scalasca

Scalable performance analysis of large-scale parallel applications

Brian Wylie & Markus Geimer
Jülich Supercomputing Centre
b.wylie@fz-juelich.de

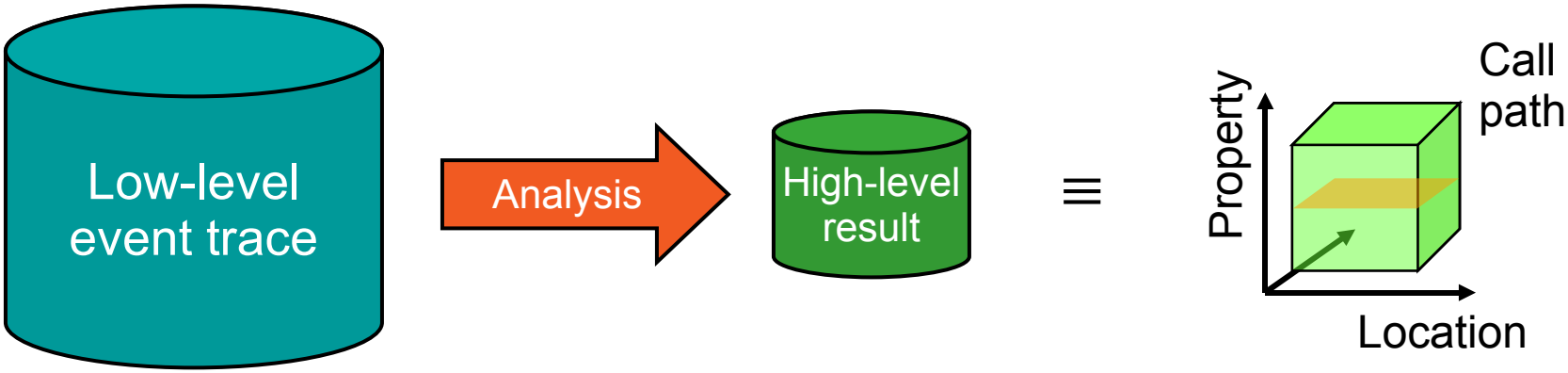
September 2009

Performance analysis, tools & techniques

- Profile analysis
  - Summary of aggregated metrics
    - per function/call-path and/or per process/thread
  - Most tools (can) generate and/or present such profiles
    - but they do so in *very* different ways, often from event traces!
  - e.g., mpiP, ompP, Tau, ***Scalasca***, Sun Studio, Vampir, ...
- Time-line analysis
  - Visual representation of the space/time sequence of events
  - Requires an execution trace
  - e.g., Vampir, Paraver, Sun Studio Performance Analyzer, ...
- Pattern analysis
  - Search for characteristic event sequences in event traces
  - Can be done manually, e.g., via visual time-line analysis
  - Can be done automatically, e.g., KOJAK, ***Scalasca***

Automatic trace analysis

- Idea
  - Automatic search for patterns of inefficient behaviour
  - Classification of behaviour & quantification of significance



  - Guaranteed to cover the entire event trace
  - Quicker than manual/visual trace analysis
  - Parallel replay analysis exploits memory & processors to deliver scalability

The Scalasca project

- Overview
  - Helmholtz Initiative & Networking Fund project started in 2006
  - Headed by Prof. Felix Wolf (RWTH Aachen University & FZJ)
  - Follow-up to pioneering KOJAK project (started 1998)
    - Automatic pattern-based trace analysis

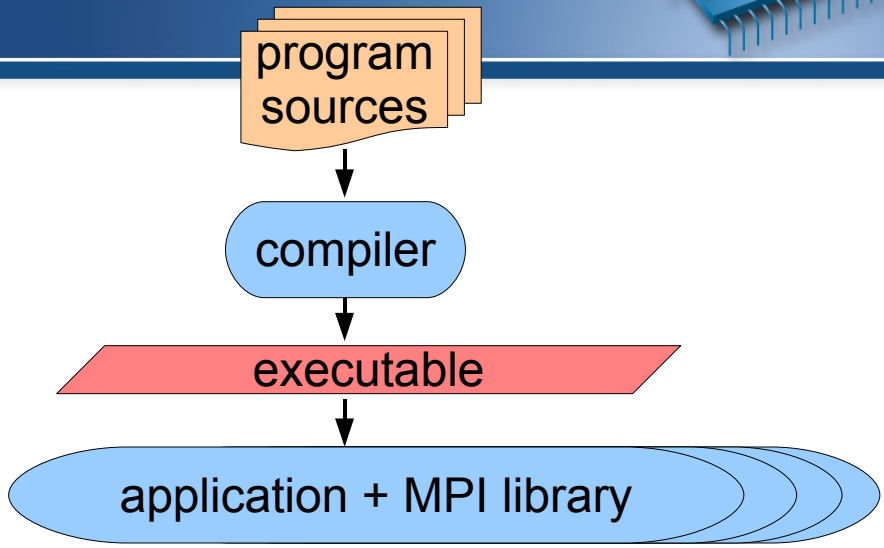
- Objective
  - Development of a **scalable** performance analysis toolset
  - Specifically targeting **large-scale** parallel applications
    - such as those running on BlueGene/P or Cray XT with 10,000s to 100,000s of processes
  - Latest release in July 2009: Scalasca v1.2
    - Available on VI-HPS Tuning Workshop Live-DVD
    - Scalasca 1.3β currently in testing

Scalasca features

- Open source, New BSD license
- Portable
  - BG/P, BG/L, IBM SP & blade clusters, Cray XT, SGI Altix, NEC SX, SiCortex, Solaris & Linux clusters, ...
- Supports parallel programming paradigms & languages
  - MPI, OpenMP & hybrid OpenMP/MPI
  - Fortran, C, C++
- Integrated measurement & analysis toolset
  - Runtime summarization (aka profiling)
  - Automatic event trace analysis

