Introduction to LONI
High Performance Computing

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Baton Rouge
November 15, 2024

Outline

- **LONI (Louisiana Optical Network Infrastructure) Overview**
- **What is High Performance Computing (HPC) and how it works?**
  - Parallel concept
  - FLOPs
- **Available LONI HPC resources**
  - QB3 and QB4
- **About us (HPC@LSU)**
  - What kind of service do we provide?

What is LONI?

- LONI is a consortium that supports public and private post-secondary institutions to conduct their research and academic business online.
- In addition, we provide services to governmental authorities enabling them to deliver online services to their constituents.
- LONI is a state-owned, state-managed asset already in the ground.
- Given that LONI is a state asset means technology can be purchased in bulk, giving universities and technical/community schools tremendous procurement leverage in software applications of every kind, enterprise solutions, learning management systems, virtual machines, and related programs, cloud and storage services, and cyber-related assets.
- As a state asset, it's a disservice to all educations systems not to leverage its potential.

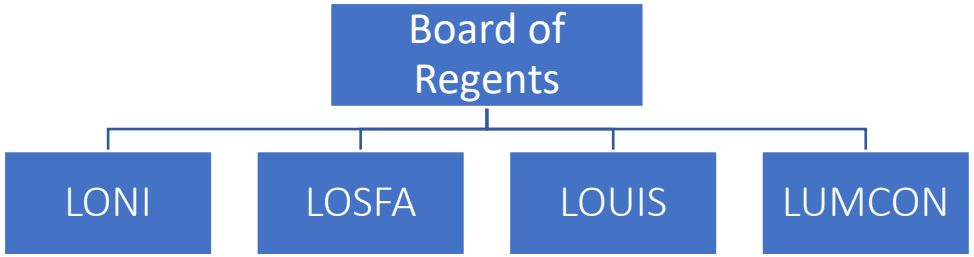
The Organization

The LONI Network is an asset owned by the Louisiana Board of Regents and operated with the assistance of the LONI Management Council and the LONI Operations Staff at LSU.

The LONI Management Council, whose members represent higher education management boards and state government, is charged with making recommendations to the Commissioner of Higher Education on the management of operations and associated business activities of LONI.

The Council's mission and recommendations are guided by what is in the best interest of LONI's sustainability defined by the Louisiana Board of Regents in response to gubernatorial and legislative directives.

Regents Statewide Programs



Who is LONI?

- We are a premier high-capacity middle-mile fiber optic network provider for Louisiana's higher education and research entities. The technology assets include a 1,600-mile long system of fiber optics cables that provides members with private and public cloud access at an improved level of service over a typical service provider and enhanced support for digital activities for teaching, learning, and administrative functions.
- We provide high-performance computing (HPC) as a service allowing researchers to conduct and store highly complex experiments using compute powers specialized for highly intensive computational processing. LONI is owned and operated under the authority of the Louisiana Board of Regents (BoR).

Abstract

Louisiana researchers and universities are leading a concentrated, collaborative effort to advance statewide research through LONI's cyberinfrastructure: computing systems, data storage systems, and people especially people who all are linked together by a shared vision and the underlying technologies that support that vision. This vision is to establish interlinked projects whether from a single research, single college, single university, or multiple institution in scope with making a significant difference to the state by creating an environment that encourages increased collaboration leading to new domain and applied research.

LONI Service Strategy

- Shared investment between Regents and LONI members
- Regents to cover the cost of the staff and large investments in fiber construction and equipment using general funds, financing and capital-outlay
- LONI members are asked to cover the operational costs through a membership fee
- LONI seeks to provide value to its member's business through innovative and practical delivery of its platform-as-a-service (PaaS).

Who is Connected to LONI

5
Higher Education Systems

17
4-Year Universities

13
2-Year Universities/Colleges

10(+1)
Content Providers

13
Other Research / Education Entities

8
State / Local Government

4
State Research Education Networks

2
Content Caches

121
Louisiana Service Sites

5
Louisiana Data Centers

5
Internet/Internet2 Connections

44
Parishes Served

LONI Network Factoids

1600
Total Miles of Fiber in the LONI Network

130
Miles of LONI Owned Fiber

497
Miles of DOTD Fiber

973
Miles of IRU fiber

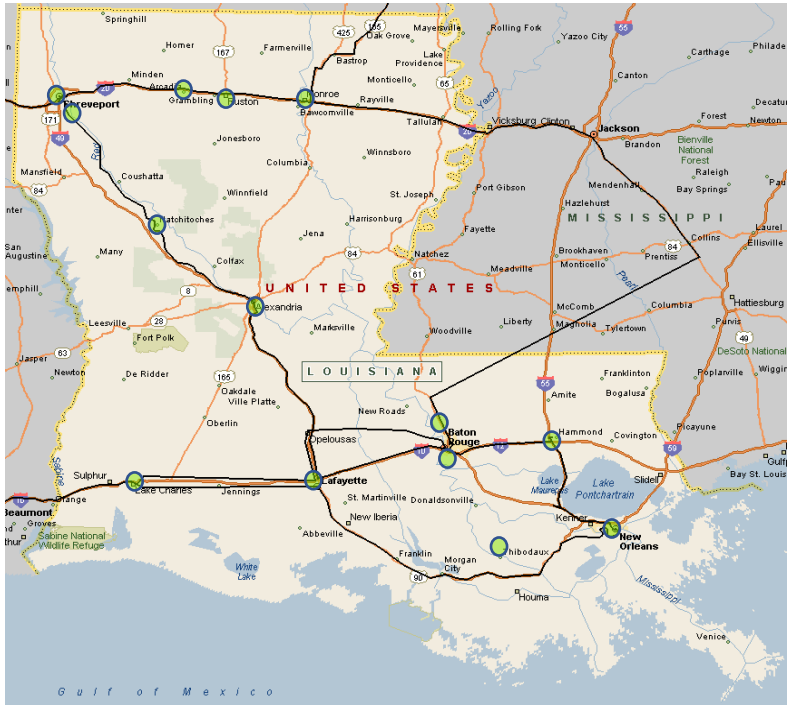
1000+
Managed Circuits

485
Managed Devices

326
Number of Live 100G Ports

$18+M
Total amount in asset in risk management less fiber

14
Number of Staff



Louisiana

- **Louisiana State University**
- **Tulane University**
- **University of Louisiana-Lafayette**
- **Louisiana Tech University**
- **Southeastern Louisiana University**
- **University of New Orleans**
- **LSU Health Sciences Center-New Orleans**
- **Southern University A&M**
- **Northwestern State University**
- **University of Louisiana-Monroe**
- **McNeese State University**
- **Delgado Community College**
- **Nicholls State University**
- **LSU Health Sciences Center-Shreveport**
- **Grambling State University**
- **LSU-Shreveport**
- **Southern University-New Orleans**
- **LSU-Alexandria**
- **Baton Rouge Community College**
- **South Louisiana Community College**
- **Bossier Parish Community College**
- **Louisiana Delta Community College**
- **Southern University-Shreveport**
- **SOWELA Technical Community College**
- **LSU-Eunice**
- **L.E. Fletcher Technical Community College**
- **Central Louisiana Technical Community College**
- **Elaine P. Nunez Community College**
- **Northwest Louisiana Technical Community College**
- **River Parishes Community College**
- **Louisiana Christian College**
- **LSU AgCenter**
- **Pennington Biomedical Research Center**
- **Southern University Law Center**
- **LCTCS System Office**
- **University of Louisiana System Office**
- **Board of Regents, LOSFA, LUMCON**
- **Research: 5 organizations**
- **State: 5 Louisiana agencies**

Return on Investment Examples

- LONI currently supports research activities funded by active external grants from agencies such as NSF, NIH, DOE, DOD, and NASA in excess of $50M annually.
- LONI makes critical contributions to matters critical to the State of Louisiana, such as long-term coastal protection and restoration as well as real-time decision support to state and federal emergency managers, first-time responders, and general decision-makers during hurricane seasons.
- For every state dollar used by LONI, its member institutions receive one to seven dollars in external funding.

