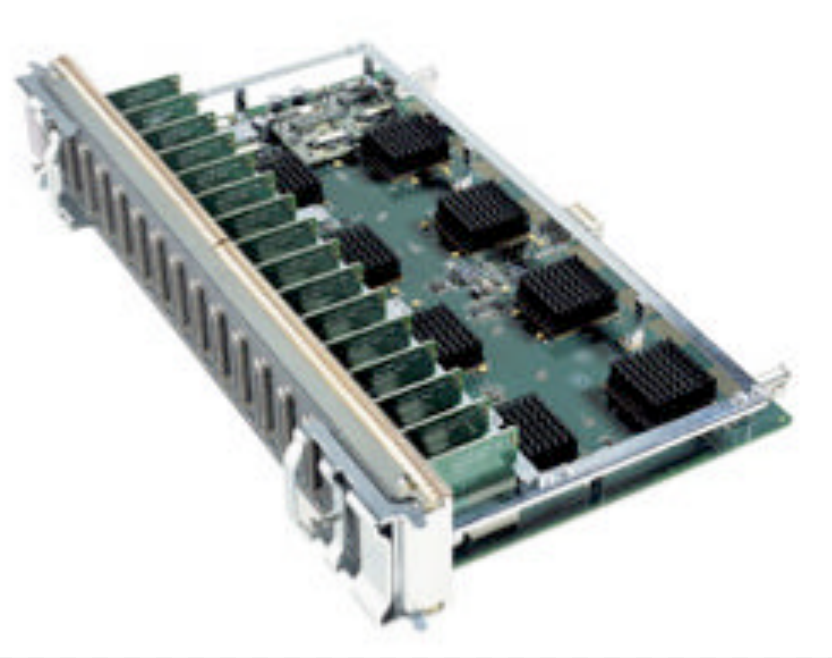
Myrinet

4	**NCSA** United States/2003	*Tungsten* **PowerEdge 1750, P4 Xeon 3.06 GHz, Myrinet** / 2500 Dell	9819 15300

- #4 System on Top500 list
- System sustains 64% of peak performance
  - But smaller systems hit 70-75% of peak

Quadrics

- QsNetII E-series
  - Released at the end of May 2004
- Deliver 128-port standalone switches
- Performance:
  - Latency: 3 us
  - Bandwidth: 900 MB/s
  - Cost/port (based on 64-port configuration): $1800
    - Switch + NIC + cable
    - http://doc.quadrics.com/Quadrics/QuadricsHome.nsf/DisplayPages/A3EE4AED738B6E2480256DD30057B227



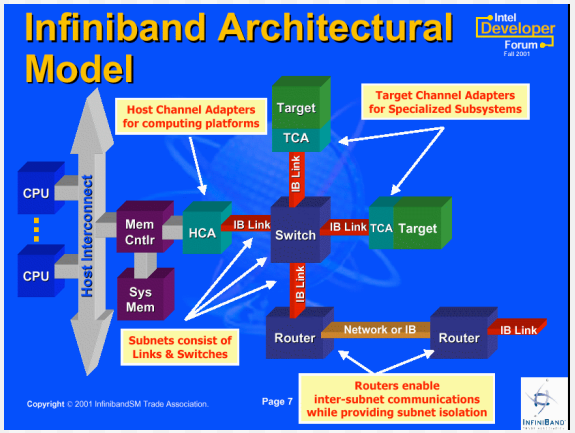
Quadrics

5	**Pacific Northwest National Laboratory** United States/2003	*Mpp2* **Integrity rx2600 Itanium2 1.5 GHz, Quadrics** / 1936 HP	8633 11616

- #5 on Top500 list
- Sustains 74% of peak
  - Other systems on Top500 list sustain 70-75% of peak

Infiniband

- Newest interconnect
- Currently shipping 32-port switches
  - Requires 20 switches to support a full bisection bandwidth network for 128 nodes
- Performance:
  - Latency: 6.8 us
  - Bandwidth: 840 MB/s
  - Estimated cost/port (based on 64-port configuration): $1700 - 3000
    - Switch + NIC + cable
    - http://www.techonline.com/community/related_content/24364



Infiniband

3	**Virginia Tech** United States/2003	*X* **1100 Dual 2.0 GHz Apple G5/Mellanox Infiniband 4X/Cisco GigE** / 2200 Self-made	10280 17600

- #3 on Top500 list
- Sustained 58% of peak
  - The other 2 Infiniband machines on Top500 list achieved 64% and 68%

Ethernet

- Latency: 80 us
- Bandwidth: 100 MB/s
- Top500 list has ethernet-based systems sustaining between 35-59% of peak

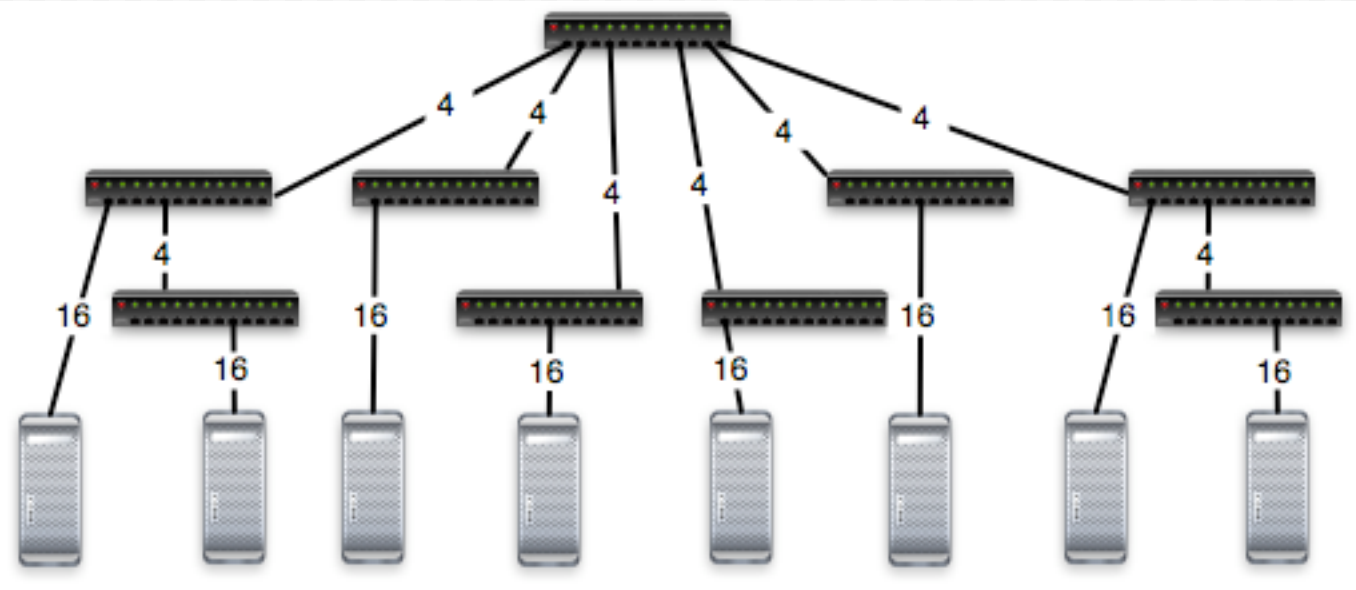
Ethernet

- What we did with 128 nodes and a $13,000 ethernet network
  - $101 / port
  - Sustained 48% of peak

