EESI System Software

WG 4.2

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WG4.2 Scope and Challenges

- Software Eco-system: between Applications and Hardware
  - Programming models, Compilers, Runtime, Tools, OS, I/O, System management
  - WG4.2 does not cover Framework, Numerical libraries, Workflow, Scientific data management, Visualization → other WGs

- Many technical challenges on all layers of the software stack
  - Scalability
  - Heterogeneity
  - Power
  - Errors, Faults, Failures
  - Reducing as much as possible Overhead, Jitter, Noise, etc.

- A trend toward community software
WG4.2 TOPICS

- System Software
  - Operating Systems, System Management
  - Job and Resource Manager
  - Runtime Systems
  - I/O systems

- Development Environments
  - Programming Models, Compilers
  - Debuggers
  - Performance tools
  - Correctness tools

- Crosscutting Dimensions
  - Resilience
  - Power management
WG4.2 Chairs, Leaders and Experts

Chairs:

- **Franck Cappello** (INRIA&UIUC, FR) - Resilience and FT
- **Benrd Mohr** (JSC, DE) - Performance tools
- **Jesus Labarta** (BSC, ES) - Programming models
- **Marc Bull** (EPCC, UK) - OpenMP / PGAS
- **François Bodin** (CAPS, FR) - Programming/Compiler for GPUs
- **Raymond Namyst** (LABRI Bordeaux, FR) - MPI&OpenMP Runtime, GPUs
- **Jean-François Méhaut** (INRIA Grenoble, FR) - Performance Modeling/Apps.
- **Matthias Müller** (TU Dresden, DE) - Validation/correctness Checking
- **Felix Wolf** (GRS, DE) - Performance Tools
- **David Lecomber** (ALINEA, UK) - Parallel debugger
- **Simon McIntosh-Smith** (U. Bristol, UK) - Computer Architecture & FT
- **Vladimir Voevodin** (MSU, RU) - Performance tools
- **Thomas Ludwig** (DKRZ, DE) - Power management
- **Olivier Richard** (INRIA, FR) - Job and Resource Manager
- **Jacques C. Lafoucriere** (CEA, FR) - I/O, File system
- **Toni Cortés** (BSC, ES) - I/O, Storage
- **Pascale Rossé** (BULL, FR) - OS, System management
- **Karl. Solchenbach** (Intel, BE) - All

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Starting point: IESP roadmap, Exascale studies, Soft. used in HPC centers

Description of the scientific and technical perimeter

Social benefits, societal, environmental and economical impact

Scientific and technical hurdles

Address cross cutting issues: Resilience, Power Mngt, Programmability, Perf optimisation and Reproducibility of the results

European strengths and weaknesses in the worldwide competition

Sources of competitiveness for Europe

Needs of education and training

Potential collaborations outside Europe

Existing funded projects and funding agencies

Timeline, needs of HR, provisional costs,

Needs for experimental platform: size, reconfigurable?, dedicated?

What software in an Exascale stack and with what level of responsibility

Next slides → only a small subset of the current results

sort of executive summaries

The roadmap with timeline, HR and cost

is not yet completed

Recommendations for EU may evolve
WG4.2 Programming model

Chair: Jesus Labarta, BSC

- **Programming models**
  - Clean separation and interaction between application developer and system (hardware and software)
  - Improve productivity, Significantly reduce maintenance costs
  - **Incremental parallelization will reduce development costs**

- **Main issues at Exascale:**
  - Concurrency, Asynchrony, Malleability, Address spaces and locality, Hierarchy, I/O, Modularity, interoperability, Productivity/portability, Incremental path,
  - **But also more decoupling between programmers and machines,**
  - Cross cutting: Power Management, Fault tolerance, Performance

- **Recommendations for EU**
  - Existing developments with demonstrated potential and willing to play a role in the future exascale software environment: HMPP, StarSs (OmpSs)
  - Important contributions to standards: MPI/OpenMP
  - **Programming models that provide expressiveness, incremental portability and performance** will boost performance, visibility and impact of applications having early access to them
WG4.2 Runtime

Chair: Raymond Namyst, U. Bordeaux, INRIA

- Bridge the gap between underlying architecture and application requirements:
  - Scheduling, load balancing, Memory management, Communications, Sync.
  - Where accurate information is available about the actual power consumption of various hardware parts

- Main issues at Exascale:
  - Mastering heterogeneity: Unified/transparent accelerator models, Support for adaptive granularity, Fine grain parallelism, Scheduling for latency/bandwidth
  - Dealing with millions of cores/nodes: Scheduling, communication
  - **Supporting multiple programming models: MPI + threading model + accelerator**
  - Robustness: reconfigure itself when resources suddenly disappear.

