



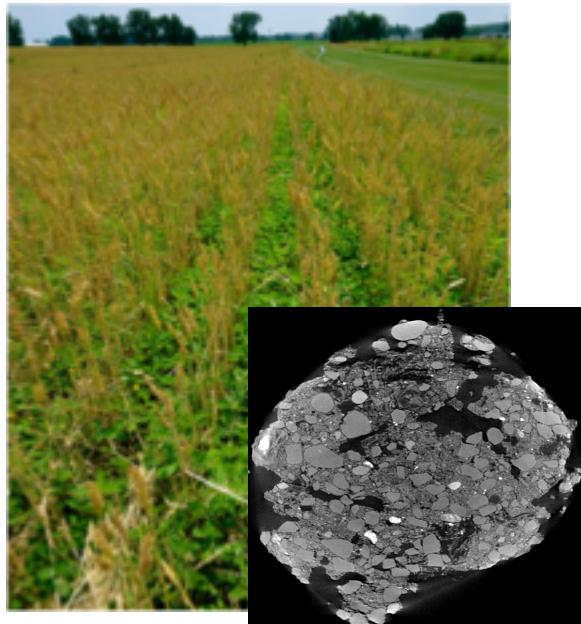
Do More, Faster: Utilizing Advanced Computing Hardware

Dr. Dirk Colbry

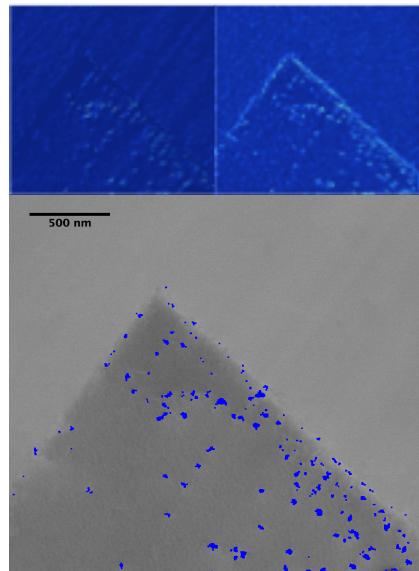
Director of HPC Studies

Department of Computational Mathematics
Science and Engineering

Some of My Research



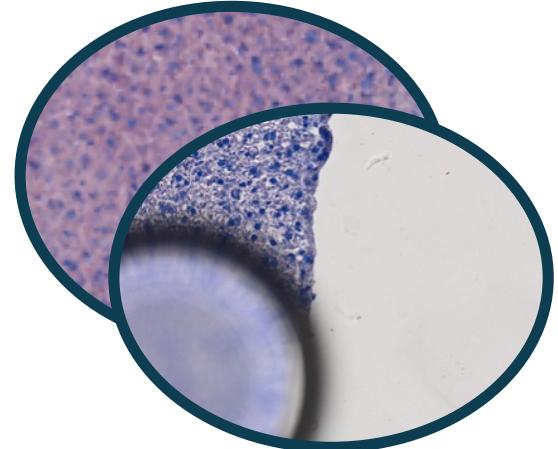
Soil carbon capture for crop yield analysis and climate change research



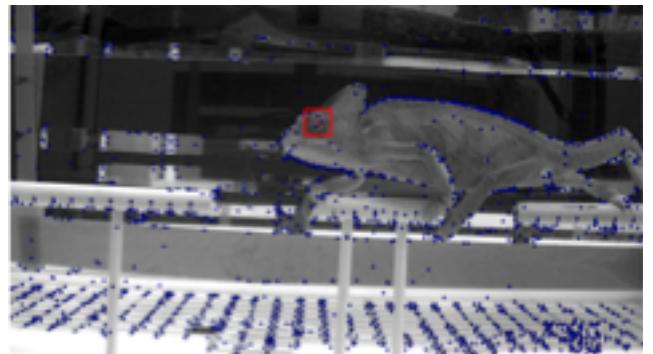
Building 3D crystalline structure of metals using ECCI and FIB technologies



Multi-channel data fusion: fMRI, EEG and 2.5D surface scanning



Large scale automated histopathology putting the researcher in the loop



Incremental machine learning for exploratory science

Using Computers to Do Science

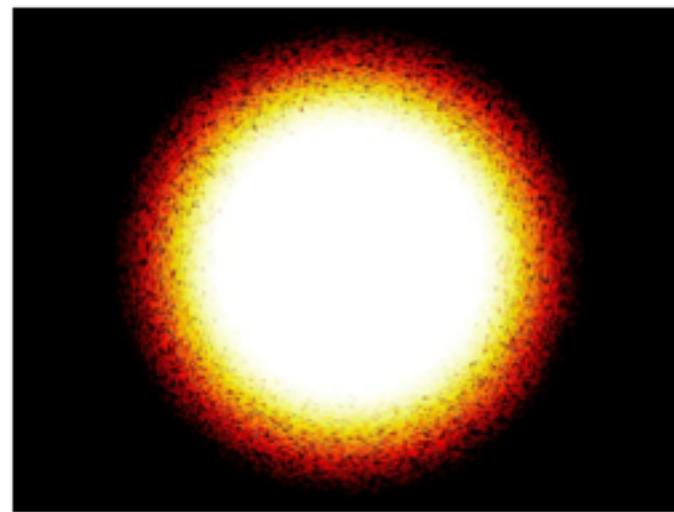
2005-present High Performance Computing Center User

2009-2014 HPCC Computational Consultant

2013-2014 XSEDE Campus Champion Leadership team

2014-2015 Director of HPCC

2015-present Director of HPC Studies, CMSE



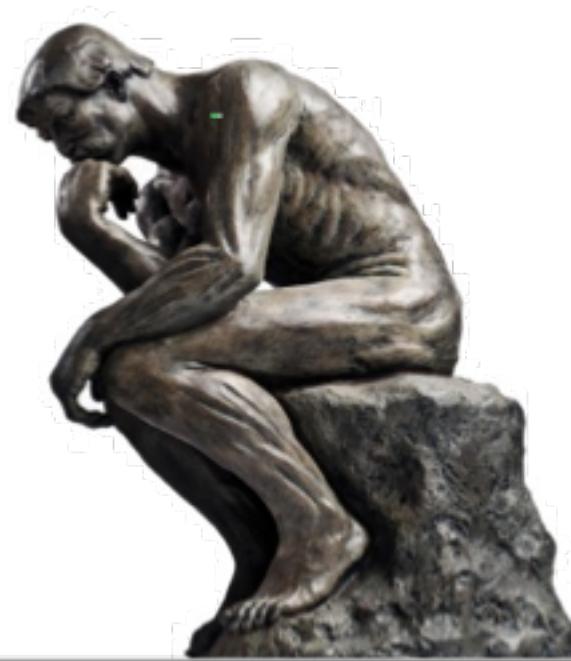
Supernova simulation, Dr. Wolfgang Bauer



Outline

- **How are computing and science related?**
- What problems are we solving?
- We can't make processors go faster.
- How do we make computers faster?