201	UCSD/Cal-IT^2/SDSC United States/2003	**Rocks V60x Cluster 2.8 GHz, Gig Ethernet** / 256 Sun	699 1433.6

- With Myrinet, would have sustained 1 Tflop
  - At a cost of ~$130,000
    - Roughly 1/3 the cost of the system

Rockstar Topology

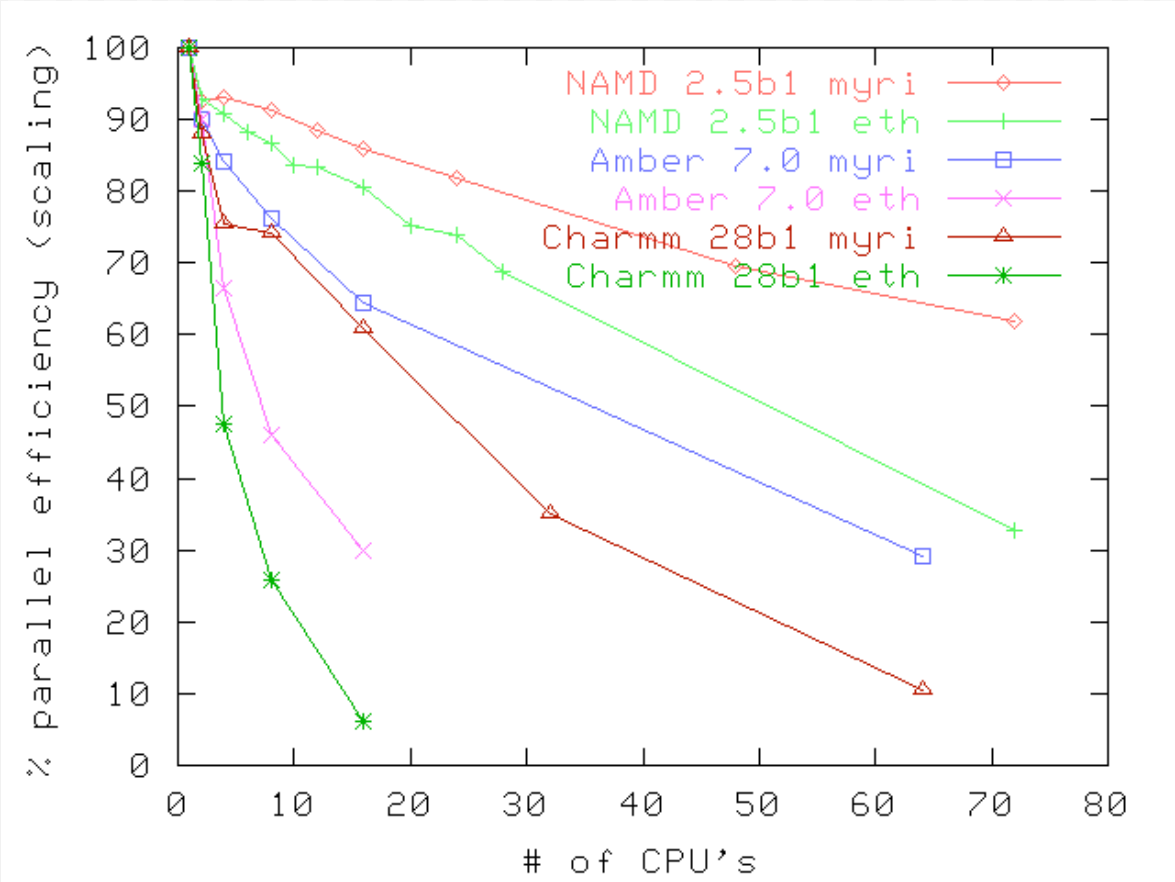


- 24-port switches
- Not a symmetric network
  - Best case - 4:1 bisection bandwidth
  - Worst case - 8:1
  - Average - 5.3:1

Low Latency Ethernet

- Bring os-bypass to Ethernet
- Projected performance:
  - Latency: less than 20 us
  - Bandwidth: 100 MB/s
- Potentially could merge management and high-performance networks
- Vendor “Ammasso”

Sample Application Benifits



Interconnect Observations

- If your application can tolerate latency, then Ethernet will deliver the best bang for the buck.
- Myrinet, Quadrics and Infiniband all have excellent low latency properties
- Myrinet delivers 2x bandwidth over Ethernet
- Quadrics and Infiniband deliver 2x bandwidth over Myrinet

Details

	Size	Unit Cost	Total Cost
Compute Nodes	128	2000	$ 256,000
Frontend Nodes	1	3000	$ 3,000
Total Node Count	129		
Racks	5	800	$ 4,000
Ethernet Switches	5	900	$ 4,500
Power Cords	135	0	$ -
Network Cables	130	5	$ 650
Power Strips	17	100	$ 1,700
Crash Cart	1	300	$ 300
Total Hardware Cost			$ 270,150

Add KVM

	Size	Unit Cost	Total Cost
Compute Nodes	128	2000	$ 256,000
Frontend Nodes	1	3000	$ 3,000
Total Node Count	129		
Racks	5	800	$ 4,000
Ethernet Switches	5	900	$ 4,500
Power Cords	135	0	$ -
Network Cables	130	5	$ 650
Power Strips	17	100	$ 1,700
Crash Cart	1	300	$ 300
KVM Cables	129	50	$ 6,450
KVM Switch	9	1000	$ 9,000
Total Hardware Cost			$ 285,600

- $15K USD additional cost (~ 5%)
- KVM's are low volume networks that will require management. Are they worth it?

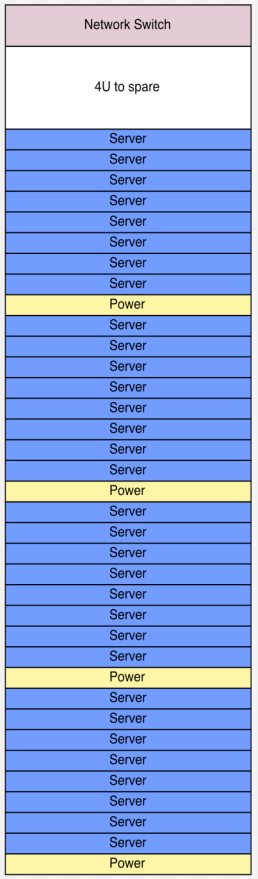
Add Myrinet

	Size	Unit Cost	Total Cost
Compute Nodes	128	2000	$ 256,000
Frontend Nodes	1	3000	$ 3,000
Total Node Count	129		
Racks	5	800	$ 4,000
Ethernet Switches	5	900	$ 4,500
Power Cords	135	0	$ -
Network Cables	130	5	$ 650
Power Strips	17	30	$ 510
Crash Cart	1	300	$ 300
Myrinet NIC	128	500	$ 64,000
Myrinet Cables	128	100	$ 12,800
Myrinet Switch	1	30000	$ 30,000
Total Hardware Cost			$ 375,760

- Added $100K USD. ~ 33% of complete system
- Often essential to get codes to scale

1U Servers

- 128 Processors
- 6 electrical circuits
- Cable count
  - 65 = power & network
  - 97 with Myrinet
  - 193 with KVM
  - 225 with Serial Port management



Cluster Software Space

Rocks is not alone

Other efforts

Where Rocks fits

The Dark Side of Clusters

- Clusters are phenomenal price/performance computational engines …
  - Can be hard to manage without experience
  - High-performance I/O is still unsolved
  - Finding out where something has failed increases at least linearly as cluster size increases
- Not cost-effective if every cluster “burns” a person just for care and feeding
- Programming environment could be vastly improved
- Technology is changing very rapidly. Scaling up is becoming commonplace (128-256 nodes)

