High Performance
Computing &
Big Data Services

hpc.uni.lu

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@ULHPC

LUXEMBOURG
LET'S MAKE IT HAPPEN

HPC, Big Data & AI in Luxembourg

... at the EuroHPC Horizon

Valentin Plugaru

University of Luxembourg

Data Science Luxembourg - Financial Aspects of AI Innovation meeting

Oct. 25th, 2018, Luxembourg

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LUXEMBOURG

About me

- **Computer Scientist** at the University of Luxembourg (UL)
  - ↪ R&D Specialist in the Parallel Computing & Optimisation Group led by Prof. Pascal Bouvry
  - ↪ Core duties on HPC facilities management
    - ✓ Over a decade of expertise with HPC technologies
- Architecting solutions and integration of HPC technologies
  - ↪ computing infrastructure and software ecosystem growth
- Building relationships and trust with stakeholders
- Knowledge transfer
  - ↪ on-boarding, Master-level teaching, HPC workshops

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On-going involvement in...

- ETP4HPC - H2020 WP18-20, 3rd Strategic Research Agenda
- PRACE-6IP - 6th Implementation Phase starting next year
- ISO/IEC JTC 1/SC 39 - Sustainability for and by IT
- National HPC and Big Data competence center

Summary

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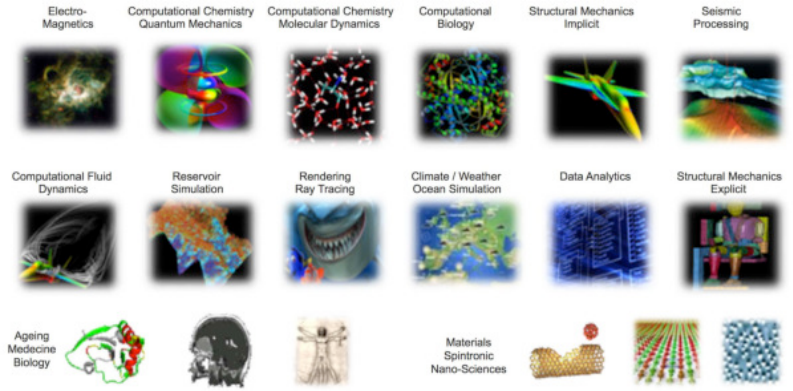
Why HPC and BD ?



HPC: **H**igh **P**erformance **C**omputing

BD: **B**ig **D**ata

Andy Grant, Head of Big Data and HPC, Atos UK&I

To out-compete you must out-compute

Increasing competition, heightened customer expectations and shortening product development cycles are forcing the pace of acceleration across all industries.

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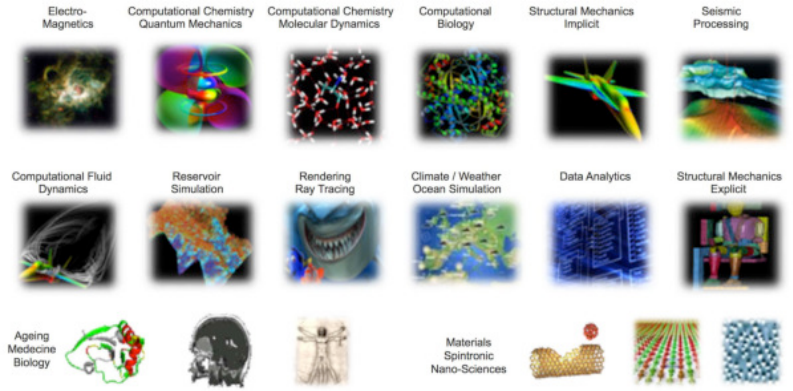

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- Essential tools for **Science, Society and Industry**
  - ↪ **Data driven economy context**
  - ↪ All scientific disciplines are becoming computational today
    - ✓ require very high computing power, handle **huge** volumes of data
- **Industry, SMEs** increasingly relying on HPC
  - ↪ to invent innovative solutions
  - ↪ . . . while reducing cost & decreasing time to market

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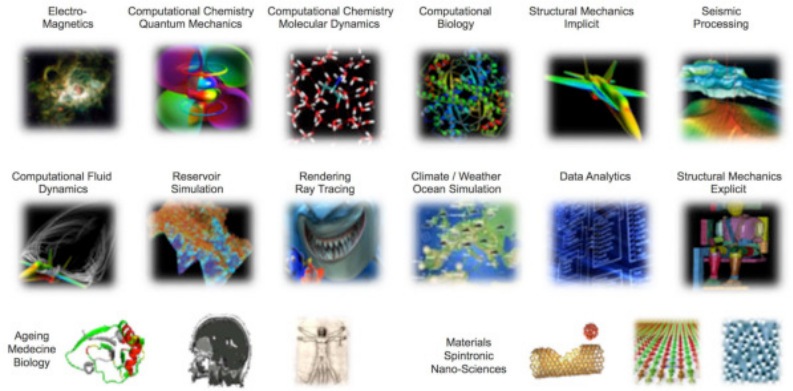

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- HPC = **global race** (strategic priority) - EU takes up the challenge:
  - ↪ PRACE / EuroHPC / IPCEI on HPC and Big Data (BD) Applications

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Prerequisites: Metrics

- **HPC**: **H**igh **P**erformance **C**omputing **BD**: **B**ig **D**ata

Main HPC/BD Performance Metrics

- **Computing Capacity**: often measured in **flops** (or **flop/s**)
  - ↪ **Fl**oating **p**oint **o**perations per **s**econds (often in DP)
  - ↪ **GFlops** $= 10^9$ **TFlops** $= 10^{12}$ **PFlops** $= 10^{15}$ **EFlops** $= 10^{18}$

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- **Storage Capacity**: measured in multiples of **bytes** $= 8$ **bits**
  - ↪ **GB** $= 10^9$ bytes **TB** $= 10^{12}$ **PB** $= 10^{15}$ **EB** $= 10^{18}$
  - ↪ **GiB** $= 1024^3$ bytes **TiB** $= 1024^4$ **PiB** $= 1024^5$ **EiB** $= 1024^6$
- Transfer rate on a medium measured in **Mb/s** or **MB/s**
- Other metrics: Sequential vs Random **R/W speed**, **IOPS** ...

Computing for Researchers: Laptop

- **Regular PC / Local Laptop / Workstation**
  - ↪ **Native OS** (Windows, Linux, Mac etc.)

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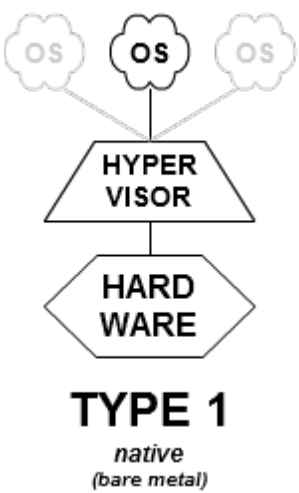
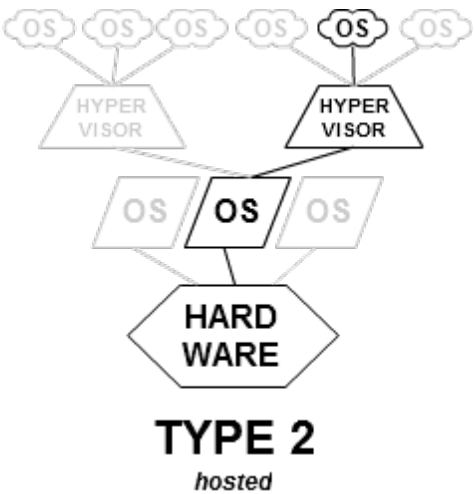
  - ↪ *Hypervisor*: core virtualization engine / environment
    - ✓ Ex: Xen, VMWare ESXi, KVM, VirtualBox
    - ✓ Non-negligible Performance loss: $\geq 20\%$





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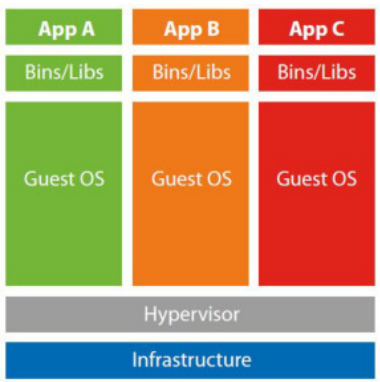
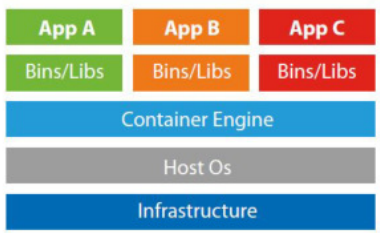
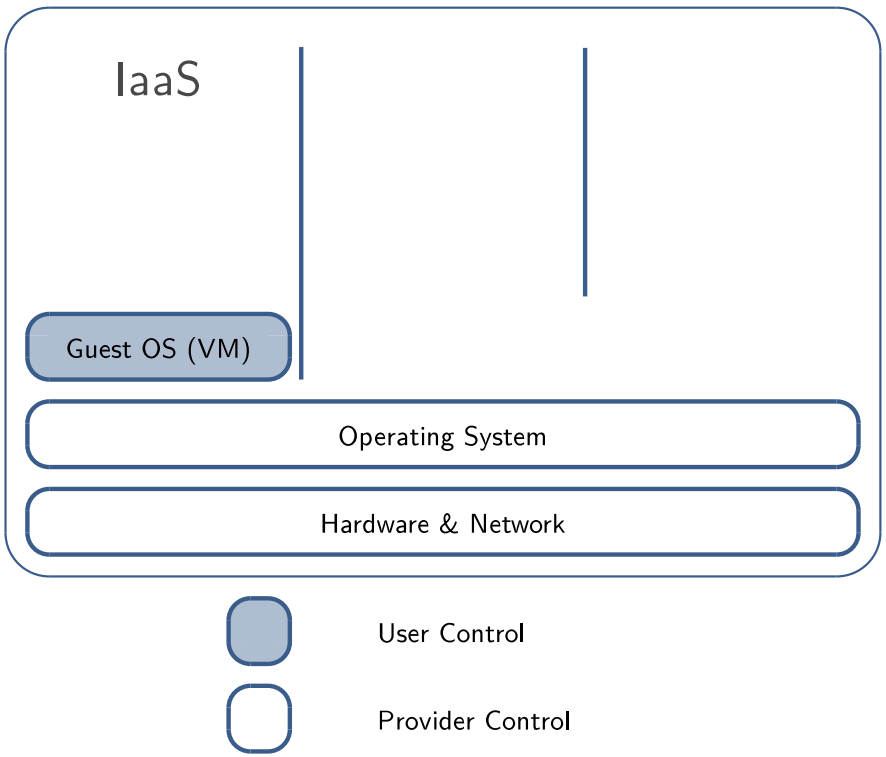
- **Container**-based Virtualization
  - ↪ similar to VMs . . .
    - ✓ **yet** containers **share** the system kernel of the host with others
    - ✓ Ex: Docker, Singularity, Shifter





Computing for Researchers: Cloud

- **Cloud Computing**
  - ↪ access to shared *(generally virtualized)* resources
  - ↪ pay-per-use approach
  - ↪ **Infrastructure** as a Service (**I**aaS)



