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JÜLICH
FORSCHUNGSZENTRUM

Modular Supercomputing

An overview of computing architecture evolution at JSC

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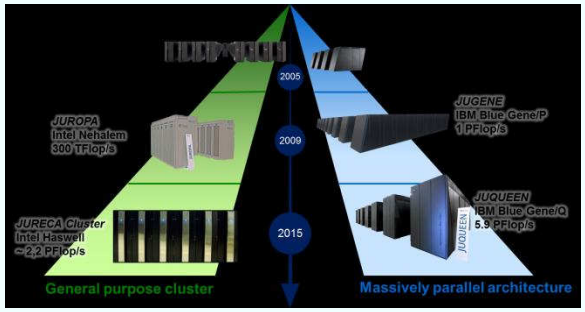
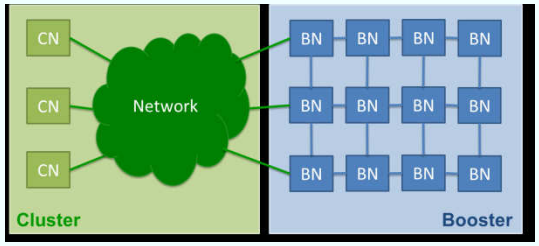
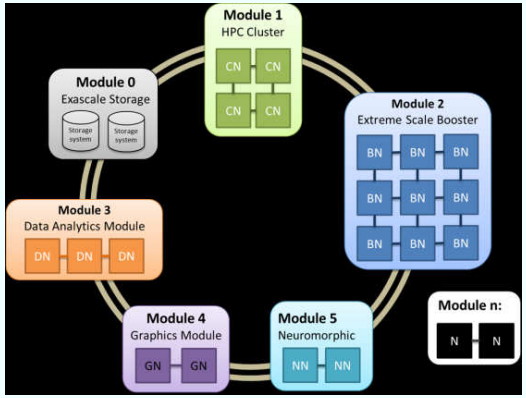
Outline

- Supercomputing evolution
  - Cluster computing
- Architectures at JSC
  - **Dual** architecture approach
  - **Cluster-Booster** architecture
    - *The DEEP projects*
  - **Modular Supercomputing** architecture
- JSC future vision



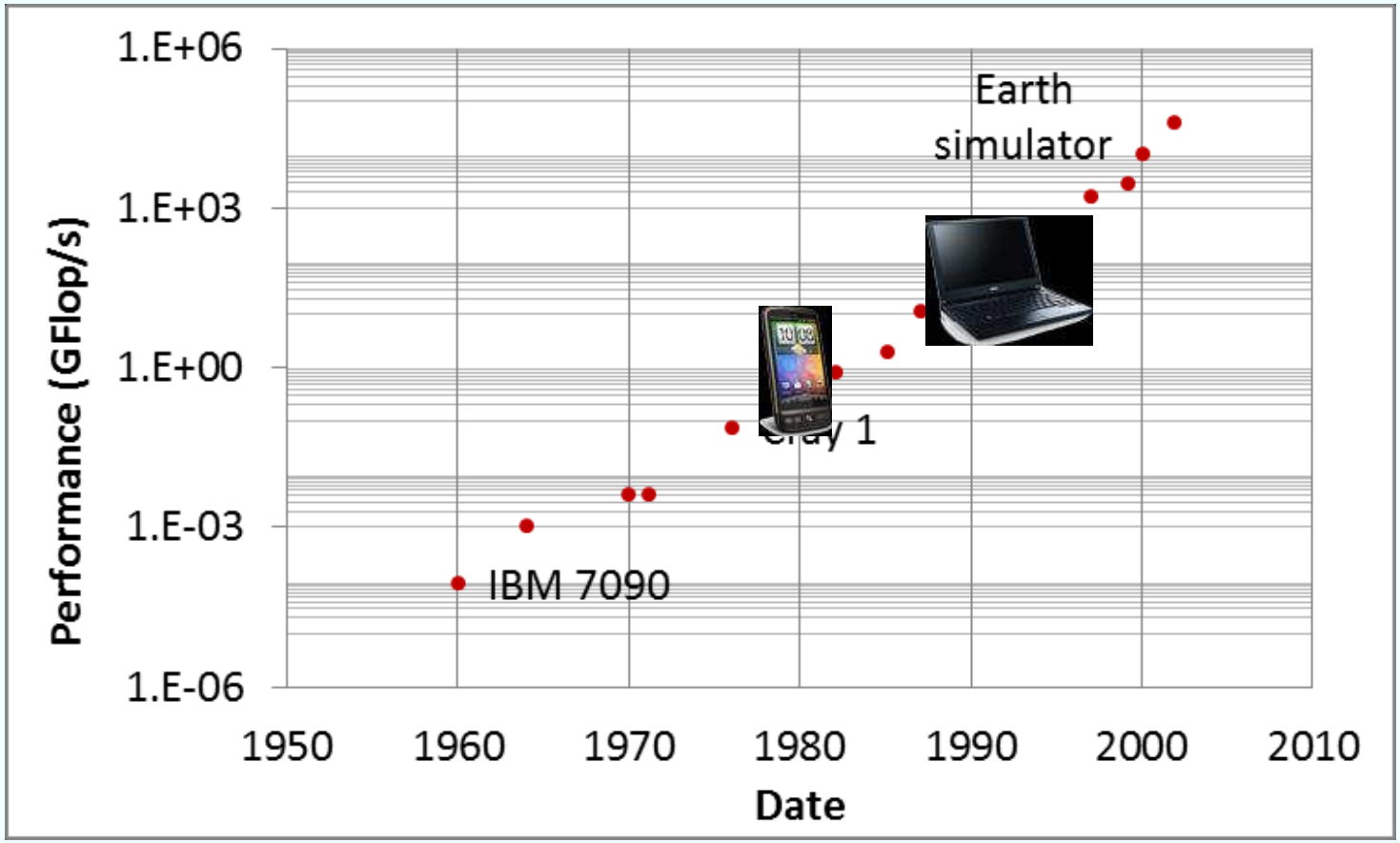




Architecture changes in time

SUPERCOMPUTING EVOLUTION

Supercomputing evolution – Performance



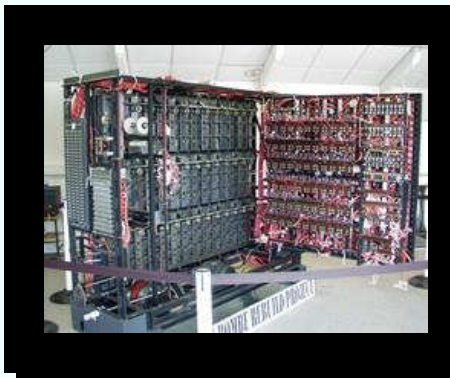
Moore's law

- Every 18-24 months the # transistors in microprocessors doubles

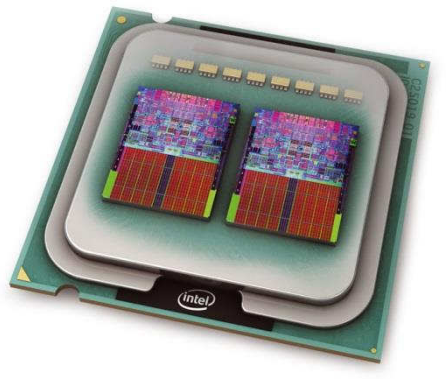
SC Evolution – Architecture paradigms

- **1940 – 1950**: first computers are Supercomputers
  - Specialized, very expensive
- **1960 – 1980**: general purpose computers appear
  - Still special machines needed to solve very complex problems → Supercomputing (High Performance Computing - HPC)

    - Focus: floating operations (linear Algebra)
    - Special purpose technologies (fast vector processors, parallel architectures)
    - Only few machines produced
- **1990 – 2000**: integrate standard processors
  - Many „computers“ connected through fast network
    - Distributed memory → MPI
  - Both in proprietary Massively Parallel (MPP) and Cluster Computing
- **2010 –** : heterogeneous cluster systems
  - Use accelerator technologies (GPU, Xeon Phi)



General purpose processors



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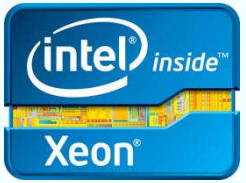
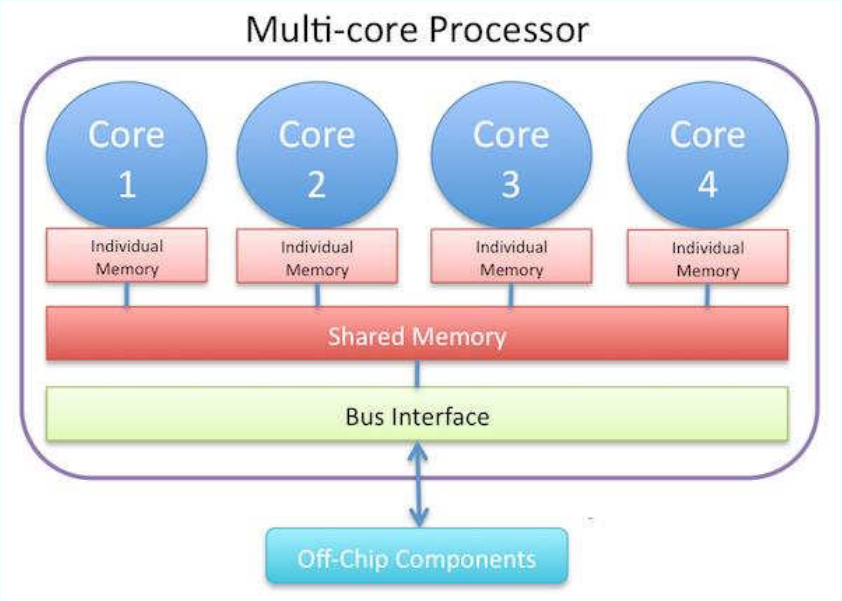


