Taking on Exascale Challenges: Key Lessons & International Collaboration Opportunities

Birds-of-a-Feather Session at SC15

Jointly organised by European Exascale Projects and ETP4HPC

Objectives of this BoF

- Present the European landscape of HPC technology research
- Discuss collaboration opportunities

Agenda

Introduction **15 min**	**Overview on the European Exascale Landscape** **By Jean-François Lavignon, ETP4HPC Chairman and Atos**
Talks **30 min**	**Presentation of Focus Technology Research Areas**
	Area 1: Architecture & Compute By Filippo Mantovani, Technical Project Coordinator Mont-Blanc, Barcelona Supercomputing Centre
	Area 2: Interconnect, Memory & Storage and Data-intensive Real-Time By Prof. Jesus Carretero, Computer Architecture Professor, Computer Science and Engineering Dep. University Carlos III of Madrid
	Area 3: Programming Tools, Algorithms & Mathematics By Stefano Markidis, Assistant Professor, KTH Royal Institute of Technology

Agenda

Panel Discussion 45 min	**International Collaboration Opportunities arising and mechanisms needed** **Featuring distinguished international guests:** **Mitsuhisa Sato**, Co-project leader of Post-K, University of Tsukuba & RIKEN AICS **Franck Capello**, Argonne National Laboratory, Senior Computer Scientist, Director of the INRIA, UIUC, ANL, BSC, JSC and Riken Joint Laboratory on Extreme Scale Computing **Eric Van Hensbergen**, Senior Principal Research Engineer, ARM **Moderated by Sai Narasimhamurthy**, Staff Engineer, Research, Seagate

Handbook and Report

1. A **European HPC Technology Project Handbook** detailing all the projects is available at the event
(Please collect one from the organisers now).

2. A **Report** from this BOF.

Please leave your **business card** and both documents will be sent to you via email.

These documents will also be published on the website of ETP4HPC (the European Technology Platform for HPC), **www.etp4hpc.eu**, and the **individual project websites.**

You can also contact the Office of ETP4HPC at **office@etp4hpc.eu** with a request to receive a copy of either.

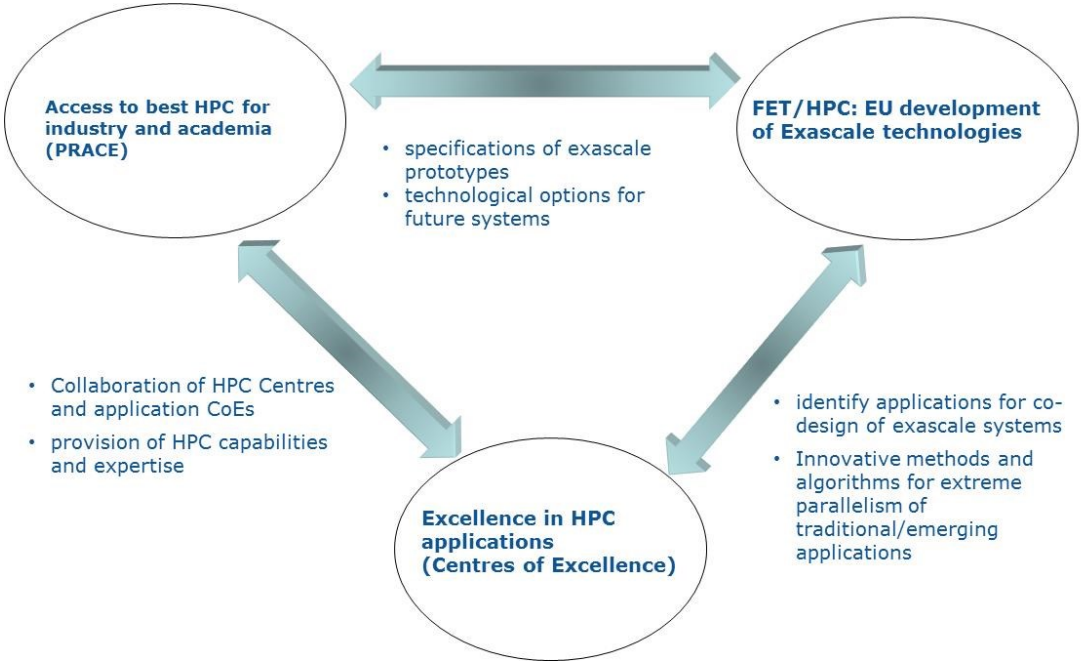
Presentation of Focus Technology Research Areas