The Top 2 Most Critical Problems

- The largest problem in clusters is *software skew*
  - When software configuration on some nodes is different than on others
  - Small differences (minor version numbers on libraries) can cripple a parallel program
- The second most important problem is adequate job control of the parallel process
  - Signal propagation
  - Cleanup

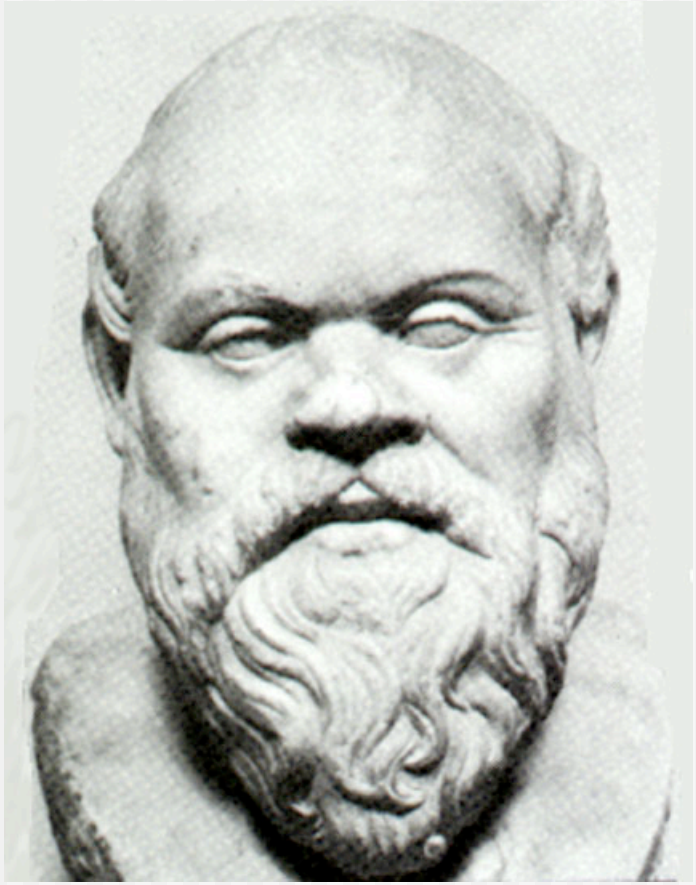
Rocks (open source clustering distribution)

www.rocksclusters.org

- Technology transfer of commodity clustering to application scientists
  - "make clusters easy"
  - Scientists can build their own supercomputers and migrate up to national centers as needed
- Rocks is a cluster on a CD
  - Red Enterprise Hat Linux (opensource and free)
  - Clustering software (PBS, SGE, Ganglia, NMI)
  - Highly programmatic software configuration management
- Core software technology for several campus projects
  - BIRN
  - Center for Theoretical Biological Physics
  - EOL
  - GEON
  - NBCR
  - OptIPuter
- First Software release Nov, 2000
- Supports x86, Opteron, Nacona, and Itanium

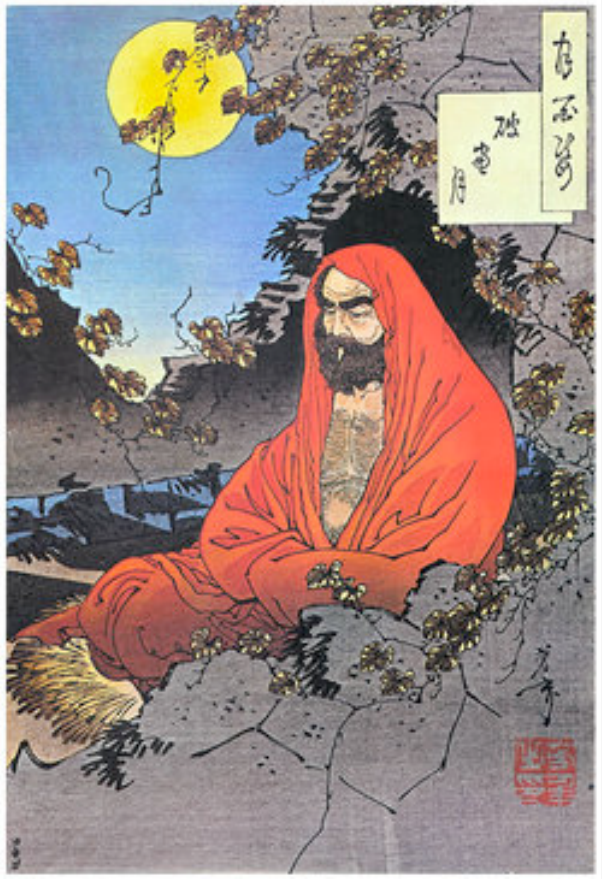
Philosophy

- Caring and feeding for a system is not fun
- System Administrators cost more than clusters
  - 1 TFLOP cluster is less than $200,000 (US)
  - Close to actual cost of a fulltime administrator
- The system administrator is the weakest link in the cluster
  - Bad ones like to tinker
  - Good ones still make mistakes



Philosophy
continued

- All nodes are 100% automatically configured
  - Zero “hand” configuration
  - This includes site-specific configuration
- Run on heterogeneous standard high volume components
  - Use components that offer the best price/performance
  - Software installation and configuration must support different hardware
  - Homogeneous clusters do not exist
  - Disk imaging requires homogeneous cluster



Philosophy
continued

- Optimize for installation
  - Get the system up quickly
  - In a consistent state
  - Build supercomputers in hours not months
- Manage through re-installation
  - Can re-install 128 nodes in under 20 minutes
  - No support for on-the-fly system patching
- Do not spend time trying to issue system consistency
  - Just re-install
  - Can be batch driven
- Uptime in HPC is a myth
  - Supercomputing sites have monthly downtime
  - HPC is not HA

OpenMosix

- Overview
  - Single system image - all nodes look like one large multiprocessor
  - Jobs migrate from machine to machine (based on machine load)
  - No changes required for apps to use system
- Interconnects supported
  - All IP-based networks
- Custom Linux Kernel
  - Download a new kernel
  - Or patch and compile
  - Install kernel on all nodes
- Supports
  - Diskfull
  - Diskless
- Looking for volunteers to create the OpenMosix Roll

Warewulf

- Overview
  - Install frontend first
    - Recommend using RPM-based distribution
  - Imaged based installation
    - “Virtual node filesystem”
  - Attacks problem of generic slave node management
- Standard cluster software not included
  - Added separately
  - Use ‘chroot’ commands to add in extra software
- Supports
  - Diskfull
  - Diskless

Scyld Beowulf

- Single System Image
  - Global process ID
  - Not a global file system
- Heavy OS modifications to support BProc
  - Patches kernel
  - Patches libraries (libc)
- Job start on the frontend and are pushed to compute nodes
  - Hooks remain on the frontend
  - Does this scale to 1000 nodes?
- Easy to install
  - Full distribution
  - Often compared to Rocks

SCore

- Research group started in 1992, and based in Tokyo.
- Score software
  - Semi-automated node integration using RedHat
  - Job launcher similar to UCB's REXEC
  - MPC++, multi-threaded C++ using templates
  - PM, wire protocol for Myrinet
- Development has started on SCore Roll

Scalable Cluster Environment
(SCE)