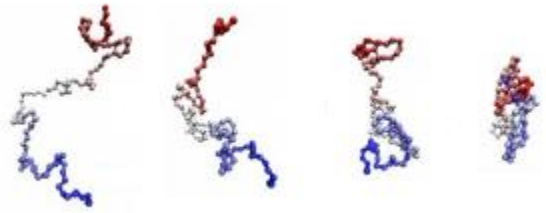
Services

- Membership
  - Platform-as-a-Service (PaaS)
- Network Services
  - Network-as-a-Service (NaaS) – Network Access via BGP, L2VPN, L3VPN, ScienceDMZ, etc.
  - Router-as-a-Service (RaaS)
  - WAN-as-a-Service (WaaS)
- Security Services
  - Firewall-as-a-Service (FaaS)
  - Security Operations Center-as-a-Service (SOCaaS)
  - Cisco Umbrella
- LONI Private Cloud
  - Cloud-as-a-Service (CaaS) – being sunsetted
- Consulting Services

Applications

Climate Modeling

AI
Data Analysis



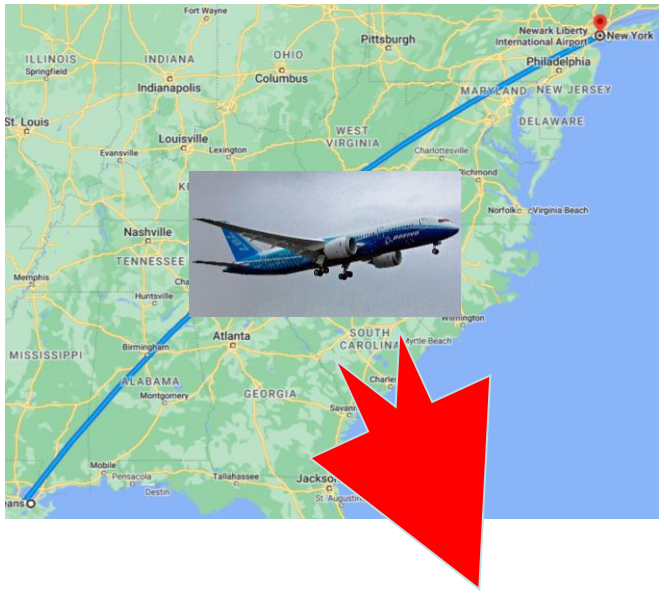
Bioinformatics

Energy Research

Drug Discovery

Introductory Problem

- **Fly from New Orleans, LA to New York, NY**



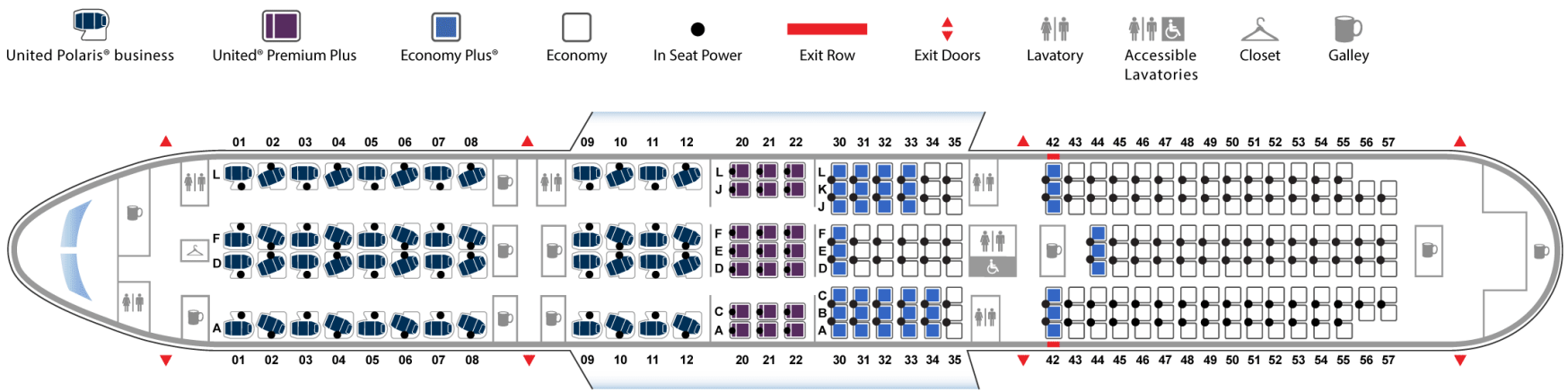
1 (one)
Boeing 787

Distance=1182 miles
Velocity =~600 mph
Time = ~2 hours

2 (two)
Boeing 787
???

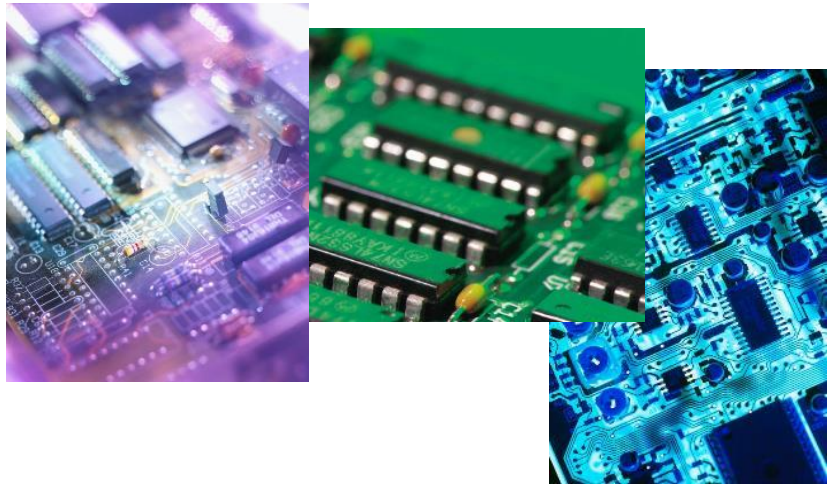
Considering number of seats?

- **787-8 Dreamliner has 248 seats**



How does HPC work?
Why Parallel?