A bit of history

- In 2004 start thinking about a HPC researcl infrastructure (HPCEUR, HET) ending with the creation of PRACE in 2010
- In 2010, expert group meetings between EC and European stake holders for a more global policy
- In 2011 creation of ETP4HPC
- Actions in FP7
  - PRACE Preparatory Phase and first Integrated Projects
  - Supports action : EESI and EESI2
  - calls for Exascale computing in WP2011 and WP2013

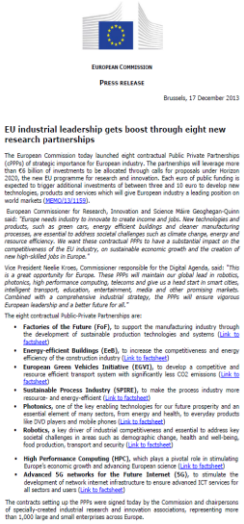
The EC communication

- High-Performance Computing: Europe's place in a Global Race issued in Feb 2012
- Policy with 3 pillars



The HPC Public Private Partnership

- Mutual commitment
  - European Commission
    - HPC as a priority of Horizon2020
    - Funding of 700 M€
  - ETP4HPC
    - Investment to match EC funding in R&D
    - Effort to maximize impact on European industry
- Partnership board
  - strategy setting
  - impact monitoring



EUROPEAN COMMISSION

PRESS RELEASE

Brussels, 17 December 2013

EU industrial leadership gets boost through eight new research partnerships

The European Commission today launched eight contractual Public Private Partnerships (cPPPs) of strategic importance for European industry. The partnerships will leverage more than €6 billion of investments to be allocated through calls for proposals under Horizon 2020, the new EU programme for research and innovation. Each euro of public funding is expected to trigger additional investments of between three and 10 euro to develop new technologies, products and services which will give European industry a leading position on world markets (MEMO/13/1159).

European Commissioner for Research, Innovation and Science Máire Geoghegan-Quinn said: *"Europe needs industry to innovate to create income and jobs. New technologies and products, such as green cars, energy efficient buildings and cleaner manufacturing processes, are essential to address societal challenges such as climate change, energy and resource efficiency. We want these contractual PPPs to have a substantial impact on the competitiveness of the EU industry, on sustainable economic growth and the creation of new high-skilled jobs in Europe."*

Vice President Neelie Kroes, Commissioner responsible for the Digital Agenda, said: *"This is a great opportunity for Europe. These PPPs will maintain our global lead in robotics, photonics, high performance computing, telecoms and give us a head start in smart cities, intelligent transport, education, entertainment, media and other promising markets. Combined with a comprehensive industrial strategy, the PPPs will ensure vigorous European leadership and a better future for all."*

The eight contractual Public-Private Partnerships are:

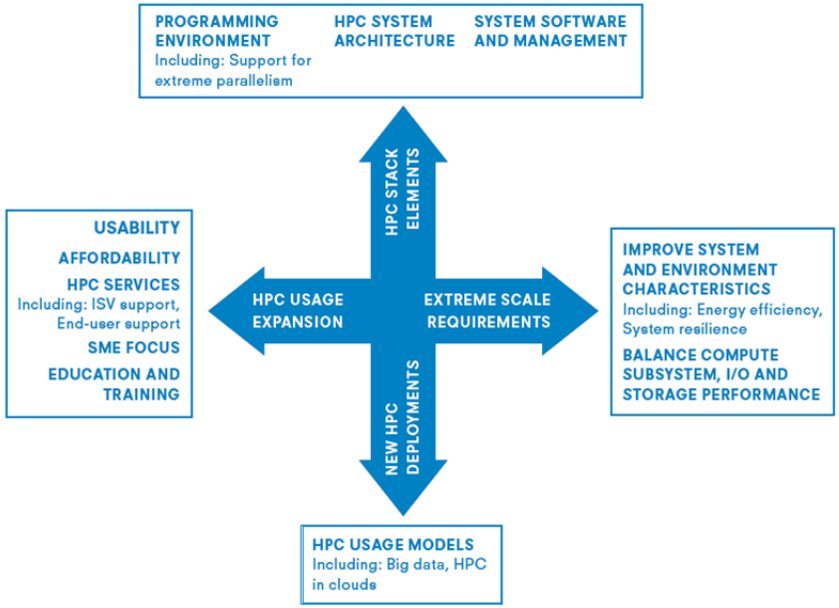
- **Factories of the Future (FoF)**, to support the manufacturing industry through the development of sustainable production technologies and systems (Link to factsheet)
- **Energy-efficient Buildings (EeB)**, to increase the competitiveness and energy efficiency of the construction industry (Link to factsheet)
- **European Green Vehicles Initiative (EGVI)**, to develop a competitive and resource efficient transport system with significantly less CO2 emissions (Link to factsheet)
- **Sustainable Process Industry (SPIRE)**, to make the process industry more resource- and energy-efficient (Link to factsheet)
- **Photonics**, one of the key enabling technologies for our future prosperity and an essential element of many sectors, from energy and health, to everyday products like DVD players and mobile phones (Link to factsheet)
- **Robotics**, a key driver of industrial competitiveness and essential to address key societal challenges in areas such as demographic change, health and well-being, food production, transport and security (Link to factsheet)
- **High Performance Computing (HPC)**, which plays a pivotal role in stimulating Europe's economic growth and advancing European science (Link to factsheet)
- **Advanced 5G networks for the Future Internet (5G)**, to stimulate the development of network internet infrastructure to ensure advanced ICT services for all sectors and users (Link to factsheet)

