VI-HPS

VIRTUAL INSTITUTE – HIGH PRODUCTIVITY SUPERCOMPUTING

Score-P – A Joint Performance Measurement Run-Time Infrastructure for Scalasca, TAU, and Vampir

VI-HPS Team

Score-P

Scalable performance measurement infrastructure for parallel codes

BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

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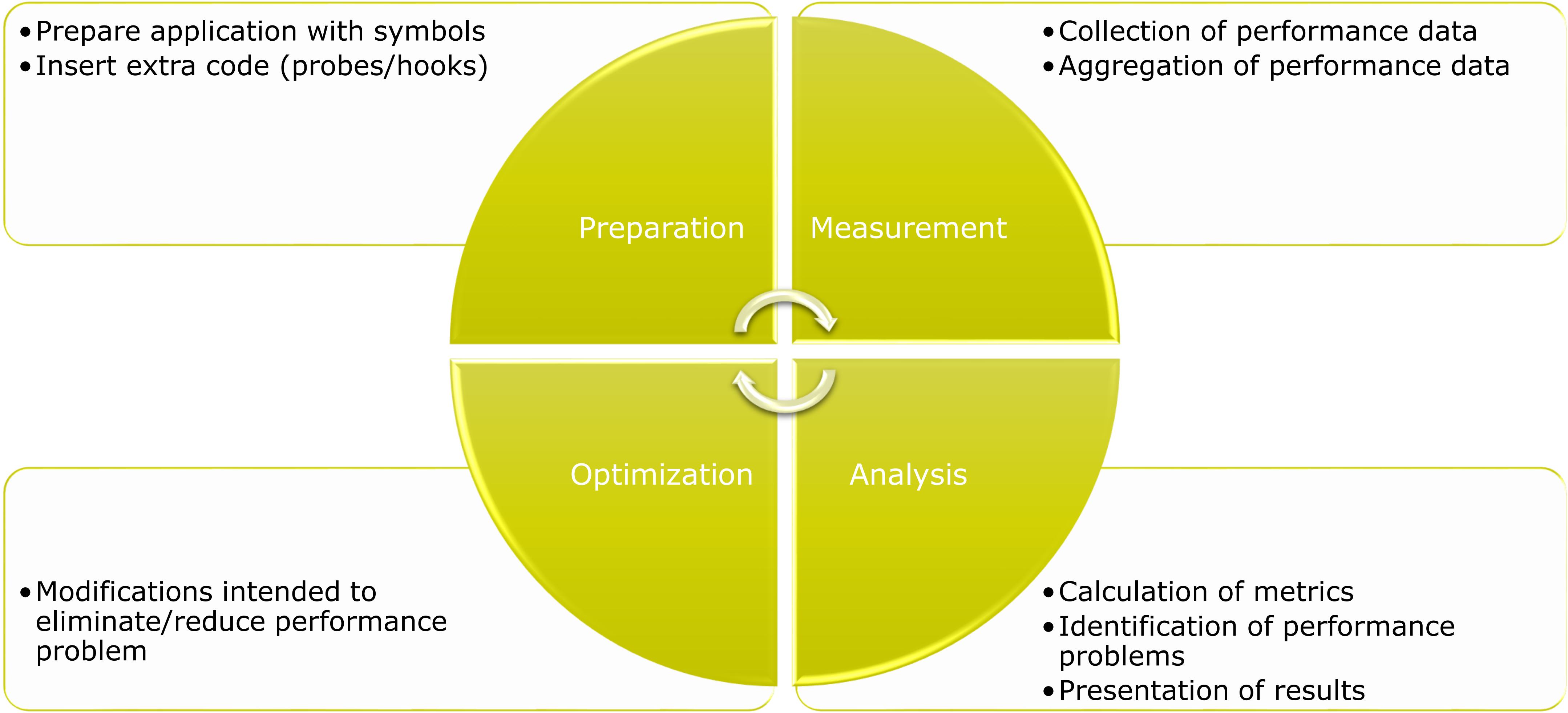
Performance engineering workflow



Preparation

- Prepare application with symbols
- Insert extra code (probes/hooks)

Measurement

- Collection of performance data
- Aggregation of performance data

Analysis

- Calculation of metrics
- Identification of performance problems
- Presentation of results

Optimization

- Modifications intended to eliminate/reduce performance problem

Score-P

- Infrastructure for instrumentation and performance measurements
- Instrumented application can be used to produce several results:
  - Call-path profiling: CUBE4 data format used for data exchange
  - Event-based tracing: OTF2 data format used for data exchange
  - Online profiling: In conjunction with the Periscope Tuning Framework
- Supported parallel paradigms:
  - Multi-process: MPI, SHMEM
  - Thread-parallel: OpenMP, Pthreads
  - Accelerator-based: CUDA, OpenCL, OpenACC, HIP