Computing for Researchers: Cloud

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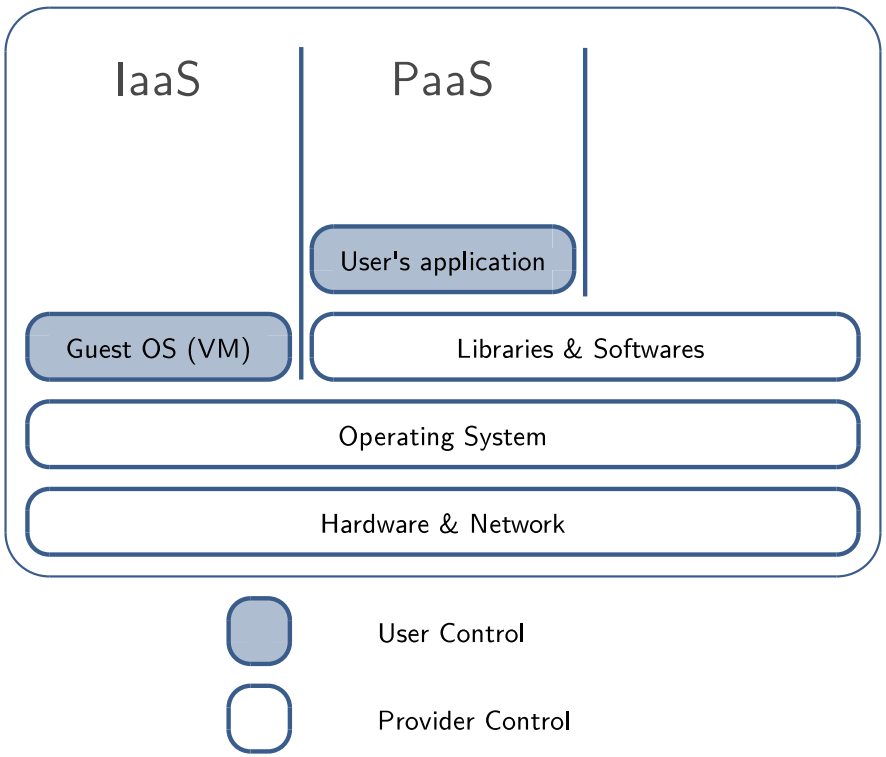

Computing for Researchers: Cloud

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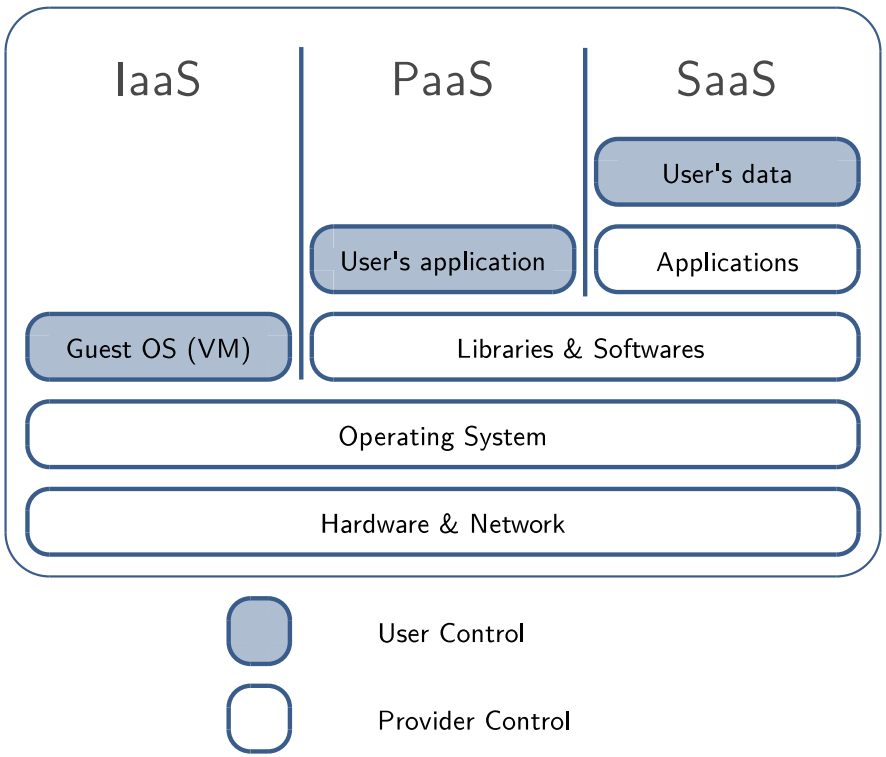
  - ↪ pay-per-use approach
  - ↪ **Software** as a Service (**S**aaS)



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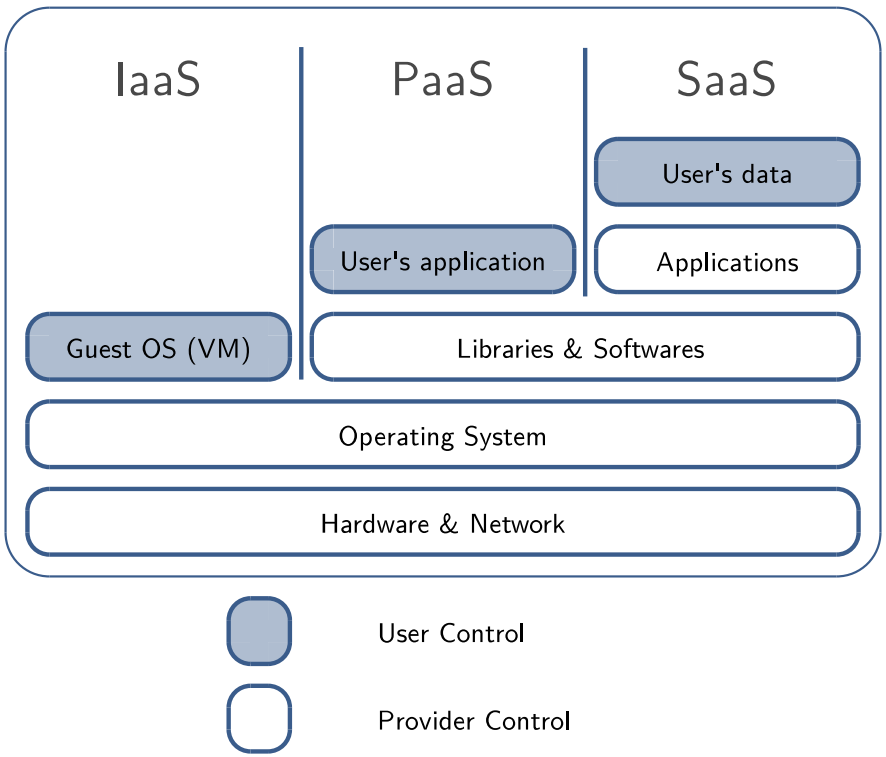

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  - ↪ For **Speedup**, **Scalability** and **Faster Time to Solution**

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$$\textbf{PC} \neq \textbf{Cloud} \neq \textbf{HPC}$$

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- High Performance Computing (HPC) platforms
  - ↪ For **Speedup**, **Scalability** and **Faster Time to Solution**

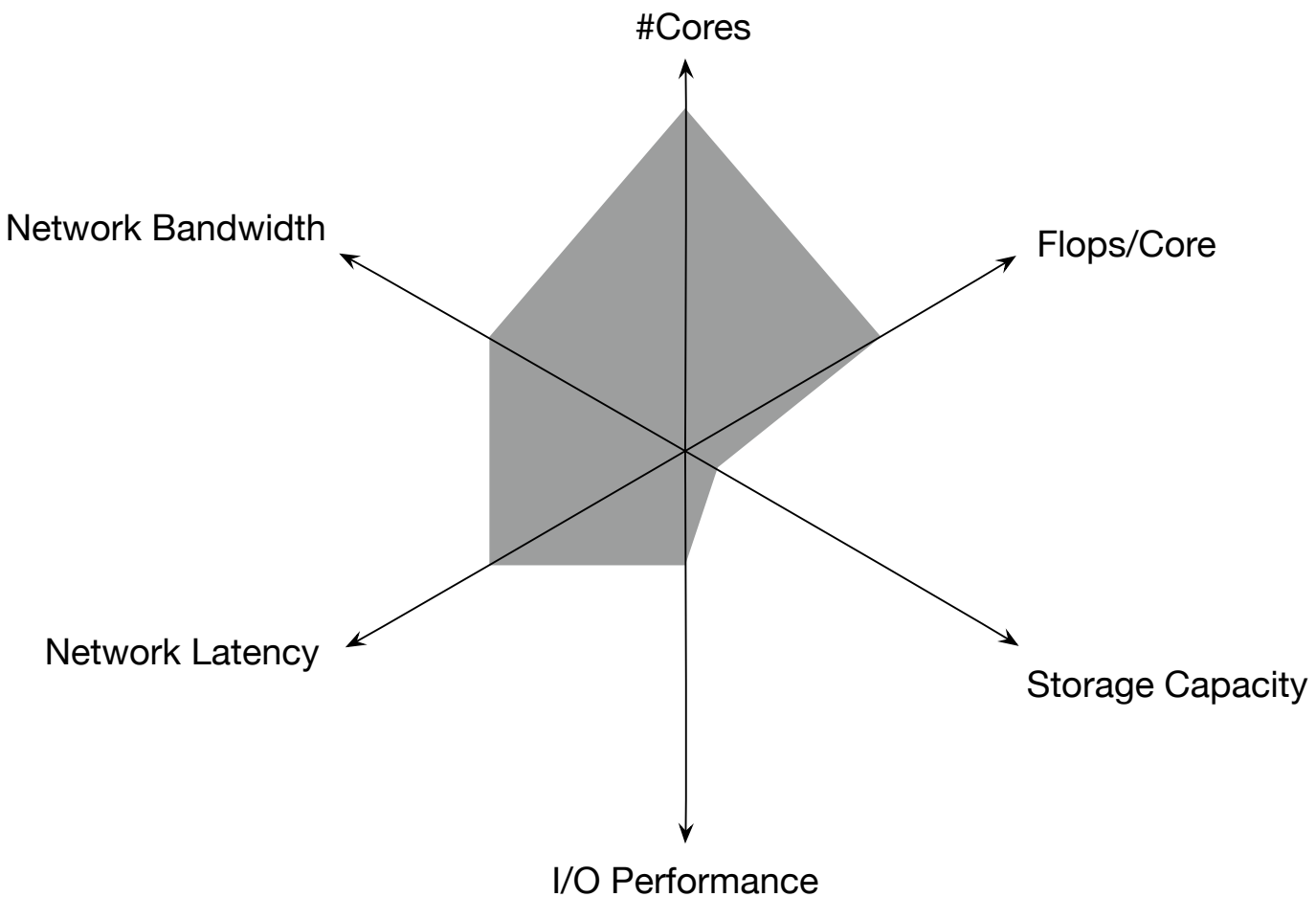
YET...