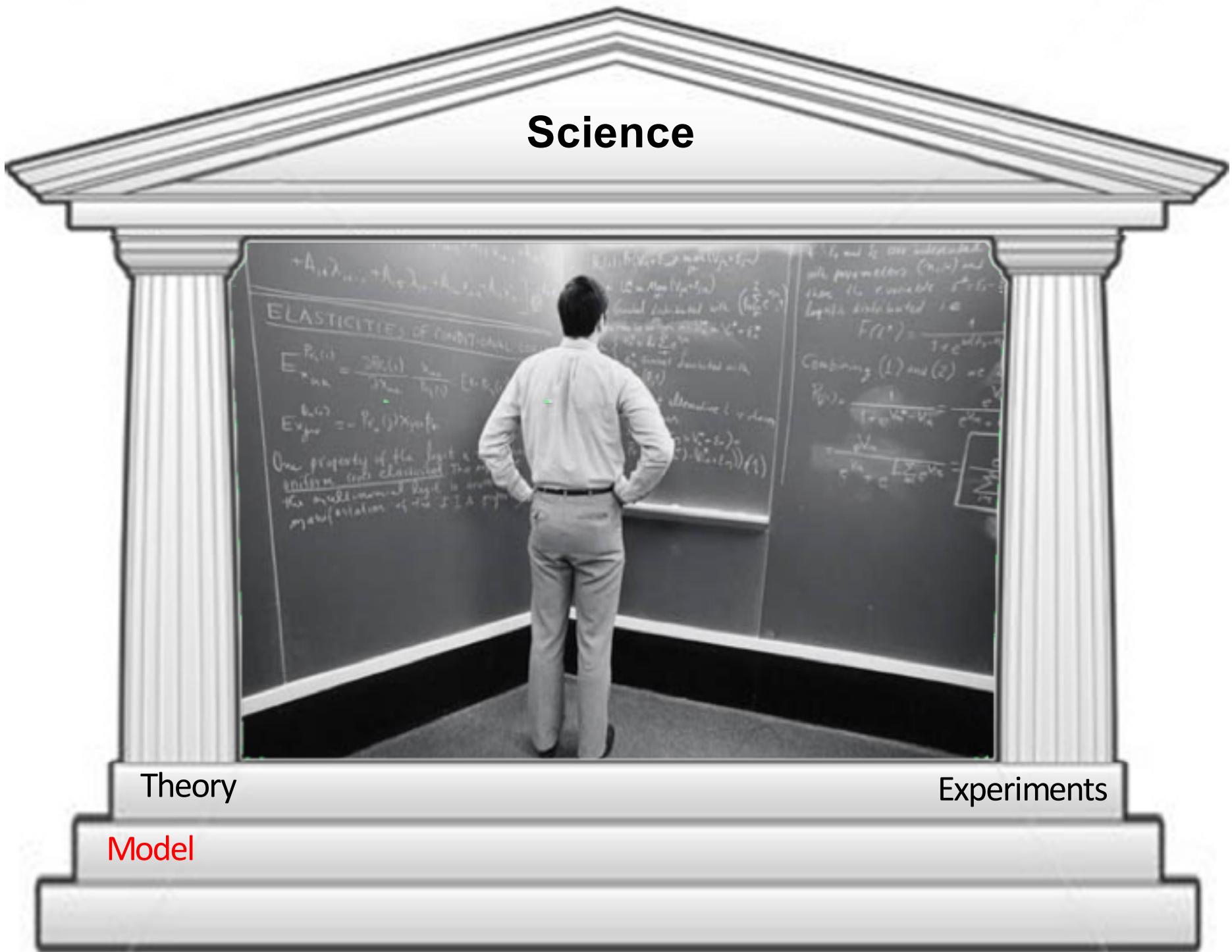
Science



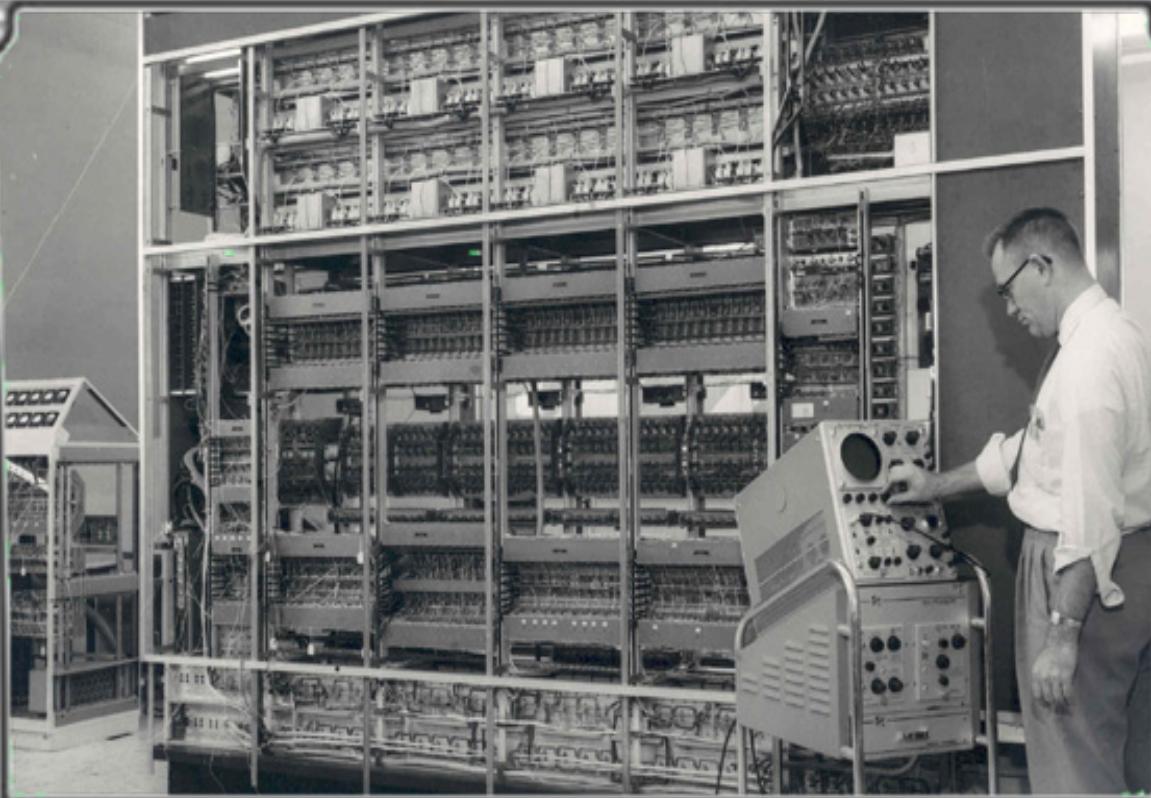
Theory

Experiments

Science



Science



Theory

Experiments

Model

Simulation



Science

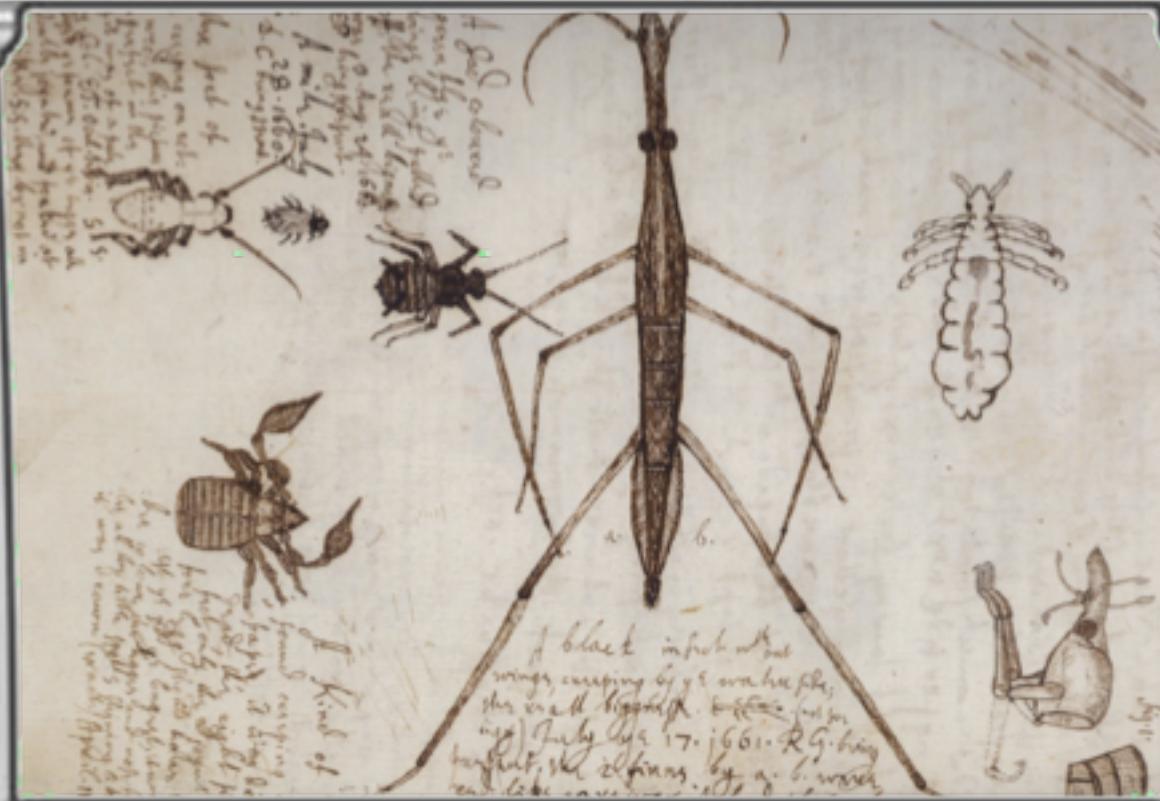
Theory

Model

Simulation (Big)

Experiments

Science



Theory

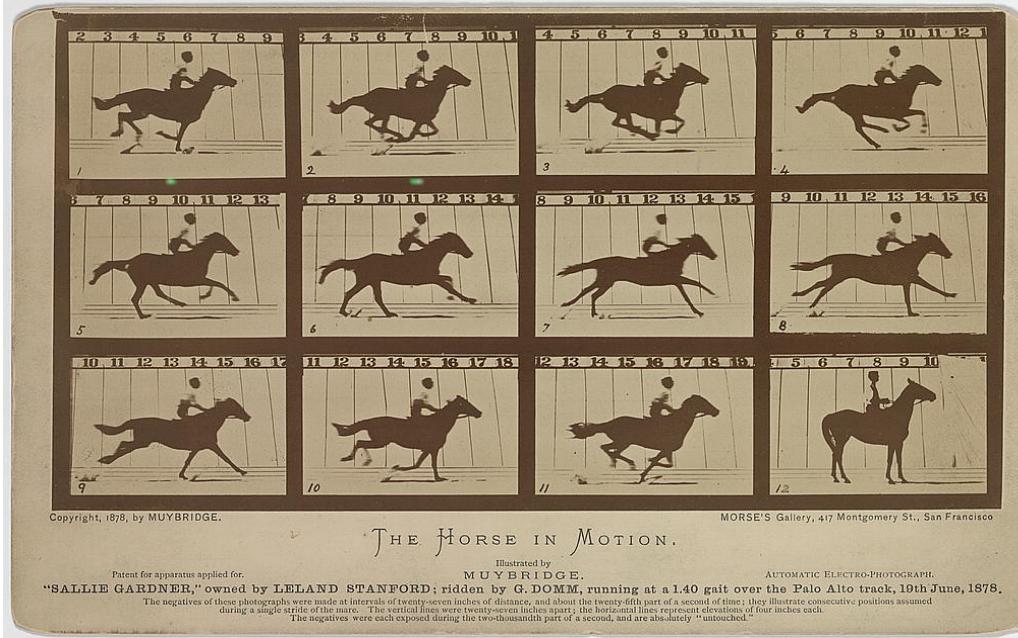
Model

Simulation (Big)

Experiments

Observations

Science



Science



Theory

Model

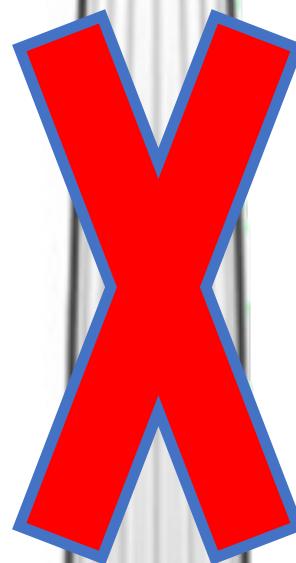
Simulation (Big)

Experiments

Observations

(Lots of) Data

Science



Theory

Computation

Experiments

Model

Observations

Simulation (Big)

(Lots of) Data

Science



CMSE

Theory

Model

Simulation (Big)

Experiments

Observations

(Lots of) Data

Computation

Outline

- How are computing and science related?
- **What problems are we solving?**
- We can't make processors go faster.
- How do we make computers faster?