Characteristics

- Broad range of capabilities
- Today always multi-core
  - Up to about 20 cores
- High single thread performance
  - High frequency
  - Out of order processing
- High memory per core
- Runs standard programming environment (MPI, OpenMP, etc.)
- Disadvantages
  - Limited energy efficiency
  - Larger $/FLOP



Accelerators

Many core (Intel Xeon Phi)

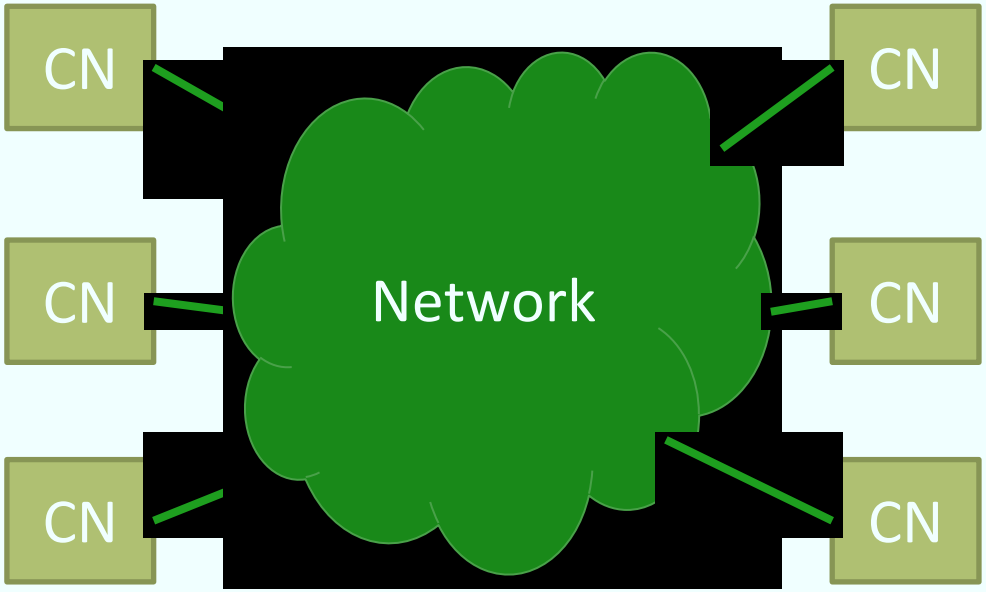
- 60 to 80 cores, 4 threads / core
- Rather low single thread performance
  - *low frequency*
- Energy efficient ($/FLOP)
- x86 architecture → standard programming with MPI, OpenMP, etc.
- Can run autonomously (without host)

GPGPU (Graphic cards)

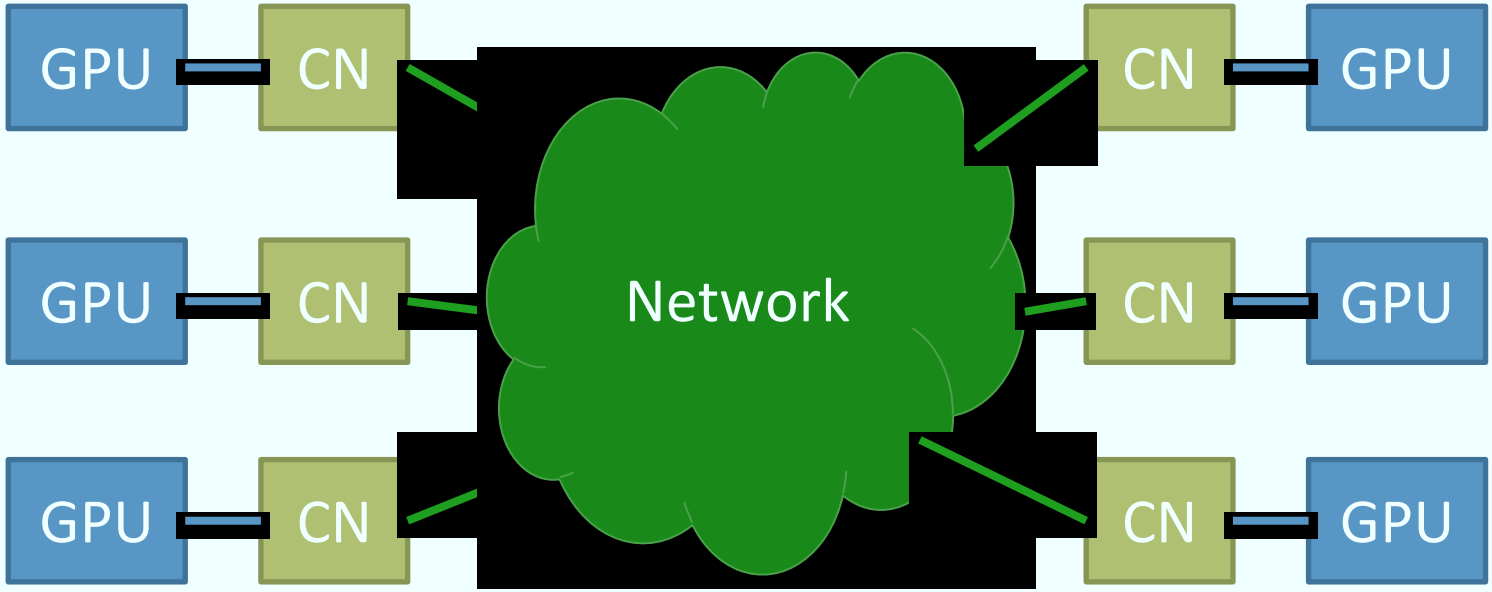
- Designed for graphics but evolved into general purpose
- Hundreds of (weak) computing cores
- Very energy efficient ($/FLOP)
- Require specific programming models (CUDA, OpenCL)
- Require a host CPU

e.g.

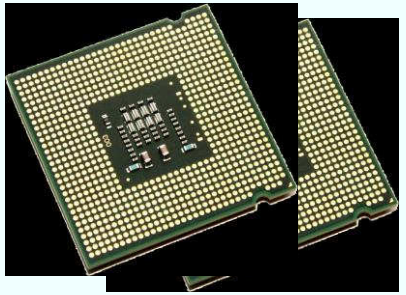
Homogeneous Cluster



Heterogeneous Cluster



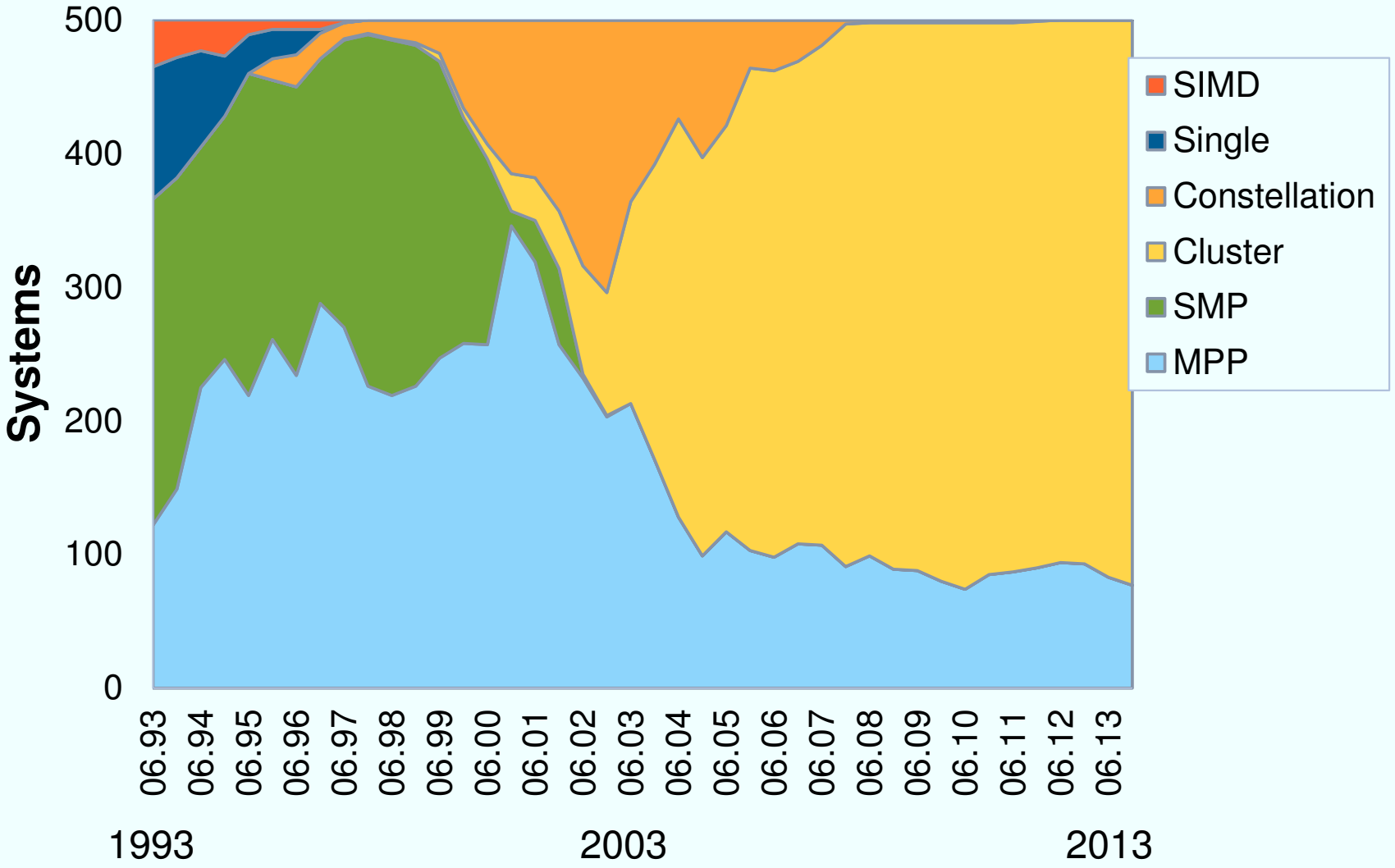
Cluster „anatomy“



Components selected/tuned to fit user needs

- **Heart**: Processor providing compute performance
- **Brain**: Memory / Storage
  - With many layers (Caches, DRAM, SSD, HD, Tape)
- **Nerve system**: Network
  - Often more than one (MPI, Administration, I/O...)
- **Consciusness**: Software
  - Including various middleware layers (node management, process management, MPI, etc.)
  - OpenSource
- **Balance** is more important than performance of individual components
  - Challenge: „slow“ memory and network evolution vs. computing performance

