Parallel Processing

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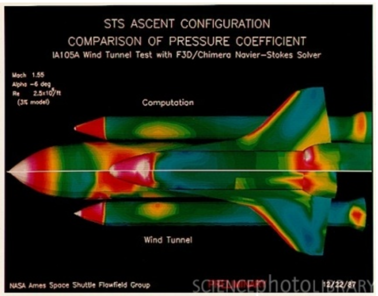
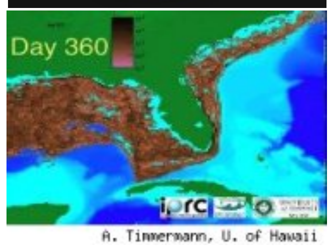
Chapter 1: Introduction

- HPC and applications
- Introduction
  - What is parallel processing?
  - Why do we use parallel processing?
- Parallelism

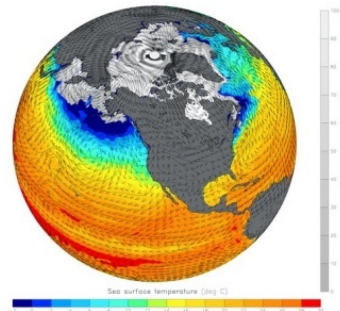
Applications (1)



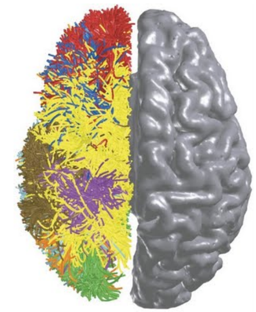
Khí động học
trong tàu vũ trụ



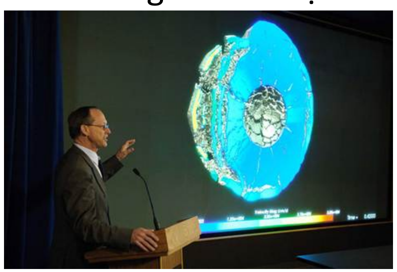
Tràn dầu của BP



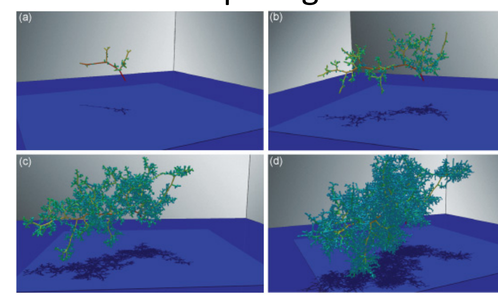
Mô hình thời tiết PCM



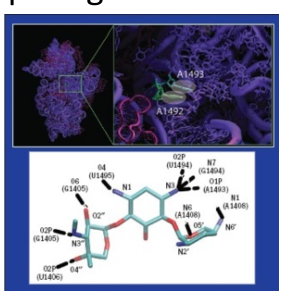
Mô phỏng não



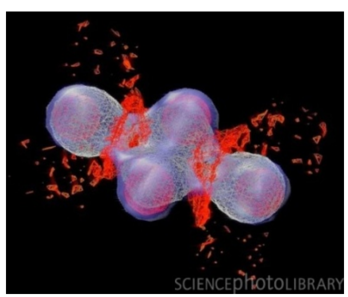
Mô phỏng tiểu hành tinh



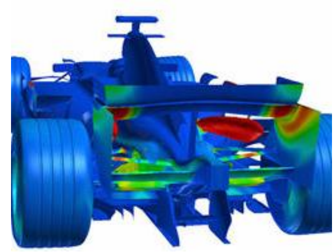
Mô phỏng Uranium-235 hình thành
từ phân rã Phutonium-239



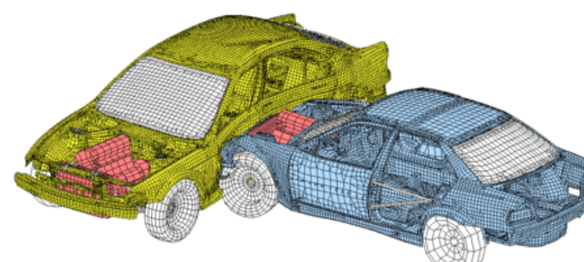
Tác dụng của thuốc ở
mức phân tử



Mô phỏng
nguyên tử Lithium



Mô phỏng Renault F1



Mô phỏng xe va chạm

Applications (2)

- Critical HPC issues
  - Global warming
  - Alternative energy
  - Financial disaster modeling
  - Healthcare
- New trends
  - Big Data
  - Internet of Things (IoT)
  - 3D movies and large scale games are fun
  - Homeland security
  - Smart cities

High Performance Computing - HPC


HPC wire

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July 30, 2015

White House Launches National HPC Strategy

John Russell and Tiffany Trader

Yesterday's executive order by President Barack Obama creating a National Strategic Computing Initiative (NSCI) is not only powerful acknowledgment of the vital role HPC plays in modern society but is also indicative of government's mounting worry that failure to coordinate and nourish HPC development on a broader scale would put the nation at risk. Not surprisingly, community has been largely positive.

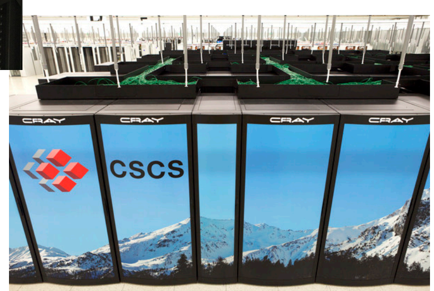
The European HPC Strategy

The Commission recognised the need for an EU-level policy in HPC to optimise national and European investments, addressing the entire HPC ecosystem. The Commission adopted its HPC Strategy on 15 February 2012 in the Communication "High Performance Computing (HPC): Europe's place in a global race" to ensure European leadership in the supply and use of HPC systems and services by 2020. The Competitiveness Council on 29/30 May 2013 adopted conclusions on this Communication, highlighting the role of HPC in the EU's innovation capacity and stressing its strategic importance to the EU's industrial and scientific capabilities as well as to its citizens.

> High-Performance Computing (HPC) is a strategic resource for Europe's future. Mastering advanced computing technologies from hardware to software has become essential for innovation, growth and jobs.