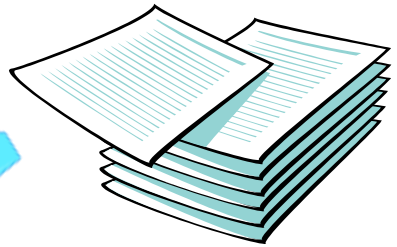
Some background



Computer runs one program at a time.

programs

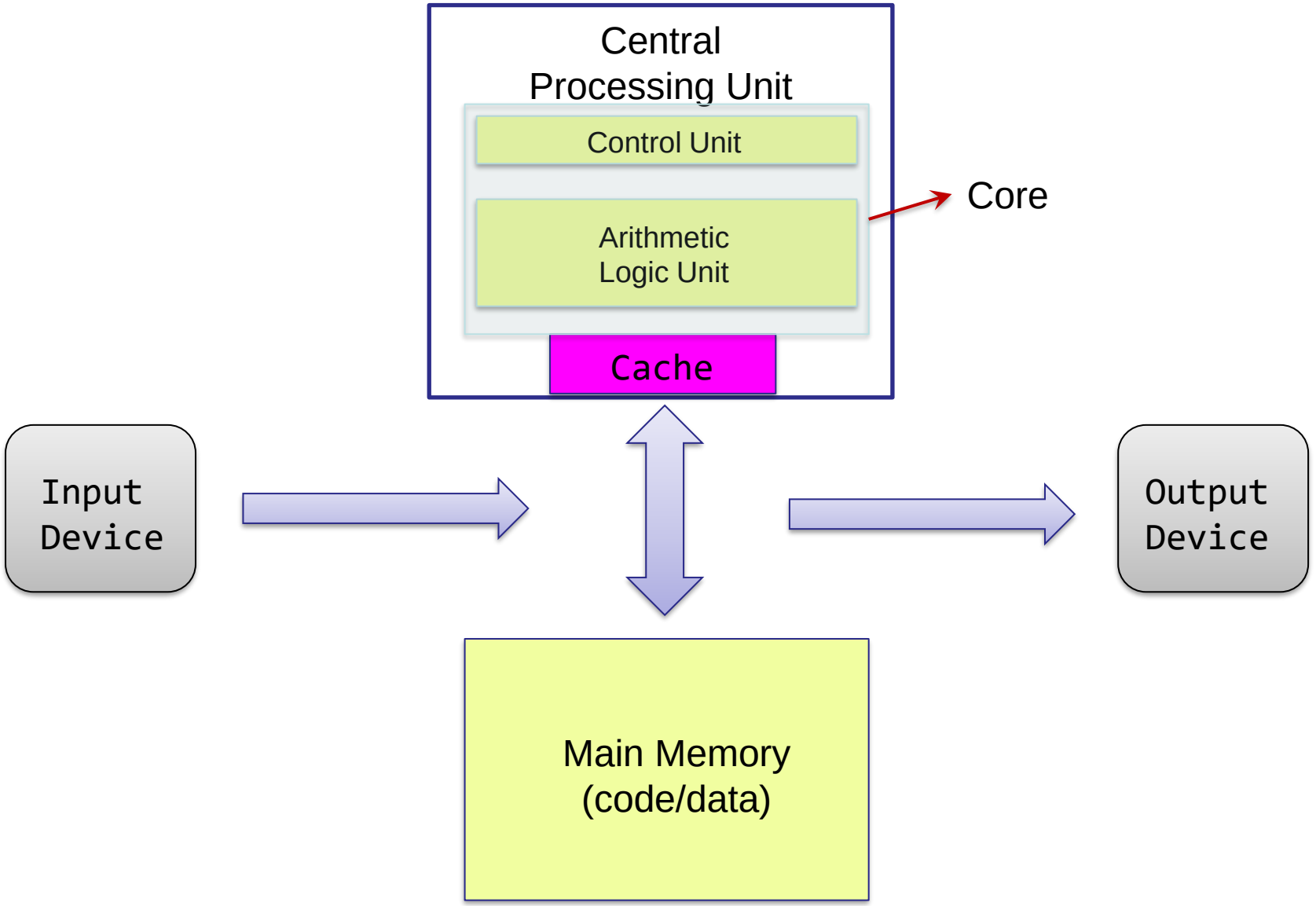
input



output

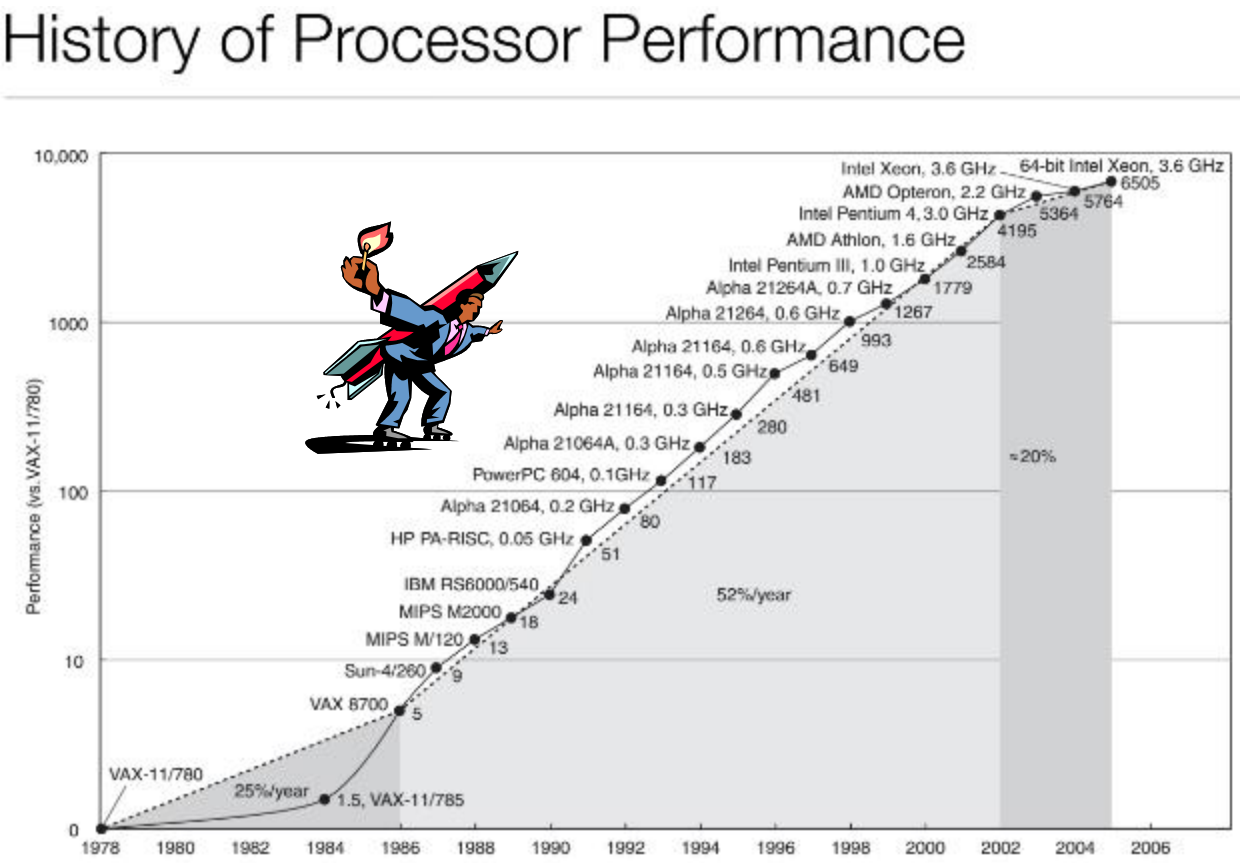
Can we have something that just run 100x faster?