The contracts setting up the PPPs were signed today by the Commission and chairpersons of specially-created industrial research and innovation associations, representing more than 1,000 large and small enterprises across Europe.

ETP4HPC

- Open association for organizations with HPC research activities in Europe
  - industry led with more than 70 members
- The Strategic Research Agenda

www.etp4hpc.eu



Support actions

- EESI and EESI2 (EU FP7)
  - run by European experts from 2008 to 2015
  - important recommendations covering technology, applications, algorithms
  - http://www.eesi-project.eu/
- NESUS (COST action)
  - sustainability in ultrascale systems, started in April 2014
  - programming models, resilience, runtime systems, data management, and energy efficiency
  - http://www.nesus.eu/
- Eurolab4HPC (H2020)
  - To build the foundation for a European Research Center of Excellence in High-Performance Computing (HPC) Systems
  - http://eurolab4hpc.eu/
- EXDCI: ecosystem development (H2020)
  - managed by PRACE and ETP4HPC, started in Sept 2015
  - support of application and technology roadmap
  - training and education; support to SMEs; international cooperation; monitoring and impact assessment of the H2020 programme
  - http://www.exdci.eu/

FP7 Projects

- Started in 2011
- EU funding: 45 Mio € + in-kind contributions by the partners (budget: more than 90 Mio € in total)
- 8 projects: CRESTA, DEEP & DEEP-ER, EPiGRAM, EXA2CT, Mont-Blanc (I+II), Numexas

The Horizon 2020 HPC projects

- First call of Horizon2020
  - 19 research projects and 2 support actions
  - Most projects start in Sept-Oct 2015 for 3 years
  - Global effort : 94 M€ for R&D projects
- Global facts
  - 170 organizations involved in this effort
  - Project repartition
    - 9 HPC core technologies and architectures
    - 5 Programming methodologies, environments, languages and tools
    - 0 APIs and system software
    - 5 New mathematical and algorithmic approaches

15,7%	industry
0,2%	non EU
68,9%	research
15,3%	SME

More will come

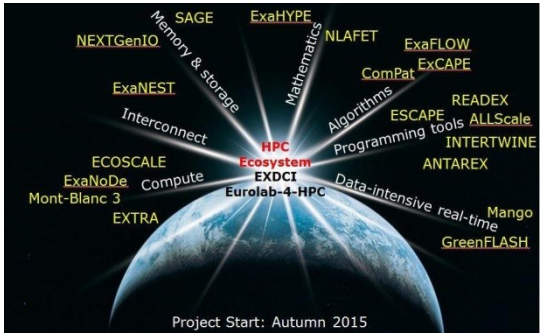
- 2 calls in Work Programme 2016-2017
  - FET HPC 1 2016 : Co-design of HPC systems and applications
    - budget : 41 M€ - deadline : 27 September 2016
  - FET HPC 2 2017 : Transition to Exascale Computing
    - 5 subtopics :
      - High productivity programming environments for exascale
      - Exascale system software and management
      - Exascale I/O and storage in the presence of multiple tiers of data storage
      - Supercomputing for Extreme Data and emerging HPC use modes
      - Mathematics and algorithms for extreme scale HPC systems and applications working with extreme data
    - budget : 40 M€ - deadline : 26 September 2017
- On-going discussion on additional Horizon2020 programme
- New HPC initiative by the European Commission

Technical areas (3)

Area 1:
Architecture and Compute

Filippo Mantovani

Barcelona Supercomputing Center



Topics covered by this area

Architecture of future HPC platforms will deal with:

- Energy efficiency
  - 1 ExaFLOP in 20 MW
- Heterogeneity
  - Name your device, please.
- Reconfigurability
  - If you have named FPGA in the previous point…
    You most probably want to reconfigure it, right?
- Resource balance
  - Mostly balance compute throughput, memory and network bandwidth
- Co-design driven
  - And now you want to balance also for CFD, QCD, MD, …
- Integration and reliability
  - 50K+ compute nodes… Heterogeneous…
  - How to detect failures? How to survive with them?