What problems are we solving?

- Boundary Simulations
- Data Analysis
- Search

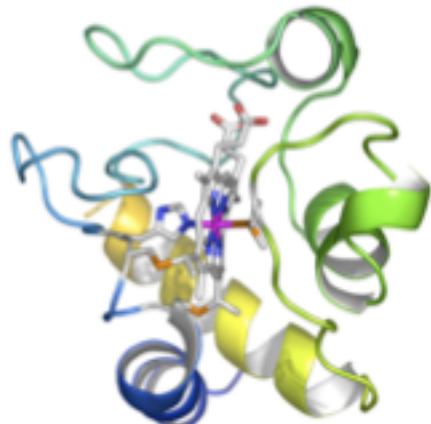
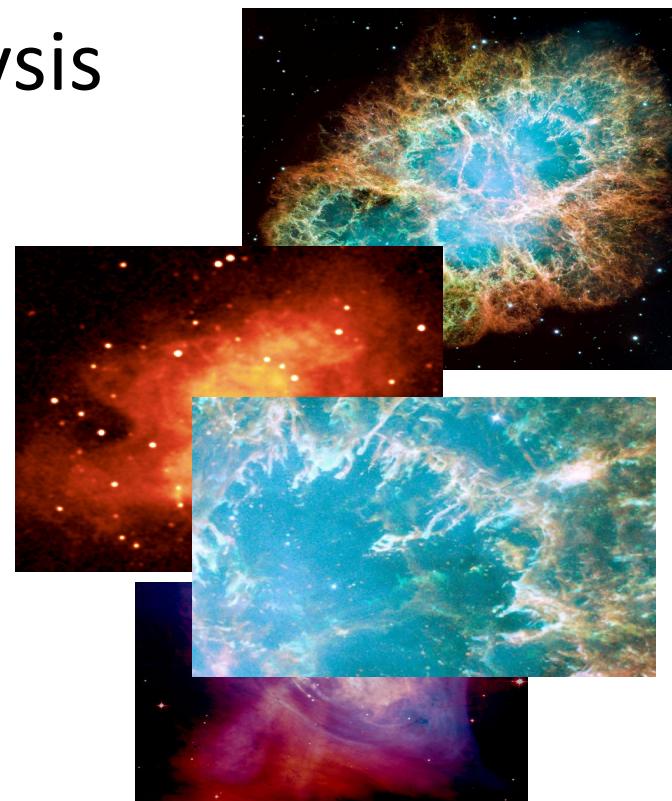
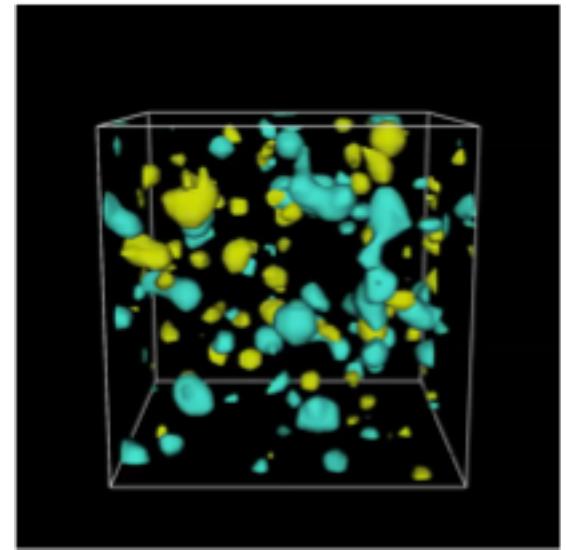


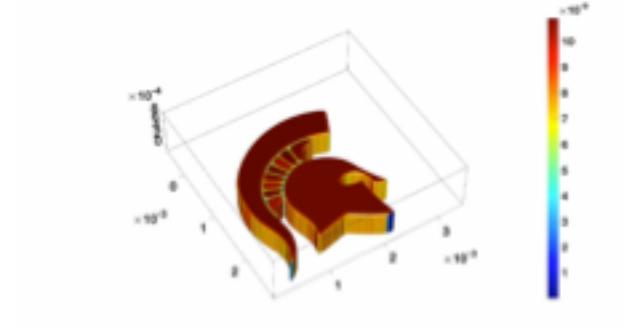
Image provided by
Dr. Warren F. Beck, MSU



Images from, "Understanding the H₂ Emission from the Crab Nebula", C.T. Richardson, J.A. Baldwin, G.J. Ferland, E.D. Loh, Charles A. Huehn, A.C. Fabian, P.Salomé



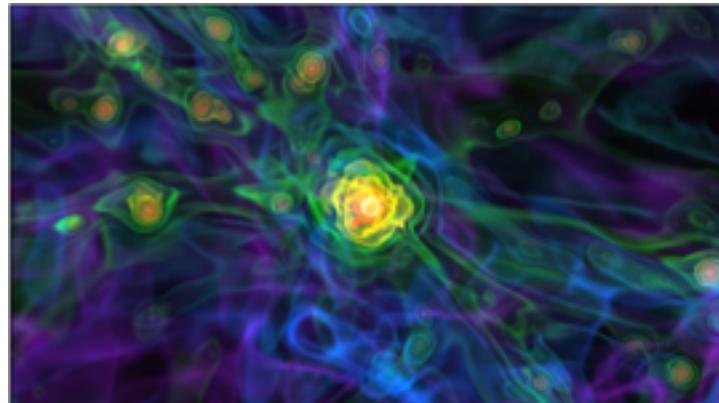
Dr. Huey-Wen Chen



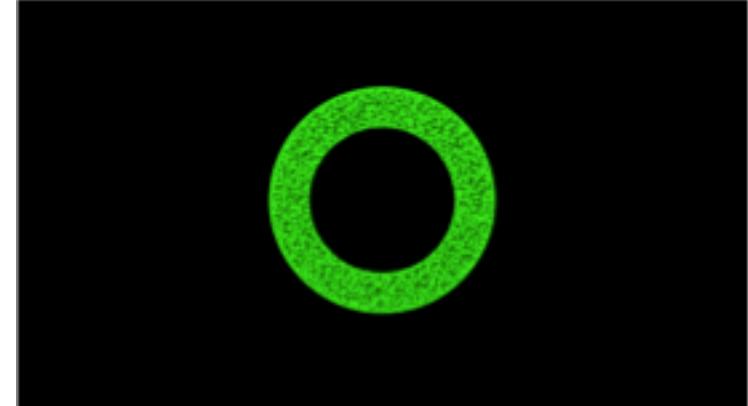
Dr. Hui-Chia Yu

Boundary Simulations

- Typically System of PDE (Partial Differential Equations)
 - Fluid dynamics
 - Finite element analysis
 - Molecular dynamics
 - Weather
 - etc.
- Mathematically equivalent to inverse of a matrix