The von Neumann Architecture



Changing Times

- **From 1986 - 2002, microprocessors were speeding like a rocket, increasing in performance an average of 50% per year.**
- **Since then, it's dropped to about 20% increase per year.**



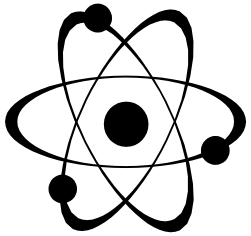
Limitation:

2 GHz Consumer
4 GHz Server

Source:
http://www.cs.columbia.edu/~sedwards/classes/2012/3827-spring/

A Little Physics Problem

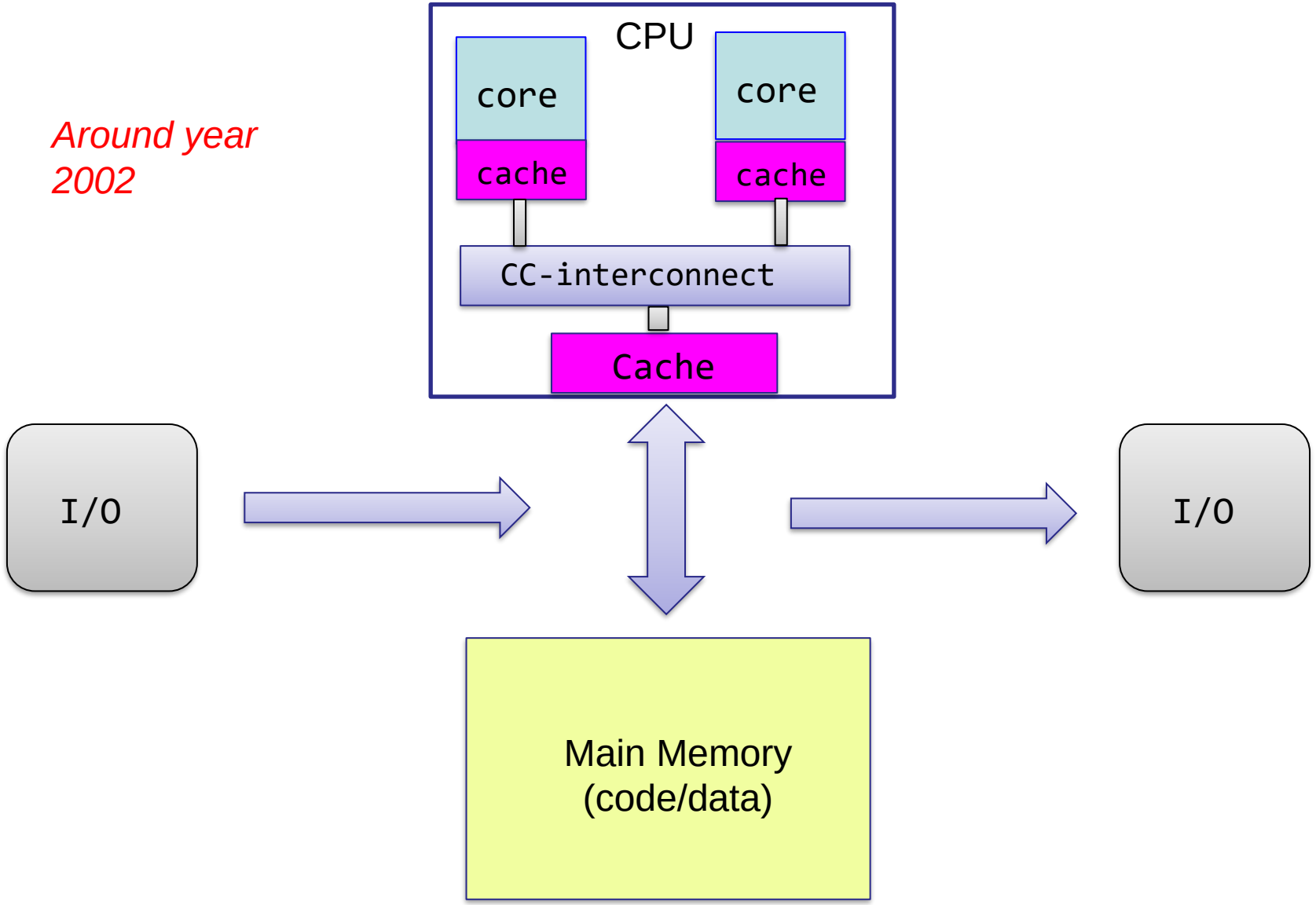
- **Smaller transistors = faster processors.**
- **Faster processors = increased power consumption.**
- **Increased power consumption = increased heat.**
- **Increased heat = unreliable processors.**



- **Solution:**
  - Move away from single-core systems to multicore processors.
  - “core” = central processing unit (CPU)
  - Introducing parallelism
    - ***What if your problem is also not CPU dominant?***