Oakforest-PACS
13.55 Petaflops
556,104 cores

Titan
17.6 Petaflops
560,640 cores



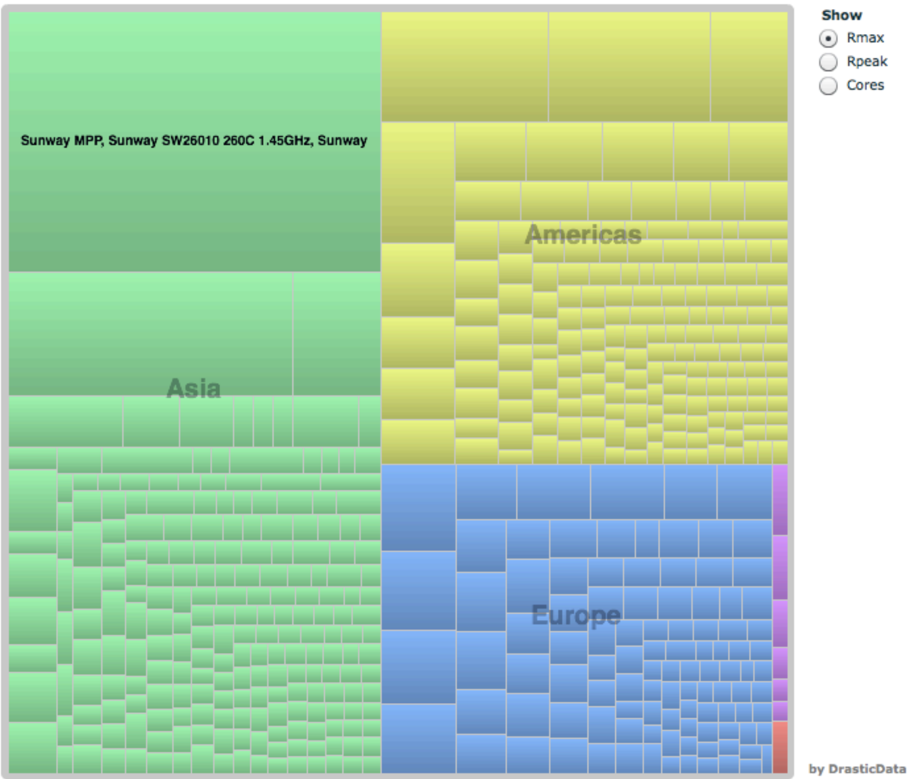
Piz Daint
19.59 Petaflops
361,760 cores

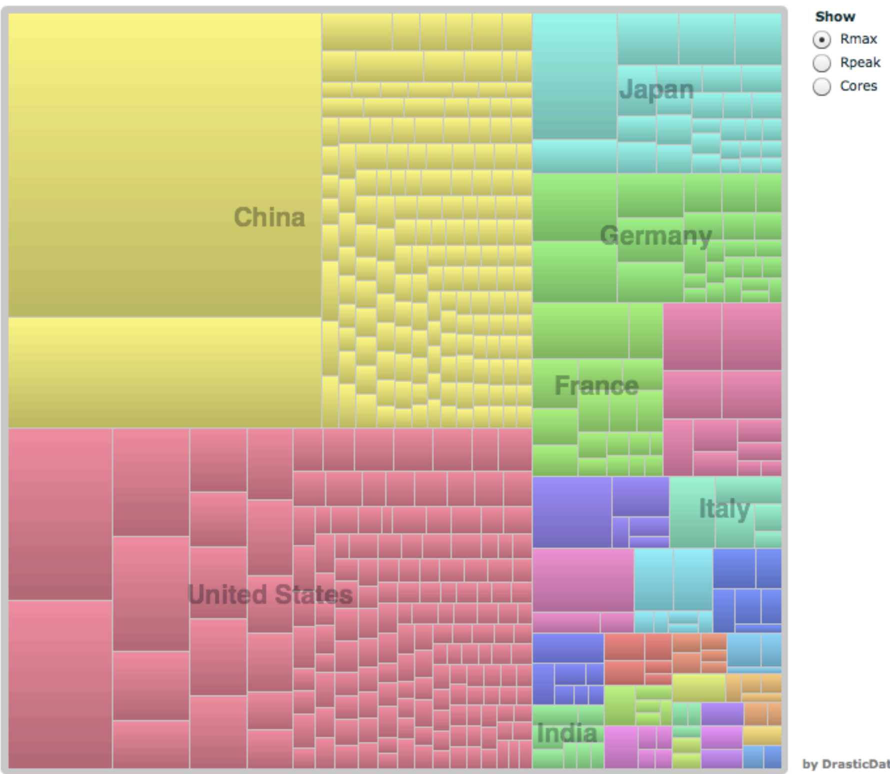
Sunway TaihuLight
93.0 Petaflops
10,649,600 cores

http://www.TOP500.org/

Rank	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway , NRCPC National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
2	**Tianhe-2 (MilkyWay-2)** - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P , NUDT National Super Computer Center in Guangzhou China	3,120,000	33,862.7	54,902.4	17,808
3	**Piz Daint** - Cray XC50, Xeon E5-2690v3 12C 2.6GHz, Aries interconnect , NVIDIA Tesla P100 , Cray Inc. Swiss National Supercomputing Centre (CSCS) Switzerland	361,760	19,590.0	25,326.3	2,272.0
4	**Titan** - Cray XK7, Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x , Cray Inc. DOE/SC/Oak Ridge National Laboratory United States	560,640	17,590.0	27,112.5	8,209
5	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom , IBM DOE/NNSA/LLNL United States	1,572,864	17,173.2	20,132.7	7,890
6	**Cori** - Cray XC40, Intel Xeon Phi 7250 68C 1.4GHz, Aries interconnect , Cray Inc. DOE/SC/LBNL/NERSC United States	622,336	14,014.7	27,880.7	3,939
7	**Oakforest-PACS** - PRIMERGY CX1640 M1, Intel Xeon Phi 7250 68C 1.4GHz, Intel Omni-Path , Fujitsu Joint Center for Advanced High Performance Computing Japan	556,104	13,554.6	24,913.5	2,718.7
8	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect , Fujitsu RIKEN Advanced Institute for Computational Science (AICS) Japan	705,024	10,510.0	11,280.4	12,659.9

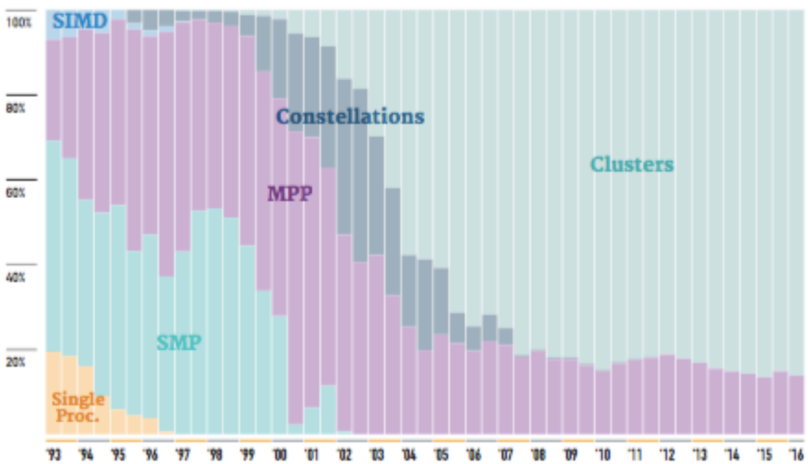
HPC distribution in TOP500 (Jun 2016)



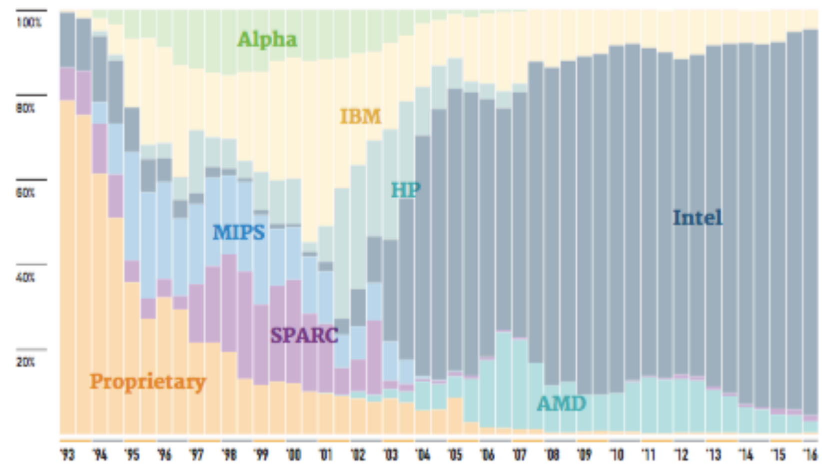


TOP500 (Jun 2016)