- Open Source; portable and scalable to all major HPC systems
- Initial project funded by BMBF
- Close collaboration with PRIMA project funded by DOE

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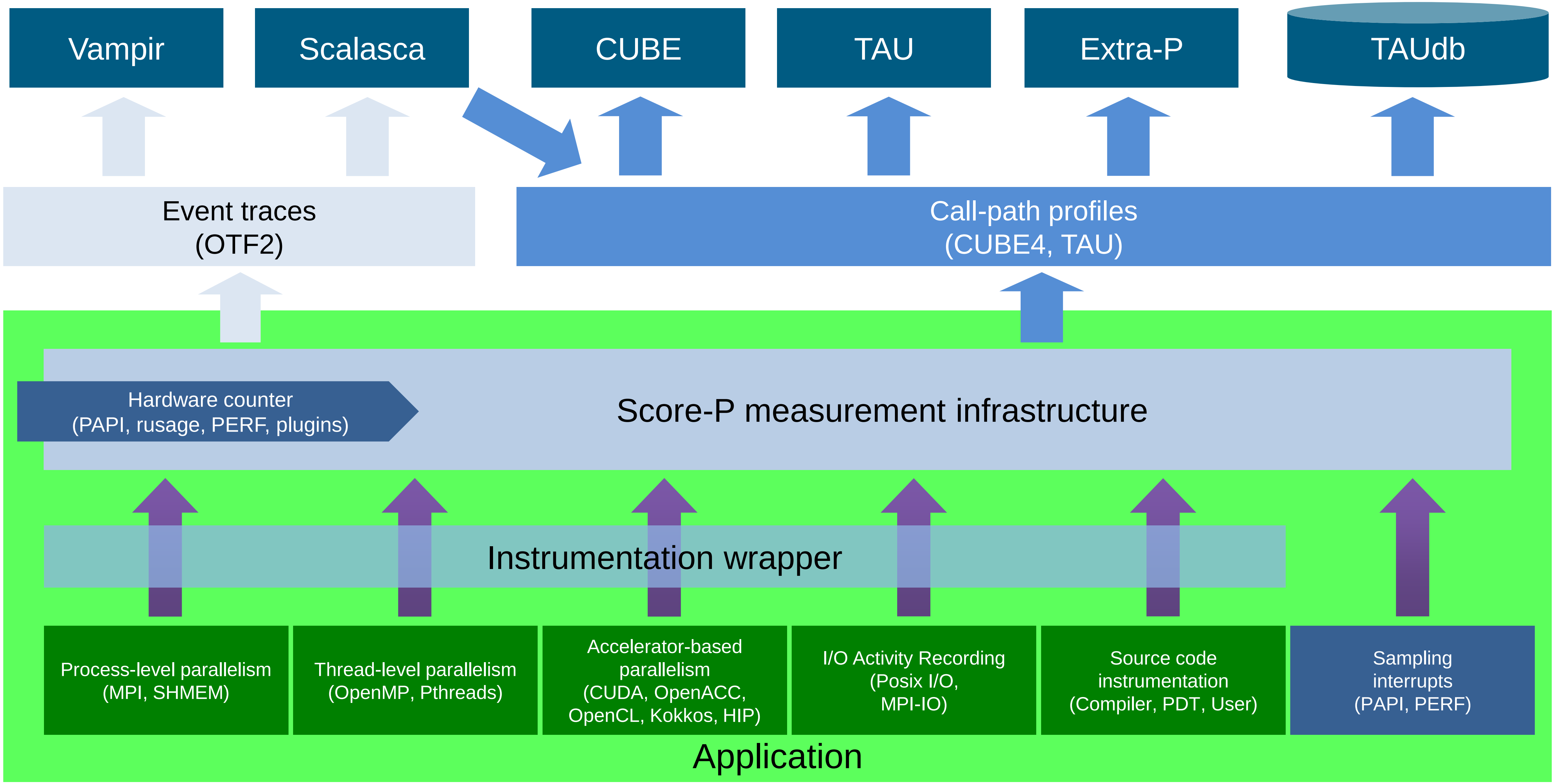
Bundesministerium
für Bildung
und Forschung


Vampir
Scalasca
CUBE
TAU
Extra-P
TAUdb
Event traces
(OTF2)
Call-path profiles
(CUBE4, TAU)
Hardware counter
(PAPI, rusage, PERF, plugins)
Score-P measurement infrastructure
Instrumentation wrapper
Process-level parallelism
(MPI, SHMEM)
Thread-level parallelism
(OpenMP, Pthreads)
Accelerator-based
parallelism
(CUDA, OpenACC,
OpenCL, Kokkos, HIP)
I/O Activity Recording
(Posix I/O,
MPI-IO)
Source code
instrumentation
(Compiler, PDT, User)
Sampling
interrupts
(PAPI, PERF)
Application