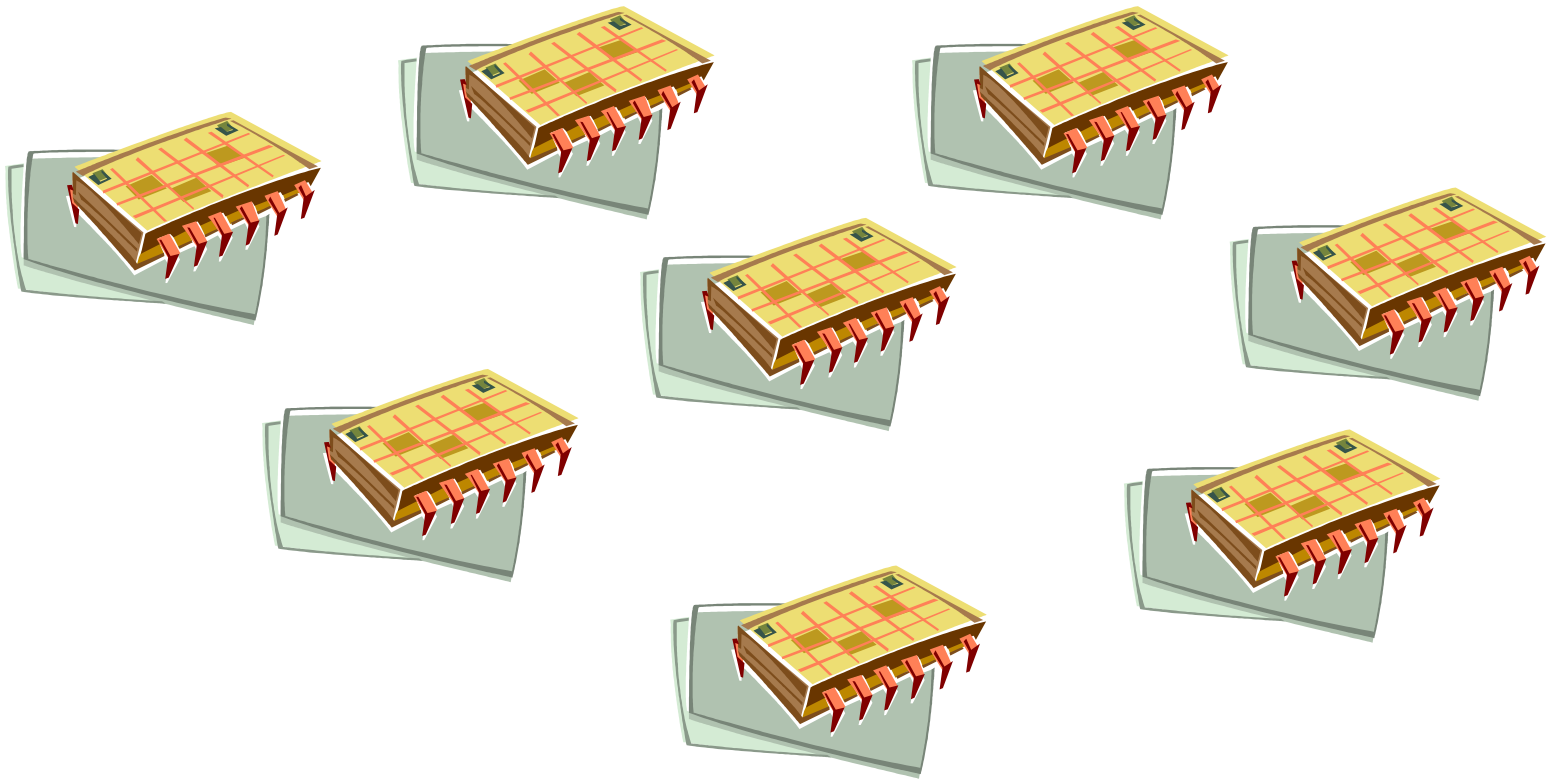
The von Neumann Architecture

Around year 2002



An intelligent solution

- **Instead of designing and building faster microprocessors, put multiple processors on a single integrated circuit.**

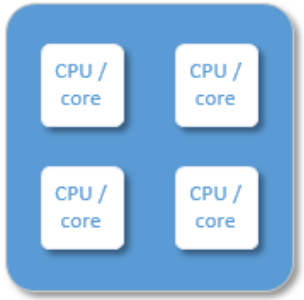


Concluding Remarks

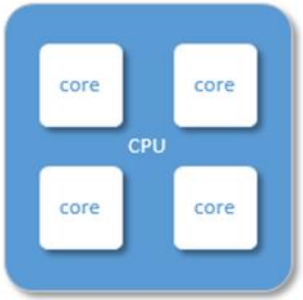
- **The laws of physics have brought us to the multi-core era.**
- **Serial programs typically don't benefit from the multi-core architecture.**
- **To get speedup, your code needs to be able to make use of multiple cores.**

Core, CPU, Processor?

- **A core is usually the basic computation unit.**
- **A CPU may have one or more cores to perform tasks at a given time.**



"CPU" referring to each core

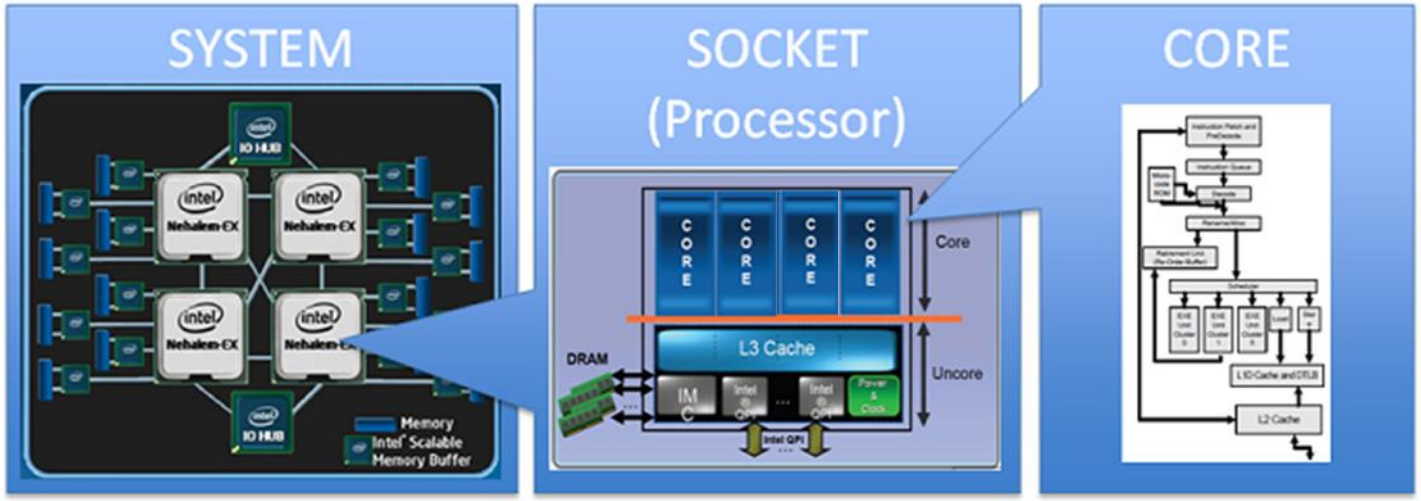


"CPU" referring to entire processor

- **In this training, CPU = processor, which has multiple cores.**

Case study – core and processor

- **How many cores does this computer have?**



- **4 cores * 4 processors = 16 total cores**

What is HPC

- **High Performance Computing (HPC) is computation at the cutting edge of modern technology, often done on a supercomputer**
- **A supercomputer is in the class of machines that rank among the fastest in the world**
  - Rule of thumb: a supercomputer could be defined to be at least 100 times as powerful as a PC

600 mph

60 mph

- **How do we evaluate the performance of HPC?**

Measure HPC performance-FLOPS

- **Performance is measured in *Floating Point Operations Per Second* (FLOPS or flop/s)**
- $FLOPS = cores \times clock \times \frac{FLOPs}{cycle}$
  - Most processors today can do 4 FLOPs per clock cycle. Therefore a single-core 2.5-GHz processor has a theoretical performance of 10 billion FLOPs = 10 GFLOPs
  - Dual core, quad core? (Intel i3, i5, i7)

Computer performance

Name	FLOPS
yottaFLOPS	10^{24}
zettaFLOPS	10^{21}
exaFLOPS	10^{18}
petaFLOPS	10^{15}
teraFLOPS	10^{12}
gigaFLOPS	10^{9}
megaFLOPS	10^{6}
kiloFLOPS	10^{3}

- **Question:**
  - A 4-core 2.5GHz desktop, each core can do 16 floating point operations per cycle
  - What is the FLOPs of my desktop?