- Recommendations for EU
  - Many European countries have a long-standing activity in runtime design
  - **Unified runtime system**, providing a unified API to deal with threads and lightweight tasks (together with their integration with MPI/PGAS communication systems)
WG4.2 Validation / Correctness

Chair: Matthias Müller, TU Dresden

- Tools and methods for validation and correctness checking:
  - Validate a program in accordance to a model/specification (ex: MUST for MPI)
  - Can detect many errors, Especially: portability and non-determinism related bugs
  - Exascale will drastically increase manifestation rates!
  - **Correctness & validation helps reducing the time to solution** (better productivity)

- Main issues at Exascale:
  - Scalability, Fault tolerance, Adaptation to new paradigms, Integration into new paradigms, **Integration into debugging workflow**

- Recommendations for EU
  - MUST and Marmot collaborations: Supercomputing vendors, especially those involved in DARPA’s HPCS program (Cray, IBM), Software companies like Rouge Wave (Totalview), National labs (LLNL, LANL, ORNL, ANL), Universities (Utah, Houston)
  - **Foster interaction of methods/groups** within and beyond Europe
  - **Horizon. interaction** of approaches/tools: compiler + runtime + classic debugger
  - **Vertical integration** of validation and correctness at all layers of software stack

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Any method to assist with the removal of software failures

- Interactive tools, user tactics, Alinea DDT, Totalview Rogue Wave's, etc.
- Primary focus on interactive tools that give user knowledge and control of program state and activity. **Limited to in single execution path.** Can be improved by static source code analysis.

- **Some overlap with automatic Validation/Correctness tools:** Automated problem detection tools: MUST (TU-Dresden), or Umpire (LLNL).

Main issues at Exascale:

- Scale: responsiveness of debugger to user command and overhead), Architectural and Programming Model Unknowns (debugging support)
- Crosscutting issues: Programmability, Resilience, I/O+Network, Reproducibility

Recommendations for EU

- **Continued financing/Sustainability** for Debugging tool developed in EU: DDT from Allinea, Globally only debugging product with Petascale ability. Collaborations with leading European research centres and initiatives and US

- **Integration into debugging workflow with validation and correctness**
WG4.2 Performance Tools

Chair: Felix Wolf, GRS

- Diagnostic programs for performance optimization of applications
  - Ideally used in combination with performance modeling
  - Huge savings in terms of time and energy, Enables new scientific discovery: by calculating larger problem sizes.

- Main issues at Exascale:
  - Million-fold concurrency, Deeper memory hierarchies, More dynamic execution, Limited reproducibility (asynchrony, faults and power managmt), Limited bandwidth to extract performance data, Multiple programming models
  - Cross cutting: resilience (tool should be FT), power, programmability

- Recommendations for EU
  - Many of the performance tools used in production today are made in Europe, Europe has leading position in this area
  - OPT (Allinea), ThreadSpotter (RogueWave), Vampir (GWT-TUD), Intel trace collector and analyzer originally from Europe
  - Popular Academic tools, Paraver/Dimemas (BSC) Scalasca (Jülich/Aachen)
  - Initiative for more integration with Score-P measurement system
  - European tool builders can make significant contribution to exascale effort, but sustainability of funding must be ensured.
Permanent storage: keep track of computing results for post processing and to start a new computation
- Online (Disk, SSD, etc.) and Offline (tapes, disk based virtual tapes)