PC $\neq$ Cloud $\neq$ HPC

- HPC $\simeq$ Formula 1
  - ↪ relies on ultra efficient hardware / interconnect (IB EDR...)
  - ↪ ... when Cloud has to stay standard ([10-25] GbE etc...)
- **The 3 approaches can be brought (and work well) together**

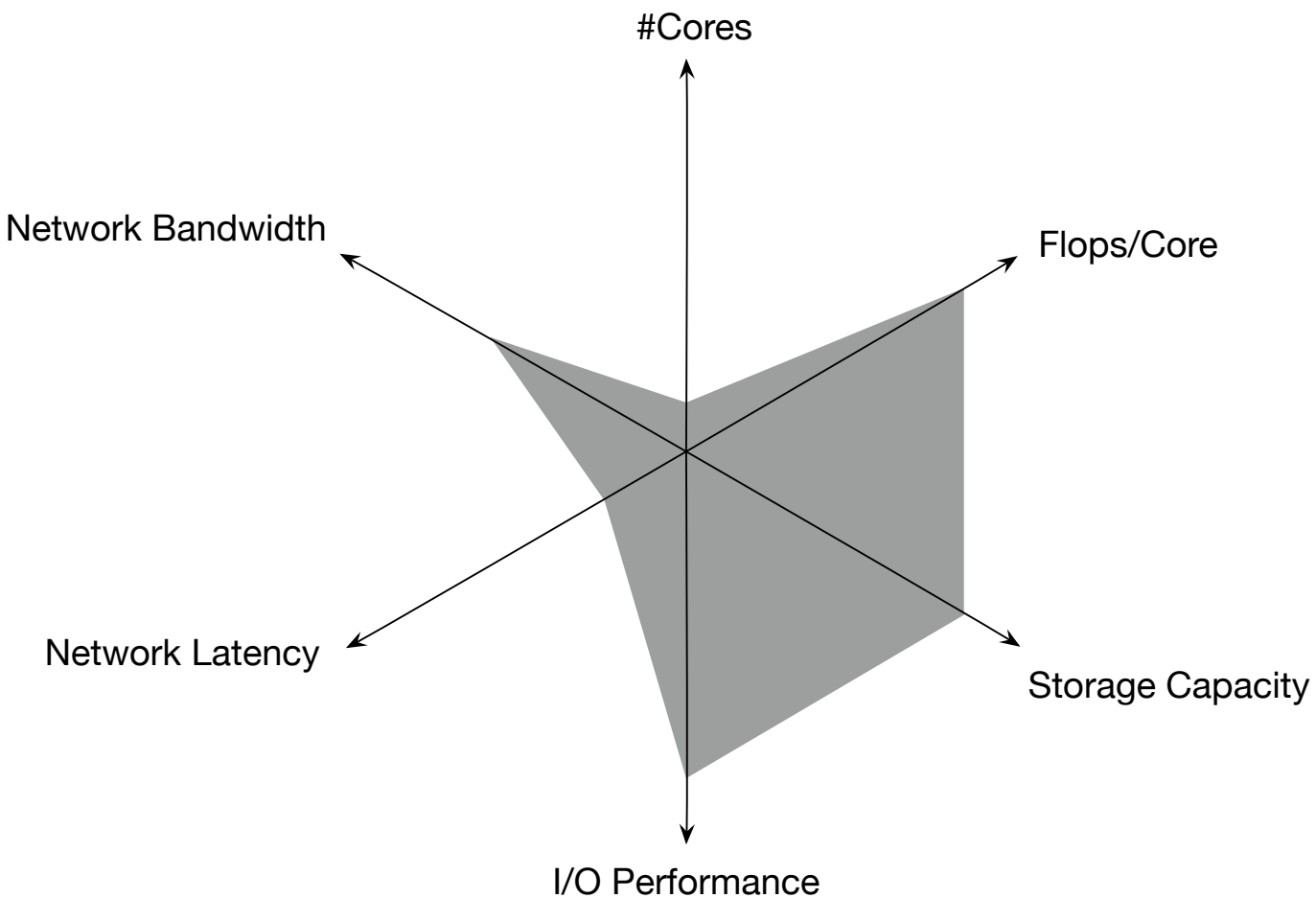
Different HPC Needs per Domains

Material Science & Engineering



Different HPC Needs per Domains

Biomedical Industry / Life Sciences



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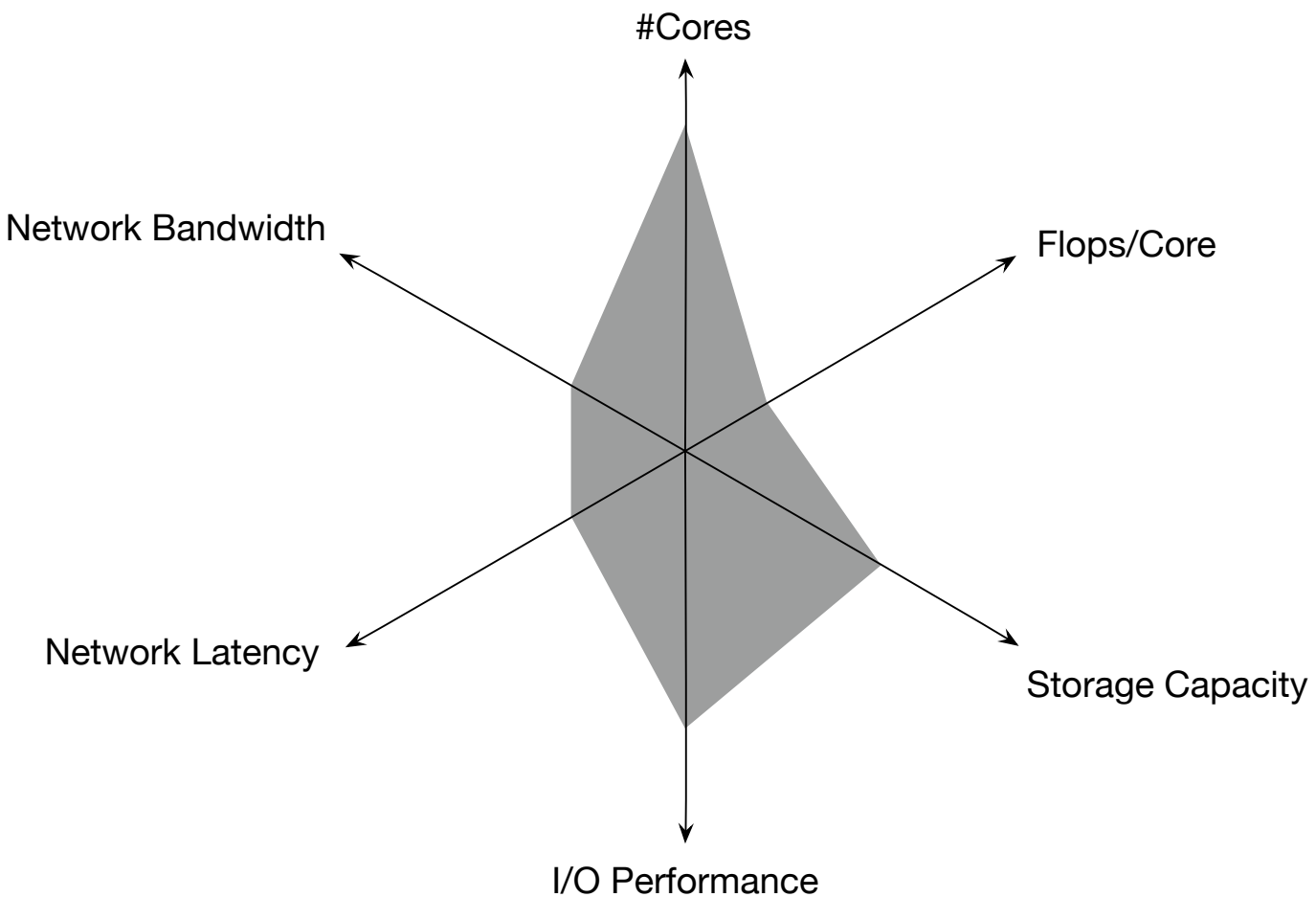
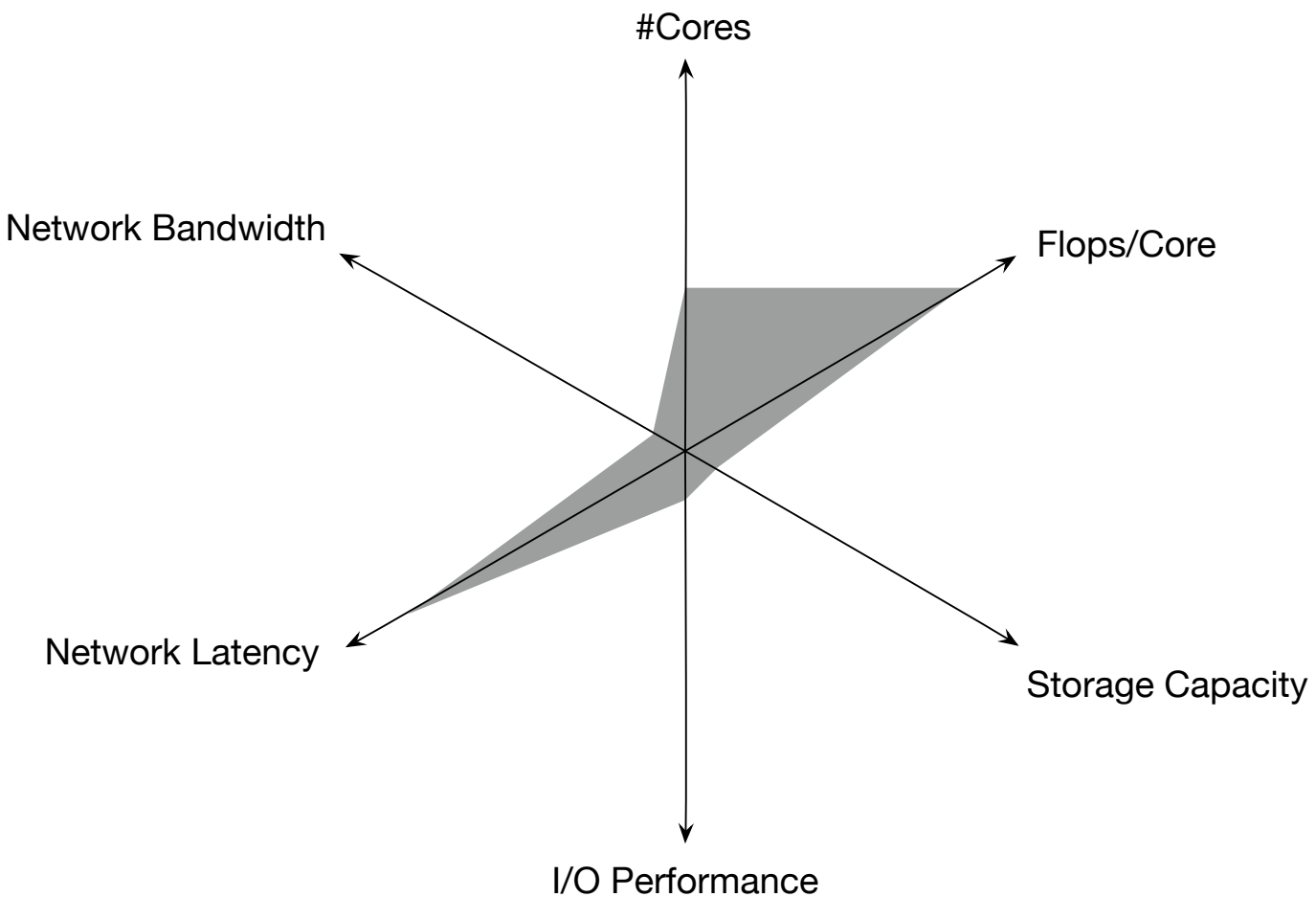
Deep Learning / Cognitive Computing