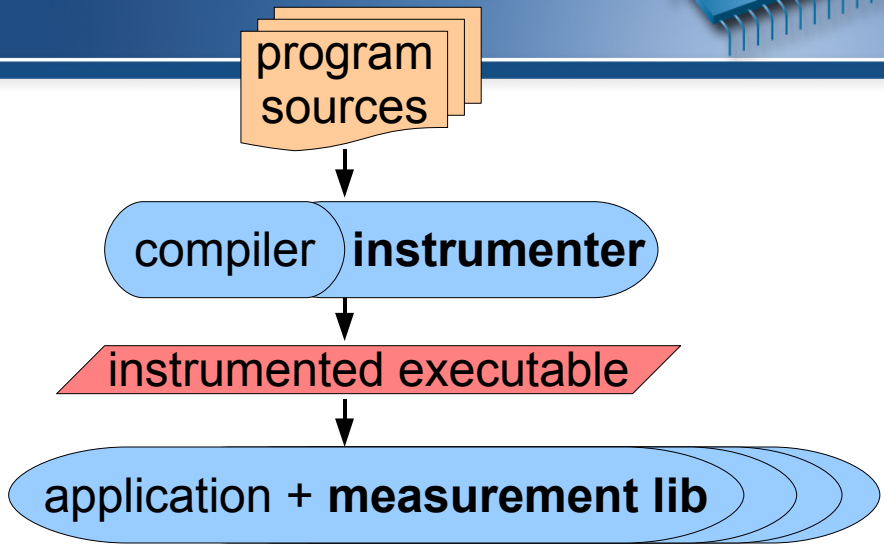
Generic MPI application build & run

- Application code compiled & linked into executable using MPICC/CXX/FC
- Launched with MPIEXEC
- Application processes interact via MPI library



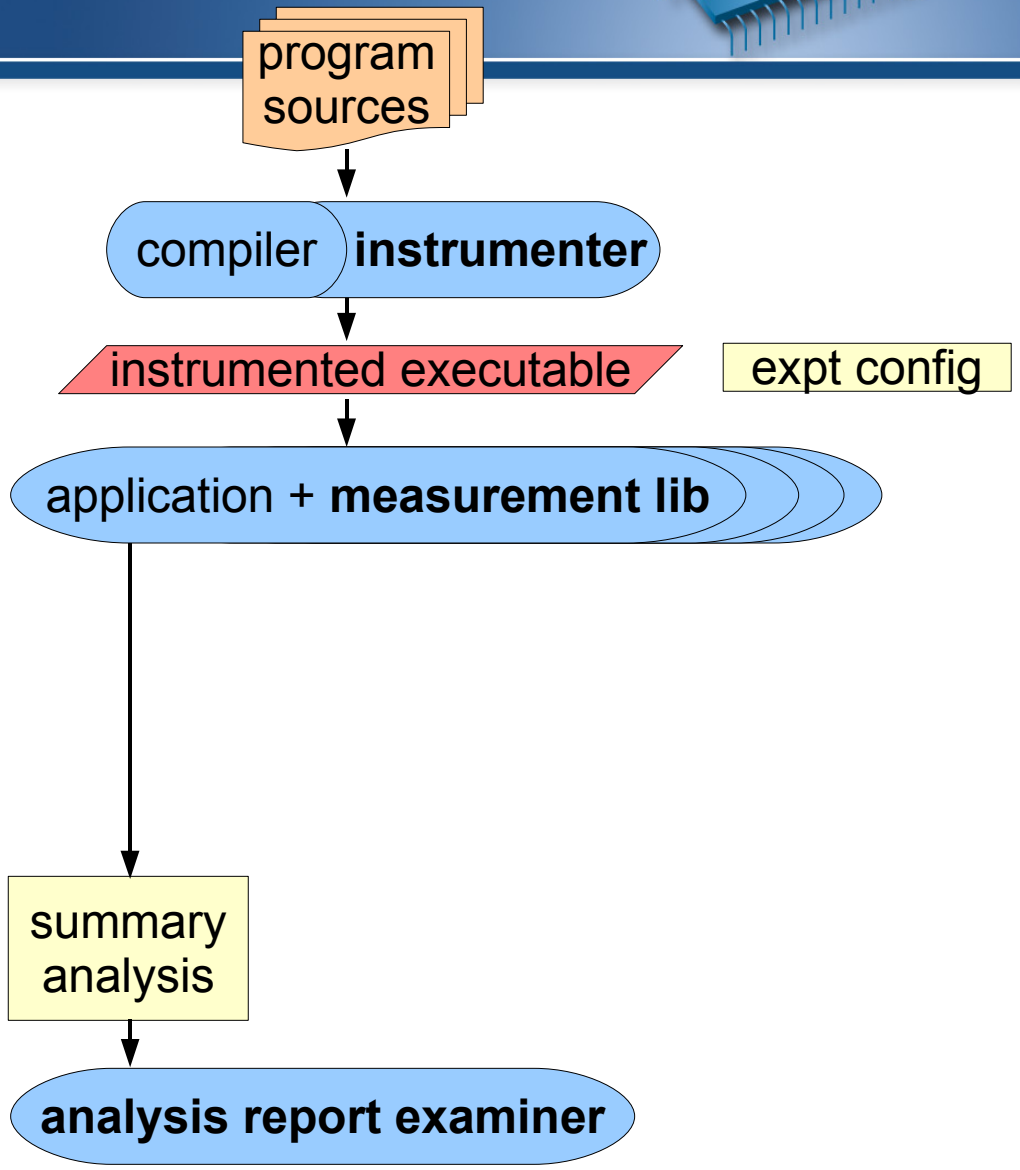
Application instrumentation

- Automatic/manual code instrumenter
- Program sources processed to add instrumentation and measurement library into application executable
- Exploits MPI standard profiling interface (PMPI) to acquire MPI events