Energy Efficiency

- Low power compute components
- Advanced nanotechnologies
- Extreme resource efficiency
- Power monitoring
- Power aware scheduling and programming
- Hot-water cooling

Mont-Blanc

DEEP

MANGO

ExaNoDe

- and of course heterogeneity (coming soon)

Heterogeneity

- Classical heterogeneity
  - CPU + accelerator
- Fine grained heterogeneity
  - Heterogeneous compute cores on chip
  - Mobile on chip GPUs
- System-level modularity
  - Cluster-Booster approach
  - Custom interconnection
- Hierarchical system partitioning
  - "Workers" grouped by address spaces

Mont-Blanc

DEEP

MANGO

ECOSCALE

Reconfigurability

- Support for specific HPC applications
  - Mapping of functions
  - Mapping of algorithms
- Hardware runtime support
- Leveraging low reconfig. overhead
- Aiming reducing data traffic

EXTRA

ECOSCALE

Balanced / Co-design driven

- Heterogeneous hardware platform with matching software stack and optimized grand-challenge HPC applications
- Analysis of requirements HPC applications, mini-apps and kernels via performance analysis tools
- Programming models enabling hw resources with minimal impact on app

DEEP

Mont-Blanc

EXTRA

ExaNoDe

Integration and Reliability

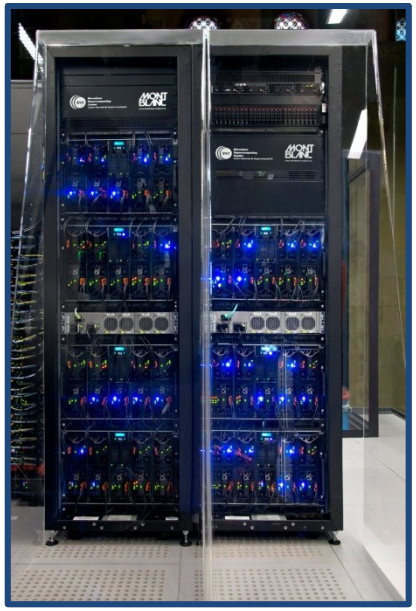
- High density
  - 2.5D technology / Interposer
  - System on Package
- Advanced cooling
  - Air/Liquid
  - Single/double loop
  - Heat reuse
- Fault tolerance
  - Error detection mechanisms
  - Reliability of large systems
  - Quality of Service

MANGO

ExaNoDe

Mont-Blanc

DEEP



Collaboration Opportunities

- Liaison with international technology companies (not only EU)
- Workshops and trainings
- Lessons learned in prototyping
- Lessons learned in co-design and software modernization
- Accessing prototype platforms
  - DEEP → 500 TFlop/s peak performance prototype installed at JSC (pmt@deep-project.eu)
  - Mont-Blanc → 1000+ nodes ARM-based cluster installed at BSC (http://montblanc-project.eu/industrial-user-group)

Area 2:
Interconnect, Memory & Storage
Data-Intensive Real Time

Jesus Carretero
University Carlos III of Madrid

Topics covered by this area

- System architecture for Exascale and data-centric HPC
  - Very Tightly Coupled Data & Computation
  - Codesign using accelerators and FPGAs
- Develop a new server architecture using next generation processors and memory advances
  - Integration of NVRAM technologies in the I/O stack
  - Extreme compute power density
  - Develop the systemware to support their use at the Exascale
- New applications and use cases emerging for HPC
  - Real-time, data-intensive, and energy efficiency

Interconnect and Memory

- Develop a new server architecture using next generation interconnection, and memory advances
  - Integration of NVRAM technologies in the I/O stack
  - Fast, distributed in-node non-volatile and network attached memory Storage
  - Extreme compute power density
  - Low-latency unified Interconnect for compute & storage traffic
  - Codesign using accelerators and FPGAs
  - Liquid cooling technologies

NextGENIO

DEEP-ER

SAGE

DEEP-ER

ExaNEST

Storage

- Develop the systemware to support new architectures use at the Exascale
  - Data Centric Computing System based on object-storage
  - Leveraging the I/O stack to enhance data-intensive computing
  - Computation off-loading to I/O system
- Model different I/O workloads and use this understanding in a co-design process
  - Very Tightly Coupled Data & Computation
  - API for massive data ingest and extreme I/O
  - Extreme data management and analysis

NextGENIO

NESUS

SAGE

Data-Intensive RTS

- Exploring New Heterogeneous Architectures For HPC Systems
  - Deeply heterogeneous manycore architectures
  - Real-time support providing a unified access to the systems via a smart interconnect
  - Adaptive programming models and compiler support to the new architectures

MANGO

DEEP-ER

NESUS

- New applications and use cases emerging for HPC arena
  - Real-time, data-intensive, and energy efficiency
  - Applications used to identify system requirements
  - Real scientific and data center applications (e.g. MAORY RTC system).