Different HPC Needs per Domains

IoT, FinTech



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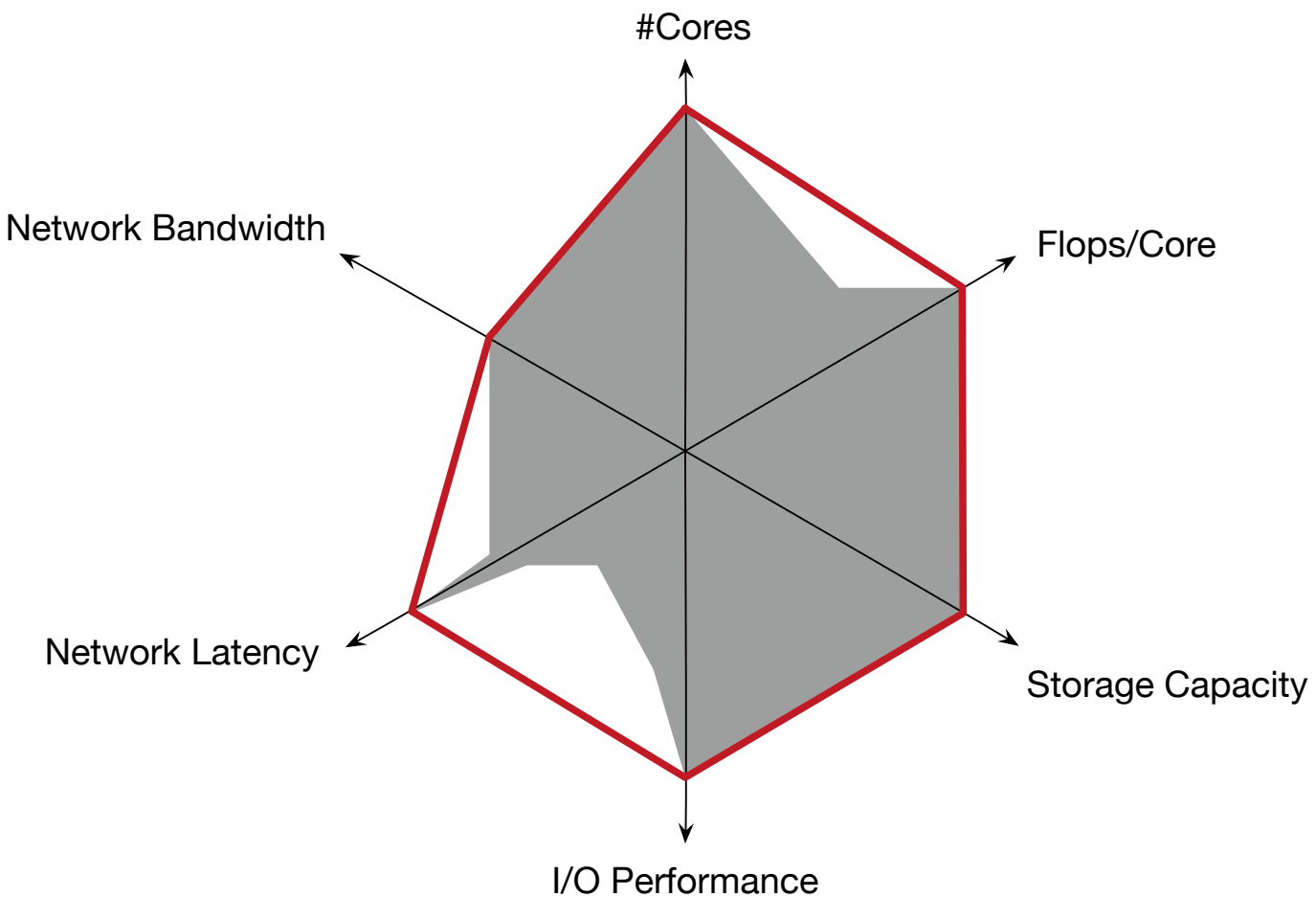
ALL Research Computing Domains



HPC facility TCO

- The HPC facility answering those needs has to consider:

  - HPC system: compute, storage, network
  - Staff: system, user support, service management
  - Power & Cooling, Data center costs

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- Resilience: both at system & service levels
- Equipment monitoring, Service measurement & reporting
- Procurement, Supplier management
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- Insurance
- Warranty, support & maintenance
- Data management
- Software licenses
- Application porting
- Documentation, User training & support

Summary

HPC Components: [GP]CPU

CPU

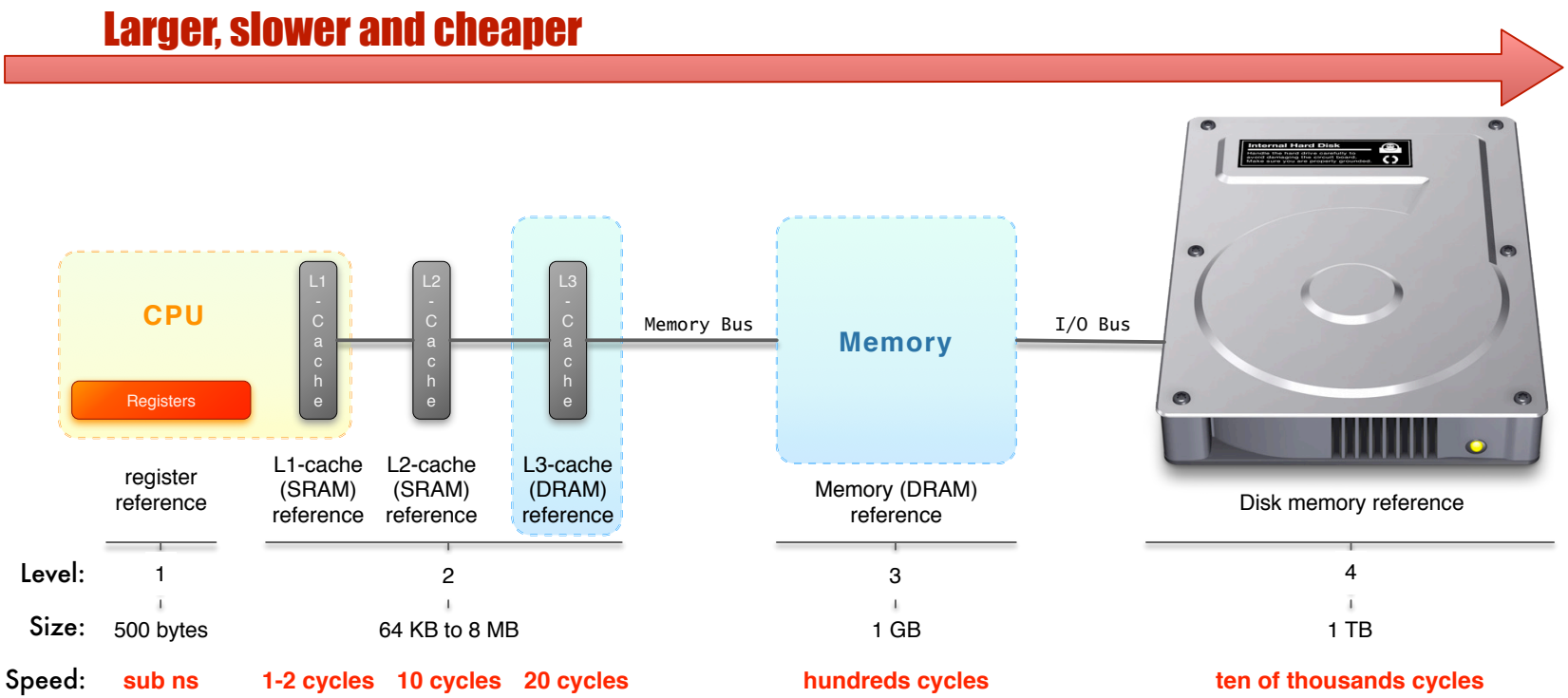
- Always multi-core
- Ex: Intel Core i7-7700K (Jan 2017) $R_{peak} \simeq 268.8$ GFlops (DP)
  - ↪ 4 cores @ 4.2GHz (14nm, 91W, 1.75 billion transistors)
  - ↪ + integrated graphics (24 EUs) $R_{peak} \simeq +441.6$ GFlops

GPU / GPGPU

- Always multi-core, optimized for vector processing
- Ex: Nvidia Tesla V100 (Jun 2017) $R_{peak} \simeq 7$ TFlops (DP)
  - ↪ 5120 cores @ 1.3GHz (12nm, 250W, 21 billion transistors)
  - ↪ focus on Deep Learning workloads $R_{peak} \simeq 112$ TFLOPS (HP)

$\simeq$ **100 Gflops** for 130$ (CPU), 214$? (GPU)

HPC Components: Local Memory

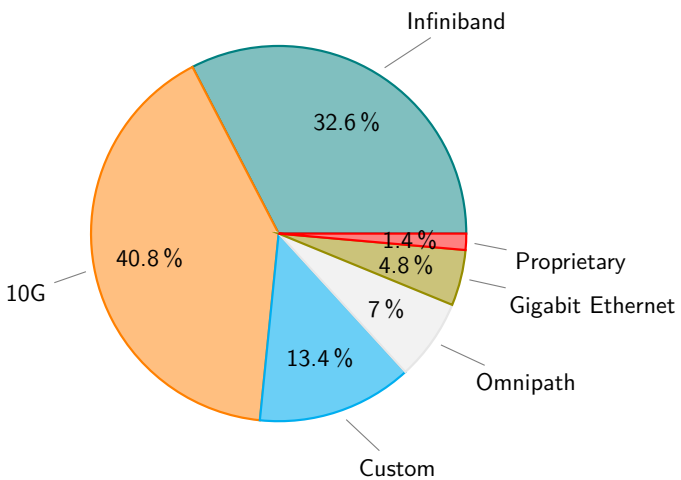


- SSD (SATA3) R/W: 550 MB/s; 100000 IOPS **450 €/TB**
- HDD (SATA3 @ 7,2 krpm) R/W: 227 MB/s; 85 IOPS **54 €/TB**

HPC Components: Interconnect

- **latency**: time to send a minimal (0 byte) message from A to B
- **bandwidth**: max amount of data communicated per unit of time

Technology	Effective Bandwidth		Latency
Gigabit Ethernet	1 Gb/s	125 MB/s	40μs to 300μs
10 Gigabit Ethernet	10 Gb/s	1.25 GB/s	4μs to 5μs
Infiniband QDR	40 Gb/s	5 GB/s	1.29μs to 2.6μs
Infiniband EDR	100 Gb/s	12.5 GB/s	0.61μs to 1.3μs
100 Gigabit Ethernet	100 Gb/s	1.25 GB/s	30μs
Intel Omnipath	100 Gb/s	12.5 GB/s	0.9μs



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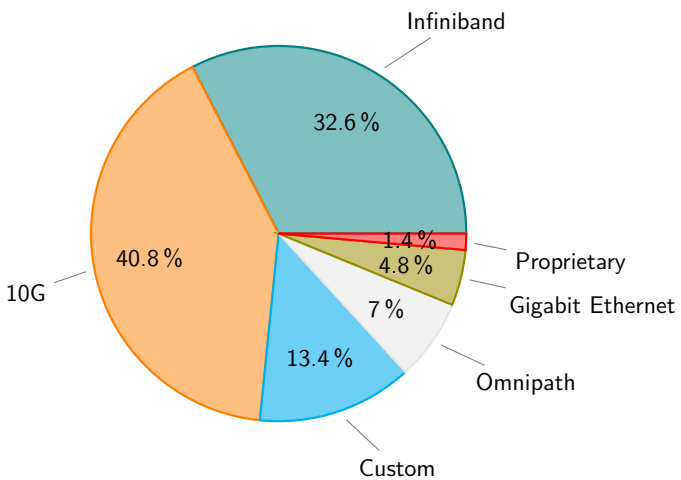

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Network Topologies

- **Direct** vs. **Indirect** interconnect
  - ↪ *direct*: each network node attaches to at least one compute node
  - ↪ *indirect*: compute nodes attached at the edge of the network only
    - ✓ many routers only connect to other routers.