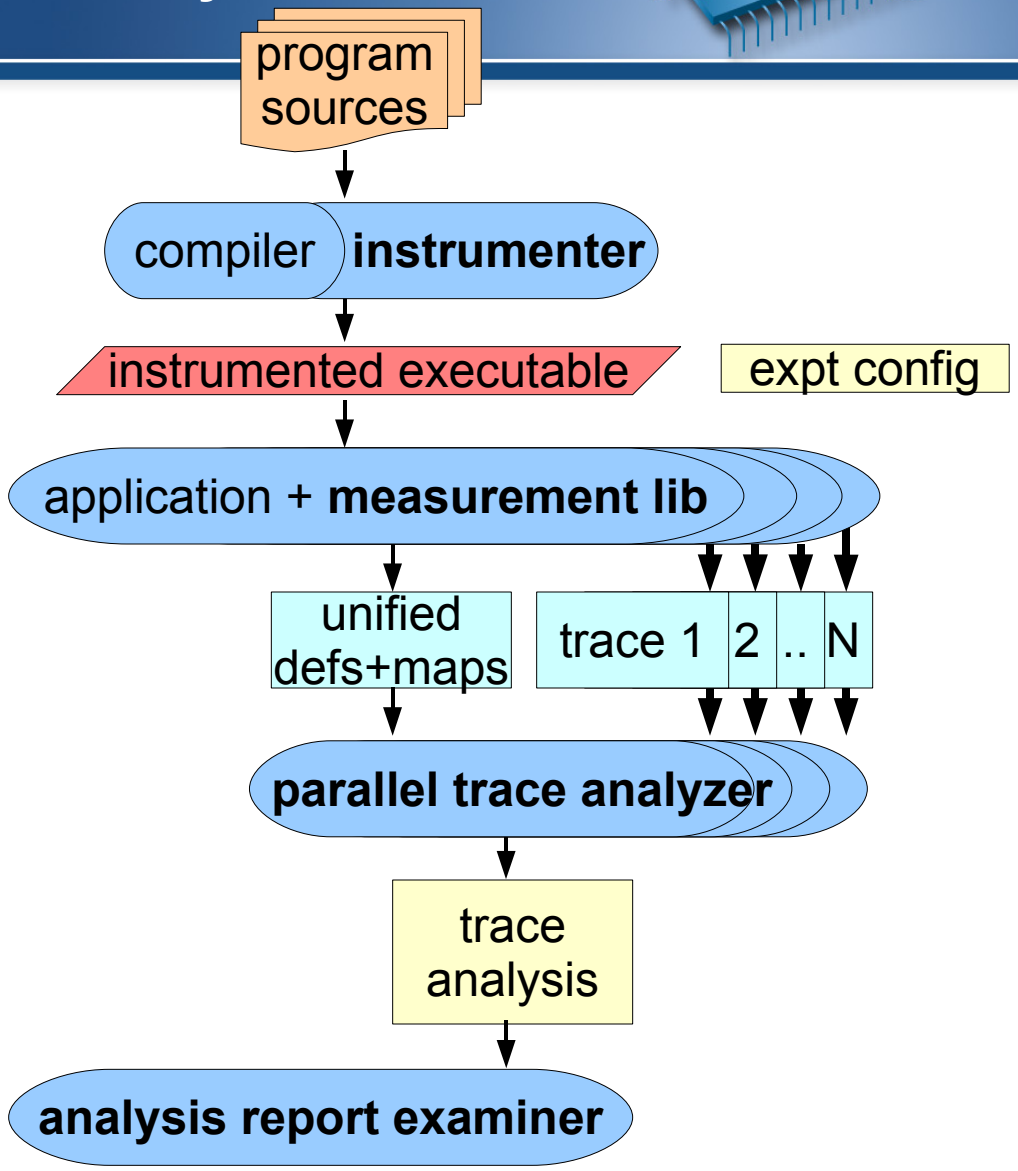
Measurement runtime summarization

- Measurement library manages threads & events produced by instrumentation
- Measurements summarized by thread & call-path during execution
- Analysis report unified & collated at finalization
- Presentation of summary analysis