Main issues at Exascale:
- Extreme concurrency level (data, metadata locking), 1M disks, End2end integrity, too many transactions (contention), check usefulness of archived data
- Storage plays a major role in Fault tolerance, NV memory \( \rightarrow \) new failure scenarios
- Some HPC centers prefer Open Source FS (or will be locked to a vendor)

Recommendations for EU
- 2 major EU companies offer storage solutions for Petascale computers
  - Xyratex: hardware and proprietary file system (Colibri)
  - Bull: hardware neutral integration of open source file systems (Lustre)
- Significant set of small groups with good impact in the storage community around Europe. SCALUS as a 1st coordination initiative
- Storage is a critical part of an Exascale solution
- EU must be a major contributor/partner to Open Source file system
OS and System management:
- OS is a key element between hardware and runtime/application
- Developing and debugging large scale HPC systems requires experts at all layers of the software stack, including OS.

Main issues at Exascale:
- Many cores, Low overhead, low noise, etc.
- Scalability: Huge amount of statistics, log data, events VS Centralized tools

Recommendations for EU
- **Hardware initiative in Europe** around ARM, AMD Fusion, Nvidia Denver, etc. should be complemented by an **OS initiative**.
- Sustain and develop further OS R&D for HPC in Europe
- **Evolution rather than revolution**. Revolution would require too much effort for runtime/apps porting
- **Standardization of event messages across sources**, **Scalable tools**
- Automatic or assisted diagnostic, root cause analysis, etc.
WG4.2 Power Management

Understand power consumption as a function of system usage:
- Develop SW to control the HW mechanisms: SW in the OS, run-time system, etc.
- Deploy next generation HW with energy saving mechanisms
- A cost efficient and cost aware high performance computing is crucial for the competitiveness in science and engineering

Main issues at Exascale:
- Resilience (switching off/on components), Programmability (manual instrumentation), Performance optimization, Reproducibility (non-deterministic methods influence performance predictability and system noise)
- Power management API standardization

Recommendations for EU:
- Trace tools: Vampir – Dresden, Scalasca – Jülich
- Control daemons: Grid monitor – ParTec Munich, Germany, Power manager – Bull Cluster management France → Power capping, Power accounting)
- Leverage European leadership in performance analysis tools, energy efficient hardware design and Know-how from embedded system
Fault tolerance is a multi-facets and crosscutting issue:
- No guarantee that all faults will be masked by hardware or tolerated by the applications efficiently (hardware correction will generate noise, global restart)

Main issues at Exascale:
- #errors, #failures, Scale, Power consumption, Performance impact

Recommendations for EU:
- 1) Establish a fault-error-failure model,
- 2) Develop automatic root cause discovery and failure prediction,
- 3) **Extend the applicability of checkpoint-restart** (API, Partial RST, NV mem.),
- 4) Need a inter software layer communication system for consistent fault-error-failure management (detection, notification, decision, etc.),
- 5) **New fault tolerance paradigms** using non-volatile memory technologies
- 6) **International Coordination**:
  - Common FT API (interface and semantic) and inter layer communication system for portability (to limit applications rewriting)
  - G8-ECS (France, Germany, USA, Japan, Canada), ARN-JST FP3C (France and Japan), INRIA-Illinois Joint-laboratory (France and USA).
<table>
<thead>
<tr>
<th>Dedicated/reconfigurable</th>
<th>Production</th>
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<tbody>
<tr>
<td><strong>-Prog. Models and Runtime</strong> (interaction of runtime with kernel scheduler)</td>
<td><strong>-Resilience</strong> (FT protocols, ABFT, NFTA, execution state storage)</td>
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<tr>
<td><strong>-Performance tools</strong> (interaction with resilience / power components)</td>
<td><strong>-Parallel debuggers</strong>? (scalability test)</td>
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<tr>
<td><strong>-OS</strong> (scheduling, memory management)</td>
<td><strong>-Performance tools</strong> (scalability of data collection and analysis)</td>
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<tr>
<td><strong>-Measure noise generation (most of the software)?</strong></td>
<td><strong>-Runtime</strong> (scalability test)</td>
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<td><strong>-I/O-File system</strong> (may be done at lower scale) (need root access for reconfiguration)</td>
<td><strong>-Prog. models</strong> (system level scalability)</td>
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<td><strong>-Job and resource manager</strong> (need root access for reconfiguration)</td>
<td><strong>-Performance modeling at scale</strong></td>
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100 Petaflops needed