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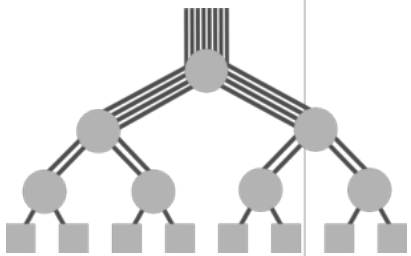
Main HPC Topologies

- **CLOS Network / Fat-Trees** [Indirect]
  - ↪ can be fully non-blocking (1:1) or blocking (x:1)
  - ↪ typically enables **best performance**
    - ✓ Non blocking bandwidth, lowest network latency



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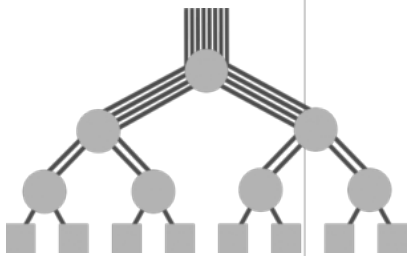
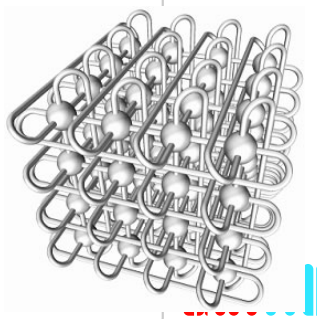
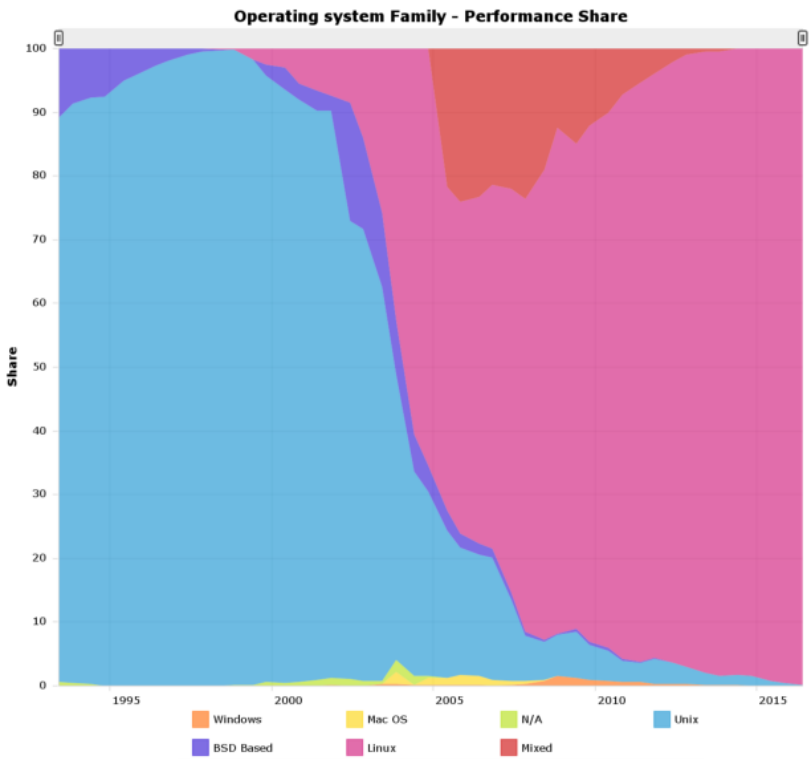


- **Mesh or 3D-torus** [Direct]
  - ↪ Blocking network, cost-effective for systems at scale
  - ↪ Great performance solutions for applications with locality
  - ↪ Simple expansion for future growth



HPC Components: Operating System



- Exclusively Linux-based (**really** 100%)
- Reasons:
  - ↪ stability
  - ↪ development flexibility

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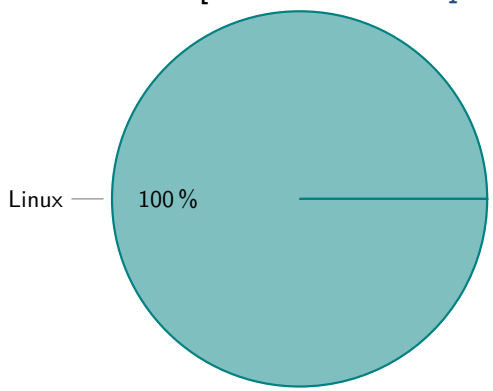

HPC Components: Software Stack

- **Remote connection to the platform** SSH
- **Identity Management / SSO**: LDAP, Kerberos, IPA...
- **Resource management**: job/batch scheduler
  - ↪ SLURM, OAR, PBS, MOAB/Torque...
- (Automatic) **Node Deployment**:
  - ↪ FAI, Kickstart, Puppet, Chef, Ansible, Kadeploy...
- (Automatic) **User Software Management**:
  - ↪ Easybuild, Environment Modules, LMod
- **Platform Monitoring**:
  - ↪ Nagios, Icinga, Ganglia, Foreman, Cacti, Alerta...

[Big]Data Management: Disk Encl.

- $\simeq$ **120 K€** - enclosure - 48-60 disks (4U)
  - ↪ incl. redundant (_i.e._ 2) RAID controllers (master/slave)

[Big]Data Management: FS Summary

- **File System (FS)**: Logical manner to *store, organize & access* data
  - ↪ (local) **Disk FS** : `FAT32`, `NTFS`, `HFS+`, `ext4`, `{x,z,btr}fs...`
  - ↪ **Networked FS**: `NFS`, `CIFS/SMB`, `AFP`
  - ↪ **Parallel/Distributed FS**: `SpectrumScale/GPFS`, `Lustre`
    - ✓ typical FS for HPC / HTC (High Throughput Computing)

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Main Characteristic of Parallel/Distributed File Systems

Capacity and Performance increase with #servers

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Name	Type	Read* [GB/s]	Write* [GB/s]
`ext4`	Disk FS	0.426	0.212
`nfs`	Networked FS	0.381	0.090
`gpfs` (iris)	Parallel/Distributed FS	**11.25**	**9,46**
`lustre` (iris)	Parallel/Distributed FS	**12.88**	**10,07**
`gpfs` (gaia)	Parallel/Distributed FS	7.74	6.524
`lustre` (gaia)	Parallel/Distributed FS	4.5	2.956

* maximum **random** read/write, per IOZone or IOR measures, using concurrent nodes for networked FS.

HPC Components: Data Center

Definition (Data Center)

- Facility to house computer systems and associated components
  - ↪ Basic storage component: **rack** (height: 42 RU)

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Challenges: Power (UPS, battery), Cooling, Fire protection, Security

- Power/Heat dissipation per rack:
  - ↪ HPC **computing** racks: **30-120 kW**
  - ↪ **Storage** racks: **15 kW**
  - ↪ **Interconnect** racks: **5 kW**
- Various **Cooling** Technology
  - ↪ Airflow
  - ↪ Direct-Liquid Cooling, Immersion...

Power Usage Effectiveness

$$PUE = \frac{Total\ facility\ power}{IT\ equipment\ power}$$

HPC Components: Summary

Running an HPC Facility involves...

- A **data center** / server room carefully designed
- Many **computing** elements: CPU, GPGPU, Other accelerators
- **Fast interconnect** elements
  - ↪ high *bandwidth* and low *latency*
- [Big]-Data **storage** elements: HDD/SDD, disk enclosure,
  - ↪ disks are virtually aggregated by RAID/LUNs/FS
  - ↪ parallel and distributed FS
- A flexible software stack
- Automated management everywhere

Above all: **expert** HPC/IT specialists !

Summary

Univ. of Luxembourg & HPC

- *With regards to HPC*, Univ. of Luxembourg offers:
  - ↪ **People**
    - ✓ Domain experts
    - ✓ Computational and data scientists
    - ✓ Specialists in parallel algorithmics
  - ↪ **Services**
    - ✓ HPC clusters and management team
    - ✓ IT team (SIU)
    - ✓ Infrastructure team in collab. w. Fonds Belval
  - ↪ **Infrastructure**
    - ✓ Data center and a set of high-end clusters
  - ↪ **Education & Training**

High Performance Computing @ UL

- **Started in 2007**
  - ↪ under resp. of Prof P. Bouvry & Dr. S. Varrette
  - ↪ expert UL HPC team
    - ✓ *S. Varrette, V. Plugaru, S. Peter, H. Cartiaux, C. Parisot*... and multiple domain experts per RU
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https://hpc.uni.lu

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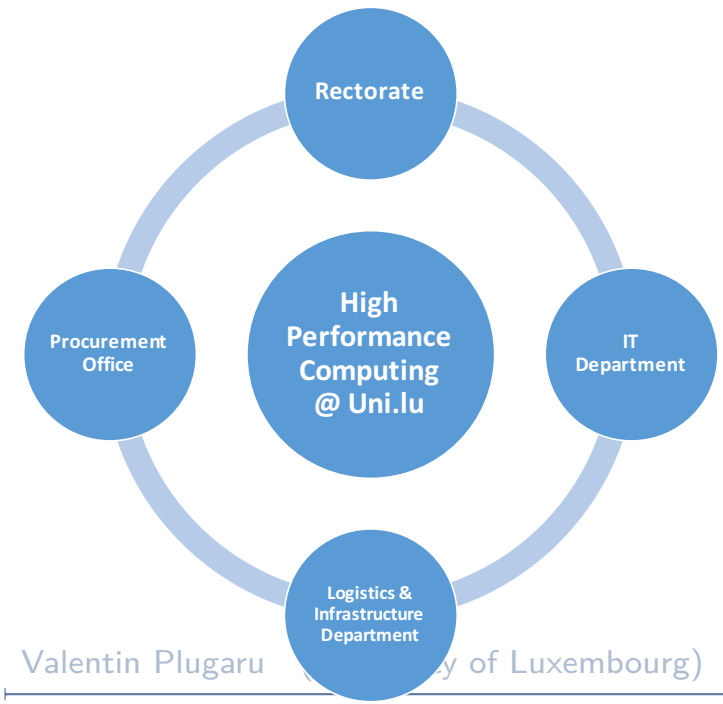