SC Evolution – Top500 architectures



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ARCHITECTURES AT JSC

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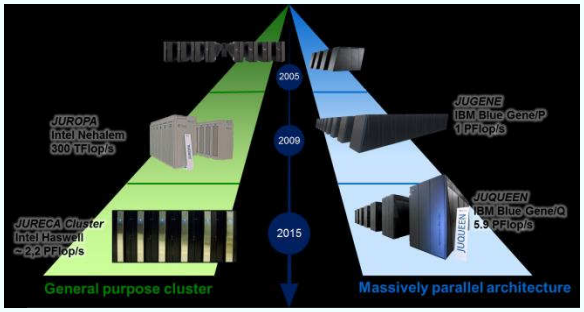
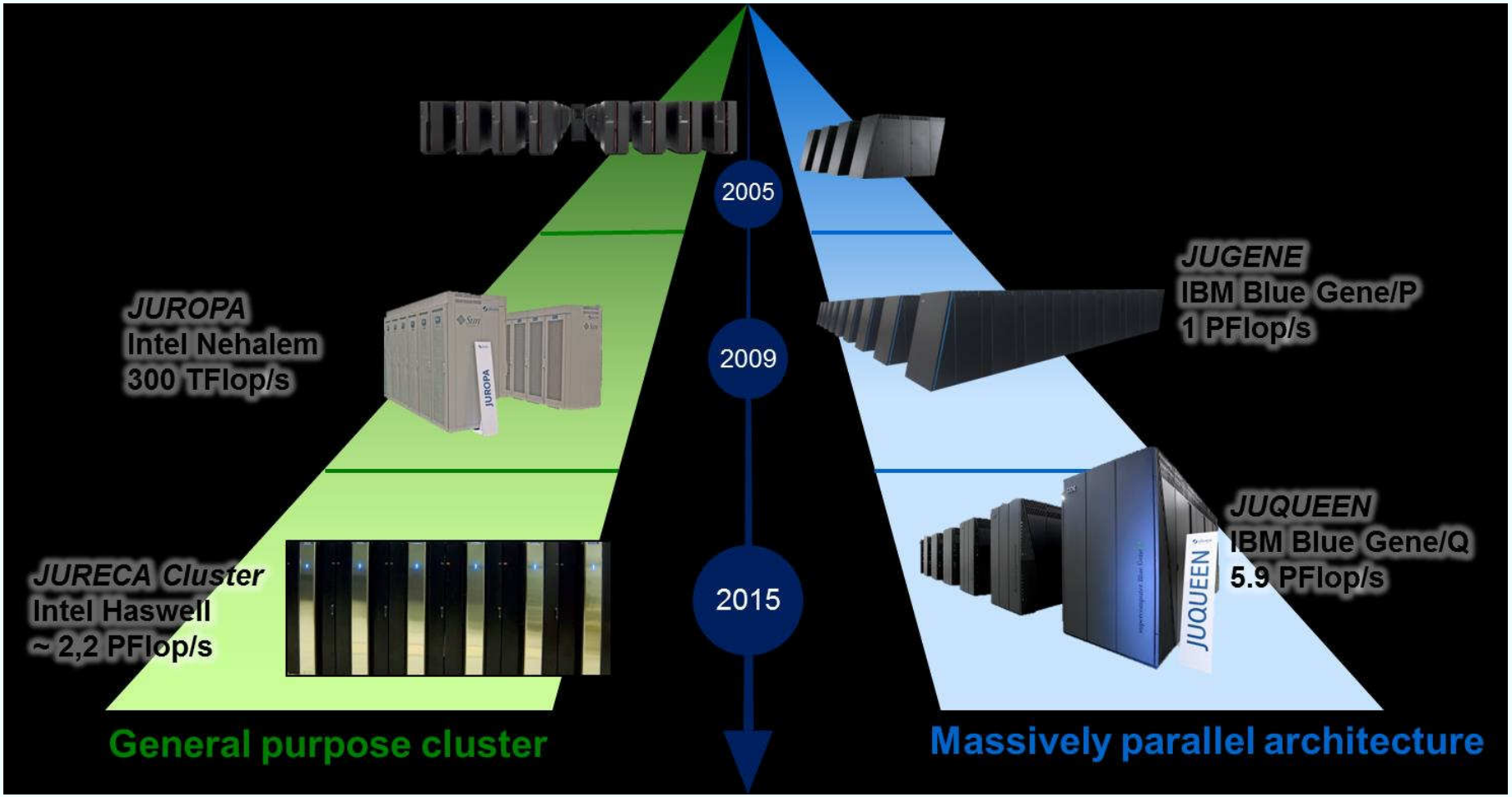
- Architectures at JSC
  - **Dual** architecture approach
  - **Cluster-Booster** architecture
    - *The DEEP projects*
  - **Modular Supercomputing** architecture
- JSC future vision