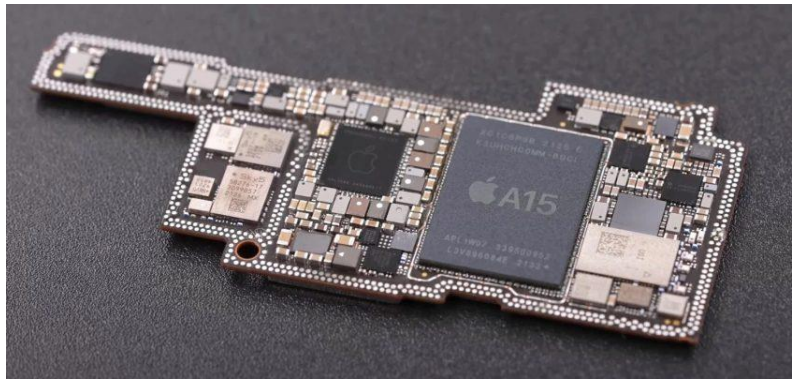
Supercomputing on a Cell Phone?

- **Hex-core processors are coming to your phone**
  - Nvidia, TI, QualComm…
  - Processing power in the neighborhood of 50 GigaFLOPS
  - Would make the top 500 supercomputer list 20 years ago
  - What is your phone's FLOPS?
- According to Apple, that iPhone 13 pro's A15 Bionic chip is capable of 15.8 trillion operations per second (TFLOPS).
- Compare to ENIAC (500 FLOPS)
- Compare to top 500 in June 2001

  #1 (12.3 TFLOPS)

Computer performance

Name	FLOPS
yottaFLOPS	10^{24}
zettaFLOPS	10^{21}
exaFLOPS	10^{18}
petaFLOPS	10^{15}
teraFLOPS	10^{12}
gigaFLOPS	10^{9}
megaFLOPS	10^{6}
kiloFLOPS	10^{3}



The Top 500 List

- **The TOP500 project provides a list of 500 fastest super- computers in the world ranked by their LINPACK performance.**
- **Semi-annually published (in the public domain)**

Current (November 2023):

Rank	Syste	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)	Power (kW)
1	**Frontier** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE DOE/SC/Oak Ridge National Laboratory United States	8,699,904	1,194.00	1,679.82	22,703
2	**Aurora** - HPE Cray EX - Intel Exascale Compute Blade, Xeon CPU Max 9470 52C 2.4GHz, Intel Data Center GPU Max, Slingshot-11, Intel DOE/SC/Argonne National Laboratory United States	4,742,808	585.34	1059.33	24,687
3	**Eagle** - Microsoft NDv5, Xeon Platinum 8480C 48C 2GHz, NVIDIA H100, NVIDIA Infiniband NDR, Microsoft Microsoft Azure United States	1,123,200	561.20	846.84	-

The Top 500 List

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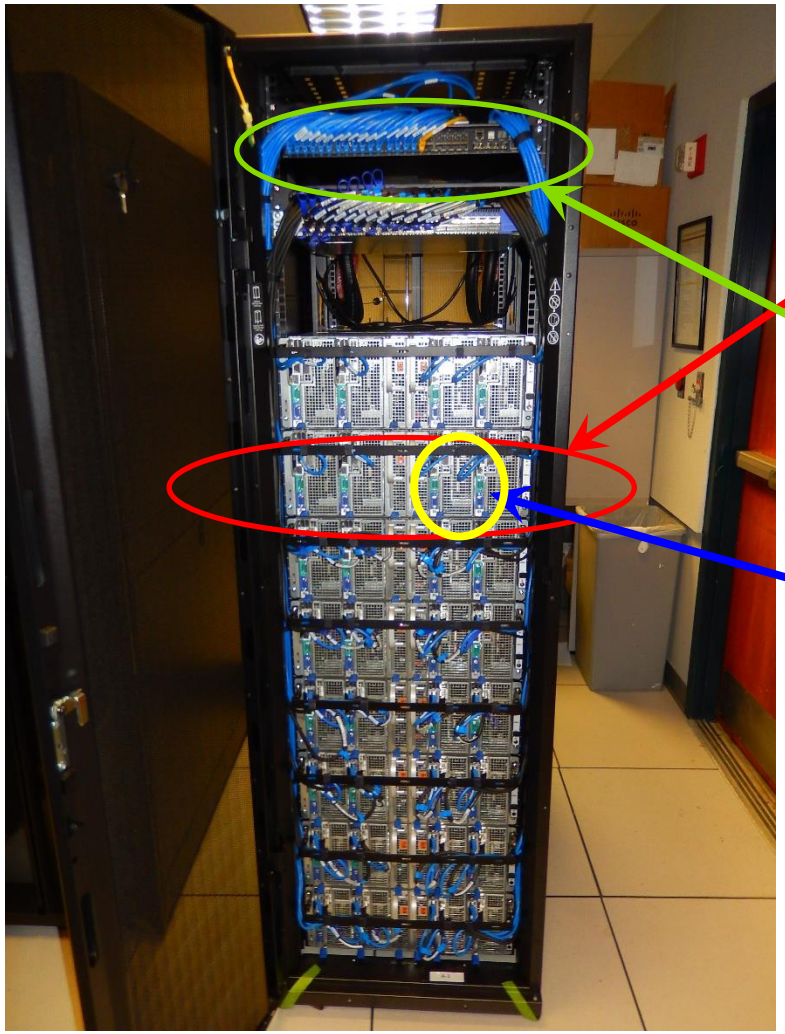
June 2019:

Rank	System	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)	Power (kW)
474	**QB-2** - Dell C8220X Cluster, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband FDR, NVIDIA K20x, DELL EMC Louisiana Optical Network Initiative United States	23,040	1.05	1.47	500