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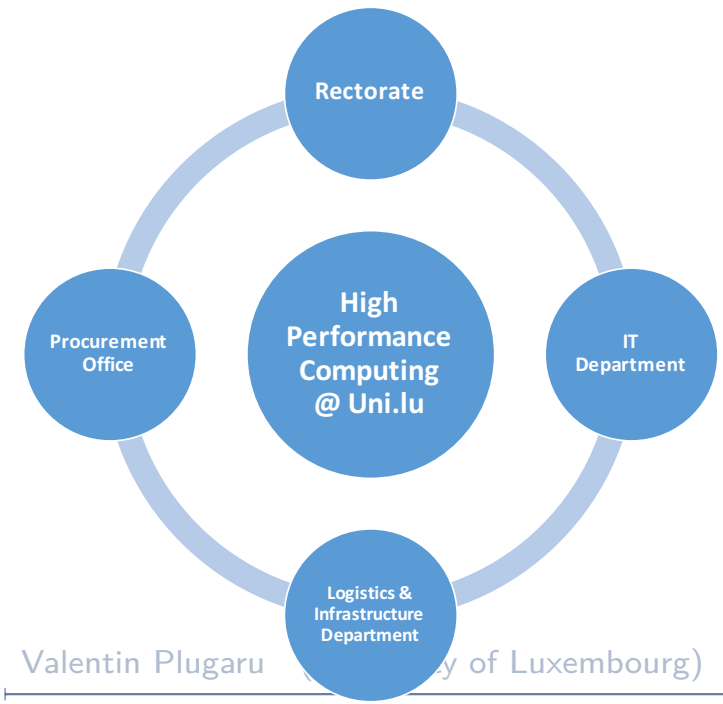


HPC/Computing Capacity

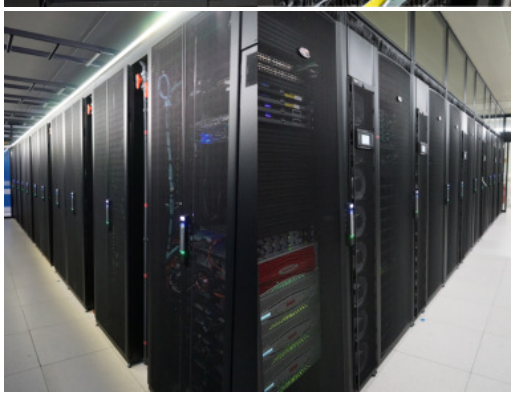
1029.342 TFlops

(incl. 612.62 GPU TFlops)

HTC/Storage Capacity

9852.4 TB storage

UL HPC Computing capacity



5 clusters / 2 sites

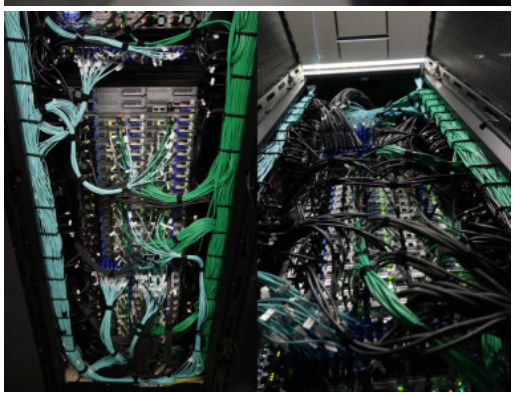
1029.342 TFlops

(incl. 612.62 GPU TFlops)

684 nodes

11084 CPU cores

(+ 489344 GPU cores)



- IB interconnect
- Fat tree topo. in general

UL HPC Storage capacity

9852.4 TB (incl. 1020TB for Backup)

2425 disks

- 4 distributed/parallel FS
  - ↪ GPFS : 3244 TB
  - ↪ Lustre: 1940 TB
  - ↪ OneFS: 3188 TB...

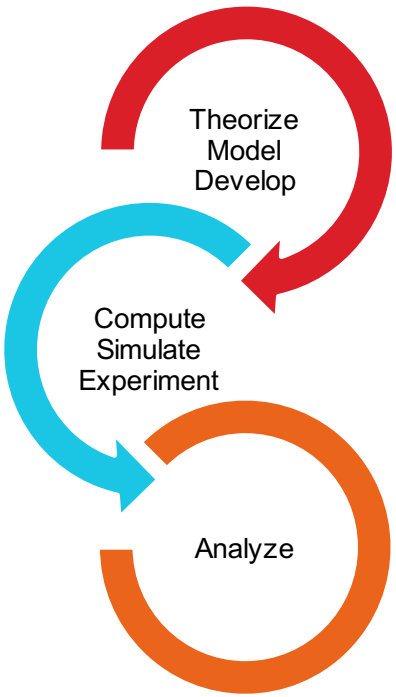
UL HPC Beneficiaries

23 computational domains accelerated on UL HPC

- for the UL Faculties, Research Units and Interdisciplinary Centres
  - ↪ incl. LCSB, SnT... and now C2DH thematics
  - ↪ UL **strategic research priorities**
    - ✓ computational sciences, finance (fintech)
    - ✓ systems biomedicine, security, reliability and trust

- UL HPC features special systems targeting specific workloads:
  - ↪ **Machine Learning & AI**: GPU accelerators
    - ✓ 10 Tesla K40 + 16 Tesla K80 + 24 Tesla M20*: **76 GPU Tflops**
    - ✓ **Q4 2018**: 18*4 V100 (part of RFP 180027): **561 GPU Tflops**
  - ↪ **BigData analytics & data driven science**: large memory systems
    - ✓ Large SMP systems with 1, 2, 3 & 4 TB RAM
  - ↪ **Scale-out workloads**: 90 HP Moonshot servers + 96 viridis ARM-based systems

Accelerating UL Research



- **over 200 software packages** available for researchers
  - ↪ via Environment modules/LMod from Easybuild

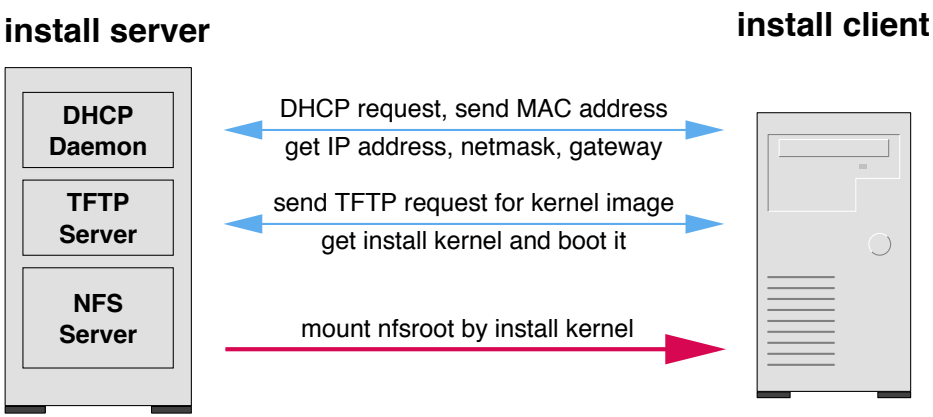
Domain	Software
Compiler Toolchains	(2018a) FOSS, Intel, PGI
MPI suites	OpenMPI, Intel MPI, MVAPICH2
Machine Learning	PyTorch, TensorFlow, Keras, Apache Spark...
Math & Optimization	Matlab, Mathematica, R, CPLEX, Gurobi...
Physics & Chemistry	GROMACS, QuantumESPRESSO, ABINIT, NAMD, VASP...
Bioinformatics	SAMtools, BLAST+, ABySS, mpiBLAST, TopHat, Bowtie2...
Computer aided engineering	ANSYS, ABAQUS, OpenFOAM...
General purpose	Allinea/ARM Forge & Perf Reports, Python, Go, Rust...
Container systems	Singularity
Visualisation	ParaView, OpenCV, XCS portal
...	

https://hpc.uni.lu/users/software/

Computing nodes Management

Node deployment by FAI/Bright Manager

- Boot via network card (PXE)
  - ↪ ensure a running diskless Linux OS



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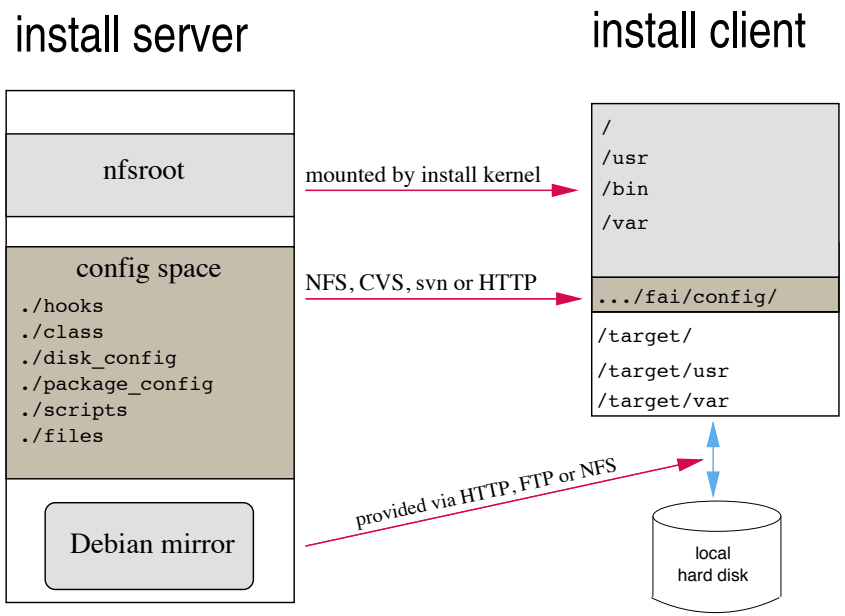

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- Get configuration data (NFS/other)
- Run the installation
  - ↪ partition local hard disks and create filesystems
  - ↪ install software using apt-get/yum command
  - ↪ configure OS and additional software
  - ↪ save log files to install server, then reboot new system

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Average (full) reinstallation time: $\simeq$ 500s

IT Serv[er|ice] Management: Puppet

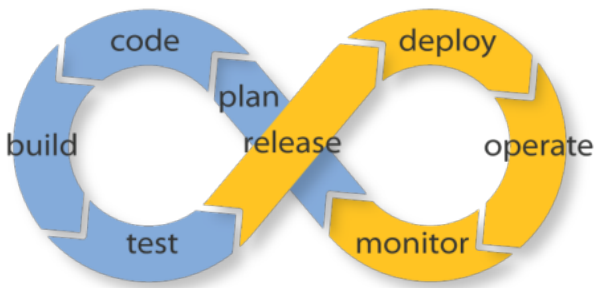
Server/Service configuration by Puppet

puppet

http://puppetlabs.com

- **IT Automation** for configuration management
  - ↪ idempotent, agent/master OR stand-alone
  - ↪ cross-platform through Puppet Resource Abstraction Layer (RAL)
  - ↪ git-based workflow with r10k (_role & profiles_ workflow)
  - ↪ PKI-based security (X.509)
- DevOps tool of choice for configuration management
  - ↪ Reusable modules
  - ↪ per-environment hierarchy lookup with hiera

https://forge.puppet.com/



Endless Possibilities: DevOps can create an infinite loop of release and feedback for all your code and deployment targets.