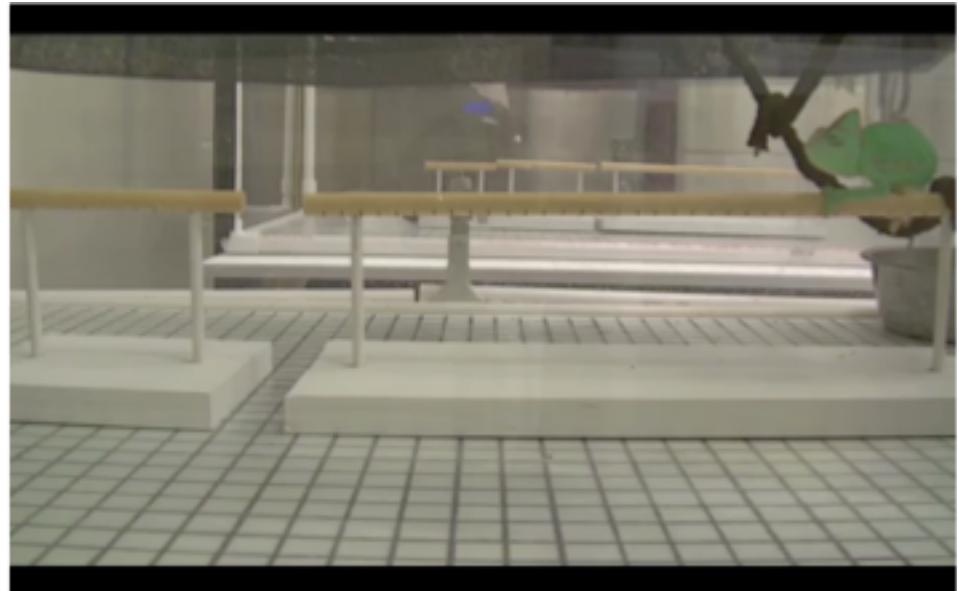
Dr. Brian O'Shea



Dr. Michael Murillo

Data Analysis

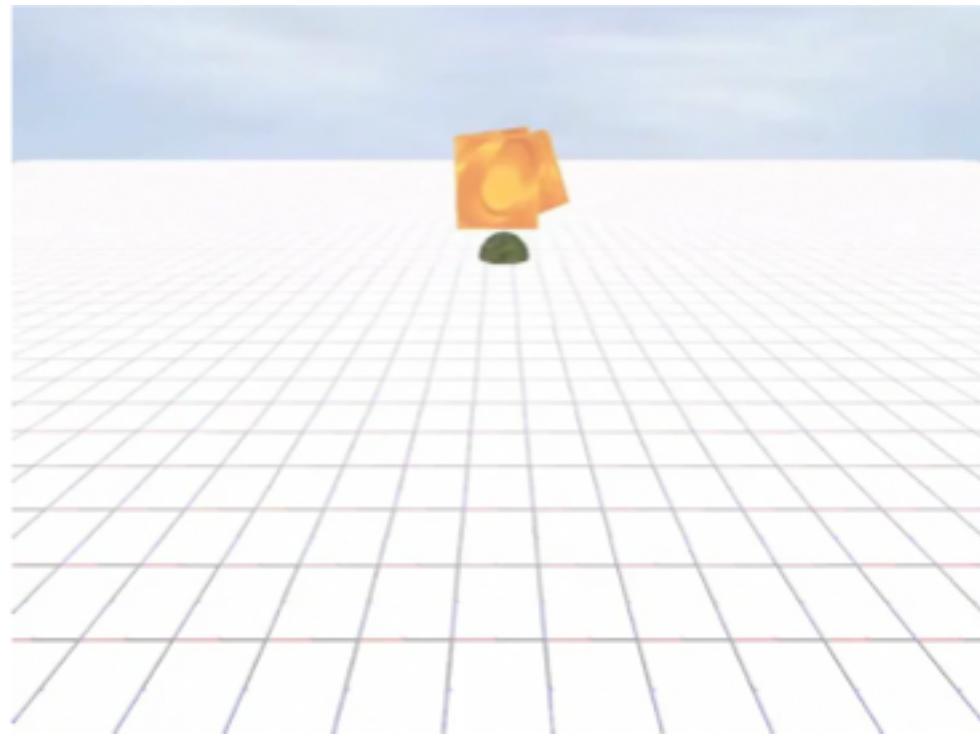
- Computer vision tasks
- Some Bioinformatics
- Astrophysics
- Machine Learning
- etc.



Video Provided by Dr. Fred Dyer

Search

- Genome sequencing
- Analytics
- Optimization
- Inverse Problems
- etc.

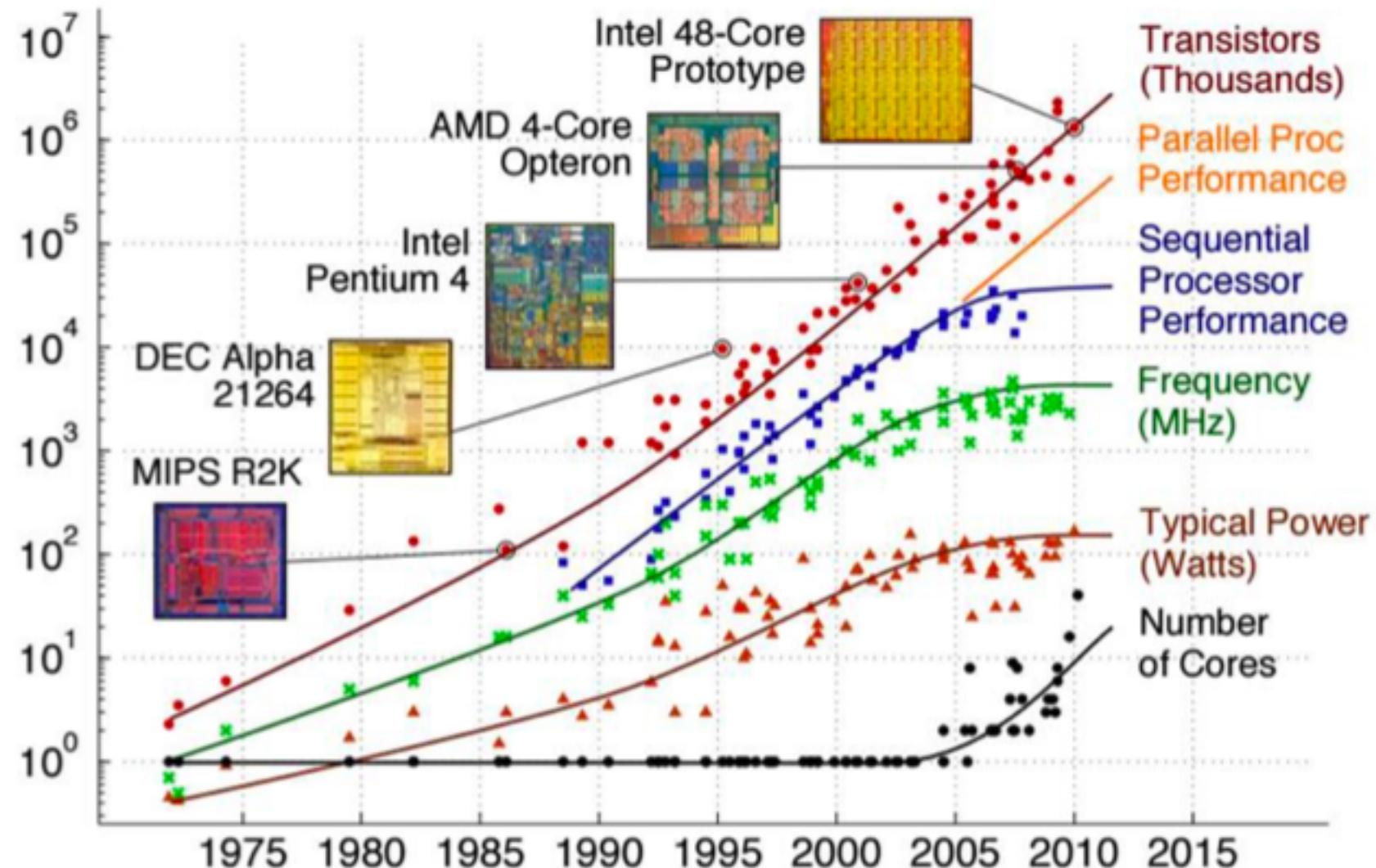


Evolution of an artificial organism that can move and forage for food, Dr. Nicolas Chaumont

Outline

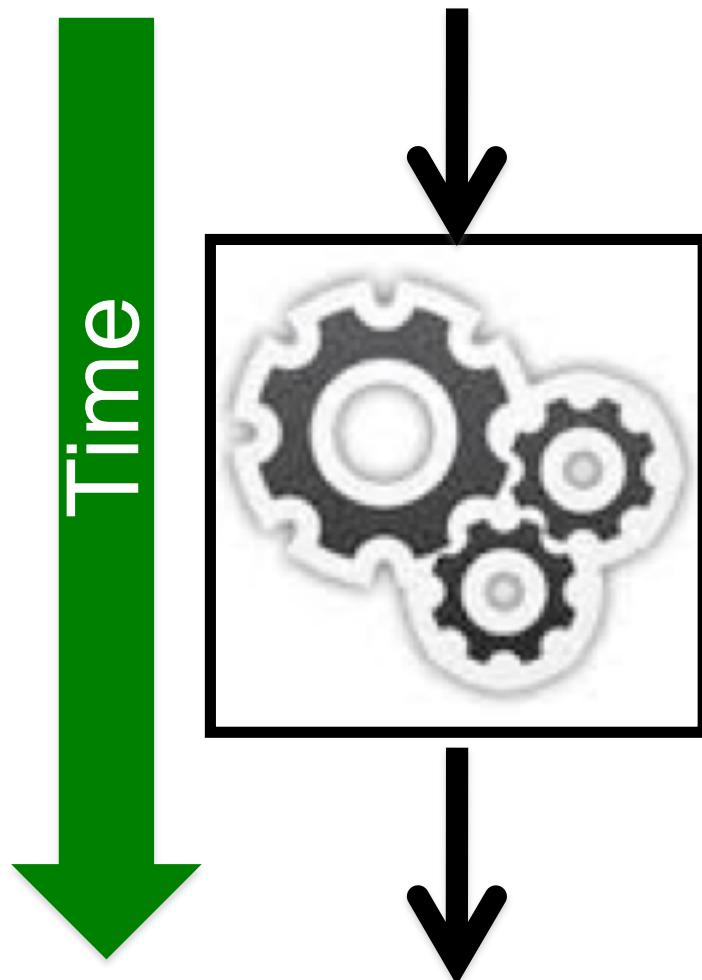
- How are computing and science related?
- What problems are we solving?
- **We can't make processors go faster.**
- How do we make computers faster?