Supercomputer Cluster Racks

Inside A Cluster Rack

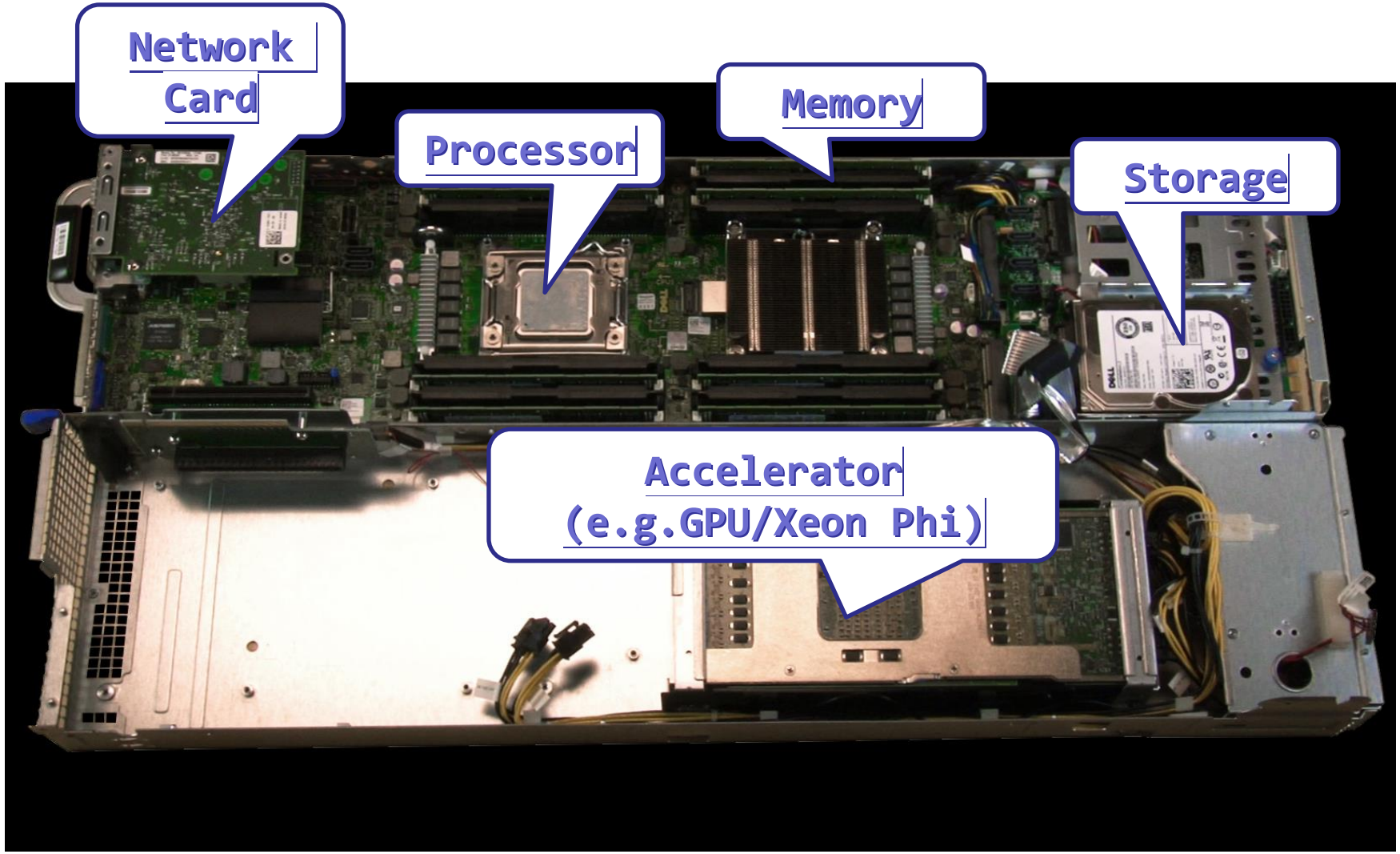


Rack

Interconnect: Infiniband Switch

Compute Node

Inside A Compute Node



Available LONI HPC Resources

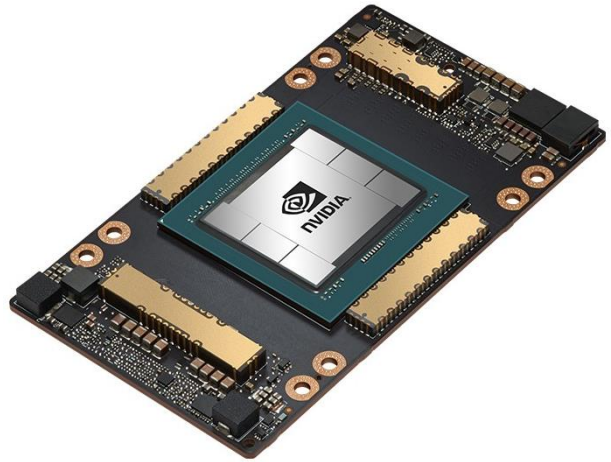
QB3	
Hostname	qbc.loni.org
Peak Performance/TFlops	857
Compute nodes	202
Processor/node	2 24-Core
Processor Speed	2.4GHz
Processor Type	Intel Cascade Lake Xeon 64bit
Nodes with Accelerators	8
Accelerator Type	NVIDIA Volta V100
OS	RHEL v7
Vendor	Dell
Memory per node	192 GB
Location	Information Systems Building, Baton Rouge
Online June 15, 2020	

QB4	
Hostname	qbd.loni.org
Peak Performance/TFlops	4,300
Compute nodes	547
Processor/node	2 32-Core
Processor Speed	2.6GHz
Processor Type	Intel Ice Lake Xeon 64bit
Nodes with Accelerators	62
Accelerator Type	NVIDIA Ampere A100
OS	RHEL v8
Vendor	Dell
Memory per node	256/512/2048 GB
Location	Information Systems Building, Baton Rouge
Detailed Cluster Description	
User Guide	
Available Software	

Ref: http://hpc.loni.org/resources/hpc/index.php

QB4

- QB4 is a 4.3 PetaFlop peak performance cluster with 35,008 CPU cores and 144 NVIDIA A100 GPUs, comprised of ***547*** compute nodes connected by 200 Gbps Infiniband fabric. All racks have been delivered and the cluster is expected to be in production early summer 2024, currently in user-friendly mode.
- **480 CPU Compute Nodes, each with:**
  - Two 32-core Intel Ice Lake (Intel® Xeon® Platinum 8358 Processor) CPUs.
  - 256 GB memory
- **52 2-GPU Compute Nodes, each with:**
  - Two 32-core Intel Ice Lake (Intel® Xeon® Platinum 8358 Processor) CPUs.
  - 512 GB memory
  - 2 NVIDIA Ampere A100 GPUs with NVLink interconnect
- **10 4-GPU Compute Nodes, each with:**
  - Two 32-core Intel Ice Lake (Intel® Xeon® Platinum 8358 Processor) CPUs.
  - 512 GB memory
  - 4 NVIDIA Ampere A100 GPUs with NVLink interconnect
- **5 Big Memory Nodes, each with:**
  - Two 32-core Intel Ice Lake (Intel® Xeon® Platinum 8358 Processor) CPUs.
  - 2 TB memory
- https://www.hpc.lsu.edu/docs/guides.php?system=QB4



Summary of LONI Clusters

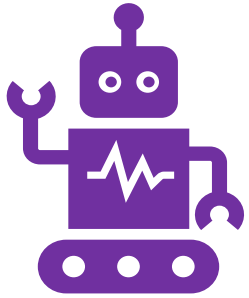
ISB: Information Services Building (Downtown Baton Rouge)

Name	Performance (CPU+GPU)	Location	Vendor	Architecture
QB3	857 TFLOPS	ISB	Dell	Linux x86_64
QB4	4.3 PFLOPS	ISB	Dell	Linux x86_64