Dual Architecture at JSC



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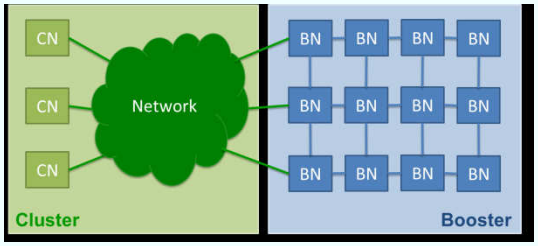
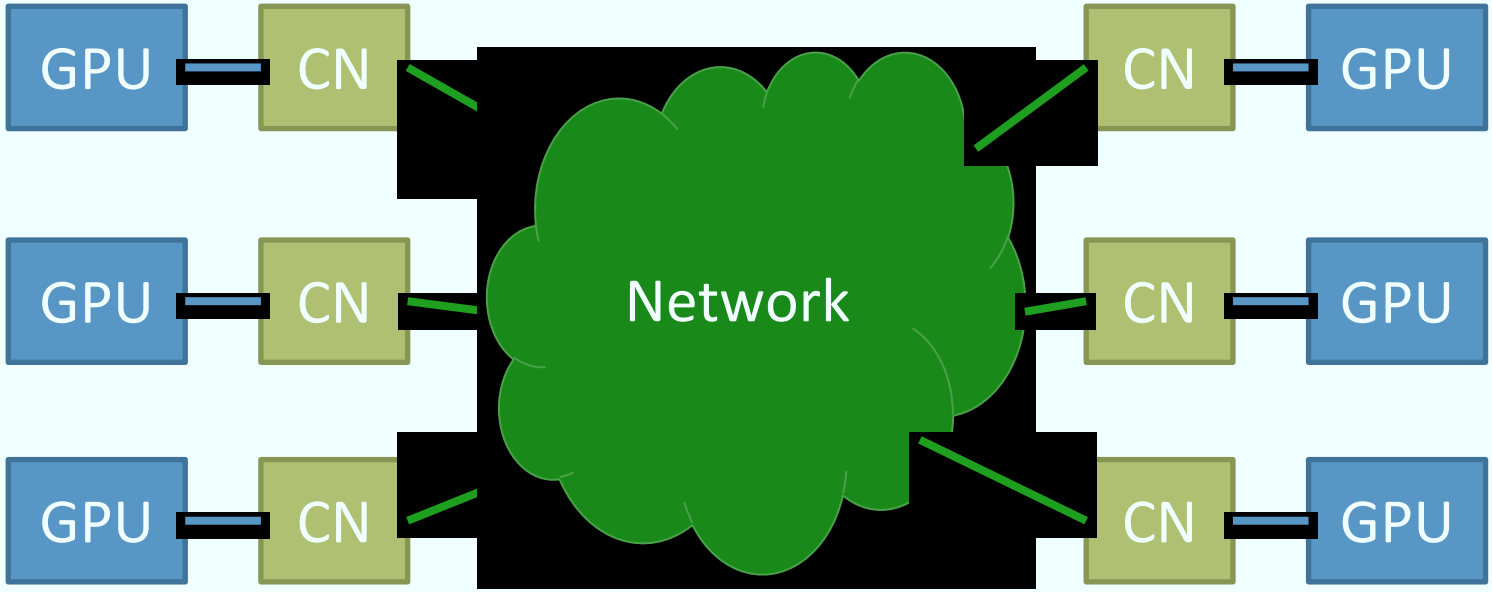
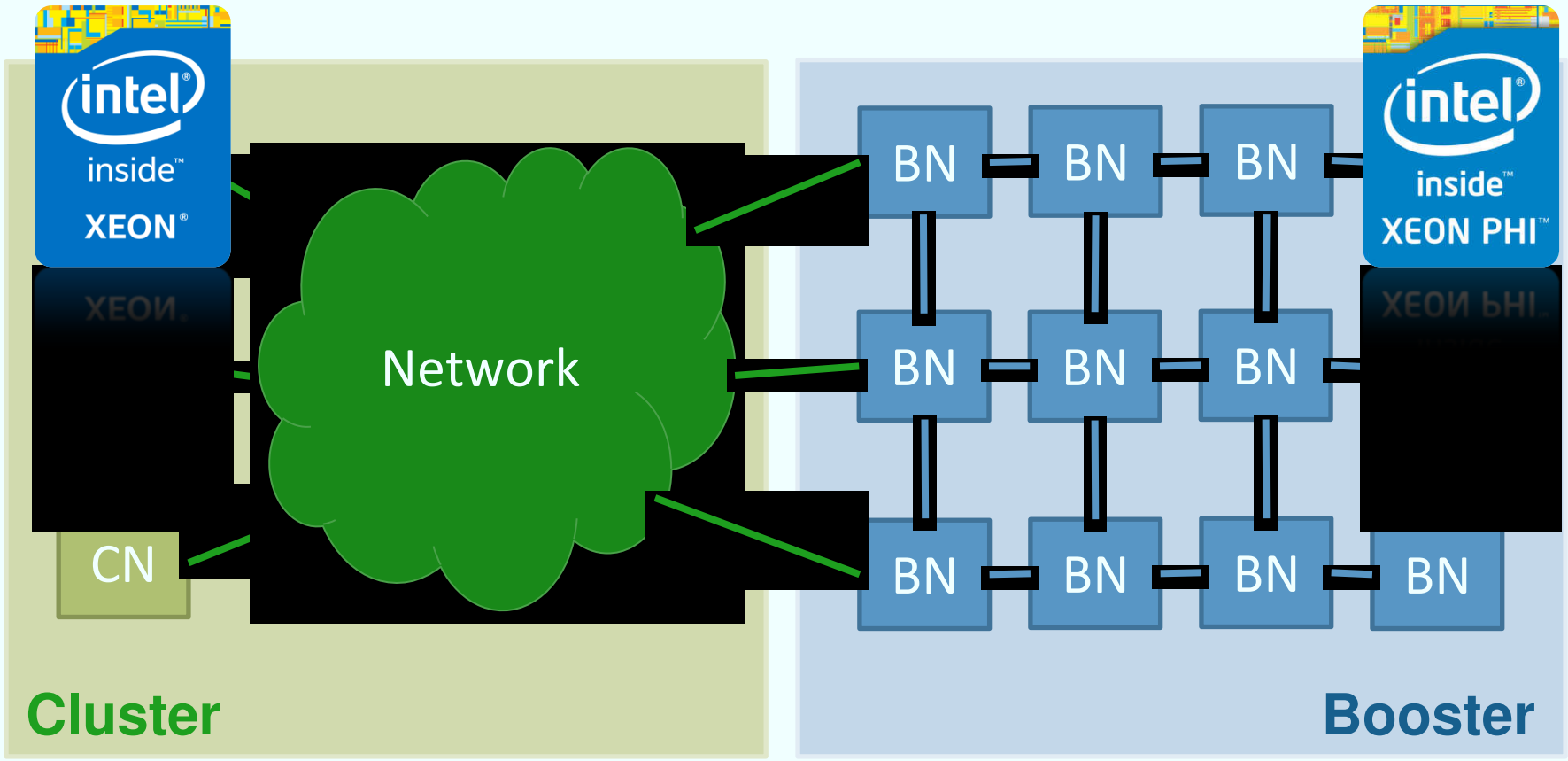