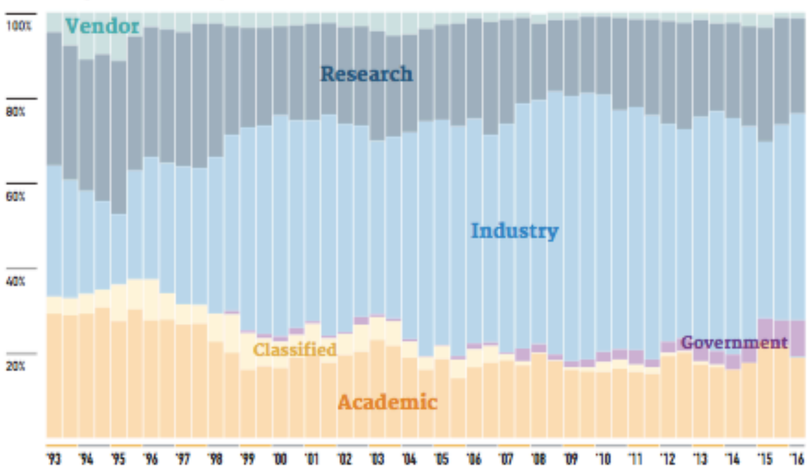
ARCHITECTURES



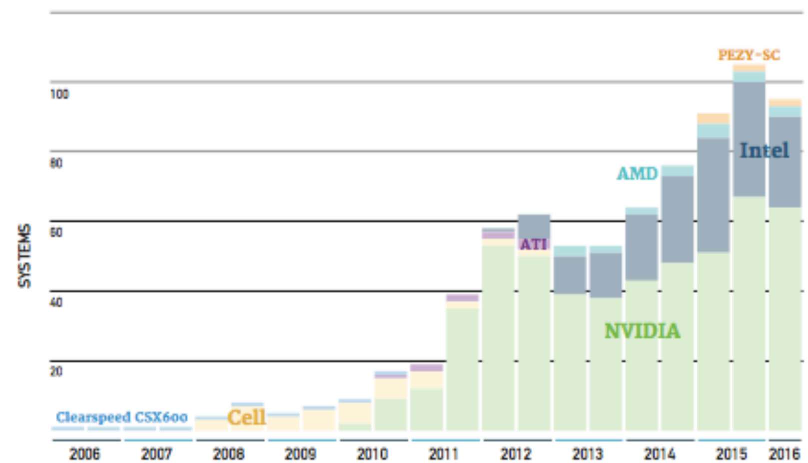
CHIP TECHNOLOGY



INSTALLATION TYPE

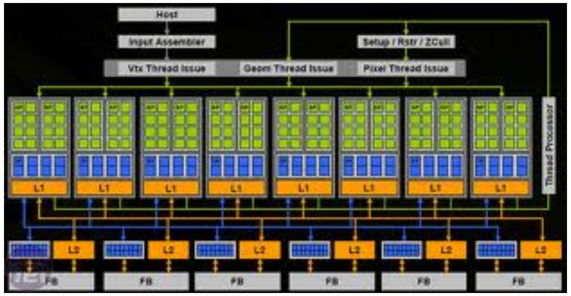


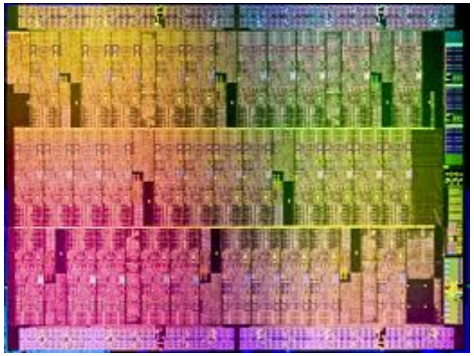
ACCELERATORS/CO-PROCESSORS



Parallel architecture

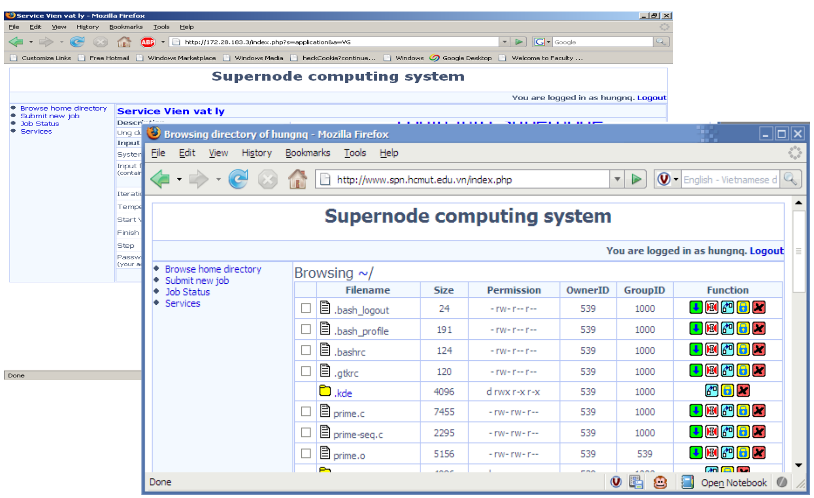
- ❑ Multi-core
- ❑ Many core
  - GPUs (Ndivia)
  - Xeon Phi (Intel)