Hands-on:
CloverLeaf_OpenACC

Score-P

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Performance analysis steps

- 0.0 Reference preparation for validation

- 1.0 Program instrumentation
- 1.1 Summary measurement collection
- 1.2 Summary analysis report examination

- 2.0 Summary experiment scoring
- 2.1 Summary measurement collection with filtering
- 2.2 Filtered summary analysis report examination

- 3.0 Event trace collection
- 3.1 Event trace examination & analysis

Local installation (Turpan)

- Set account and default environment (NVHPC + OpenMPI) via helper script:

```
% source /tmpdir/vi-hps/opt/setup.sh
```

- Load the modules for the tool environment:

```
% module load  scorep/8.3-nvhpc-openmpi-gpu  cube
```

- Copy tutorial sources to your WORK directory (or your personal workspace)
  - Only required if not done already (for opening exercise)

```
% cd $WORK
% tar xf /tmpdir/vi-hps/material/handsons/CloverLeaf_OpenACC.tar.gz
% cd CloverLeaf_OpenACC
```

CloverLeaf_OpenACC: Makefile

```
#Crown Copyright 2012 AWE
#
# This file is part of CloverLeaf.
#
# CloverLeaf is free software...
#
# Agnostic, platform independent Makefile for the CloverLeaf benchmark code.
# It is not meant to be clever in any way, just a simple build script.
#
# this works as well:-
#
# make COMPILER=PGI [OPENMP=1]
#

...

#PREP=scorep --openacc --cuda --user

MPI_COMPILER=$(PREP) mpifort

# No preposition for C/CXX_MPI_COMPILER!
C_MPI_COMPILER=mpicc
CXX_MPI_COMPILER=mpic++

...
```

Specify the suite of compilers (and optionally OpenMP)

No instrumentation by default

Set/uncomment PREP macro for instrumenter preposition

Instrumenting clover_leaf

Score-P instrumenter options:

--compiler: source code routines (default)

--mpp=mpi: MPI determined by heuristics

--openacc: enable OpenACC

--cuda: enable CUDA

--user: enable Score-P user API (optional)

```
% make clean
% make PREP="scorep --openacc --cuda --user"

mpicc -c timer_c.c
scorep --openacc --cuda --user  mpif90 -O3 -acc=gpu -ta=nvidia \
    data.f90 definitions.f90 pack_kernel.f90 clover.F90 report.f90 timer.f90 \
    parse.f90 read_input.f90 initialise_chunk_kernel.f90 initialise_chunk.f90 build_field.f90 \
    update_tile_halo_kernel.f90 update_tile_halo.f90 update_halo_kernel.f90 update_halo.f90 \
    ideal_gas_kernel.f90 ideal_gas.f90 start.f90 generate_chunk_kernel.f90 generate_chunk.f90 \
    initialise.f90 field_summary_kernel.f90 field_summary.f90 viscosity_kernel.f90 viscosity.f90 \
    calc_dt_kernel.f90 calc_dt.f90 timestep.f90 accelerate_kernel.f90 accelerate.f90 \
    revert_kernel.f90 revert.f90 PdV_kernel.f90 PdV.f90 flux_calc_kernel.f90 flux_calc.f90 \
    advec_cell_kernel.f90 advec_cell_driver.f90 advec_mom_kernel.f90 advec_mom_driver.f90 \
    reset_field_kernel.f90 reset_field.f90 hydro.F90 clover_leaf.F90 visit.f90 \
    timer_c.o \
    -o bin/clover_leaf
```

Mastering build systems

- Hooking up the Score-P instrumenter `scorep` into complex build environments like *Autotools* or *CMake* was always challenging
- Score-P provides convenience wrapper scripts to simplify this
- *Autotools* and *CMake* need the used compiler already in the *configure step,* but instrumentation should not happen in this step, only in the *build step*

```
% SCOREP_WRAPPER=off \
> cmake .. \
> -DCMAKE_C_COMPILER=scorep-nvcc \
> -DCMAKE_CXX_COMPILER=scorep-nvc++ \
> -DCMAKE_Fortran_COMPILER=scorep-nvfortran
```

Disable instrumentation in the *configure step*

Specify the wrapper scripts as the compiler to use

- Allows to pass addition options to the Score-P instrumenter and the compiler via environment variables without modifying the *Makefiles*
- Run `scorep-wrapper --help` for a detailed description and the available wrapper scripts of the Score-P installation