< 100 Petaflops enough

WG4.2 Testbed needs in 2015 (draft)

- Performance tools (system level): measure and minimize overheads induced at the full scale by low-level performance monitoring infrastructure tightly integrated with OS

- Prog. Models and Runtime (interaction of runtime with kernel scheduler)?
WG4.2 Contributions to an Exa Stack (draft)

- **Programming models**
  - **StarSs**: Node level programming model offering programmers a natural interface to an underlying data-flow execution model and aiming allowing the “same” source code to run on “any” target architecture. In particular, **OmpSs** implementation that integrates OpenMP and the StarSs concept (SMP, GPUs,...) and nicely integrates with MPI. [http://www.bsc.es/smpsuperscalar](http://www.bsc.es/smpsuperscalar) and [http://www.bsc.es/OmpSs](http://www.bsc.es/OmpSs), BSC
  - **HMPP**: Based on a set of directives, programming model designed to handle hardware accelerators, [www.caps-entreprise.com/hmpp.html](http://www.caps-entreprise.com/hmpp.html), CAPS
  - **OpenHMPP** will be announced at SC11. Members of the consortium will be major HPC users, compiler companies such as Pathscale, INRIA
  - **T-Platforms Exascale API environments**: a new scalable version of MPI and a PGAS library with a new set of compilers and tools, Russia
  - European PGAS development called GPI (from Fraunhofer), [www.gpi-site.org](http://www.gpi-site.org)

- **Runtime**
  - **StarPU runtime system**, StarPU is a task scheduler exploiting multi-GPU multi-core platform efficiently, using adaptive performance models to carefully dispatch tasks over the available heterogeneous processing units. [http://runtime.bordeaux.inria.fr/StarPU/](http://runtime.bordeaux.inria.fr/StarPU/)

- **Parallel Debugger**
  - **DDT**: scalable parallel debugger for debugging MPI and multi-threaded codes, Alinea

- **Validation/correctness**
  - **MUST**: scalable Runtime Error Detection in MPI Progrannms, TU Dresden

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Performance tools

- **Scalasca**: Performance-analysis tool German Research School for Simulation Sciences and Juelich Supercomputing Centre
- **Score-P**: Generic measurement infrastructure for several performance tools including Periscope, Scalasca, TAU, Vampir, Virtual Institute - High Productivity Supercomputing [http://www.vi-hps.org](http://www.vi-hps.org)
- **BSC Integrated tools environment**: instrumentation (Extrae), visualization (Paraver), Simulation (Dimemas) and other analysis modules such as clustering, combined sampling and instrumentation, [Par](http://www.bsc.es), BSC
- Persicope (Technical University of Munich) [http://www.lrr.in.tum.de/~petkovve/psc/](http://www.lrr.in.tum.de/~petkovve/psc/)
- Vampir (Technical University of Dresden) [http://www.vampir.eu/](http://www.vampir.eu/)

OS and system management

- **T-Platforms Clusterx** Exascale OS and system management: a highly scalable exascale-oriented OS and system software stack (highly scalable real-time monitoring and management system), Russia
- **Clustershell**: start commands on the cluster nodes (in parallel, with a high scalability based on tree) and to get a usable output (summary, differences, ...) for human [sourceforge.net/projects/clustershell/](http://sourceforge.net/projects/clustershell/), CEA
- **Ganesha**: "protect" the computing centre NFS servers from the load of the NFS clients [sourceforge.net/projects/nfs-ganesha/](http://sourceforge.net/projects/nfs-ganesha/), CEA
- **Robinhood**: a FS monitor/space manager optimized for huge FS (PB today, EB in the future) [sourceforge.net/projects/robinhood](http://sourceforge.net/projects/robinhood), CEA
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Address cross cutting issues : Resilience, Power Mngt, Programmability, Perf optimization and Reproducibility of the results,
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Needs for experimental platform: size, reconfigurable?, dedicated?
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