Heterogeneous Cluster



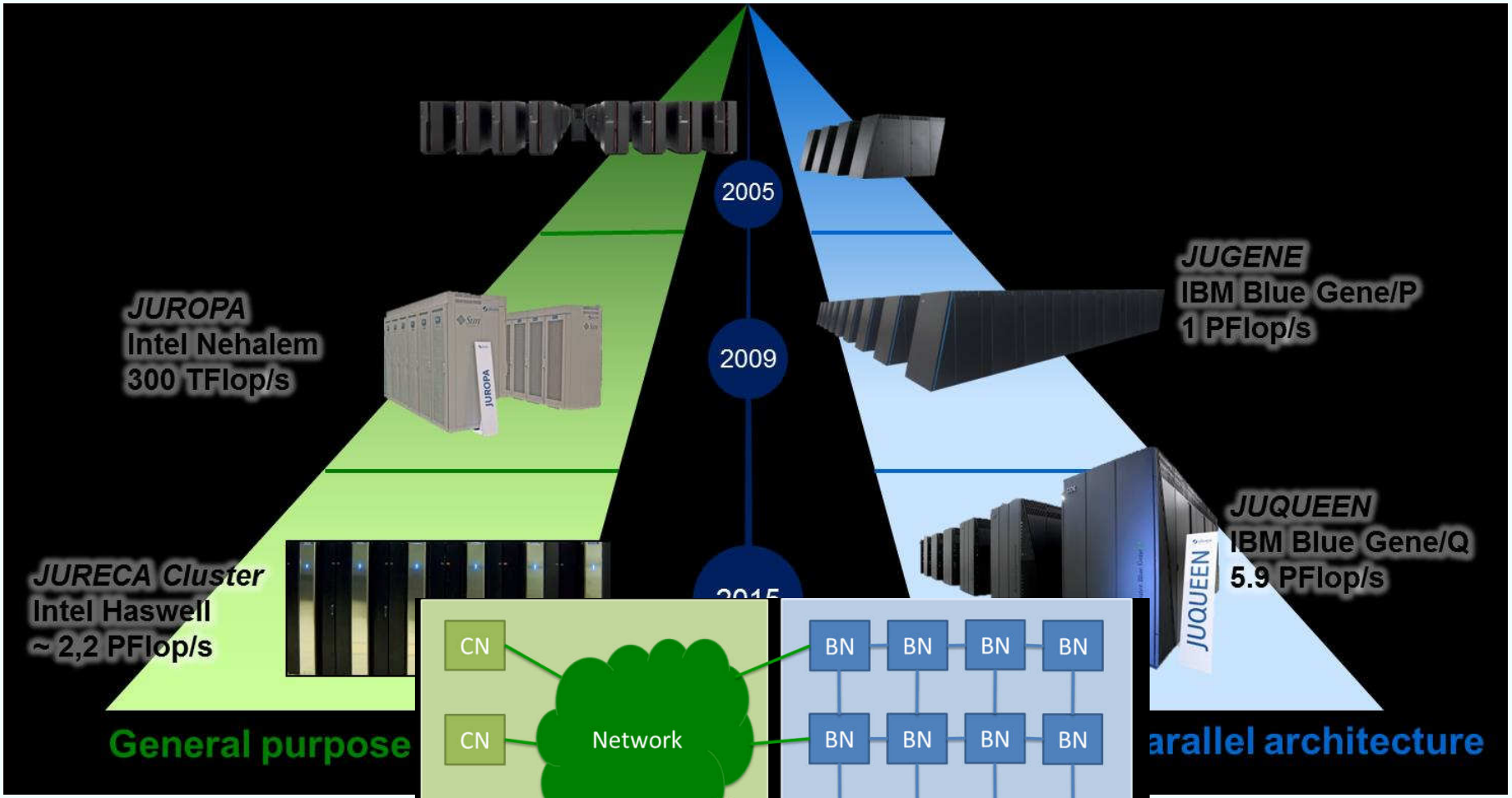
Cluster-Booster architecture



Low/Medium scalable code parts

Highly scalable code parts

Dual Architecture at JSC



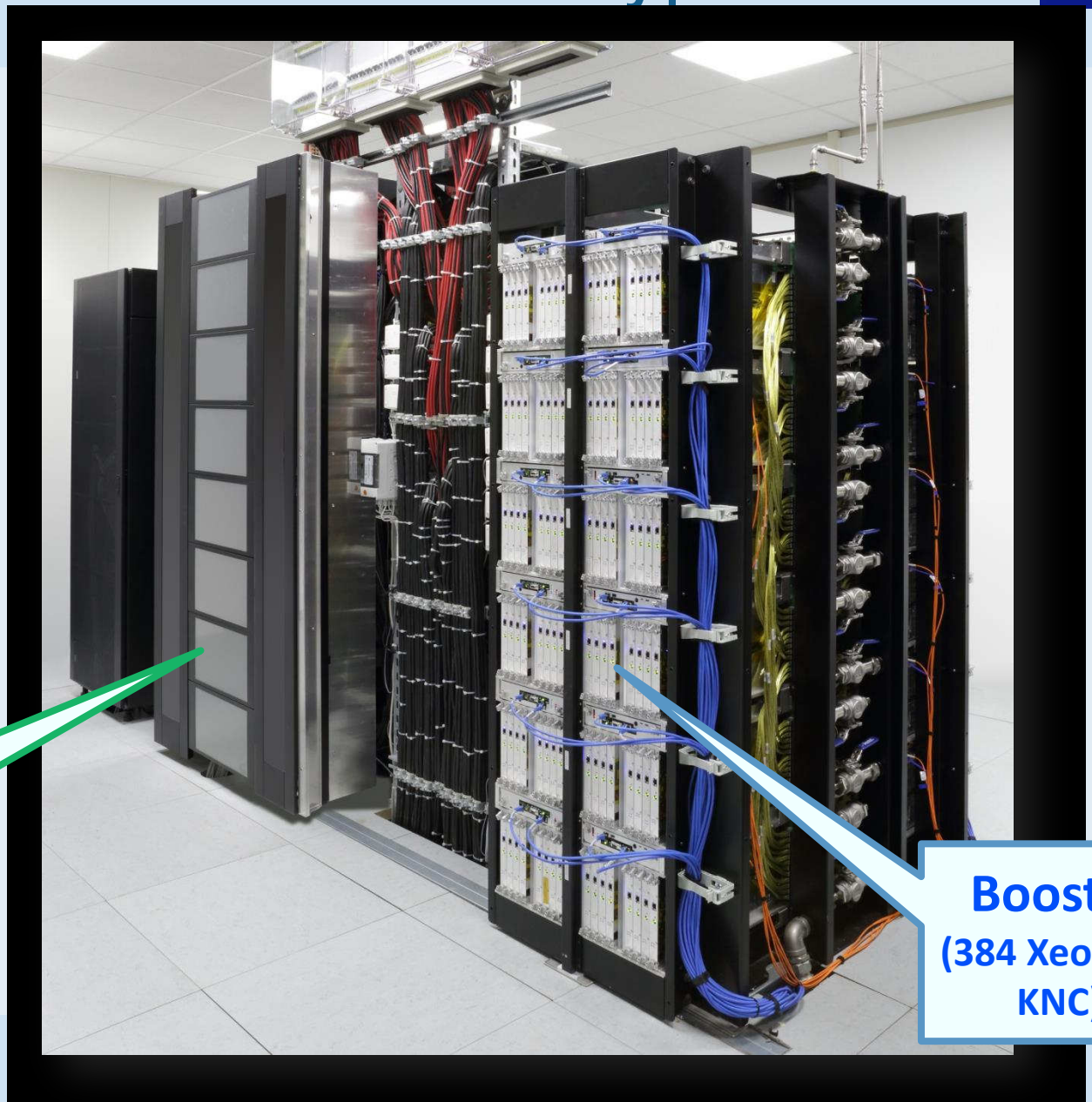
The DEEP Projects

- 3x EU Exascale projects
  - DEEP
  - DEEP-ER
  - DEEP-EST
- 27 partners
  - Coordinated by JSC
- EU-funding: 30 M€
- Nov 2011 – Jun 2020

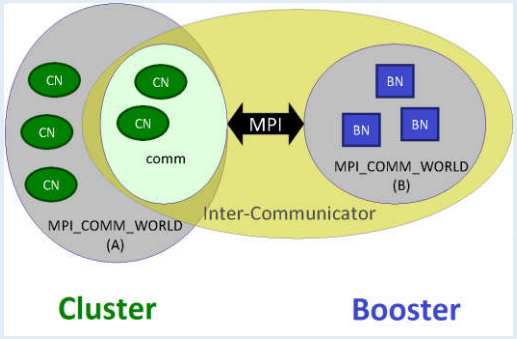
Co-design:
- Hardware
- Software
- Applications

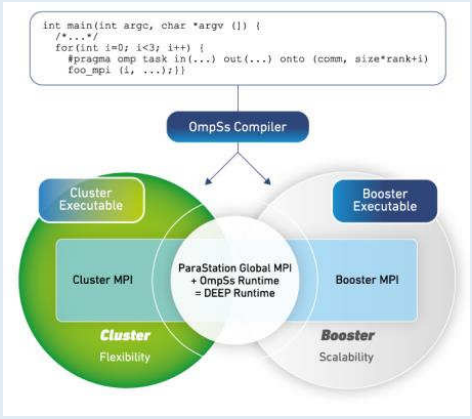
DEEP Prototype

- Installed at JSC
- 1,5 racks
- 500 TFlop/s (peak perf.)
- 3.5 GFlop/s/W
- Water cooled



Software environment



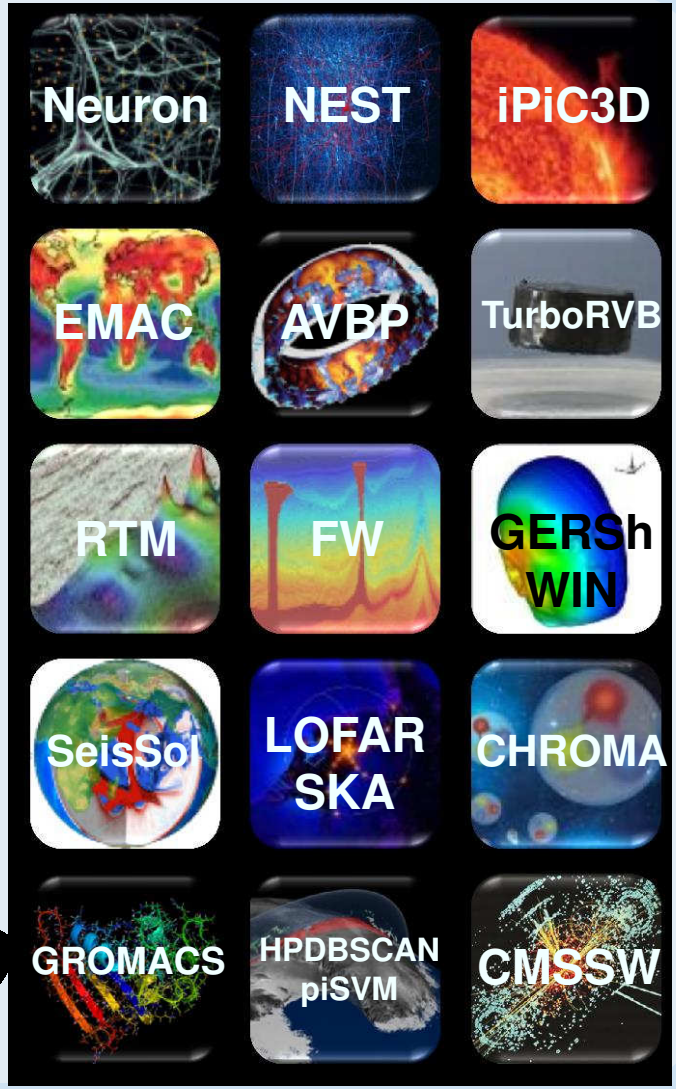


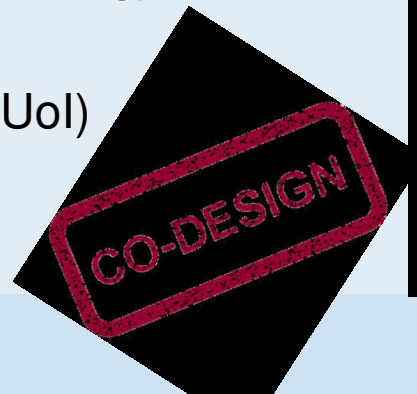
- **Low-level SW:** Cluster-Booster protocol
- **Scheduler**: Torque/Maui → SLURM
- **Filesystem**: BeeGFS
- **Compilers**: Intel, gcc, PGI
- **Debuggers**: Intel Inspector, TotalView
- **Programming**: ParaStation MPI (mpich), OpenMP, OmpSs
- **Performance analysis tools**: Scalasca, Extrae/Paraver, Intel Advisor, VTune…
- **Benchmarking tools:** JUBE
- **Libraries**: SIONlib, SCR, E10, HDF5…

Application-driven approach

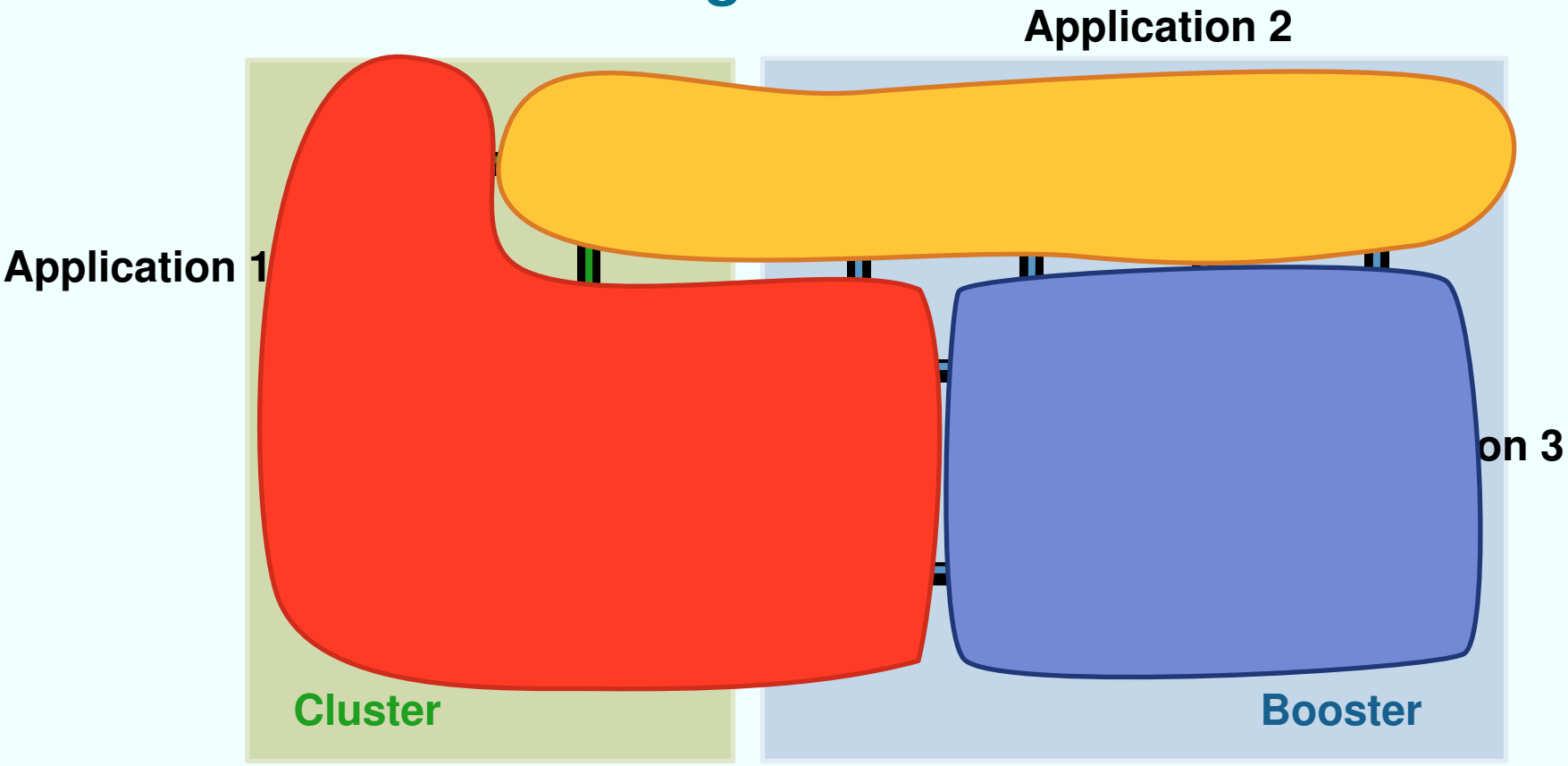
DEEP projects applications (15):