- Developed at Kasetsart University in Thailand
- SCE is a software suite that includes
  - Tools to install, manage, and monitor compute nodes
    - Diskless (SSI)
    - Diskfull (RedHat)
  - A batch scheduler to address the difficulties in deploying and maintaining clusters
  - Monitoring tools (SCMSWeb)
- User installs frontend with RedHat and adds SCE packages.
- Rocks and SCE are working together
  - Rocks is good at low level cluster software
  - SCE is good at high level cluster software
  - SCE Roll is now available for Rocks

Open Cluster Group
(OSCAR)

- OSCAR is a collection of clustering best practices (software packages)
  - PBS/Maui
  - OpenSSH
  - LAM/MPI
- Image based installation
  - Install frontend machine manually
  - Add OSCAR packages to frontend
  - Construct a “golden image” for compute nodes
  - Install with system imager
  - No Opteron support, Itanium only on RHEL3 AS
- Started as a consortium of industry and government labs
  - NCSA, ORNL, Intel, IBM, Dell, others
  - NCSA, IBM, and Dell have recently left the project

System Imager

- From VA/Linux (used to sell clusters)
- System imaging installation tools
  - Manages the files on a compute node
  - Better than managing the disk blocks
- Use
  - Install a system manually
  - Appoint the node as the golden master
  - Clone the “golden master” onto other nodes
- Problems
  - Doesn’t support heterogeneous
  - Not method for managing the software on the “golden master”

Cfengine

- Policy-based configuration management tool for UNIX or NT hosts
  - Flat ASCII (looks like a Makefile)
  - Supports macros and conditionals
- Popular to manage desktops
  - Patching services
  - Verifying the files on the OS
  - Auditing user changes to the OS
- Nodes pull their Cfengine file and run every night
  - System changes on the fly
  - One bad change kills everyone (in the middle of the night)
- Can help you make changes to a running cluster

Kickstart

- RedHat
  - Automates installation
  - Used to install desktops
  - Foundation of Rocks
- Description based installation
  - Flat ASCII file
  - No conditionals or macros
  - Set of packages and shell scripts that run to install a node

LCFG

- Edinburgh University
  - Anderson and Scobie
- Description based installation
  - Flat ASCII file
  - Conditionals, macros, and statements
    - Full blown (proprietary) language to describe a node
- Compose description file out of components
  - Using file inclusion
  - Not a graph as in Rocks
- Do not use kickstart
  - Must replicate the work of RedHat
- Very interesting group
  - Design goals very close to Rocks
  - Implementation is also similar

Rocks Basic Approach

- Install a frontend
  1. Insert Rocks Base CD
  2. Insert Roll CDs (optional components)
  3. Answer 7 screens of configuration data
  4. Drink coffee (takes about 30 minutes to install)
- Install compute nodes:
  1. Login to frontend
  2. Execute insert-ethers
  3. Boot compute node with Rocks Base CD (or PXE)
  4. Insert-ethers discovers nodes
  5. Goto step 3
- Add user accounts
- Start computing

Optional Rolls

- Condor
- Grid (based on NMI R4)
- Intel (compilers)
- Java
- SCE (developed in Thailand)
- Sun Grid Engine
- PBS (developed in Norway)
- Area51 (security monitoring tools)
- Many Others …

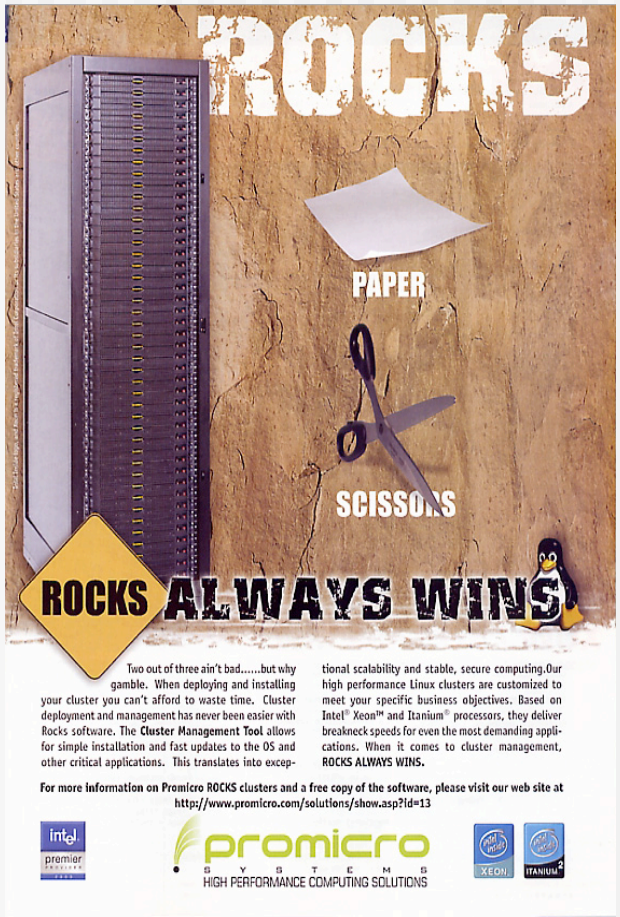
Minimum Requirements

- Frontend
  - 2 Ethernet Ports
  - CDROM
  - 18 GB Disk Drive
  - 512 MB RAM
- Compute Nodes
  - 1 Ethernet Port
  - 18 GB Disk Drive
  - 512 MB RAM
- Complete OS Installation on all Nodes
- No support for Diskless (yet)
- Not a Single System Image
- All Hardware must be supported by RHEL