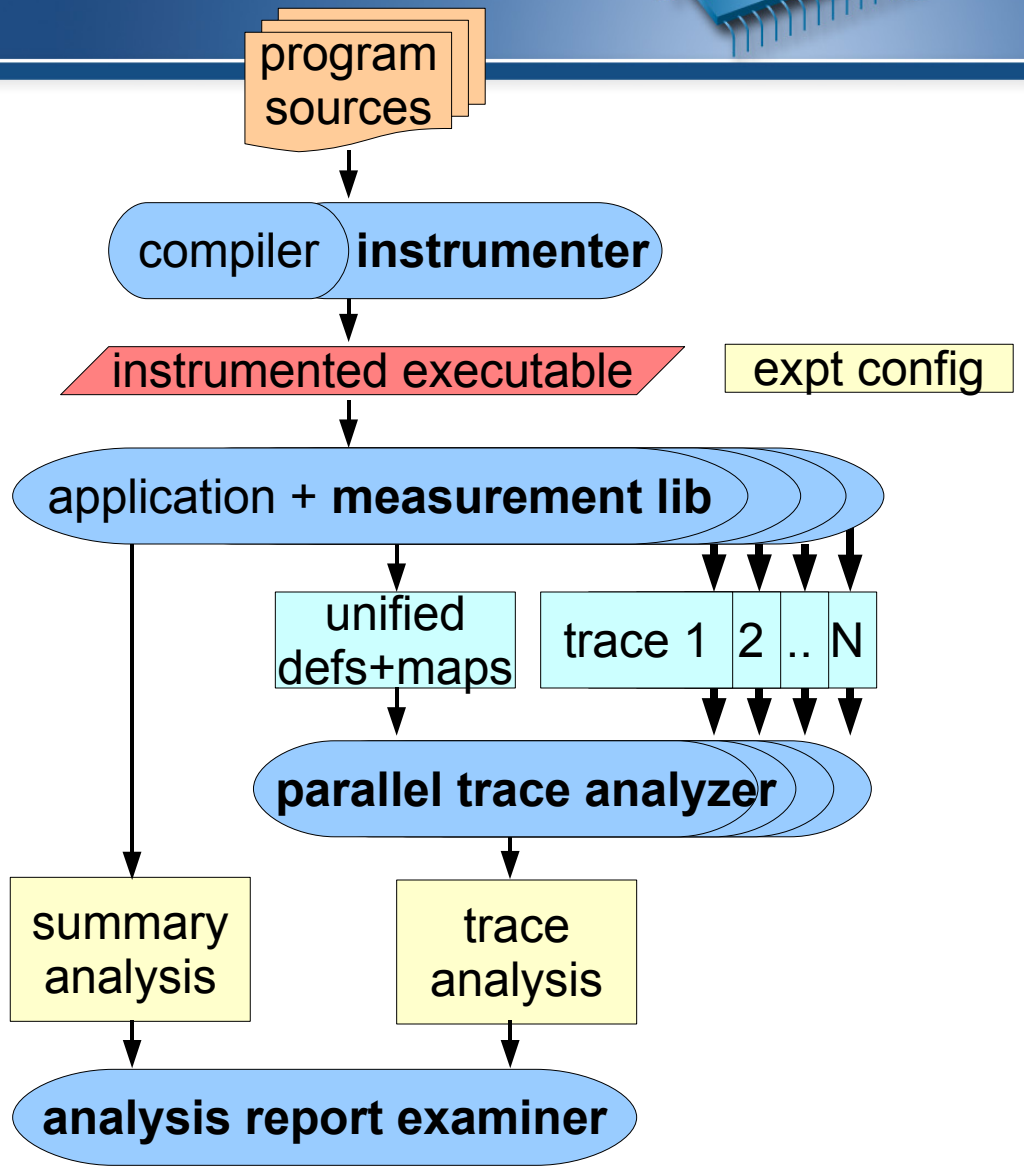
Measurement event tracing & analysis

- During measurement time-stamped events buffered for each thread
- Flushed to files along with unified definitions & maps at finalization
- Follow-up analysis replays events and produces extended analysis report
- Presentation of analysis report