- Brain simulation (EPFL + NMBU)
- Space weather simulation (KULeuven)
- Climate simulation (Cyprus Institute)
- Computational fluid engineering (CERFACS)
- High temperature superconductivity (CINECA)
- Seismic imaging (CGG + BSC)
- Human exposure to electromagnetic fields (INRIA)
- Geoscience (LRZ)
- Radio astronomy (Astron)
- Lattice QCD (University of Regensburg)
- Molecular dynamics (NCSA)
- Data analytics in Earth Science (UoI)
- High Energy Physics (CERN)



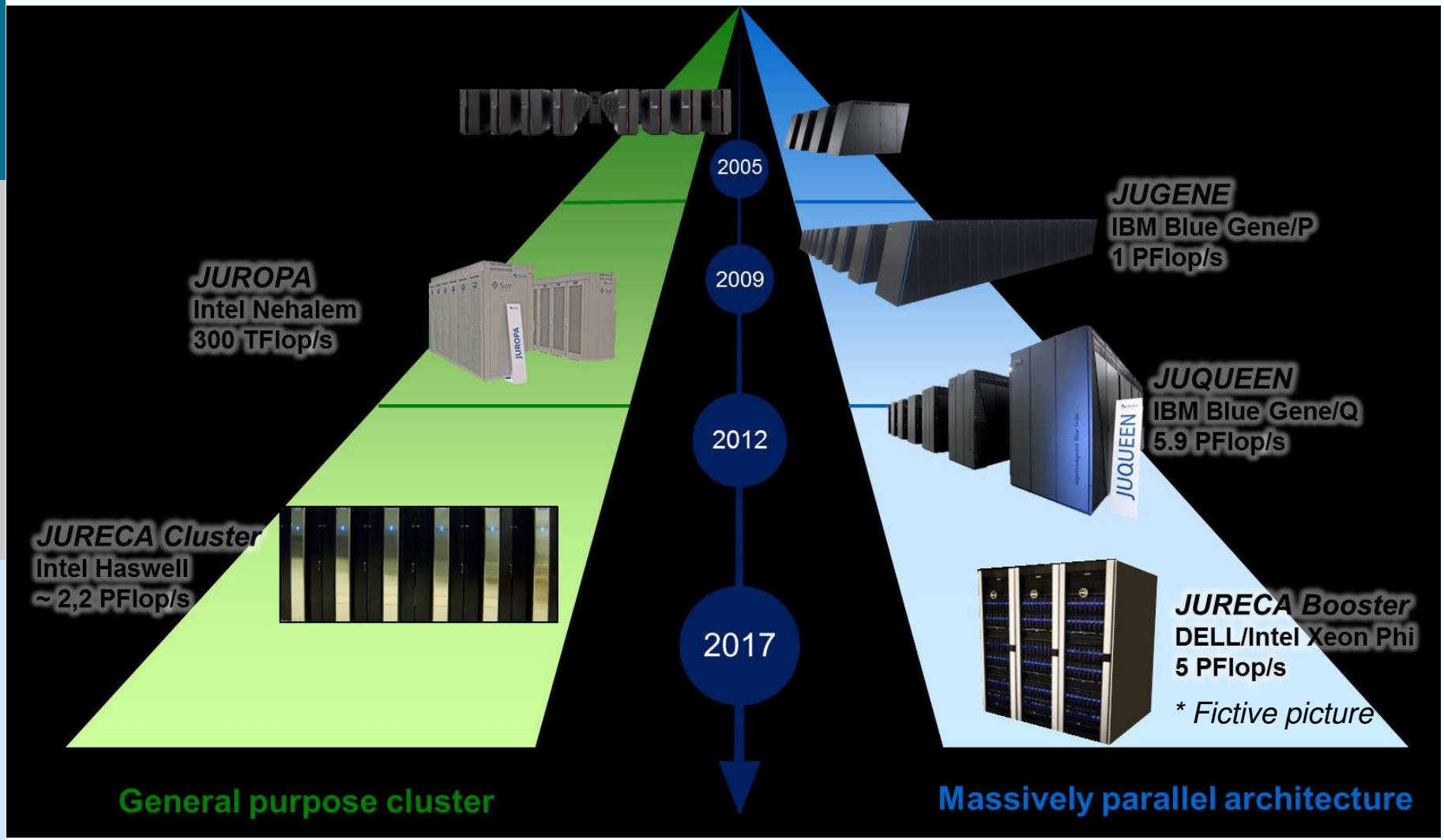


Cluster-Booster advantages

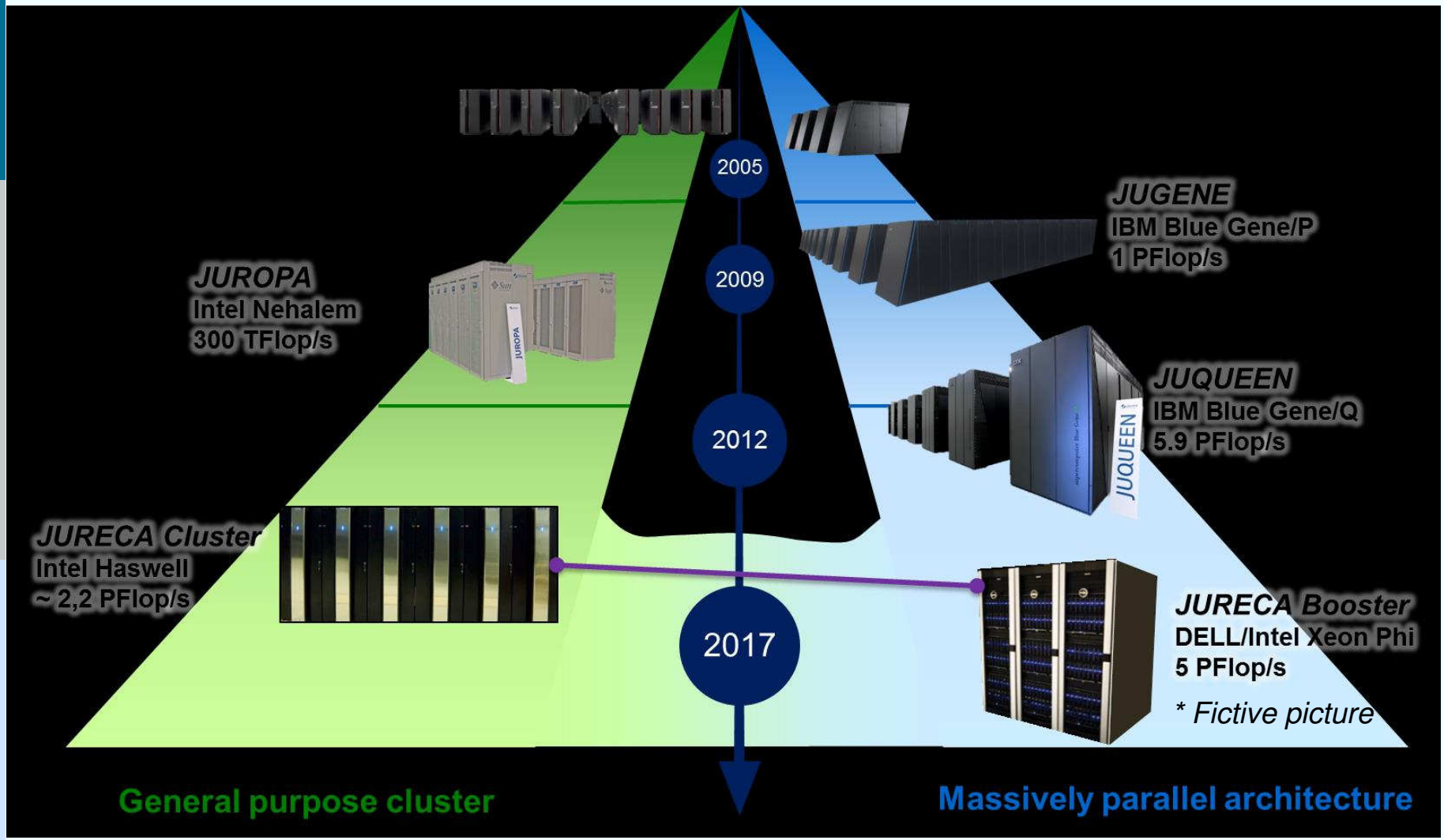


- Full **user flexibility** – many possible use modes
- **Efficient resources use** – only used nodes are blocked