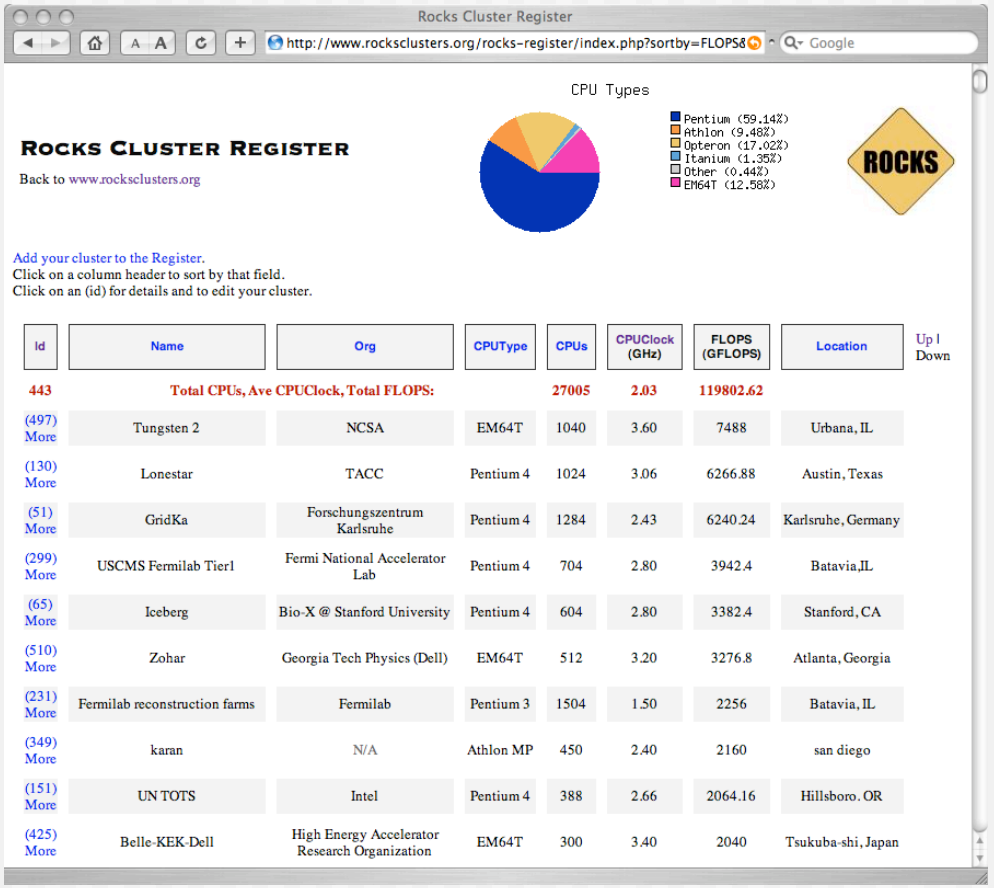
HPCwire Reader's Choice Awards for 2004

- Rocks won in three categories:
  - Most Important Software Innovation (Reader's Choice)
  - Most Important Software Innovation (Editor's Choice)
  - Most Innovative - Software (Reader's Choice)

Commercial Interest

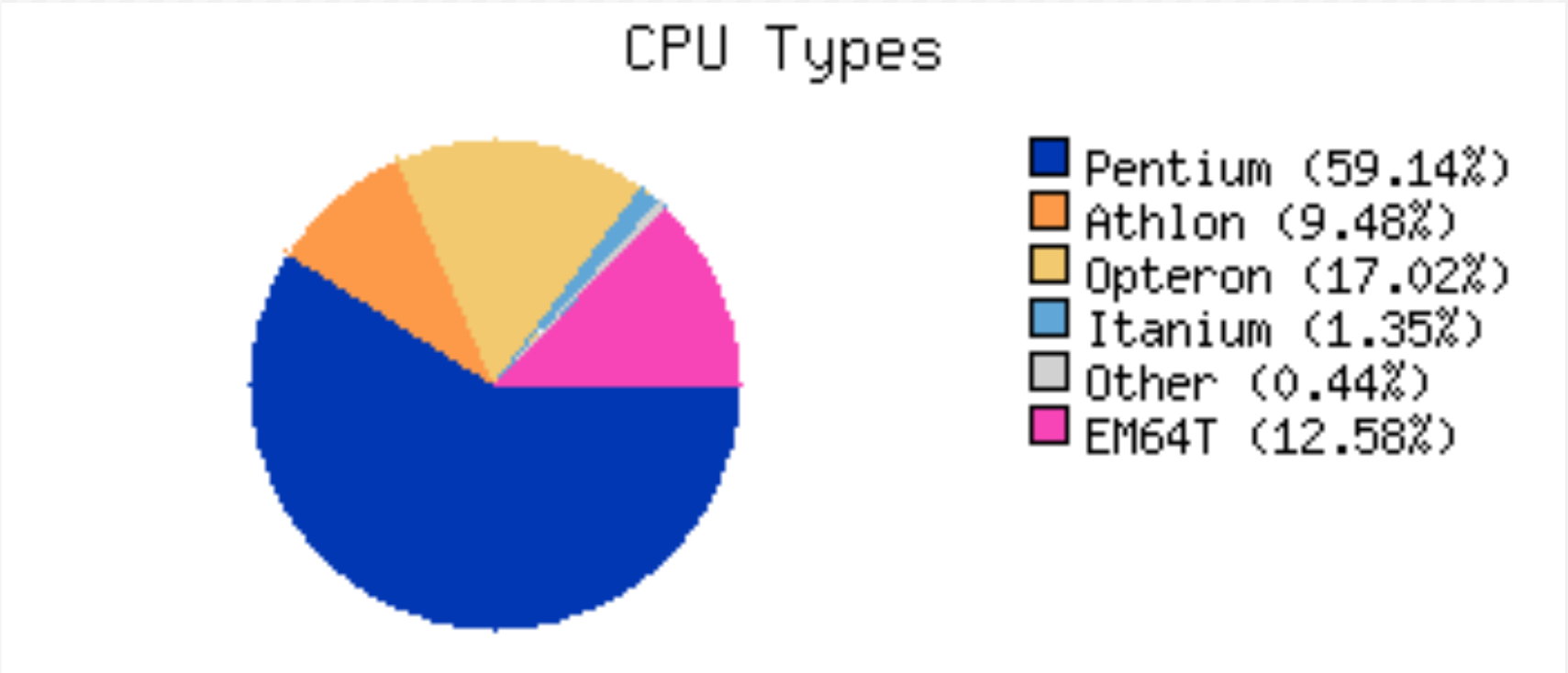


Registration Page
(optional)



Id	Name	Org	CPUType	CPUs	CPUClock (GHz)	FLOPS (GFLOPS)	Location	Up / Down
443	Total CPUs, Ave CPUClock, Total FLOPS:			27005	2.03	119802.62		
(497) More	Tungsten 2	NCSA	EM64T	1040	3.60	7488	Urbana, IL	
(130) More	Lonestar	TACC	Pentium 4	1024	3.06	6266.88	Austin, Texas	
(51) More	GridKa	Forschungszentrum Karlsruhe	Pentium 4	1284	2.43	6240.24	Karlsruhe, Germany	
(299) More	USCMS Fermilab Tier1	Fermi National Accelerator Lab	Pentium 4	704	2.80	3942.4	Batavia,IL	
(65) More	Iceberg	Bio-X @ Stanford University	Pentium 4	604	2.80	3382.4	Stanford, CA	
(510) More	Zohar	Georgia Tech Physics (Dell)	EM64T	512	3.20	3276.8	Atlanta, Georgia	
(231) More	Fermilab reconstruction farms	Fermilab	Pentium 3	1504	1.50	2256	Batavia, IL	
(349) More	karan	N/A	Athlon MP	450	2.40	2160	san diego	
(151) More	UN TOTS	Intel	Pentium 4	388	2.66	2064.16	Hillsboro. OR	
(425) More	Belle-KEK-Dell	High Energy Accelerator Research Organization	EM64T	300	3.40	2040	Tsukuba-shi, Japan	