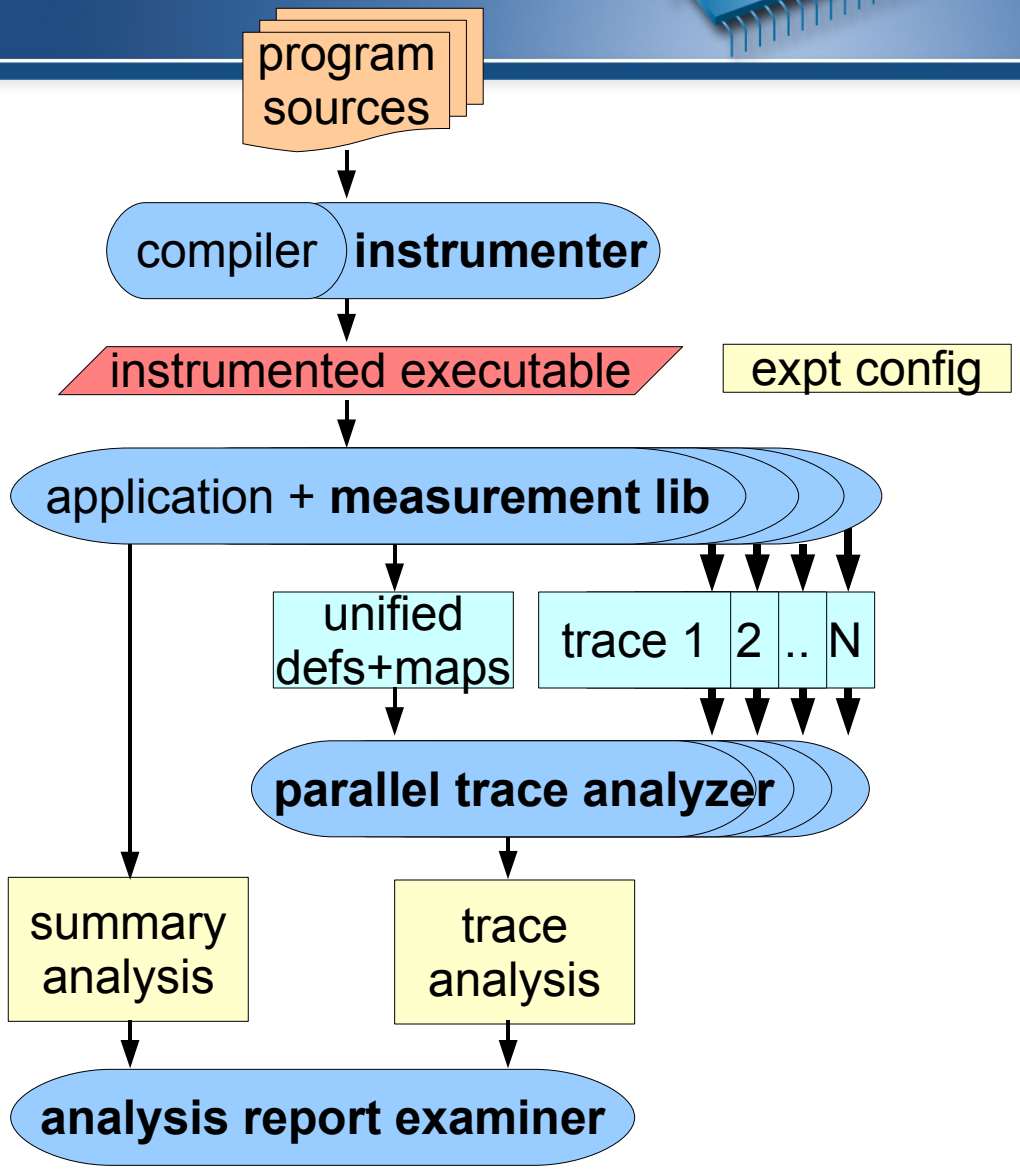
Generic parallel tools architecture

- Automatic/manual code instrumenter
- Measurement library for runtime summary & event tracing
- Parallel (and/or serial) event trace analysis when desired
- Analysis report examiner for interactive exploration of measured execution performance properties



Scalasca toolset components

- Scalasca instrumenter = SKIN
- Scalasca measurement collector & analyzer = SCAN
- Scalasca analysis report examiner = SQUARE



EPIK

- Measurement & analysis runtime system
  - Manages runtime configuration and parallel execution
  - Configuration specified via EPIK.CONF file or environment
    - epik_conf reports current measurement configuration
  - Creates experiment archive (directory): **epik_*<title>***
  - Optional runtime summarization report
  - Optional event trace generation (for later analysis)
  - Optional filtering of (compiler instrumentation) events
  - Optional incorporation of HWC measurements with events
    - via PAPI library, using PAPI preset or native counter names
- Experiment archive directory
  - Contains (single) measurement & associated files (e.g., logs)
  - Contains (subsequent) analysis reports

- One command for everything

  % **scalasca**

  Scalasca 1.2

  Toolset for scalable performance analysis of large-scale apps

  usage: scalasca [-v][-n] {action}

  1. prepare application objects and executable for measurement:
     scalasca *-instrument* <compile-or-link-command> # ***skin***
  2. run application under control of measurement system:
     scalasca *-analyze* <application-launch-command> # ***scan***
  3. interactively explore measurement analysis report:
     scalasca *-examine* <experiment-archive|report> # ***square***

  [-h] show quick reference guide (only)

scalasca actions

- One command for everything

  % **scalasca** -usage

  % scalasca **-inst**rument [options] <*compile-or-link-command*>

  % scalasca **-anal**yze [options] <*application-launch-command*>

  % scalasca **-exam**ine [options] <experiment-archive|report>

... that does nothing!

  - simply a shell script wrapper for action commands:

  % **skin** [options] <*compile-or-link-command*>

    - prepare application objects and executable for measurement

  % **scan** [options] <*application-launch-command*>

    - run application under control of measurement system

  % **square** [options] <experiment-archive|report>

    - interactively explore measurement analysis report

OPARI

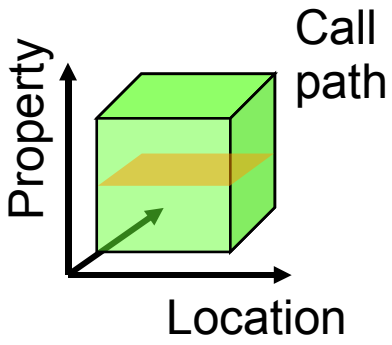
- Automatic instrumentation of OpenMP & POMP directives via source pre-processor
  - Parallel regions, worksharing, synchronization
  - Currently limited to OpenMP 2.5
    - No special handling of guards, dynamic or nested thread teams
  - Configurable to disable instrumentation of locks, etc.
  - Typically invoked internally by instrumentation tools
- Used by Scalasca/Kojak, ompP, TAU, VampirTrace, etc.
  - Provided with Scalasca, but also available separately
    - OPARI 1.1 (October 2001)
    - OPARI 2.0 currently in development

CUBE3

- Parallel program analysis report exploration tools
  - Libraries for XML report reading & writing
  - Algebra utilities for report processing
  - GUI for interactive analysis exploration
    - requires Qt4 or wxGTK widgets library
    - can be installed independently of Scalasca instrumenter and measurement collector/analyzer, e.g., on laptop or desktop
- Used by Scalasca/Kojak, Marmot, ompP, PerfSuite, etc.
  - Provided with Scalasca, but also available separately
    - CUBE 3.2 (July 2009)