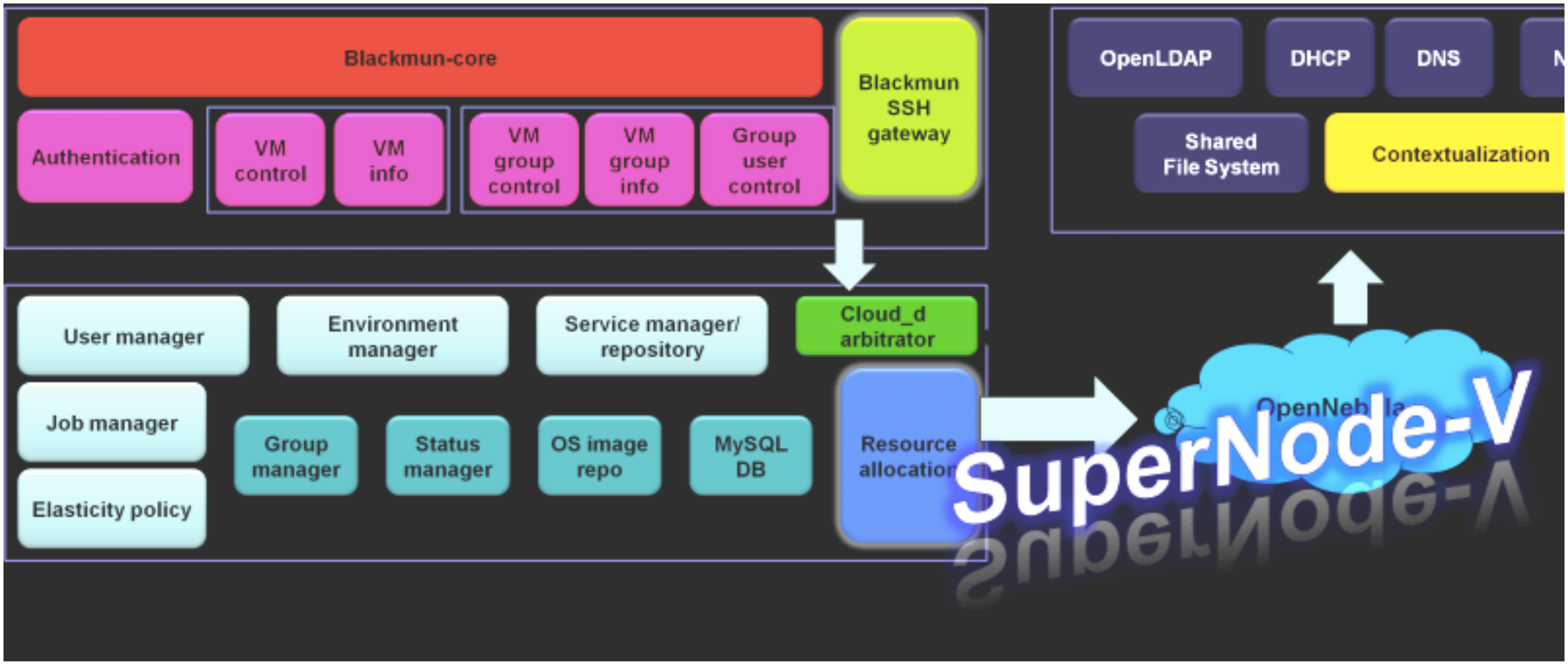
SuperNode I & II

SuperNode I in 1998-2000



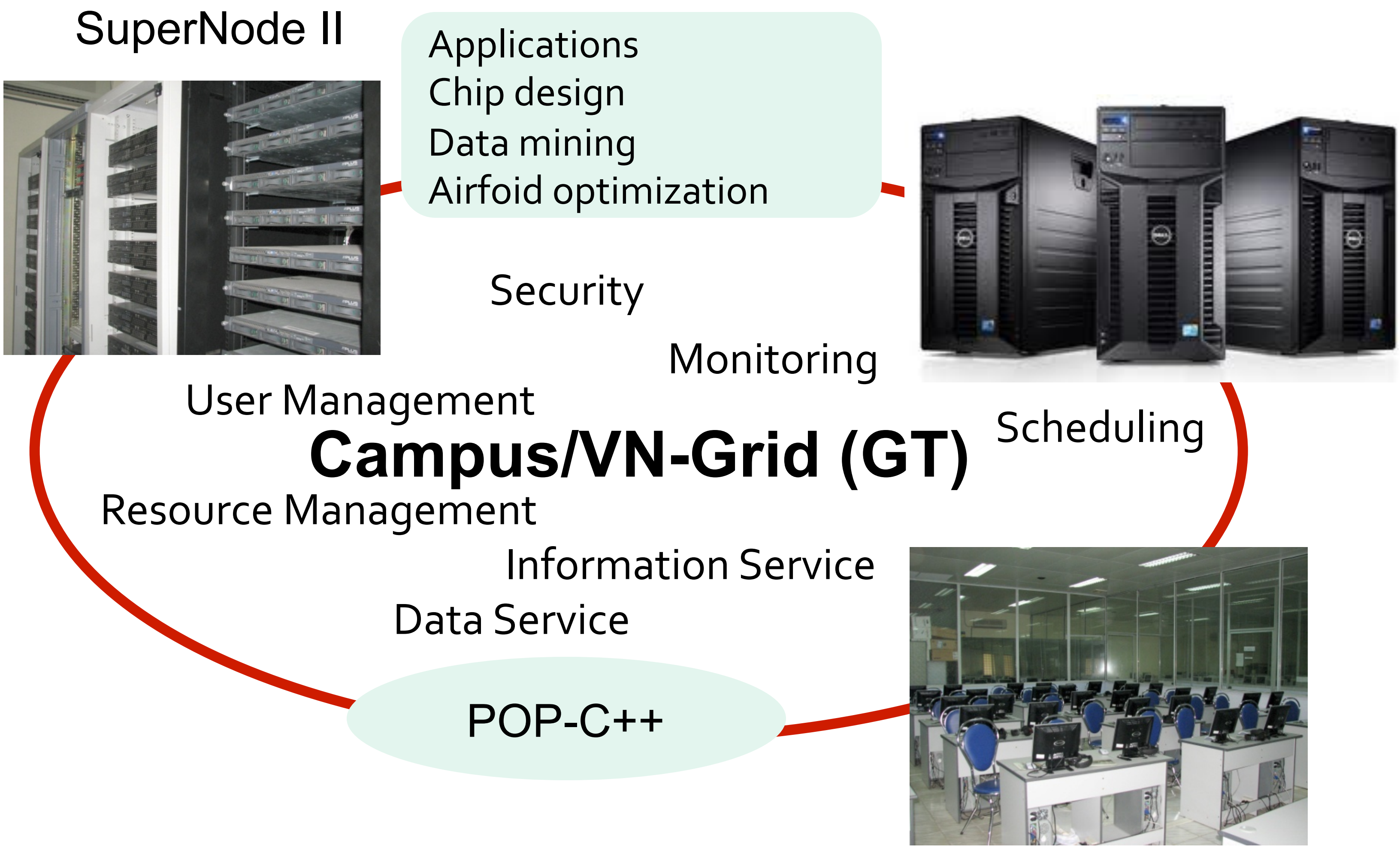
SuperNode II in 2003-2005

SuperNode V

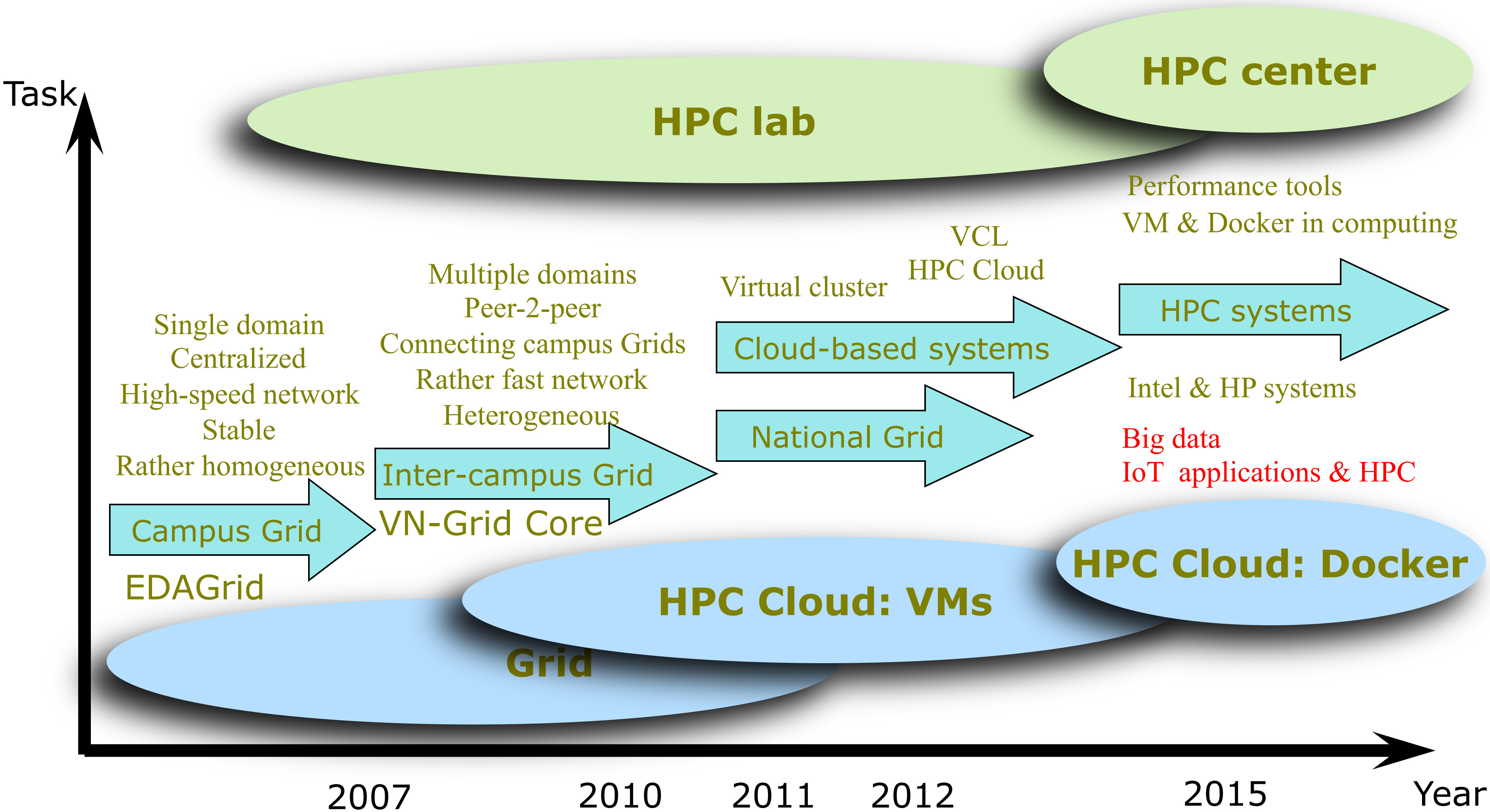


SuperNode-V project: 2010-2012

EDA-Grid & VN-Grid

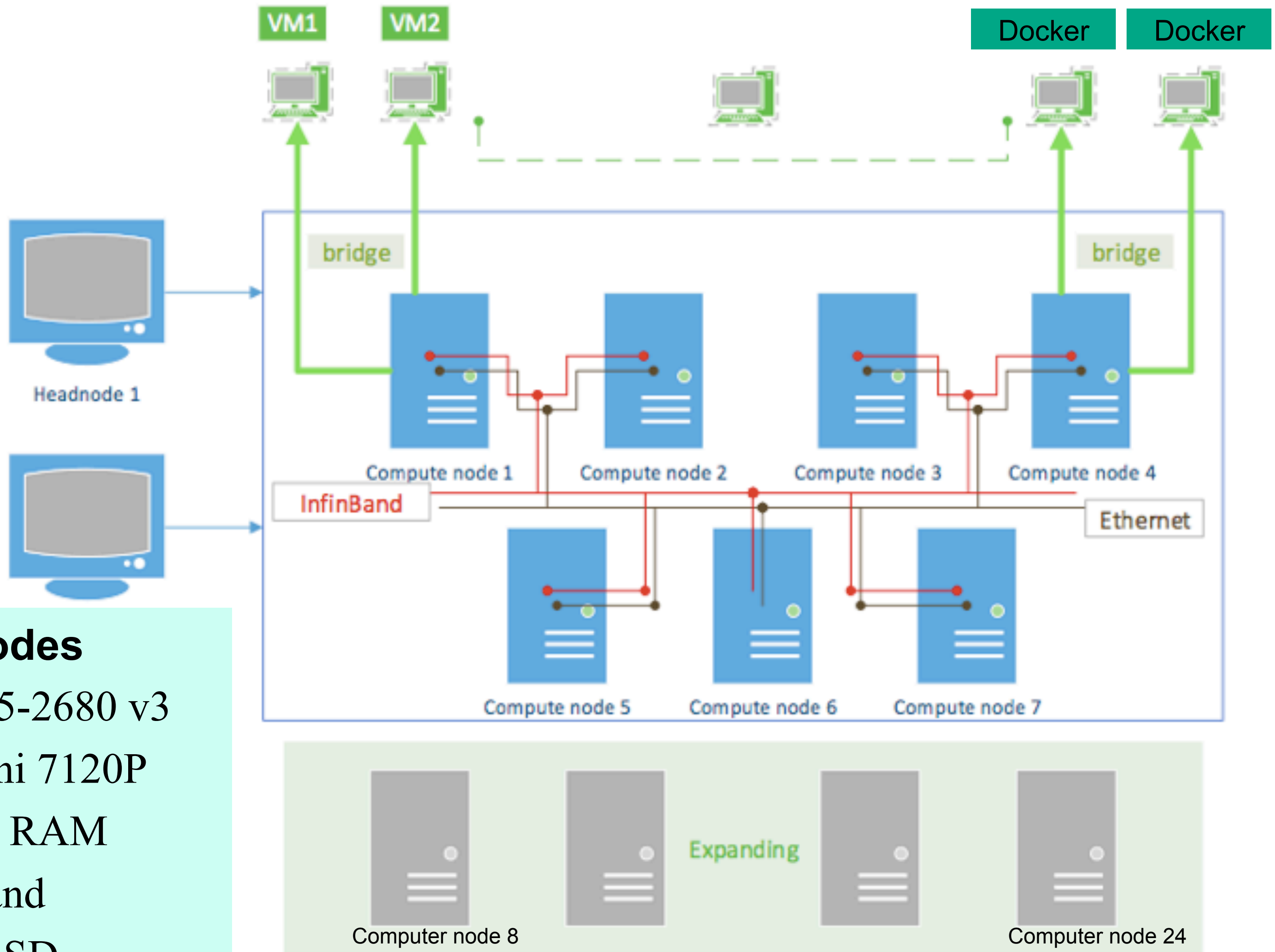