User Base

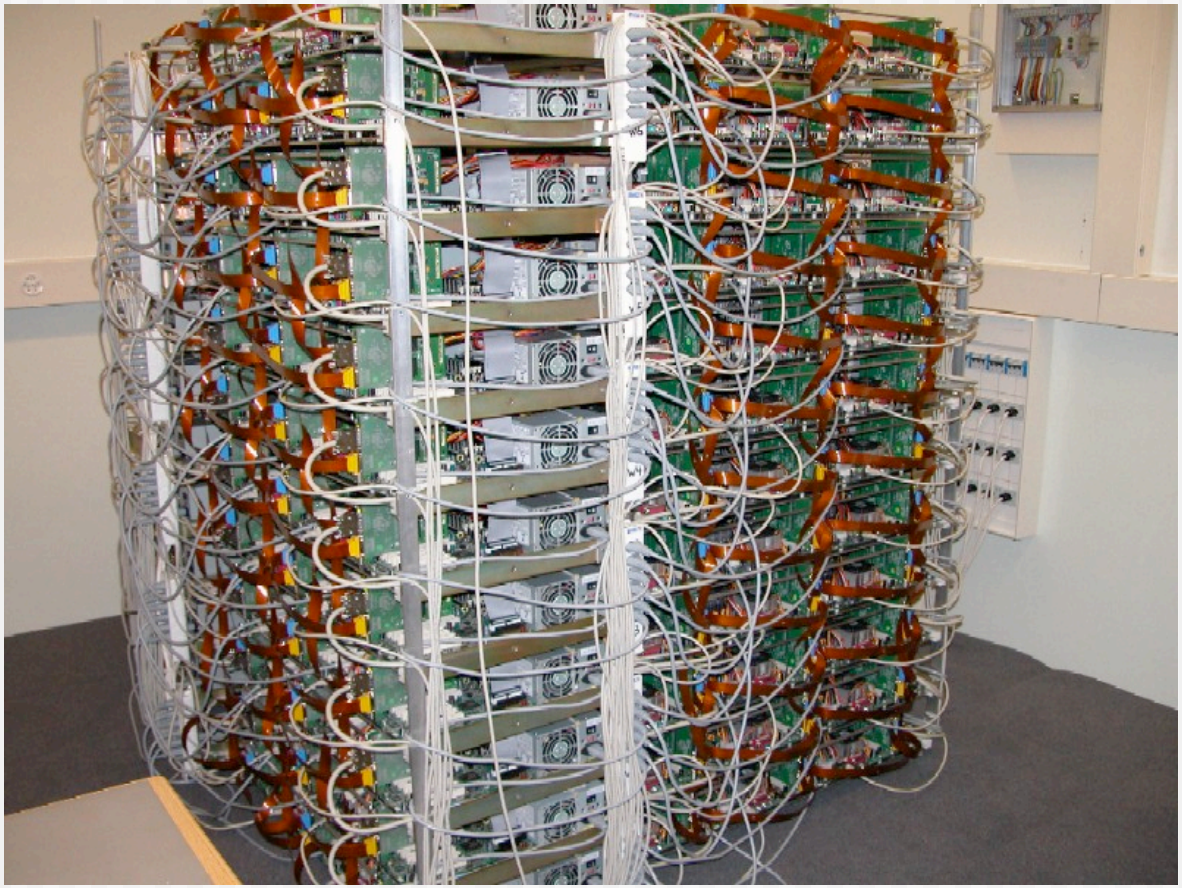


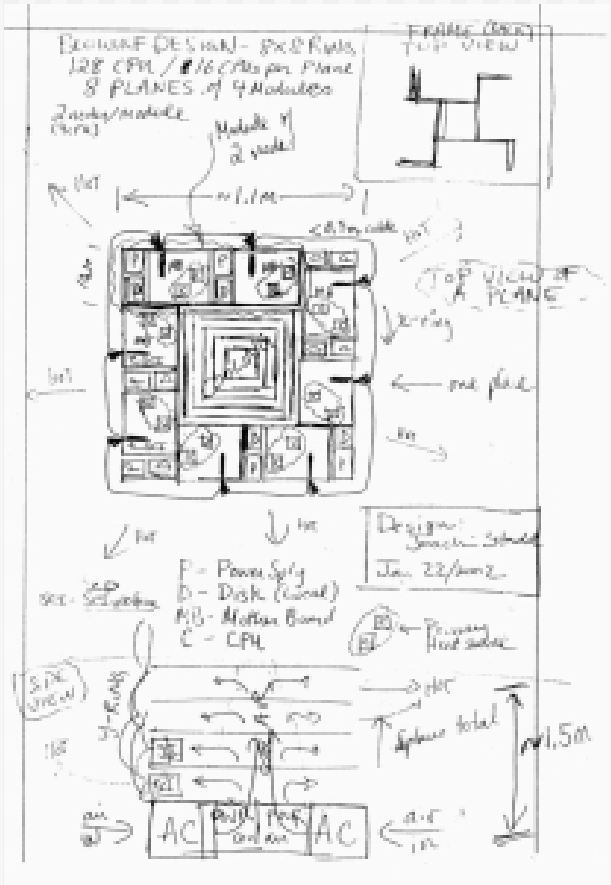
Beowulf Mentality

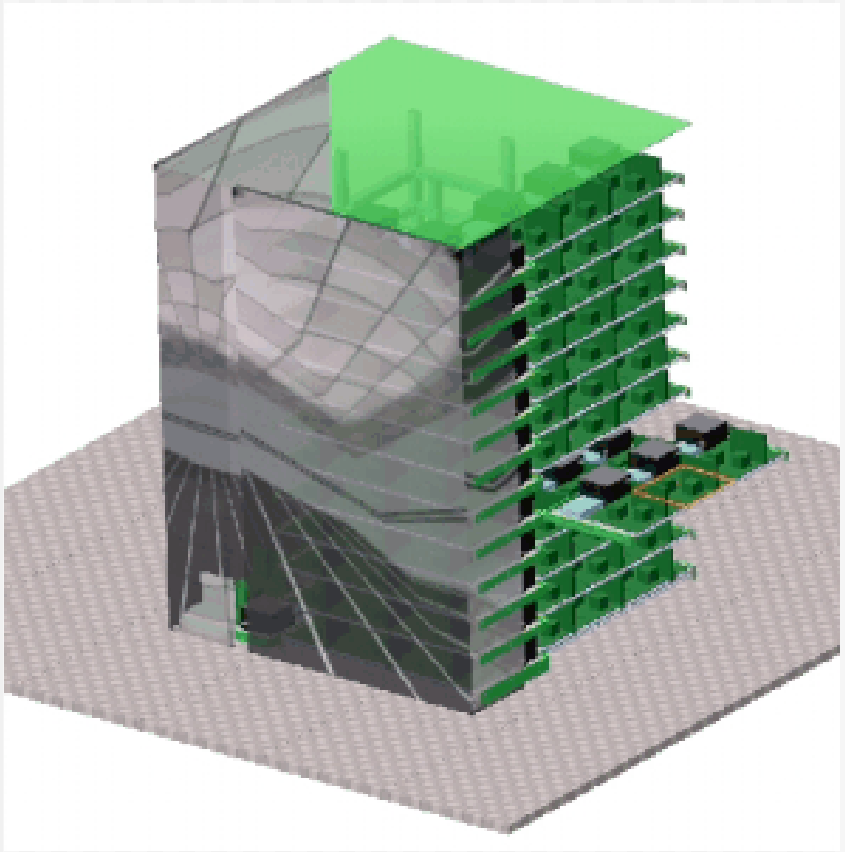
Why DIY is wrong

A Tale of a Cluster Tuner

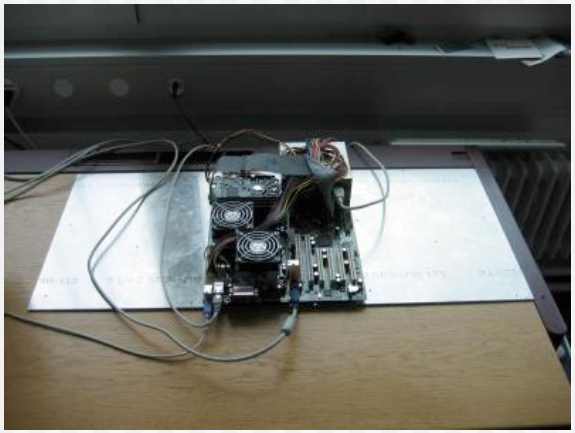
(288 AthlonMP Hand Built Machine)