Green FLASH

Collaboration Opportunities

- Deeply heterogeneous system architecture for Exascale and data-centric HPC
  - Integration of NVRAM technologies in the I/O stack
  - Develop the systemware to support their use at the Exascale
- Leveraging the I/O stack for Exascale systems
- Data staging coordination and control for Exascale applications
  - API for massive data ingest and extreme I/O
- New applications and use cases needing Real-time, data-intensive, and energy efficiency

Area 3:
Programming Models, Algorithms and Mathematics

Stefano Markidis

KTH Royal Institute of Technology, Sweden

EU HPC PROJECTS LANDSCAPE

- 8 **Programming Models/tools** Projects:
  - AllScale, Antarex, CRESTA, Exa2CT, EPiGRAM,ESCAPE, Intertwine, READEX
- 6 **Algorithms and Mathematics** Projects:
  - ComPAT, ExCAPE, ExaFLOW, ExaHYPE, NLAFET, NUMEXAS

PROGRAMMING MODELS

- Innovative Programming Models for Exascale
  - **AllScale**: An exascale programming, multi-objective optimization and resilience management system supporting nested recursive parallelism.
- Enhanced MPI and PGAS: the incremental approach
  - **CRESTA**: Enhancing programming models and system software by co-design. Large-scale real-world applications to guide the development of the software stack for exascale.
  - **EPiGRAM**: MPI and GPI for exascale. Combing best features of Message-Passing and PGAS programming model.
  - **Exa2CT**: cutting edge of the development of solvers, related algorithmic techniques, and HPC software architects for GASPI communication.

INTEROPERABILITY & AUTOTUNING

- Interoperability of programming models: the ”+” issue
  - **Intertwine**: enhanced programming and runtime systems for effective interoperability.
- Autotuning for energy efficiency and green HPC:
  - **READEX**: developing a tools-aided methodology for dynamic auto-tuning of HPC applications to exploit the dynamically changing resource requirements for improved energy-efficiency.
  - **ANTAREX**: providing a breakthrough approach to express by a DSL the application self-adaptivity and to runtime manage and autotune applications for green and heterogeneous HPC

ALGORITHMS

- Computational Fluid Dynamics for Exascale
  - **ExaFLOW**: addressing algorithmic challenges to enable the use of accurate simulation models on exascale with focus on error control, AMR in complex geometries, heterogenous modeling, energy efficiency, and in-site I/O.
  - **NUMEXAS**: develop, implement and demonstrate the next generation of numerical simulation methods with focus on industrial applications and on pre- and post-processing
  - **ESCAPE**: developing next generation IFS numerical blocks for weather forecast.
- Multiscale Applications
  - **ComPAT**: development of the High Performance Multiscale Computing paradigm.

ALGORITHMS AND MATHEMATICS

- Machine Learning:
  - **ExCAPE**: better machine learning algorithms for predicting biological activity of drugs and their deployment on HPC systems.
- Solvers:
  - **NLAFET**: linear solvers for exascale with novel algorithms, communication avoiding, advanced scheduling strategies and autotuning
  - **ExaHyPE**: High-order Discontinous Galerkin hyperbolic PDE engine for geo- and astrophysics.

Opportunities for International Collaboration

- Programming and Autotuning Systems
  - Stellar group on HPX
  - MPI Forum and main MPI implementors (MPICH, OPENMPI)
  - OpenMP ARB
  - PNNL (Auto-tuning)
- Algorithms
  - University of Tennessee for magma and plasma libraries

Panel discussion

Mitsuhisa Sato, Co-project leader of Post-K, University of Tsukuba & RIKEN AICS

Franck Capello, Argonne National Laboratory, Senior Computer Scientist, Director of the INRIA, UIUC, ANL, BSC, JSC and Riken Joint Laboratory on Extreme Scale Computing

Eric Van Hensbergen, Senior Principal Research Engineer, ARM

Moderated by **Sai Narasimhamurthy**, Staff Engineer, Research, Seagate