Dual → Cluster Booster



Dual → Cluster Booster



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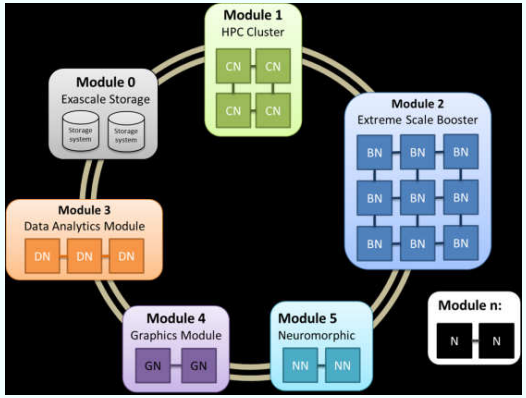
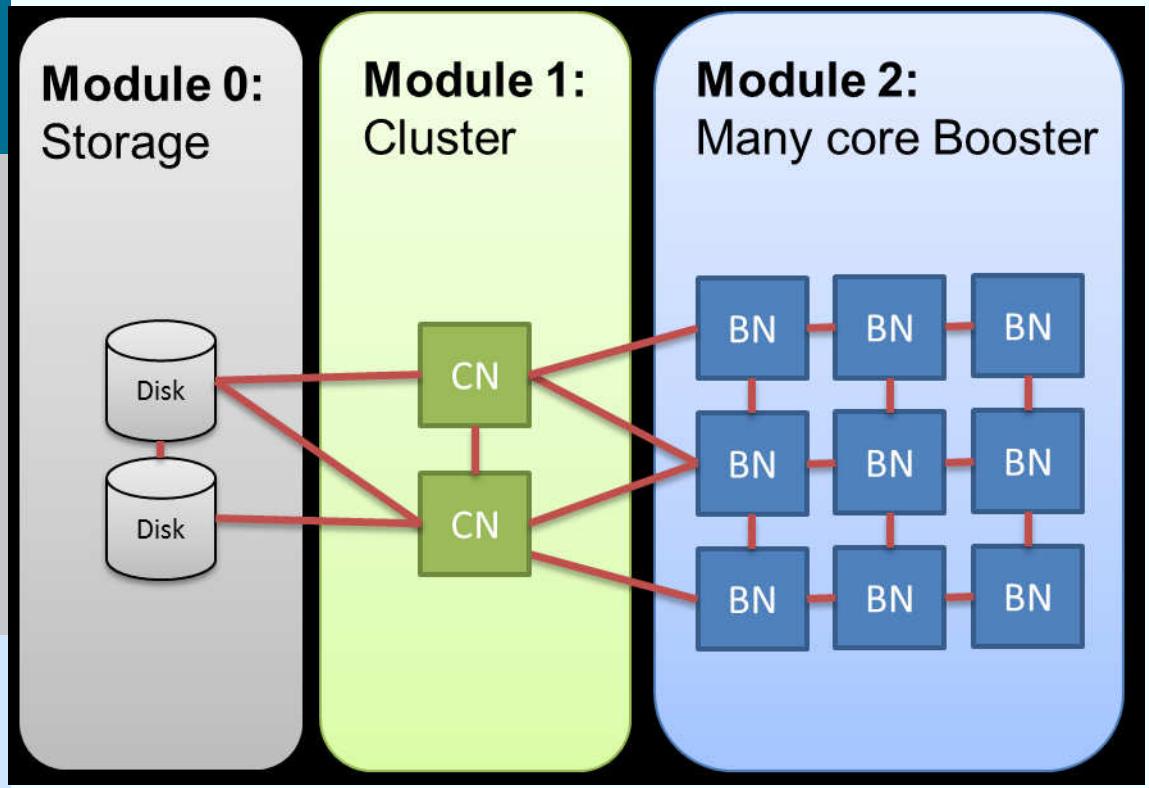
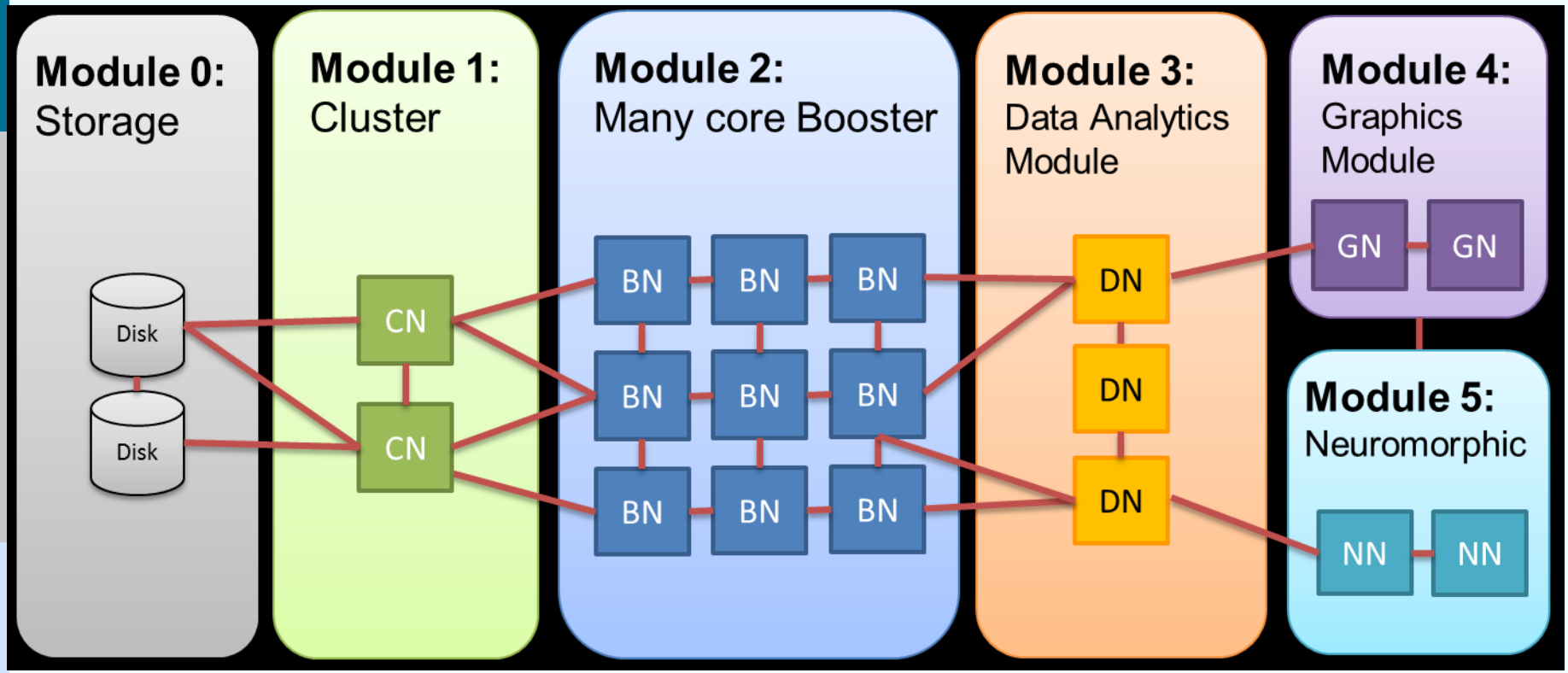