08.2002 - 11.2002: Construction

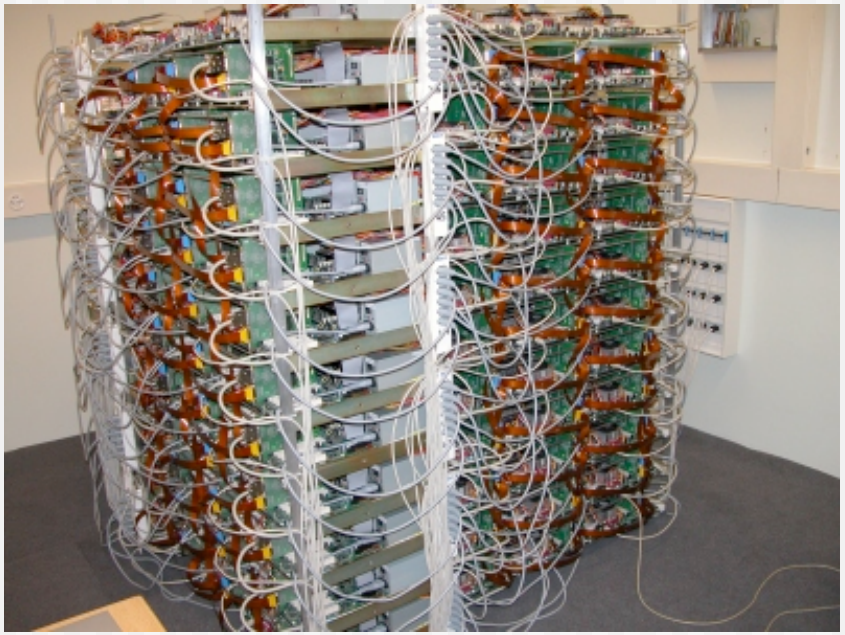


12.2002: Build Complete & Celebration

- Machine only 50% operational
- But, they are getting results
- Machine is fully operational 3 months later

Summary

- 07.2002
  - Design system
- 08.2002 - 11.2002
  - Build system
- 03.2003
  - System in Production
- **7 months** (maybe 8)
  - **Concept to Cluster**
  - Still just a Beowulf
  - Moore-cycle is 18 months
    - Half life for performance
    - Half life for cost
  - Useful life is 36-48 months
- What did they optimize for?



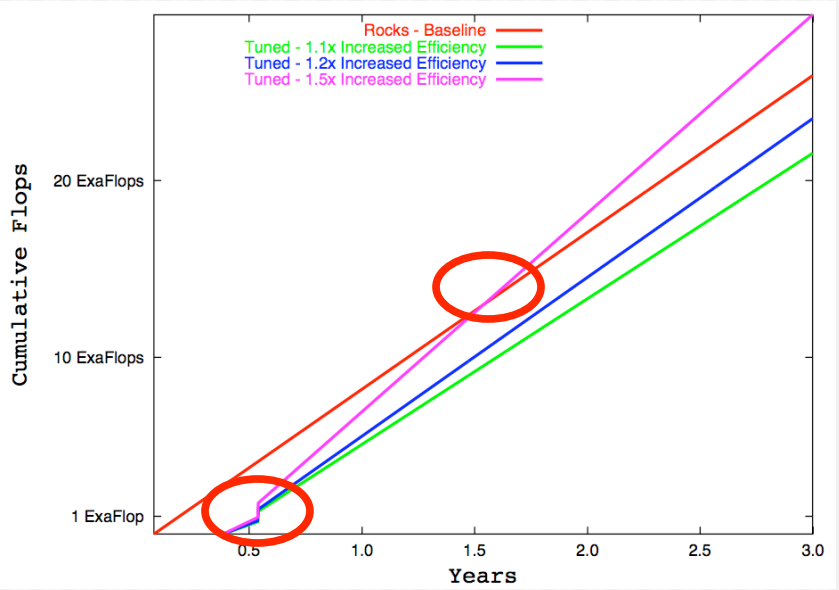
Rocks Cluster Timeline

- Day 1 - Idea
- Day 30 - Production

- Not just us, world wide user base has done the same

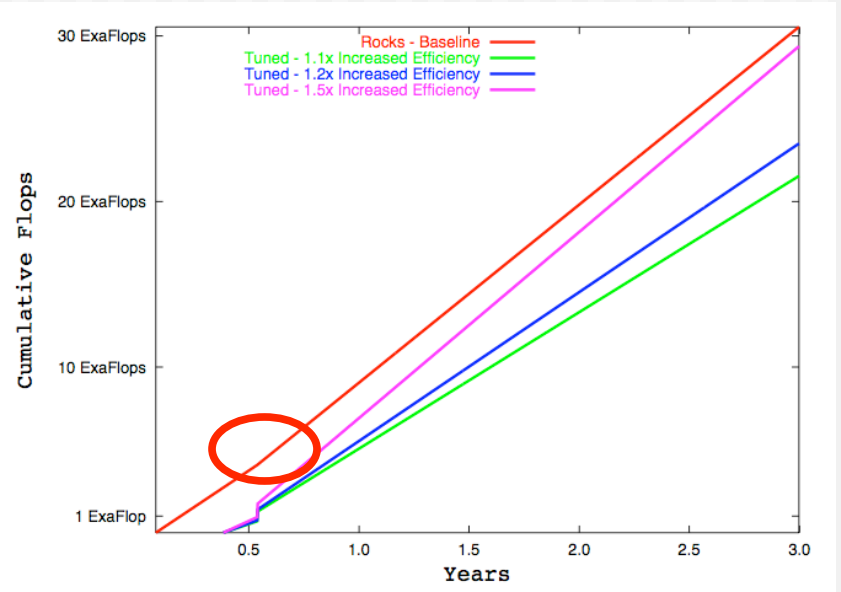
Lost Time = Lost Computation

- Assumption
  - Rocks
    - 256 2.2 GHz Pentium IV
    - 1,126 GFlops
    - Available at same time as tuner build
    - 1 month to build
  - Tuner
    - 144 - 264 Athlon-MP 2200+
    - 512 - 950 Gflops
    - 5 - 7 months to build
- Baseline of 50% CPU efficiency for Rocks
- Tuner improvement beyond baseline
  - 10% (55% efficiency)
  - 20% (60% efficiency)
  - 50% (75% efficiency)
- Tuner must have 50% gain to catch baseline after 1.5 years



Invest in Hardware not People

- Assumptions
  - Two salaried tuners
  - “Full burden” (salary, grant overhead, office space, etc) is $180k / year.
- Invest
  - 5 months salary into baseline
  - $150k (5 months)
  - Just buy more nodes
    - $2500k / node
- Month 7
  - Baseline cluster grows
  - 54 2.2 GHz servers
  - Ignoring Moore’s Law!
- Baseline wins



Other Tuners

- Kernel Tuning
  - “My handcrafted kernel is X times faster.”
- Distribution Tuning
  - “Distribution Y is X times faster.”
  - RFP: “Vendor will be penalized for a Red Hat only solution”
- White-box Tuning
  - “White-box vendor Y has a node that is X times cheaper.”