Measurement configuration: scorep-info

```
% scorep-info config-vars --full
SCOREP_ENABLE_PROFILING
  Description: Enable profiling
 [...]
SCOREP_ENABLE_TRACING
  Description: Enable tracing
 [...]
SCOREP_TOTAL_MEMORY
  Description: Total memory in bytes for the measurement system
 [...]
SCOREP_EXPERIMENT_DIRECTORY
  Description: Name of the experiment directory
 [...]
SCOREP_FILTERING_FILE
  Description: A file name which contain the filter rules
 [...]
SCOREP_METRIC_PAPI
  Description: PAPI metric names to measure
 [...]
SCOREP_METRIC_RUSAGE
  Description: Resource usage metric names to measure
 [...]
SCOREP_OPENACC_ENABLE
  Description: OpenACC measurement features
 [... More configuration variables ...]
```

- Score-P measurements are configured via environmental variables

Required for OpenACC measurements.
[yes|default] recommended to start.
Additional CUDA measurement optional.

Mastering heterogeneous applications

For all available options check:
scorep-info config-vars --full

- Record CUDA application events and device activities

```
% export SCOREP_CUDA_ENABLE=default
```

- Record OpenCL application events and device activities

```
% export SCOREP_OPENCL_ENABLE=api,kernel
```

- Record OpenACC application events

```
% export SCOREP_OPENACC_ENABLE=regions,wait,enqueue
```

  - Can be combined with CUDA if it is a NVIDIA device

```
% export SCOREP_CUDA_ENABLE=kernel,kernel_callsite,idle
```

CloverLeaf_OpenACC summary measurement collection

```
% cd bin.scorep
% cat scorep.sbatch
...
# Score-P measurement configuration
export SCOREP_OPENACC_ENABLE=default
export SCOREP_CUDA_ENABLE=default
#export SCOREP_CUDA_BUFFER=48M

#export SCOREP_EXPERIMENT_DIRECTORY=scorep-clover_leaf-6
#export SCOREP_FILTERING_FILE=../config/scorep.filter
#export SCOREP_ENABLE_TRACING=true
#export SCOREP_TOTAL_MEMORY=250M

# Run the application
mpiexec ./clover_leaf

% sbatch scorep.sbatch
```

- Change to the directory containing the new executable before running it with the desired configuration
- Check settings

Leave these lines commented out for the moment

- Submit job

CloverLeaf_OpenACC summary measurement execution

```
% cat slurm-<job_id>.out
+ mpiexec ./clover_leaf
MPI rank    0 (0) using device   0/2 on turpancomp0
MPI rank    1 (1) using device   1/2 on turpancomp0
MPI rank    4 (0) using device   0/2 on turpancomp2
MPI rank    5 (1) using device   1/2 on turpancomp2
MPI rank    2 (0) using device   0/2 on turpancomp1
MPI rank    3 (1) using device   1/2 on turpancomp1

    Clover Version 1.300
       MPI Version
   OpenACC Version 201711
   Task Count      6

 Output file clover.out opened. All output will go there.

 Step    1 time   0.0000000 control sound timestep  3.85E-04   1, 1 x  3.26E-04 y  3.26E-04
 Step    2 time   0.0003852 control sound timestep  2.35E-04   1, 1 x  3.26E-04 y  3.26E-04
 Step    3 time   0.0006203 control sound timestep  2.99E-04   1, 1 x  3.26E-04 y  3.26E-04
[...]
 Step   87 time   0.0310703 control sound timestep  3.66E-04   1, 1 x  3.26E-04 y  3.26E-04

 Wall clock     6.195748090744019
 First step overhead   2.0323038101196289E-002
```

- Verify the reported execution configuration and that the test execution passed

Compare to previous reference execution without instrumentation

CloverLeaf_OpenACC summary analysis report examination

```
% ls
clover_leaf* clover.in clover.out  slurm-<job_id>.out
scorep.sbatch  scorep-clover_leaf-6/

% ls scorep-clover_leaf-6
MANIFEST.md  profile.cubex  scorep.cfg







% cube scorep-clover_leaf-6/profile.cubex

       [CUBE GUI showing summary analysis report]
```

Hint:
Copy ‘profile.cubex’ to local system (laptop) using ‘scp’ to improve responsiveness of GUI

- Creates experiment directory including
  - A brief content overview (MANIFEST.md)
  - A record of the measurement configuration (scorep.cfg)
  - The analysis report that was collated after measurement (profile.cubex)
- Interactive exploration with Cube

Further information

- Community instrumentation & measurement infrastructure
  - Instrumentation (various methods)
  - Basic and advanced profile generation
  - Event trace recording
  - Online access to profiling data
- Available under 3-clause BSD open-source license
- Documentation & Sources:
  - https://www.score-p.org
- User guide also part of installation:
  - <prefix>/share/doc/scorep/{pdf,html}/
- Support and feedback: support@score-p.org
- Subscribe to news@score-p.org, to be kept informed