HPC plan at HCMUT



50 TFlops machine

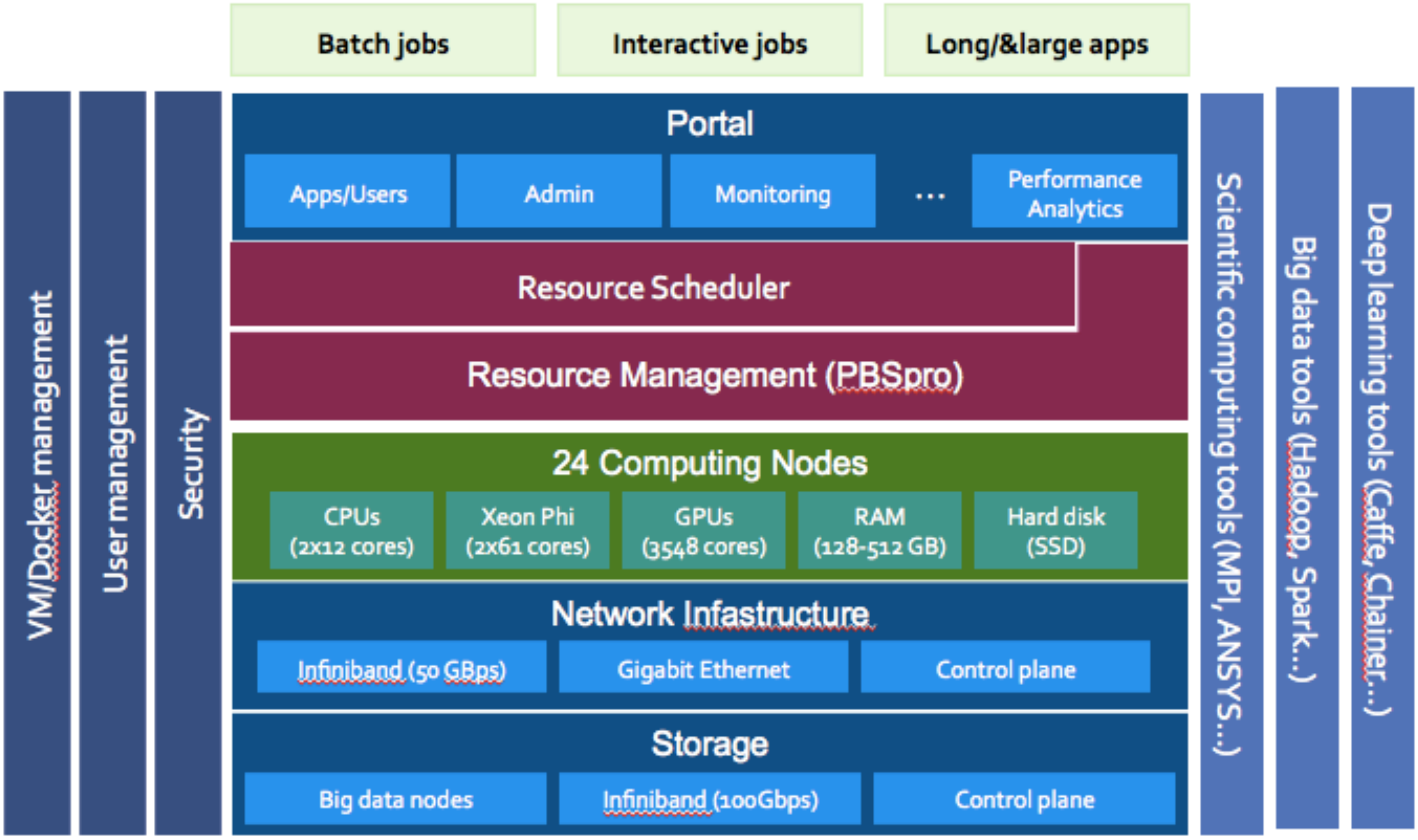
- Vendors: HPE
- Intel Xeon processors
- Intel Xeon Phi
- Infiniband



24 Computing nodes

- 2 x Intel Xeon E5-2680 v3
- 2 x Intel Xeon Phi 7120P
- 512/256/128 GB RAM
- 56 Gbps Infiniband
- 2 TB hard disk/SSD