Analysis presentation and exploration

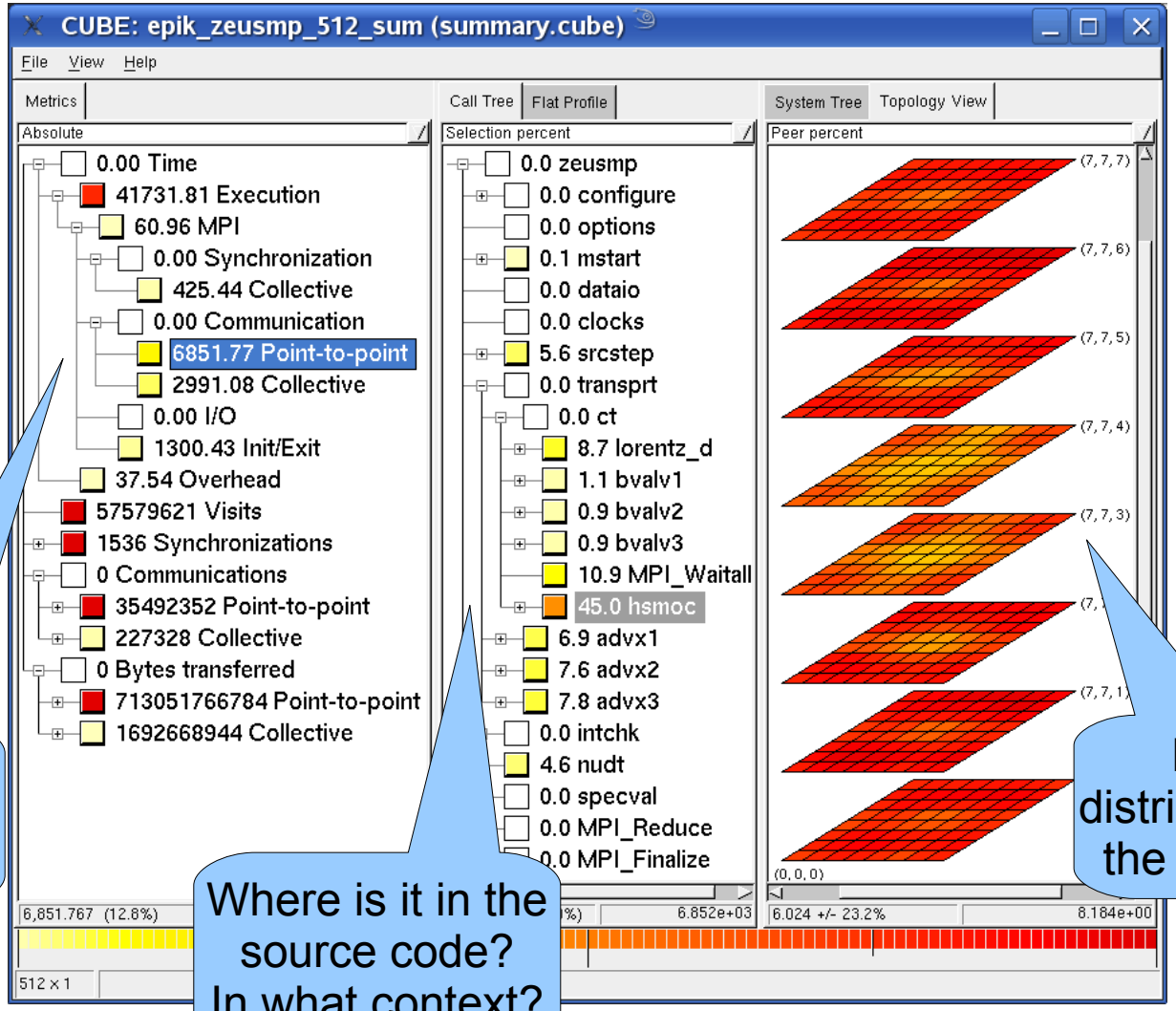
- Representation of values (severity matrix) on three hierarchical axes
  - Performance property (metric)
  - Call-tree path (program location)
  - System location (process/thread)