IT Serv[er|ice] Management: Puppet

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https://forge.puppet.com/

Average server installation/configuration time: $\simeq$ 3-6 min

Software/Modules Management

http://hpcugent.github.io/easybuild/

- Easybuild: open-source framework to (automatically) build scientific software
- **Why?**: *"Could you please install this software on the cluster?"*
  - ↪ Scientific software is often **difficult** to build
    - ✓ non-standard build tools / incomplete build procedures
    - ✓ hardcoded parameters and/or poor/outdated documentation
  - ↪ EasyBuild helps to facilitate this task
    - ✓ **consistent** software **build and installation** framework
    - ✓ includes testing step that helps validate builds
    - ✓ **automatically generates LMod modulefiles**

```
$> module use $LOCAL_MODULES
$> module load tools/EasyBuild
$> eb -S HPL    # Search for recipes for HPL software
$> eb HPL-2.2-intel-2017a.eb # Install HPL 2.2 w. Intel toolchain
```

Summary

HPC International State of Affairs

Global race toward Exascale Technology

IDC-Projected Exascale Investment Levels (In Addition to System Purchases)

U.S.

- $1 to $2 billion a year in R&D (including NRE)
- Investments by both governments & vendors
- Plans are to purchase multiple exascale systems

EU

- About 5 billion euros in total
- Investments in multiple exascale and pre-exascale systems
- Investments mostly by country governments with a little from the EU

China

- Over $1billion a year in R&D
- Investments by both governments & vendors
- Plans are to purchases multiple exascale systems each year
- Already investing in 3 pre-exascale systems by 2017/18

Japan

- Planned investment of just over $1billion* (over 5 years) for both the R&D and purchase of 1 exascale system
- To be followed by a number of smaller systems ~$100M to $150M each
- Creating a new processor and a new software environment

©Hyperion Research 2017

** Note that this includes both the system and R&D*

HPC International State of Affairs

Global race toward Exascale Technology

IDC-Projected Exascale Dates and Suppliers

U.S.
- Sustained ES: 2023
- Peak ES: 2021
- Vendors: U.S.
- Processors: U.S.
- Initiatives: NSCI/ECP
- Cost: $300-500M per system, plus heavy R&D investments

EU
- Sustained ES: 2023-24
- Peak ES: 2021
- Vendors: U.S., Europe
- Processors: U.S., ARM
- Initiatives: PRACE, ETP4HPC
- Cost: $300-$350 per system, plus heavy R&D investments

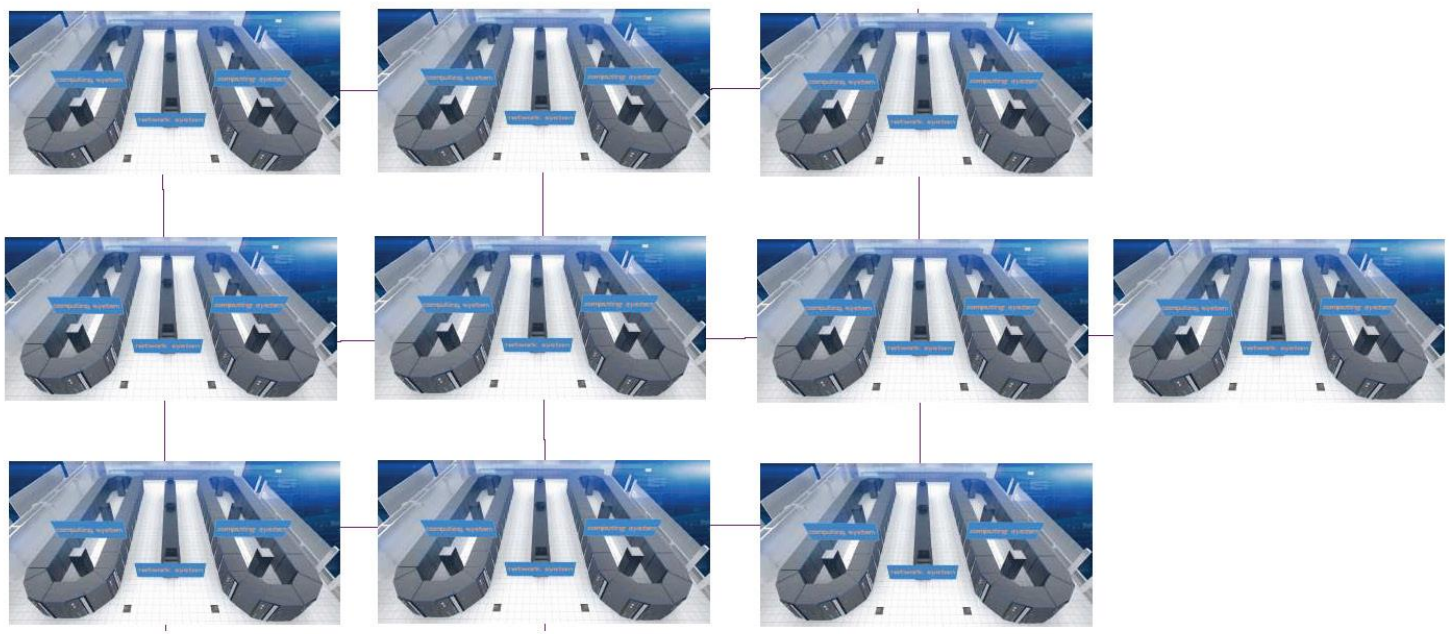
China
- Sustained ES: 2023
- Peak ES: ~~2020~~ 2019…
- Vendors: Chinese
- Processors: Chinese (plus ~~U.S.~~?)
- 13th 5-Year Plan
- Cost: $350-500M per system, plus heavy R&D

Japan
- Sustained ES: 2023-24
- Peak ES: Not planned
- Vendors: Japanese
- Processors: Japanese
- Cost: $600-850M, this includes both 1 system and the R&D costs…will also do many smaller size systems

Exascale Feasibility

We Can Build an Exascale System Today?

Connect together 10 Sunway TaihuLight systems



Require 150 MW of power, programming for 100 M threads, and $2.7B price tag

22

European HPC strategy

- EU HPC strategy initiated in 2012
  - ↪ implementation within H2020 program

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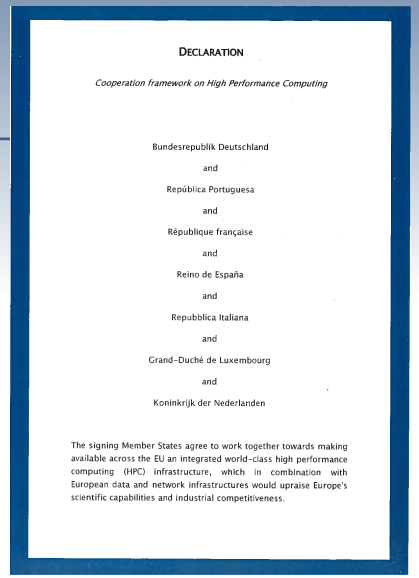
  - ↪ implementation within H2020 program

- More recently:
  - ↪ IPCEI on HPC and Big Data (BD) Applications (Nov. 2015)
    - ✓ Luxembourg (leader), France, Italy & Spain
    - ✓ Testbed around Personalized Medicine, Smart Space, Industry 4.0, Smart Manufacturing, New Materials, FinTech, Smart City...

European HPC strategy


DECLARATION

Cooperation framework on High Performance Computing

Bundesrepublik Deutschland
and
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Reino de España
and
Repubblica Italiana
and
Grand-Duché de Luxembourg
and
Koninkrijk der Nederlanden

The signing Member States agree to work together towards making available across the EU an integrated world-class high performance computing (HPC) infrastructure, which in combination with European data and network infrastructures would upraise Europe's scientific capabilities and industrial competitiveness.

- EU HPC strategy initiated in 2012
  - ↪ implementation within H2020 program
- More recently:
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    - ✓ Luxembourg (leader), France, Italy & Spain
    - ✓ Testbed around Personalized Medicine, Smart Space, Industry 4.0, Smart Manufacturing, New Materials, FinTech, Smart City...
- **Latest advances**:
  - ↪ EU Member States sign EuroHPC (Mar. 2017)
    - ✓ common effort to create/grow European supercomputing ecosystem
    - ✓ Federation of national/regional HPC centers (see also PRACE2)
  - ↪ EU Objective with EuroHPC:
    - ✓ EuroHPC JU effectively operational starting **Jan 1st, 2019**
    - ✓ 2-3 **Pre-exascale** systems 2020, **2 exascale** systems by 2022

EU HPC Strategy Implementation

- **European Technology Platform (ETP) for HPC**
  - ↪ Industry-led forum feat. HPC stakeholders
  - ↪ Providing EU framework to define HPC research priorities/actions
    - ✓ UL (P. Bouvry, S. Varrette, V.Plugaru) part of ETP4HPC (2016-)
    - ✓ See Strategic Research Agenda, 2017 European HPC Handbook...

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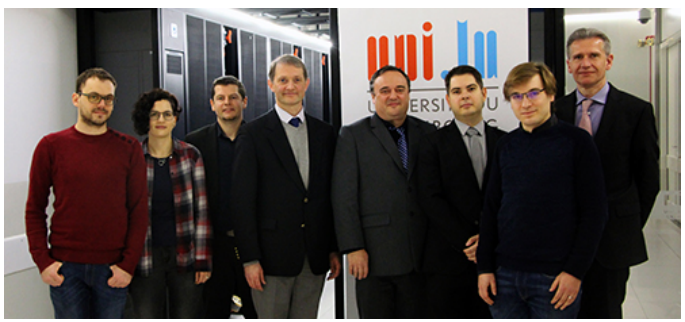
    - ✓ See Strategic Research Agenda, 2017 European HPC Handbook...

- **PRACE** - Partnership for Advanced Computing in Europe
  - ↪ Non-profit association, 25 member countries, now entering PRACE2
  - ↪ Providing access to **Five EU Tier-0** compute & data resources
  - ↪ (Oct. 2017) **Luxembourg 25th country to join PRACE**
    - ✓ Official Delegate/Advisor (P. Bouvry/S. Varrette) from UL



EU HPC Strategy Implementation

- **European High-Performance Computing Joint Undertaking**
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    - ✓ administrative management from Luxembourg
  - ↪ Public and private members
    - ✓ EC, 14 MS, representatives from supercomputing/BD stakeholders
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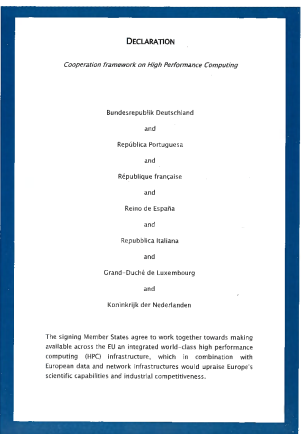

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The signing Member States agree to work together towards making available across the EU an integrated world-class high performance computing (HPC) infrastructure, which in combination with European data and network infrastructures would upraise Europe's scientific capabilities and industrial competitiveness.