SuperNode-XP Architecture

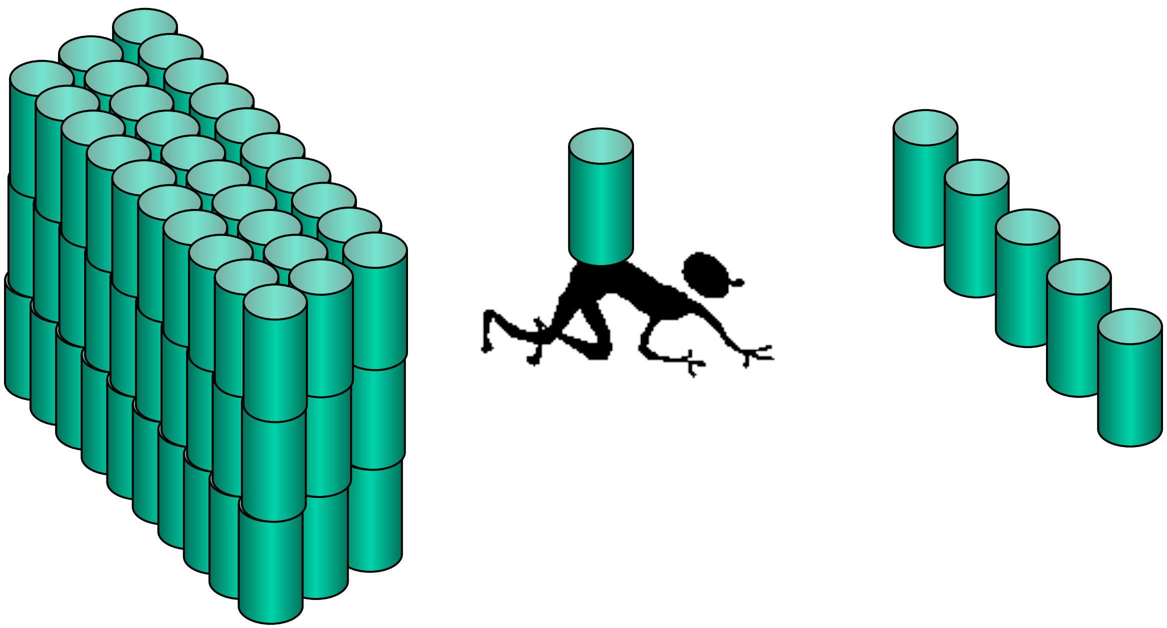


How to do

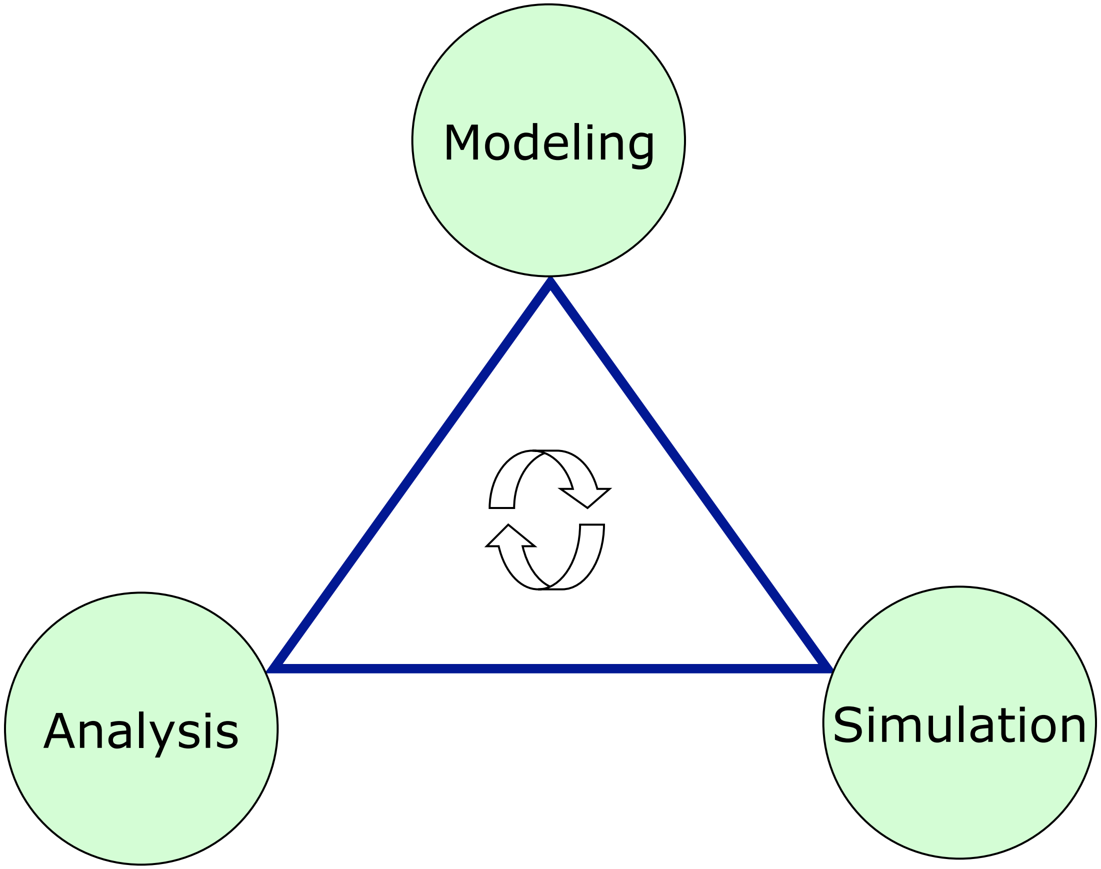
Parallel processing

Sequential Processing

- 1 CPU
- Simple
- Big problems???



New Approach

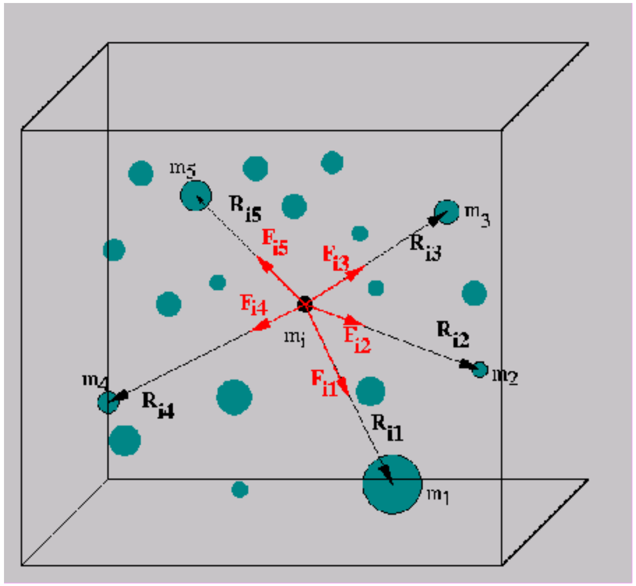


Grand Challenge Problems

- A grand challenge problem is one that cannot be solved in a reasonable amount of time with today's computers
- Ex:
  - Modeling large DNA structures
  - Global weather forecasting
  - Modeling motion of astronomical bodies

N-body

- The N^2 algorithm:
  - N bodies
  - N-1 forces to calculate for each bodies
  - N^2 calculations in total
  - After the new positions of the bodies are determined, the calculations must be repeated



Galaxy

- **10^7** stars and so **10^{14}** calculations have to be repeated
- Each calculation could be done in 1µs (10^{-6}s)
- It would take ~**3 years** for one iteration (~26800 hours)
- But it only takes **10 hours** for one iteration with **2680** processors

Solutions

- Power processor
  - 50 Hz -> 100 Hz -> 1 GHz -> 4 Ghz -> ... -> Upper bound?
- Smart worker
  - Better algorithms
- Parallel processing