We can't make computers faster



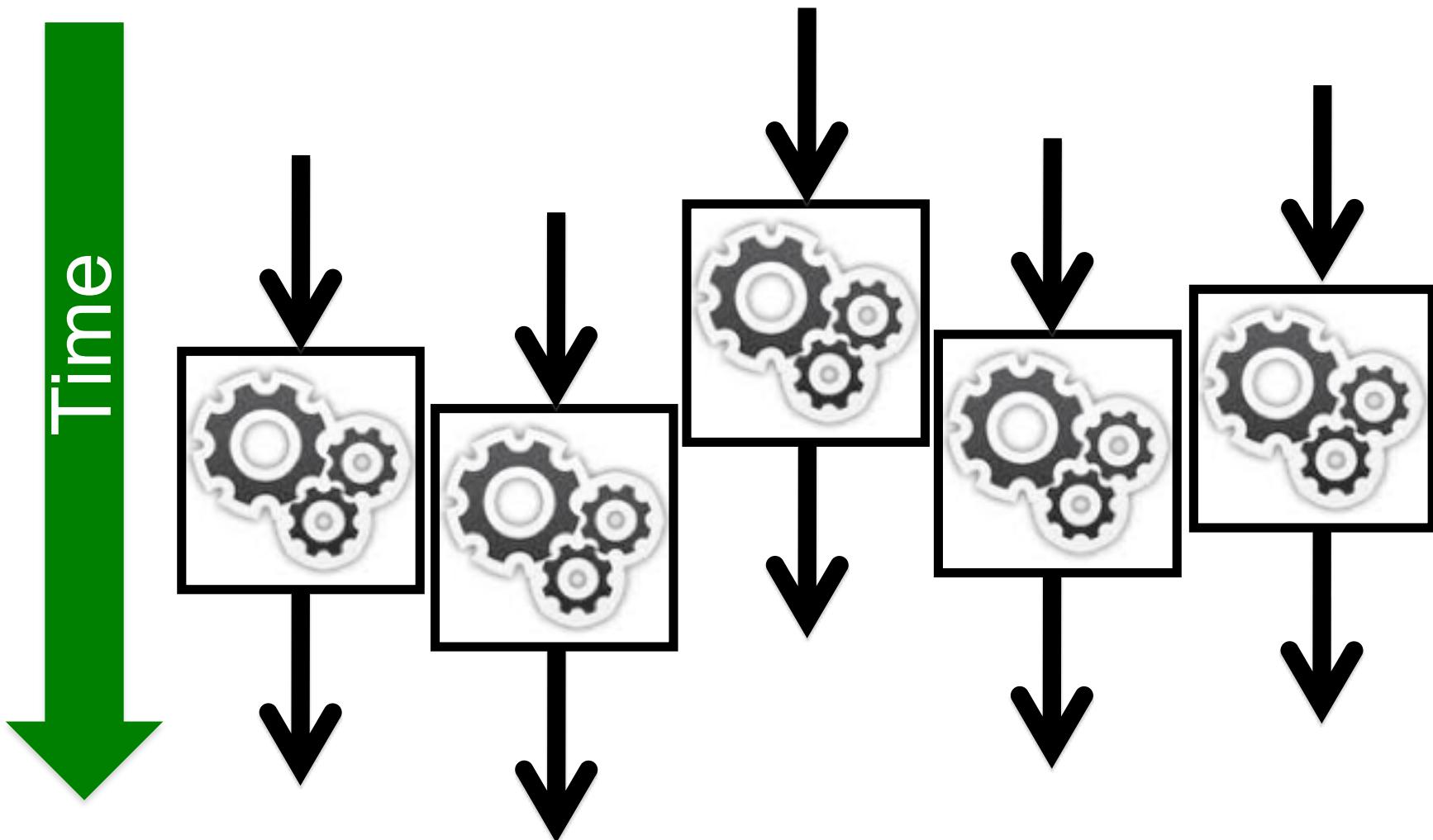
Data partially collected by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond

Single Thread Jobs

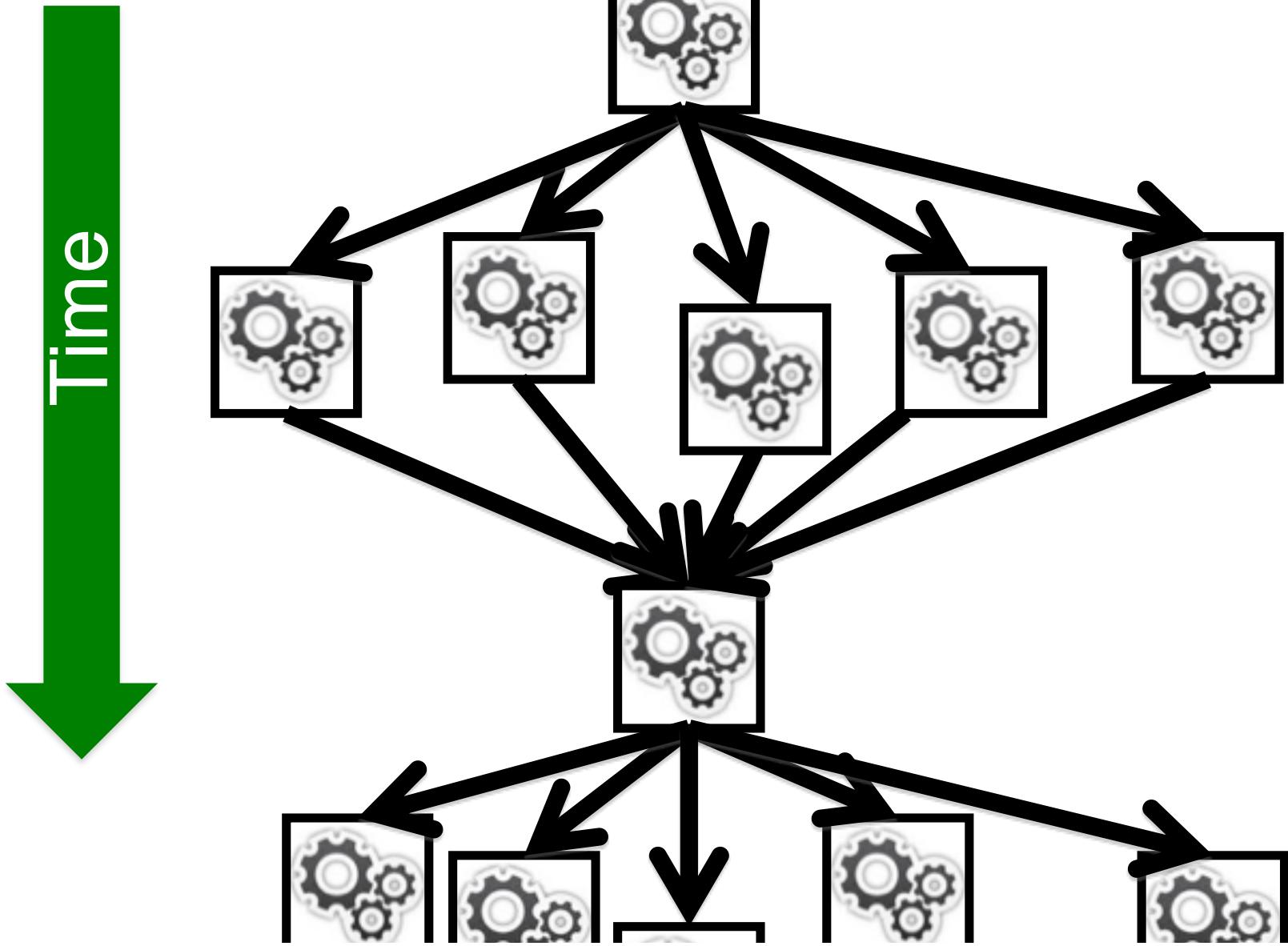


One CPU can only run one thing at a time. (sort of)