Our *Free* Service for LONI Researchers

User support on LONI/LSU HPC resources

Research computing training classes



Application support Trouble shooting

Grant proposal support

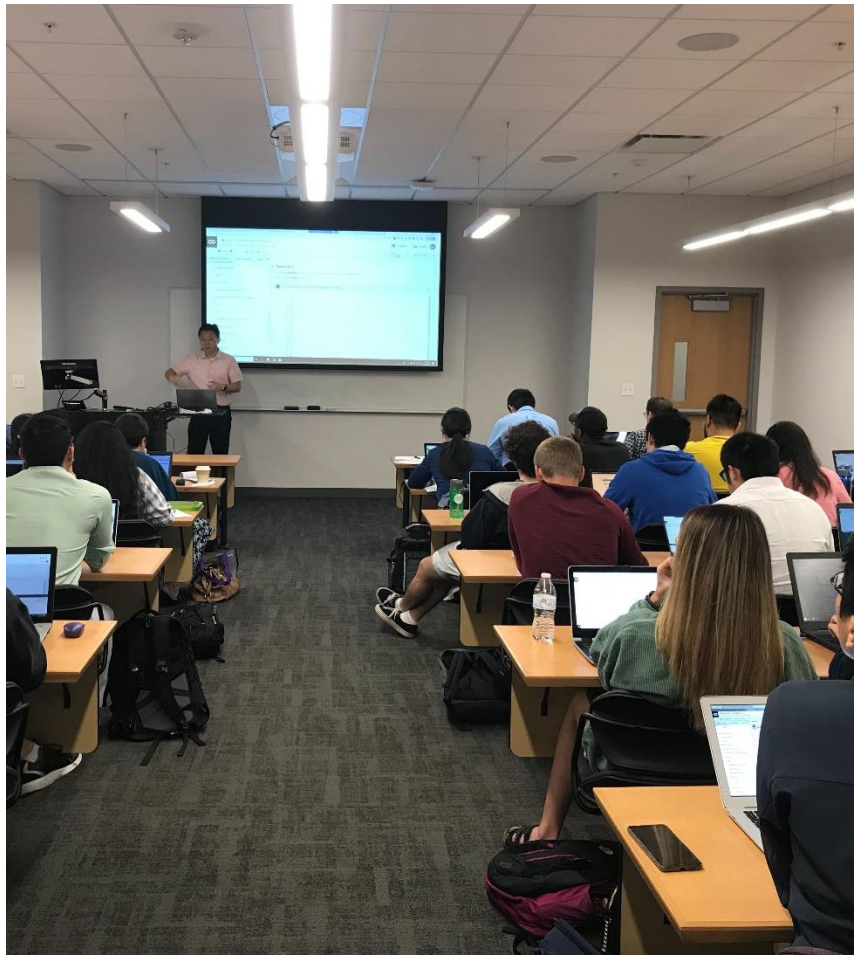
Our Goals

- **Provide reliable HPC computing resources.**
- **Provide a high level of expertise, technical support and knowledge domain consulting and training in order to enable better leverage of computing resources.**
- **Provide both existing and emerging HPC solutions that enable them to expand their research opportunities and capabilities.**
- **Respond to researchers' changing software requirements.**

HPC Training

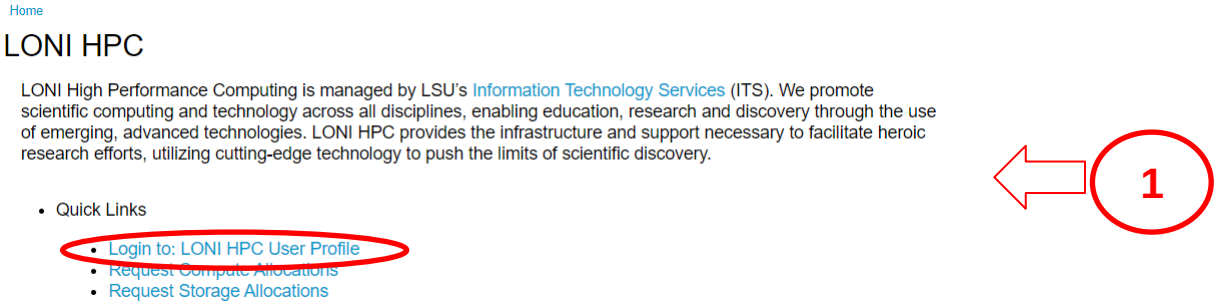
HPC@LSU invites you to attend our weekly training scheduled every Wednesdays, except university holidays. Selected Topics:

- Introduction to Linux
- HPC User Environment
- Basic Shell Scripting
- Parallel Programming using MPI/OpenMP
- Python/R/Deep Learning

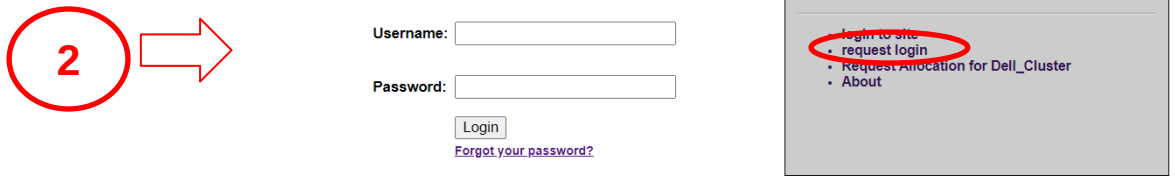


How to get started?

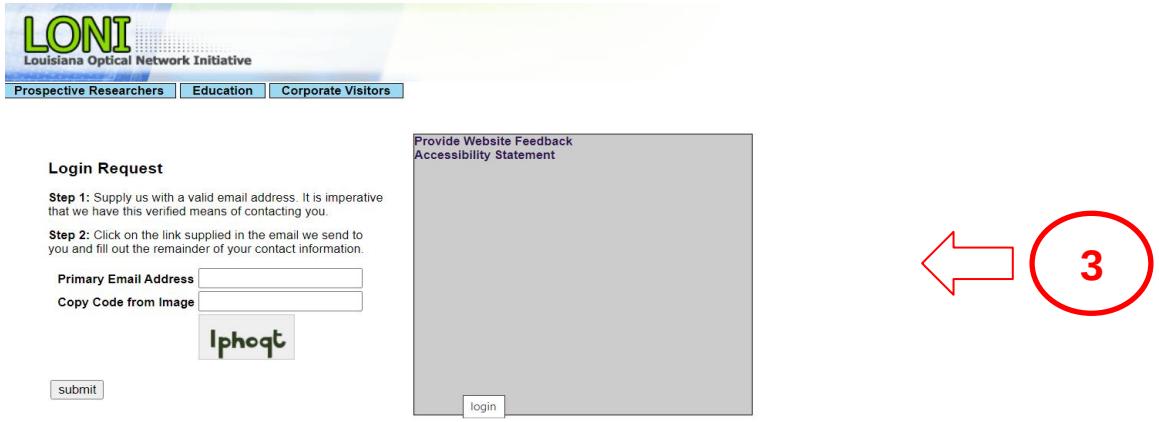
1. Apply for a LONI HPC account
   - find a full-time professor that can sponsor yc research work
   - Navigate to https://hpc.loni.org/



2. Attend our HPC training tutorials:
   - Live:
     - http://hpc.loni.org/training/tutorials.php
   - Archived:
     - http://hpc.loni.org/training/archive/tutorials.php



3. Run your jobs!
   - ➢ Migrate your code/program to the LONI cluster environment
   - ➢ Know how your job is running (getting speedup?)



LONI Open OnDemand Web Portal

QB3: https://ondemand.qbc.loni.org/

QB4: https://ondemand.qbd.loni.org/