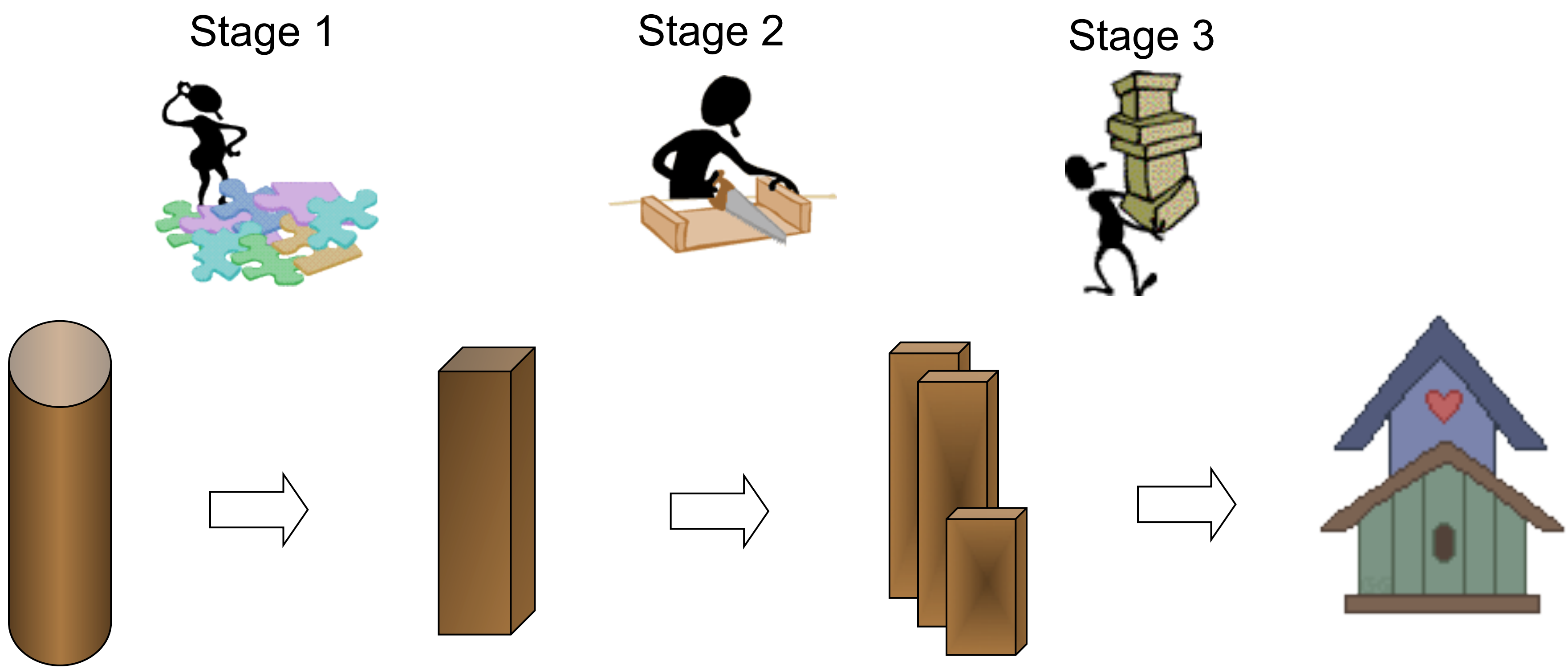
Parallel Processing Terminology

- ❑ Parallel processing
- ❑ Parallel computer
  - – Multi-processor computer capable of parallel processing
- ❑ Throughput:
  - – The throughput of a device is the number of results it produces per unit time.
- ❑ Speedup

  S = Time(the most efficient sequential algorithm)/Time(parallel algorithm)
- ❑ Parallelism:
  - – Pipeline
  - – Data parallelism
  - – Control parallelism

Pipeline

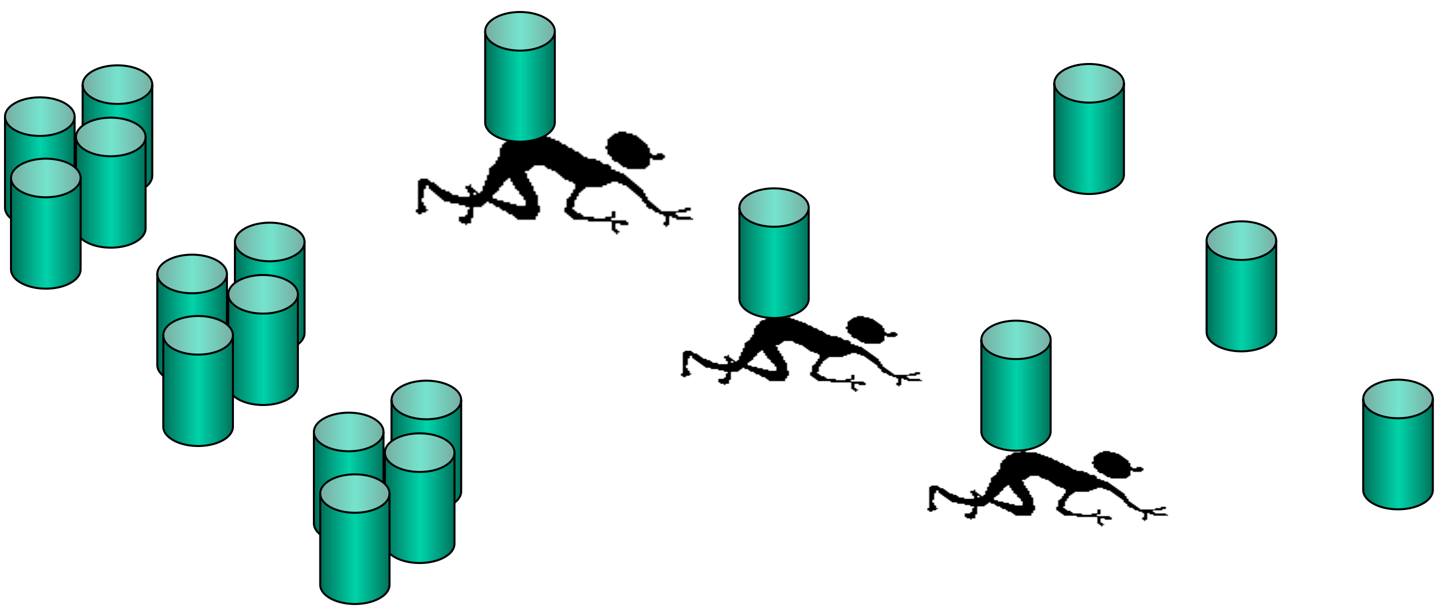
- A number of steps called **segments** or **stages**
- The output of one segment is the input of other segment



Data Parallelism

- Distributing the data across different parallel computing nodes

Applying the same operation simultaneously to elements of a data set

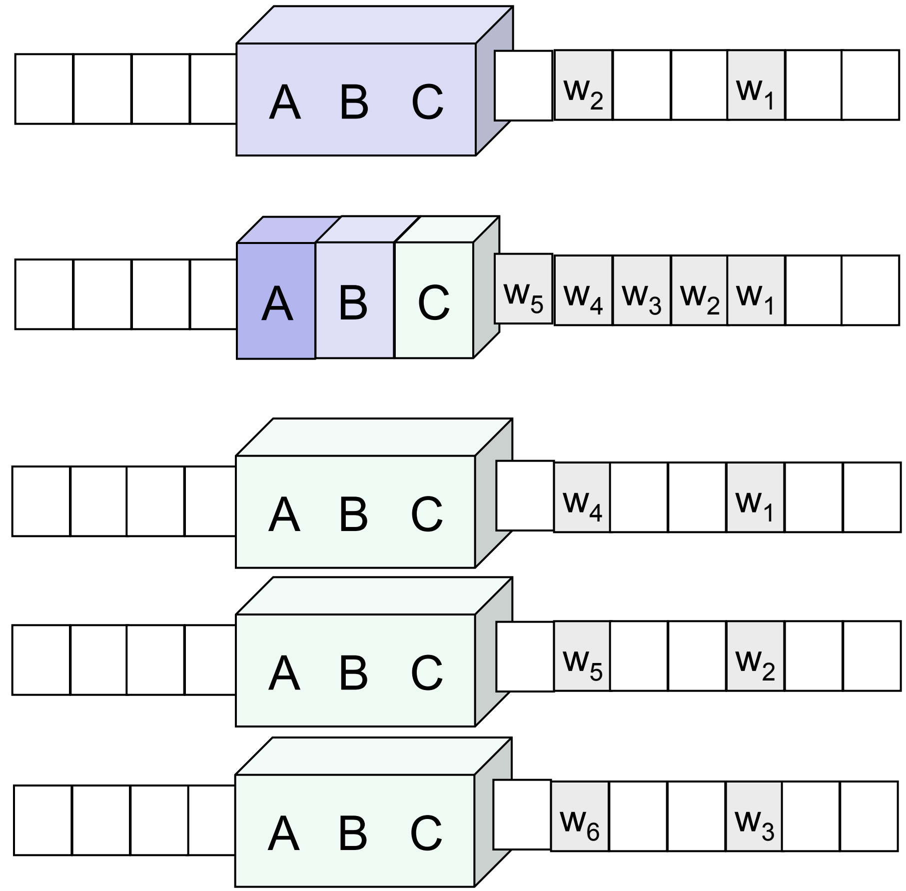


Pipeline & Data Parallelism

1. Sequential execution

2. Pipeline

3. Data Parallelism



Pipeline & Data Parallelism

- Pipeline is a special case of control parallelism
- T(s): Sequential execution time