Cluster – Booster architecture

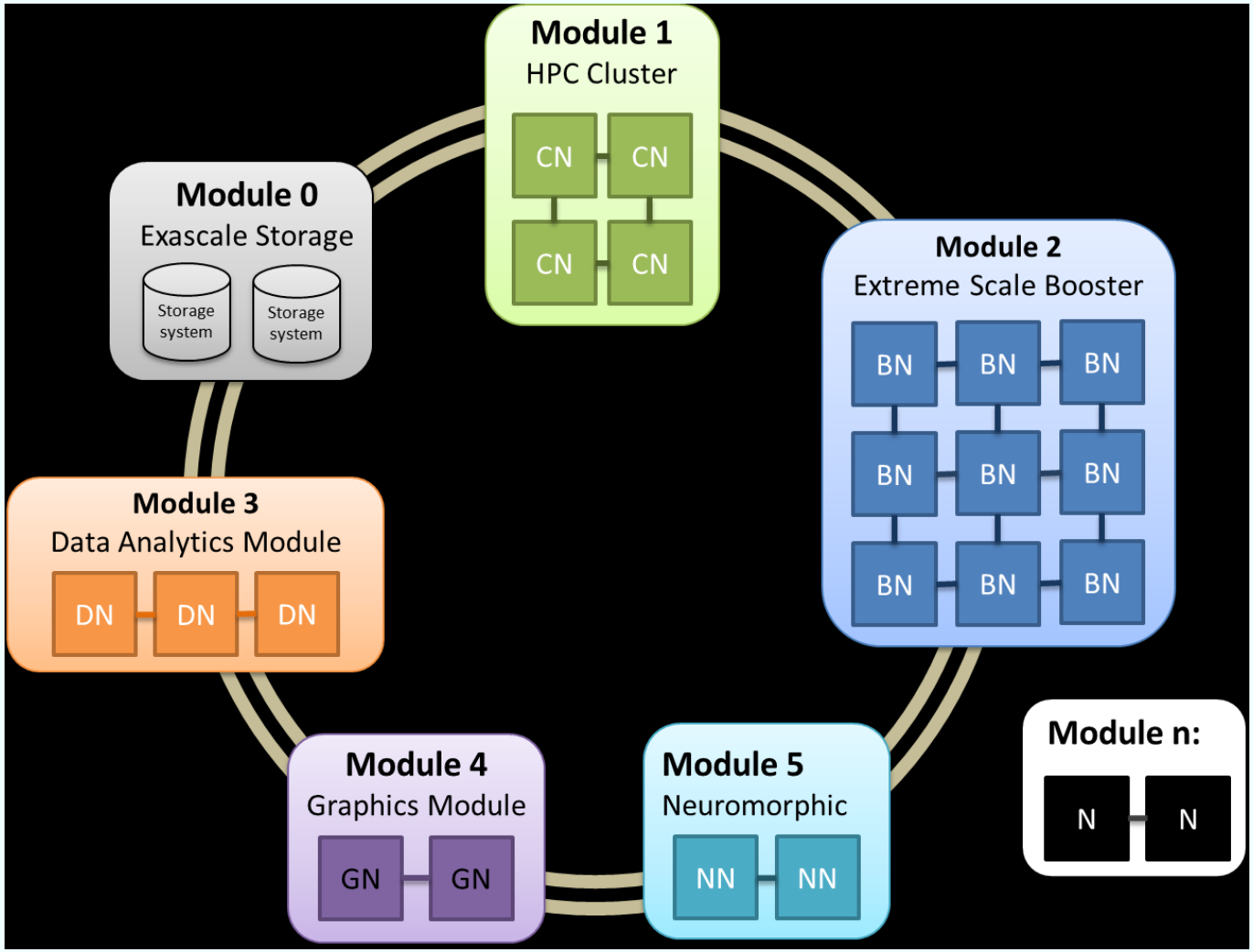


Modular Supercomputing



Generalization of the Cluster-Booster concept

Modular Supercomputing



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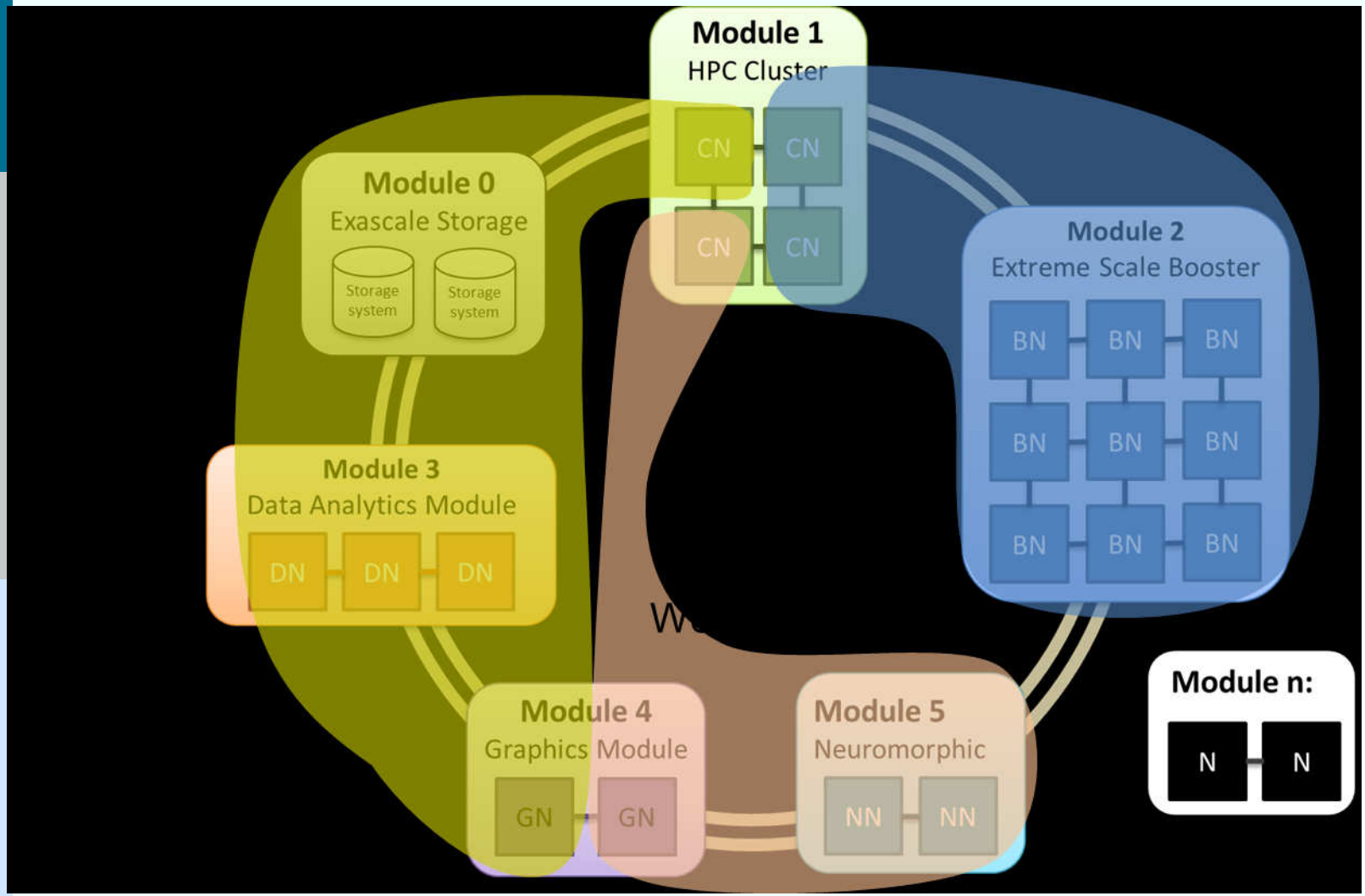
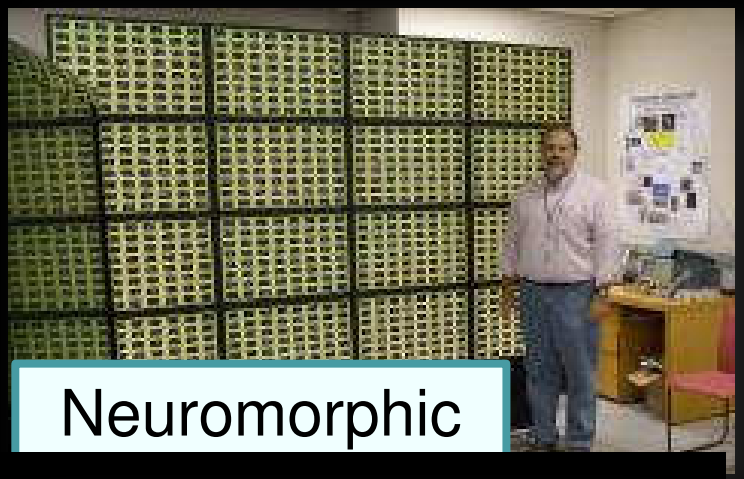


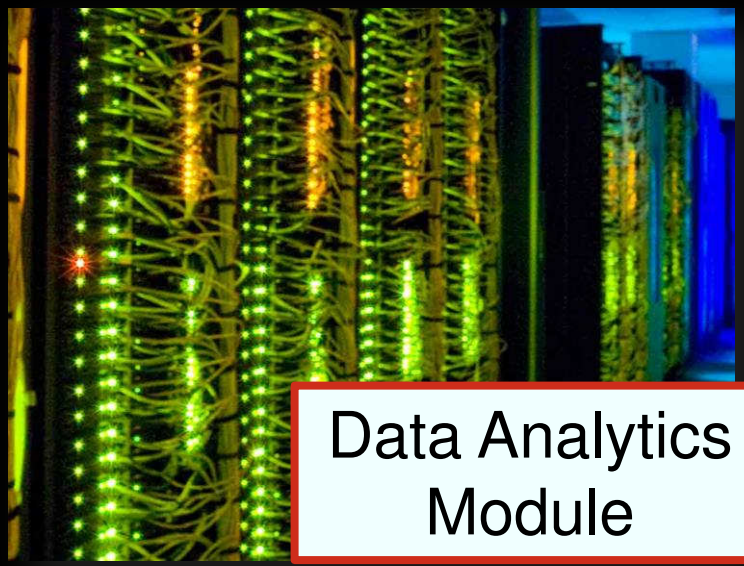
JSC future vision



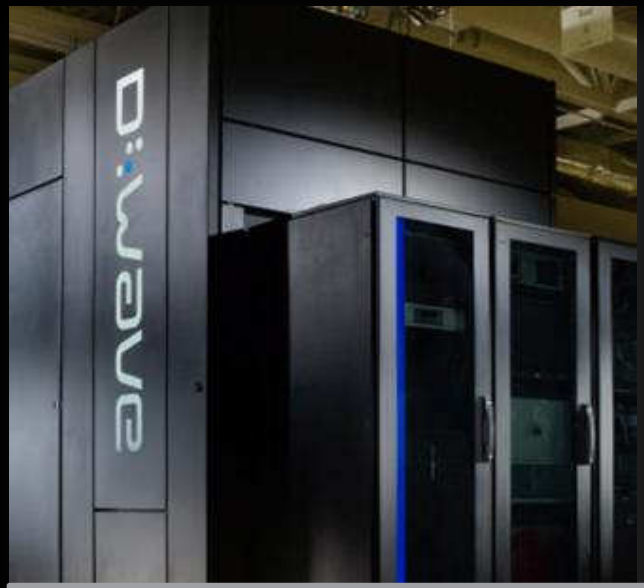
Neuromorphic

Cluster

Booster



Data Analytics Module



Quantum Computer