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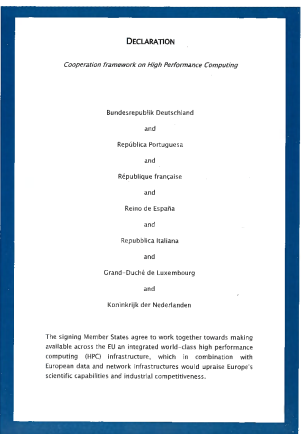
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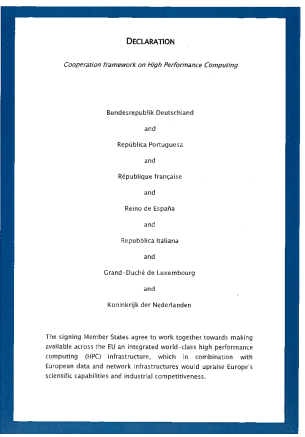
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EuroHPC Budget: 2×486 M€

- **European Processor Initiative (EPI)**
  - ↪ Initial plan vs current plan...
  - ↪ **120 M€** via Framework Partnership Agreement (FPA)

Summary

Summary

New Trends in HPC

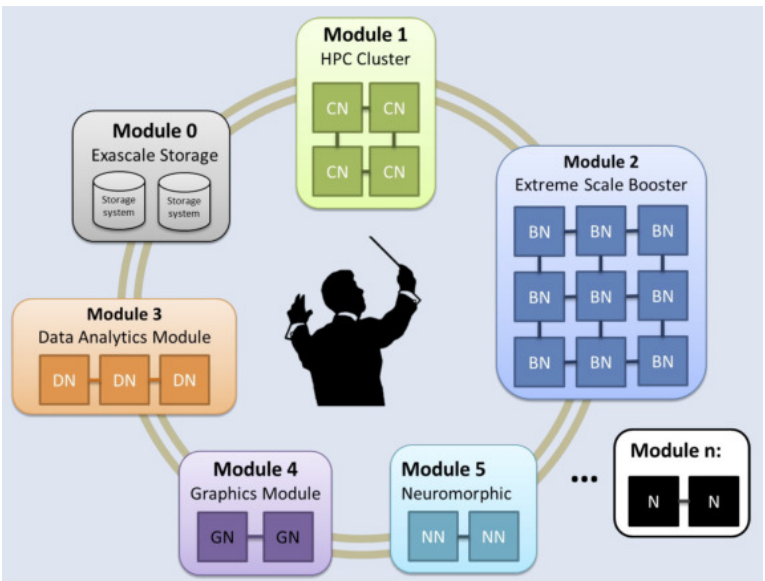
- **Continued scaling** of scientific, industrial & financial applications
  - ↪ . . . well beyond Exascale
- New trends changing the landscape for HPC
  - ↪ Emergence of **Big Data analytics**
  - ↪ Emergence of (_Hyperscale_) **Cloud Computing**
  - ↪ **Data intensive Internet of Things (IoT)** applications
  - ↪ **Deep learning & cognitive computing** paradigms

[Source : EuroLab-4-HPC]

[Source : IDC RIKEN report, 2016]

Toward Modular Computing

- Aiming at **scalable**, **flexible HPC infrastructures**
  - ↪ *Primary* processing on CPUs and accelerators
    - ✓ **HPC & Extreme Scale Booster** modules
  - ↪ *Specialized modules* for:
    - ✓ **HTC & I/O intensive** workloads;
    - ✓ **[Big] Data Analytics & AI**



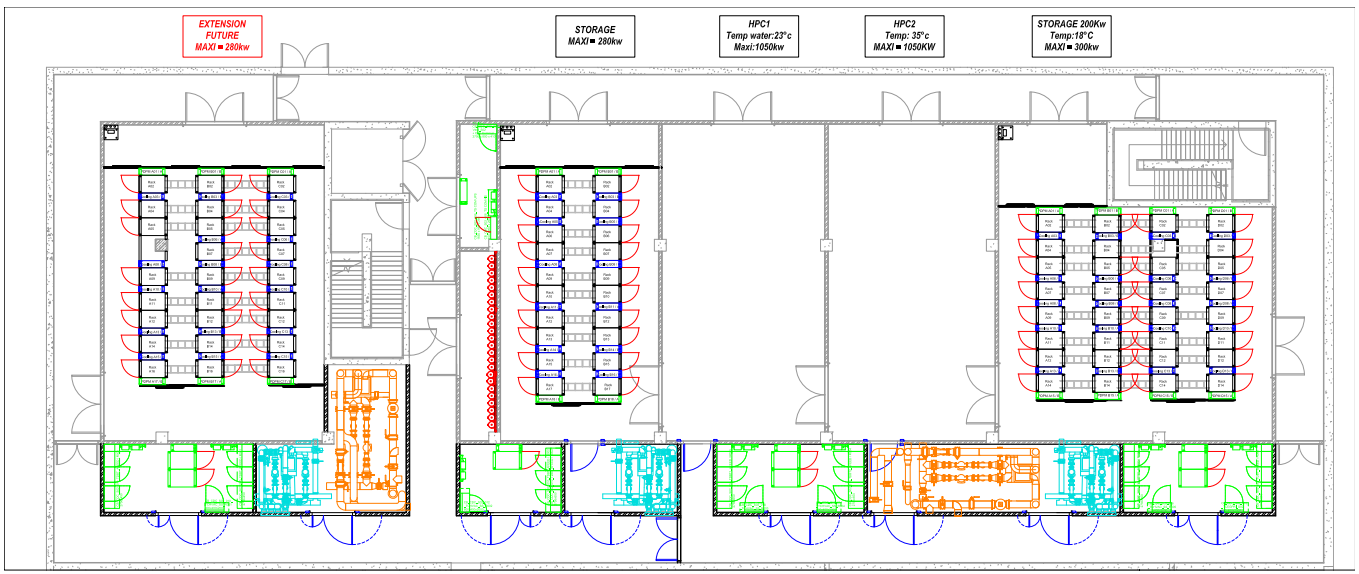
[Source : "Towards Modular Supercomputing: The DEEP and DEEP-ER projects", 2016]

Summary

Uni.lu CDC (Centre de Calcul)

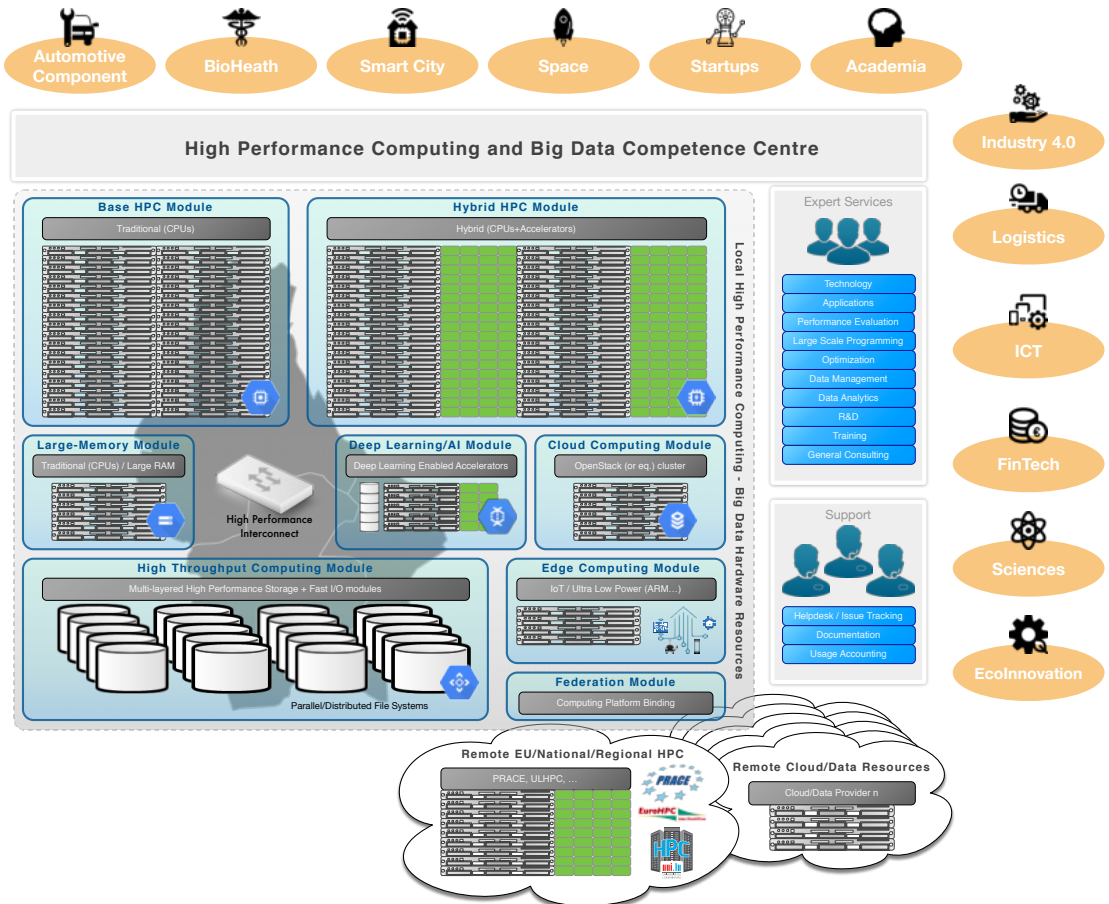
- **Toward Energy-Efficient HPC enabling DLC**
  - ↪ 2x500 m^2 deployed since 2015, one floor for HPC developments

Location	Cooling	Usage	Max Capacity [kW]
CDC S-02-001	Airflow	*Future extension*	280 kW (120 m2)
CDC S-02-002	Airflow	Storage / Traditional HPC /Cloud/FPGA	280 kW (88 m2)
CDC S-02-003	**DLC**	**High Density/Energy efficient HPC**	**1050 kW (90 m2)**
CDC S-02-004	**DLC**	**High Density/Energy efficient HPC**	**1050 kW (92 m2)**
CDC S-02-005	Airflow	Storage / Traditional HPC (`iris` cluster)	300 kW (128 m2)



National HPC-BD Competence Center

- Built by ministerial, academic, industrial stakeholders
  - ↪ **Inspired by national research computing centers**



- Comprehensive centre:
  - ↪ HPC
  - ↪ data infrastructure
  - ↪ Techn. Expertise
  - ↪ Domain knowledge
- *More than just computing services*
- **Inspiration**:
  - ↪ **EU**: JSC, TGCC...
  - ↪ **US**: OSC, SDSC, TACC, LLNL...
  - ↪ **Singapore**: A*STAR

Summary

Conclusion

- **Luxembourg government priority on HPC**
  - ↪ sustained by University of Luxembourg HPC developments
  - ↪ consolidate and extend Europe efforts on HPC/Big Data

UL HPC (as of 2018)

1029.342 TFlops / 9852.4TB (shared)

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Several On-going Strategic HPC efforts in Europe...

- . . . **in which UL *(HPC)* is involved** . . .
  - ↪ ETP4HPC, EU COST Action NESUS etc.
  - ↪ **PRACE** - Official representative for Luxembourg from UL
  - ↪ EuroHPC / IPCEI on HPC and Big Data (BD) Applications
  - ↪ **National HPC-BD Competence Center**
  - ↪ NVidia Cooperation agreement on AI and HPC

Questions?

http://hpc.uni.lu

High Performance Computing @ uni.lu

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Valentin Plugaru
Sarah Peter
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