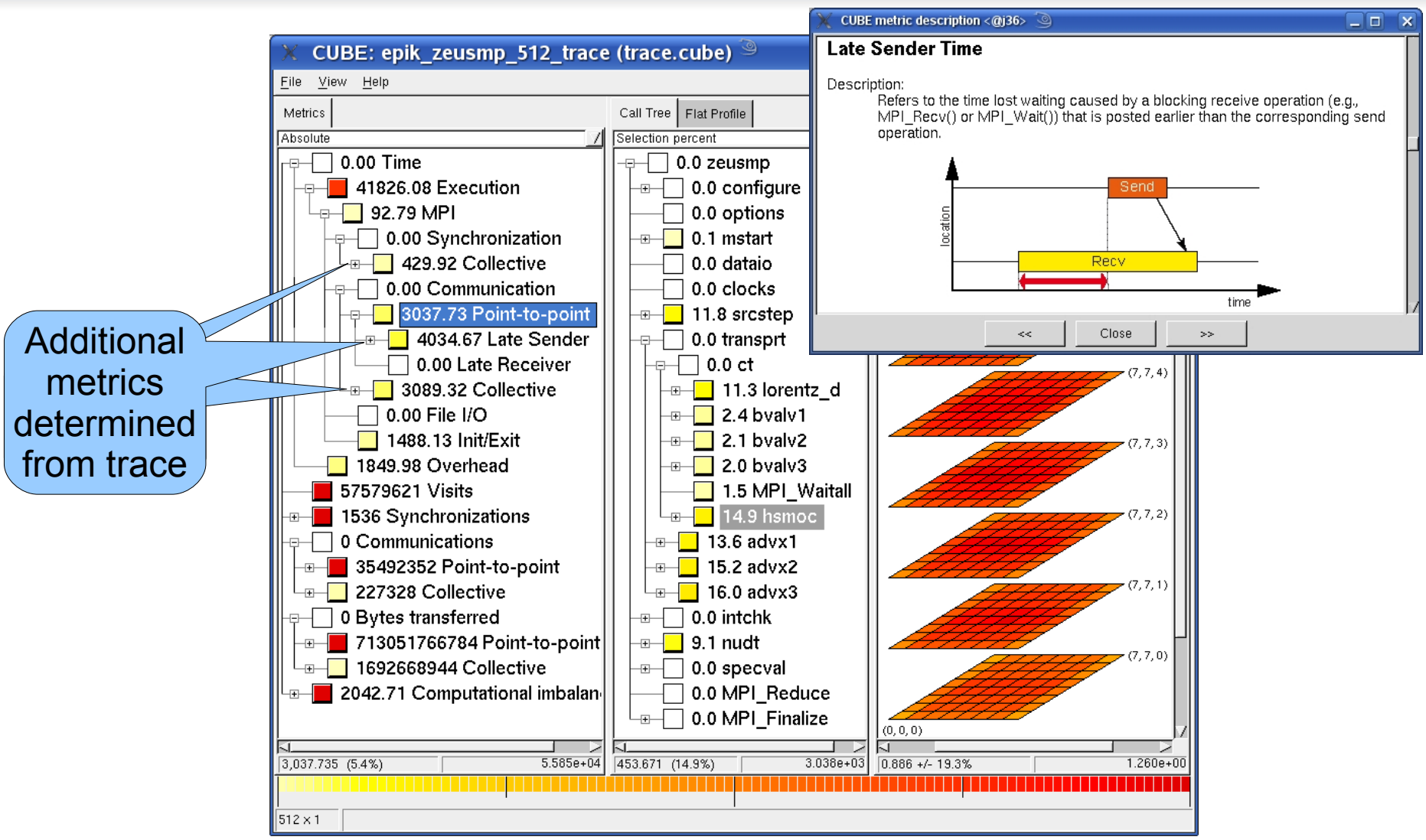
- Three coupled tree browsers

- CUBE3 displays severities
  - As value: for precise comparison
  - As colour: for easy identification of hotspots
  - Inclusive value when closed & exclusive value when expanded
  - Customizable via display mode

Scalasca analysis report explorer (summary)



Scalasca analysis report explorer (trace)

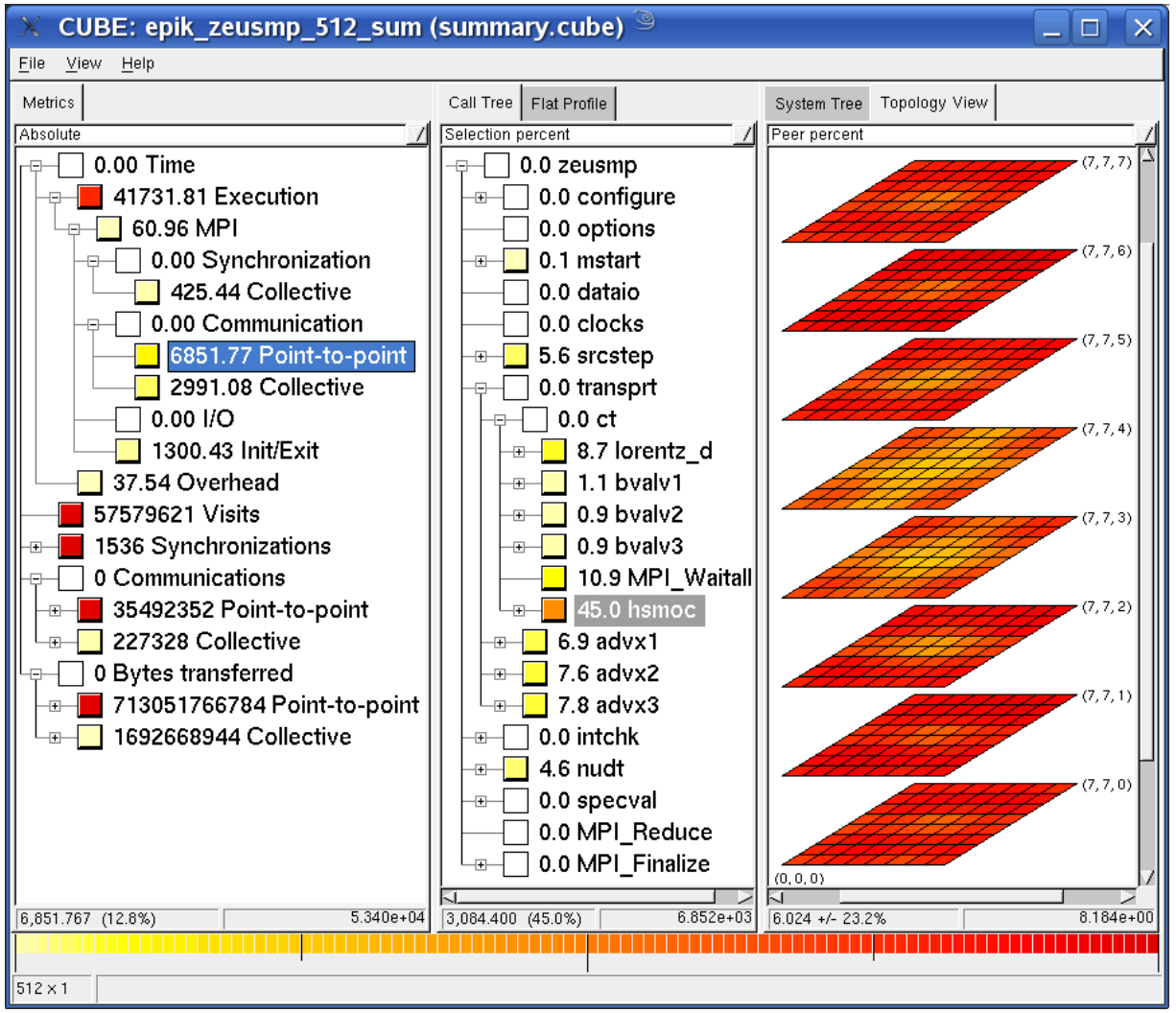


ZeusMP2/JUMP case study

- Computational astrophysics
  - (magneto-)hydrodynamic simulations on 1-, 2- & 3-D grids
  - part of SPEC MPI2007 1.0 benchmark suite (132.zeusmp2)
  - developed by UCSD/LLNL
  - >44,000 lines Fortran90 (in 106 source modules)
  - provided configuration scales to 512 MPI processes
- Run with 512 processes on JUMP
  - IBM p690+ eServer cluster with HPS at JSC
- Scalasca summary and trace measurements
  - ~5% measurement dilation (full instrumentation, no filtering)
  - 2GB trace analysis in 19 seconds
  - application's 8x8x8 grid topology automatically captured from MPI Cartesian