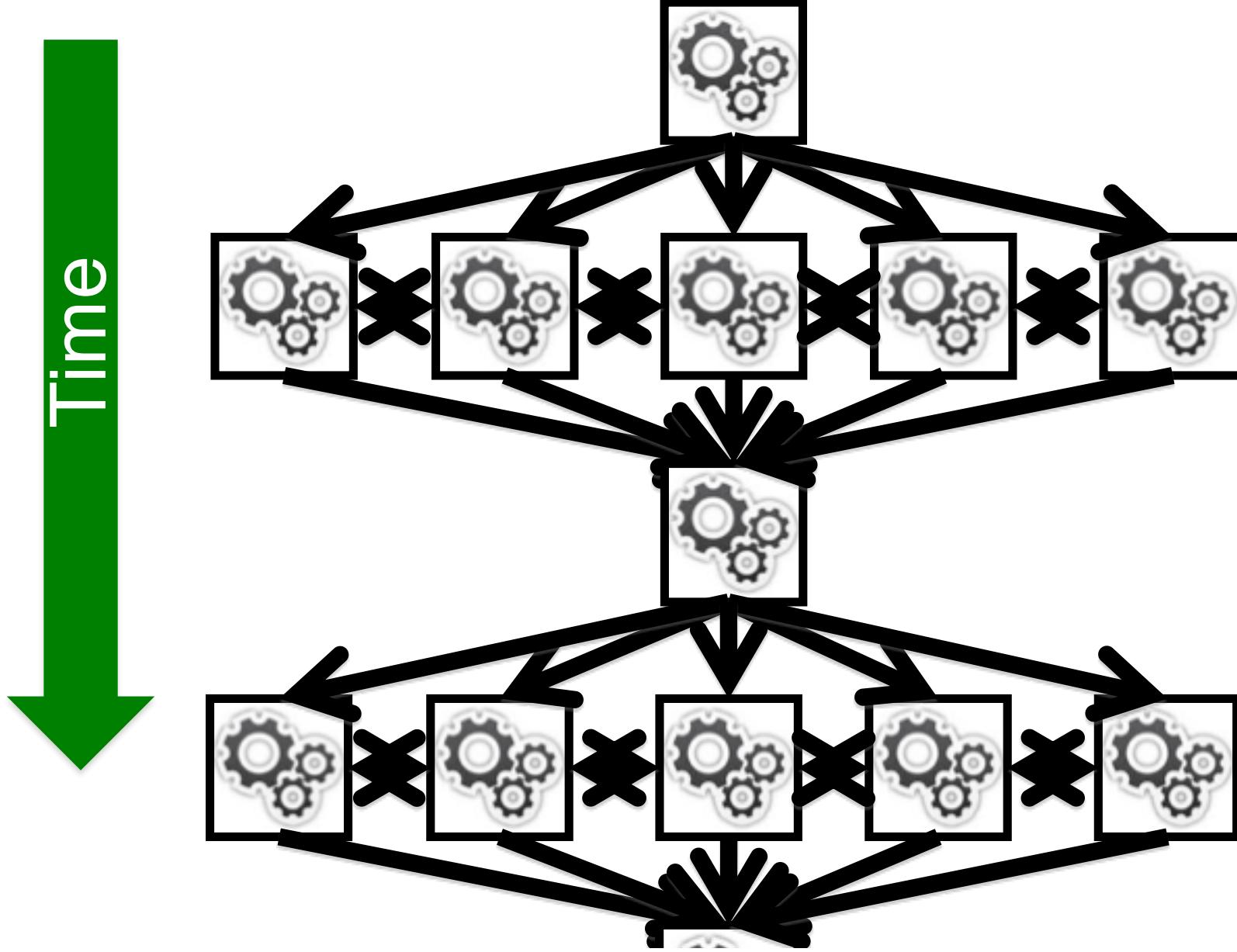
Pleasantly Parallel



Loosely Coupled



Tightly Coupled



Outline

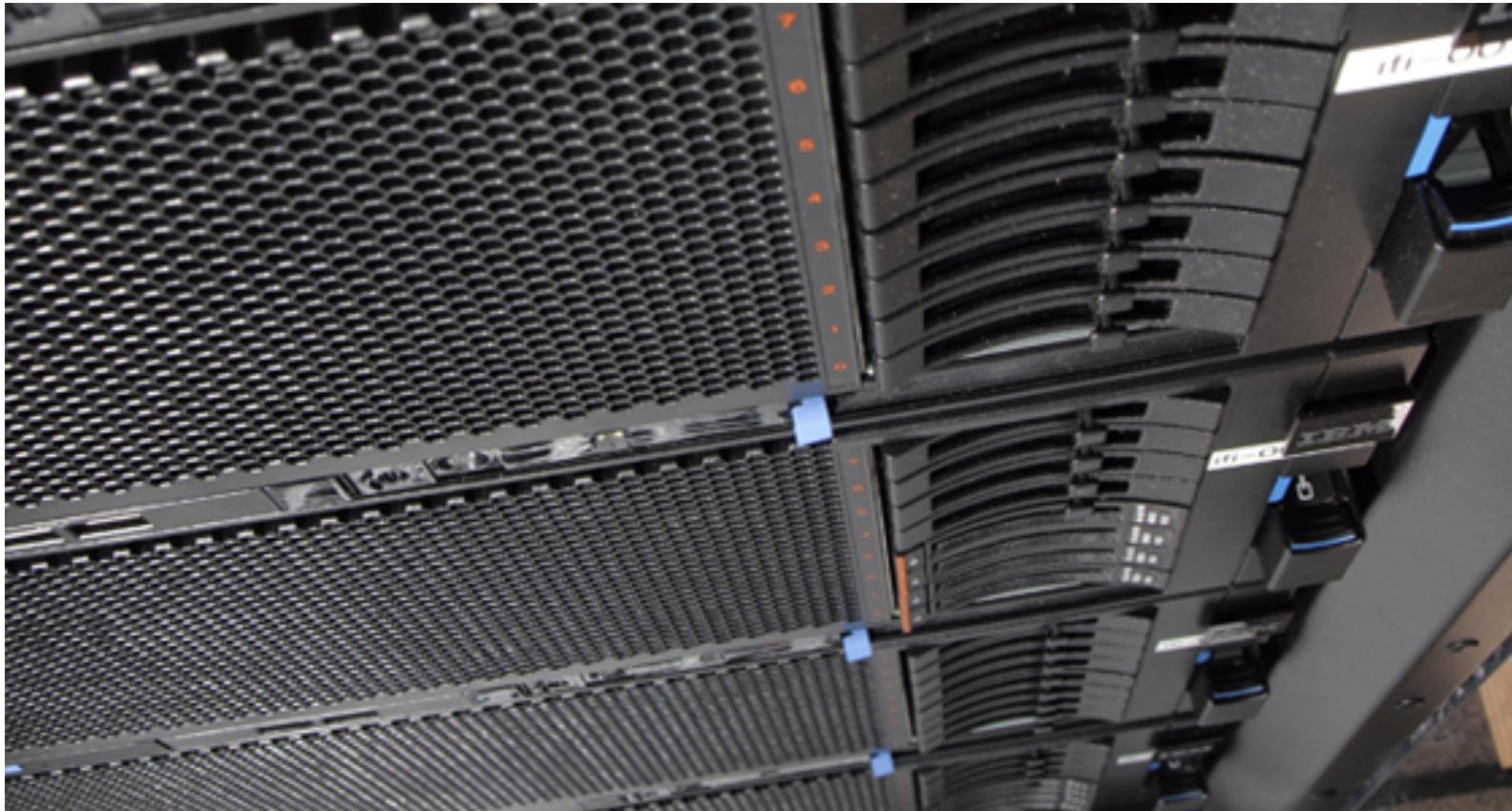
- How are computing and science related?
- What problems are we solving?
- We can't make processors go faster.
- **How do we make computers faster?**

Communication

- Shared Memory
- Shared Network
- Distributed Network
- Dedicated Accelerators
- Hybrid Systems

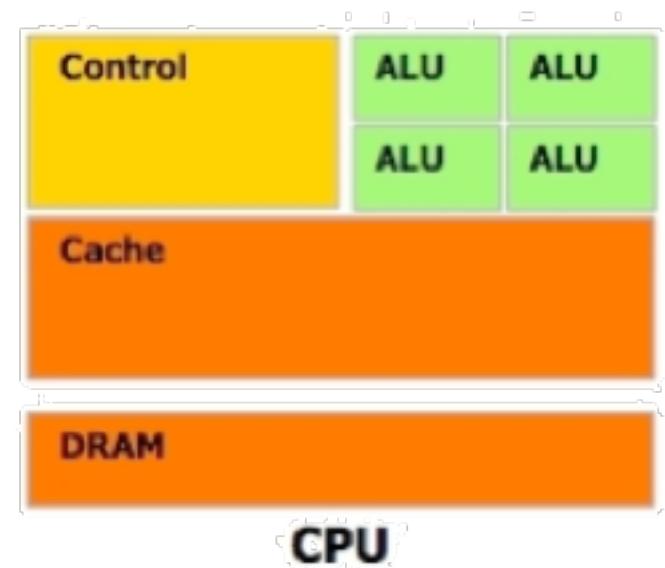
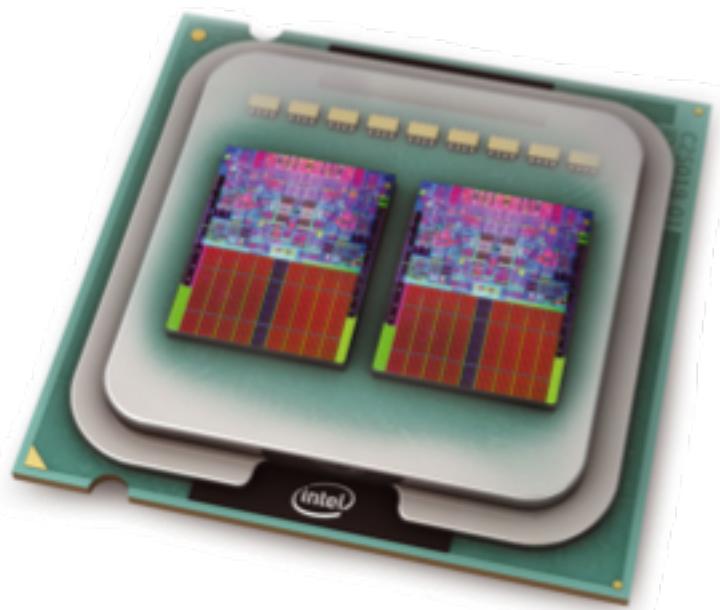


Shared Memory Systems



Shared Memory Communication

- Multiple Cores on a processor share the same memory
- Multiple Chips in a computer



- Memory is fast
- There is a limit to how many chips we can fit on a computer

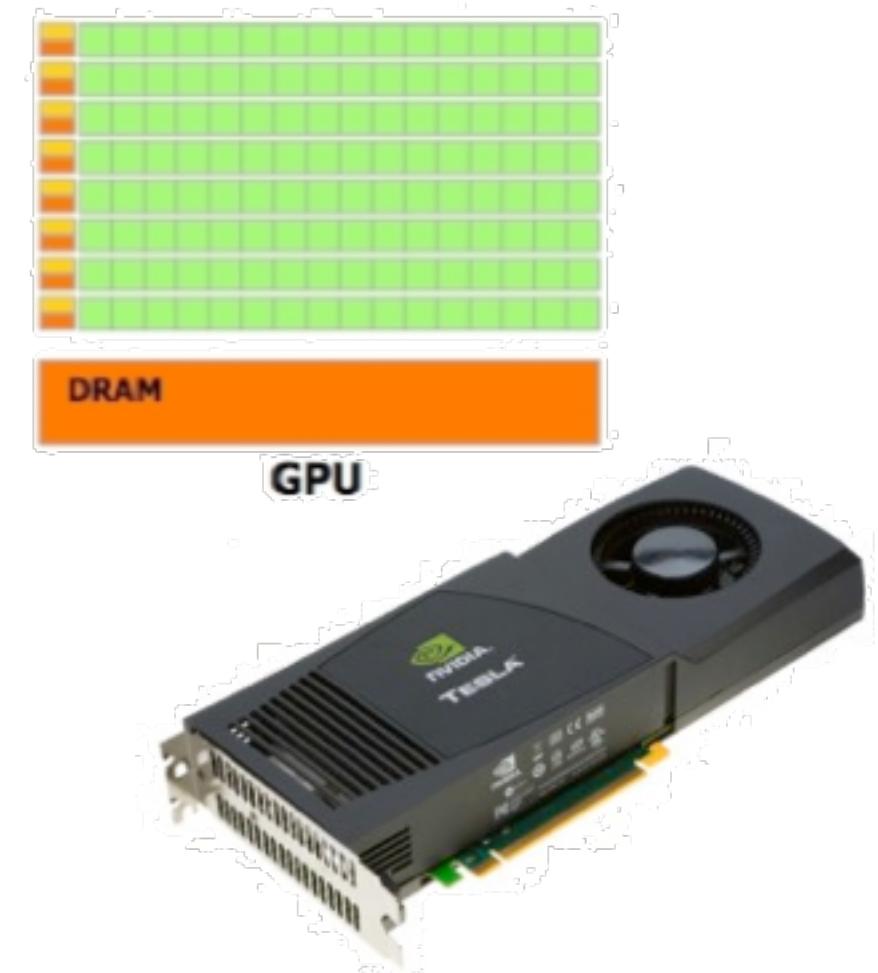
How do we go faster?