  T(p): Pipeline execution time (with 3 stages)

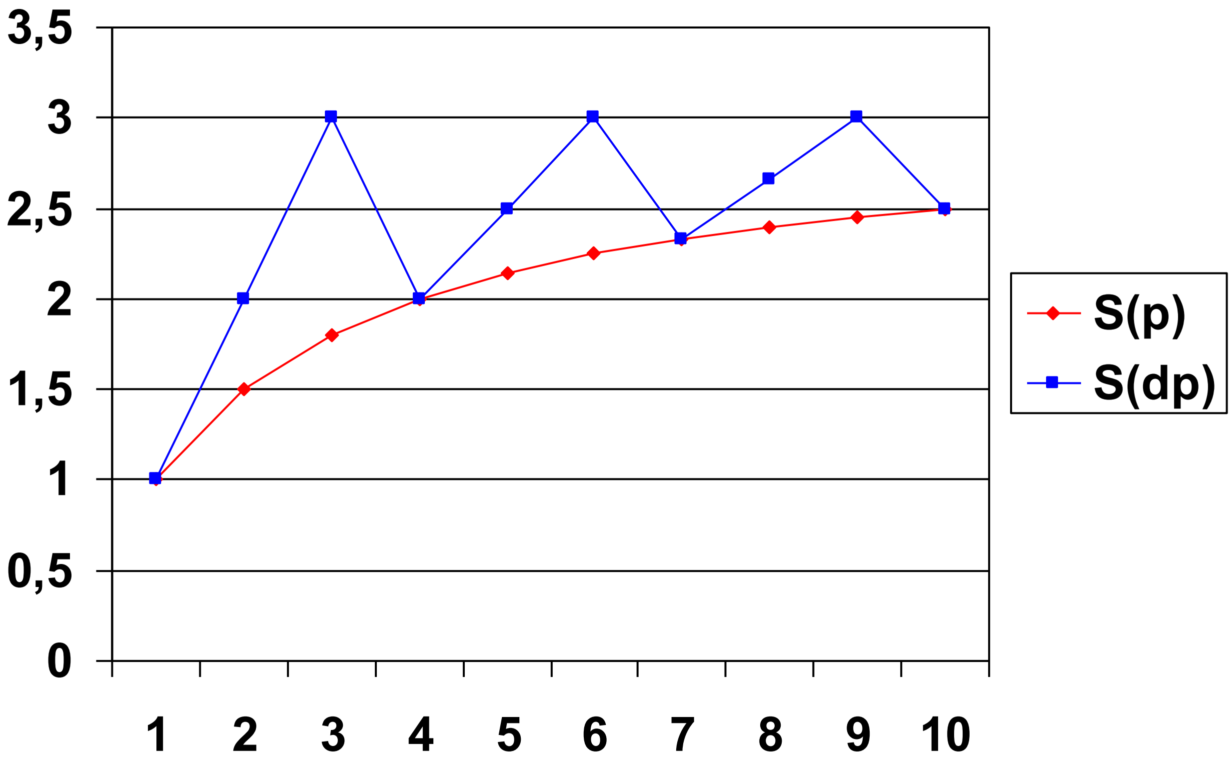
  T(dp): Data-parallelism execution time (with 3 processors)

  S(p): Speedup of pipeline

  S(dp): Speedup of data parallelism

Widget	1	2	3	4	5	6	7	8	9	10
T(s)	3	6	9	12	15	18	21	24	27	30
T(p)	3	4	5	6	7	8	9	10	11	12
T(dp)	3	3	3	6	6	6	9	9	9	12
S(p)	1	1+1/2	1+4/5	2	2+1/7	2+1/4	2+1/3	2+2/5	2+5/11	2+1/2
S(dp)	1	2	3	2	2+1/2	3	2+1/3	2+2/3	3	2+1/2

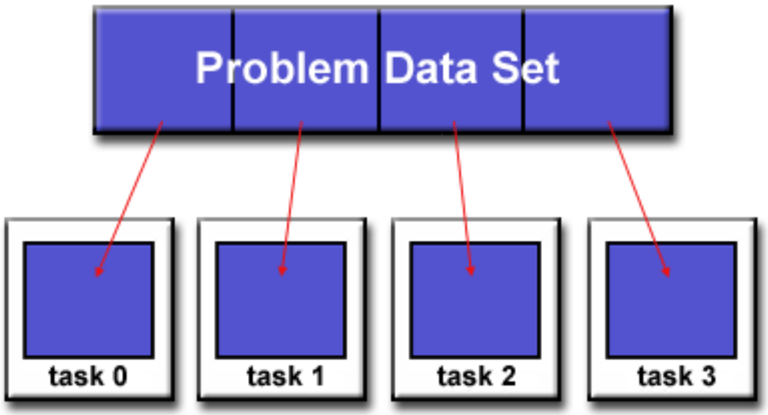
Pipeline & Data Parallelism



Control Parallelism

- Task/Function parallelism
- Distributing execution processes (threads) across different parallel computing nodes

Applying different operations to different data elements simultaneously



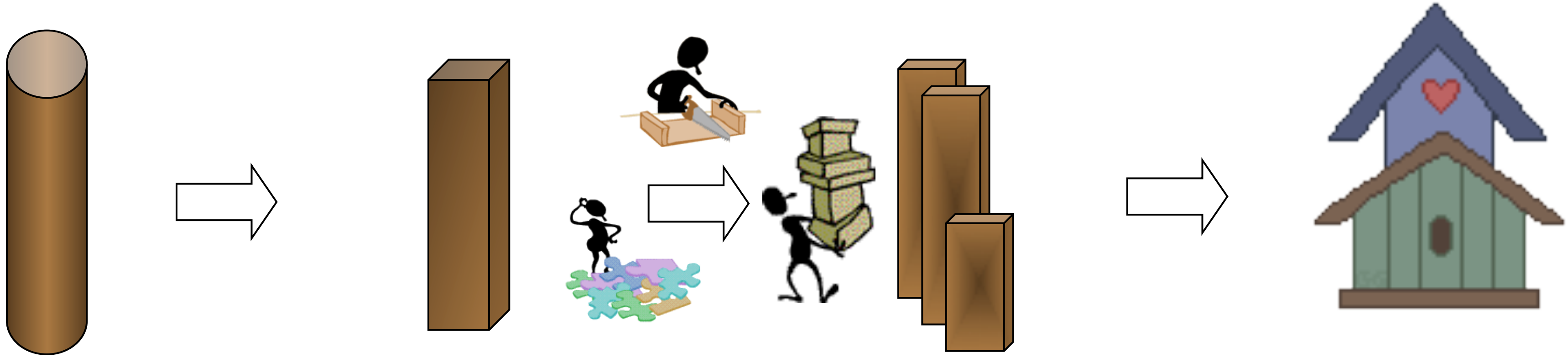
Example

{Milk, Sugar, Bread}

{Milk, Sugar, Bread, Tea}
{Bread, Milk, Coffee, Meat}
{Milk, Sugar}
{Milk, Bread, Sugar, Salt}
{Apple, Orange, Banana, Sugar, Milk}
…
{Milk, Bread, Sugar, Beer}

- Pipeline?
- Control parallelism?
- Data parallelism?

Throughput: Woodhouse problem



- 5 persons complete 1 woodhouse in 3 days
- 10 persons complete 1 woodhouse in 2 days
- How to build 2 houses with 10 persons?
  - (1) 10 persons building the 1st woodhouse and then the 2nd one later (sequentially)
  - (2) 10 persons building 2 woodhouses concurrently; it means that each group of 5 persons complete a woodhouse

Throughput

- The **throughput** of a device is the number of results it produces per unit time

- **High Performance Computing (HPC)**
  - Needing large amounts of computing power for short periods of time in order to completing the task as soon as possible
- **High Throughput Computing (HTC)**
  - How many jobs can be completed over a long period of time instead of how fast an individual job can complete

Scalability

- An algorithm is scalable if the level of parallelism increases at least linearly with the problem size.
- An architecture is scalable if it continues to yield the same performance per processor, albeit used in large problem size, as the number of processors increases.

- Data-parallelism algorithms are more scalable than control-parallelism algorithms