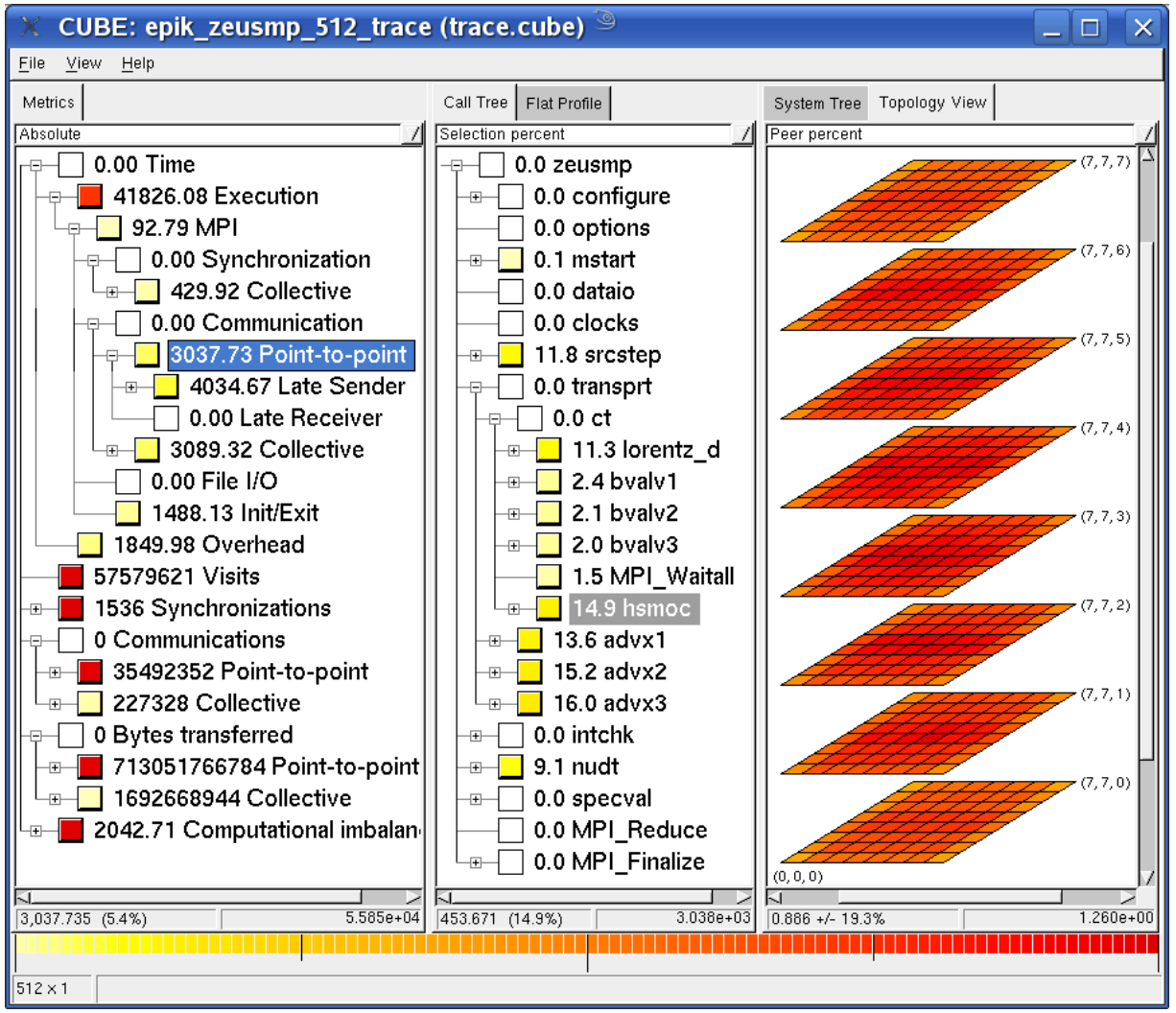
Scalasca summary analysis: zeusmp2 on jump

- 12.8% of time spent in MPI point-to-point communication
- 45.0% of which is on program callpath `transprt/ct/hsmoc`
- With 23.2% std dev over 512 processes
- Lowest values in 3rd and 4th planes of the Cartesian grid



Scalasca trace analysis: zeusmp2 on jump

- MPI point-to-point communication time separated into transport and Late Sender fractions
- Late Sender situations dominate (57%)
- Distribution of transport time (43%) indicates congestion in interior of grid



Scalasca 1.2 functionality

- Automatic function instrumentation (and filtering)
  - GCC, IBM, Intel, PathScale & PGI compilers
- MPI measurement & analyses
  - scalable runtime summarization & event tracing
  - only requires application executable re-linking
  - MPI File I/O operation analysis
  - limited analyses of non-blocking point-to-point, RMA, ...
- OpenMP measurement & analysis
  - requires (automatic) application source instrumentation
  - runtime summaries include OpenMP metrics
  - serial event trace analysis (of merged traces)
- Hybrid OpenMP/MPI measurement & analysis
  - combined requirements/capabilities
  - parallel trace analysis requires uniform thread teams

Scalasca 1.2 added functionality

- OpenMP measurement & analysis
  - run-time summaries include OpenMP metrics (for all threads)
    - not all threads need to participate in parallel regions
  - trace collection & analysis unchanged
- Hybrid OpenMP/MPI measurement & analysis
  - run-time summaries include OpenMP metrics (for all threads)
    - not all threads need to participate in parallel regions
  - trace collection complemented with hybrid trace analysis
    - requires all threads to participate in parallel regions
- MPI File I/O analysis
  - file operations (reads/writes), collective read/write time
- Improved support for Cray XT, NEC SX
- Improved support for PGI compilers