Accelerators



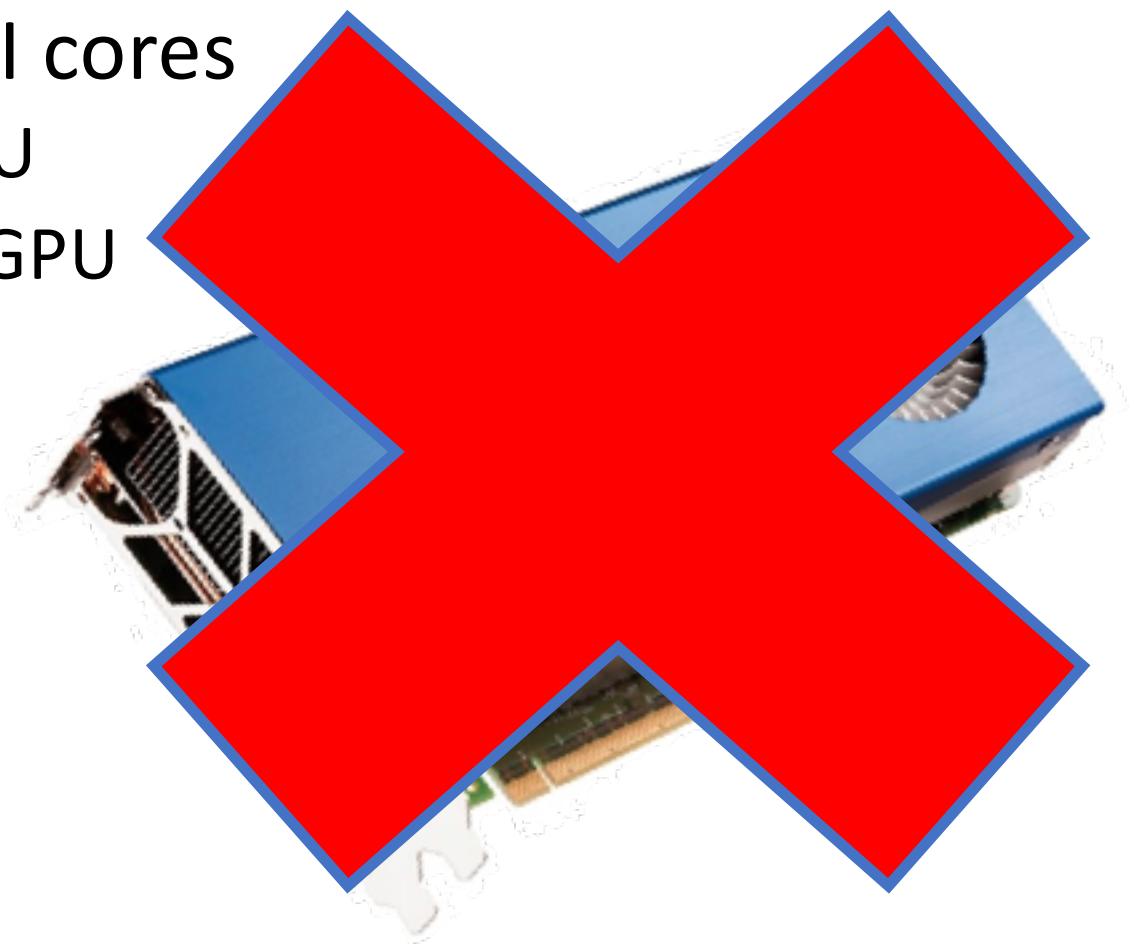
GPUs

- Cards used to render graphics on a computer
- Hundreds of cores
- Not very smart cores
- But, if you can make your research look like graphics rendering you may be able to run really fast!



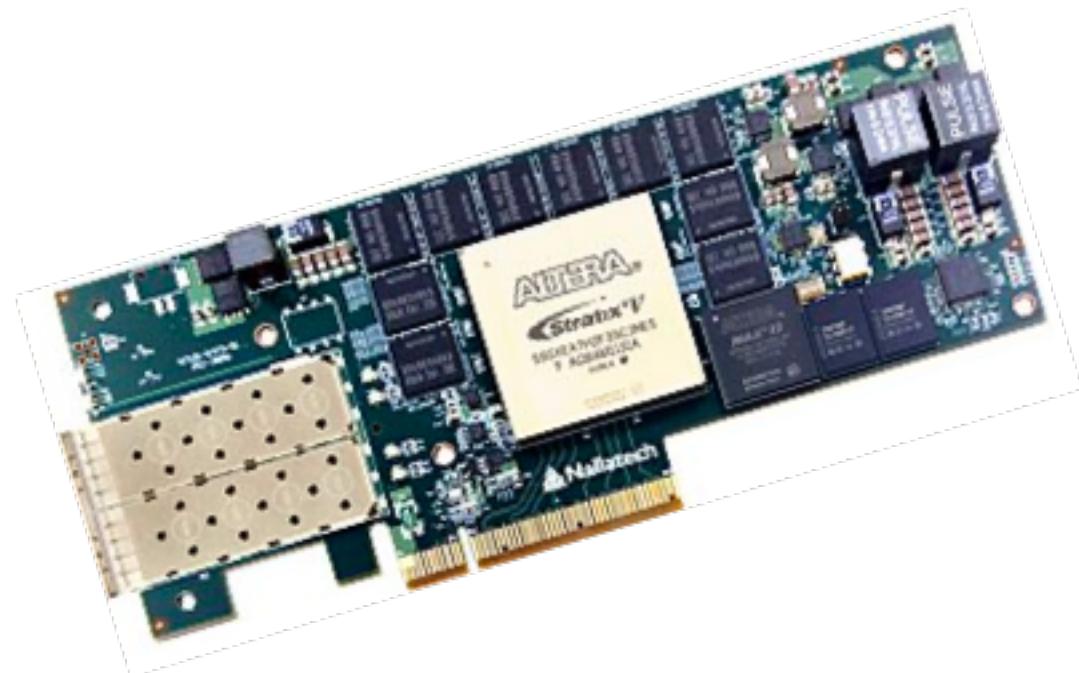
Intel Xeon Phi

- Cross between CPU and GPU
- About 60 Pentium I cores
 - Less cores than GPU
 - Easier to use than GPU
 - OpenMP
 - MP



Field Programmable Gate Arrays (FPGA)

- New Life into an old technology
- Programmable hardware
- Chameleon Chip (In theory can be any chip)
- Could be really fast

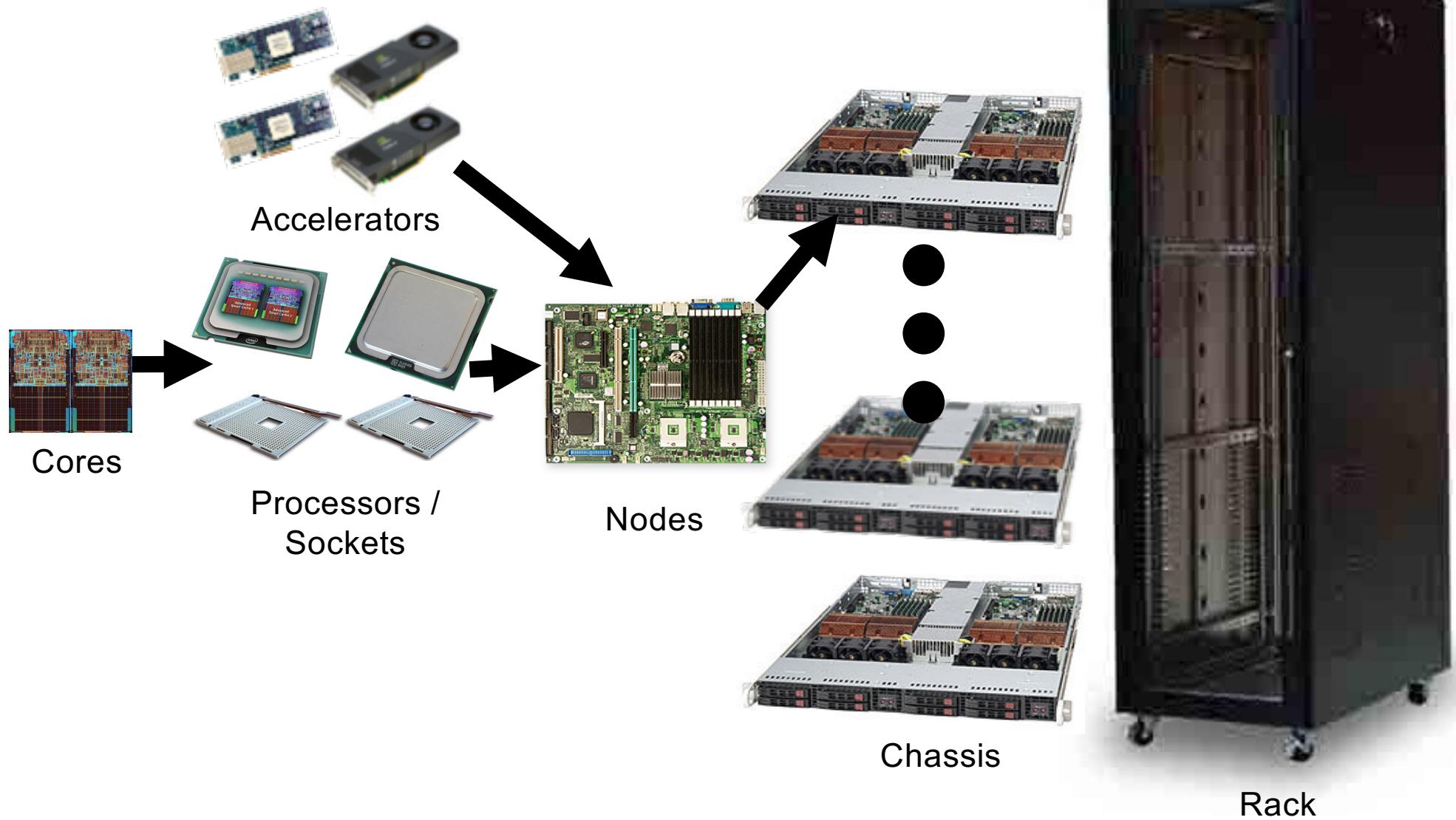


How do we go faster?