Rocks

Making Clusters Easy

SDSC

When You Need Power Today

Young Frankenstein - Gene Wilder, Peter Boyle

Two Examples

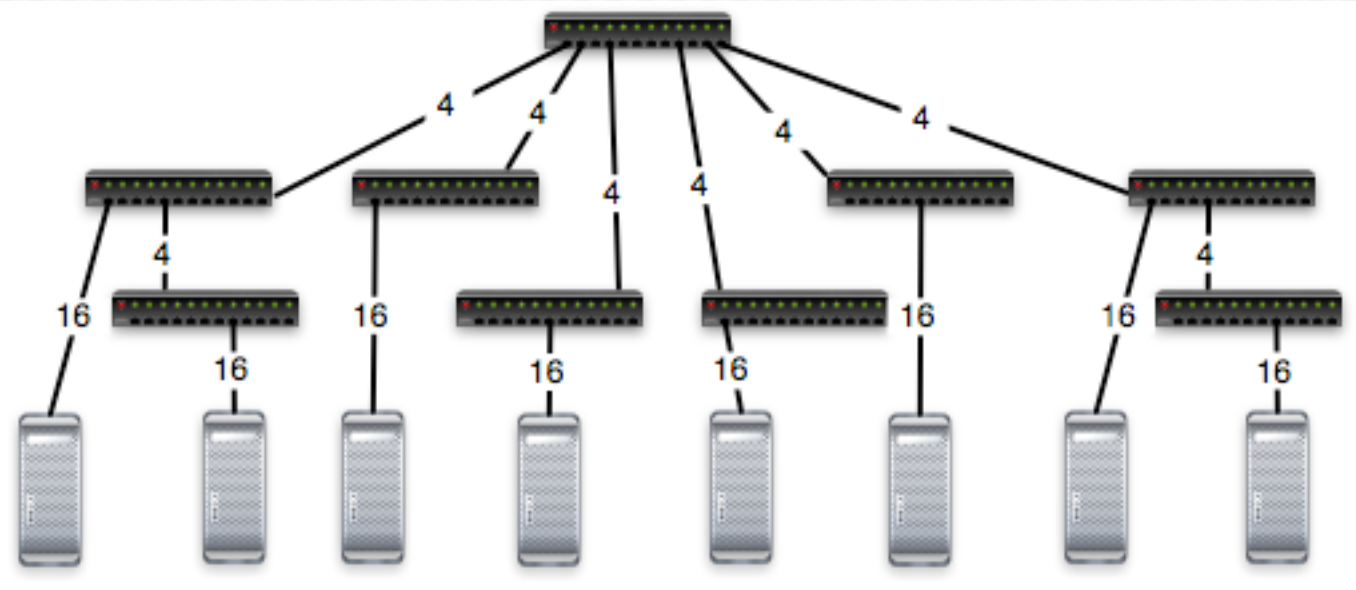
Rockstar - SDSC

Tungsten2 - NCSA

Rockstar Cluster

- 129 Sun Fire V60x servers
  - 1 Frontend Node
  - 128 Compute Nodes
- Gigabit Ethernet
  - $13,000 (US)
  - 9 24-port switches
  - 8 4-gigabit trunk uplinks
- Built live at SC'03
  - In under two hours
  - Running applications
- Top500 Ranking
  - 11.2003: 201
  - 06.2004: 433
  - 49% of peak

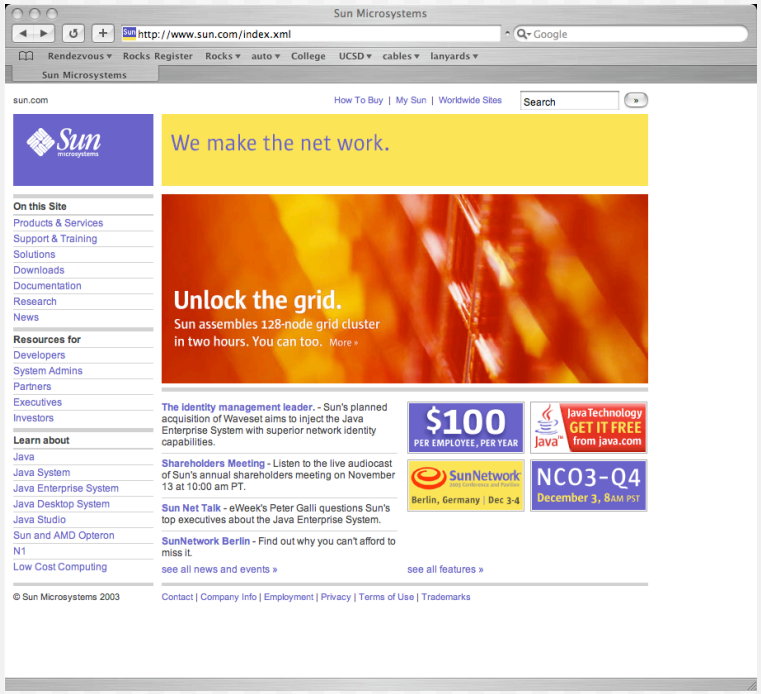
Rockstar Topology



- 24-port switches
- Not a symmetric network
  - Best case - 4:1 bisection bandwidth
  - Worst case - 8:1
  - Average - 5.3:1

Super Computing 2003 Demo

- We wanted to build a Top500 machine live at SC'03
  - From the ground up (hardware and software)
  - In under two hours
- Show that anyone can build a super computer with:
  - Rocks (and other toolkits)
  - Money
  - No army of system administrators required
- HPC Wire Interview
  - **HPCwire**: What was the most impressive thing you've seen at SC2003?
  - **Larry Smarr**: I think, without question, the most impressive thing I've seen was Phil Papadopoulos' demo with Sun Microsystems.

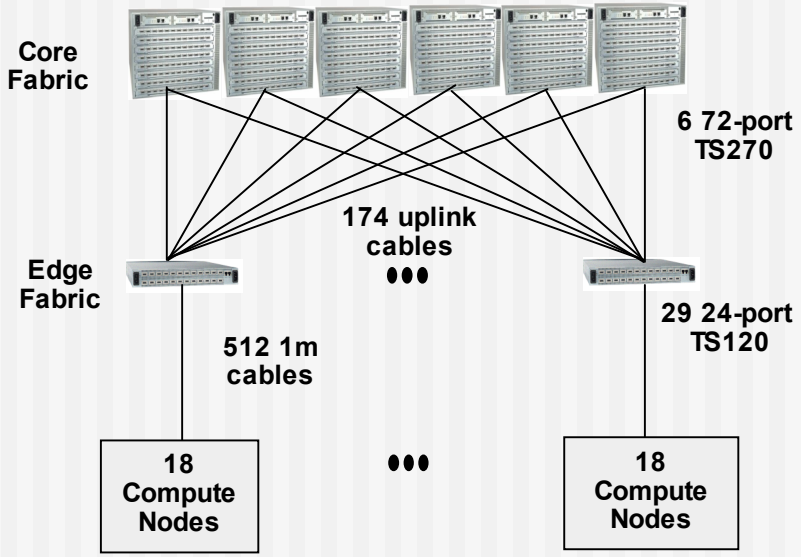


Building Rockstar

NCSA

National Center for Supercomputing Applications

- Tungsten2
  - 520 Node Cluster
  - Dell Hardware
  - Topspin Infiniband
- Deployed 11.2004
- Easily in top 100 of the 06.2005 top500 list
- "**We went from PO to crunching code in 2 weeks**. It only took another 1 week to shake out some math library conflicts, and we have been in production ever since." -- *Greg Keller, NCSA (Dell On-site Support Engineer)*



Id	Name	Org	CPUType	CPUs	CPUClock (GHz)	FLOPS (GFLOPS)	Location
435	Total CPUs, Ave CPUClock, Total FLOPS:			26571	2.02	117134.22	
(497) More	Tungsten 2	NCSA	EM64T	1040	3.60	7488	Urbana, IL

Largest registered Rocks cluster

source: topspin (via google)