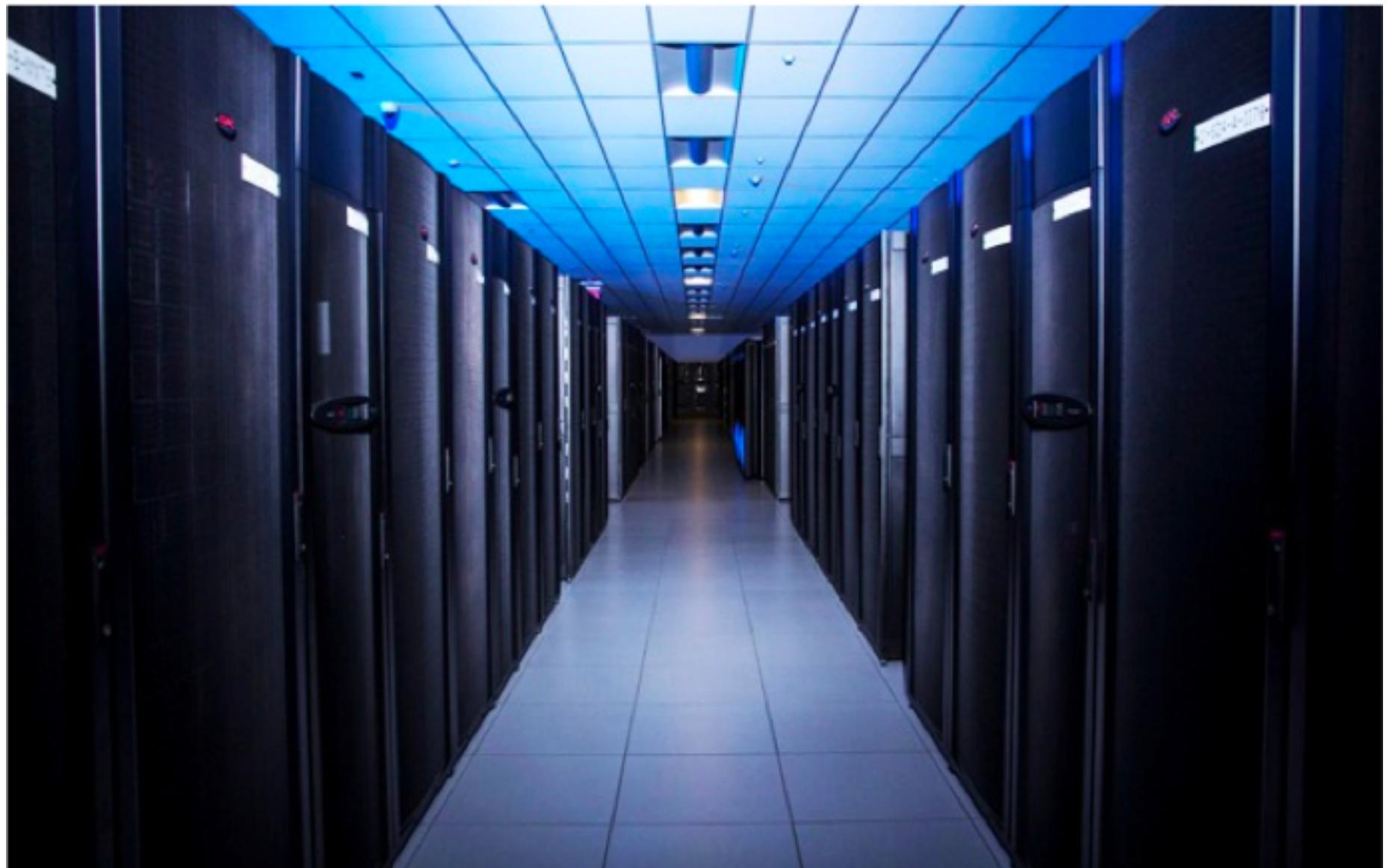
High Throughput Computing



Commodity Cluster



Data Center





Portable HPC



facebook



YAHOO!

“Cloud” Computing

(Data, Hardware and Services over the Internet)

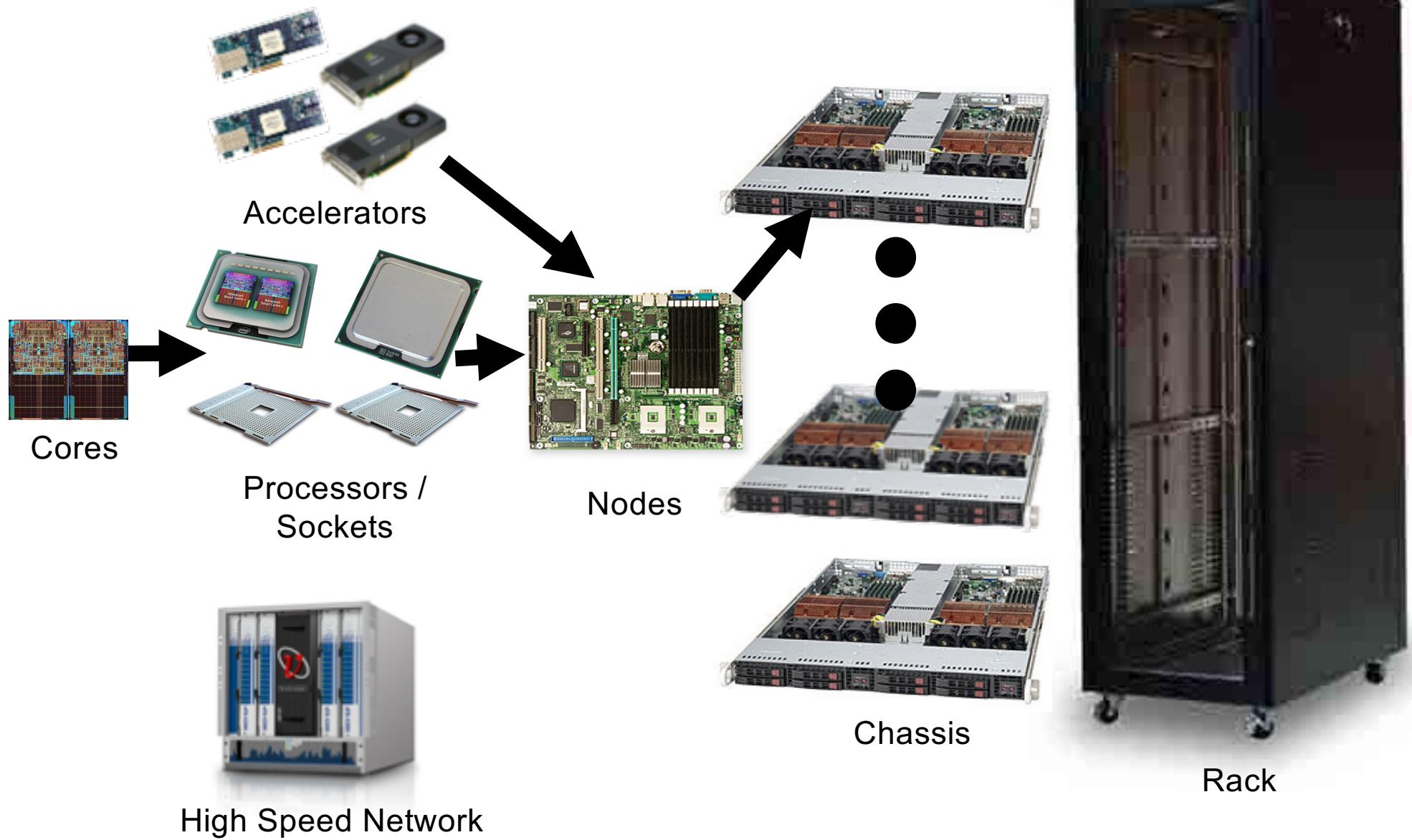


How do we go faster?

High Performance Computing



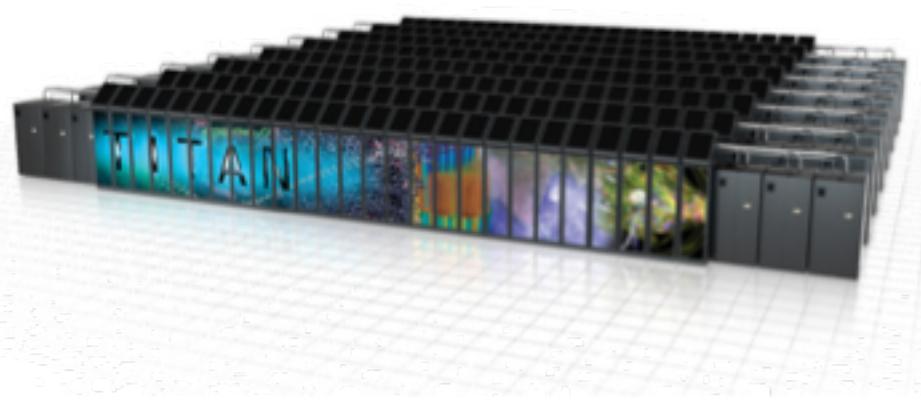
Commodity Cluster



Computing Resources?



Extreme Science and Engineering
Discovery Environment



Questions?

colbrydi@msu.edu